JOINT VENTURE STATEMENT

We the undersigned do hereby give notice to our agreement to propose as a joint venture on the Project and by submitting the foregoing form and related information; have read such documents; and that such documents are true and correct and contain no material misrepresentations.

____

(Name of Joint Venture)

____

(Name of Firm)

____

(Signature)

Signed and sworn to me before this __________ day of ____________________, 20___.

____

(Notary Public)

My commission expires:

____

____

(Name of Firm)

____

(Signature)

Signed and sworn to me before this __________ day of ____________________, 20___.

____

(Notary Public)

My commission expires:

END OF SECTION

ADDENDUM NO. 5

NORTH TEXAS MUNICIPAL WATER DISTRICT

CONSTRUCTION MANAGER AT RISK LOWER BOIS D'ARC CREEK RESERVOIR DAM AND INTAKE PROJECT

PROJECT NO. 344

NTD13565

February 12, 2015

PROPOSAL DATE: FEBRUARY 18, 2015

The following additions, deletions, modifications, or clarifications shall be made to the appropriate sections of the plans and specifications and shall become a part of the Contract Documents. Proposers shall acknowledge receipt of this Addendum in the space provided on the Proposal Form.

BIDDING REQUIREMENTS:

1. 00 72 00 Paragraph 6.19(D): Delete in its entirety and replace with, " D. The duration of the warranty shall be for one year from the date of final completion of the entire Work or any part of the Work as may be agreed to in writing by the parties based on the overall schedule for the Project. Except as otherwise agreed in writing by the Owner, partial occupancy or use of some or all of the Work or any part thereof shall not commence the warranty obligations."

2. 00 72 00 Paragraph 6.02 (B): Delete, "without Owner's written consent" from the second sentence. Insert after the second sentence, a new third sentence, "Work performed on the Site between 6:00 p.m. and 7:00 a.m. and Work performed on Saturday, Sunday or any District holiday will be allowed only with the Owner's written consent, which shall not be unreasonably withheld."

3. 00 72 00 Paragraph 5.04 (C): In the Table titled "Workers' Compensation, etc.", Delete: "$1,000,000" in three places and replace with "$500,000" in three places.

4. 00 72 00 Paragraph 5.04 (D): Delete in its entirety the table tilted "Insurance for Claims of Damages" and replace with the table below:

Insurance for Claims of Damages	
1) General Aggregate (Except Products - Completed Operations)	$1,000,000 / Occurrence $2,000,000 / Aggregate
2) Products - Completed Operations Aggregate	$1,000,000 / Occurrence $2,000,000 / Aggregate
3) Personal and Advertising Injury (One Person/Organization)	$1,000,000
4) Each Occurrence (Bodily Injury and Property Damage)	$1,000,000
5) Limit Per Person – Medical Expense	$5,000
6) Personal Injury Liability coverage will include claims arising out of Employment Practices Liability, limited to coverage provided under standard contract.	1,000,000
7) Property Damage Liability insurance will provide explosion, collapse and underground coverage where applicable	$1,000,000
8) Watercraft Liability Policy. Coverage shall apply to all self-propelled vessels	$1,000,000
9) Excess Liability, Umbrella Form to include coverage of Watercraft Liability. General Aggregate - Each Occurrence	$1,000,000

5. 00 72 00 Paragraph 5.04 (G): Delete in its entirety the table titled, " CMAR's Contractual Liability Insurance" and replace with the table below:

CMAR's Contractual Liability Insurance	
1) General Aggregate	$1,000,000
2) Each Occurrence (Bodily Injury and Property Damage)	$1,000,000

END OF ADDENDUM NO. 5

STATE OF TEXAS
JEFFREY A. PAYNE
90732
LICENSED PROFESSIONAL ENGINEER

2/12/15

FREESE AND NICHOLS, INC.
TEXAS REGISTERED
ENGINEERING FIRM
F-2144

DIVISION 01

GENERAL REQUIREMENTS

01 01 01 CONSTRUCTION MANAGER AT RISK SERVICES

1.00 GENERAL

1.01 SERVICES INCLUDED

A. Provide the Construction Manager at Risk (CMAR) Services (the "Services") (CMAR) for the development and construction of the Project in accordance with the terms of the Contract Documents**, including but not limited to the balance of this document**.

B. Provide the Services in accordance with the applicable sections of Texas Government Code Chapter 2269 and any applicable Laws and Regulations.

C. Coordinate with various local and state agencies as required, obtain permits and arrange for inspections by building officials.

D. Attend meeting with stakeholders, including regulatory agencies

E. Support the materials testing and quality assurance activities of the Owner.

F. Manage quality control on the Project to see that the construction meets the intent of the Contract Documents.

G. Provide bonds and insurance.

H. Provide safe working conditions at the Site meeting OSHA standards as a minimum.

I. Assist Owner and Engineer in resolving any issues or conflicts.

J. Coordinate and manage the startup, initial operation of the facility and transition to Owner operations.

K. Provide follow up to correct defects during the 1 year warranty period.

L. Provide CMAR Services in accordance with professional standards of skill, care and diligence in a timely manner in accordance with the Project schedule and so that the Project shall be completed as expeditiously and economically as possible within the Owner's Budget and in the best interest of the Owner.

M. **It is anticipated that all the preconstruction and procurement services for the work described in 00 11 19 1.01 A will be provided in the time period of 2015.**

1.02 KEY PERSONNEL AND CONSULTANTS

A. Provide the services of the Key Personnel identified in the Proposal for the duration of the Project. Substitution of other individuals for the Key Personnel and Alternate Key Personnel identified in the Proposal or individuals previously approved can only be made with the written consent of the Owner. Not providing the Key Personnel or Alternate Key Personnel proposed may be the grounds for termination of this Agreement.

B. The CMAR may provide Services through one or more CMAR Team Members employed by the CMAR provided, however, the CMAR shall remain responsible to the Engineer and the Owner for all duties and obligations of the CMAR under this Agreement. Require CMAR Team Member to comply with all terms and conditions of these Contract Documents unless a written waiver is authorized by the Owner. The Services provided by the any CMAR Team Member identified in the Proposal must be provided for the duration of the Project.

Substitution of other CMAR team members for CMAR Team Members identified in the Proposal or previously approved can only be made with the written consent of the Owner. Not providing the CMAR Team Members proposed may be the grounds for termination of this Agreement.

1.03 LIMITATIONS OF AUTHORITY

A. The CMAR shall have authority to act on behalf of the Engineer and the Owner only to the extent provided in the Contract Documents. The CMAR does not have authority to bind the Engineer or the Owner for the payment of any costs or expenses without the express written approval of the Engineer or the Owner except as indicated by these Contract Documents. In the event of an emergency affecting the safety of persons, the Project or adjacent property, the CMAR, without special instruction or authorization, shall act reasonably to prevent or minimize any threatened damage, injury or loss. The CMAR's authority to act on behalf of the Engineer or the Owner shall be modified only by Change Order or Amendment.

1.04 QUALITY OF SERVICES

A. The Engineer, with the concurrence of the Owner, has the right to reject or disapprove any portion of the CMAR's Services for the Project. Written notice stating the reason for the rejection or disapproval will be provided by the Engineer. Proceed with revisions to the Services to attempt to satisfy the objections when requested by the Engineer. The CMAR acknowledges that any review or approval by the Engineer and the Owner of any Services performed by the CMAR pursuant to this Agreement shall not relieve the CMAR of the CMAR's responsibility to properly and timely perform such Services.

1.05 PRE-CONSTRUCTION SERVICES FOR TERMINAL STORAGE RESERVOIR AND IMPOUNDMENT CLEARING

△1

A. ~~The pre-construction services for this work will commence at an earlier design complete date and will include the additional Services described below in paragraphs B and C. It is anticipated that these services will be provided in the time period of 2018.~~

The pre-construction services for the work described in 00 11 19 1.01 B will commence at an earlier design complete date and will include the additional Services described immediately below in paragraphs B and C. It is anticipated that all the preconstruction and procurement services for the work described in 00 11 19 1.01 B for the clearing will be in 2015 and for the TSR it will be the 3Q and 4Q 2017 and 1Q 2018.

B. Prior to 30% design complete include a preliminary evaluation of the scope of this work and budget requirements to determine that CMAR will be able to construct the facilities described in that program within the Owner's Budget using conceptual estimating techniques. Discuss this preliminary appraisal along with any other quality management and design review comments in accordance with paragraph 2.04 below with the Engineer and Owner. Provide a preliminary schedule.

C. Prepare a more detailed estimate with supporting data as well as provide quality management and design review comments when preliminary 30% design documents have been prepared by the Engineer and approved by the Owner. Provide a preliminary master schedule. Update and refine this estimate at appropriate intervals agreed to by the Owner, Engineer and CMAR.

2.00 PRE-CONSTRUCTION SERVICES

2.01 PROJECT MANAGEMENT

A. Attend periodic design meetings to provide consultation on aspects of the design that will impact the budget, schedule and quality of the completed Project. Assume two meetings per month.

   1. Advise, assist, and provide recommendations on all aspects of the planning and design of the Work: Consult with the Engineer and Owner regarding Site use and improvements, and the selection of materials, building systems and equipment.

   2. Provide recommendations on construction feasibility; actions designed to minimize adverse effects of labor or material shortages; time requirements for procurement, installation and construction completion; and factors related to construction cost including estimates of alternative designs or materials, preliminary budgets and possible opportunities for savings.

B. Provide input to the Owner and Engineer regarding current construction market, bidding climate, status of key Subcontractor and Supplier markets, and other local economic conditions. Develop Subcontractor and Supplier interest in the Project, consistent with Laws and Regulations. Furnish Owner and Engineer a list of possible Subcontractors and Suppliers, from whom Bids will be requested for each principal portion of the Work. Identify preferred providers based on CMAR's previous experience for quality of work, on time delivery and ability to complete work within bid amounts. Submission of this list is for information and discussion purposes only and not for prequalification. The review of this list will not require the Owner or Engineer to investigate the qualifications of proposed Subcontractors and Suppliers, nor shall it waive the right of the Owner or Engineer to later object to or reject any proposed Subcontractor or Supplier when Bids are considered.

C. Recommend a schedule for procurement of early Work Packages (which may include long-lead time items) required to meet the Project schedule to the Owner and Engineer. Determine if these items must be procured before execution of the GMP Amendment for the entire Work or if such procurement must occur before that time to meet the Project schedule. Assist the Owner and Engineer with the procurement of these Early Work Packages by obtaining competitive Bids for these items..

D. Prepare GMP Proposals for Early Work Packages and the GMP for the entire Work.

E. Meet with Owner and Engineer to discuss GMP proposals.

F. Identify critical elements of the Work that may require special procurement processes, such as prequalification of Subcontractors or Suppliers, requirement of certified or pre-qualified installers or alternative contracting methods.

2.02 TIME MANAGEMENT

A. Provide a preliminary master schedule for the Project based on the design existing at the time of Agreement execution. Incorporate the Engineer's schedule for design into the preliminary master schedule and include allowances provided by Engineer and Owner for reasonable periods required for the review and approval of items by the Engineer and the Owner and for approvals of governmental authorities having jurisdiction over the Project. Prepare the preliminary master schedule in a way that the detailed construction schedule can be incorporated into the master schedule as the Project becomes better defined.

B. Identify critical design Milestones that must be met in order to keep the Project on schedule. Coordinate and integrate the preliminary Project schedule with the activities of the Owner, Engineer, and CMAR. Update the preliminary Project schedule as design progresses to indicate proposed activity sequences and durations, Milestone dates for receipt and approval of pertinent information, submittal of GMP Proposals preparation and processing of Shop Drawings and Samples, delivery of materials or equipment requiring long-lead time procurement, and Owner's occupancy requirements.

C. Make appropriate recommendations to the Owner and Engineer if preliminary Project schedule updates indicate that previously approved schedules may not meet Contract Time requirements.

D. Revise the master schedule after the Guaranteed Maximum Price is established.

E. Prepare schedules in accordance with the requirements of Section 01 32 16 "Construction Progress Schedules".

2.03 COST MANAGEMENT

A. Provide a preliminary evaluation based on the existing design as of the date of Agreement execution of the Owner's program and budget requirements to determine that CMAR will be able to construct the Project described in that program within the Owner's Budget using conceptual estimating techniques. Discuss this preliminary appraisal with the Engineer and Owner.

B. Prepare a detailed estimate with supporting data for review by the Owner and Engineer when design development documents (60% design) have been completed by the Engineer and approved by the Owner. Update and refine this estimate at appropriate intervals agreed to by the Owner, Engineer and CMAR during the preparation of the Construction Documents.

C. Prepare a pre-Bid line item estimate to be used for comparison of Bids received at the Bid opening. Include a line item in the estimate for each anticipated Bid package, as well as line items for general conditions, contingencies and other cost that will be incorporated into the Guaranteed Maximum Price for the Project.

D. Make appropriate recommendations to the Owner and Engineer if any estimate exceeds previously approved budgets or if volatility in the cost of selected materials or equipment may drive cost above the Owner's Budget when Bids are received for Work. Identify areas where costs may be lower than original estimates and cost savings may be used to balance the budget. Report to the Owner the cost of various design and construction alternatives, including CMAR's assumptions in preparing its analysis, a variance analysis between budget and preliminary estimate, and recommendations for any adjustments to the budget. Consider costs relating to efficiency, usable life, maintenance, energy, and operation as part of the cost analysis.

E. Revise the construction cost estimate to reflect actual cost as determined by Bid amounts. Use this revised estimate to establish the Schedule of Values used for periodic Applications for Payment.

F. Notify the Owner and Engineer immediately if any construction cost estimate exceeds the Owner's Budget.

G. Work with the Owner and Engineer at each stage in the design process to develop a GMP within the Owner's Budget and a master schedule within Owner's schedule.

2.04 QUALITY MANAGEMENT / DESIGN REVIEW

A. Review in-progress design documents, including the documents generally described as design development documents (60%), and the 90% design complete Construction Documents and provide input and advice on constructability, materials and equipment selections, and availability. Provide timely suggestions for modifications to improve:

1. Constructability, including sequencing or coordination issues:
    a. Adequacy of details for construction.
    b. Potential conflicts during construction.
    c. Feasibility of construction.
    d. Construction sequencing.
    e. Ability to coordinate among Subcontractors and Suppliers.
    f. Coordination between Contract Documents.
2. Operability:
    a. Ability to minimize disruptions to existing operations.
    b. Ability to complete construction connections to existing facilities or utilities.
    c. Modifications to facilitative initial startup and/or performance testing.
    d. Ability of Owner to operate/maintain the facility when completed.
3. Risk Management:
    a. Analyze construction risk to assess risk impact and develop appropriate risk management strategies to minimize associated costs.
    b. Provide recommendations for appropriate allocation of construction risks.
    c. Identify additional information that will help with risk assessment.
    d. Suggest procurement strategies to minimize risk.
4. Possible use of patented or copyrighted products.
5. Legal requirements for Subcontractor and equipment procurement.
6. Construction cost.
7. Construction duration.
8. Completeness, consistency and clarity.

9. Provide review comments in writing using the processes or procedures prescribed by the Engineer.

B. The CMAR is not responsible for design of the Project. The CMAR does not control the Project design or contents of the Contract Documents and does not assume responsibility or liability for the Project design by performing these reviews. The CMAR's review of the Project design and Contract Documents and providing recommendations are only advisory to the Engineer and Owner.

3.00 PROCUREMENT SERVICES

3.01 ASSEMBLE BID PACKAGES

A. Assemble appropriate Bid packages from the Contract Documents for distribution to prospective Bidders for providing all elements of Work not included in the General Conditions.

3.02 ADVERTISE FOR BIDS

A. Publicly advertise the Project soliciting Bids from Subcontractors and Suppliers for providing all elements of Work not included in the General Conditions in accordance with provisions of Texas Government Code 2267.

1. Include a notice in the advertisement for Bids that:
    a. Describes the Work.
    b. States the location at which Bidding Documents, Drawings, Specifications, and other documents made available to the CMAR can be examined by all bidders.
    c. States the time and place for submitting Bids.
    d. States the time and place Bids will be opened.
2. Publish the advertisement in a manner that meets the requirements placed on the Owner by Laws and Regulations.
    a. Publish the advertisement at least twice in one or more newspapers of general circulation in the county in which the Work is to be performed.
    b. Publish the second notice on or before the 10th day before the first date Bids may be submitted.
3. Mail notices to Subcontractor and Suppliers identified in accordance with Paragraph 2.01.B or any organization that requests in advance that notices for Bids be sent to it on or before the date the first newspaper advertisement is published.
4. Send notices to at least two selected plan rooms that serve the area of the Project. Digital copies of the Contract Documents will be provided for use in internet based systems for procurement.

B. Maintain a list of all entities that have requested Bid documents for any portion of the Project (plan holders) until Bids are received. Provide weekly updates of the planholders list to the Engineer and Owner.

C. Encourage multiple Subcontractors and Suppliers to submit Bids on the Project so that a minimum of three Bids are received for each trade or Bid package. If less than three Bids are received, the Owner shall decide to continue with review, selection and award or re-evaluate the circumstances and decide on a different course of action.

D. Submit a Bid complying with the requirements for Bids from other Subcontractors and Suppliers for any portion of the Work that the CMAR may wish to perform. The CMAR may self-perform this portion of the Work if the Owner determines that the Bid of the CMAR provides the best value to the Owner.

3.03 PRE-BID CONFERENCES

A. Conduct a pre-Bid conference with prospective Subcontractor and Suppliers to familiarize them with:

1. Bid opportunities.
2. Special requirements of the Contract Documents.
3. Small, minority and women-owned business requirements.
4. Equal employment opportunity requirements.
5. Prevailing wage requirements.

B. Obtain responses from the Engineer to all questions at pre-Bid conferences which require a modification to the Contract Documents. Prepare a record of the discussions at the pre-Bid conference to assist the Engineer in preparing Addenda as appropriate. Review and comment on Addenda prepared by the Engineer to incorporate responses to questions raised during or as a result of the conference.

3.04 ADDENDA

A. Receive Addenda prepared by the Engineer. Review Addenda for clarity, consistency and coordination. CMAR is not acting in a manner to assume responsibility or liability, in whole or in part, for all or any part of the Project design or the content of the Contract Documents by performing these reviews. Distribute Addenda regarding any changes in the Bid process or Contract Documents to all plan holders. Require verification from plan holders that Addenda have been received.

3.05 OPENING BIDS

A. Open bids submitted by Subcontractors and Suppliers for all elements of Work not included in the General Conditions at the time and location so indicated in the advertisement for Bid or as altered by addendum sent to all plan holders.

B. Require sealed Bids submitted to Engineer for all Work which the CMAR proposes to perform with their own resources. CMAR must also submit to Engineer a sealed Bid for this work to be opened at the same time that other Bids for this Work are to be opened. CMAR will be allowed to self-perform that Work for which they demonstrate best value in terms of cost, schedule and quality of Work.

C. Review all Bids submitted in the presence of the Owner and Engineer in a way that does not disclose the contents of the bid during the selection process to any entity other than the Owner, Engineer and CMAR.

D. Compare Bids received to the line item budget prepared for the Project prior to the opening of Bids in accordance with Paragraph 2.03.D. Resolve discrepancies or overlaps in Bid packages to eliminate duplications or the omission of elements of the Work that are not included in the General Conditions. Discuss each Bid received with the Owner and Engineer and recommend which Bid received will provide best value for the Owner.

E. Evaluate any substitutions or alternate Bids submitted by Bidders. Engineer will evaluate the substitute or alternate Bids to determine the technical merit and to determine that the modifications offered are consistent with the intent of the Contract Documents. The Engineer will determine if the substitution or alternate is acceptable. Substitutions will be evaluated in accordance with provisions of Section 01 33 00 "Submittal Procedures."

F. Owner will adjust the Guaranteed Maximum Price if the Owner requires the CMAR to contract with a Subcontractor or Supplier different from the entity submitting the Bid on which the Guaranteed Maximum Price is based. This adjustment will be made in the Guaranteed Maximum Price or by Change Order if the Guaranteed Maximum Price has already been established by Amendment.

G. Fulfill the contract requirements of any Subcontractor or Supplier that defaults in the performance of the Work or fails to execute a contract after being selected. The Work of this Subcontractor or Supplier may be performed directly by the CMAR or through a replacement Subcontractor or Supplier at the discretion of the CMAR and Owner. The Owner may direct the CMAR to obtain Bids for this Work if the cost proposed by the CMAR or substitute Subcontractor or Supplier for this Work differs from the line item estimate by more than ten percent of the line item amount. The CMAR will not be required to advertise for this Work as required in Paragraph 3.01.

H. Make all Bids public after the award of contracts or not later than 7 days after the date of the final selection of bids or proposals.

3.06 OPTIONS FOR COSTS EXCEEDING THE PROJECT BUDGET

A. Advise the Owner of market conditions, Bid issues, design issues or other factors which may have had an impact causing bid prices to be higher than estimated. Discuss opportunities for bringing the Project within budget with the Owner and Engineer to assist with making a decision on how to proceed.

B. Proceed with the Project if the ~~option described in the Agreement Section 9.02A 3.06.A.1 is selected~~ **GMP exceeds the Owner's Budget.** Provide CMAR services as described in these Contract Documents without additional compensation for Pre-construction Services or Procurement Services. Other fees and expenses related to the cost of Work will be adjusted in accordance with the new cost of Work. △1

C. Proceed with re-Bidding the Project ~~if the option described in the Agreement Section 9.02B is selected~~ **and ~~D~~ determine** if restructuring Bid packages may lead to lower Bid prices. Re-Bid selected original bid packages or restructured Bid packages for portions of the Work identified as having the potential to reduce the overall cost of construction to the Owner's Budget if re-Bid. Advise the Owner and Engineer of impact to the schedule resulting from re-Bidding portions of the Project. Provide CMAR Services for re-Bidding these portions of the Project without additional compensation. △1

D. **If the option described in the Agreement Section 9.02C is selected, ~~A~~ assist** Engineer and Owner in studies to revise the scope of the Project to bring the Project cost within the Owner's Budget ~~if the option described in the Agreement Section 9.02C is selected~~. Provide research and cost estimates to evaluate the potential cost savings of each proposed change in scope. Advise the Owner and Engineer of impact to the schedule resulting from re-Bidding portions of the Project and changes in Contract Time that will result from the changed scope of Work. Provide CMAR services for consultation in modifying the Project scope and rebidding these portions of the Project without additional compensation. △1

E. Revise the Project master schedule incorporating delays caused by actions taken to Project within the Owner's Budget.

4.00 CONSTRUCTION SERVICES

4.01 SERVICES INCLUDED

A. Provide administration and management of the Project, schedule Work and coordination of the Subcontractors and Suppliers, and manage construction Site safety and all other duties and obligations that would be customary for a General Contractor to construct the Project in accordance with the Contract Documents. Undertake and complete the Work through self-performed Work, Subcontractors Work and Suppliers Work in accordance with the Contract Documents. Maintain a competent, full-time staff at the Project at all times that Work is in preparation or progress on the Project and establish and implement on-Site organization and authority so that the Work on the Project may be accomplished on-time and within the Guaranteed Maximum Price.

B. Services not specifically identified as being included in the Cost of Work related to providing construction phase and post construction phase services.

4.02 TIME MANAGEMENT

A. Update the master schedule for the Project. Incorporate the schedules of Subcontractors and Suppliers into the master schedule and include allowances mutually agreeable to Owner, Engineer and CMAR for reasonable periods required for the review and approval of items by the Engineer and the Owner and for approvals of governmental authorities having jurisdiction over the Project. Prepare schedules in accordance with the requirements of Section 01 32 16 "Construction Progress Schedules."

B. Require each Subcontractor and Supplier to provide records for any materials that require long lead-time and to certify to the CMAR that such materials have been ordered for timely delivery to the Project. Review the sufficiency of the Subcontractor's and Suppliers' workforce and the number and types of equipment assigned and provided by each to the Project. Manage Subcontractors and Suppliers to maintain adequate workforce and equipment to complete the Project within the Contract Time.

C. Comply with the requirements for time management included in the Contract Documents.

4.03 COST MANAGEMENT

A. Provide a revised anticipated cash flow based on the construction schedule that is consistent with the Guaranteed Maximum Price. Provide an Earned Value Report each month with the Application for Payment in the format prescribed by the Engineer. Maintain and audit report based on the preliminary base line cost breakdown developed during Procurement Services to show initial estimate, bids received, bid selected, amount awarded and amount drawn against that amount each month. Show all funds used from contingency funds, and the current total for this amount.

B. Comply with the requirements for cost management included in the Contract Documents.

4.04 QUALITY MANAGEMENT

A. Manage the quality of construction on the Project so that the completed Project will meet the requirements of the Contract Documents. Inspect the Work of each Subcontractor or Supplier for conformance with the Contract Documents. Correct defective Work performed by the CMAR, Subcontractors or Suppliers. Report defective Work to the Engineer.

B. Comply with the requirements for quality management included in the Contract Documents.

4.05 WARRANTY CORRECTION WORK

A. Provide Services for the correction of defects in the Work during the 1 year warranty period and subsequent follow up on warranty items.

END OF SECTION

01 11 00 SUMMARY OF WORK

1.00 GENERAL

1.01 WORK INCLUDED

A. Construct Work as described in the Contract Documents.

1. Provide the materials, equipment, and incidentals required to make the Project completely operable.
2. Provide the labor, equipment, tools, and consumable supplies required for a complete Project.
3. Provide the civil, architectural, structural, mechanical, electrical, instrumentation and all other Work required for a complete and operable Project.
4. Test and place the completed Project in operation.
5. Provide the special tools, spare parts, lubricants, supplies, or other materials as indicated in Contract Documents for the operation and maintenance of the Project.
6. Install Owner provided products and place in operation.
7. Drawings and Specifications do not indicate or describe all of the Work required to complete the Project. Additional details required for the correct installation of selected products are to be provided by the Contractor and coordinated with the Engineer.

1.02 JOB CONDITIONS

A. The General Conditions, the Supplementary Conditions, and General Requirements apply to each Section of the Specifications.

B. Comply with all applicable state and local codes and regulations pertaining to the nature and character of the Work being performed.

1.03 WORK UNDER OTHER CONTRACTS

A. In the event that work under other contracts becomes necessary, Contractor is to coordinate effort for this additional work through the Engineer.

1.04 WORK BY OWNER

A. The Owner does not plan to perform Work that may impact construction scheduling, testing, and startup.

B. Owner will provide normal operation and maintenance of the existing facilities during construction, unless otherwise stated.

1.05 OWNER-SELECTED PRODUCTS

A. There are no products pre-selected by Owner for this project. It is anticipated that all products will be purchased by the CMAR.

1.06 OWNER-PROVIDED PRODUCTS

A. There are no products to be provided directly by Owner for this project. It is anticipated that all products will be purchased by the CMAR.

1.07 CONSTRUCTION OF UTILITIES

A. Utility companies or their contractors will provide new or enhanced utilities for this Project. Coordinate with others performing Work connected to this Project. Cost associated with providing permanent power will be included in the Cost of Work.

B. Power and Electrical Services:

1. Owner will provide permanent power connections for the Site through the power utility.
2. Cost for providing permanent power will be paid for by the Owner.
3. Contractor is required to coordinate and cooperate with others performing this Work.
4. Power company will provide the construction to the property line or other point shown on the Drawings.
5. Provide conduit, conductors, pull boxes, manholes, and other appurtenances for the installation of power cable between the property line and the transformer and between the transformer and the main power switch.
6. Test conductors in accordance with Section 01 40 00 "Quality Requirements" and coordinate with the power company to energize the system when ready.
7. Pay for temporary power, including but not limited to construction cost, meter connection, fees and permits.
8. When permanent power is available at the Site, the Contractor may use this power source in lieu of temporary power source he has been using.
    a. Notify Engineer and Owner of intent to use the permanent power source.
    b. Arrange with the power utility and pay the charges for connections and monthly charges for use of this power.
9. Pay for the temporary power consumed until the Project has been accepted as substantially complete.

C. Telephone Services:

1. Owner will provide permanent telephone service for the Site through the telephone utility.
2. Cost for providing permanent telephone service will be paid for by the Owner as a Cost of Work.
3. Coordinate and cooperate with others performing this Work.
4. Telephone company will provide construction to the property line or other point shown on the Drawings.
5. Provide conduit, cable, pull boxes, manholes, and other appurtenances for the installation of telephone cable between the property line or other point shown on the Drawings and the main telephone terminal board.

6. Test all cable and connections in accordance with Section 01 40 00 "Quality Requirements" and coordinate with the telephone company to ring out all lines on the system when ready.
7. Pay for temporary service, including, but not limited to construction cost, telephones and equipment, connection fees and permit.
8. When permanent telephone is available at the Site, the Contractor may use this system in lieu of temporary lines he has been using.
    a. Notify Engineer and Owner of intent to use the permanent telephone system.
    b. Arrange with the Telephone Utility and pay the charges for connections and monthly charges for use of this service.
9. Pay for the service until the Project has been accepted as substantially complete.

1.08 NOMINATED SUBCONTRACTOR

A. There are no Subcontractors nominated by Owner for this project. It is anticipated that all subcontract will be provided by the CMAR.

1.09 OCCUPANCY

A. As soon as any portion of the structure and equipment are ready for use, the Owner shall have the right to operate the portion upon written notice to the Contractor.

B. Testing of equipment and appurtenances including specified test periods, training, and startup does not constitute acceptance for operation.

C. Owner may accept the facility for continued use after startup and testing at the option of the Owner. If acceptance is delayed at the option of the Owner, shut down facilities per approved Operation and Maintenance procedures.

D. The execution of bonds is understood to indicate the consent of the surety to these provisions.

E. Provide an endorsement from the insurance carrier permitting occupancy of the structures and use of equipment during the remaining period of construction.

F. Conduct operations to insure the least inconvenience to the Owner and general public.

2.00 PRODUCTS

2.01 MATERIALS

A. Provide materials and products per the individual Sections of the Specifications.

END OF SECTION

01 29 00 PAYMENT PROCEDURES

1.00 GENERAL

1.01 WORK INCLUDED

A. Payments for Work shall conform to the provisions of the General Conditions, the Supplementary Conditions, the Agreement, and this Section.

B. Submit Applications for Payment at the prices indicated in the Agreement.

1. Prices for each item in the Agreement shall include but not be limited to cost for:
    a. Mobilization, demobilization, cleanup, bonds, and insurance.
    b. Professional services including but not limited to engineering and legal fees.
    c. The products to be permanently incorporated into the Project.
    d. The products consumed during the construction of the Project.
    e. The labor and supervision to complete the Project.
    f. The equipment, including tools, machinery, and appliances required to complete the Project.
    g. The field and home office administration and overhead costs related directly or indirectly to the Project.
    h. Any and all kinds, amount or class of excavation, backfilling, pumping or drainage, sheeting, shoring and bracing, disposal of any and all surplus materials, permanent protection of all overhead, surface or underground structures; removal and replacement of any poles, conduits, pipelines, fences, appurtenances and connections, cleaning up, overhead expense, bond, public liability and compensation and property damage insurance, patent fees, and royalties, risk due to the elements, and profits, unless otherwise specified.
2. Provide Work not specifically set forth as an individual payment item but required to provide a complete and functional system. These items are a subsidiary obligation of the Contractor and are to be included in the Contract Price.
3. Payment will be made for materials on hand.
    a. Store materials properly on-Site per Section 01 31 00 "Project Management and Coordination."
        1). Payment will be made for the invoice amount less the specified retainage.
        2). Provide invoices at the time materials are included on the materials-on-hand tabulation.
    b. Provide documentation of payment for materials on hand with the next payment request. Adjust payment to the amount actually paid if this differs from the invoice amount. Remove items from the materials on hand tabulation if this documentation is not provided so payment will not be made.
    c. Payment for materials on hand is provided for the convenience of the Contractor and does not constitute acceptance of the product.

4. The Work covered by progress payments becomes the property of the Owner at the time of payment.

1.02 SCHEDULE OF VALUES AND PAYMENTS

A. Submit a detailed Schedule of Values for the Work to be performed on the Project.

   1. Submit schedule within 10 days prior to submitting the first Application for Payment.
   2. Line items in the Agreement are to be used as line items in the schedule.
   3. Payment will be made on the quantity of Work completed per Contract Documents during the payment period and as measured per this Section.
      a. Payment amount is the Work quantity measured multiplied by the unit prices for that line item in the Agreement.
      b. Payment on a unit price basis will not be made for Work outside finished dimensions shown in the Contract Documents.
      c. Partial payments will be made for lump sum line items in the Agreement.
         1). Lump sum line items in the Agreement are to be divided into smaller unit prices to allow more accurate determination of the percentage of the item that has been completed.
            a). Provide adequate detail to allow more accurate determination of the percentage of Work completed for each item.
            b). Provide prices for items that do not exceed $50,000.00. An exception may be made for equipment packages that cannot be subdivided into units or subassemblies.
            c). Separate product costs and installation costs.
               (1). Product costs include cost for product, delivery and unloading costs, royalties and patent fees, taxes, and other cost paid directly to the Subcontractor or Supplier.
               (2). Installation costs include cost for the supervision, labor and equipment for field fabrication, erection, installation, startup, initial operation and Contractor's overhead and profit.
            d). Lump sum items may be divided into an estimated number of units.
               (1). The estimated number of units times the cost per unit must equal the lump sum amount for that line item.
               (2). Contractor will receive payment for all of the lump sum line item.
            e). Include a directly proportional amount of Contractor's overhead and profit for each line item.
            f). Divide principal subcontract amounts into an adequate number of line items to allow determination of the percentage of Work completed for each item.
         2). These line items may be used to establish the value of Work to be added or deleted from the Project.

      3). Correlate line items with other administrative schedules and forms:
         a). Progress Schedule.
         b). List of Subcontractors.
         c). Schedule of allowances.
         d). Schedule of alternatives.
         e). List of products and principal Suppliers.
         f). Schedule of Submittals.
      4). Costs for mobilization shall be listed as a separate line item and shall be actual cost for:
         a). Bonds and insurance.
         b). Transportation and setup for equipment.
         c). Transportation and/or erection of all field offices, sheds and storage facilities.
         d). Salaries for preparation of submittals required before the first Application for Payment.
         e). Salaries for field personnel assigned to the Project related to the mobilization of the Project.
            (1). Mobilization may not exceed 3 percent of the total Contract Price. Cost for mobilization may be submitted only for Work completed.
      5). The sum of all values listed in the schedule must equal the total Contract amount.
   4. Submit a schedule indicating the anticipated schedule of payments to be made by the Owner. Schedule shall indicate:
      a. The Application for Payment number.
      b. Date the request is to be submitted.
      c. Anticipated amount of payment to be requested.
   5. Update the Schedule of Values quarterly or more often if necessary to provide a reasonably accurate indication of the funds that the Owner will need to have available to make payment to the Contractor for the Work performed.

B. Provide written approval of the Schedule of Values, Application for Payment form, and method of payment by the Surety Company providing performance and payment bonds prior to submitting the first Application for Payment. Payment will not be made without this approval.

1.03 PAYMENT PROCEDURES FOR CONSTRUCTION MANAGER AT RISK SERVICES

A. Submit Applications for Payment per the procedures indicated in Section 01 33 00 “Submittal Procedures.” Payment for Construction Manager at Risk services for Pre-construction Services, Procurement Services and Construction Services are to be based the earned value of the lump sum fee. Submit a Schedule of Values in the Application for Payment format to be used. This Schedule of Values is to be based on the detailed cost breakdown submitted with the Proposal.

B. Submit Applications for Construction Manager at Risk fees no more frequently than monthly. Show the earned value as the percent complete for each task in the Schedule of Values for Construction Manager Fees.

1.04 PAYMENT PROCEDURES FOR CONSTRUCTION

A. Submit Applications for Payment per the procedures indicated in Section 01 33 00 "Submittal Procedures." Submit a Schedule of Values in the Application for Payment format to be used.

B. Applications for Payment may be submitted on a pre-printed form as indicated in Section 01 31 13 13 "Forms" or may be generated by computer. Computer generated payment requests must have the same format and information indicated in the pre-printed form and be approved by the Engineer.

1. Indicate the total Contract Price and the Work completed to date on the Tabulation of Values for Original Contract Performed (Attachment "A".)
2. Include only approved Change Order items in the Tabulation of Extra Work on Approved Change Orders (Attachment "B".)
3. List all materials on hand that are presented for payment on the Tabulation of Materials on Hand (Attachment "C".) Once an item has been entered on the tabulation it is not to be removed.
4. Include the Project Summary Report (Attachment "D") with each Application for Payment. Data included in the Project Summary Report are to be taken from the other tabulations. Include a completed summary as indicated in with each Applications for Payment submitted.
    a. Number each application sequentially and indicate the payment period.
    b. Show the total amounts for value of original Contract performed, extra work on approved Change Orders, and materials on hand on the Project Summary Report. Show total amounts that correspond to totals indicated on the attached tabulation for each.
    c. Note the number of pages in tabulations in the blank space on the Project Summary Report to allow a determination that all sheets have been submitted.
    d. Execute Contractor's certification by the Contractor's agent of authority and notarize for each Application for Payment.
5. Do not alter the Schedule of Values and the form for the submission of requests without the written approval of the Engineer once these have been approved by the Engineer.
6. Final payment requires additional procedures and documentation per Section 01 70 00 "Execution and Closeout Requirements."

C. Progress payments shall be made as the Work progresses on a monthly basis.

1. End the payment period on the day indicated in the Agreement and submit an Application for Payment for Work completed and materials received since the end of the last payment period.
2. At the end of the payment period, submit a draft copy of the Application for Payment for that month to the Owner. Agreement is to be reached on:
    a. The percentage of Work completed for each lump sum item.
    b. The quantity of Work completed for each unit price item.
    c. The percentage of Work completed for each approved Change Order item.
    d. The amount of materials on hand.
3. On the basis of these agreements the Contractor is to prepare a final copy of the Application for Payment and submit it to the Owner for approval.
4. The Engineer will review the payment request and if appropriate will recommend payment of the request to the Owner.

D. Provide a revised and up-to-date Progress Schedule per Section 01 32 16 "Construction Progress Schedules" with each Application for Payment.

E. Provide Project photographs per Section 01 32 33 "Photographic Documentation" with each Application for Payment.

1.05 ALTERNATES AND ALLOWANCES

A. Include amounts for specified Alternate Work in the Agreement in accordance with Section 01 23 10 "Alternates and Allowances."

B. Include amounts for specified Allowances for Work in the Agreement in accordance with 01 23 10 "Alternates and Allowances."

1.06 MEASUREMENT PROCEDURES

A. Measure the Work described in the Agreement for payment. Payment will be made only for the actual measured and/or computed length, area, solid contents, number and weight, unless otherwise specifically provided. No extra or customary measurements of any kind will be allowed.

END OF SECTION

01 31 00 PROJECT MANAGEMENT AND COORDINATION

1.00 GENERAL

1.01 WORK INCLUDED

A. Furnish equipment, manpower, products, and other items necessary to complete the Project with an acceptable standard of quality and within the Contract Time. Construct Project in accordance with current safety practices.

B. Manage Site to allow access to Site and control construction operations.

C. Provide labor, materials, equipment and incidentals necessary to construct temporary facilities to provide and maintain control over environmental conditions at the Site. Remove temporary facilities when no longer needed.

D. Remove temporary controls at the end of the Project.

1.02 QUALITY ASSURANCE

A. Employ competent workmen, skilled in the occupation for which they are employed. Provide Work meeting quality requirements of the Contract Documents as determined by the Engineer.

B. Remove defective Work from the Site immediately unless provisions have been made and approved by the Engineer to allow repair of the product at the Site. Clearly mark the Work as "defective" until it is removed or allowable repairs have been completed.

1.03 SUBMITTALS

A. Provide submittals in accordance with Section 01 33 00 “Submittal Procedures”:

1. Provide copies of Supplier’s printed storage instructions prior to furnishing materials or products and installation instructions prior to beginning the installation. Maintain one copy of these documents at the Site until the Project is complete. Incorporate this information into submittals.
2. Incorporate field notes, sketches, recordings, and computations made by the Contractor in record drawings.

1.04 STANDARDS

A. Perform Work to comply with local, State and Federal ordinances and regulations.

1.05 PERMITS

A. The Owner will obtain construction permits and licenses for highway and railroad crossings and other permits

B. Retain copies of permits and licenses at the Site and observe and comply with all regulations and conditions of the permit or license, including additional insurance requirements.

C. Obtain and pay for all other necessary permits including any and all necessary highway, street and road permits for transporting pipe and/or heavy equipment necessary for construction of the Project.

D. Obtain and pay for other permits necessary to conduct any part of the Work.

E. Arrange for inspections and certification by agencies having jurisdiction over the Work.

F. Make arrangements with private utility companies and pay for fees associated with obtaining services, or for inspection fees.

1.06 COORDINATION

A. Coordinate the Work of various trades having interdependent responsibilities for installing, connecting to, and placing equipment in service.

B. Coordinate requests for substitutions to provide compatibility of space, operating elements, effect on the Work of other trades, and on the Work scheduled for early completion.

C. Coordinate the use of Project space and the sequence of installation of equipment, walks, mechanical, electrical, plumbing, or other Work that is indicated diagrammatically on the Drawings.

1. Follow routings shown for tubes, pipes, ducts, conduits, and other items as closely as practical, with due allowance for available physical space.
2. Utilize space efficiently to maximize accessibility for Owner's maintenance and repairs.
3. Schematics are diagrammatic in nature. Adjust routing of piping, ductwork, utilities, and location of equipment as needed to resolve spatial conflicts between the various trades. Document changes in the indicated routings on the record drawings.

D. Conceal ducts, pipes, wiring, and other non-finish items within construction in finished areas, except as otherwise shown. Coordinate locations of concealed items with finish elements.

E. Where installation of one part of the Work is dependent on installation of other components, either before or after its own installation, schedule construction activities in sequence required to obtain best results.

F. Make adequate provisions to accommodate items scheduled for later installation, including:

1. Accepted alternates.
2. Installation of products purchased with allowances.
3. Work by others.
4. Owner-supplied, Contractor-installed items.

G. Sequence, coordinate, and integrate the various elements of mechanical, electrical, and other systems, materials, and equipment. Comply with the following requirements:

1. Coordinate mechanical and electrical systems, equipment, and materials installation with other components.
2. Verify all dimensions by field measurements.
3. Arrange for chases, slots, and openings during progress of construction.
4. Coordinate the installation of required supporting devices and sleeves to be set in poured-in-place concrete and other structural components as they are constructed.

5. Install systems, materials, and equipment as permitted by codes to provide the maximum headroom possible where mounting heights are not detailed or dimensioned.
6. Coordinate the connection of systems with exterior underground and overhead utilities and services. Comply with the requirements of governing regulations, franchised service companies, and controlling agencies. Provide required connection for each service.
7. Install systems, materials, and equipment to conform with approved submittal data, including coordination drawings, to the greatest extent possible. Conform to arrangements indicated by the Contract Documents, recognizing that portions of the Work are shown only in diagrammatic form. Adjust routing of piping, ductwork, utilities, and location of equipment as needed to resolve spatial conflicts between the various trades at no additional cost. Document changes in the indicated routings on the record drawings.
8. Install systems, materials, and equipment level and plumb, parallel and perpendicular to structure's surfaces.
9. Install systems, materials, and equipment to facilitate servicing, maintenance, and repair or replacement of components. As much as practical, connect for ease of disconnecting, with minimum of interference with other installations. Extend grease fittings to accessible locations.
10. Install systems, materials, and equipment giving right-of-way priority to systems required to be installed at a specified slope.

1.07 SAFETY REQUIREMENTS

A. Assume sole responsibility for safety at the Site. Protect the safety and welfare of persons at the Site.

B. Provide safe access to move through the Site. Provide and maintain barricades, guard rails, covered walkways, and other protective devices to warn and protect from hazards at the Site.

C. Comply with latest provisions of the Occupational Health and Safety Administrations and other regulatory agencies in performing Work.

D. Cooperate with accident investigations related to the Site. Provide two copies of all reports prepared concerning accidents, injury, or death on the Site to the Engineer as Record Data per Section 01 33 00 "Submittal Procedures."

E. A risk management program emergency response map and narrative to access sites containing chlorine gas will be distributed during the pre-construction conference. The Contractor's personnel will be required to abide by the plan in the event of an emergency.

1.08 CONTRACTOR'S USE OF SITE

A. Limit the use of Site for Work and storage to those areas designated on the Drawings or approved by the Engineer. Coordinate the use of the premises with the Engineer.

B. Repair or correct any damage to existing facilities, including contamination, caused by the Contractor's personnel, visitors, materials, or equipment.

C. Do not permit alcoholic beverages or illegal substances on the Site. Do not allow persons under the influence of alcoholic beverages or illegal substances to enter or remain on the Site at any time. Persons on Site under the influence of alcoholic beverages or illegal substances will be permanently prohibited from returning to the Site. Criminal or civil penalties may also apply.

D. Park construction equipment in designated areas only and provide spill control measures as discussed in Paragraph 1.23 "Pollution Control."

E. Park employees' vehicles in designated areas only.

F. Obtain written permission of the Owner before entering privately-owned land outside of the Owner's property, rights-of-way, or easements.

G. Do not allow the use of loud radios, obnoxious, vulgar or abusive language, or sexual harassment in any form. These actions will cause immediate and permanent removal of the offender from the premises. Criminal or civil penalties may apply.

H. Require Workers to wear clothing that is inoffensive and meets safety requirements. Do not allow sleeveless shirts, shorts, exceedingly torn, ripped or soiled clothing to be worn on the Project.

I. Do not allow firearms or weapons of any sort to be brought on to the Site under any conditions. No exception is to be made for persons with concealed handgun permits. Remove any firearms or weapons and the person possessing these firearms or weapons permanently and immediately from the Site.

1.09 POINTS OF ACCESS TO THE SITE

A. Restrict entry into Site to points where the easements cross state and county roads and highways or other publicly owned roads and streets. Keep operations within the easement.

B. Use state, county, or city roadways for construction traffic only with written approval of the appropriate representatives of each entity. State, county, or city roadways may not all be approved for construction traffic. Obtain written approval to use state, county, city or private roads to deliver pipe and/or heavy equipment to the Site. Copies of the written approvals must be furnished to the Owner as Record Data before Work begins. No additional compensation will be paid because the Contractor is unable to gain access to the easement from public roadways. Damage to existing public roads will be repaired and the roads maintained according to agreements with local authorities at no additional costs to the Owner. Improvements to certain roads will be included in the Project.

C. Maintain access to the facilities at all times. Do not obstruct roads, pedestrian walks, or access to the various buildings, structures, stairways, or entrances. Provide safe temporary walks or other structures to allow access for normal operations during construction.

D. Provide adequate and safe access for inspections. Leave ladders, bridges, scaffolding and protective equipment in place until inspections have been completed. Construct additional safe access if required for inspections.

E. Provide security at the construction Site as necessary to protect against vandalism and loss by theft.

F. Maintain security of the Site and access leading to it.

1. Close gates and keep locked.
2. Obtain permission of any landowners whose property must be crossed in gaining access to the Site.
3. Install a gate lock consisting of a chain with two locks. Give one lock and key to the landowner. Use one lock for the Contractor, Engineer and Owner. Provide keys to the Contractor's lock to Owner and Engineer.
4. At the end of the Project, remove the Contractor's lock from the assembly or leave Owner's lock on gate and give all keys to the Owner.

1.10 PROPERTY PROVISIONS

A. Make adequate provisions to maintain the flow of storm sewers, drains and water courses encountered during the construction. Restore structures which may have been disturbed during construction to their original position as soon as construction in the area is completed.

B. Protect trees, fences, signs, poles, guy wires, and all other property unless their removal is authorized. Restore any property damaged to equal or better condition per Paragraph 1.11.

C. Provide temporary fencing, with gates, to restrain livestock in areas where livestock are pastured unless the Contractor makes satisfactory arrangements with the property owner and/or tenant. Install temporary fence on the easement lines and removed after the trench has been backfilled. Pay damages for losses resulting from failure to maintain such barriers or failure of barriers to exclude livestock. Install temporary fencing on any tract in order to contain construction activities within easement limits if directed by the Owner.

1.11 PROTECTION OF EXISTING STRUCTURES AND UTILITIES

A. The Drawings show existing piping, valves, manholes, electrical conduits, utility poles, and other facilities based on information from available records. Examine the Site and review the available information concerning the Site.

   1. Verify the type, size and location of all existing piping, valves, electrical conduit, telephone cable, and other utilities in the construction area prior to preparation of pipe Shop Drawings. Advise the Engineer of any utilities not shown or incorrectly shown.
   2. Verify the type size and location of streets, driveways, fences, drainage structures, sidewalks, curbs, and gutters. Verify the elevations of the structures adjacent to excavations. Report discrepancies between these elevation and elevations shown on the Drawings to the Engineer before beginning construction.

B. Determine if existing structures, poles, piping, or other utilities at excavations will require relocation or replacement. Prepare a Plan of Action per Section 01 35 00 “Special Procedures.” Coordinate Work with Engineer, local utility company and others. Include cost of demolition and replacement, restoration or relocation of these structures in the Contract Price.

C. Protect buildings, utilities, street surfaces, driveways, sidewalks, curb and gutter, fences, wells, drainage structures, piping, valves, manholes, electrical conduits, and other systems or structures unless they are shown to be replaced or relocated on the Drawings. Restore damage to items to be protected to the satisfaction of the Engineer, utility owner or governing city without additional compensation from the Owner.

D. Carefully support and protect all structures and/or utilities so that there will be no failure or settlement where excavation or demolition endangers adjacent structures and utilities. Do not take existing utilities out of service unless shown in the Contract Documents or approved by the Engineer. Notify and cooperate with the utility owner if it is necessary to move services, poles, guy wires, pipelines or other obstructions. Include the cost of relocation of existing utilities in the Contract Price.

1.12 DISRUPTION TO SERVICES / CONTINUED OPERATIONS

A. Existing facilities are to continue in service as usual during the construction unless noted otherwise. Owner or utilities must be able to operate and maintain the facilities. Disruptions to existing utilities, piping, process piping, or electrical services shall be kept to a minimum.

1. Do not restrict access to critical valves, operators, or electrical panels.
2. Do not store materials or products inside structures.
3. Limit operations to the minimum amount of space needed to complete the specified Work.
4. Maintain storm sewers and sanitary sewers in service at all times. Provide temporary service around the construction or otherwise construct the structure in a manner that the flow is not restricted.

B. Provide a Plan of Action in accordance with Section 01 35 00 "Special Procedures" if facilities must be taken out of operation.

1.13 FIELD MEASUREMENTS

A. Perform complete field measurements for products required to fit existing conditions prior to purchasing products or beginning construction.

B. Verify property lines, control lines, grades, and levels indicated on the Drawings.

C. Verify pipe class, equipment capacities, existing electrical systems and power sources for existing conditions.

D. Check Shop Drawings and indicate the actual dimensions available where products are to be installed.

E. Include field measurements in record drawings as required in Section 01 31 13 "Project Coordination."

1.14 REFERENCE DATA AND CONTROL POINTS

A. The Engineer will provide the following control points:

1. Base line or grid reference points for horizontal control.
2. Benchmarks for vertical control.
3. Designated control points may be on an existing structure or monument.

B. Locate and protect control points prior to starting the Work and preserve permanent reference points during construction. Do not change or relocate points without prior approval of the Engineer. Notify Engineer when the reference point is lost, destroyed, or requires relocation. Replace Project control points on the basis of the original survey.

C. Provide complete engineering layout of the Work needed for construction.

   1. Provide competent personnel. Provide equipment including accurate surveying instruments, stakes, platforms, tools, and materials.

   2. Provide surveying with accuracy meeting the requirements established for Category 5 Construction Surveying as established in the Manual of Practice of Land Surveying in Texas published by the Texas Society of Professional Surveyors, latest revision.

   3. Record Data and measurements per standards.

1.15 DELIVERY AND STORAGE

A. Deliver products and materials to the Site in time to prevent delays in construction.

B. Deliver packaged products to Site in original undamaged containers with identifying labels attached. Open cartons as necessary to check for damage and to verify invoices. Reseal cartons and store until used. Leave products in packages or other containers until installed.

C. Deliver products that are too large to fit through openings to the Site in advance of the time enclosing walls and roofs are erected. Set in place, raised above floor on cribs.

D. Assume full responsibility for the protection and safekeeping of products stored at the Site.

E. Store products at locations acceptable to the Engineer and to allow Owner access to maintain and operate existing facilities.

F. Store products in accordance with the Supplier's storage instructions immediately upon delivery. Leave seals and labels intact. Arrange storage to allow access for maintenance of stored items and for inspection. Store unpacked and loose products on shelves, in bins, or in neat groups of like items.

G. Obtain and pay for the use of any additional storage areas as needed for construction. Store products subject to damage by elements in substantial weather-tight enclosures or storage sheds. Provide and maintain storage sheds as required for the protection of products. Provide temperature, humidity control and ventilation within the ranges stated in the Supplier's instructions. Remove storage facilities at the completion of the Project.

H. Protect the pipe interior. Keep all foreign materials such as dirt, debris, animals, or other objects out of the pipe during the Work. Cap or plug ends of installed pipe in an approved manner when pipe is not being installed. Wash out pipe sections that become contaminated before continuing with installation. Take precautions to prevent the pipe from floating or moving out of the proper position during or after laying operations. Immediately correct any pipe that moves from its correct positions.

I. Provide adequate exterior storage for products that may be stored out-of-doors.

   1. Provide substantial platforms, blocking, or skids to support materials and products above ground; slope to provide drainage. Protect products from soiling or staining.

2. Cover products subject to dislocation or deterioration from exposure to the elements, with impervious sheet materials. Provide ventilation to prevent condensation below covering.
3. Store loose, granular materials on clean, solid surfaces, on rigid sheet materials, or in large enough quantities to prevent mixing with foreign matter.
4. Provide surface drainage to prevent erosion and ponding of water.
5. Prevent mixing of refuse or chemically injurious materials or liquids with stored materials.
6. Pipes and conduits stored outdoors are to have open ends sealed to prevent the entrance of dirt, moisture, and other injurious materials. Protect PVC pipe from ultraviolet light exposure.
7. Store light weight products to prevent wind damage.

J. Protect and maintain mechanical and electrical equipment in storage.

   1. Provide Supplier's service instructions on the exterior of the package.
   2. Service equipment on a regular basis as recommended by the Supplier. Maintain a log of maintenance services. Submit the log as Record Data at the completion of the Project.
   3. Provide power to and energize space heaters for all equipment for which these devices are provided.
   4. Provide temporary enclosures for all electrical equipment, including electrical systems on mechanical devices. Provide and maintain heat in the enclosures until equipment is energized.

K. Maintain storage facilities. Inspect stored products on a weekly basis and after periods of severe weather to verify that:

   1. Storage facilities continue to meet specified requirements.
   2. Supplier's required environmental conditions are continually maintained.
   3. Surfaces of products exposed to the elements are not adversely affected.

L. Replace any stored item damaged by inadequate protection or environmental controls.

M. Payment may be withheld for any products not properly stored.

1.16 BLASTING

A. Blasting for excavations will be allowed with an approved blasting plan.

   1. The Contractor shall assume responsibility for any damage resulting from blasting operations and restore any damaged area to its original condition.
   2. The Contractor shall provide provisions in insurance policies specifically covering blasting operations.
   3. Blasting shall not be permitted within 500 feet of any concrete that has been placed in any structure at the Site. Once any reinforced concrete has been placed on the site,

reduced blasting effort will be required and described in the blasting plan. Vibration monitoring of existing structures may be required.

4. Blasting shall be in strict compliance with the local, State and Federal ordinances, laws and safety regulations and with written approval of the local agency of jurisdiction.

1.17 ARCHAEOLOGICAL REQUIREMENTS

A. Cease operations immediately and contact the Owner for instructions if an historical or archaeological find is made during construction.

B. Conduct all construction activities to avoid adverse impact on the Sites where significant historical or archaeological sites have been identified at the Site.

   1. Obtain details for working in these areas.
   2. Maintain confidentiality regarding the Site.
   3. Adhere to the requirements of the Texas Historical Commission.

C. Do not disturb archaeological sites.

   1. Obtain the services of a qualified archaeological specialist to instruct construction personnel on how to identify and protect archaeological finds on an emergency basis.
   2. Coordinate activities to permit archaeological work to take place within the area.
      a. Attempt to archaeologically clear areas needed for construction as soon as possible.
      b. Provide a determination of priority for such areas.

D. Assume responsibility for any unauthorized destruction that might result to such sites by construction personnel, and pay all penalties assessed by the State or Federal agencies for non-compliance with these requirements.

E. Contract Time will be modified to compensate for delays caused by such archaeological finds. No additional compensation shall be paid for delays.

1.18 STORM WATER POLLUTION CONTROL

A. Comply with the current requirements of TPDES General Permit No. TXR15000 (General Storm Water Permit) set forth by the Texas Commission on Environmental Quality for the duration of the Project:

   1. Develop a Storm Water Pollution Prevention Plan meeting all requirements of the General Storm Water Permit.
   2. Submit of a Notice of Intent to the Texas Commission on Environmental Quality.
   3. Develop and implement appropriate Best Management Practices as established by local agencies of jurisdiction.
   4. Provide all monitoring and/or sampling required for reporting to the Texas Commission on Environmental Quality
   5. Submit reports to the Texas Commission on Environmental Quality as required as a condition of the permit

6. Submit copies of the reports to the Engineer as Record Data in accordance with Section 01 33 00 "Submittal Procedures."
7. Retain copies of these documents on-Site at all times for review and inspection by the Owner or regulatory agencies. Post a copy of the permit as required by regulations.
8. Pay all costs associated with complying with the provisions of the General Storm Water Permit. Assume sole responsibility for implementing, updating, and modifying the General Storm Water Permit per regulatory requirements the Storm Water Pollution Prevention Plan and Best Management Practices.

B. Use forms required by the Texas Commission on Environmental Quality to file the Notice of Intent. Submit the Notice of Intent at least 2 days prior to the start of construction. Develop the Storm Water Pollution Prevention Plan prior to submitting the Notice of Intent. Provide draft copies of the Notice of Intent, Storm Water Pollution Prevention Plan, and any other pertinent Texas Commission on Environmental Quality submittal documents to Owner for review prior to submittal to the Texas Commission on Environmental Quality.

C. Return any property disturbed by construction activities to either specified conditions or pre-construction conditions as set forth in the Contract Documents. Provide an overall erosion and sedimentation control system that will protect all undisturbed areas and soil stockpiles/spoil areas. Implement appropriate Best Management Practices and techniques to control erosion and sedimentation and maintain these practices and techniques in effective operating condition during construction. Permanently stabilize exposed soil and fill as soon as practical during the Work.

D. Assume sole responsibility for the means, methods, techniques, sequences, and procedures for furnishing, installing, and maintaining erosion and sedimentation control structures and procedures and overall compliance with the General Storm Water Permit. Modify the system as required to effectively control erosion and sediment.

E. Retain copies of reports required by the General Storm Water Permit for 3 years from date of final completion.

1.19 POLLUTION CONTROL

A. Prevent the contamination of soil, water or atmosphere by the discharge of noxious substances from construction operations. Provide adequate measures to prevent the creation of noxious air-borne pollutants. Prevent dispersal of pollutants into the atmosphere. Do not dump or otherwise discharge noxious or harmful fluids into drains or sewers, nor allow noxious liquids to contaminate public waterways in any manner.

B. Provide equipment and personnel and perform emergency measures necessary to contain any spillage.

1. Contain chemicals in protective areas and do not dump on soil. Dispose of such materials at off-Site locations in an acceptable manner.
2. Excavate contaminated soil and dispose at an off-Site location if contamination of the soil does occur. Fill resulting excavations with suitable backfill and compact to the density of the surrounding undisturbed soil.
3. Provide documentation to the Owner which states the nature and strength of the contaminant, method of disposal, and the location of the disposal site.

4. Comply with local, State and Federal regulations regarding the disposal of pollutants.

C. Groundwater or run-off water which has come into contact with noxious chemicals, sludge, or sludge-contaminated soil is considered contaminated. Contaminated water must not be allowed to enter streams or water courses, leave the Site in a non-contained form or enter non-contaminated areas of the Site.

1. Pump contaminated water to holding ponds constructed by the Contractor for this purpose, or discharge to areas on the interior of the Site, as designated by the Engineer.
2. Construct temporary earthen dikes or take other precautions and measures as required to contain the contaminated water and pump to a designated storage area.
3. Wash any equipment used for handling contaminated water or soil within contaminated areas three times with uncontaminated water prior to using such equipment in an uncontaminated area. Dispose of wash water used to wash such equipment as contaminated water.

1.20 EARTH CONTROL

A. Place and excess soil, spoil materials and other earth not utilized in the compacted fill at the time of generation in approved stockpile locations or approved waste areas. Control stock pile material to eliminate interference with Contractor and Owner's operations.

1.21 MANAGEMENT OF WATER

A. Manage water resulting from rains or ground water at the Site. Maintain trenches and excavations free of water at all times.

B. Lower the water table in the construction area by acceptable means if necessary to maintain a dry and workable condition at all times. Provide drains, sumps, casings, well points, and other water control devices as necessary to remove excess water.

C. Provide continuous operation of water management actions. Maintain standby equipment to provide proper and continuous operation for water management.

D. Ensure that water drainage does not damage adjacent property. Divert water into the same natural watercourse in which its headwaters are located, or other natural stream or waterway as approved by the Owner. Assume responsibility for the discharge of water from the Site.

E. Remove the temporary construction and restore the Site in a manner acceptable to the Engineer and to match surrounding material at the conclusion of the Work.

1.22 CLEANING DURING CONSTRUCTION

A. Provide positive methods to minimize raising dust from construction operations and provide positive means to prevent air-borne dust from disbursing into the atmosphere. Control dust and dirt from demolition, cutting, and patching operations.

B. Clean the Project as Work progresses and dispose of waste materials, keeping the Site free from accumulations of waste or rubbish. Provide containers on the Site for waste collection. Do not allow waste materials or debris to blow off of the Site. Control dust from waste materials. Transport waste materials with as few handlings as possible.

C. Comply with codes, ordinances, regulations, and anti-pollution laws. Do not burn or bury waste materials. Remove waste materials, rubbish and debris from the Site and legally dispose of these at public or private dumping areas.

1.23 MAINTENANCE OF ROADS, DRIVEWAYS, AND ACCESS

A. Maintain adjacent public roads and streets in a manner that is suitable for safe operations of public vehicles during all phases of construction unless the Owner approves a street closing. Submit a written request for Owner's approval of a street closing. The request shall state:

1. The reason for closing the street.
2. How long the street will remain closed.
3. Procedures to be taken to maintain the flow of traffic.
4. Do not close public roads overnight.

B. Construct temporary detours, including by-pass roads around construction, with adequately clear width to maintain the free flow of traffic at all times. Maintain barricades, signs, and safety features around the detour and excavations.

C. Maintain road and driveway access to occupied buildings. Coordinate temporary closures or blockage with property owners, utilities, emergency service providers, Owner and Engineer. Property owners must be notified a minimum of 2 weeks or other time established by Owner prior to closure. Limit the time road or driveways are out of service to that established in the Contract Documents.

D. Maintain barricades, signs, and safety features around the Work in accordance with all provisions of the latest edition of the Manual on Uniform Traffic Control Devices (MUTCD.)

E. Assume responsibility for any damage resulting from construction along roads or drives.

1.24 CUTTING AND PATCHING

A. Perform cutting, fitting, and patching required to complete the Work or to:

1. Uncover Work to provide for installation of new Work or the correction of defective Work.
2. Provide routine penetrations of non-structural surfaces for installation of mechanical, electrical, and plumbing work.
3. Uncover Work that has been covered prior to observation by the Engineer.

B. Submit written notification to the Engineer in advance of performing any cutting which affects:

1. Work of any other contractors or the Owner.
2. Structural integrity of any structure or system of the Project.
3. Integrity or effectiveness of weather exposed or moisture resistant structure or systems.
4. Efficiency, operational life, maintenance, or safety of any structure or system.
5. Appearance of any structure or surfaces exposed occasionally or constantly to view.

C. The notification shall include:

1. Identification of the Project.
2. Location and description of affected Work.
3. Reason for cutting, alteration, or excavation.
4. Effect on the work of any separate contractor or Owner.
5. Effect on the structural or weatherproof integrity of the Project.
6. Description of proposed Work, including:
   a. Scope of cutting, patching, or alteration.
   b. Trades that will perform the Work.
   c. Products proposed for use.
   d. Extent of refinishing to be performed.
   e. Cost proposal, when applicable.
7. Alternatives to cutting and patching.
8. Written authorization from any separate contractor whose work would be affected.
9. Date and time Work will be uncovered or altered.

D. Examine the existing conditions, including structures subject to damage or to movement during cutting or patching.
   1. Inspect conditions affecting installation of products or performance of the Work after uncovering the Work.
   2. Provide a written report of unacceptable or questionable conditions to the Engineer. The Contractor shall not proceed with Work until Engineer has provided further instructions. Beginning Work will constitute acceptance of existing conditions by the Contractor.

E. Protect the structure and other parts of the Work and provide adequate support to maintain the structural integrity of the affected portions of the Work. Provide devices and methods to protect adjacent Work and other portions of the Project from damage. Provide protection from the weather for portions of the Project that may be exposed by cutting and patching Work.

F. Execute cutting and demolition by methods which will prevent damage to other Work, and will provide proper surfaces to receive installation of repairs.

G. Execute fitting and adjustment of products to provide a finished installation to comply with specified products, functions, tolerances, and finishes.

H. Cut, remove, and legally dispose of selected mechanical equipment, components, and materials as indicated, including but not limited to, the removal of mechanical piping, heating units, plumbing fixtures and trim, and other mechanical items made obsolete by the modified Work.

I. Restore Work which has been cut or removed. Install new products to provide completed Work per the Contract Documents.

J. Fit Work air-tight to pipes, sleeves, ducts, conduit, and other penetrations through the surfaces. Where fire rated separations are penetrated, fill the space around the pipe or insert with materials with physical characteristics equivalent to fire resistance requirements of penetrated surface.

K. Patch finished surfaces and building components using new products specified for the original installation.

L. Refinish entire surfaces as necessary to provide an even finish to match adjacent finishes:

   1. For continuous surfaces, refinish to the nearest intersection.
   2. For an assembly, refinish the entire unit.

1.25 PRELIMINARY OCCUPANCY

A. Owner may deliver, install and connect equipment, furnishings, or other apparatus in buildings or other structures. These actions do not indicate acceptance of any part of the building or structure and does not affect the start of warranties or correction periods.

B. Protect the Owner's property after installation is complete.

C. Owner or Engineer may use any product for testing or determine that the product meets the requirements of the Contract Documents. This use does not constitute acceptance by either the Owner or Engineer. These actions do not indicate acceptance of any part of the product and does not affect the start of warranties or correction periods.

1.26 INITIAL MAINTENANCE

A. Maintain equipment until the Project is accepted by the Owner. Ensure that mechanical equipment is properly maintained as recommended by the Supplier.

B. Prior to acceptance of equipment, provide maintenance and startup services per Section 01 75 00 "Starting and Adjusting."

C. Remove and clean screens and strainers in piping systems.

D. Clean insects from intake louver screens.

2.00 PRODUCTS

2.01 MATERIALS

A. Provide materials in accordance with the requirements of the individual Sections of the Specifications.

3.00 EXECUTION

3.01 PERFORMANCE OF THE WORK

A. Perform the Work per the Supplier's published instructions. Do not omit any preparatory step or installation procedure unless specifically exempted or modified by Field Order.

END OF SECTION

01 31 13 PROJECT COORDINATION

1.00 GENERAL

1.01 WORK INCLUDED

A. Administer Contract requirements to construct the Project. Provide documentation per the requirements of this Section. Provide information as requested by the Engineer, Engineer, or Owner.

1.02 SUBMITTALS

A. Provide submittals in accordance with Section 01 33 00 "Submittal Procedures."

1.03 COMMUNICATION DURING THE PROJECT

A. The Engineer is to be the first point of contact for all parties on matters concerning this Project.

B. The Engineer will coordinate correspondence concerning:

1. Submittals, including Applications for Payment.
2. Clarification and interpretation of the Contract Documents.
3. Contract modifications.
4. Observation of work and testing.
5. Claims.

C. The Engineer will normally communicate only with the Contractor. Any required communication with Subcontractors or Suppliers will only be with the direct involvement of the Contractor.

D. Direct written communications to the Engineer at the address indicated at the Pre-construction Conference. Include the following with communications as a minimum:

1. Name of the Owner.
2. Project name.
3. Contract title.
4. Project number.
5. Date.
6. A reference statement.

E. Submit communications on the forms referenced in this Section or in Section 01 33 00 "Submittal Procedures."

1.04 PROJECT MEETINGS

A. Pre-construction Conference:

1. Attend a pre-construction meeting.

2. The location of the conference will be determined by the Engineer.
3. The time of the meeting will be determined by the Engineer but will be after the Notice of Award is issued and not later than 15 days after the Notice to Proceed is issued.
4. The Owner, Engineer, representatives of utility companies, the Contractor's project manager and superintendent, and representatives from major Subcontractors and Suppliers may attend the meeting.
5. Provide and be prepared to discuss:
    a. Preliminary construction schedule per Section 01 32 16 "Construction Progress Schedule."
    b. Preliminary submittal schedule per Section 01 33 00 "Submittal Procedures."
    c. Schedule of Values and anticipated schedule of payments per Section 01 29 00 "Payment Procedures."
    d. List of Subcontractors and Suppliers.
    e. Contractor's organizational chart as it relates to this Project.
    f. Letter indicating the agents of authority for the Contractor and the limit of that authority with respect to the execution of legal documents, Contract modifications and payment requests.

B. Progress Meetings

1. Attend meetings with the Engineer and Owner.
    a. Meet on a monthly basis or as requested by the Engineer to discuss the Project.
    b. Meet at the Site or other location as designated by the Engineer.
    c. Contractor's superintendent and other key personnel are to attend the meeting. Other individuals may be requested to attend to discuss specific matters.
2. Provide information as requested by the Engineer or Owner concerning this Project.
    a. Prepare to discuss:
        1). Status of overall Project schedule.
        2). Contractor's detailed schedule for the next month.
        3). Anticipated delivery dates for equipment.
        4). Coordination with the Owner.
        5). Status of submittals.
        6). Information or clarification of the Contract Documents.
        7). Claims and proposed modifications to the Contract.
        8). Field observations, problems, or conflicts.
        9). Maintenance of quality standards.
    b. Notify the Engineer of any specific items to be discussed a minimum of 1 week prior to the meeting.

3. Review minutes of meetings and notify the Engineer of any discrepancies within 10 days of the date of the memorandum.
    a. Following that date, the minutes will stand as shown or as corrected.
    b. Corrections will be reflected in the minutes of the following meeting. Issues discussed will be documented and old issues will remain on minutes of subsequent meetings until the issue is resolved.

C. Pre-submittal and Pre-installation Meetings:
    1. Attend pre-submittal and pre-installation meetings as required in the individual technical Specification Sections or as determined necessary by the Engineer (for example, instrumentation, roofing, concrete mix design, etc.).
    2. The location of the meeting will be determined by the Engineer.
    3. The time of the meeting will be determined by the Contractor when ready to proceed with the associated work, subject to submission of a Notification by Contractor (NBC) on the form shown in Section 01 31 13.13 "Forms" and acceptance by the Engineer and Owner of the proposed time.
    4. The Owner, Engineer, the Contractor's project manager and superintendent, and representatives from affected Subcontractors and Suppliers shall attend the meeting.

1.05 REQUESTS FOR INFORMATION

A. Submit Request for Information (RFI) to the Engineer to obtain additional information or clarification of the Contract Documents.
    1. Submit a separate RFI for each item on the form shown in Section 01 31 13.13 "Forms."
    2. Attach adequate information to permit a written response without further clarification. Engineer will return requests that do not have adequate information to the Contractor for additional information. Contractor is responsible for all delays resulting from multiple submittals due to inadequate information.
    3. A response will be made when adequate information is provided. Response will be made on the RFI form or in attached information.

B. Response to an RFI is given to provide additional information, interpretation, or clarification of the requirements of the Contract Documents, and does not modify the Contract Documents.

C. Engineer will initiate a Contract Modification Request per Paragraph 1.07 if the RFI indicates that a Contract modification is required.

1.06 NOTIFICATION BY CONTRACTOR

A. Notify the Engineer of:
    1. Need for testing.
    2. Intent to work outside regular working hours.
    3. Request to shut down facilities or utilities.
    4. Proposed utility connections.

5. Required observation by Engineer or inspection agencies prior to covering Work.
6. Training.

B. Provide notification a minimum of 2 weeks in advance in order to allow Owner and Engineer time to respond appropriately to the notification.

C. Use "Notification by Contractor" form shown in Section 01 31 13.13 "Forms."

1.07 REQUESTS FOR MODIFICATIONS

A. Submit a request to the Engineer for any change in the Contract Documents.

1. Use the "Contract Modification Request" (Contract Modification Request) form shown in Section 01 31 13.13 "Forms."
2. Assign a number to the Contract Modification Request when issued.
3. Include with the Contract Modification Request:
   a. A complete description of the proposed modification.
   b. The reason the modification is requested.
   c. A detailed breakdown of the cost of the change (necessary only if the modification requires a change in Contract Price). The itemized breakdown is to include:
      1). List of materials and equipment to be installed.
      2). Man hours for labor by classification.
      3). Equipment used in construction.
      4). Consumable supplies, fuels, and materials.
      5). Royalties and patent fees.
      6). Bonds and insurance.
      7). Overhead and profit.
      8). Field office costs.
      9). Home office cost.
      10). Other items of cost.
   d. Provide the level of detail outlined in the paragraph above for each Subcontractor or Supplier actually performing the Work if Work is to be provided by a Subcontractor or Supplier. Indicate appropriate Contractor mark ups for Work provided through Subcontractors and Suppliers. Provide the level of detail outlined in the paragraph above for self-performed Work.
   e. Provide a revised schedule indicating the effect on the critical path for the Project and a statement of the number of days the Project may be delayed by the modification.
4. Submit a Contract Modification Request to the Engineer to request a field change.
5. A Contract Modification Request is required for all substitutions or deviations from the Contract Documents.

6. Engineer will evaluate the request for a Contract modification.

B. Owner will initiate changes through the Engineer.

   1. Engineer will prepare a description of proposed modifications to the Contract Documents.
   2. Engineer will use the Contract Modification Request form. Engineer will assign a number to the Contract Modification Request when issued.
   3. Return Contract Modification Request with a proposal to incorporate the requested change. Include a breakdown of costs into materials and labor in the detail outline above to allow evaluation by the Engineer.

C. Engineer will issue a Field Order or a Change Order per the General Conditions if a Contract modification is appropriate.

   1. Modifications to the Contract can only be made by a Field Order or a Change Order.
   2. Changes in the Project will be documented by a Field Order or by a Change Order.
   3. Field Orders may be issued by the Engineer for Contract modifications that do not change the Contract Price or Contract Time.
   4. Any modifications that require a change in Contract Price or Contract Time can only be approved by Change Order.
      a. Proposals issued by the Contractor in response to a Contract Modification Request will be evaluated by the Engineer.
      b. If a Change Order is recommended, the Engineer will prepare the Change Order.
      c. The Change Order will be sent to the Contractor for execution with a copy to the Owner recommending approval.
      d. Change Orders can only be approved by the Owner.
         1). Work performed on the proposed Contract modifications prior to the approval of the Change Order will be performed at the Contractor's risk.
         2). No payment will be made for Work on Change Orders until approved by the Owner.

D. The Contractor may be informed that the Contract Modification Request is not approved and construction is to proceed in accordance with the Contract Documents.

1.08 RECORD DRAWINGS

A. Maintain at the Site one complete record copy of:

   1. Drawings.
   2. Specifications.
   3. Addenda.
   4. Contract modifications.
   5. Approved Shop Drawings and Record Data.

6. One set of construction photographs.
7. Test records.
8. Clarifications and other information provided in Request for Information responses.
9. Reference standards.

B. Store documents and Samples in the Contractor's field office.

1. Documents are to remain separate from documents used for construction. Do not use these documents for construction.
2. Provide files and racks for the storage of documents.
3. Provide a secure storage space for the storage of Samples.
4. Maintain documents in clean, dry, legible conditions, and in good order.
5. Make documents and Samples available at all times for inspection by the Engineer and Owner.

C. Marking Drawings:

1. Label each document as "Project Record" in large printed letters.
2. Record information as construction is being performed.
    a. Do not conceal any Work until the required information is recorded.
    b. Mark Drawings to record actual construction, including the following:
        1). Depths of various elements of the foundation in relation to finished first floor datum or the top of walls.
        2). Horizontal and vertical locations of underground utilities and appurtenances constructed and existing utilities encountered during construction.
        3). Location of internal utilities and appurtenances concealed in the construction. Refer measurements to permanent structure on the surface. Include the following equipment:
            a). Piping.
            b). Ductwork.
            c). Equipment and control devices requiring periodic maintenance or repair.
            d). Valves, unions, traps, and tanks.
            e). Services entrance.
            f). Feeders.
            g). Outlets.
        4). Changes of dimension and detail.
        5). Changes made by Field Order and Change Order.
        6). Details not on the original Drawings. Include field verified dimensions and clarifications, interpretations, and additional information issued in response to Requests for Information.

c. Mark Specifications and Addenda to identify products provided.

    1). Record product name, trade name, catalog number, and each Supplier (with address and phone number) of each product and item of equipment actually installed.

    2). Record changes made by Field Order and Change Order.

d. Mark additional Work or information in erasable pencil.

    1). Use red for new or revised indication.

    2). Use purple for Work deleted or not installed (lines to be removed).

    3). Highlight items constructed per the Contract Documents in yellow.

e. Submit record documents to Engineer for review and acceptance 30 days prior to final completion of the Project.

    1). Provide one set of marked up Drawings.

D. Applications for Payment will not be recommended for payment if record documents are found to be incomplete or not in order. Final payment will not be recommended without complete record documents.

END OF SECTION

01 31 13.13 FORMS

1.00 GENERAL

1.01 WORK INCLUDED

A. Use the forms shown in this Section for Contract administration, submittals and documentation of test results. A disk with these forms in Microsoft Word or Excel will be provided to the Contractor before or at the pre-construction conference. Forms included are listed below:

B. Contract Administration Forms:

1. Request for Information.
2. Notification by Contractor.
3. Contractor's Modification Request.

C. Application for Payment Forms:

1. Consent of Surety Company to Payment Procedures.
2. Application for Payment forms.

D. Submittal Forms:

1. Submittal Transmittal.
2. Shop Drawing Deviation Request.
3. Concrete Mix Design.
    a. Attachment "A" – Basis for Mix Design – Field Strength Test Record.
    b. Attachment "B" – Basis for Mix Design – Trial Mixture.
4. Authorization request for System Shut-Down and Tie-In.

E. Testing Forms:

1. Medium Voltage Cable Test Report.
2. Motor Start Up Report.
3. Pipeline Test Report Exfiltration Test Report.
4. Pressure Pipe Test Report.
5. Protective Coating Test Report.
6. Switchgear Test Report.
7. Transformer Test Report.
8. 600 Volt Cable Test Report.

F. Equipment Installation and Documentation Forms:

1. Equipment Installation Report.
2. O&M Manual Review Report.

G. Project Closeout Forms:

1. Consent of Surety Company to Final Payment.
2. Consent of Surety Company to Reduction of or Partial Release of Retainage.
3. Contractor's Affidavit of Payment of Debts and Claims.
4. Contractor's Affidavit of Release of Liens.

END OF SECTION

01 32 16 CONSTRUCTION PROGRESS SCHEDULE

1.00 GENERAL

1.01 REQUIREMENTS

A. Prepare and submit a Progress Schedule for the Work and update the schedule on a monthly basis for the duration of the Project.

B. Provide schedule in adequate detail to allow Owner to monitor the Work progress, to anticipate the time and amount of Applications for Payment, and to relate submittal processing to sequential activities of the Work.

C. Incorporate and specifically designate the dates of anticipated submission of submittals and the dates when submittals must be returned to the Contractor into the schedule.

D. Assume complete responsibility for maintaining the progress of the Work per the submitted schedule.

E. Take all requirements of Section 01 35 00 "Special Procedures" into consideration when preparing schedule.

1.02 SUBMITTALS

A. Submit Progress Schedules in accordance with Section 01 33 00 "Submittal Procedures." Submit schedules within the following times:

1. Preliminary schedule within 10 days after the Notice of Award. The schedule is to be available at the pre-construction conference.
2. Detailed schedule at least 10 days prior to the first payment request.

B. Submit Progress Schedules with Applications for Payment. Schedules may be used to evaluate the Applications for Payment. Failure to submit the schedule may cause delay in the review and approval of Applications for Payment.

1.03 SCHEDULE REQUIREMENTS

A. Schedule is to be in adequate detail to:

1. Assure adequate planning, scheduling, and reporting during the execution of the Work.
2. Assure the coordination of the Work of the Contractor and the various Subcontractors and Suppliers.
3. Assist in monitoring the progress of the Work.
4. Assist in evaluating proposed changes to Contract Time and Project schedule.
5. Assist the Owner in review of Contractor's Application for Payment.

B. Prepare Schedules using Primavera P6 and provide copies of updates as requested.

C. Provide personnel with 5 years minimum experience in scheduling construction work comparable to this Project.

D. Provide the schedule in the form of a time scaled horizontal bar chart which indicates graphically the Work scheduled at any time during the Project. The graph is to indicate:

1. Complete sequence of construction by activity.
2. Identification of the activity by structure, location, and type of Work.
3. Chronological order of the start of each item of Work.
4. The activity start and stop dates.
5. The activity duration.
6. Successor and predecessor relationships for each activity. Group related activities or use lines to indicate relationships.
7. A clearly indicated critical path. Indicate only one critical path on the schedule. The subsystem with the longest time of completion is the critical path where several subsystems each have a critical path. Float time is to be assigned to other subsystems.
8. Projected percentage of completion, based on dollar value of the Work included in each activity as of the day Applications for Payment are due, for each month.

E. Submit a separate submittal schedule indicating the dates when the submittals are to be sent to the Engineer.

1. List specific dates submittal is to be sent to the Engineer.
2. List specific dates submittal must be processed in order to meet the proposed schedule.
3. Allow a reasonable time to review submittals, taking into consideration the size and complexity of the submittal, the submission of other submittals, and other factors that may affect review time.
4. Allow time for re-submission of the submittals for each item. Contractor is responsible for delays associated with additional time required to review incomplete or erroneous submittals and for the time lost when submittals are submitted for products that do not meet the requirements of the Specifications.

F. Update the schedule at the end of each monthly partial payment period to indicate the progress made on the Project to that date.

1.04 SCHEDULE REVISIONS

A. Submit a written report if the schedule indicates that the Project is more than 30 days behind schedule. The report is to include:

1. Number of days Project is behind schedule.
2. Narrative description of the steps to be taken to bring the Project back on schedule.
3. Anticipated time required to bring the Project back on schedule.

B. Submit a revised schedule indicating the action that the Contractor proposes to take to bring the Project back on schedule.

C. Revise the schedule to indicate any adjustments in Contract Time approved by Change Order.

1. Revised schedule is to be included with Contract Modification Request for which an extension of time is requested.
2. Failure to submit a revised schedule indicates that the modification shall have no impact on the ability of the Contractor to complete the Project on time and that the cost associated with the change of additional plant or work force have been included in the cost proposed for the modification.

D. Updating the Project schedule to reflect actual progress is not considered a revision to the Project schedule.

E. Applications for Payment will not be recommended for payment without a revised schedule, and if required, the report indicating the Contractor's plan for bringing the Project back on schedule.

1.05 FLOAT TIME

A. Define float time as the amount of time between the earliest start date and the latest start date of a chain of activities on the construction schedule.

B. Float time is not for the exclusive use or benefit of either the Contractor or Owner.

C. Contract Time cannot be changed by the submission of this schedule. Contract Time can only be modified by approved Change Order.

D. Schedule completion date must be the same as the Contract completion date. Time between the end of construction and the Contract completion date is to be indicated as float time.

END OF SECTION

01 32 34 VIDEO AND PHOTOGRAPHIC DOCUMENTATION

1.00 GENERAL

1.01 WORK INCLUDED

A. Provide a video recording of the Site prior to the beginning of construction.

   1. Record the condition of all existing facilities in or abutting the construction area (right-of-way) including but not limited to streets, curb and gutter, utilities, driveways, fencing, landscaping, etc. per Paragraph 2.02.
   2. Record after construction staking is complete but prior to any clearing.
   3. Provide one copy of the recording, dated and labeled to the Engineer before the start of construction. Provide additional recording as directed by the Engineer if the recording provided is not considered suitable for the purpose of recording pre-existing conditions. The submitted video must be approved by the Engineer prior to start of any clearing operations.

B. Furnish an adequate number of photographs of the Site to clearly depict the completed Project.

   1. Provide a minimum of ten different views.
   2. Photograph a panoramic view of the entire Site.
   3. Photograph all significant areas of completed construction.
   4. Completion photographs are not to be taken until all construction trailers, excess materials, trash and debris have been removed.
   5. Employ a professional photographer approved by the Engineer to photograph the Project.
   6. Provide one aerial photograph of the Site from an angle and height to include the entire Site while providing adequate detail.

C. All photographs, video recordings and a digital copy of this media are to become the property of the Owner. Photographs or recordings may not be used for publication, or public or private display without the written consent of the Owner.

1.02 QUALITY ASSURANCE

A. Provide clear photographs and recordings taken with proper exposure. View photographs and recordings in the field and take new photographs or recordings immediately if photos of an adequate print quality cannot be produced or video quality is not adequate. Provide photographs with adequate quality and resolution to permit enlargements.

1.03 SUBMITTALS

A. Submit two DVDs of the video recording as Record Data in accordance with Section 01 33 00 "Submittal Procedures."

B. Submit Photographic Documentation as Record Data in accordance with Section 01 33 00 "Submittal Procedures."

2.00 PRODUCTS

2.01 PHOTOGRAPHS

A. Provide photographs in digital format with a minimum resolution of 1280 x 960, accomplished without a digital zoom.

B. Take photographs at locations acceptable to the Engineer.

C. Provide two color prints of each photograph and a digital copy on a DVD of the photographs taken.

D. Identify each print on back with:

   1. Project name.

   2. Date, time, location, and orientation of the exposure.

   3. Description of the subject of photograph.

E. Submit photograph in clear plastic sheets designed for photographs. Place only one photograph in each sheet to allow the description on the back to be read without removing the photograph.

F. Final photographs are to include two 8-by-10-inch glossy color prints for each of ten photographs selected by the Owner. These photographs are in addition to normal prints.

2.02 VIDEO RECORDING

A. Provide digital format on digital media (flash drive, external hard drive, etc.) that can be played with Windows Media Player in common format in full screen mode.

B. Identify Project on video by audio or visual means.

C. Video file size should not exceed 12 GB.

D. Video resolution shall be 1080p.

E. The quality of the video must be sufficient to determine the existing conditions of the construction area. Camera panning must be performed while at rest, do not pan the camera while walking or driving. Camera pans should be performed at intervals sufficient to clearly view the entire construction area (100-foot maximum interval).

F. DVD shall be labeled with construction stationing and stationing should be called out, voice recorded, in the video.

G. The entire construction area recording shall be submitted at once. Sections submitted separately will not be accepted.

H. Pipeline projects should be recorded linearly from beginning to end.

I. Pump Stations, Ground Storage tanks, water treatment plants and other Site components shall be video recorded in an organized sequential order with major components identified.

J. Submit DVD in a hard plastic case, clearly label the date(s) the DVD was made, the Project name and Owner's Project number. If there is more than one DVD, then indicate number as 1 of 2, 2 of 2, etc.

END OF SECTION

01 33 00 SUBMITTAL PROCEDURES

1.00 GENERAL

1.01 WORK INCLUDED

A. Submit documentation as required by the Contract Documents and as reasonably requested by the Owner, Construction Manager and Engineer to:

1. Record the products incorporated into the Project for the Owner.
2. Provide information for operation and maintenance of the Project.
3. Provide information for the administration of the Contract.
4. Allow the Engineer to advise the Owner if products proposed for the Project by the Contractor conform, in general, to the design concepts of the Contract Documents.

B. Contractor's responsibility for full compliance with the Contract Documents is not relieved by the Engineer's review of submittals. Contract modifications may only be approved by Change Order or Field Order.

1.02 CONTRACTOR'S RESPONSIBILITIES

A. Review all submittals prior to submission.

B. Determine and verify:

1. Field measurements.
2. Field construction requirements.
3. Location of all existing structures, utilities and equipment related to the submittals.
4. Submittals are complete for their intended purpose.
5. Conflicts between the submittals related to the various Subcontractors and Suppliers have been resolved.
6. Quantities and dimensions shown on the submittals.

C. Submit information per the procedures described in this Section and the detailed Specifications.

D. Furnish the following submittals:

1. As specified in the Section 01 33 00.01 Table of Required Submittals and as revised during detailed design. The preliminary Table of Required Submittals is provided to allow the CMAR to estimate the level of effort required in determining fees. Provision are to be made for some variation is the actual list of submittals and CMAR should include allowances for these variation in the Contract Price.
2. Schedules, data and other documentation as described in detail in this Section or referenced in the General Conditions.
3. Documentation required for the administration of the Contract per Section 01 31 13 "Project Coordination."

4. Shop Drawings required for consideration of a Contract modification per Paragraph 1.08.
5. Submittals as required in the Specifications.
6. Submittals not required will be returned without Engineer's review.

E. Submit a schedule indicating the date submittals will be sent to the Engineer and proposed dates that the product will be incorporated into the Project. Make submittals promptly in accordance with the schedule so as to cause no delay in the Project.

1. Send submittals to the Engineer allowing a reasonable time for delivery, review and marking submittals. Include time for review of a resubmission if necessary. Allow adequate time for the submittal review process, ordering, fabrication, and delivery of the product so as to not delay progress on the Project.
2. Schedule submittal to provide all information for interrelated Work at one time. No review will be performed on submittals requiring coordination with other submittals. Engineer will return submittals for resubmission as a complete package.

F. Submit information for all of the components and related equipment required for a complete and operational system in the same submittal.

1. Include electrical, mechanical, and other information required to indicate how the various components of the system function.
2. Provide certifications, warranties, and written guarantees with the submittal package for review when they are required.

G. Fabrication or installation of any products prior to the approval of Shop Drawings is done at the Contractor's risk. Products not meeting the requirements of Contract Documents are defective and may be rejected at the Owner's option.

H. Payment will not be made for products for which submittals are required until the submittals have been received. Payment will not be made for products for which Shop Drawings or Samples are required until these are approved by the Engineer.

1.03 QUALITY ASSURANCE

A. Submit legible, accurate, complete documents presented in a clear, easily understood manner. Submittals not meeting these criteria will be returned without review.

B. Demonstrate that the proposed products are in full and complete compliance with the design criteria and requirements of the Contract Documents including Drawings and Specifications as modified by Addenda, Field Orders, and Change Orders.

C. Furnish and install products that fully comply with the information included in the submittal.

D. Review and approve submittals prior to submitting them to the Engineer for review. Submittals will not be accepted from anyone other than the Contractor.

1.04 SUBMITTAL PROCEDURES

A. Submit an electronic copy of each submittal through the project portal (website) provided by the Engineer. The Contractor will be provided access to log onto the website to post submittal documents and check the status of submittals.

1. The complete contents of each submittal, including associated drawings, Product Data, etc., shall be submitted in Portable Document Format (PDF.) Submit PDF document with adequate resolution to allow documents to be printed in a format equivalent to the document original. Documents are to be scalable to allow printing on standard 8-1/2 x 11 or 11 x 17 papers.

2. Create and submit color PDF documents where color is important to the evaluation of the submittal and / or where comments will be lost if only black and white PDF documents are provided. Submit Sample and color charts per Paragraph 1.04.H.

B. Transmit all submittals, with a properly completed Submittal Transmittal Form as indicated in Section 01 31 13.13 "Forms."

1. Use a separate transmittal form for each specific product, class of material, and equipment system.

2. Submit items specified in different Sections of the Specifications separately unless they are part of an integrated system.

C. Assign a Contractor's submittal number to the documents originated to allow tracking of the submittal during the review process.

1. Assign the number consisting of a prefix, a sequence number, and a letter suffix. Prefixes shall be as follows:

Prefix	Description	Originator
PR	Payment Request	Contractor
CO	Change Order	Engineer
CMR	Contract Modification Request	Contractor
CTR	Certified Test Report	Contractor
EIR	Equipment Installation Report	Contractor
FO	Field Order	Engineer
NBC	Notification by Contractor	Contractor
O&M	Operation & Maintenance Manuals	Contractor
PD	Photographic Documentation	Contractor
RD	Record Data	Contractor
RFI	Request for Information	Contractor
SAM	Sample	Contractor
SD	Shop Drawing	Contractor
SCH	Schedule of Progress	Contractor

2. Issue sequence numbers in chronological order for each type of submittal.

3. Issue numbers for resubmittals that have the same number as the original submittal followed by an alphabetical suffix indicating the number of times the same submittal has been sent to the Engineer for processing. For example: SD 025 A represents a shop

drawing that is the twenty-fifth submittal of this type and is the second time this submittal has been sent for review.

4. Clearly note the submittal number on each page or sheet of the submittal.
5. Correct assignment of numbers is essential since different submittal types are processed in different ways.

D. Submit documents with uniform markings and page sizes.

1. Paper size shall allow for ease of reproduction.
    a. Submit documents on 8-1/2 x 11 paper where practical.
    b. Use 11 x 17 paper for larger drawings and schematics.
    c. Use full size sheets for fabrications and layout drawings. Reproducible drawings may be submitted in lieu of prints.
2. Mark submittals to:
    a. Indicate Contractor's corrections in green.
    b. Highlight items pertinent to the products being furnished in yellow and delete items that are not pertinent when the Supplier's standard drawings or information sheets are provided.
    c. Cloud items and highlight in yellow where selections by the Engineer or Owner are required.
    d. Mark dimensions with the prefix FD to indicate field verified dimensions on the Drawings.
    e. Provide a blank 8-by-3-inch space for Contractor's and Engineer's stamp.
3. Define abbreviations and symbols used in Shop Drawings.
    a. Use terms and symbols in Shop Drawings consistent with the Drawings.
    b. Provide a list of abbreviations and their meaning as used in the Shop Drawings.
    c. Provide a legend for symbols used on Shop Drawings.

E. Mark submittals to reference the Drawing number and/or Section of the Specifications, detail designation, schedule or location that corresponds with the data submitted. Other identification may also be required, such as layout drawings or schedules to allow the reviewer to determine where a particular product is to be used.

F. Deliver Samples required by the Specifications to the Site. Provide a minimum of two Samples.

G. Construct mock-ups from the actual products to be used in construction per the Specifications.

H. Submit color charts and Samples for every product requiring color, texture or finish selection.

1. Submit all color charts and Samples at one time.

2. Do not submit color charts and Samples until all Record Data have been submitted or Shop Drawings for the products have been approved.
3. Submit color charts and Samples not less than 30 days prior to when these products are to be ordered or released for fabrication to comply with the schedule for construction of the Project.

I. Submit Contract Modification Request per Section 01 31 13 "Project Coordination" to request modifications to the Contract Documents.

J. For non-electronic submittals, the number of copies of each submittal to be sent by the Contractor and the number of copies of each submittal to be returned are:

Prefix	Description	No. of Copies Sent	No. of Copies Returned
PR	Payment Request	4	1
O&M	Final O&M Manuals	4	0
PD	Photographic Documentation	2	0
SAM	Sample	2	0

K. Submit an electronic copy of each submittal through the project portal (website) provided by the Engineer. The Contractor will be provided access to log onto the Portal website to post submittal documents and check the status of submittals. The complete contents of each submittal, including associated drawings, Product Data, etc., shall be submitted in Adobe Acrobat PDF format, or other format approved by Engineer.

1.05 REVIEW PROCEDURES

A. Shop Drawings are reviewed in the order received, unless Contractor request that a different priority be assigned.

B. Mark a submittal as "Priority" to place the review for this submittal ahead of submittals previously delivered. Priority submittals will be reviewed before other submittals for this Project which have been received but not reviewed. Use discretion in the use of "Priority" submittals as this may delay the review of submittals previously submitted. Revise the Schedule of Contractor's Submittals for substantial deviations from the previous schedule.

C. Review procedures vary with the type of submittal as described in Paragraph 1.06.

1.06 SUBMITTAL REQUIREMENTS

A. Shop Drawings are required for those products that cannot adequately be described in the Contract Documents to allow fabrication, erection or installation of the product without additional detailed information from the Supplier.

1. Shop Drawings are requested so that the Engineer can:
    a. Assist the Owner in selecting colors, textures or other aesthetic features.
    b. Compare the proposed features of the product with the specified features so as to advise the Owner that the product does, in general, conform to the Contract Documents.

        c. Compare the performance features of the proposed product with those specified so as to advise the Owner that it appears that the product will meet the designed performance criteria.
        d. Review required certifications, guarantees, warranties, and service agreements for compliance with the Contract Documents.
    2. Certify that Contractor has reviewed the Shop Drawings and made all necessary corrections such that the products, when installed, will be in full compliance with the Contract Documents per Section 00 73 00 "Supplementary Conditions." Shop Drawings submitted without this certification will be returned without review.

B. Furnish the following Submittals:
    1. Products as indicated in Section 01 33 00.01 "Table of Required Submittals."
    2. When a substitution or equal product is proposed in accordance with Paragraph 1.08 of this Section.
    3. Shop Drawings required for consideration of a Contract modification per Paragraph 1.07.
    4. When a substitution or equal product is proposed in accordance with Paragraph 1.08 of this Section.

C. Include a complete description of the material or equipment to be furnished. Information is to include:
    1. Type, dimensions, size, arrangement, model number, and operational parameters of the components.
    2. Weights, gauges, materials of construction, external connections, anchors, and supports required.
    3. Performance characteristics, capacities, engineering data, motor curves, and other information necessary to allow a complete evaluation of mechanical components.
    4. All applicable standards such as ASTM or Federal specification numbers.
    5. Fabrication and installation drawings, setting diagrams, manufacturing instructions, templates, patterns, and coordination drawings.
    6. Wiring and piping diagrams and related controls.
    7. Mix designs for concrete, asphalt, or other materials proportioned for the Project.
    8. Complete and accurate field measurements for products which must fit existing conditions. Indicate on the submittal that the measurements represent actual dimensions obtained at the Site.

D. Provide all required statements of certification, guarantees, extended service agreements, and other related documents with the Shop Drawing. The effective date of these documents shall be the date of acceptance of the Work by the Owner.

E. Comments will be made on items called to the attention of the Engineer for review and comment. Any marks made by the Engineer do not constitute a blanket review of the submittal or relieve the Contractor from responsibility for errors or deviations from the Contract requirements.

1. Submittals that are reviewed will be returned with one or more of the following designations:
    a. Approved: Submittal is found to be acceptable as submitted.
    b. Approved as Noted: Submittal is acceptable with corrections or notations made by Engineer and may be used as corrected.
    c. Revise and Resubmit: Submittal has deviations from the Contract Documents, significant errors, or is inadequate and must be revised and resubmitted for subsequent review.
    d. Not Approved: Products are not acceptable.
2. Drawings with a significant or substantial number of markings by the Contractor may be marked "Approved as Noted" and "Revise and Resubmit". These drawings are to be revised to provide a clean record of the submittal.
3. Dimensions or other data that do not appear to conform to the Contract Documents will be marked as "At Variance With" (AVW) the Contract Documents or other information provided. The Contractor is to make revisions as appropriate to comply with Contract Documents.

F. Certifications, Warranties and Service Agreements include documents as specified in the detailed Specifications, as shown in the submittal schedule or as follows:

1. Certified Test Reports (CTR): A report prepared by an approved testing agency giving results of tests performed on products to indicate their compliance with the specifications (refer to Section 01 40 00 “Quality Requirements”).
2. Certification of Local Field Service (CLS): A certified letter stating that field service is available from a factory or Supplier approved service organization located within a 300 mile radius of the Site. List names, addresses, and telephone numbers of approved service organizations on or attach to the certificate.
3. Extended Warranty (EW): A guarantee of performance for the product or system beyond the normal 1 year correction period described in the General Conditions. Issue the warranty certificate in the name of the Owner.
4. Extended Service Agreement (ESA): A Contract to provide maintenance beyond that required to fulfill requirements for warranty repairs, or to perform routine maintenance for a definite period of time beyond the warranty period. Issue the service agreement in the name of the Owner.
5. Certification of Adequacy of Design (CAD): A certified letter from the manufacturer of the equipment stating that they have designed the equipment to be structurally stable and to withstand all imposed loads without deformation, failure, or adverse effects to the performance and operational requirements of the unit. The letter shall state that mechanical and electrical equipment is adequately sized to be fully operational for the conditions specified or normally encountered by the product's intended use.
6. Certification of Applicator/Subcontractor (CSQ): A certified letter stating that the Subcontractor or Supplier proposed to perform a specified function is duly designated as factory authorized and trained for the application of the specified product.

G. Submit Record Data to provide information to allow the Owner to adequately identify the products incorporated into the Project and allow replacement or repair at some future date.

  1. Provide Record Data for all products. Record Data is not required for items for which Shop Drawings and/or operations and maintenance manuals are required.
  2. Provide information only on the specified products. Submit a Contract Modification Request for approval of deviations or substitutions and obtain approval by Field Order or Change Order prior to submitting Record Data.
  3. Provide the same information required for Shop Drawings.
  4. Record Data will be received by the Engineer, logged, and provided to Owner for the Project record.
     a. Record Data may be reviewed to see that the information provided is adequate for the purpose intended. Inadequate drawings will be returned as unacceptable.
     b. Record Data is not reviewed for compliance with the Contract Documents. Comments may be returned if deviations from the Contract Documents are noted during the cursory review performed to see that the information is adequate.

H. Provide Samples for comparison with products delivered to the Site for use on the Project.

  1. Samples shall be of sufficient size and quantity to clearly illustrate the functional characteristics of the product, with integrally related parts and attachment devices.
  2. Indicate the full range of color, texture, and patterns.
  3. Dispose of Samples when related Work has been completed and approved, and disposal is requested by the Engineer. At Owner's option Samples will become the property of the Owner.

I. Submit Operation and Maintenance manuals (O&M) for all equipment, mechanical devices, or components described in the Contract Documents per Section 01 78 23 “Operation and Maintenance Data.” Include copies of approved Shop Drawings in the manual.

J. Submit Request for Information (RFI) in accordance with Section 01 31 13 “Project Coordination.”

K. Submit a Schedule of Values and Application for Payment (AP) in accordance with Section 01 29 00 “Payment Procedures.”

L. Submit Progress Schedules (SCH) in accordance with Section 01 32 16 “Construction Progress Schedules.”

M. Submit Certified Test Reports (CTR) from independent testing laboratories in accordance with Section 01 40 00 “Quality Requirements.”

  1. Submit test reports for material fabricated for this Project with Shop Drawings for that product.
  2. Submit test reports produced at the point of production for standard production products with the Record Data for that product.

N. Submit a list of Suppliers and Subcontractors as Record Data in accordance with Section 01 31 13 “Project Coordination.”

O. Submit Equipment Installation Reports (EIR) in accordance with Section 01 75 00 "Starting and Adjusting."

P. Submit Notifications by Contractor (NBC) in accordance with Section 01 31 13 "Project Coordination."

Q. Submit Photographic Documentation (PD) in accordance with Section 01 32 34 "Video and Photographic Documentation."

R. Submit Process Performance Bonds (PPB) in accordance with Section 00 73 00 "Supplementary Conditions" and the detailed equipment Specifications.

1.07 REQUESTS FOR DEVIATION

A. Submit requests for deviations from the Contract Documents for any product that does not fully comply with the Contract Documents.

B. Submit request for deviations by Contract Modification Request (CMR) per Section 01 31 13 "Project Coordination." Identify the deviations and the reason the change is requested.

C. Include the amount of cost savings to the Owner for deviations that result in a reduction in cost. A Change Order or Field Order will be issued by the Engineer for deviations approved by the Owner if deviations are requested after the Guaranteed Maximum Price has been established.

D. Deviations from the Contract Documents may only be approved by Change Order or Field Order.

1.08 SUBMITTALS FOR EQUAL NON SPECIFIED PRODUCTS

A. The products of the listed Suppliers are to be furnished where detailed Specifications list several manufacturers but do not specifically list "or equal" or "or approved equal" products. Use of any products other than those specifically listed is a substitution and must be approved per Paragraph 1.09.

B. Contractor may submit other manufacturers' products that are in full compliance with the Specifications where the detailed Specifications list one or more manufacturers followed by the phase "or equal" or "or approved equal".

1. Submit Shop Drawings of adequate detail to document that the proposed product is equal or superior to the specified product.
2. Prove that the product is equal. It is not the Engineer's responsibility to prove the product is not equal.
    a. Indicate on a point by point basis for each specified feature that the product is equal to the Contract Document requirements.
    b. Make a direct comparison with the specified manufacturer's published data sheets and available information. Provide this printed material with the submittal.
    c. The decision of the Engineer regarding the acceptability of the proposed product is final.
3. Provide a typewritten certification that, in furnishing the proposed product as an equal, the Contractor:

        a. Has thoroughly examined the proposed product and has determined that it is equal or superior in all respects to the product specified.
        b. Has determined that the product will perform in the same manner as the specified product.
        c. Will provide the same warranties and/or bonds as for the product specified.
        d. Will assume all responsibility to coordinate any modifications that may be necessary to incorporate the product into the Work and will waive all claims for additional materials or effort which may be necessary to incorporate the product into the Project.
        e. Will maintain or improve the delivery and installation schedule as for the specified product.
    4. A modification request is not required for any product that is in complete compliance with the Contract Documents.

1.09 SUBMITTALS FOR SUBSTITUTIONS

A. Substitutions are defined as any product that the Contractor proposes to provide for the Project in lieu of the specified product.

B. Submit the following for consideration of approval of a Supplier or product which is not specified:

1. Contract Modification Request for deviation from the Contract Documents per Paragraph 1.07.
2. Prove that the product is acceptable as a substitute. It is not the Engineer's responsibility to prove the product is not acceptable as a substitute.
    a. Indicate on a point by point basis for each specified feature that the product is acceptable to meet Contract Documents requirements.
    b. Make a direct comparison with the specified Supplier's published data sheets and available information. Provide this printed material with the submittal.
    c. The decision of the Engineer regarding the acceptability of the proposed substitute product is final.
3. Provide a typewritten certification that, in making the substitution request, the Contractor:
    a. Has determined that the substituted product will perform in substantially the same manner and result in the same ability to meet the specified performance as the specified product.
    b. Will provide the same warranties and/or bonds for the substituted product as specified or as would be provided by the manufacturer of the specified product.
    c. Will assume all responsibility to coordinate any modifications that may be necessary to incorporate the substituted product into the Project and will waive all claims for additional Work which may be necessary to incorporate the substituted product into the Project which may subsequently become apparent.

d. Will maintain the same time schedule as for the specified product.

C. Pay engineering cost for review of substitutions.

1. Cost for additional review time will be billed to the Owner by the Engineer for the actual hours required for the review and marking of Shop Drawings by Engineer and in accordance with the rates listed in Paragraph SC-14.02, Section 00 73 00 "Supplementary Conditions" if this request is made after the Guaranteed Maximum Price has been established.

2. Cost for the additional review shall be paid to the Owner by the Contractor on a monthly basis.

1.10 WARRANTIES AND GUARANTEES

A. Submit warranties and guarantees required by the Contract Documents with the Shop Drawings or Record Data.

B. Provide additional copies for equipment and include this additional copy in the Operation and Maintenance Manuals. Refer to Section 01 78 23 "Operation and Maintenance Data."

C. Provide a separate manual for warranties and guarantees.

1. Provide a log of all products for which warranties or guarantees are provided, and for all equipment. Index the log by Specification Section number on forms provided by the Engineer.

2. Indicate the start date, warranty or guarantee period and the date upon which the Warranty or guarantee expires for product or equipment which a warranty or guarantee is required.

3. Indicate the date for the start of the correction period specified in the General Conditions for each piece of equipment and the date on which the specified correction period expires.

4. Provide a copy of the warrantee or guarantee under a tab indexed to the log.

1.11 RESUBMISSION REQUIREMENTS

A. Make all corrections or changes in the submittals required by the Engineer and resubmit until approved.

B. For Shop Drawings:

1. Revise initial drawings or data and resubmit as specified for the original submittal.

2. Highlight in yellow those revisions which have been made in response to the first review by the Engineer.

3. Highlight in blue any new revisions which have been made or additional details of information that has been added since the previous review by the Engineer.

C. For Samples:

1. Submit new Samples as required for the initial Sample.

2. Remove Samples which have been rejected.

D. For mock ups:

   1. Construct a new mock up as initially required.
   2. Dispose of mock ups which have been rejected.

E. Engineering cost for excessive review of Shop Drawings will be paid by the Contractor.

   1. Excessive review of Shop Drawings is defined as any review required after the original review has been made and the first resubmittal has been checked to see that corrections have been made.
   2. Cost for additional review time will be billed to the Owner by the Engineer for the actual hours required for the review and marking of Shop Drawings by Engineer and in accordance with the rates listed in Item SC-14.02, Section 00 73 00 "Supplementary Conditions."
   3. Pay cost for the additional review to the Owner on a monthly basis as billed by the Owner.
   4. Need for more than one resubmission or any other delay of obtaining Engineer's review of submittals, will not entitle the Contractor to an extension of Contract Time. All costs associated with such delays shall be at the Contractor's expense.

1.12 ENGINEER'S DUTIES

A. Review the submittals and return with reasonable promptness.

B. Affix stamp, indicate approval, rejection, and the need for resubmittal.

C. Distribute documents

END OF SECTION

01 33 00.01 TABLE OF REQUIRED SUBMITTALS

1.00 GENERAL

1.01 REQUIRED SUBMITTALS

A. The following tabulation list the submittals required for each Submittal Section. Each Section of the Specifications may provide more detailed information regarding the data to be provided for each product, materials, equipment or component required by the Section. Provide additional documentation as required by the Contract Documents in accordance with Section 01 33 00 “Submittal Procedures” and each Section and as reasonably requested by the Owner, Construction Manager and Engineer.

B. Incorporate each submittal in the Construction Schedule and Indicate the date each submittal is anticipated to be submitted.

SUBMITTAL SCHEDULE

Spec Number	Description	Shop Drawing	Sample	Certified Test Report	Certification of Local Field Service	Extended Warranty	Extended Service Agreement	Certificate of Adequacy of Design	Certification of Applicator/Subcontractor	Record Data	Operation and Maintenance Manuals	Equipment Installation Report	Process Performance Bond
03 11 00	Concrete Forming												
03 15 16	Concrete Anchors	X											
03 21 00	Reinforcing Steel			X						X			
03 30 00	Cast-In-Place Concrete	X		X									
03 30 53	Miscellaneous Cast-In-Place Concrete	X		X									
03 37 13	Shotcrete												
03 37 19	Pneumatically Placed Concrete			X									
03 37 23	Roller-Compacted Concrete			X									
03 41 00	Precast Concrete Buildings												
03 48 00	Precast Concrete Products												
05 05 13	Shop-Applied Coatings for Metal												
05 12 00	Structural Steel Framing							X		X			
05 50 00	Metal Fabrications	X											
05 51 00	Metal Stairs												
05 52 00	Metal Railings												

SUBMITTAL SCHEDULE

Spec Number	Description	Shop Drawing	Sample	Certified Test Report	Certification of Local Field Service	Extended Warranty	Extended Service Agreement	Certificate of Adequacy of Design	Certification of Applicator/Subcontractor	Record Data	Operation and Maintenance Manuals	Equipment Installation Report	Process Performance Bond
05 52 13	Pipe and Tube Railings	X											
05 53 00	Metal Gratings												
05 58 00	Formed Metal Fabrications												
09 91 00	Painting		X							X			
09 91 13	Exterior Painting												
09 91 23	Interior Painting												
09 96 00	High-Performance Coatings		X							X			
09 96 00.01	High-Performance Coatings		X							X			
09 97 13	Steel Coatings												
09 97 16	Pipeline Coatings and Linings												
09 97 26	Cementitious Coatings												
26 01 26	Maintenance Testing of Electrical Systems												
26 05 00	Common Work Results for Electrical												
26 05 00.02	Overcurrent Protective Devices	X									X		
26 05 13	Medium-Voltage Cables			X						X	X		

SUBMITTAL SCHEDULE

Spec Number	Description	Shop Drawing	Sample	Certified Test Report	Certification of Local Field Service	Extended Warranty	Extended Service Agreement	Certificate of Adequacy of Design	Certification of Applicator/Subcontractor	Record Data	Operation and Maintenance Manuals	Equipment Installation Report	Process Performance Bond
26 05 19	Low-Voltage Electrical Power Conductors and Cables			X						X	X		
26 05 19.02	Wire Connections and Devices									X			
26 05 26	Grounding and Bonding for Electrical Systems									X			
26 05 29	Hangers and Supports for Electrical Systems									X			
26 05 33	Raceways and Boxes for Electrical Systems												
26 05 33.01	Conduits									X			
26 05 33.02	Wireways									X			
26 05 33.03	Outlet Boxes									X			
26 05 33.04	Pull and Junction Boxes									X			
26 05 36	Cable Trays for Electrical Systems									X			
26 05 53	Identification for Electrical Systems												
26 09 00	Instrumentation and Control for Electrical Systems												
26 09 13	Electrical Power Monitoring	X									X		
26 09 23	Lighting Control Devices												
26 09 23.01	Lighting Controls												

SUBMITTAL SCHEDULE

Spec Number	Description	Shop Drawing	Sample	Certified Test Report	Certification of Local Field Service	Extended Warranty	Extended Service Agreement	Certificate of Adequacy of Design	Certification of Applicator/Subcontractor	Record Data	Operation and Maintenance Manuals	Equipment Installation Report	Process Performance Bond
26 13 00.01	Switchgear												
26 20 00.01	Low-Voltage AC Induction Motors												
26 21 00	Low-Voltage Electrical Service Entrance												
26 22 13	Low-Voltage Distribution Transformers	X									X		
26 24 13	Switchboards	X									X		
26 24 16.01	Panelboards	X									X		
26 24 16.02	Lighting and Branch Panelboards	X									X		
26 24 19	Motor-Control Centers	X									X		
26 25 00	Enclosed Bus Assemblies												
26 27 13	Electricity Metering												
26 27 26.01	Wiring Devices									X			
26 28 00.01	Contactors	X									X		
26 28 19	Disconnects	X											
26 29 00	Low-Voltage Controllers	X									X		
26 42 00	Cathodic Protection												

SUBMITTAL SCHEDULE

Spec Number	Description	Shop Drawing	Sample	Certified Test Report	Certification of Local Field Service	Extended Warranty	Extended Service Agreement	Certificate of Adequacy of Design	Certification of Applicator/Subcontractor	Record Data	Operation and Maintenance Manuals	Equipment Installation Report	Process Performance Bond
26 42 13	Passive Cathodic Protection for Underground and Submerged Piping												
26 50 00	Lighting									X			
28 16 43	Perimeter Security Systems												
28 23 00	Video Surveillance												
31 05 16	Aggregates for Earthwork			X									
31 05 16.01	Aggregate Fill Classifications												
31 05 23.13	Soil Cement		X										
31 10 00	Site Clearing												
31 11 00	Clearing and Grubbing [Civil]												
31 23 10	Structural Excavation and Backfill			X									
31 23 19	Dewatering												
31 23 23.16	Compacted Earth Fill			X									
31 23 23.33	Flowable Fill	X		X									
31 23 33	Trenching and Backfill [Utilities]			X									

SUBMITTAL SCHEDULE

Spec Number	Description	Shop Drawing	Sample	Certified Test Report	Certification of Local Field Service	Extended Warranty	Extended Service Agreement	Certificate of Adequacy of Design	Certification of Applicator/Subcontractor	Record Data	Operation and Maintenance Manuals	Equipment Installation Report	Process Performance Bond
31 23 33.14	Trench Safety [Civil]												
31 24 13	Roadway Embankments												
31 25 13.13	Seeding for Erosion Control									X			
31 37 00	Riprap			X									
31 37 00.13	Grout for Riprap			X						X			
31 63 29	Drilled Concrete Piers	X		X									
31 68 13	Rock Foundation Anchors									X			
31 91 19.13	Topsoil Placement and Grading												
32 01 90.13	Fertilizing												
32 12 16	Asphalt Paving	X		X									
32 12 16.16	Road-Mix Asphalt Paving												
32 12 19	Asphalt Paving Wearing Courses			X									
32 13 13	Concrete Paving	X		X									
32 13 73	Concrete Paving Joint Sealants												
32 16 13	Curbs and Gutter									X			

SUBMITTAL SCHEDULE													
Spec Number	Description	Shop Drawing	Sample	Certified Test Report	Certification of Local Field Service	Extended Warranty	Extended Service Agreement	Certificate of Adequacy of Design	Certification of Applicator/Subcontractor	Record Data	Operation and Maintenance Manuals	Equipment Installation Report	Process Performance Bond
32 17 23	Paving Markings									X			
32 31 13	Chain Link Fences and Gates												
32 31 13.53	High-Security Chain Link Fences and Gates												
32 31 15	Cantilevered Barrier Arm Gates	X						X		X			
32 90 00.01	Landscaping									X			
32 91 13	Soil Preparation												
32 92 13	Hydro-Mulching									X			
33 05 01.02	Ductile Iron Pipe and Fittings												
33 05 01.03	Prestressed Concrete Cylinder Pipe and Fittings	X		X				X					
33 05 01.05	Bar-Wrapped Concrete Cylinder Pipe Fittings												
33 05 01.07	Low Head Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe			X						X			
33 05 01.09	Polyvinyl Chloride (PVC) Pressure Pipe and Fittings			X						X			
33 05 13	Manholes and Structures												
33 05 23.13	Utility Horizontal Directional Drilling												

SUBMITTAL SCHEDULE

Spec Number	Description	Shop Drawing	Sample	Certified Test Report	Certification of Local Field Service	Extended Warranty	Extended Service Agreement	Certificate of Adequacy of Design	Certification of Applicator/Subcontractor	Record Data	Operation and Maintenance Manuals	Equipment Installation Report	Process Performance Bond
33 05 23.33	Pipeline Crossing [Hwys, Streets, and R.R.'s by Boring, Tunneling, or Open Cut]	X											
33 11 13.11	Steel Pipe Polyurethane Coating	X		X				X					
33 11 13.13	Steel Pipe and Fittings												
33 12 16	Ball Valves												
33 12 16.13	Miscellaneous Valves										X		
33 12 16.16	Air Release and Air and Vacuum Valves							X			X		
33 12 16.19	Eccentric Plug Valves										X		
33 12 16.23	Gate Valves										X		
33 12 16.26	Butterfly Valves										X		
33 12 16.33	Swing Check Valves										X		
33 49 00	Storm Drainage Structures												
33 49 00.01	Storm Drainage System												
33 71 19.13	Electrical Manholes and Handholes	X								X			
33 71 39.23	Underground High-Voltage Wiring												

SUBMITTAL SCHEDULE

Spec Number	Description	Shop Drawing	Sample	Certified Test Report	Certification of Local Field Service	Extended Warranty	Extended Service Agreement	Certificate of Adequacy of Design	Certification of Applicator/Subcontractor	Record Data	Operation and Maintenance Manuals	Equipment Installation Report	Process Performance Bond
33 73 23	Dry-Type Transformers [600 V and Less]												
40 05 53	Identification for Process Piping and Equipment												
40 90 02	Supervisory Control and Data Acquisition (SCADA) System	X		X							X		
40 92 13.13	Electrically Operated Primary Control Valves [Butterfly]										X	X	
40 92 13.14	Pump Control Ball Valves												
40 92 13.18	Pump Control Cone Valve												
40 92 13.20	Pump Control Valves												
40 94 23	Distributed Process Control Systems	X		X							X		

END OF SECTION

01 35 00 SPECIAL PROCEDURES

1.00 GENERAL

1.01 CONSTRUCTION SEQUENCE

- A. Perform the Work as required to complete the entire Project within the Contract Time.

1.02 SHUT DOWNS AND PLANS OF ACTION

- A. Shut downs of operations or equipment must be planned and scheduled.
  - 1. Submit a written plan of action for approval for shutting down essential services. These include:
    - a. NTMWD Pipelines.
    - b. Electrical power.
    - c. Control power.
    - d. Other designated functions.
  - 2. Describe the following in the Plan of Action:
    - a. Construction necessary.
    - b. Utilities, piping, or services affected.
    - c. Length of time the service or utility will be disturbed.
    - d. Procedures to be used to carry out the Work.
    - e. Plan of Action to handle emergencies.
    - f. Contingency plan that will be used if the original schedule cannot be met.
  - 3. Plan must be received by the Owner 2 weeks prior to beginning the Work.

1.03 CRITICAL OPERATIONS

- A. The Owner will identify "Critical Operations" that must not be out of service longer than the designated maximum out of service time and/or must be performed only during the designated times.
- B. Submit a written plan of action for approval for Critical Operation.
  - 1. Describe the following in the Plan of Action:
    - a. Construction necessary.
    - b. Utilities, piping, or services affected.
    - c. Length of time the service or utility will be disturbed.
    - d. Procedures to be used to carry out the Work.
    - e. Plan of Action to handle emergencies.
    - f. Contingency plan that will be used if the original schedule cannot be met.

        g. List of manpower, equipment, and ancillary supplies. Identify backups for key pieces of equipment such as excavators and pumps and key personnel such as welders.

    2. Plan must be received by the Owner 2 weeks prior to beginning the Work.

C. Work affecting "Critical Operations" is to be performed on a 24-hour a day basis until Owner's normal operations have been restored.

D. Provide additional work force and equipment as required to complete the Work affecting "Critical Operations" within the allotted time.

E. Include the cost for Work affecting "Critical Operations" in the Proposal.

F. Liquidated damages will be assessed if Work on "Critical Operations" is not completed within the time indicated.

    1. These items are critical to the plant operation, operation of the existing distribution system or other critical operations.

    2. Loss of plant operation, operation of the existing distribution system or other critical operations can subject the Owner to loss of revenue, additional operations cost, and fines from regulatory agencies.

    3. Liquidated damages have been established for each critical operation:

G. Designated Critical Operations will be described in more detail in the design documents.

H. The Owner will assist the Contractor in draining the existing pipelines as much as possible through existing blow-off valves. The Contractor will be responsible for providing dewatering pumps, etc. required to completely dewater the facilities and handle any leakage past closed valves.

END OF SECTION

01 40 00 QUALITY REQUIREMENTS

1.00 GENERAL

1.01 CONTRACTOR'S RESPONSIBILITIES

A. Control the quality of the Work and verify that the Work meets the standards of quality established in the Contract Documents.

1. Inspect the Work of the Contractor, Subcontractors and Suppliers. Correct defective Work.
2. Inspect products and materials to be incorporated into the Project. Ensure that Suppliers of raw materials, parts, components, assemblies, and other products have adequate quality control system to ensure that quality products are produced. Provide only products that comply with the Contract Documents.
3. Provide and pay for the services of an approved professional materials testing laboratory acceptable to the Owner to insure that products proposed for use fully comply with the Contract Documents.
4. Provide all facilities and calibrated equipment required for quality control tests.
5. Provide consumable construction materials of adequate quality to provide a finished product that complies with the Contract Documents.
6. Perform tests as indicated in this and other Sections of the Specifications. Schedule the time and sequence of testing with the Construction Manager. All quality control testing is to be observed by the Construction Manager or designated representative.
7. Maintain complete inspection and testing records at the Site and make them available to Owner, Engineer and Construction Manager.

B. Designate a quality control manager before Work begins with authority to monitor the Work effectively and to prepare implement and enforce a Quality Management Plan as described in Paragraph 1.11.

C. Should requirements of this Section conflict with the requirements of the technical Specifications, the technical Specifications shall govern.

1.02 QUALITY ASSURANCE ACTIVITIES BY THE OWNER

A. Owner may perform its own quality assurance test independent of the Contractor's Quality Control Program or as otherwise described in the Contract Documents. Provide labor, materials, tools, equipment, and related items for testing by the Owner including, but not limited to temporary construction required for testing and operation of new and existing utilities. Assist the Owner, Engineer, Construction Manager, and testing organizations in performing quality assurance activities.

1. Provide access to the Work and to the Supplier's operations at all times Work is in progress.
2. Cooperate fully in the performance of sampling, inspection, and testing.
3. Furnish labor and facilities to:

        a. Provide access to the Work to be tested.
        b. Obtain and handle Samples for testing at the Site or at the source of the product to be tested.
        c. Provide calibrated scales and measuring devices for the Owner's use.
        d. Facilitate inspections and tests.
        e. Provide adequate lighting to allow Owner observations.
        f. Store and cure test Samples.
    4. Furnish copies of the tests performed on materials and products.
    5. Provide adequate quantities of representative product to be tested to the laboratory at the designated location.
    6. Give the Construction Manager adequate notice before proceeding with Work that would interfere with testing.
    7. Notify the Construction Manager and the testing laboratory prior to the time that testing is required. Lead time is to be adequate to allow arrangements to be made for testing.
    8. Do not proceed with any Work until testing services have been performed and results of tests indicate that the Work is acceptable.
    9. Provide complete access to the Site and make Contract Documents available.
    10. Provide personnel and equipment needed to perform sampling or to assist in making the field tests.
    11. Quality assurance testing performed by the Owner will be paid for by the Owner, except for verification testing performed by the Owner, which shall be paid for by the Contractor as described in Paragraph 1.06.

B. Quality assurance activities of the Owner, Engineer or Construction Manager through their own forces or through contracts with materials testing laboratories and survey crews are for the purpose of monitoring the results of the Contractor's Work to see that it is in compliance with the requirements of the Contract Documents.

C. Quality assurance activities of the Owner and Engineer or non-performance of quality assurance activities:
    1. Do not relieve the Contractor of its responsibility to perform Work and furnish materials and products and constructed Work conforming to the requirements of the Contract Documents.
    2. Do not relieve the Contractor of its responsibility for providing adequate quality control measures.
    3. Do not relieve the Contractor of responsibility for damage to or loss of the material, product or Work before Owner's acceptance.
    4. Do not constitute or imply Owner's acceptance.
    5. Do not affect the continuing rights of the Owner after Owner's acceptance of the completed Work.

D. The presence or absence of the Owner's Resident Representative or Engineer does not relieve the Contractor from any contract requirement, nor is the Owner's Resident Representative or Engineer authorized to change any term or condition of the Contract Documents without the Owner's written authorization in a Field Order or Change Order.

E. Failure on the part of the Owner, Engineer or Construction Manager to perform or test products or constructed works in no way relieves the Contractor of the obligation to perform Work and furnish materials conforming to the Contract Documents.

F. All materials and products are subject to Owner's quality assurance observations or testing at any time during preparation or use. Material or products which have been tested or observed or approved by Owner at a supply source or staging area may be re-observed or re-tested by Owner before or during or after incorporation into the Work, and rejected if they do not comply with the Contract Documents.

1.03 SUBMITTALS

A. Submittals shall be in accordance with Section 01 33 00 "Submittal Procedures" and shall include:

1. A written Quality Management Plan that establishes the methods of assuring compliance with the Contract Documents. Submit this program as Record Data
2. A Statement of Qualification for the proposed testing laboratory. The statement of qualifications is to include a list of the engineers and technical staff that will provide testing services on the Project, descriptions of the qualifications of these individuals, list of tests that can be performed, equipment used with date of last certification and a list of recent projects for which testing has been performed with references for those projects.
3. Test reports per Paragraph 1.07. Reports are to certify that products or constructed works are in full compliance with the Contract Documents or indicate that they are not in compliance and describe how they are not in compliance.
4. Provide Certified Test Reports on materials or products to be incorporated into the Project. Reports are to indicate that material or products are in full compliance with the Contract Documents or indicate that they are not in compliance and describe how they are not in compliance.

1.04 STANDARDS

A. Provide a testing laboratory that complies with the ACIL (American Council of Independent Laboratories) "Recommended Requirements for Independent Laboratory Qualifications".

B. Perform testing per recognized test procedures as listed in the various sections of the Specifications, standards of the State Department of Highways and Public Transportation, American Society of Testing Materials (ASTM), or other testing associations. Perform tests in accordance with published procedures for testing issued by these organizations.

1.05 DELIVERY AND STORAGE

A. Handle and protect test specimens of products and construction materials at the Site in accordance with recognized test procedures.

1.06 VERIFICATION TESTING

A. Provide verification testing when tests indicate that materials or the results of construction activities are not in conformance with Contract Documents.

B. Verification testing is to be provided at the Contractor's expense to verify products or constructed works are in compliance after corrections have been made.

C. Tests must comply with recognized methods or with methods recommended by the testing laboratory and approved by the Engineer.

1.07 TEST REPORTS

A. Test reports are to be prepared for all tests.

  1. Tests performed by testing laboratories may be submitted on their standard test report forms. These reports must include the following:

     a. Name of the Owner, Project title and number, equipment installer and general Contractor.

     b. Name of the laboratory, address, and telephone number.

     c. Name and signature of the laboratory personnel performing the test.

     d. Description of the product being sampled or tested.

     e. Date and time of sampling, inspection, and testing.

     f. Date the report was issued.

     g. Description of the test performed.

     h. Weather conditions and temperature at time of test or sampling.

     i. Location at the Site or structure where the test was taken.

     j. Standard or test procedure used in making the test.

     k. A description of the results of the test.

     l. Statement of compliance or non-compliance with the Contract Documents.

     m. Interpretations of test results, if appropriate.

  2. Submit reports on tests performed by Contractor or his suppliers or vendors on the forms provided in Section 01 31 13.13 "Forms."

  3. Engineer will prepare test reports on tests performed by the Engineer.

B. Distribute copies of the test reports to the Construction Manager within 24 hours of completing the test. Flag tests reports with results that do not comply with Contract Documents for immediate attention. Hard copies of test reports are to be distributed to individuals designated at the pre-construction conference:

Recipient	No. of Copies
Owner	2
Engineer	1
Construction Manager	1
Contractor	1

C. Payment for Work subject to testing may be withheld until the Contractor's quality control test reports of the Work are submitted to the Owner's Resident Representative.

1.08 NON-CONFORMING WORK

A. Immediately correct any Work that is not in compliance with the Contract Documents or submit a written explanation of why the Work is not to be corrected immediately and when corrective Work will be performed.

B. Payment for non-conforming Work shall be withheld until Work is brought into compliance with the Contract Documents.

1.09 LIMITATION OF AUTHORITY OF THE TESTING LABORATORY

A. The testing laboratory representatives are limited to providing consultation on the test performed and in an advisory capacity.

B. The testing laboratory is not authorized to:

1. Alter the requirements of the Contract Documents.
2. Accept or reject any portion of the Work.
3. Perform any of the duties of the Contractor.
4. Stop the Work.

1.10 QUALITY CONTROL PLAN

A. Submit Contractor's Quality Control Plan that identifies personnel, procedures, control, instructions, tests, records, and forms to be used. Construction will be permitted to begin only after acceptance of the Quality Control Plan or acceptance of an interim plan applicable to the particular feature of Work to be started. Work outside of the features of Work included in an accepted interim plan will not be permitted to begin until acceptance of a Quality Control Plan or another interim plan containing the additional features of Work to be started.

B. Content of the Quality Control Plan: The Quality Control Plan shall include, as a minimum, the following to address all construction operations, both on-Site and off-Site, including Work by Subcontractors and Suppliers:

1. A description of the quality control organization, including a chart showing lines of authority and acknowledgement that the quality control staff shall implement the quality control program for all aspects of the Work specified.

2. The name, qualifications (in resume format), duties, responsibilities, and authorities of each person assigned a quality control function.
3. A copy of the letter to the Quality Control Manager signed by an authorized official of the firm which describes the responsibilities and delegates sufficient authorities to adequately perform the functions of the Quality Control Manager, including authority to stop Work which does not comply with the Contract Documents or will result in Work that does not comply with the Contract Documents. The Quality Control Manager shall issue letters of direction to all other various quality control representatives outlining duties, authorities, and responsibilities. Copies of these letters shall also be furnished to the Construction Manager.
4. Procedures for scheduling, reviewing, certifying, and managing submittals, including those of Subcontractors and Suppliers.
5. Control, verification, and acceptance testing procedures for each specific test to include the test name, Specification paragraph requiring test, feature of Work to be tested, test frequency, person responsible for each test, applicable industry testing standards and laboratory facilities to be used for the test.
6. Procedures for tracking phases of quality control, verification, and acceptance tests including documentation.
7. Procedures for tracking construction deficiencies from identification through acceptable corrective action. Indicate how verification that identified deficiencies have been corrected is to be documented.
8. Reporting procedures, including proposed reporting formats
9. The name of the proposed testing laboratory along with documentation of qualifications, a list of tests that can be performed, and a list of recent projects for which testing has been performed with references from those projects.

C. Notification of Changes: After submittal of the Quality Control Plan, the Contractor shall notify the Owner in writing of any proposed changes.

D. Coordination Meeting: After the Pre-construction Meeting and before start of construction, the Contractor shall meet with the Owner, Engineer and Construction Manager to discuss the Contractor's Quality Control Plan. The Quality Control Plan shall be submitted a minimum of 14 calendar days prior to the Coordination Meeting. During the meeting, a mutual understanding of the system details shall be developed, including the forms for recording the Quality Control operations, testing, administration of the system for both on-Site and off-Site Work, and the interrelationship of Contractor's management and control with the Owner's Quality Assurance. Revise the Quality Management Plan to reflect comments and recommended changes resulting from this meeting.

1.11 QUALITY CONTROL ORGANIZATION

A. Provide a designated quality control manager and an alternate quality control manager to serve in the absence of the quality control manager. The quality control manager and alternate quality control manager shall be persons other than the Contractor's site superintendent or project manager. No Work shall take place without the Contractor's quality control manager, alternate quality control manager or appropriate specialist to observe and inspect the Work. Substitutions of the Contractor's quality control staff will not be allowed without prior written approval from the Owner or Construction Manager. Any substitution in the Contractor's quality control staff must meet or exceed the qualifications and experience requirements of those individuals proposed in the Contractors statement of qualifications. Owner has absolute discretion in determining the acceptability of the Contractor's quality control staff.

B. Personnel Requirements: The requirements for the quality control organization are a quality control manager, alternate and sufficient number of additional qualified personnel to ensure Contract compliance. Provide personnel identified in the Contract Documents as requiring specialized qualifications and skills to ensure Work is being properly performed as part of the quality control organization. The Contractor's quality control staff shall maintain a presence at the Site at all times during progress of the Work and have complete authority and responsibility to take any action necessary to ensure Contract compliance.

   1. Quality Control Manager: Designate an individual in the Quality Control Plan as the quality control manager who shall be responsible for overall management of quality and have the authority to act in all quality matters for the Contractor. An alternate for the quality control manager shall be identified in the Quality Control Plan to serve in the event of the manager's absence. The quality control manager shall be assigned no other duties, The quality control manager and alternate quality control manager shall have the qualifications stated in the Instructions to Bidders.

   2. Quality Control Personnel: Provide specialized personnel to assist the quality control manager with quality control of such specialty Work as electrical, mechanical, civil, structural, environmental, materials, and testing as part of the quality control organization. These individuals shall be directly responsible to the quality control manager; be physically present at the construction site during Work on their areas of responsibility; and have the necessary education and/or experience to effectively manage the quality of the Work being performed.

   3. Organizational Changes: Maintain adequate quality control staff at all times to ensure that quality Work is being performed. Revise the Quality Control Plan to reflect the changes when it is necessary to make changes to the quality control staff. Submit the changes to the Owner and Construction Manager for approval.

2.00 PRODUCTS

2.01 TESTING APPARATUS

A. Furnish testing apparatus and related accessories necessary to perform the tests.

3.00 EXECUTION

3.01 QUALITY CONTROL PROGRAM

A. Perform quality control observations and testing as required in each Section of the Specifications and where indicated on the Drawings.

B. Provide a quality control program that includes the following phases for each definable Work task. A definable Work task, one which is separate and distinct from other tasks, has separate control requirements, may be provided by different trades or disciplines, or may be work by the same trade in a different environment.

1. Planning Phase: Perform the following before beginning each definable Work task:
   a. Review the Drawings.
   b. Review submittals and determine that they are complete in accordance with the Contract Documents.
   c. Check to assure that all materials and/or equipment have been tested, submitted, and approved.
   d. Examine the work area to assure that all required preliminary Work has been completed and is in compliance with the Contract Documents.
   e. Examine required materials, equipment, and Sample Work to assure that they are on hand, conform to submittals, and are properly stored.
   f. Review requirements for quality control inspection and testing.
   g. Discuss procedures for controlling quality of the Work. Document construction tolerances and workmanship standards for the Work task.
   h. Check that the portion of the plan for the Work to be performed incorporates submittal comments.
   i. Discuss results of planning with the Construction Manager. Conduct a meeting attended by the quality control manager, the Construction Manager, superintendent, other quality control personnel as applicable, and the foreman responsible for the Work task. Instruct applicable workers as to the acceptable level of workmanship required in order to meet the requirements of the Contract Documents. Document the results of the preparatory phase actions by separate meeting minutes prepared by the quality control manager and attached to the quality control report.
   j. Do not move to the next phase unless results of investigations required for the planning phase indicate that requirements have been met.
2. Work Phase: Complete this phase after the Planning Phase.
   a. Notify the Construction Manager at least 24 hours in advance of beginning the Work and discuss the review of the planning effort to indicate that requirements have been met.
   b. Check the Work to ensure that it is in full compliance with the Contract Documents.
   c. Verify adequacy of controls to ensure full compliance with Contract Documents. Verify required control inspection and testing is performed.
   d. Verify that established levels of workmanship meet acceptable workmanship standards. Compare with required Sample panels as appropriate.
   e. Repeat the initial phase for each new crew to work on-Site, or any time acceptable specified quality standards are not being met.
3. Follow-up Phase: Perform daily checks to assure control activities, including control testing, are providing continued compliance with Contract requirements.

a. Make checks daily and record observations in the quality control documentation.

b. Conduct follow-up checks to correct all deficiencies prior to the start of additional Work tasks that may be affected by the defective Work. Do not build upon nor conceal non-conforming Work.

c. Conduct a review of the Work 1 month prior to the expiration of the correction period prescribed in the General Conditions with the Owner and Construction Manager. Correct defects noted during the review.

C. Conduct additional planning and review if:

1. The quality of on-going Work is unacceptable.
2. Changes are made in applicable quality control staff, onsite production supervision or work crew.
3. Work on a task is resumed after a substantial period of inactivity.
4. Other quality problems develop.

3.02 CAST-IN-PLACE CONCRETE TESTING

A. Test cast-in-place concrete in accordance with Section 03 30 00 "Cast-In-Place Concrete."

3.03 PROTECTIVE COATINGS

A. Test protective coatings per Section 09 96 00 "High-Performance Coatings" and Section 09 91 00 "Painting."

3.04 LEAKAGE TESTS FOR STRUCTURES

A. Test structures that will contain water on a full time or intermittent basis for leaks. Perform tests prior to installing equipment or materials within the structure. In the event that the structure fails to pass the test, drain the structure, repair the leaks, re-fill, and re-test the structure. Repeat tests until the structure passes the test. The Owner may repeat the test at any time during the correction period established in the General Conditions.

B. Test the structure for leakage using the following procedure:

1. Determine the evaporation allowance for loss of water.
   a. Use a standard circular pan procedure established by the U.S. Weather Bureau to measure evaporation rate.
   b. Calculate evaporation allowance by multiplying the evaporation rate in gallons per 24 hours per square foot of surface are by the open surface area of the water in the structure.
2. Calculate the allowable leakage for the structure. Allowable leakage is calculated as 0.03 gallons per square foot of concrete area in contact with the water per 24 hours.
3. Fill the structure to the overflow level with water at a rate not to exceed 2 feet per hour.
4. Allow the structure to set for 3 days.
5. Observe the perimeter of the structure and identify all leaks.

6. Repair structure walls and floors where leaks have been identified.
7. Mark the water level at the structure wall. Measure the fall in water level over a 24-hour period to the nearest 1/8 inch at least twice a day to determine the quantity of water lost. Provide a stilling well for measurement if required to allow accurate measurement.
8. Calculate the amount of water lost during this time period.
9. Compare the amount of water lost to the allowable loss.

C. Drain the structure, determine the sources of leakage and repair if the amount of water lost exceeds the allowable leakage plus the evaporation allowance.

3.05 PIPING SYSTEMS

A. Test Requirements:

1. Perform test on piping systems including piping installed between or connected to existing pipe.
2. Conduct tests on buried pipe to be hydrostatically tested after the trench is completely backfilled. If field conditions permit and if approved by the Engineer, partially backfill the trench and leave the joints open for inspection and conducting of the initial service leak test. Do not conduct the acceptance test until backfilling is complete.
3. Pneumatically test the buried piping and expose joints of the buried piping for the acceptance test.
4. Conduct the test on exposed piping after the piping is completely installed, including supports, hangers, and anchors, but prior to insulation and coating application.
5. Do not perform testing on pipe with concrete thrust blocking until the concrete has cured at least 5 days.
6. Determine and remedy the cause of the excessive leakage for any pipe failing to meet the specified requirements for water or air tightness.
7. Tests must be successfully completed and reports filed before piping is accepted.
8. Submit a comprehensive plan and schedule for testing to the Engineer for review at least 10 days prior to starting each type of testing.
9. Remove and dispose of temporary blocking material and equipment after completion and acceptance of the piping test.
10. Repair any damage to the pipe coating.
11. Clean pipelines so they are totally free flowing prior to final acceptance.
12. Test piping independently from tests on structures.
    a. Test method and test pressure depend upon the application of the piping.
    b. Pressure pipe is defined as piping that is part of a pumped or pressurized system. Perform test for pressure pipe per the procedures indicated in Paragraph 3.05.B.
    c. Gravity pipe is defined as piping that depends upon the force of gravity for flow through the pipe, with the exception of process piping described in paragraph

3.05.A.12.d. Perform test for gravity pipe per the procedures indicated in Paragraph 3.05.C, 3.05.D, or 3.05.E.

d. Chemical processing lines are to be tested as pressure pipe regardless of the operating conditions. The test pressure is to be 1.5 times the pressure rating of the pipe.

e. Process piping between hydraulic structures is to be considered as pressure pipe. Perform the test for this pipe per Paragraph 3.05.B. The test pressure is to be the maximum hydrostatic head plus 10 feet. The maximum hydrostatic head is the difference in elevation of the pipe at its lowest point and the maximum top of the wall

B. Pressure and Leakage Tests of Pressure Piping:

1. Perform hydrostatic pressure and leakage tests in accordance with Section 01 45 16.16 "Hydrostatic Testing."

C. Tests for Plumbing Drainage and Vent Systems:

1. Plug openings as necessary.
2. Test drainage and venting systems by filling piping with water to the level of the highest vent stack for 30 minutes.
3. Make the examination for leakage at joints and connections.
4. Test fail if there is any drop in water level.

3.06 ELECTRICAL TESTING

A. Qualifications:

1. Perform testing using qualified personnel with a minimum of 5 years' experience installing and testing electrical equipment and machinery, unless otherwise specified.
2. Use testing firms or individuals to perform tests that have not provided services or materials used on the Project or are otherwise related or affiliated with other Contractors or Suppliers for this Project unless permitted by the Owner.

B. Report Forms: Complete appropriate test report neatly and in ink for the items being tested. Note listed data that is not applicable or cannot be obtained as "N/A" or document with an explanation for the omission. Incomplete test forms will not be witnessed by the Construction Manager. Repeat tests no accepted. Substitute forms recording similar data and test equipment as that specified may be used if approved by the Engineer.

C. Test Equipment:

1. Provide test equipment and materials necessary to perform the requested tests.
2. Test equipment and apparatus shall be appropriate for the full range and duration of the test to be performed.
3. Demonstrate that the test equipment is functioning properly, prior to the commencement of the test. Suspend the test and repair or replace the equipment if test equipment fails during any portion of a test. Repeat the test in its entirety or as otherwise required by the Construction Manager.

4. Provide a copy of the test equipment calibration certificate to the Construction Manager prior to the commencement of the test. Provide test equipment that has been calibrated with 6 months of the date of the test using methods approved by the National Institute of Standards and Technology.

D. Execution:

1. Make appropriate repairs or replacements if the circuit, equipment or machinery being tested does not pass. Repeat test as directed by the Construction Manager.
2. The more rigid requirement prevails if test procedures or equipment conflicts occur between the various sections and/or Supplier's recommendations.

E. Electrical Cable:

1. Communication Cable and Conductors: Submit test forms to the Owner's for approval prior to performing the following tests:
2. Test shielded pair, telephone, paging, signaling and computer cables for continuity, short circuits and grounds with a low voltage source, not to exceed the insulation rating of the conductors or jacket.
3. Test fiber-optic cable between terminating ends for each circuit per the Supplier's recommendation. Cables, splices (where permitted), and connectors shall be tested for continuity, band width (maximum), and attenuation losses.

F. 600 Volt Cable and Conductors:

1. Test power and control conductors rated at 600 volts with an insulation resistance tester at 1000 volts, with respect to ground, and at 1000 volts with respect to all other conductors in each circuit.
2. Verify suitable ground connections are provided and maintained throughout the test.
3. Perform tests and record results as required by the "600 Volt Cable Test Report" or form provided by the Engineer.
4. Test each circuit and record the results for continuity between terminating ends with a low voltage source.

G. 5 kV Cable and Conductors:

1. Perform insulation resistance test on 5 kV cable for insulation resistance tested at 2500 volts with respect to ground and at 2500 volts with respect to all other conductors in each circuit.
2. H-Pot test 5 kV cables incrementally to 25 kV DC for 15 minutes per ANSI/IEE STD 400. Record leakage current in the spaces provided, at the time intervals shown, on the "Medium Voltage Cable Test Report." Do not exceed the cable Supplier's maximum test values or procedures.
3. Perform Individual conductor resistance tests and recorded results. Test each circuit for continuity between terminations ends and record the test results. Provide additional tests and checks as requested by the Supplier.

H. 15kV Cable and Conductors:

1. Perform insulation resistance test on 15 kV cable at 2500 volts with respect to all other conductors in each circuit.
2. H-Pot test 15 kV cable incrementally to 55 kV DC for 15 minutes per ANSI/IEE STD. 400. Record leakage current at the time interval, shown, on the "Medium Voltage Cable Test Report." Do not exceed the cable Supplier's recommended maximum test values or procedures. Perform individual conductor resistance tests and record the results. Test each circuit for continuity between terminating ends and record the results. Provide additional tests and checks as required by the Supplier.

I. Switchgear:

1. Test electrical switchgear and electrical devices and controls mounted on or in the switchgear in accordance with the "Switchgear Test Report" form.
2. Record the following information and attach to the test report:
    a. Resistance reading across joints of each horizontal and vertical bus.
    b. Verify proper operation of electrical, mechanical and keyed interlocking systems.
    c. Operate devices to both their open and close states. Operate stored energy devices mechanically and electrically as applicable. Operate remotely controlled devices from their remote location.
    d. Verify proper operation of draw-out circuit breakers and switches. Remove and re-install each unit. Verify proper operation of shutters and barriers.
    e. Disconnect electrical and electronic sensing and protective devices not rated to withstand insulation resistance test potentials. Reconnect the devices before energizing the switchgear.
    f. Perform insulation resistance tests at the test voltages shown below for the following equipment. Do not exceed the Supplier's recommended maximum test values or procedures.

Equipment Rating	Test Voltage
0-250 volts	500 volts
251-600 volts	1000 volts
601-5000 volts	2500 volts
5001-15,000 volts	2500 volts
15,001-39,000 volts	5000 volts

    g. Provide additional tests and checks as recommended by the Supplier before energizing.
    h. Energize switchgear. Measure and record instrument indications for no load and connected load conditions.

J. Transformers:

1. Test single-phase and three-phase, liquid filled and dry transformers rated 5 kVA and larger in accordance with the "Transformer Test Report," form.

2. Record the following information and attach to the test report.
    a. Verify proper operation of all fans, alarms, and other auxiliary and monitoring devices.
    b. Verify "tap changer" operation, if applicable, in all positions. Set and secure "tap changer" to position recommended by the Construction Manager or Engineer.
    c. Obtain insulating liquid Sample from all liquid filled transformers. Submit Sample to testing laboratory, approved by the Owner for analysis. Perform standard insulating liquid tests as required by the Construction Manager or Engineer. Deliver test results to the Owner within 30 days after sampling.
    d. Perform insulation resistance tests at the test values shown below for the following equipment.
    e. Perform tests from each winding to ground and winding to winding. Primary and secondary sections shall be tested separately.
    f. Do not exceed the Supplier's recommended maximum test values or procedures.

Transformer Coil Rating	Test Voltage
0-600 volts	1000 volts
601-5000 volts	2500volts
5001-15,000volts	5000 volts
15,001-39,000 volts	10,000 volts

    g. Provide additional tests and checks as recommended by the Supplier before energizing.
    h. Energize transformer. Measure and record primary and secondary volts and amps under no load and connected load conditions.

K. Motors:

1. Test electric motors in accordance with the "Motor Startup Report" form.
2. Check and record motor winding continuity phase to phase with a low voltage source.
3. Check and record motor winding insulation resistance, each phase with respect to ground, at the test values shown below for A.C. induction motors per REF. IEEE Standard 43.
4. Do not exceed the Supplier's recommended maximum test values or procedures.

Motor Voltage Rating	Test Voltage
250 V and below	500
above 250 V	1000
2360 V, 3 Phase	Per manufacturer's startup instructions or as otherwise directed by the Engineer.
4160 V, 3 Phase	Per manufacturer's startup instructions or as otherwise directed by the Engineer.

5. Check and record motor circuit voltage before starting motor.
6. Verify operation of motor space heater if applicable.
7. Provide additional tests and checks as recommended by the Supplier before energizing.
8. Start motor and verify immediately correct shaft rotation.
9. Check and record motor running volts and amps.
10. Verify correct operation of all interlocking and protective devices.

END OF SECTION

01 45 16.16 HYDROSTATIC TESTING

1.00 GENERAL

1.01 WORK INCLUDED

A. Perform a hydrostatic pressure test on each valved or plugged section of newly laid pipe after the pipe has been backfilled. Perform hydrostatic pressure test by raising the pressure in the pipe section to the required test pressure for the duration defined in Paragraph 3.02.

B. Plugs may be installed in concrete cylinder or steel pipe at intermediate locations for the purpose of testing shorter lengths of pipe at the Contractor's option. No additional compensation will be paid to the Contractor for testing at intermediate locations if Contractor uses this option.

C. Obtain water from the Owner for filling the pipeline for the hydrostatic test. Provide the necessary piping, connection, pressure reducing and backflow prevention equipment required to conduct the test. Fill the new pipeline through a backflow prevention device. Leave the pipeline full of water upon completion of the hydrostatic test, unless internal test plugs must be removed to allow construction to continue or where pipe will gravity drain.

D. Purchase water required for re-testing of the pipeline from the Owner. Water will be sold to the Contractor at published rates.

1.02 SUBMTTALS

A. Submit Hydrostatic Pipe Test Reports per Section 01 33 00 "Submittal Procedures."

1.03 STANDARDS

A. The applicable provisions of the following standards shall apply as if written here in their entirety:

American Water Works Association (AWWA)	
AWWA M9	Concrete Pressure Pipe
AWWA M11	Steel Pipe – A Guide for Design and Installation

2.00 PRODUCTS (NOT APPLICABLE)

3.00 EXECUTION

3.01 GENERAL

A. Perform hydrostatic test on bar-wrapped, concrete cylinder pipe in accordance with AWWA M9 and the pipe Supplier's recommendations.

B. Perform hydrostatic test on steel pipe in accordance with AWWA M11 and the pipe Supplier's recommendations.

3.02 TEST CONDITIONS

A. Test pipe at the test pressure for the duration as indicated below for the various pipe materials:

	Pipe Type	**Duration (hours)**	**Test Pressure (psi)**
A	Bar-wrapped concrete cylinder pipe	8	
B	Pre-stressed concrete cylinder pipe	8	
C	Steel pipe	8	

3.03 PROCEDURE

A. Bar-Wrapped Concrete Cylinder Pipe, Pre-stressed Concrete Cylinder Pipe, and Steel Pipe:

1. Hydrostatically test the pipe after backfill over the test section of pipe has been completed for 7 days. Slowly fill the line with water and vent all air from the pipeline during filling.
2. Allow the pipe to stand under a slight pressure for at least 48 hours to allow the mortar lining to become saturated and/or to allow the escape of remaining air trapped in the line. Examine bulkheads, valves, manholes, flanges, and connections for leaks during this period.
3. Stop leaks before continuing with the test.
4. Measure water volume during the test if existing valves in the main line leak during the test. Measure the water volume leaking from the valve through a meter or by other means approved by the Construction Manager. Furnish all necessary equipment and include the cost for this effort in the Contract Price.
5. Expel all air from the pipe before applying the specified test pressure. Provide taps in the line to expel air from high points where air valves are not provided. These taps must be made by the pipe manufacturer and approved by the Engineer. Tightly plug the tap after tests are complete. Include the cost for these taps in the Contract Price.

3.04 EXAMINATION UNDER PRESSURE

A. Inspect the pipe during the test to locate any leaks or breaks, defective joints, cracked or defective pipe, fittings, or valves. Correct defective Work identified during the pressure test.

B. Correct all identified leaks even if leakage is within the parameters for permissible make up water per Paragraph 3.05.

C. Test the pipe again after defective Work has been corrected. Repeat the test and correction of defective Work until satisfactory test results are obtained.

3.05 PERMISSIBLE MAKEUP WATER

A. Measure make up water required for the section of pipe being tested. Makeup water is the volume of water pumped into the test section of pipe necessary to maintain the specified test pressure after the pipe has been filled with water and the air expelled.

B. The maximum acceptable volume of makeup water for steel or bar-wrapped pipe installations is 10 gallons per inch of pipe diameter per mile of pipe tested per 24 hours. Calculate the maximum acceptable volume of makeup water using the following equation:

$$V_m = \frac{10DL}{5280}$$

Where:

V_m is the maximum acceptable volume of makeup water in gallons for 24 hours

D is the nominal pipe diameter in inches

L is the length of the pipe test section in feet

As an example the allowable amount of makeup water for a test section of 2500 feet of 60 inch diameter pipe would be:
10 x 60 x 2500 / 5280= 284 gallons

END OF SECTION

01 50 00 TEMPORARY FACILITIES AND CONTROLS

1.00 GENERAL

1.01 WORK INCLUDED

A. Furnish temporary facilities, including the Contractor's field offices, storage sheds, and temporary utilities needed to complete the Work.

B. Furnish, install, and maintain temporary Project identification signs. Provide temporary on-Site informational signs to identify key elements of the construction facilities. Do not allow other signs to be displayed.

C. Furnish temporary offices per Paragraph 2.02A for Engineer and Owner. Cost associated with providing these facilities is to be included in the Cost of Work. Providing utilities for these offices are to be included in the Contractors fees for General Conditions.

1.02 QUALITY ASSURANCE

A. Design Criteria: Furnish a total electrical heating and cooling system for the Resident Representative's field office capable of maintaining the following minimum design criteria:

1. Heating: Minimum 75 degrees ID temp @ 10 ambient.
2. Cooling: Minimum 75 degrees ID temp @ 105 ambient.
3. Relative humidity: 48 to 54 percent.

B. Testing: Inspect and test each service before placing temporary utilities in use. Arrange for all required inspections and tests by regulatory agencies, and obtain required certifications and permits for use.

1.03 DELIVERY AND STORAGE

A. Arrange transportation, loading, and handling of temporary buildings and sheds.

1.04 JOB CONDITIONS

A. Locate buildings and sheds at the Site as indicated or as approved by the Owner.

B. Prepare the Site by removing trees, brush, or debris and performing demolition or grubbing needed to clear a space adequate for the structures.

C. Pay for the utilities used by temporary facilities during construction.

D. Provide each temporary service and facility ready for use at each location when the service or facility is first needed to avoid delay in the performance of the Work. Provide Resident Representative's field office completely installed and ready for occupancy and use within 7 days of the Notice to Proceed.

E. Maintain, expand as required, and modify temporary services and facilities as needed throughout the progress of the Work.

F. Do not remove services and facilities until they are no longer needed.

G. Operate temporary facilities in a safe and efficient manner.

1. Do not overload temporary services or facilities.
2. Do not let temporary services or facilities interfere with the progress of the Work.
3. Do not allow unsanitary conditions, public nuisance, or hazardous conditions to develop or exist at the Site.
4. Do not permit freezing of pipes, flooding, or the contamination of water.
5. Maintain Site security and protection of the facilities.

1.05 OPTIONS

A. Construction offices may be prefabricated buildings on skids or mobile trailers.

B. Storage sheds may be prefabricated buildings on skids or truck trailers.

2.00 PRODUCTS

2.01 SIGN MATERIALS

A. Provide new or used signs, wood or metal with structure and framing in sound condition. Materials are to be structurally adequate and suitable for the indicated finish.

B. Provide 3/4-inch exterior grade A/D face veneer plywood with medium density overlay for sign surface.

C. Bolts, brackets, fasteners, and other hardware are to be galvanized or stainless steel.

D. Provide exterior quality coatings.

2.02 TEMPORARY OFFICES

A. Furnish and continuously maintain throughout the Project duration a field office for the Owner and the Engineer's use which meets the following requirements:

1. Minimum size of 12 x 60 feet.
    a. The building is to be divided into three separate spaces (two offices and conference room) by full height walls with a single 3-foot by 6-foot-8-inch door for passage in each wall. The office spaces are to be located at each end of the building and are to be 12 by 12 feet.
    b. Each space is to have an exterior 3-foot by 6-foot-8-inch weather tight door located on one side of building.
    c. Each office space is to have a minimum of one 4-by-5-foot window.
    d. Flooring may be plywood, vinyl, or VCT tile. Do not use carpet.
2. Separate from Contractor's office.
3. Structurally sound, weather-tight, and have floor raised above the ground.
4. Adequately braced and anchored to prevent movement.
5. Heated and air conditioned.

6. Provide a fully plumbed indoor restroom located in one corner of the center section of the building. The restroom shall contain a flush toilet, sink, medicine cabinet with mirror, and storage shelving. Connect fixtures to complete potable water, sanitary, and vent systems.
7. Make connections to electrical power source and provide electrical service to building for duration of the Project.
8. Provide a skirt around perimeter of building of same material as building siding.
9. Construct a porch with steps and covered overhang at each entrance. Construct a handicap accessible ramp to main entrance. Provide railing around porch, steps, and ramp.
10. Provide burglar bars on all windows and hinged burglar bars on outside doors with padlocks or door locks.
11. Provide operable, screened windows with locks.
12. Provide Venetian type blinds for all windows.
13. Provide electric water cooler with bottled water supply for the duration of the Project.
14. Provide furnishings manufactured by HON, or approved equal as follows:

Qty.	Furnishings
3	2'-6" x 5'-0" office desks with credenza
3	Fabric covered, cushioned adjustable arm chairs with swivel/tilt/roll capabilities
3	Protective floor mats
1	3'-0" x 8'-0" folding table
2	2'-6" x 5'-0" folding tables
10	Padded folding chairs
2	Cushioned drafting stool with back
2	Drafting tables or layout tables similar to Mayline Model 7737-B
1	Plan holding rack similar to Planhold Model 43CRI-30 with 10 holders
10	Legal size, four-drawer filing cabinets
3	Four-shelf metal book shelves
3	Wastepaper baskets similar to Lawson Model H9-334-09

15. Provide telephone services.
    a. Provide three separate outside telephone lines. One line will be used for the fax machine. One line will be used for Internet service. One line will be the main office phone number.
    b. Provide rollover capability with the main phone line and fax line such that any incoming calls from the main phone line will rollover to the fax line whenever the main line is in use.

   c. Provide voicemail, call waiting, and caller ID for the main phone line.
   d. Provide three telephones equal to Southwestern Bell TeleMatrix Two Line Caller ID Business Speakerphone. Furnish a minimum of four telephone jacks for each line at locations designated by the Owner/Engineer.

16. Provide Internet service for the duration of the Project. The service is to include provisions for at least one e-mail address that is accessible to the Owner and Engineer's off-Site e-mail systems.
17. Provide long distance calling service for Resident Representative's field office for the duration of the Project. The Contractor shall be responsible for Engineer/Owner's monthly long distance charges of up to $100 per month.
18. Provide a Hewlett Packard Laserjet 3200se Printer/Fax/Copier/Scanner, or approved equal.
19. Provide a new or leased copier.
    a. Konica 3135 copier with auto feed/sort/collate features and 11 x 17 copying capabilities, or approved equal
    b. Provide service and maintenance agreement throughout duration of the Project.
20. Provide a Sony MVC-CD1000 digital camera or approved equal. Provide camera accessories including battery charger and leather carrying case.
21. Furnish and maintain office supply stock, including but not limited to, pens, pencils, markers, staples, notepads, paper, posted notes, floppy disks, CD-WR computer disks, file folders, paper clips, binder clips, etc., for duration of the Project. The Contractor shall be responsible for Engineer/Owner's office supply purchases of up to $50 per month.
22. Furnish a microwave unit with a minimum cooking volume of 1.5 cubic feet.
23. Furnish a refrigerator with minimum storage capacity of 3.5 cubic feet. Refrigerator shall include a freezer section.
24. Provide sufficient lighting for office environment using fluorescent light fixtures with lenses energized by wall switches. Provide switches adjacent to doorway into each space.
25. Provide three duplex receptacles in each office space and four duplex receptacles for the remainder of the building.
26. Provide a fire extinguisher and first aid kit.
27. Provide an electronic alarm system that monitors all entry points into the building and will automatically notify a local security system of any unauthorized entry.
28. Contract with a local security service to monitor and respond to any intrusion alarms throughout duration of the Project.
29. Office and/or materials of construction may be new or used but must be in good condition acceptable to the Owner/Engineer, serviceable, adequate for the intended purpose, and must not violate codes or regulations.

30. Field office and furniture will remain the property of the Contractor. Computer equipment, printer/fax machine, and digital camera shall be turned over to the Owner at the end of the Project.

B. Prior to installation of Owner/Engineer field office, submit the following information for approval:

   1. Office Trailer/Building: Floor plan including square footage of floor area.
   2. Telephone Equipment: Catalog cut sheets.
   3. Security/Alarm System: Catalog cut sheets.
   4. Office Furniture: Catalog cut sheets.

C. Furnish a field office for Contractor's use of adequate size to allow meetings of about 15 people.

D. Provide access to and reserved parking spaces for 10 vehicles adjacent to the Owner and Resident Representative's field office. The parking area surface shall be covered by a durable surface to prevent erosion, mud, dust, or rutting caused by vehicles. The surface shall be a flexible crushed limestone base material, with a 2-inch HMAC overlay meeting the requirements of TxDOT Standard Specification, Item 340.

E. Other trades may provide their own offices only when space is available on the Site, and both the Owner and the Contractor agree.

2.03 TEMPORARY STORAGE BUILDINGS

A. Furnish storage buildings of adequate size to store any materials or equipment delivered to the Site that might be affected by weather.

2.04 TEMPORARY SANITARY FACILITIES

A. Provide sanitary facilities at the Site from the Notice to Proceed until Project conclusion. Maintain these facilities in a clean and sanitary condition at all times and comply with the requirements of the local health authority. On large sites, provide portable toilets at such locations that no point in the Site shall be more than 600 feet from a toilet.

B. Use these sanitary facilities. Do not use rest rooms within existing or Owner-occupied buildings.

2.05 TEMPORARY HEAT

A. Provide heating devices needed to protect the building during construction.

   1. Provide fuel needed to service the heating devices.
   2. Attend heating devices at all times.
   3. Do not allow heaters to operate overnight without someone in attendance.

2.06 TEMPORARY UTILITIES

A. Provide all temporary utilities needed during construction, testing, disinfection, and startup of the Work, including electrical power, water, and telephone. Include costs associated with furnishing temporary utilities in the Contract Price.

   1. Provide a source of temporary electrical power of adequate size for the construction procedures.

      a. Provide electrical pole and service that complies with OSHA and other safety requirements and the requirements of the power company.

      b. Make the electrical power available to the trades as needed.

      c. Provide extensions to the various parts of the buildings as needed.

      d. Provide junction boxes in such an arrangement that distribution boxes are available within 75 feet of any part of the structure.

   2. Provide for temporary water. Extend water to the Site and maintain source until such time that the permanent water supply can be extended to the Site. Include the cost of water, costs for construction, testing, disinfection, and startup of the Work in the Contract Price.

   3. Provide telephone service to the Site and install telephones inside the Contractor's and the Engineer's office.

B. Make arrangements with the local utility company, comply with utility company's requirements and pay for the utility costs during construction, testing disinfection, and startup of the Work.

C. Make utilities available to the trades during construction, testing, disinfection, and startup.

3.00 EXECUTION

3.01 LOCATION OF TEMPORARY FACILITIES

A. Locate all temporary facilities in an area that will not interfere with any Work to be performed under this Contract.

B. Construct and install signs at locations as required by applicable regulatory agencies or as selected by the Owner. Install informational signs at the height of optimum visibility, on ground-mounted poles or attached to temporary structural surfaces.

3.02 PROJECT IDENTIFICATION AND SIGNS

A. Provide Project identification signs of the size, lettering, and construction indicated by the Owner and in accordance with specified requirements.

3.03 TEMPORARY LIGHTING

A. Once a building envelope is complete and waterproof, provide temporary lighting inside the building.

   1. Lighting shall be adequate to perform Work within any space.

   2. Lights shall be left in position in such a manner that every space has temporary light at all times.

3. Temporary lights may be removed once the permanent lighting is in service.

B. Provide portable flood lights at any time that Work will be performed outside the structure at night. Provide adequate lighting to provide sufficient light at any location Work is being performed.

3.04 DRINKING WATER

A. Provide field offices with potable water for Owner's and Engineer's office. Bottled drinking water is to be provided with a dispenser and cooling apparatus.

B. Pay for services and maintain daily.

3.05 CONSTRUCTION FENCE

A. Install and maintain a construction fence around the Site and/or around the storage yard as indicated. Fence may be wood picket or chain link construction. Provide gates with padlocks.

3.06 REMOVAL OF TEMPORARY FACILITIES

A. Remove temporary buildings, sheds, and utilities at the conclusion of the Project and restore the Site to original condition or finished in accordance with the Contract Documents.

B. Remove informational signs upon completion of construction.

C. Remove Project identification signs, framing, supports, and foundations upon completion of the Project.

3.07 MAINTENANCE AND JANITORIAL SERVICE

A. Provide janitorial service (sweeping/mopping) for the Owner's and Engineer's office on a weekly basis or as requested. Trash receptacles are to be emptied daily.

B. Maintain signs and supports in a neat, clean condition. Repair damage to structures, framings, or signs.

C. Repair any damage to permanent structures or finishes caused by placement or removal of temporary signage.

END OF SECTION

01 57 00 TEMPORARY CONTROLS

1.00 GENERAL

1.01 WORK INCLUDED

A. Provide labor, materials, equipment and incidentals necessary to construct temporary facilities to provide and maintain control over environmental conditions at the Site. Remove temporary facilities when no longer needed.

B. Construct temporary impounding works, channels, diversions, furnishing and operation of pumps, installing piping and fittings, and other construction for control of conditions at the Site. Remove temporary controls at the end of the Project.

C. Provide a Storm Water Pollution Prevention Plan in accordance with TCEQ General Permit TXR150000, file required legal notices and obtain required permits prior to beginning any construction activity.

D. Provide labor, materials, equipment, and incidentals necessary to prevent storm water pollution for the duration of the Project. Provide and maintain erosion and sediment control structures as required to preventive sediment and other pollutants from the Site from entering any storm water system, including open channels. Remove pollution control structures when no longer required to prevent storm water pollution.

1.02 QUALITY ASSURANCE

A. Construct storm water pollution prevention measures prior to the beginning of construction and maintain these during construction until final stabilization has been achieved for the area protected.

B. Plan and conduct all land-disturbing activities to minimize the area to be exposed at any one time. Minimize the time of exposure, off-Site erosion, sedimentation, and adverse water quality impacts.

C. Manage surface water runoff originating upgrade of an exposed area to minimize erosion and sediment loss during the period of exposure.

D. Install measures to control both the velocity and rate of release so as to minimize erosion and sedimentation of the receiving water body (i.e., ditch, channel, stream) in accordance with regulatory requirements and as directed by the Owner, Engineer or the Engineer.

E. Periodically clean out and dispose of all sediment and other pollutants as necessary to maintain the treatment capacity of each pollution control feature. Clean out and properly dispose of all sediment and other storm water pollutants at the time of completion of the Work.

1.03 SUBMITTALS

A. Provide copies of notices, records and reports required by Paragraph 1.05 as Record Data in accordance with Section 01 33 00 “Submittal Procedures.”

1.04 STANDARDS

A. Provide a Storm Water Pollution Prevention Plan that complies with Local, State, and Federal requirements. Comply with all requirements of the Texas Commission on Environmental Quality General Permit (TXR150000) for storm water discharges from construction activities under the Texas Pollutant Discharge Elimination System (TPDES) program.

B. Perform Work to comply with "Best Practice" as established by the North Central Texas Council Of Governments (NCTCOG) integrated Storm Water Management (iSWM) Design Manual for Construction or the local agency of jurisdiction.

1.05 PERMITS

A. Submit the following to the TCEQ and the Operator of any Municipal Separate Storm Sewer System (MS4) receiving construction site discharge from the Site:

1. Notice of Intent (NOI) at least 48 hours prior to beginning construction activity. Construction activity may commence 24 hours after the submittal of an electronic NOI.
2. Notice of Change (NOC) letter when relevant facts or incorrect information was submitted in the NOI, or if relevant information in the NOI changes during the course of construction activity.
3. Notice of Termination (NOT) when the Project has been completed and stabilized.

B. Post a copy of the NOI at the Site in a location where it is readily available for viewing by the general public and Local, State, and Federal authorities prior to starting construction activities and maintain the posting until completion of the construction activities.

C. Maintain copies of a schedule of major construction activities, inspection reports, and revision documentation with the Storm Water Pollution Prevention Plan (SWPPP) required under the TPDES General Permit (TXR150000) for Storm Water Discharges from Construction Activities for all projects.

1.06 POLLUTION CONTROL

A. Prevent the contamination of soil, water or atmosphere by the discharge of noxious substances from construction operations. Provide adequate measures to prevent the creation of noxious air-borne pollutants. Prevent dispersal of pollutants into the atmosphere. Do not dump or otherwise discharge noxious or harmful fluids into drains or sewers, nor allow noxious liquids to contaminate public waterways in any manner.

B. Provide equipment and personnel and perform emergency measures necessary to contain any spillage.

C. Contain chemicals in protective areas and do not dump on soil. Dispose of such materials at off-Site locations in an acceptable manner.

D. Excavate contaminated soil and dispose at an off-Site location if contamination of the soil does occur. Fill resulting excavations with suitable backfill and compact to the density of the surrounding undisturbed soil.

E. Provide documentation to the Owner which states the nature and strength of the contaminant, method of disposal, and the location of the disposal site.

F. Comply with local, State and Federal regulations regarding the disposal of pollutants.

G. Groundwater or run-off water which has come into contact with noxious chemicals, sludge, or sludge-contaminated soil is considered contaminated. Contaminated water must not be allowed to enter streams or water courses, leave the Site in a non-contained form or enter non-contaminated areas of the Site.

H. Pump contaminated water to holding ponds constructed by the Contractor for this purpose, or discharge to areas on the interior of the Site, as designated by the Engineer.

I. Construct temporary earthen dikes or take other precautions and measures as required to contain the contaminated water and pump to a designated storage area.

J. Wash any equipment used for handling contaminated water or soil within contaminated areas three times with uncontaminated water prior to using such equipment in an uncontaminated area. Dispose of wash water used to wash such equipment as contaminated water.

1.07 MAINTENANCE OF WATER

A. Manage water resulting from rains or ground water at the Site. Maintain trenches and excavations free of water at all times. Provide and maintain pumps as necessary to remove excess water. Direct water away from the Site to prevent damage to surrounding property.

2.00 PRODUCTS

2.01 MATERIALS

A. Provide materials meeting regulatory requirements.

3.00 EXECUTION

3.01 CONSTRUCTING, MAINTAINING AND REMOVING TEMPORARY CONTROLS

A. Construct temporary controls in accordance with regulatory requirements.

B. Maintain controls in accordance with regulatory requirements were applicable, or in accordance with the requirements of the Contract Documents.

C. Remove temporary controls when no longer required, but before the Project is complete. Correct any damage or pollution that occurs as the result of removing controls before the point where they are no longer required.

END OF SECTION

01 60 00 PRODUCT REQUIREMENTS

1.00 GENERAL

1.01 WORK INCLUDED

A. Provide products for this Project that comply with the requirements of this Section. Specific requirements of the detailed equipment Specifications govern in the case of a conflict with the requirements of this Section.

B. Comply with applicable specifications and standards.

C. Comply with size, make, type, and quality specified or as modified per Section 01 31 13 "Project Coordination."

1.02 QUALITY ASSURANCE

A. Design Criteria:

1. Assume responsibility for the design of the products to include structural stability and operational capability.
2. Design members to withstand all loads imposed by installation, erection, and operation of the product without deformation, failure, or adversely affecting the operational requirements of the product. Size and strength of materials for structural members are specified as minimums only.
3. Design mechanical and electrical components for all loads, currents, stresses, and wear imposed by startup and normal operations of the equipment without deformation, failure, or adversely affecting the operation of the unit. Mechanical and electrical components specified for equipment are specified as the minimum acceptable for the equipment.

B. Coordination:

1. Provide coordination of the entire Project, including verification that structures, piping, and equipment components to be furnished and installed for this project are compatible.
2. Determine that the equipment furnished for this Project is compatible with the Contract Document requirements and with the equipment and materials furnished by others.
3. Electrical components provided for equipment shall comply with all provisions of the Contract Documents.
4. Protective coatings and paints applied to equipment shall be fully compatible with the final coatings to be field applied in accordance with the Contract Documents.

C. Adaptation of Equipment:

1. Drawings and Specifications are prepared for the specified products. Make modifications to incorporate the products into the Project at no cost to the Owner, if a substitution for a product is requested and approved in accordance with Section 01 31 13 "Project Coordination."

2. Do not provide a product with a physical size that exceeds the available space. Consideration may be given to the acceptance of these products or equipment if the Construction Manager assumes all costs necessary to incorporate the item and the Engineer approves such revisions.
3. Coordinate electrical requirements for the products to be installed in the Project, including revisions in electrical equipment components wiring and other factors necessary to incorporate the component.

1.03 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00 "Submittal Procedures" and shall include:

   1. Certificates of Adequacy of Design as described in Section 01 33 00 "Submittal Procedures."
   2. Equipment Installation Reports per Section 01 75 00 "Starting and Adjusting."
   3. Other documentation as required by detailed equipment Specifications.

1.04 STANDARDS

A. The applicable industry standards referenced in the Specifications shall apply as if written here in its entirety.

B. Except where otherwise indicated, structural and miscellaneous fabricated steel used in items of equipment shall conform to the Standards of the American Institute of Steel Construction (AISC).

1.05 GUARANTEES AND WARRANTIES

A. Guarantee and or warranty products furnished by the Construction Manager under this Contract against:

   1. Faulty or inadequate design.
   2. Improper assembly or erection.
   3. Defective workmanship or materials.
   4. Leakage, breakage, or other failure.

B. Guarantee and or warranty the products installed under this Contract, including products furnished by the Owner, against leakage, breakage, or other failure due to improper assembly or erection and against improper installation of the equipment. The guarantee and or warranty period shall be as defined in the General Conditions. Individual Sections of the Specifications may have more stringent warranty requirements than stated in the General Conditions. The most stringent warranty will be required in the event of any difference in the two aforementioned locations.

2.00 PRODUCTS

2.01 MATERIALS

A. Design, fabricate, assemble, deliver and install according to normally accepted engineering and shop practices, except where a higher standard of quality is required by the Contract Documents.

B. Manufacture like parts of duplicate units to standard sizes and gages. Like parts are to be interchangeable.

C. Two or more items of the same kind are to be identical and made by the same Supplier.

D. Provide products suitable for the intended service.

E. Adhere to the equipment capacities, sizes, and dimensions indicated by the Contract Documents.

F. Do not use products for any purpose other than that for which it is designed.

G. Provide new products unless previously used products are specifically allowed in the Contract Documents.

H. Equipment shall not have been in service at any time prior to delivery, except as required by tests.

I. Materials shall be suitable for service conditions.

J. Iron castings shall be tough, close-grained gray iron free from blowholes, flaws, or excessive shrinkage and shall conform to ASTM A48.

K. Structural members shall be considered as subject to shock or vibratory loads.

L. Unless otherwise indicated, steel which will be submerged, all or in part, during normal operation of the equipment shall be at least 1/4 inch thick. All edges are to be chamfered to preclude any sharp exposed edges.

2.02 ELECTRIC MOTORS

A. Unless otherwise required by the detailed equipment Specifications, motors furnished with equipment shall comply with the following requirements:

   1. Motors shall be designed and applied in compliance with NEMA, ANSI, IEEE, and AFBMA standards and the NEC for the specific duty imposed by the driven equipment.
   2. Where frequent starting occurs, motors shall be designed for frequent starting duty equivalent to the duty service required by the driven equipment.
   3. Unless recognized and defined by the standards and codes for intermittent duty as a standard industry practice, motors shall be rated for continuous duty at 40 C ambient. Motor temperature rise above 40 C ambient on continuous operation at nameplate horsepower shall not exceed the NEMA limit.
   4. Motors shall be designed to start with appropriate starter or variable speed drive.
   5. Motor bearing life shall be based upon the actual operating load conditions imposed by the driven equipment.
   6. Motors shall be sized for the altitude at the location where the equipment is to be installed.

7. Motors with 1.0 service factor shall not be loaded more than 87 percent of the nameplate horsepower. Motors with a 1.15 service factor shall not be loaded more than 100 percent of the nameplate horsepower.
8. Where the detailed equipment Specifications call for encapsulated motor windings, the following process shall be used:
    a. After stator assembly, the stator assembly shall be sealed vacuum-pressure impregnation (VPI) of epoxy resin. The stator shall receive two VPI treatments, each treatment consisting of a dip followed by an oven bake. After the final cure, the stator assembly shall receive a final (third) coating of a durable epoxy varnish to further protect against dust, moisture, and a chemical degradation. The windings shall comply with the latest applicable provisions of NEMA MG1.
9. Motors shall have a clamp-type grounding terminal inside the motor conduit box.
10. Motors with external conduit boxes shall have oversized conduit boxes.
11. Maximum starting current shall be per NEMA MG1, Class H.
12. Efficiency shall be per NEMA MG1 for Premium efficiency motors.
13. Minimum insulation shall be Type F.
14. Motors shall be random wound with copper coils.
15. Motors located in a hazardous location shall be rated for the appropriate classification.

B. It is intended that the Supplier use his standard motor on integrally constructed motor driven equipment such as appliances, hand tools, etc., which would otherwise require redesign of the complete unit in order to provide a motor having the specified features.

C. Unless otherwise required by the detailed equipment Specifications, motors within the horsepower ranges indicated below shall be rated and constructed as follows:
1. Below 1/2 HP:
    a. 115-Volt, 60-Hertz, 1-phase.
    b. Dripproof in clean and dry locations; TEFP in all other locations.
    c. Permanently lubricated sealed bearings.
    d. Built-in manual-reset thermal protector; or furnished with integrally mounted stainless steel enclosed manual motor-overload switch.
2. 1/2 to 1 HP:
    a. 230/460-Volt, 60-Hertz, 3-phase.
    b. Dripproof in clean and dry locations; TEFC in all other locations.
    c. Permanently lubricated sealed bearings.
3. 1-1/2 HP and Above:
    a. 230/460-Volt, 60-Hertz, 3-phase.
    b. Dripproof in clean and dry locations; TEFC in all other locations.
    c. Oil or grease lubricated anti-friction or oil lubricated sleeve bearings.

    d. Vertical motors shall have 15-year average life thrust bearings.

D. Motors with horsepower ratings of 15 horsepower or greater shall be provided with space heaters to operate on 120-Volt, single-phase service.

2.03 EQUIPMENT APPURTENANCES

A. Cover belt or chain drives, fan blades, couplings, and other moving or rotating parts on all sides by a safety guard.

    1. Fabricate safety guards from 16 USS gage or heavier galvanized or aluminum-clad sheet steel or 1/2-inch mesh galvanized expanded metal.
    2. Design guards for easy installation and removal.
    3. Provide galvanized supports and accessories for each guard.
    4. Provide stainless steel bolts and hardware.
    5. Provide safety guards in outdoor locations designed to prevent the entrance of rain and dripping water.

2.04 ANCHOR BOLTS

A. Provide suitable anchor bolts for each product.

B. Provide anchor bolts, with templates or setting drawings, sufficiently early to permit setting the anchor bolts when the structural concrete is placed.

C. Provide two nuts for each bolt.

D. Provide anchor bolts for products mounted on baseplates that are long enough to permit 1-1/2 inches of grout beneath the baseplate and to provide adequate anchorage into structural concrete.

E. Provide stainless steel anchor bolts, nuts, and washers.

2.05 SPECIAL TOOLS AND ACCESSORIES

A. Furnish tools, instruments, lifting and handling devices, and accessories necessary for proper maintenance and adjustment that are available only from the Supplier or are not commonly available.

2.06 EQUIPMENT IDENTIFICATION PLAQUES

A. Provide a plaque for each piece of equipment in accordance with Section 40 05 53 "Identification for Process Piping and Equipment."

2.07 LUBRICATION SYSTEMS FOR EQUIPMENT

A. Provide equipment lubricated by systems which:

    1. Require attention no more frequently than weekly during continuous operation.
    2. Do not require attention during startup or shutdown.
    3. Do not waste lubricants.

B. Provide lubricants to fill lubricant reservoirs and to replace lubricant consumed during testing, startup, and operation prior to acceptance of equipment by the Owner.

2.08 INSULATION OF PIPING

A. Insulate all piping on or related to equipment as required to prevent freezing under any condition. Insulate piping per the Supplier's written instruction or per Section 23 07 19 "HVAC Piping Insulation," whichever is more stringent.

3.00 EXECUTION

3.01 INSTALLATION

A. Install equipment including equipment pre-selected or furnished by the Owner as part of this Project as if this equipment had been selected and purchased by the Construction Manager. Assume responsibility for proper installation, startup and making the necessary adjustments so that the equipment is placed in proper operating condition per Section 01 75 00 "Starting and Adjusting."

3.02 LUBRICATION

A. Lubricate all products provided or installed for this Project, including products furnished by the Owner, per the Supplier's written recommendations until the product is accepted by the Owner.

END OF SECTION

01 70 00 EXECUTION AND CLOSEOUT REQUIREMENTS

1.00 GENERAL

1.01 WORK INCLUDED

A. Comply with requirements of the General Conditions and specified administrative procedures in closing out the construction Contract.

1.02 SUBMITTALS

A. Submit affidavits and releases on forms shown in Section 01 31 13.13 "Forms."

1.03 SUBSTANTIAL COMPLETION

A. Submit written notification that the Work or designated portion of the Work is substantially complete to the Engineer when the Work is considered to be substantially complete per the General Conditions. Include a list of the items remaining to be completed or corrected before the Project will be considered to be complete.

B. Engineer shall visit the Site to observe the Work within a reasonable time after notification is received to determine the status of completion.

C. Engineer shall issue notification to the Contractor that the Work is either substantially complete or that additional Work must be performed before the Project may be considered substantially complete.

  1. Engineer shall notify the Contractor in writing of items that must be completed before the Project can be considered substantially complete.

     a. Correct the noted deficiencies in the Work.

     b. Issue a second written notice with a revised list of deficiencies when Work has been completed.

     c. Engineer shall revisit the Site and the procedure shall begin again.

  2. Engineer shall issue a tentative Certificate of Substantial Completion to the Owner when the Project is considered to be substantially complete. Certificate shall include a tentative list of items to be corrected before final payment.

     a. Owner will review and revise the list of items and notify the Engineer of any objections or other items that are to be included in the list.

     b. Engineer shall prepare and send to the Contractor a definite Certificate of Substantial Completion with a revised tentative list of items to be corrected or completed.

     c. Review the list and notify the Engineer in writing of any objections within 10 days of receipt of Certificate of Substantial Completion.

1.04 FINAL INSPECTION

A. Submit written certification in the form indicated in Section 01 31 13.13 "Forms" when the Project is complete and:

1. Contract Documents have been reviewed.
2. Work has been completed in compliance with the Contract Documents.
3. Equipment and systems have been tested per Contract Documents and are fully operational.
4. Final Operations and Maintenance Manuals have been provided to the Owner and all operators training has been completed.
5. Specified spare parts and special tools have been provided.
6. Work is complete and ready for final inspection.

B. Engineer shall make an inspection with the Owner and appropriate regulatory agencies to determine the status of completeness within a reasonable time after the receipt of the Certificate.

C. Engineer shall issue notice that the Project is complete or notify the Contractor that Work is not complete or is defective.

1. Submit the request for final payment with Closeout submittals described in Paragraph 1.07 if notified that the Project is complete and the Work is acceptable.
2. Upon receipt of notification from the Engineer that Work is incomplete or defective, take immediate steps to remedy the stated deficiencies. Send a second certification to the Engineer when Work has been completed or corrected.
3. Engineer shall re-visit the Site and the procedure will begin again.

1.05 RE-INSPECTION FEES

A. Pay fees to the Owner to compensate the Engineer for re-inspection of the Work required by the failure of the Work to comply with the claims of status of completion made by the Contractor.

B. Owner may withhold the amount of these fees from the Contractor's final payment.

C. Cost for additional inspections will be billed to the Owner by the Engineer for the actual hours required for the inspection and preparation of related reports in accordance with the rates in the Supplemental Conditions

1.06 CLOSEOUT SUBMITTALS TO THE ENGINEER

A. Record drawings per Section 01 31 00 “Project Coordination.”

B. Keys and keying schedule.

C. Warranties and bonds.

D. Evidence of payment or release of liens on the form indicated in Section 01 31 13.13 “Forms” and as required by the General Conditions.

E. Releases from property owners of land outside the easement which were used by the Contractor.

F. Consent from Surety to Final Payment.

G. Equipment Installation Reports on equipment.

H. Shop Drawings, Record Data, Operations and Maintenance Manuals, and other submittals as required by the Contract Documents.

I. Specified spare parts and special tools.

J. Certificates of Occupancy, operating certificates, or other similar releases required to allow the Owner unrestricted use of the Work and access to services and utilities.

K. Evidence of final, continuing insurance, and bond coverage as required by the Contract Documents.

1.07 FINAL PAYMENT REQUEST

A. Submit a preliminary final payment request. This request is to include adjustments to the Contract Amount for:

1. Approved Change Orders.
2. Allowances not previously adjusted by Change Order.
3. Unit prices.
4. Deductions for defective Work that has been accepted by the Owner.
5. Penalties and bonuses.
6. Deductions for liquidated damages.
7. Deductions for re-inspection payments per Paragraph 1.05.
8. Other adjustments.

B. Engineer shall prepare a final Change Order, reflecting the approved adjustments to the Contract amount which have not been covered by previously approved Change Orders.

C. Submit the final Application for Payment per the General Conditions, including the final Change Order.

1.08 TRANSFER OF UTILITIES

A. Transfer utilities to the Owner when the Substantial Completion has been issued, final cleaning has been completed and the Work has been accepted by the Owner.

B. Submit final meter readings for utilities and similar data as of the date the Owner occupied the Work.

1.09 WARRANTIES, BONDS, AND SERVICES AGREEMENTS

A. Provide warranties, bonds, and service agreements required by Section 01 33 00 "Submittal Procedures" or by the individual Sections of the Specifications.

B. The date for the start of warranties, bonds, and service agreements is established per the General Conditions.

C. Compile warranties, bonds, and service agreements and review these documents for compliance with the Contract Documents.

1. Each document is to be signed by the respective manufacturer, Supplier, and Subcontractor.

2. Each document is to include:
   a. The product or Work item description.
   b. The firm, with the name of the principal, address, and telephone number.
   c. Scope of warranty, bond or services agreement.
   d. Date, duration, and expiration date for each warranty bond and service agreement.
   e. Procedures to be followed in the event of a failure.
   f. Specific instances that might invalidate the warranty or bond.

D. Submit two copies of each document to the Engineer for review and transmittal to the Owner.
   1. Submit duplicate sets.
   2. Documents are to be submitted on 8-1/2 x 11 paper, punched for a standard three-ring binder.
   3. Submit each set in a commercial quality three-ring binder with a durable and cleanable plastic cover. The title "Warranties, Bonds, and Services Agreements", the Project name and the name of the Contractor are to be typed and affixed to the cover.

E. Submit warranties, bonds and services agreements:
   1. At the time of final completion and before final payment.
   2. Within 10 days after inspection and acceptance for equipment or components placed in service during the progress of construction.

1.10 CLAIMS AND DISPUTES

A. Claims and disputes must be resolved prior to recommendations of final payment. Acceptance and final payment by the Contractor will indicate that any outstanding Claims or disputed issues have been resolved to the full satisfaction of the Contractor.

END OF SECTION

01 74 23 FINAL CLEANING

1.00 GENERAL

A. This Section specifies administrative and procedural requirements for final cleaning at Substantial Completion.

1.02 WORK INCLUDED

A. Perform a thorough cleaning of the Site, buildings, or other structures prior to Owner occupancy of the buildings, and prior to final completion. Leave the Project clean and ready for occupancy.

1.03 SUBMITTALS

A. Provide data for maintenance per Section 01 78 23 "Operation and Maintenance Data."

1.04 QUALITY CONTROL

A. Use experienced workmen or professional cleaners for final cleaning.

2.00 PRODUCTS

2.01 MATERIALS

A. Furnish the labor and products needed for cleaning and finishing as recommended by the manufacturer of the surface material being cleaned.

B. Use cleaning products only on the surfaces recommended by the Supplier.

C. Use only those cleaning products which will not create hazards to health or property and which will not damage surfaces.

3.00 EXECUTION

3.01 FINAL CLEANING

A. Thoroughly clean the entire Site and make ready for occupancy.

1. Remove construction debris, boxes, and trash from the Site.
2. Remove construction storage sheds and field offices.
3. Restore grade to match surrounding condition and remove excess dirt.
4. Sweep all drives and parking lots clean of dirt and debris. Use water truck or hose down paved site to like new appearance.

B. Clean floors and inspect for damage.

1. Remove oil, grease, paint drippings, and other contaminants from floors, then mop repeatedly until thoroughly clean. Replace damaged flooring.

2. Clean resilient flooring with an approved cleaner and apply one coat liquid floor polish as recommended by the flooring Supplier. Polish to a buffed appearance with powered floor buffer.

3. Vacuum all carpets with powered floor sweeper to remove dirt and dust. Remove glue or other substances from nap of carpet.

C. Clean and polish inside and outside glass surfaces. Wash with window cleaner and water, apply a coat of high quality glass polish and wipe clean. Do not scratch or otherwise mar glass surfaces.

D. Clean wall surfaces to remove dirt or scuff marks. Remove excess adhesive along top edges of wall base. Remove adhesive from surfaces of vinyl wall coverings.

E. Align tile to fit properly in grid and replace cracked or damaged tile. Remove smear marks and other dirt from tile and clean surface of grid system.

F. Spot paint nicks and other damage. If spot-painting does not blend into the existing color and texture of the surrounding surfaces, repaint wall from inside corner to inside corner. Touch up damaged surfaces on factory finished equipment using special paint furnished by the manufacturer.

G. Clean plumbing fixtures, valves, and trim. Clean toilet seats and covers. Remove labels and adhesive from fixtures. Remove floor drains and clean baskets or buckets. Polish strainers and exposed chrome or brass.

H. Remove dirt, oil, grease, dust and other contaminants from floors, equipment and apparatus in mechanical and electrical rooms with vacuum.

I. Clean and polish ceramic tile floors and wall surfaces to remove mildew or other stains. Tuck point defective joints.

J. Inspect exterior painted surfaces. Spot paint any damaged surfaces.

K. Clean permanent filters and replace disposable filters on heating, ventilating, and air conditioning systems. Clean ducts, blowers, and coils if units were operated without filters during construction.

L. Clean roof areas of debris; flush roof drainage systems with water until clear.

M. Broom clean exterior paved surfaces and rake clean other surfaces of the grounds.

N. Clean and polish all electrical equipment and exposed conduits. Remove paint overspray. Provide a blemish free appearance on all exposed equipment and conduits.

END OF SECTION

01 75 00 STARTING AND ADJUSTING

1.00 GENERAL

1.01 WORK INCLUDED

A. Provide step-by-step procedures for starting provided systems, including equipment, pumps and processes.

B. Provide pre-startup inspections by equipment manufacturers.

C. Provide instruction and demonstration of operation, adjustment, and maintenance of each system and the component parts.

D. Place each system in service and operate the system to prove performance and to provide for initial correction of defects in workmanship, calibration, and operation.

E. Provide for initial maintenance and operation.

1.02 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00 "Submittal Procedures."

1. Provide a Plan of Action for testing, checking, and starting major equipment and process piping systems. Submit reports as required by this Section.
2. Provide Equipment Installation Reports on form shown in Section 01 31 13.13 "Forms" per Section 01 33 00 "Submittal Procedures."
3. Provide Operation and Maintenance Manuals per Section 01 78 23 "Operation and Maintenance Data."

1.03 STANDARDS

A. Comply with any standards associated with the testing or startup of equipment, as listed in the various Sections of the Specifications.

1.04 SPECIAL JOB CONDITIONS

A. Do not start or test any apparatus until the complete unit has been installed and thoroughly checked.

B. Furnish the services of a representative of the Supplier to witness tests and startup procedures as required by the Specifications.

2.00 PRODUCTS

2.01 TESTING INSTRUMENTATION

A. Furnish any instrumentation or other testing devices needed to conduct tests.

3.00 EXECUTION

3.01 SERVICES OF SUPPLIER'S REPRESENTATIVES

A. Provide the services of a Supplier's representative for inspection, supervision of installation, and training. Supervisor's representative must be an experienced and competent technical (not sales) representative of the Supplier.

B. Perform installation, adjustment, and testing of the equipment under the direct supervision of the Supplier's representative where specified.

C. Provide the services of the Supplier's representative to instruct the Owner or his authorized personnel on operational procedures and maintenance requirements.

D. Include the cost of the services of the Supplier's representative in the equipment price which is included in the Contract Price.

3.02 INSPECTION AND STARTUP

A. Inspect equipment prior to placing any equipment or system into operation. Make adjustments as necessary for proper operation.

1. Check for adequate and proper lubrication.
2. Determine that parts or components are free from undue stress from structural members, piping or anchorage.
3. Adjust equipment for proper balance and operations.
4. Determine that vibrations are within acceptable limits.
5. Determine that equipment operates properly under full load conditions.
6. Determine that the equipment is in true alignment.

B. Have the Supplier's representative present when the equipment is placed in operation.

1. The Supplier is to be on-Site as often as necessary for proper and trouble free operation.
2. Ensure that the proper procedure is employed in startup of systems.

C. Provide Equipment Installation Reports for Equipment on the form indicated in Section 01 31 13.13 "Forms."

1. Certify that the equipment and related appurtenances have been thoroughly examined and approved for startup and operation.
2. Include the date when Owner's personnel were instructed in the proper operation and maintenance of the equipment in the report.

3.03 STARTING REQUIREMENTS

A. Refer to the individual Sections of the Specifications for specific startup procedures.

3.04 INITIAL OPERATION

A. Start, test, and place equipment and systems into operation for 30 days to allow the Owner and Engineer to observe the operation and overall performance of the equipment and to determine that controls function as intended.

B. Equipment which operates on a limited or part-time basis shall be operated in the presence of the Engineer to demonstrate that controls function as specified.

C. Perform acceptance test as specified in individual Sections of the Specifications. Demonstrate that equipment and systems meet the specified performance criteria.

D. Unless specifically stated otherwise in the individual equipment Specifications, equipment and systems are not Substantially Complete until the end of this initial operation period. If an exception to this requirement is specifically noted in an individual equipment Specification, the exception shall only apply to that particular piece of equipment and not to the remaining components provided under the Project.

3.05 OPERATOR TRAINING

A. Provide instruction and demonstration of the care and operation of the equipment to the Owner's personnel. Instruction is to include classroom and hands-on training.

B. Provide training in adequate detail to ensure that the trainees who complete the program will be qualified and capable of operating and maintaining the equipment, products, and systems provided.

C. Operations training is to include but not be limited to:

1. Orientation to provide an overview of system/subsystem configuration and operation
2. Terminology, nomenclature, and display symbols.
3. Operations theory.
4. Equipment appearance, functions, concepts, and operation.
5. Operating modes, practices and procedures under normal, diminished, and emergency conditions.
6. Startup and shutdown procedures.
7. Safety precautions.
8. On-the-job operating experience for monitoring functions, supervisory, or command activities. Include functions and activities associated with diminished operating modes, failure recognition, and responses to system/subsystem and recovery procedures.
9. Content and use of Operation and Maintenance manuals and related reference materials.

D. Provide training for performing on-Site routine, preventive, and remedial maintenance of the equipment, product, or system. Maintenance training is to include but not be limited to:

1. Orientation to provide an overview of system/subsystem concept, configuration, and operation.
2. Operations theory and interfaces.
3. Instructions necessary to ensure a basic theoretical and practical understanding of equipment appearance, layout and functions.
4. Safety precautions.
5. Use of standard and special tools and test equipment.
6. Adjustment, calibration, and use of related test equipment.

7. Detailed preventive maintenance activities.
8. Troubleshooting, diagnostics, and testing.
9. Equipment assembly and disassembly.
10. Repair and parts replacement.
11. Parts ordering practices and storage.
12. Failure and recovery procedures.
13. Cabling and/or interface connectors.
14. Content and use of Operation and Maintenance Manuals and related reference materials.
15. Procedures for warranty repairs.
16. Lubrication.
17. Procedures, practices, documentation, and materials required to commence system maintenance.

E. Provide a training plan that indicates the schedule and sequence of the training programs. The training plan is to include for each course:

1. Number of hours for the course.
2. Agenda and narrative description, including the defined objectives for each lesson.
3. Draft copy of training handbooks.
4. A descriptive listing of suggested reference publications.
5. Audio-visual equipment required for training.
6. Type and number of tools or test equipment required for each training session.

F. Provide and use training aids to complement the instruction and enhance learning.

1. Provide training handbooks for use in both the classroom and the hands-on phases of training for each course.
2. Provide instructional materials which include references to the Operation and Maintenance Manuals and identify and explain the use of the manual.
3. Provide a copy of all audio/visual training materials used in the presentations.

G. Provide qualified instructors to conduct the training.

1. Provide instructors with knowledge of the theory of operation and practical experience with the equipment, product, or system.
2. Provide instructors that have successfully conducted similar training courses.

H. Training may be recorded by the Owner or its consultants for use in future training. Provide legal releases or pay additional fees required to allow training by the Supplier to be recorded.

I. Schedule for training is to be approved by Owner.

1. Schedule training and startup operations for no more than one piece of equipment or system at a time.
2. Owner may require re-scheduling of training if operations personnel are not available for training on a scheduled date.
3. Provide a minimum of 2 weeks' notice if training must be rescheduled.
4. Training is to be limited to 24 hours per week.
5. Time required for training is to be considered in the development of the Project schedule.

J. Schedule and coordinate training for equipment, products, or systems which depend upon other equipment or systems for proper operation so that trainees can be made familiar with the operation and maintenance of the entire operating system.

K. Conduct a training course for the equipment products and systems provided. Training is to be adequate to meet the training objectives described above and is to be for at least the minimum time indicated.

3.06 INITIAL MAINTENANCE

A. Maintain equipment until the Project is accepted by the Owner.

1. Insure that mechanical equipment is properly greased, oiled, or otherwise cared for as recommended by the Supplier.
2. Operate air handling equipment only when filters are in place and are clean. Change filters weekly during construction.

B. Service equipment per the Supplier's instructions immediately before releasing the equipment to the Owner.

1. Replace replaceable filters and clean permanent filters associated with air handling units or other packaged equipment.
2. Remove and clean screens at strainers in piping systems.
3. Clean insects from intake louver screens.

END OF SECTION

01 78 23 OPERATION AND MAINTENANCE DATA

1.00 GENERAL

1.01 WORK INCLUDED

A. Prepare a complete and detailed Operation and Maintenance Manual for each type and model of equipment or product furnished and installed under this Contract.

B. Prepare the manuals in the form of an instruction manual for the Owner. The manual is to be suitable for use in providing operation and maintenance instruction as required by Section 01 75 00 "Starting and Adjusting."

C. Provide complete and detailed information specifically for the products or systems provided for this Project. Include the information required to operate and maintain the product or system.

D. Manuals are to be in addition to any information packed with or attached to the product when delivered. This information is to be taken from the product and provided as an attachment to the manual.

1.02 SUBMITTALS

A. Submit manuals in accordance with Section 01 33 00 "Submittal Procedures." Attach to each manual a copy of the Operation and Maintenance Manual Review Form as shown in Section 01 31 13.13 "Forms" with pertinent information completed.

1.03 GUARANTEES

A. Provide copies of the manufacturer's warranties, guarantees, or service agreements in accordance with Section 01 70 00 "Execution and Closeout Requirements."

2.00 PRODUCTS

2.01 MATERIALS

A. Print manuals on heavy, first quality paper.

1. Paper shall be 8-1/2 x 11 paper.
    a. Reduce drawings and diagrams to 8-1/2 x 11 paper size.
    b. When reduction is not practical, fold drawings and place each separately in a clear, super heavy weight, top loading polypropylene sheet protector designed for ring binder use. Provide a typed identification label on each sheet protector.
2. Punch paper for standard three-ring binders.

B. Place manuals in Wilson Jones 385 Line D-Ring Dubllock Presentation Binders.

1. Binders are to have clear front, back, and spine covers.
2. Sheet lifters are to be provided.
3. Minimum size is 2-inch capacity. Maximum size is 3-inch capacity.

C. Provide tab indexes for each section of the manual.

   1. Indexes are to be constructed of heavy-duty paper with a reinforced binding edge and punched with 9/32-inch holes to fit the binders.
   2. Index is to have clear insertable tabs for a typed insert.

D. Provide indexed PDF version of manual on a CD.

E. Provide a parts list on a CD in Microsoft Excel format which includes all information required by Paragraph 3.02.

3.00 EXECUTION

3.01 MANUAL ORGANIZATION AND CONTENTS

A. Provide a Table of Contents listing each section of the manual for each product or system.

   1. Identify each product or system using the nomenclature shown in the Contract Documents.
   2. Assign a number and letter to each section in the manual.
      a. Assign a number to each product or system. The number is to correspond to the Owner's equipment numbering system or other system designated by the Engineer.
      b. A cross reference is to be provided for the Owner's numbering system and designations for equipment indicated in the Contract Documents.
      c. The letter assigned will represent the part of the manual, consistent with the manual contents as required by Paragraph 3.02.
   3. Provide index tabs for each section in the manual.
   4. The designation on each index tab is to correspond to the number and letter assigned in the Table of Contents.

B. Include only the information that pertains to the product described. Annotate each sheet to:

   1. Clearly identify the specific product or component installed.
   2. Clearly identify the data applicable to the installation.
   3. Delete reference to inapplicable information.

C. Supplement manual information with drawings as necessary to clearly illustrate relations of component parts of equipment and systems, and control and flow diagrams.

D. Identify each manual by placing a printed cover sheet in the front cover of the binder and as the first page in the manual. The first page is to be placed in a clear polypropylene sheet protector. The information on first page and the cover page are to include:

   1. Name of Owner.
   2. Project name.
   3. Volume number.
   4. The Table of Contents for that volume.

E. Insert the Table of Contents into the spine of each manual.

F. Manuals for several products or systems may be provided in the same binder.

   1. Sections for each product or system must be included in the same binder.
   2. Sections must be in numerical order from volume to volume.

G. Correlate the data into related groups when multiple binders are used.

H. Fill binders to only three/fourths of its indicated capacity to allow for addition of materials to each binder by the Owner.

3.02 EQUIPMENT AND SYSTEMS MANUAL CONTENT

A. Manual shall provide the following information:

   1. A description of the unit and component parts.
   2. Operating instructions for startup, normal operations, regulation, control, shutdown, emergency conditions, and limiting operating conditions.
   3. Maintenance instructions including assembly, installation, alignment, adjustment, and checking instructions.
   4. Lubrication schedule and lubrication procedures. Include a cross reference for recommended lubrication products.
   5. Troubleshooting guide.
   6. Schedule of routine maintenance requirements.
   7. Description of sequence of operation by the control manufacturer.
   8. Warnings for detrimental maintenance practices.
   9. Parts lists including:
      a. Part numbers for ordering new parts.
      b. Assembly illustrations showing an exploded view of the complex parts of the product.
      c. Predicted life of parts subject to wear.
      d. List of the manufacturer's recommended spare parts, current prices with effective date and number of parts recommended for storage.
      e. Directory of a local source of supply for parts with company name, address, and telephone number.
      f. Complete nomenclature and list of commercial replacement parts.
   10. Outline cross-section and assembly drawings, engineering data, test data, and performance curves.
   11. Control schematics and point to point wiring diagrams prepared for field installation, including circuit directories of panel boards and terminal strips.
   12. Other information as may be required by the individual sections of the Specifications.

3.03 LIST OF SERVICE ORGANIZATIONS

A. Provide a directory of authorized service organizations with company name, address, telephone number, and the contact person for warranty repair.

END OF SECTION

SWIFT Funding Information

North Texas Municipal Water District

Lower Bois D'Arc Creek Reservoir
Project No. 317

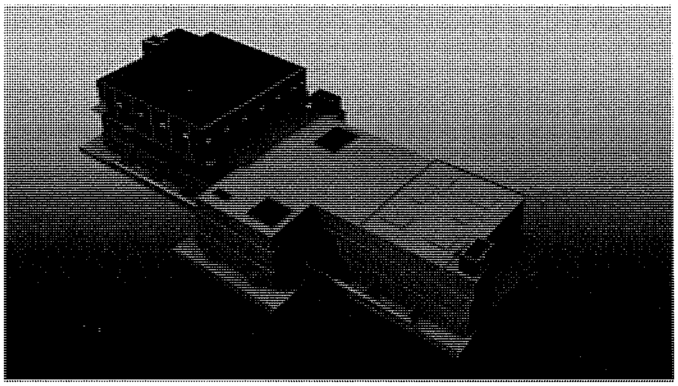
Vol. 4

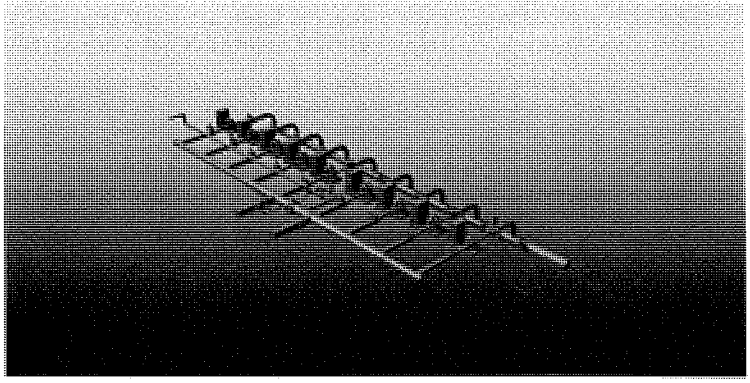
- Part D #54 Pump Station PDR
- Part D #54 LBR TSR Site Analysis
- Part D #54 WTP Preliminary Design Technical Memorandums
- Part D #54 TWPL Alignment Alternatives
- Part D #56 - Narrative
- Part D #56 LBCR Project Location Map
- Part D #57 Census Tracts
- Part D #58 Project Schedule Narrative
- Part D #58 LBCR Program Schedule - Permit April 2018_2017.01.16

PART D
#54

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service





THE Lower Bois d'Arc Creek
RESERVOIR
NORTH TEXAS MUNICIPAL WATER DISTRICT

Preliminary Design Report

Lower Bois d'Arc Intake and Pump Station
Fannin, Texas
(Project No. 358)

Prepared for:

North Texas Municipal Water District

June 2015

Prepared by:

FREESE AND NICHOLS, INC.
2711 North Haskell Avenue, Suite 3300
Dallas, Texas 75204
214-217-2200
NTD14295

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

Preliminary Design Report
Lower Bois d'Arc Intake and Pump Station
Fannin, Texas
(Project No. 358)

Prepared for: North Texas Municipal Water District

THE Lower Bois d'Arc Creek
RESERVOIR
NORTH TEXAS MUNICIPAL WATER DISTRICT

DRAFT
THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF INTERIM REVIEW UNDER THE AUTHORITY OF SAM MEISNER, P.E.,
TEXAS NO. 94677 ON JUNE 17, 2015.
IT IS NOT TO BE USED FOR CONSTRUCTION, BIDDING OR PERMIT PURPOSES.
FREESE AND NICHOLS, INC.
TEXAS REGISTERED ENGINEERING FIRM F- 2144

DRAFT
THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF INTERIM REVIEW UNDER THE AUTHORITY OF JEFF PAYNE, P.E.,
TEXAS NO. 90732 ON JUNE 17, 2015.
IT IS NOT TO BE USED FOR CONSTRUCTION, BIDDING OR PERMIT PURPOSES.
FREESE AND NICHOLS, INC.
TEXAS REGISTERED ENGINEERING FIRM F- 2144

Prepared by:

FREESE AND NICHOLS, INC.
2711 North Haskell Avenue, Suite 3300
Dallas, Texas 75204
214-217-2200
NTD14295

TABLE OF CONTENTS

List of Figures

List of Tables

APPENDICES

1.0 INTRODUCTION

Lower Bois d'Arc Creek Reservoir (LBCR) is a proposed reservoir on Lower Bois d'Arc Creek, a tributary of the Red River. The North Texas Municipal Water District (NTMWD) will construct a raw water intake and raw water pump station (RWPS) at the proposed LBCR as a part of an overall system of raw water storage, transmission, and treatment facilities that will ultimately provide water to the growing northern areas of the NTMWD's service area. FNI was tasked with evaluating the RWPS and intake site locations, and designing the RWPS and intake.

1.1 PROJECT BACKGROUND

By contract dated April 2, 2014, the NTMWD authorized Freese and Nichols, Inc. (FNI) to perform further analysis of the intake and raw water pump station siting and detailed intake configuration. This included analysis of two alternative intake locations, two raw water pump station locations, and two substation locations. As an amendment to this contract, on August 28, 2014, the NTMWD authorized FNI to proceed with preliminary engineering services for the intake and RWPS. This Preliminary Design Report (PDR) summarizes the intake, RWPS, and substation siting analysis, documents the technical decisions that were made, and provides FNI's recommendation for the intake and raw water pump station design.

1.2 PREVIOUS REPORTS

Additional background and project information can be found in the following previous reports:

- "Preliminary Pipeline Routing Study and Conceptual Raw Water Pump Station Design Report" dated September 2009.
- "Design Report for Lower Bois d'Arc Creek Reservoir Raw Water Pipeline" dated February 2014.
- "Lake Raw Water Pump Station Alternative Analysis Report" dated May 2014.
- "Lower Bois D'Arc Creek Reservoir Preliminary Design Report" dated January 2015.
- Technical Memorandum for "Leonard WTP Terminal Storage Reservoir Site Analysis" dated January 2014.
- "Proposed Lower Bois d'Arc Creek Reservoir, Fannin County, Texas, MITIGATION PLAN", dated January 2014.

- "Report Supporting an Application for a Texas Water Right for Lower Bois d'Arc Creek Reservoir", two volumes dated December 2006.
- "Section 404 Permit Application and Jurisdictional Determination Report", dated June 2008.
- "Environmental Report Supporting an Application for a 404 Permit for Lower Bois d'Arc Creek Reservoir", dated June 2008.
- "Supplemental Data Supporting and Application for a 404 Permit for Lower Bois d'Arc Creek Reservoir", dated December 2013.

1.3 PROJECT SCOPE

The scope of services for this project includes further analysis of the intake and raw water pump station. In particular, this project includes preliminary civil, structural, electrical, instrumentation, and controls design of the intake. The final design and construction of the intake will be accomplished as part of the dam (NTMWD Project No. 344). The RWPS portion of the scope includes layout and site civil design, evaluation of pump and raw water system hydraulics, preliminary RWPS discharge pipe design, structural, architectural, mechanical, electrical, instrumentation, and controls design.

1.4 ABBREVIATIONS

Table 1-1 displays a list of abbreviations used frequently in this report.

Table 1-1 List of Abbreviations

Abbreviation	Full Nomenclature
AFD	Adjustable Frequency Drive
AOR	Allowable Operating Range
BFV	Butterfly Valve
CFD	Computational Fluid Dynamics
CMAR	Construction Manager-at-Risk
FNI	Freese and Nichols, Inc.
FPS	Feet per Second
LBCR	Lower Bois d'Arc Creek Reservoir
LF	Linear Feet
HGL	Hydraulic Grade Line
HIS	Hydraulic Institute Standards
HP	Horsepower
MG	Million Gallons
MGD	Million Gallons per Day
MSL	Mean Sea Level
MUD	Municipal Utility District
NPSH	Net Positive Suction Head
NTMWD	North Texas Municipal Water District
OPCC	Opinion of Probable Construction Cost
PMF	Probable Max Flood
PSI	Pounds per Square Inch
RPM	Revolutions per Minute
RWPS	Raw Water Pump Station
TAS	Texas Accessibility Standards
TDH	Total Dynamic Head
TSR	Terminal Storage Reservoir
WSL	Water Surface Level
WTP	Water Treatment Plant

2.0 DESIGN CRITERIA

2.1 DESIGN FLOW

The Leonard Water Treatment Plant will be sized to treat all of the water available from LBCR as well as water from other future sources. Based on the yield of LBCR, the ultimate annual average pumping will be 110 MGD. The maximum diversion rate from LBCR in the water right permit application is 236 MGD. The proposed operations and the maximum annual diversion of 175,000 acre-feet will limit pumping duration at a peak rate of 236 MGD; however designing for this peak rate will allow greater flexibility for the NTMWD to manage their raw water supplies for normal and extraordinary operations.

The maximum flow the pipeline and RWPS will be designed for is the maximum permitted diversion of 236 MGD. The pumping equipment will be designed for an initial firm capacity of at least 72 MGD and an ultimate firm capacity of 236 MGD. The treatment plant is planned to be constructed in four phases with the initial phase producing a capacity of 70 MGD treated water. A 3% loss in the delivery system from LBCR to treated water system is assumed, meaning about 72 MGD of raw water pumping capacity will be provided for 70 MGD treatment capacity. A similar ratio of raw water pumping capacity to treatment capacity will be provided for future phases.

2.2 GOVERNING STANDARDS

The standards listed below will generally be followed in the design of the LBCR Raw Water Pump Station and Intake. These standards, in conjunction with FNI's experience on similar projects, will be the design basis for the design of the RWPS and intake. If necessary, design will be adjusted to the current set of codes at the time we begin final design.

- American Water Works Association (AWWA)
- American National Standards Institute (ANSI)
- American Society for Testing and Materials (ASTM)
- Hydraulic Institute Standards (HIS)
- Illuminating Engineering Society of North America (IESNA)
- Institute of Electrical and Electronic Engineers (IEEE)
- 2015 International Code Council (ICC) publications for Building, Mechanical, Plumbing and Energy Conservation
    - 2015 International Building Code

  - 2015 International Energy Conservation Code
  - 2015 International Fire Code
  - 2015 International Mechanical Code
  - 2015 International Plumbing Code
- Local Electrical Ordinances
- 2014 National Electrical Code (NEC, NFPA 70)
- National Electrical Safety Code (NESC)
- National Electrical Manufacturers Association (NEMA)
- National Fire Protection Association (NFPA)
- 2015 Life Safety Code (NFPA 101)
- Occupational Safety and Health Administration (OSHA)
- 2012 Texas Accessibility Standards
- Texas Commission on Environmental Quality (TCEQ)
- Underwriter's Laboratory (UL)

3.0 INTAKE, RAW WATER PUMP STATION AND SUBSTATION SITING ANALYSIS

3.1 INTAKE LOCATION

Selection criteria and assumptions were established to identify the preferred location for the intake tower within the reservoir. As detailed in previous studies, it is recommended that the lowest intake invert elevation be 467 feet MSL and located near the intersection of Honey Grove Creek and the proposed dam. A channel will be constructed to connect Lower Bois d'Arc Creek to Honey Grove Creek. This channel will also be used for diversion of flows during construction of the dam. The intake channel will need to be excavated and maintained at elevations below 480 feet MSL, which is the natural floodplain of the surrounding area, in order to uphold the intake invert elevation of 467 feet MSL. For this phase of the study, the intake channel is assumed to be 50 feet wide with a 4:1 side slope. Dimensions and design of the channel for flow diversions will be determined in final design of the dam.

Two intake locations were initially reviewed. Intake towers are shown at location A1 and B in **Figure 3-1**. Intake tower A1 is located within Honey Grove Creek, utilizing the naturally lower ground elevations in that vicinity. Intake Tower B is located approximately 330 linear feet southeast along the dam centerline. The main advantage of Intake Tower A1 is that it utilizes the naturally lower ground elevations to limit excavation. It is also along the natural flow line of Honey Grove Creek, therefore additional channelization will not have to be constructed to the intake tower. The main advantage of Intake Tower B is that it will cross less of the dam structure and slightly reduce the total length of intake pipe necessary.

The borings performed for the dam, service spillway, and emergency spillway are relatively close to the proposed intake tower locations and the nearest boring location was selected and analyzed. Borings at more exact locations have been performed in later phases for final design. For Intake Tower A1 it appears that the rock is located at approximately elevation 467 feet MSL. For Intake Tower B the rock is approximately at elevation 475 feet MSL. The current design elevation of the bottom of the intake tower structure is 454 feet MSL. This will be further refined during final design of the intake foundation and tower, however, it is an advantage to have the foundation of the intake tower on rock. It will also be advantageous to have the intake pipes crossing the dam embedded in the natural rock of the area to provide support and limit differential settlement. Excavation into the rock is not anticipated to be significantly more time consuming or costly than excavation of the natural soils in the area. Two borings were obtained at the proposed intake tower location and the borings show the shale at elevation 462, confirming the foundation will be within the rock.

During the final stages of construction of the dam, storm flows will be diverted through the dam. A diversion channel will connect the flows from Honey Grove Creek and Lower Bois d'Arc Creek. When this section of the dam is being closed, flows will be diverted from Lower Bois d'Arc Creek to Honey Grove Creek and into the intake tower. It has been determined that the location of intake tower A1 is too close to Honey Grove Creek and the risk of flooding the intake tower construction area is too great in its initial location. Intake tower B is the furthest tower from both Lower Bois d'Arc Creek and Honey Grove Creek, and will therefore require a longer channel excavation to reach the intake tower. In order to achieve the greatest advantage in terms of the volume of excavation required, proximity to deepest water, and locating the intake tower foundation on rock, a third location, intake tower A was developed. This intake tower is just outside the existing banks of Honey Grove Creek. This location will allow flows to be diverted from Honey Grove Creek and reduce the chance of flooding the intake tower construction zone.

3.2 PUMP STATION LOCATION

A conceptual footprint and layout of the pump station was identified in the previous May 2014 study to construct a structure below-grade housing horizontal split case pumps downstream of the dam embankment. The footprint identified was used as the initial basis for site planning. There were several criteria developed to determine the preferred site for the pump station. The first major criterion is to place the pump station finished floor and all electrical equipment above the probable maximum flood elevation (PMF) of Bois d'Arc Creek downstream of the dam. The PMF elevation downstream of the dam is 496.5 feet MSL. The second major criterion is to locate an area with five to ten feet of fall across the site in an attempt to limit the site work necessary. The site plan will include an electrical yard at the station for the anticipated transformers and pad mounted switches, as well as an access road surrounding the station that will allow driveway access to the pump station at the ground floor level. Detailed station layout and orientation are addressed in further detail in this report.

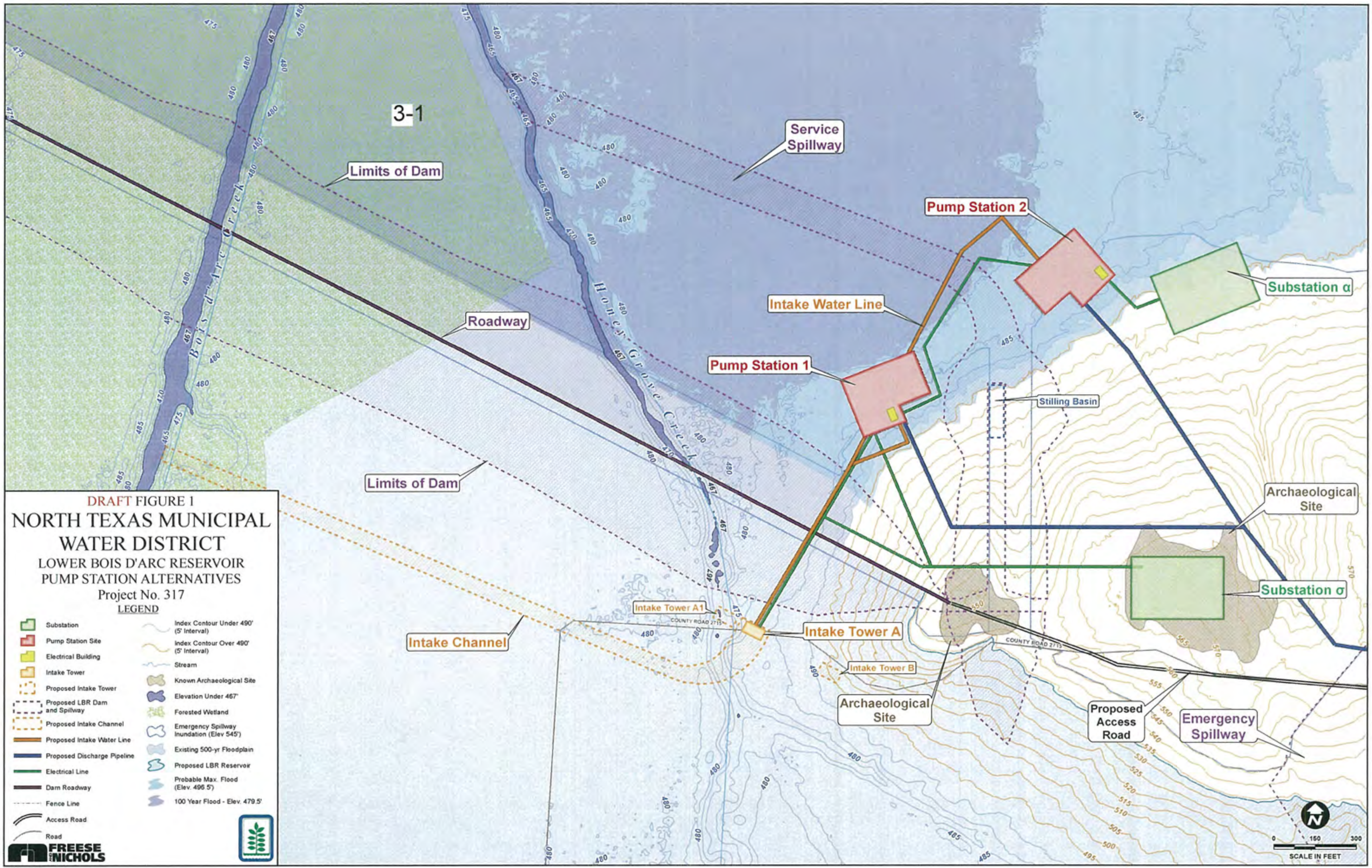
Unfortunately, the areas on the downstream side of the dam that appear to have the most level grading are well below the design flood elevation. Preparing a relatively flat pump station site will require adding fill around the constructed building to reach the desired finished floor elevation. Another goal of the selected site is to balance the required excavation and fill. Two alternate pump station locations were identified to meet the criteria and are shown in **Figure 3-1.**

Pump Station Option 1 is located directly between the dam embankment and the service spillway and Pump Station Option 2 is located between the service spillway and the emergency spillway. There appears to be adequate room for construction between the dam and service spillway for Pump Station Option 1. There also appears to be adequate space between the pump station building and the toe of the dam for a drainage buffer and to provide sufficient separation for the large excavation required to construct the pump station. Option 1 is closer to the intake tower and makes use of lower ground elevations to limit excavation for the below grade portion of the structure. This option will require crossing the service spillway with the 90-inch discharge pipe upstream of the stilling basin and chute. This is advantageous because the discharge pipe will be shallower and in an area that will already be armored for the spillway. Ultimately, Pump Station Option 1 provides the greatest benefit for the project and is the recommended location for the pump station.

3.3 SUBSTATION LOCATION

The site planning materials received from Rayburn Electric in May 2014 was used to locate the substation. This site plan requires an area of 230 feet by 340 feet to accommodate their proposed layout. Generally it is the expressed opinion that a level site is preferred for ease of construction and design. The site will also need to be located in an area that is raised above the PMF. Concepts to level the site using retaining walls were considered to limit the area necessary to dedicate to the utility, however it was determined that the retaining walls required to level the site would cost more than the mass grading work necessary, and the excess excavation spoils could be used as fill for the dam.

Initially, two options were developed for the substation locations. These are shown as Substation Option α and Substation Option σ shown in **Figure 3-1**. In later phases of the preliminary design in 2015 an additional request from the utility to locate the substation on the east side of the emergency spillway was received. This will allow access to the substation by the utility if the emergency spillway is ever engaged. A level surface has been identified in this area large enough to accommodate the latest site plan received. This revised site is shown in **Figure 7-4**. Finalizing the substation location will require further coordination by NTMWD and the utility in future phases.



3-1

DRAFT FIGURE 1

NORTH TEXAS MUNICIPAL WATER DISTRICT

LOWER BOIS D'ARC RESERVOIR
PUMP STATION ALTERNATIVES
Project No. 317

4.0 INTAKE DESIGN

4.1 INTAKE ALTERNATIVE ANALYSIS

The purpose of the intake alternative analysis study is to:

- Evaluate alternate concepts for the intake tower;
- Update the size of the screen openings and velocity through the screens;
- Analyze hydraulics for the intake structure and intake pipes;
- Provide a recommendation for screens, gates, and stop logs;
- Evaluate hoisting systems for all appurtenances;
- Evaluate accessibility and other pertinent maintenance procedures;
- Examine intake gate levels.

In order to develop design concepts for the intake structure, several design assumptions were made based on previous studies conducted for NTMWD. For the design of the gates, stop logs, and screens, the 100-year flood elevation of 541 feet MSL was used. The lowest gate invert is positioned at elevation 467 feet MSL. It is also assumed that the intake channel will share much of the diversion channel. The majority of the lake bottom is a floodplain at about elevation 480 feet MSL, therefore, the intake channel will need to be excavated and maintained by dredging for purposes of accessing water at extremely low lake elevations below 480 feet MSL. The intake tower is sized to handle a maximum flow of at least 144 MGD for each side, providing half of the planned water treatment plant capacity with only half of the intake system in service. The system will allow the maximum diversion for water supply at 236 MGD with both sides of the intake in service. The May 2014 report states that all environmental releases (0.6 to 323 MGD, 1 to 500 cfs) will be routed through the intake tower. However, this design approach has been improved and the larger environmental releases will be made through the gates at the service spillway. The revised service spillway design will now accommodate all environmental releases over about 13 MGD (20 cfs). The smaller releases will be made through the intake tower system.

Another criterion used for the design of the intake system is that all structures allow for two methods of isolation for safe personnel entry into the tower and intake conduits. For all structure designs a gate and stop log will provide the two levels of protection of any personnel within the interior of the dewatered tower. To provide two levels of protection for the gates, two stop log slots will be provided on the outside of the intake tower. Given that zebra mussels have a presence in North Texas, provisions will be made to address possible infestation within the LBCR watershed. All screens will be specified with anti-fouling or foul-release coatings/materials. All gates and other moving components will be reviewed for the possibility of fouling and special steps to mitigate problems caused by fouling may be required. This will be further evaluated in detail and incorporated into the design in future phases. To facilitate ease of maintenance, all screens and stop logs will be removable for manual cleaning outside of the reservoir. The concept will allow the screens and stop logs to be lifted out of their guides above the top of the intake tower. A hoisting system will be installed to assist with lifting the screens and stop logs.

4.1.1 Intake Capacity

It is assumed that there will be a 3% loss in the delivery system from LBCR to the treated water system, meaning about 72 MGD of raw water pumping capacity will be necessary for 70 MGD treatment capacity. The intake tower is divided into two cells designed with a redundant intake capacity of 144 MGD in each cell. This will allow half of the intake structure to be taken out of service for maintenance while maintaining pumping capacity to the water treatment plant during average demand periods. Intake gate levels will be discussed later in this chapter.

The water that passes through the intake in the reservoir will either be pumped to the Leonard Water Treatment Plant or will be released into the channel below the service spillway as required for environmental releases. The required environmental releases will vary from between 1 cfs and 20 cfs (0.6 to 13 MGD). There is further discussion of required environmental releases in Section 7.6.5. Detailed analysis of sizes, type and location options for control valves required for these releases will be undertaken in later phases of design. The remaining water from the intake tower will be pumped to the Leonard Water Treatment Plant. The treatment plant will have an initial capacity of 70 MGD and will expand in intervals of 70 MGD as shown in **Table 5-3**.

4.1.2 Intake Access Bridge

Access to the proposed intake tower will require a bridge that originates from the access roadway on top of the dam. The top of the intake tower will be at the same elevation as the top of the access roadway on the dam (elev. 553 feet) so that the bridge is not sloped one way or the other. Sloping the bridge raises concern of overturning forces acting on the tower. Initially a bridge width of 26 feet was used as the design criteria to fit all necessary construction access equipment. After further evaluation it was determined that a minimum bridge width of 32 feet is necessary to accommodate future maintenance equipment (e.g. a large mobile crane) that may be necessary as well as providing working space around the equipment. This will be further refined in later design phases.

4.1.3 Intake Pipe Layout

The intake pipes will exit the tower and continue under the dam to the Pump Station. The dual 78-inch intake pipes will exit the tower near the center and be constructed in a reinforced concrete encasement for both pipes. The spacing between pipes will be reviewed in final design for coordination with bridge piers and overall encasement design details.

It is preferred for the intake pipes to cross the dam and service spillway channel (if required, depending on pump station site selected) perpendicular to the centerline. Skewing the crossing will require more compacted backfill and concrete encasement within the dam.

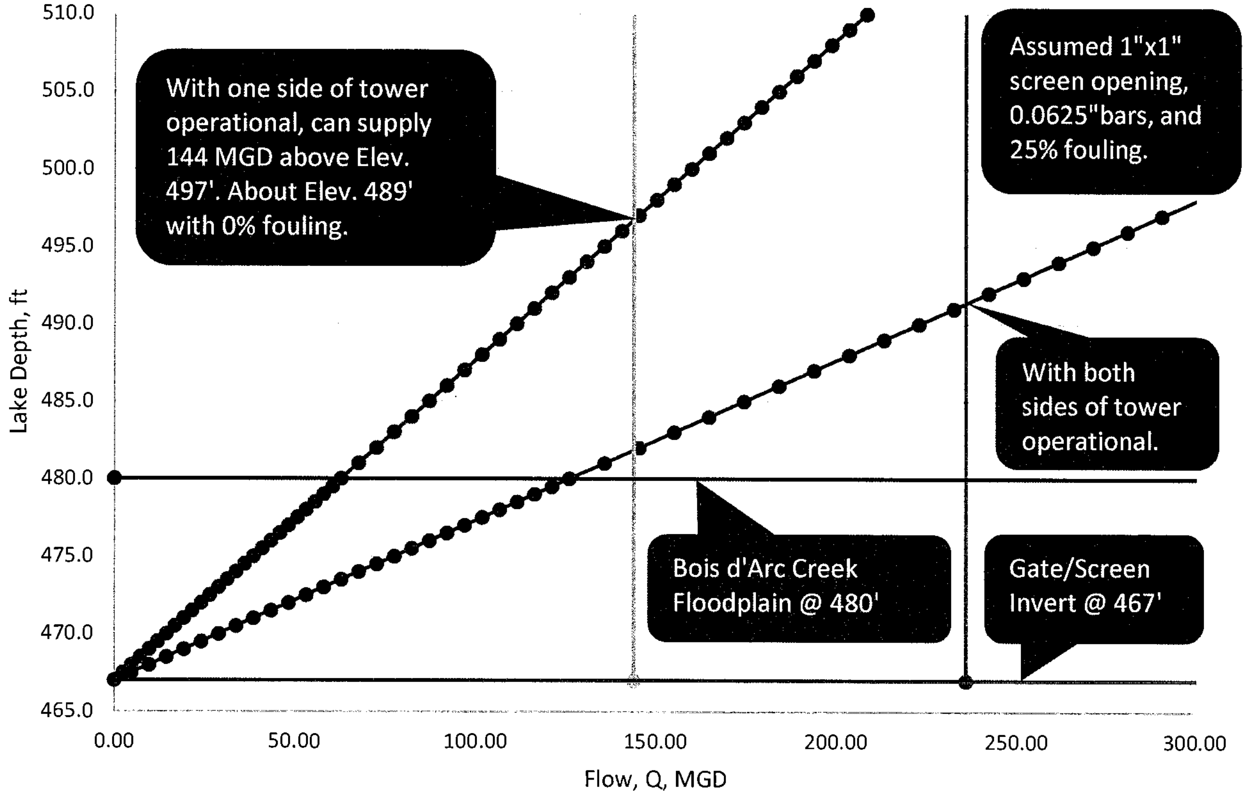
4.1.4 Intake Screens

In preliminary phases of the LBCR study the intake tower concept was based on using barrel screens with a 0.5-inch clear opening and an entrance velocity of 0.5 feet per second. For a 72 MGD capacity each, these screens were approximately 16.3 feet wide and dictated the size of the original intake structure. Since the preliminary phase, indications are that the individual permit for the project will allow a 1-inch clear opening with a 1 foot per second entrance velocity through the screen. This new criteria significantly reduces the overall required size of the screens and the intake tower structure. Box screen and flat screen alternatives have been reviewed and will allow for a smaller tower structure.

The first of these options is a box screen. This box screen wraps the screen mesh around five sides, which allows the overall size of the screen to be reduced, while maintaining the required surface area of 125 sf for 72 MGD capacity. This concept reduces the width of the screen to approximately 6.5 feet, and allows a smaller intake structure to facilitate the same flows. These screens will be lowered on rails to the desired intake elevation and raised to the surface when cleaning is necessary.

The second option reviewed is a set of flat screens that span from the bottom of the intake tower to the top. The flat screen has been selected as the most advantageous screen alternative. The District will be able to lift and maintain the flat screens easier than the box screens. Using a flat screen in lieu of a box screen to achieve the surface area required to meet the entrance velocity criteria results in a more efficient intake tower design. The flat screen will span 10 feet wide across the full height of the tower structure in order to provide enough surface area to limit the entrance velocity. The screen entrance velocity criteria of 1 fps will limit pumping at low lake elevations. **Figure 4-1** below displays the available capacity based on the current screen design while maintaining velocity under 1 fps.

Figure 4-1 Screen Rating Curve for Flow vs. Lake Elevation to Maintain Screen Velocity at <1 fps



The screen option will be reviewed in detail for possible zebra mussel control in later design phases. The flow patterns of the selected option will also be modeled using computational fluid dynamics (CFD) to analyze the velocity across the screens and through the nearby gates.

4.1.5 Intake Accessibility

Adequate accessibility for operation and maintenance at the top of the intake tower is required. Various design vehicles were considered including a fork lift or boom lift. The intent is to provide enough room on the top of the structure so that operators will be able to maneuver maintenance equipment. The top slab is considered to be the only typical entry point into the intake structure. Access to the interior of the tower structure for operation and maintenance of gates, screens, intake conduits, and the structure itself is required. Any openings in the top slab are designed so that a two-person man-basket may be lowered to inspect and maintain gates, stems, and other components that are normally submerged. Removable grating will be used to access the interior of the tower. The grating will be designed for a HS-20 design load rating where susceptible to vehicle loads. The grating and associated support beams will be more susceptible to corrosion and will require some effort to maintain coatings over the life of the structure. Grating will cover the intake structure above the proposed gates and a portion of the inner cell. The center of the intake tower top slab will be concrete also be designed for HS-20 load rating. This will allow a truck or trailer to back onto the intake structure.

Removable guardrails and tie-off points will be installed around the perimeter of the removable grating sections to provide safe access to the components on top of the intake tower such as gate operators, instruments, etc. This will allow grating to be removed for an extended period of maintenance while still allowing safe operation and maintenance of active intake systems.

4.1.6 Intake Hoisting Methods

Hoisting alternatives were evaluated for the expected maintenance activities on screens, stop logs, gates, and other components. The District has an existing 40-ton mobile crane which will be able to reach all of the gates and screens from the bridge. It has been indicated that the District's mobile crane is frequently in high demand and the preference is to install a permanent crane system for the intake tower.

The permanent hoisting system for accessing all necessary equipment on the intake tower will be a 10-ton, underhung, singe-girder bridge crane. This system will be similar to the bridge crane systems NTMWD has at many of their facilities. The top of tower floor footprint was expanded slightly on the lake side to allow the bridge crane to access all of the required stop log slots. No additional reinforcing beams are required to be added to the structure to accommodate this hoisting system as the crane frame can be built into the top of the structure's walls. This hoisting option can be custom manufactured to reach all areas necessary.

A mobile crane may also be used to access all equipment on the intake tower. The bridge crane framing has been kept as open as possible to allow use of a mobile crane, however some obstructions due to the framing may be unavoidable. A 40 ton mobile crane will be necessary to access all equipment on and within the intake structures, while restricting the crane to the bridge deck only. This will need to be verified in later stages of design as equipment weights are updated.

4.1.7 Intake Levels & Water Quality Assumptions

In previous studies of the reservoir the lowest gate for the intake has been set at an elevation in order to access all available storage. Based on this design criterion, the bottom intake gate invert will be at elevation 467 feet MSL. The other design criterion is that the maximum diversion rate of 236 MGD be possible at all elevations, however as shown in **Figure 4-1** above, this is limited some at lower lake levels. In order to provide the most flexibility possible, four levels of 7 feet by 7 feet intake gates will be installed. The second lowest gate invert is at elevation 484 feet MSL. The upper two gate inverts are 16 feet from each other at elevations 501 and 517 feet MSL.

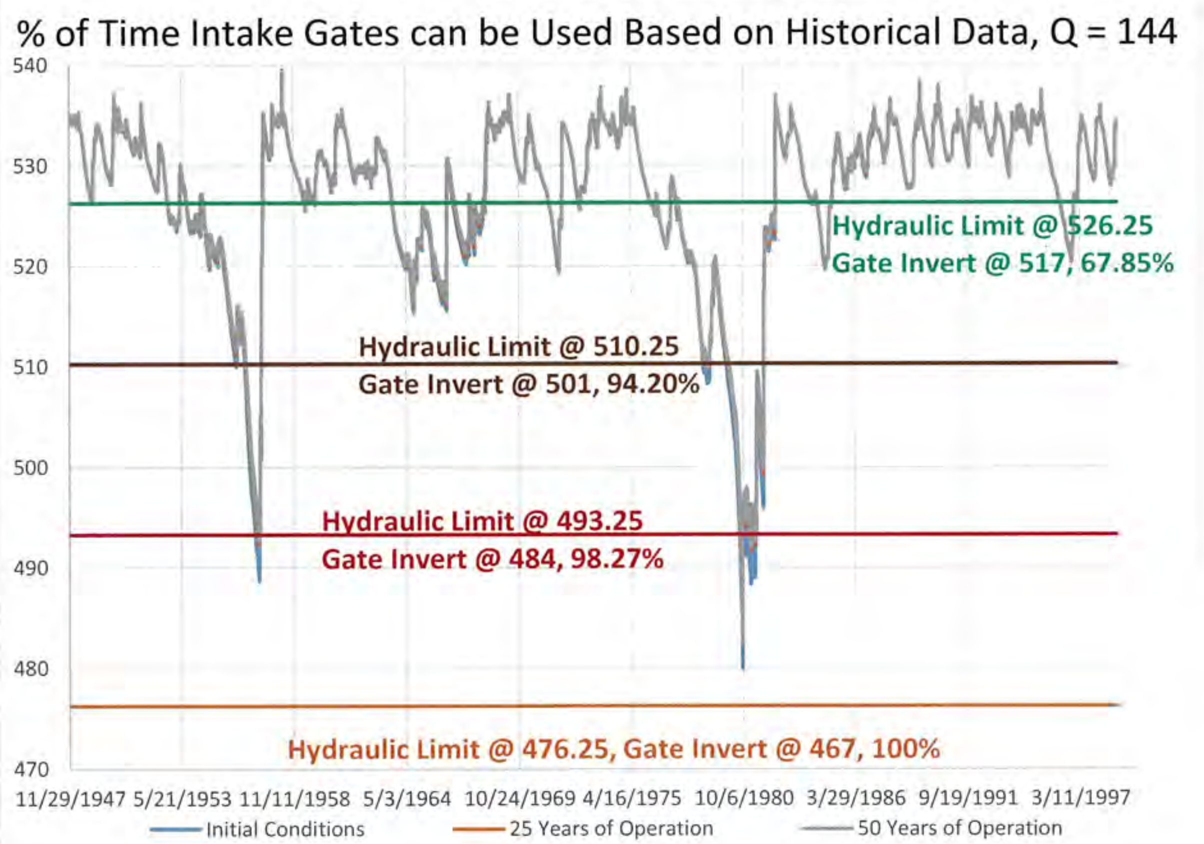
Manganese and dissolved oxygen (DO) is a concern with intakes in Texas. Manganese and DO are difficult to treat and it is desired to design intake levels such that water with lower levels of manganese and higher levels of DO can be withdrawn from the lake. Higher manganese concentrations are commonly seen in the top and bottom 10 feet of reservoirs and are typically highest during the lake turnover twice a year. During this lake turnover, higher DO is typically seen deeper in the reservoir than the rest of the year. Studies have shown that an increase in manganese correlates to low levels of DO. As the depth of intake increases and temperatures decrease the DO levels also tend to decrease. In order to avoid the highest levels of manganese and lowest DO, it is recommended to avoid the top and bottom 10 feet of the reservoir and intake water from the highest elevations possible, except during lake turnover. Four intake gates allow the District to generally pull from higher water levels throughout the reservoir service conditions. This will generally allow for an intake level with low manganese and high DO to be selected more often. A more detailed water quality analysis will need to be conducted by the water treatment plant design engineer.

Another concern with water intake quality is drawing water from too large of a span within the reservoir. Currently, the intake gates are seven (7) feet tall. Due to this concern, the intake gate heights will remain less than 10 feet during design. Drawing in more water at a lower lake level is an advantage that shorter gates provide.

Historical hydrologic data from previous yield analysis in the area was used to compare what the lake levels in the proposed reservoir would have been over the past 50 years and compared to the design gate elevations. The lake levels in the analysis are based on the average annual yield being diverted from the reservoir. The purpose is to review most advantageous intake gate elevations within the reservoir. Hydraulic calculations determined the head loss across the intake system, through multiple 7' x 7' intake gates to provide a total of 144 MGD through each intake pipe. This will require a lake elevation about 9.25 feet above the top of the gates at elevations above the intake channel.

Using this information, **Figure 4-2** was developed to determine what percentage of time various intake gate elevations could be used to draw full capacity from the reservoir.

Figure 4-2 Percent of Time Gate Can Be Utilized



Compiling the data above, the intake invert elevations for 7' x 7' gates are 467, 484, 501, and 517 feet. The minimum spacing for the intake inverts are controlled by the vertical separation required for the overlap of the gate frames, overall constructability and structural design considerations for the tower. By locating gates at four different elevations, the District will be able to withdraw from the anticipated higher water quality zone a majority of the time as well as having the flexibility to draw water out of various intake levels as the reservoir rises and falls.

4.1.8 Intake Gate Analysis & Arrangement

Two arrangements of the gates are possible for the intake tower: gates oriented for seating head and unseating head. The seating head arrangement refers to the gates installed on the outside of the structure using hydrostatic pressure on the gates pushing them back onto the structure against its seat. The unseating head arrangement refers to the gates installed on the inside of the structure with the hydrostatic pressure against the gate and pushing it off of its seat. Manufacturers generally recommend using gates in a seating head arrangement when possible.

The intake tower utilizes a design with all eight (8) intake gates installed in a seating head arrangement. Two gates connecting the intake tower cells will be unseating head gates. Wall thimbles are necessary for the unseating head gates, but not for the seating head gates. However, to provide a more reliable installation wall thimbles will be used for all gates, regardless of arrangement. This will allow for better seating and the entire gate to be removed from the structure.

An analysis of the intake gates was required to determine a recommended gate alternative and included the comparison of fabricated stainless steel slide gates (AWWA C561) and cast iron slide gates (AWWA C560). The cast iron gates have also historically been referred to sluice gates. The results, which are discussed in further detail below, are that stainless steel gates are generally superior to cast iron gates in terms of unseating head design. Historically, cast iron gates have been considered superior to stainless steel gates in a seating head design. However, both types can be used successfully and for several reasons discussed below, stainless steel fabricated slide gates are the recommended gates for the LBCR Intake Structure. Further details will be reviewed as specifications are developed at later stages of the design.

AWWA standard C561 governs the fabricated stainless steel slide gate design and AWWA standard C560 governs cast iron slide (sluice) gate design. The main difference in these two standards is that the fabricated slide gate is designed with a safety factor of 4 and the cast iron slide gate is designed with a safety factor of 5. Another key difference between the two standards is that AWWA C561 requires a maximum leakage rate of 0.10 gpm/foot of seated perimeter. AWWA C560 has the same leakage rate requirements for seating head conditions, however if the gate is in the unseating position the leakage rate doubles. Where the unseating head exceeds 20 feet, the leakage rate also increases to a minimum of 0.10 + 0.005 * unseating head (feet).

Cast iron and fabricated slide gates both have different maintenance concerns. Both gates must be exercised on a regular basis. There is a greater concern with the cast iron gates seizing than the fabricated slide gates due to the materials of construction (cast iron and bronze versus stainless steel and UHMW polyethylene) if gates are not exercised consistently. Cast iron gates have a higher risk of corrosion than stainless steel slide gates, however that does not appear to be a deciding factor for the service in fresh water at this intake tower. In order to make repairs to the gate the cast iron gates always have to be removed from the wall, while fabricated gates may be repaired while the gate is on the wall. Necessary maintenance for the fabricated slide gates can be performed underwater with a diver, however, due to the extreme difficulty of working underwater and inspecting repairs made by divers, it is recommended to completely remove the gate and frame from the wall thimble and bring it up to the surface to perform major maintenance.

Both gates include seals that will need to be replaced within the life of the structure. The fabricated slide gate seals are self-adjusting and have an expected life span of at least 10-15 years. The replacement of these seals may be done while the gate is on the wall. Cast iron gates have a non-replaceable seal that must be manually adjusted, and have an expected life span of 50 years. When the seals wear out on cast iron gates, a new gate must be purchased and installed.

Typically, manufacturing and delivery of fabricated slide gates is quicker than cast iron gates, however lead time for gates required at this tower will not be a limiting factor. During the gate analysis, the largest and best-known cast iron gate manufacturer started the process of reorganizing their company and stated that they will not be manufacturing and taking orders for new cast iron gates for at least the next 12 months. In the future all of their casting will be done in China when the manufacturing begins again. FNI recommends reviewing this in later phases of design when finalizing design specifications. This may eliminate the one manufacturer of cast iron gates that FNI recommends. There are several manufacturers FNI will recommend for supply of fabricated stainless steel slide gates. The NTMWD has a history of better performance using fabricated stainless steel slide gates than using cast iron slide gates when used in similar applications. The fabricated stainless steel slide gates are recommended due to the current market conditions and availability, past experience, and overall suitability for the application.

4.1.9 Stop Log and Screen Arrangement

The original concept for the screens used a barrel screen as described earlier. With the final requirements of the individual permit, the use of a box screen and flat screen was evaluated. The flat screen design accommodated the intake tower design the best and will be used for the intake tower. The screen mesh will be set into a frame that will then be inserted into the guides behind the stop log system. This screen system makes use of one large screen system for all gates on one side of the intake tower instead of individual screens paired with each gate. The size of flat screen will match the size of the stop logs and is estimated to be about 7.5'x10' with 1-inch mesh inside the frame. This arrangement will likely require additional screen panels compared to the number of box screens required, however the shape of the flat panel screen will allow for a simpler lifting mechanism to be used. Fabrication will also be simpler for the initial installation and possible future replacement if an individual screen panel were damaged.

4.1.10 Intake Tower Location in Relation to Dam

The location of the intake tower along the dam centerline at approximately Sta. 105+50, as well as distance from the centerline of the dam at about 200 feet has been set and it is not anticipated to move. The intake tower is set as close to the dam as possible without risking any unnecessary overturning forces and thus allowing shorter intake pipes and bridge. Approach walls will be located on the front face of the intake tower and will be sloped with the excavation of the channel.

4.1.11 Intake Tower Arrangements

Several different shapes were analyzed for the intake tower. These include a square, rectangle, octagon, circle, and hexagon. When laying out the gates on the structures, it became obvious that the rectangle and hexagon were the most advantageous shapes. The octagon did not include enough sides to accommodate all gates without increasing the structure size to something larger than the other alternatives. A round intake structure is not conducive to efficiently accommodate the required size of the gates. A square intake structure would require that all four sides accommodate two gates, including the side facing the dam. This would push the intake structure farther into the reservoir. Access around the intake tower to all of the gates for maintenance and dredging would also be restricted. There would also be concern of something falling from the dam side of the intake tower and damaging the screens and/or stop logs. Of the arrangements evaluated, the final option developed is a rectangular seating head option arrangement.

4.1.12 Rectangular Seating Head Flat Screen Option

The rectangular seating head option features two structural walls for the construction of the intake tower and utilizes a flat screen. The outer wall contains the screen and stop log guides and the inner wall contains the seating-head intake gates with a continuous bay in-between. This continuous bay will allow one screen system on each side of the tower for water to pass through. The screen openings will span the entire height of the tower for a total surface area of approximately 860 square feet each. There is a space of 7 feet between the walls to provide room for a two-person man-basket to be lowered. This option accommodates up to four different intake levels. The overall footprint of the structure is 71 feet by 50.5 feet. The hoisting system for this option will be a bridge crane oriented to keep the center of the tower clear for access. This option requires 10 gates, two 74 feet tall stop log systems, and three 86 feet tall flat screen systems (one to be a spare while out of service for desiccating and manual cleaning). The intake structure can be seen in more detail in **Figures 4.3** through **4.9**.

4.2 INTAKE ELECTRICAL, INSTRUMENTATION AND CONTROLS

The intake structure is served in a single transmission distribution service provider area that can only be served by Fannin County Electric Cooperative (FCEC). It is anticipated that a 25KV aerial feeder will be routed to the intake structure and spillway. Location of the aerial feed and associated power poles, electrical equipment and feeder devices will be resolved during the design phase. Both intake structure and spillway locations will utilize a pad-mounted, liquid-filled service transformer to derive 480V service voltage. The liquid inside the transformer and location of the pad will be reviewed in final design to verify leakage and contamination in the lake is minimized. Metering equipment will be installed at either the FCEC substation or at each service transformer.

Power for the intake structure will be routed underground from the service transformer location to the bridge. The service lateral will then transition from underground to above the bridge, routed on the inside of the concrete rail. The service lateral will terminate to a disconnect switch adjacent to the electrical room on the intake structure. A separate enclosure housing receptacles for a portable generator connection will be installed near the disconnect switch. Power will then be routed from the disconnect switch to 480V panelboard inside the electrical room. Electrical equipment will include a dry-type stepdown transformer and 208Y/120V panelboard for 120V circuits. All gate operators (motors) are planned to be 480V, 3-phse, either 5HP or 10HP. 120V power will serve convenience outlets and electrical room ventilating equipment. All panelboards will incorporate Surge Protection Devices (SPD's).

All conduit is planned to be rigid aluminum or PVC-coated Rigid Galvanized Steel (RGS) conduit. Aluminum EMT may be used inside the electrical room. Conductors are planned to be copper with XHHW insulation.

Lighting will be provided for the bridge, inside the electrical room, and on the intake structure. Lighting fixtures will be state-of-the-art LED type, with minimum 5-year manufacturer's warranty on the drivers, LED modules and fixture components. A photocell with timeclock and H/O/A switch will control all exterior fixtures. Lighting fixtures will be arranged to provide security and task lighting with minimal glare, in accordance with IESNA guidelines.

Instrumentation will consist of ultrasonic level sensors mounted at the top of the intake cell structure. No cabling or instrument parts will contact the water. Ultrasonic level sensors are preferred over pressure transducers when evaluating maintenance and operation concerns with potential zebra mussel populations. One ultrasonic level sensor is planned for each intake structure cell (two total). Final configuration is dependent on the hydraulic analysis which will yield more conclusive information on the dynamics of the water surface inside the intake structure cells. A SCADA cabinet mounted inside the electrical room will collect data from the level sensors and the gate controllers (operators). Connectivity from the intake structure SCADA system and the pump station will be thru underground fiber optic cabling. Operators at the pump station and remotely-connected workstations will be able to view water levels and gate operator positions.

Security and access control devices will be connected to a headend cabinet inside the electrical room. Connectivity to the pump station will be similar to the SCADA system, with dedicated fiber optic cabling routed underground to the pump station. Card readers will be installed at the gate controlling entry to the intake structure bridge and the door to the electrical room. IP-based video cameras are planned to cover the bridge, maintenance platform on the intake structure, and both card reader locations. Pan-Tilt-Zoom feature will be used on all cameras. Intrusion alarm for the electrical room will be integrated with the security system.

4.3 SUMMARY AND PREFERRED ALTERNATIVE

The design options considered for the intake tower include a balance of advantages and disadvantages for initial construction cost and long-term operation and maintenance. The following is a summary of recommendations presented above for the intake tower.

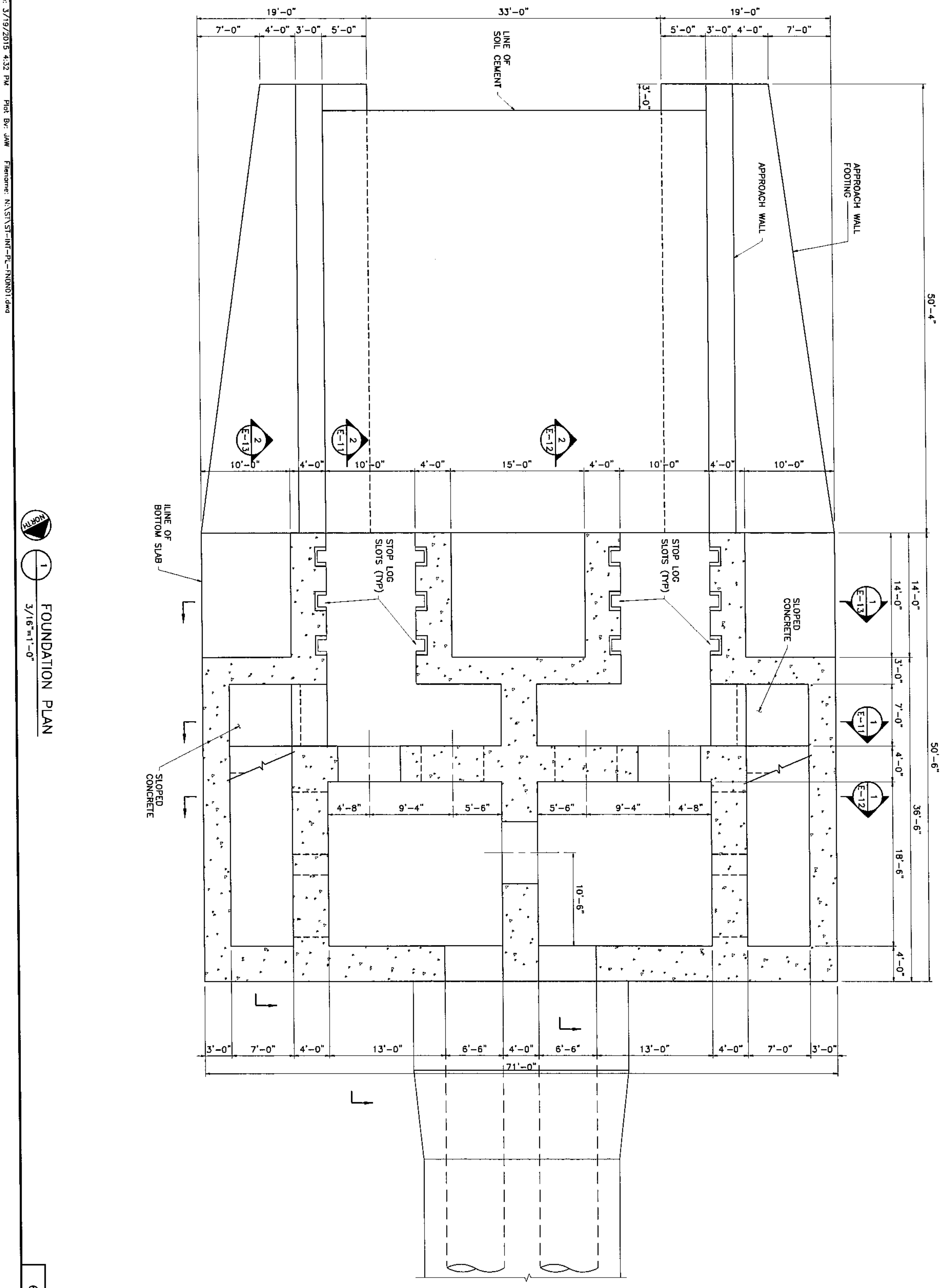
- Bridge width of 32 feet or more to accommodate a mobile crane for future maintenance

- Bridge crane on top of the intake tower to allow for reaching all elements for future maintenance
- Grating on the top of the tower to access gates and interior galley
- Staggered intake gates at four or more elevations
- Stainless steel fabricated slide gates installed in a seating head arrangement
- Flat panel screens with two slots for stop logs upstream of the screen
- Masonry electrical building at the tower with transformer at the crest of the dam

Additional analysis is required for many of the elements associated with the intake tower and will be updated during final design phases.

ACAD Rel: 19.1s (LMS Tech)
Filename: N:\ST\ST-INT-PL-FNDN01.dwg
Last Saved: 3/17/2015 12:56 PM Saved By: JAW

Plot Date: 3/19/2015 4:32 PM Plot By: JAW Filename: N:\ST\ST-INT-PL-FNDN01.dwg



0 4' 8'
3/16"=1'-0"

60% SUBMITTAL

Figure 4-3

Freese and Nichols, Inc.
Texas Registered Engineering Firm F-2144

SEQ.	SHEET	NO.	ISSUE	BY	DATE	
.	E-7					F&N JOB NO. NTD13565
						DATE MAR. 2015
						DESIGNED MMT
						DRAWN JAW
						REVISED
		VERIFY SCALE 0 1	Bar is one inch on original drawing. If not one inch on this sheet, adjust scale.	FILE NAME ST-INT-PL-FNDN01.dwg		CHECKED AD

NORTH TEXAS MUNICIPAL WATER DISTRICT

LOWER BOIS D'ARC CREEK RESERVOIR

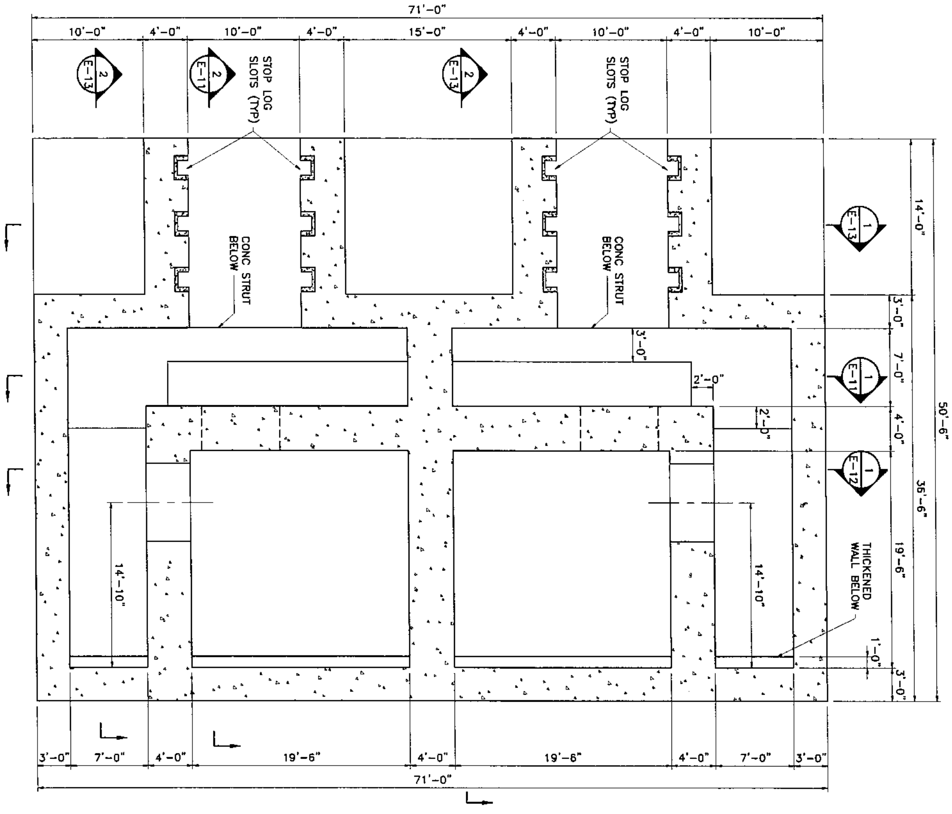
E – PUMP STATION INTAKE

INTAKE TOWER FOUNDATION PLAN

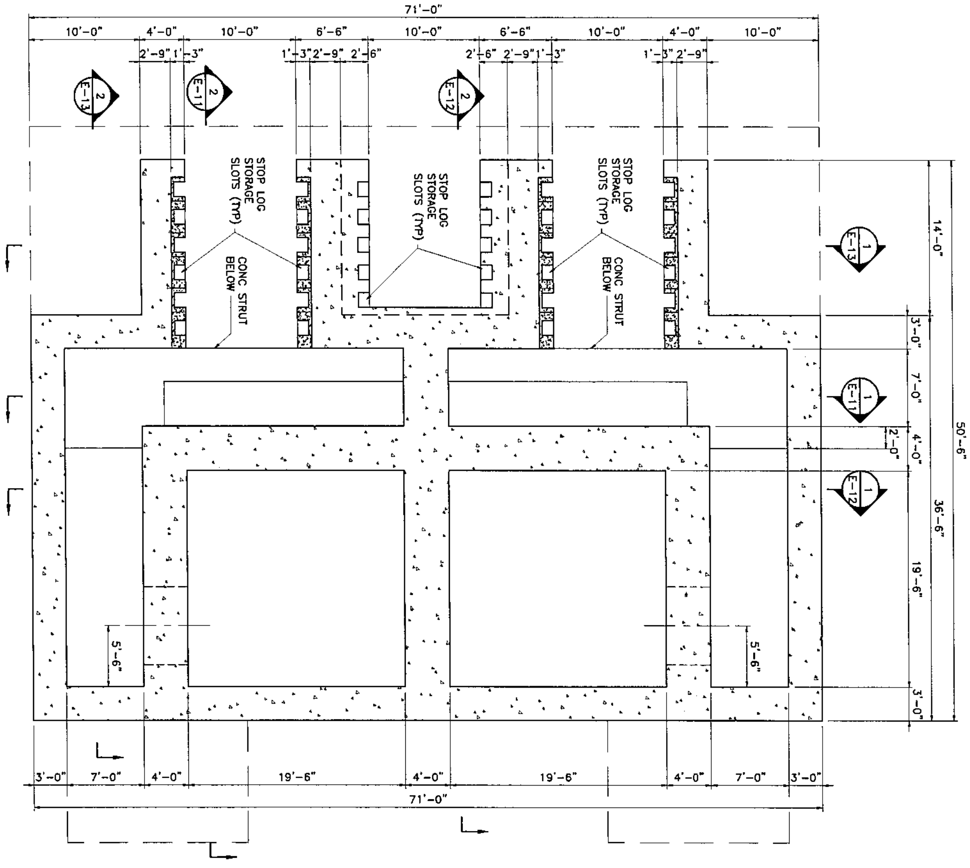
FREESE NICHOLS
4055 International Plaza, Suite 200
Fort Worth, Texas 76109-4895
Phone – (817) 735-7300
Fax – (817) 735-7491
Web – www.freese.com

ACAD Rel: 19.1s (LMS Tech)
Filename: N:\ST\ST-INT-PL-SECT01.dwg
Last Saved: 3/17/2015 12:57 PM Saved By: JAW

Plot Date: 3/19/2015 4:32 PM Plot By: JAW Filename: N:\ST\ST-INT-PL-SECT01.dwg



① SECTIONAL PLAN @ EL 502.0
3/16"=1'-0"



② SECTIONAL PLAN @ EL 543.0
3/16"=1'-0"

60% SUBMITTAL

0 4' 8'
3/16"=1'-0"

Figure 4-4

Freese and Nichols, Inc.
Texas Registered Engineering Firm F-2144

NO.	ISSUE	BY	DATE	
				F&N JOB NO. NTD13565
				DATE MAR. 2015
				DESIGNED MMT
				DRAWN JAW
				REVISED
			FILE NAME ST-INT-PL-SECT01.dwg	CHECKED AD

VERIFY SCALE Bar is one inch on original drawing. If not one inch on this sheet, adjust scale.
0 1

NORTH TEXAS MUNICIPAL WATER DISTRICT

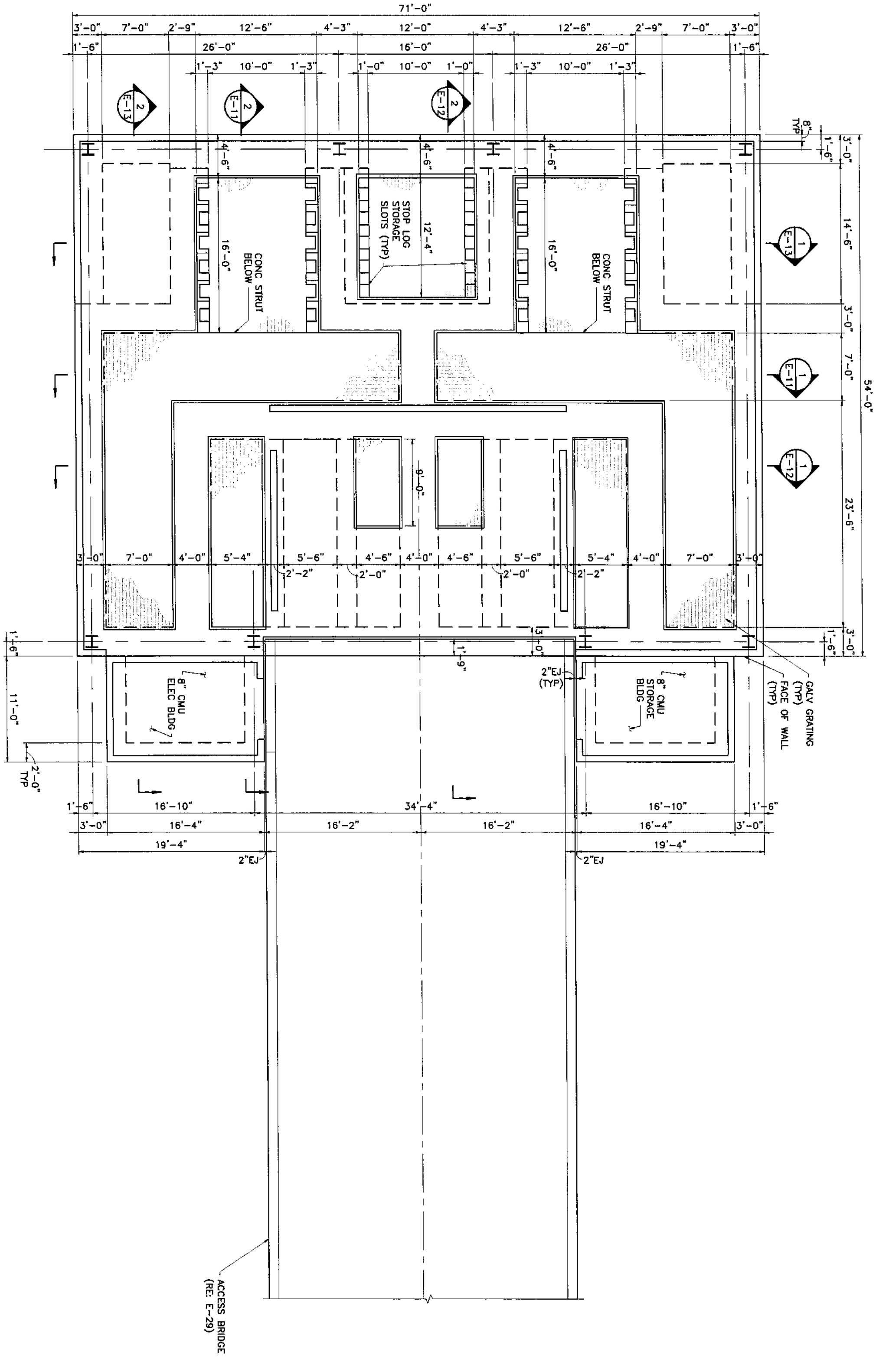
LOWER BOIS D'ARC CREEK RESERVOIR

E – PUMP STATION INTAKE

INTAKE TOWER SECTIONAL PLANS

FREESE AND NICHOLS
4055 International Plaza, Suite 200
Fort Worth, Texas 76109-4895
Phone – (817) 735-7300
Fax – (817) 735-7491
Web – www.freese.com

SHEET E-8
SEQ.



1 TOP PLAN
3/16"=1'-0"

60% SUBMITTAL

0 4' 8'
3/16"=1'-0"

Figure 4-5

Freese and Nichols, Inc.
Texas Registered Engineering Firm F-2144

SEQ.	SHEET	NO.	ISSUE	BY	DATE	
	E-9					F&N JOB NO. NTD13565
						DATE MAR. 2015
						DESIGNED MMT
						DRAWN JAW
						REVISED
		VERIFY SCALE 0 1	Bar is one inch on original drawing. If not one inch on this sheet, adjust scale.		FILE NAME ST-INT-PL-TOPP.dwg	CHECKED AD

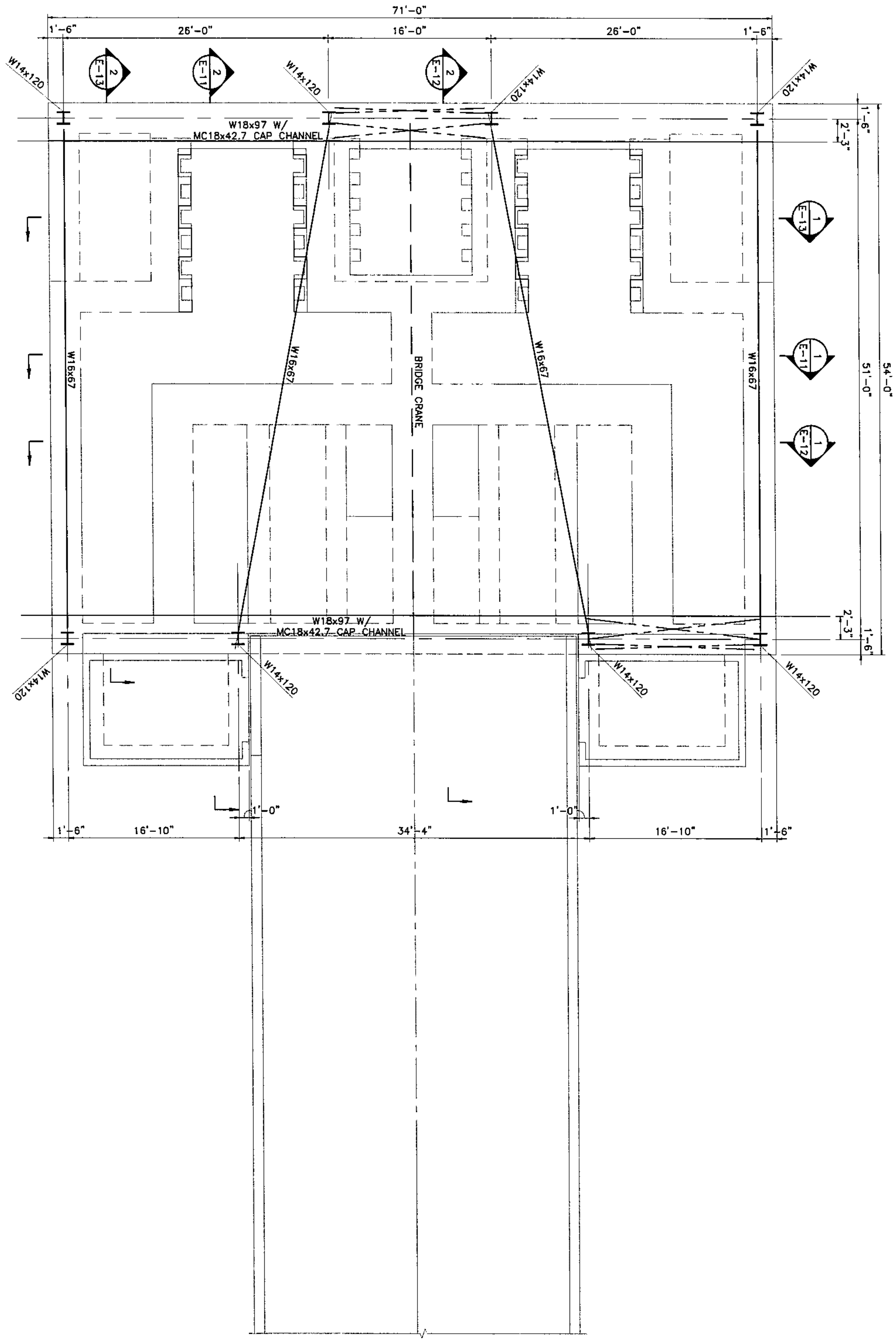
NORTH TEXAS MUNICIPAL WATER DISTRICT

LOWER BOIS D'ARC CREEK RESERVOIR

E – PUMP STATION INTAKE

INTAKE TOWER TOP PLAN

FREESE NICHOLS
4055 International Plaza, Suite 200
Fort Worth, Texas 76109-4895
Phone – (817) 735-7300
Fax – (817) 735-7491
Web – www.freese.com



1 FRAMING PLAN
3/16"=1'-0"

60% SUBMITTAL

0 4' 8'
3/16"=1'-0"

Figure 4-6

Freese and Nichols, Inc.
Texas Registered Engineering Firm F-2144

SEQ.	SHEET	NO.	ISSUE	BY	DATE	
	E-10					F&N JOB NO. NTD13565
						DATE MAR. 2015
						DESIGNED MMT
						DRAWN JAW
						REVISED
		VERIFY SCALE 0 1	Bar is one inch on original drawing. If not one inch on this sheet, adjust scale.		FILE NAME ST-INT-PL-FRMG01.dwg	CHECKED AD

NORTH TEXAS MUNICIPAL WATER DISTRICT

LOWER BOIS D'ARC CREEK RESERVOIR

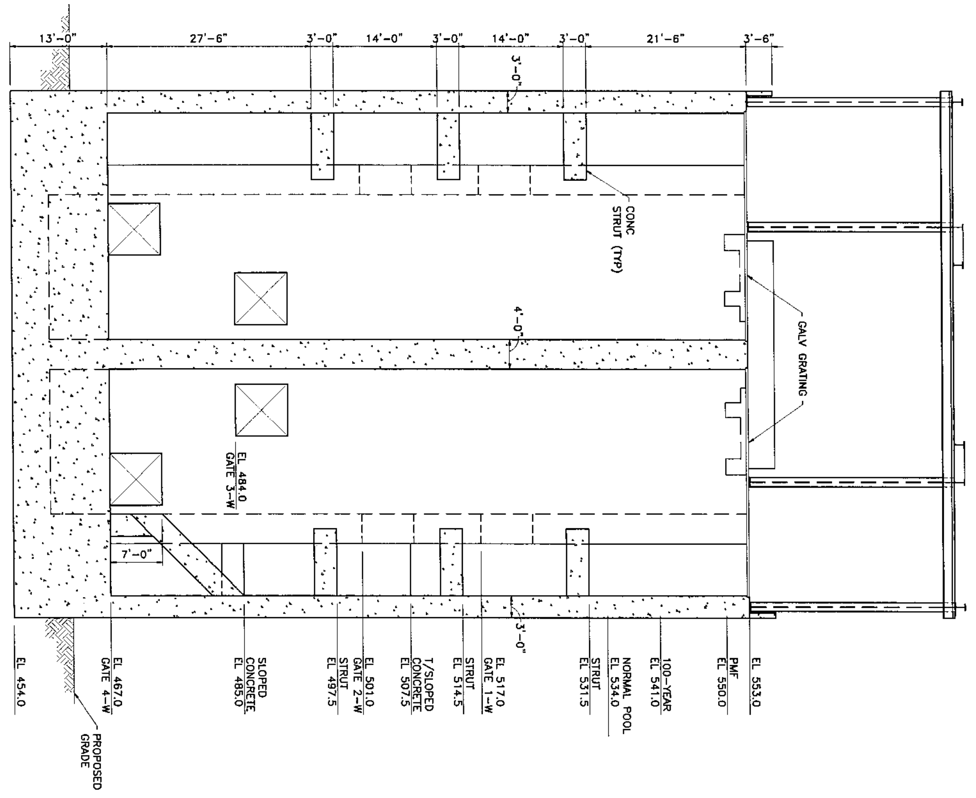
E – PUMP STATION INTAKE

INTAKE TOWER FRAMING PLAN

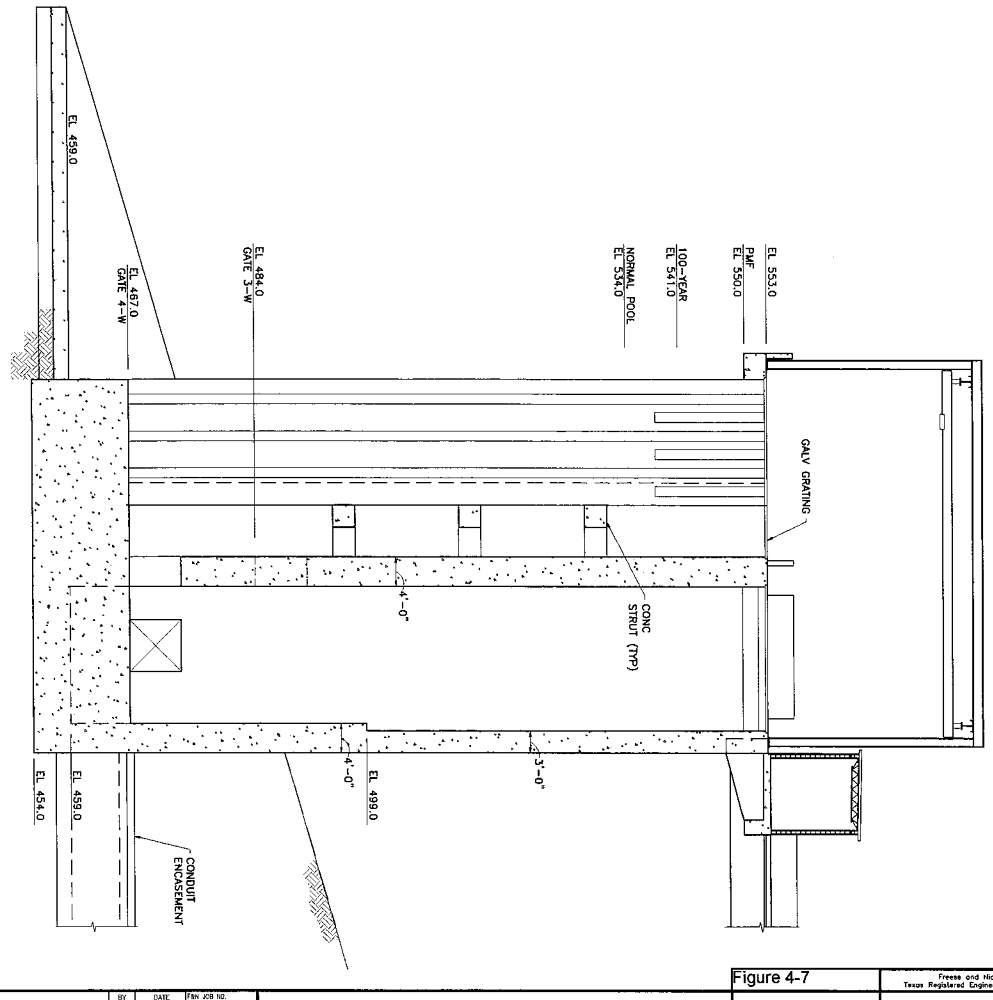
FREESE AND NICHOLS
4055 International Plaza, Suite 200
Fort Worth, Texas 76109-4895
Phone – (817) 735-7300
Fax – (817) 735-7491
Web – www.freese.com

ACAD Rel: 19.1s (LMS Tech)
Filename: N:\ST\ST-INT-SC-TOWR01.dwg
Last Saved: 3/17/2015 3:28 PM Saved By: JAW

Plot Date: 3/19/2015 4:32 PM Plot By: JAW Filename: N:\ST\ST-INT-SC-TOWR01.dwg



1 / E-7 SECTION
1/8"=1'-0"



2 / E-7 SECTION
1/8"=1'-0"

0 4' 8' 16'
1/8"=1'-0"

60% SUBMITTAL

Figure 4-7

Freese and Nichols, Inc.
Texas Registered Engineering Firm F-2144

NO.	ISSUE	BY	DATE	
				F&N JOB NO. NTD13565
				DATE MAR. 2015
				DESIGNED MMT
				DRAWN JAW
				REVISED
				CHECKED AD

VERIFY SCALE 0 1 Bar is one inch on original drawing. If not one inch on this sheet, adjust scale.

FILE NAME ST-INT-SC-TOWR01.dwg

NORTH TEXAS MUNICIPAL WATER DISTRICT

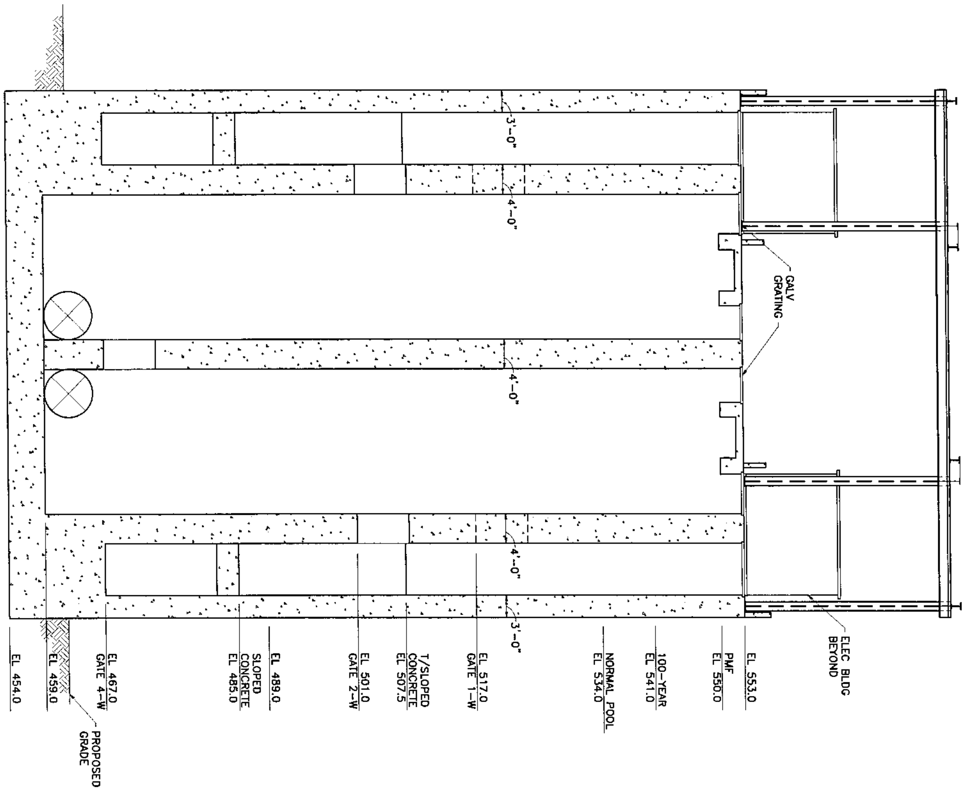
LOWER BOIS D'ARC CREEK RESERVOIR

E – PUMP STATION INTAKE

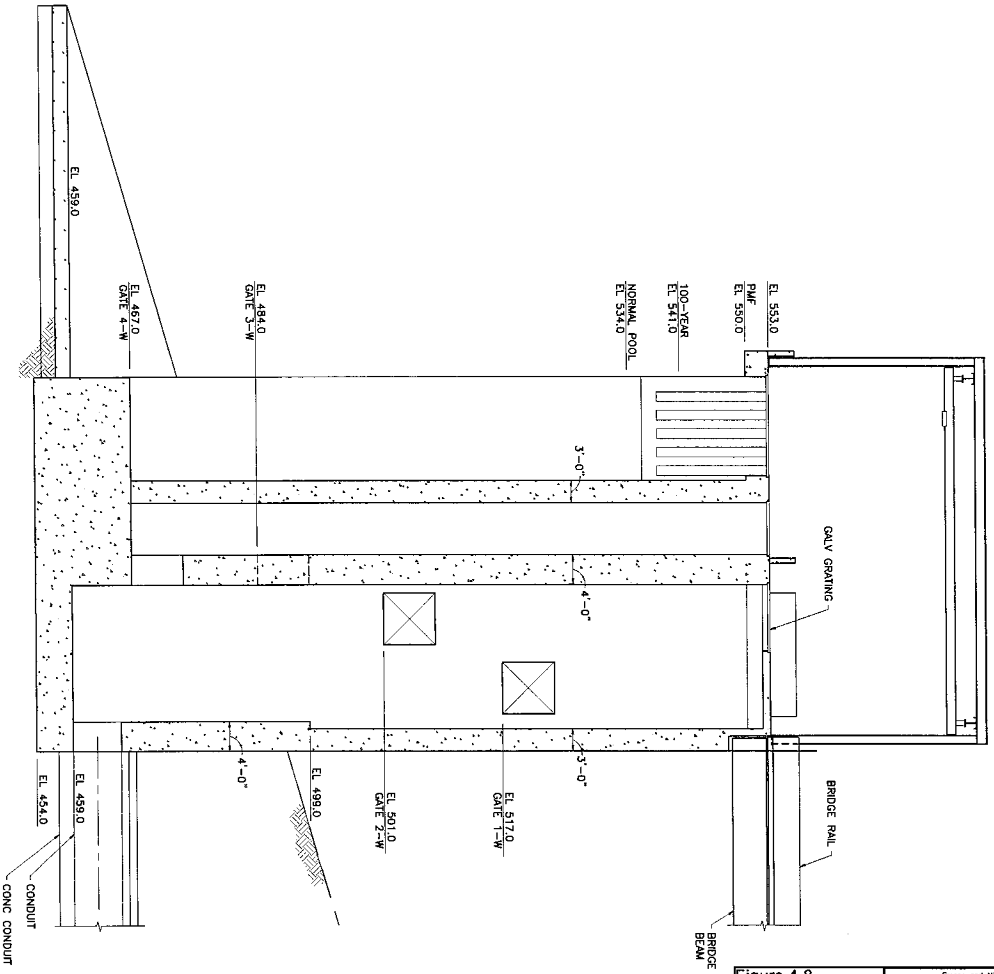
INTAKE TOWER SECTIONS

FREESE AND NICHOLS
4055 International Plaza, Suite 200
Fort Worth, Texas 76109-4895
Phone – (817) 735-7300
Fax – (817) 735-7491
Web – www.freese.com

SEQ.
SHEET E-11



① E-7 SECTION
1/8"=1'-0"



② E-7 SECTION
1/8"=1'-0"

0 4' 8' 16'
1/8"=1'-0"

60% SUBMITTAL

Figure 4-8

Freese and Nichols, Inc.
Texas Registered Engineering Firm F-2144

NO.	ISSUE	BY	DATE

VERIFY SCALE
0 1
Bar is one inch on original drawing. If not one inch on this sheet, adjust scale.

F&N JOB NO. NTD13565
DATE MAR. 2015
DESIGNED MMT
DRAWN JAW
REVISED
CHECKED AD
FILE NAME ST-INT-SC-TOWR02.dwg

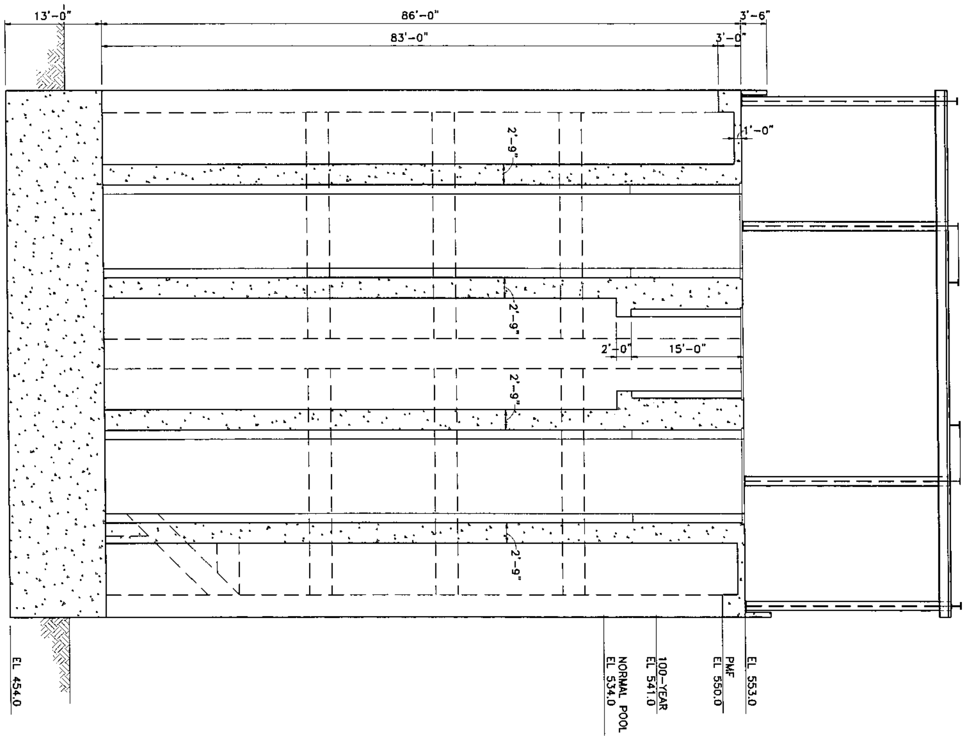
NORTH TEXAS MUNICIPAL WATER DISTRICT
LOWER BOIS D'ARC CREEK RESERVOIR
E - PUMP STATION INTAKE
INTAKE TOWER SECTIONS

FREESE NICHOLS
4055 International Plaza, Suite 200
Fort Worth, Texas 76109-4895
Phone - (817) 735-7300
Fax - (817) 735-7491
Web - www.freese.com

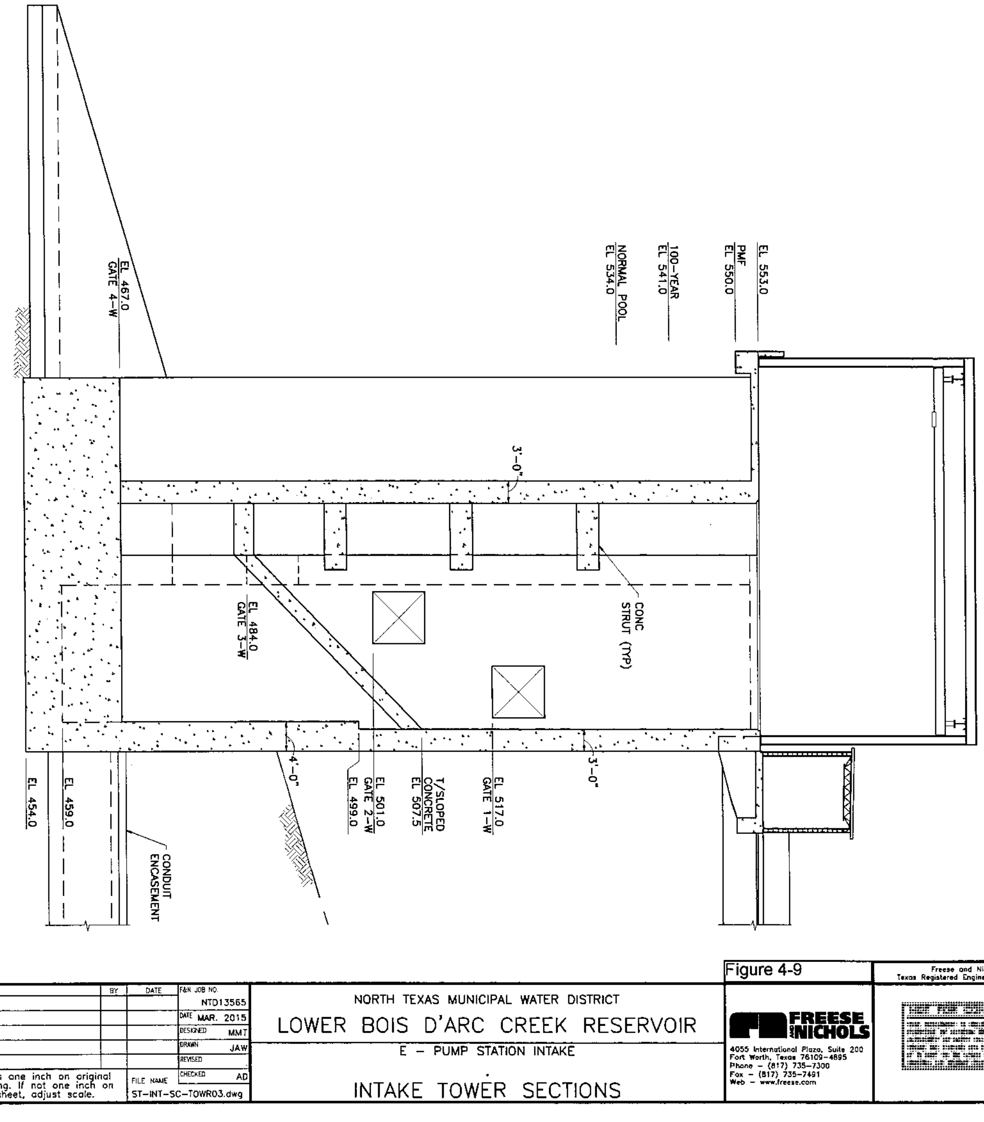
SHEET E-12
SEQ.

ACAD Rel: 19.1s (LMS Tech)
Filename: N:\ST\ST-INT-SC-TOWR03.dwg
Last Saved: 3/17/2015 3:22 PM Saved By: JAW

Plot Date: 3/19/2015 4:32 PM Plot By: JAW Filename: N:\ST\ST-INT-SC-TOWR03.dwg



1 E-7 SECTION
1/8"=1'-0"



2 E-7 SECTION
1/8"=1'-0"

0 4' 8' 16'
1/8"=1'-0"

60% SUBMITTAL

Figure 4-9

Freese and Nichols, Inc.
Texas Registered Engineering Firm F-2144

NO.	ISSUE	BY	DATE

VERIFY SCALE 0 1 Bar is one inch on original drawing. If not one inch on this sheet, adjust scale.

F&N JOB NO. NTD13565
DATE MAR. 2015
DESIGNED MMT
DRAWN JAW
REVISED
CHECKED AD
FILE NAME ST-INT-SC-TOWR03.dwg

NORTH TEXAS MUNICIPAL WATER DISTRICT

LOWER BOIS D'ARC CREEK RESERVOIR

E – PUMP STATION INTAKE

INTAKE TOWER SECTIONS

FREESE NICHOLS
4055 International Plaza, Suite 200
Fort Worth, Texas 76109-4895
Phone – (817) 735-7300
Fax – (817) 735-7491
Web – www.freese.com

SEQ.
SHEET
E-13

5.0 TRANSMISSION SYSTEM HYDRAULICS

5.1 HYDRAULIC ANALYSIS

The hydraulic analysis of the transmission system was conducted using H2OMAP Water software by Innovyze. The purpose of developing this model was to prepare an extended period simulation (EPS) of the raw water pumping system on a daily basis for one year. Unlike several of the NTMWD's remote raw water pump stations, pumping from the Leonard WTP will directly impact pumping required at the Lower Bois d'Arc Reservoir (LBCR).

The model consisted of the LBCR Raw Water Pump Station, the 90-inch diameter pipeline between the raw water pump station and terminal storage reservoir (TSR), TSR at the pipeline's outfall, and two parallel 102-inch pipelines connecting the TSR to the Leonard WTP. A Hazen-Williams roughness c-factor value of 120 was used for all pipes in the model, consistent with friction losses in raw water applications. The system was analyzed with the LBCR water surface level (WSL) at 525 feet MSL. The minimum WSL of the TSR was modeled at 714 feet MSL. The analysis sought to determine the level of pumping at the LBCR required to serve demands at the Leonard WTP while operating within the bounds of different TSR levels.

5.2 DEMAND ANALYSIS

Figure 5-1 displays historical daily raw water pumping data for the years 2008 through 2011. This data was normalized in order to project future daily demands. **Figure 5-2** displays the normalized historical daily usage demands. A fairly consistent pattern is observed in these four years. The normalized pattern from 2011 was used to estimate the daily flow from the Leonard WTP for all planning scenarios. More recent years were not included because of high variability in the supply patterns due to drought conditions and water restrictions.

Figure 5-1 Historical Daily Water Usage

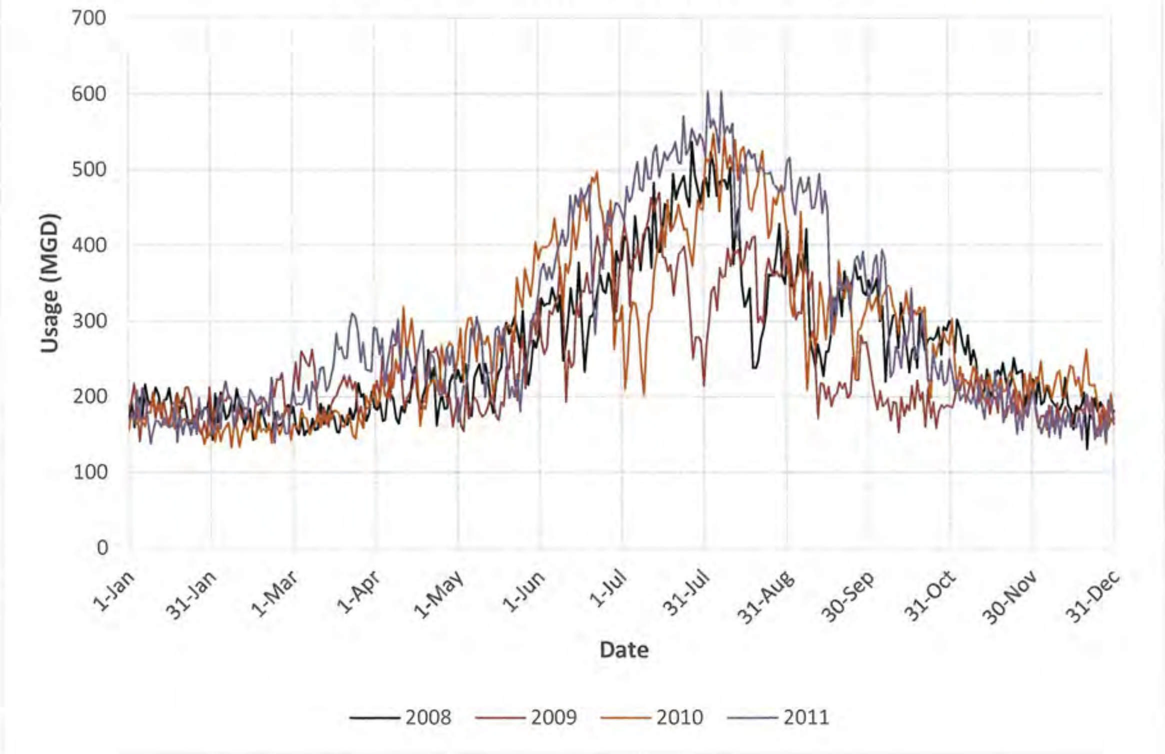


Figure 5-2 Normalized Historical Daily Water Usage Data

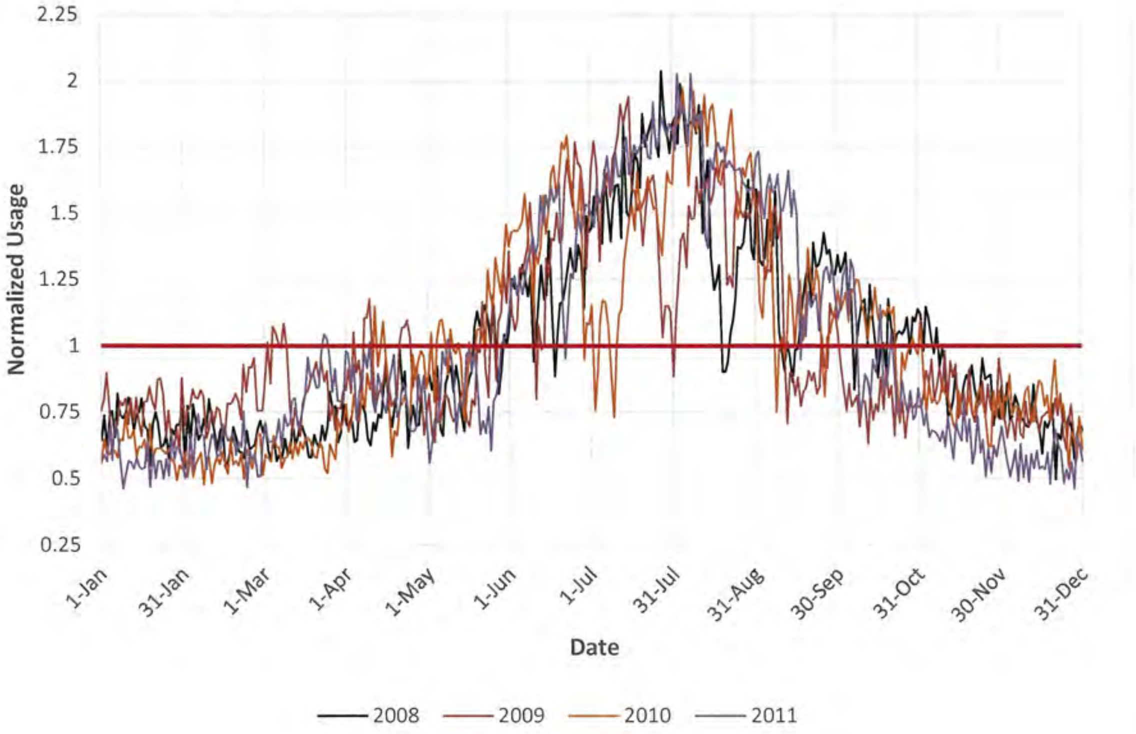


Figure 5-3 displays the projected daily supply from the Lower Bois d'Arc Creek Reservoir for 2020 through 2025 based on the Leonard WTP capacity of 70 MGD. A delivery loss of 3% was incorporated to account for losses between the LBCR Raw Water Pump Station and the Leonard WTP for all daily demand patterns. The projected daily usage results in an average annual usage of 35 MGD from the Lower Bois d'Arc Creek Reservoir; this pattern is based on a normal year instead of a dry year. Supply from LBCR in a dry year is estimated to be around 45 MGD. Based on timing of the proposed pipeline from the Texoma raw water pipeline to the Leonard WTP, it is assumed that LBCR is the only water supply for the Leonard WTP through 2031.

Figure 5-3 Projected LBCR Daily Supply for 2020-2025

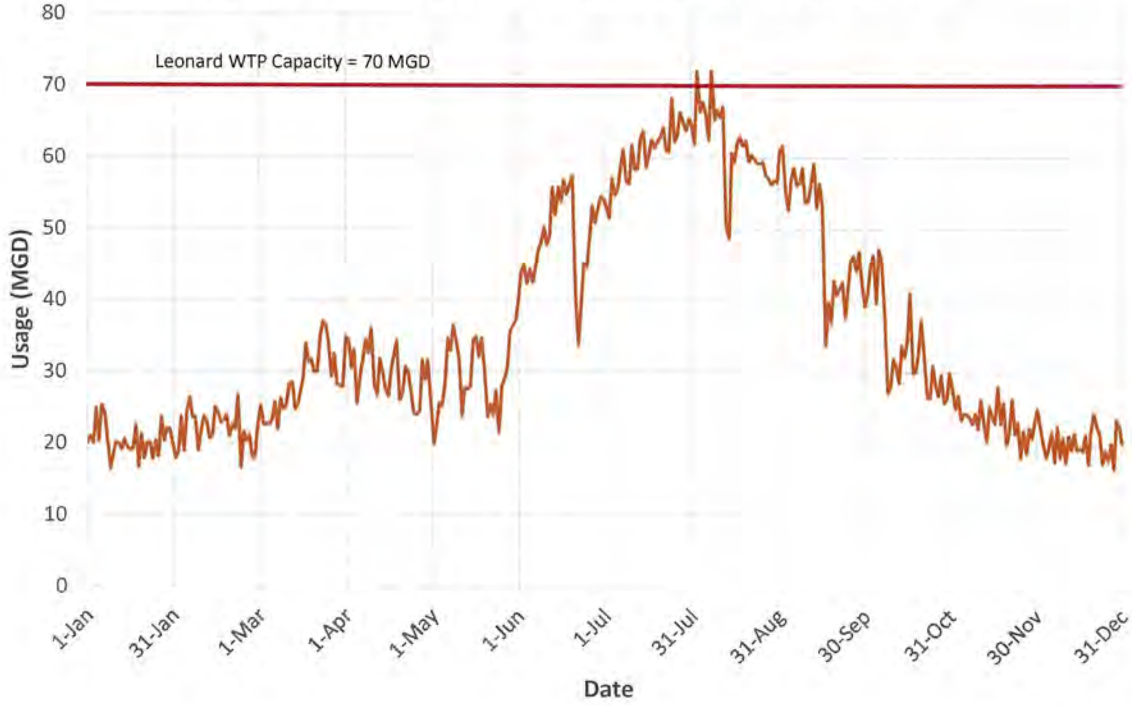


Figure 5-4 displays the projected daily supply from the Lower Bois d'Arc Creek Reservoir for 2026 through 2031 based on a proposed Leonard WTP capacity of 140 MGD. The projected daily usage results in an average annual usage of 70 MGD from the Lower Bois d'Arc Creek Reservoir; this pattern is based on a normal year instead of a dry year. Supply from LBCR in a dry year is estimated to be around 90 MGD.

Figure 5-4 **Projected LBCR Daily Supply for 2026-2031**

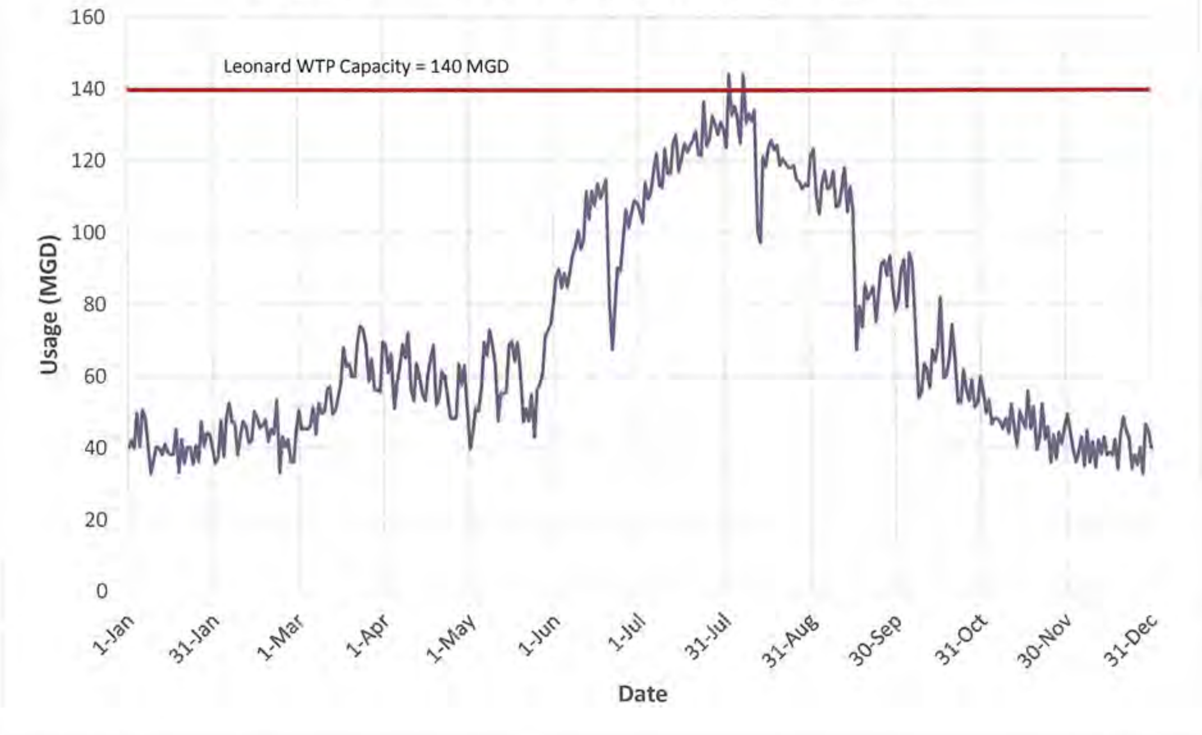


Figure 5-5 displays the projected total daily supply from the Leonard WTP and the projected daily supply from the Lower Bois d'Arc Creek Reservoir and Lake Texoma for 2032 through 2035 based on the Leonard WTP capacity of 210 MGD. During this phase, it is assumed the LBCR will supply 75% of the Leonard WTP demands while Lake Texoma will supply 25% of the Leonard WTP demands. The average annual supply from LBCR is projected as 78 MGD; this pattern is based on a normal year instead of a dry year.

Figure 5-6 displays projected total daily supply from the Leonard WTP and the breakdown of supply from the Lower Bois d'Arc Creek Reservoir and Lake Texoma based on the ultimate capacity of the Leonard WTP of 280 MGD. The same proportion of supply from the LBCR and Lake Texoma was assumed, including 75% from LBCR and 25% from Lake Texoma. The average annual usage of the LBCR for the Leonard WTP capacity of 280 MGD is projected to be 105 MGD. The permitted capacity is between 108 and 109 MGD on an annual basis.

Figure 5-5 **Projected Leonard WTP Daily Supply from LBCR and Texoma for 2032-2035**

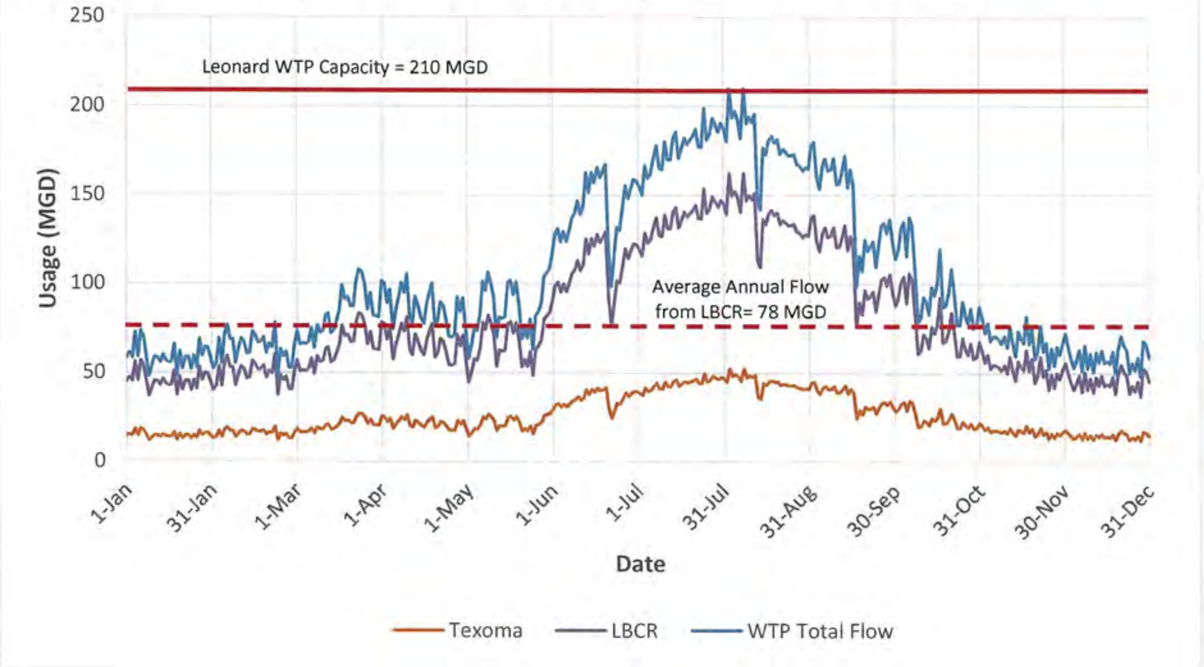
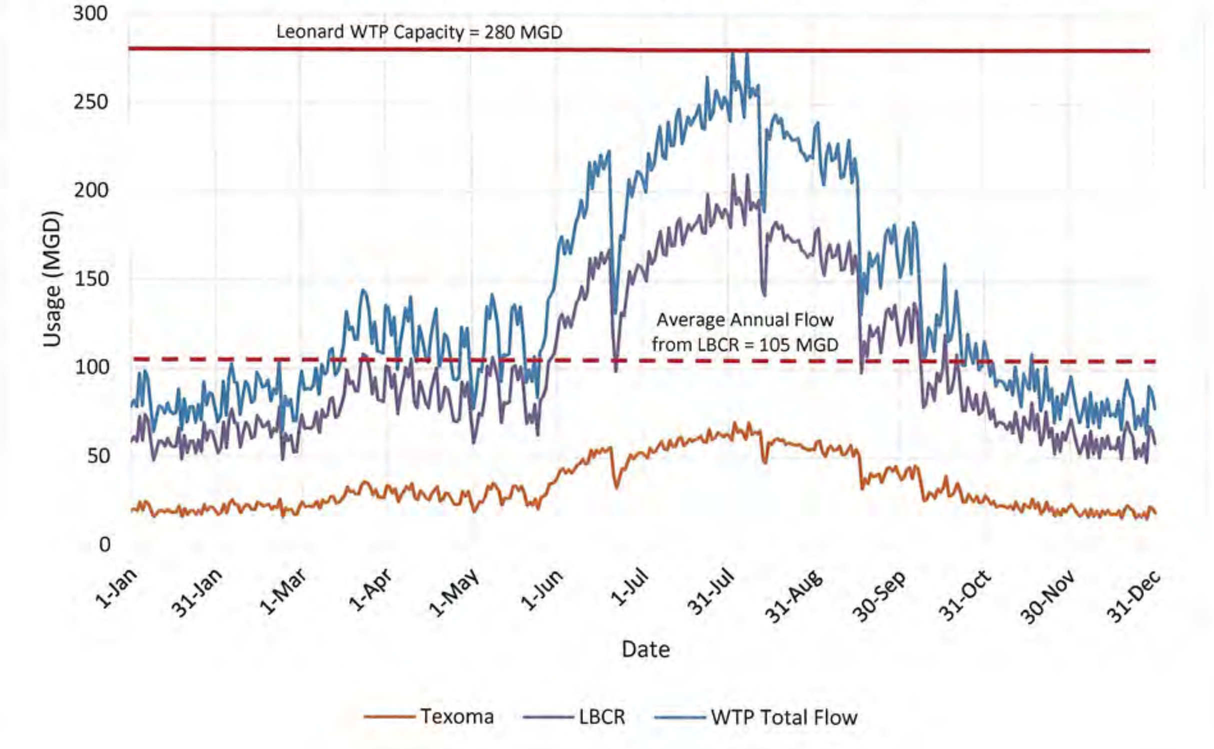


Figure 5-6 **Projected Leonard WTP Daily Supply from LBCR and Texoma Beyond 2035**



5.3 PHASED EXPANSIONS

Table 5-1 summarizes phasing of improvements related to the LBCR system and the corresponding projected capacity at the Leonard WTP and supply from the LBCR. It is assumed that the LBCR raw water pump station expansions correspond with Leonard WTP expansions and the raw water pipeline between the Texoma raw water pipeline and the Leonard WTP is in service in 2032. These expansions are recommended to meet projected system demands as well as utilize projected water supply. The pumping capacity requirements to meet demands in each expansion phase are detailed in **Section 5.5**.

Table 5-1 Proposed Infrastructure Phasing

Planning Period	Leonard WTP Capacity (MGD)	Leonard WTP TSR Capacity (MG)	Average Annual Supply from LBCR (MGD)
2021-2025	70	210	35
2026-2031	140	210/420[2]	70
2032-2035	210	420	78[1]
Beyond 2035	280	420	105[1]

[1] The supply from LBCR assumes 75% supply from LBCR and 25% supply from Lake Texoma.

[2] The second cell of the Leonard WTP TSR is estimated to be in service in February 2029 based on the NTMWD February 2015 CIP.

5.4 STORAGE

Plans for the LBCR raw water pump station and pipeline include a terminal storage reservoir (TSR) at the pipeline's outfall, connected to the Leonard WTP by two parallel 102-inch diameter lines. The ultimate capacity of the proposed two-cell TSR is 420 million gallons (MG). NTMWD plans to phase the construction of the TSR cells, with Phase I including one 210 MG cell completed and in service in 2020. Phase II includes construction of the second 210 MG cell and is estimated to be in service in 2032. The bottom of both TSR cells is 710 feet MSL, and the recommended minimum water surface level of the TSR is 714 feet MSL. The recommended maximum level of the TSR is the normal pool elevation of 731 feet MSL.

The TSR is a variable area reservoir. **Table 5-2** displays the elevation – area – capacity curve for the TSR. **Table 5-2** only displays capacity above the minimum WSL as the water between 710 and 714 feet MSL is considered dead storage and does not add to the total storage volume of the reservoir. The hydraulic model also discounts the dead storage and uses the minimum WSL of 714 feet MSL as the effective bottom of the reservoir.

Table 5-2 TSR Elevation – Area – Capacity Curve

Elevation (feet MSL)	One Cell Capacity (MG)	Two Cell Capacity (MG)
714	0	0
715	11	22
716	22	44
717	34	68
718	45	90
719	57	114
720	69	138
721	81	162
722	93	186
723	105	210
724	118	236
725	131	262
726	143	286
727	156	312
728	169	338
729	183	366
730	196	392
731	210	420
732	223	446
733	237	474
734	251	502
735	266	532
736	280	560
737	295	590
738	309	618

To determine recommended minimum TSR elevations, it was assumed that one TSR cell is in service for the Leonard WTP capacities of 70 and 140 MGD and two TSR cells in service for the Leonard WTP capacities of 210 and 280 MGD. The recommended minimum elevation for the Leonard WTP capacity of 70 MGD is 720 feet MSL based on maintaining a minimum volume in the TSR equal to the plant capacity. The recommended minimum elevation for the Leonard WTP capacity of 140 MGD is 726 feet MSL based on maintaining a minimum volume in the TSR equal to the plant capacity. The recommended minimum elevation is 723 feet MSL for the Leonard WTP capacity of 210 and 280 MGD based on maintaining a minimum volume equal to the peak day flow from LBCR of 210 MGD. The recommended minimum levels are based on the normal pool elevation of 731 feet MSL for the maximum level.

5.5 EXTENDED PERIOD SIMULATIONS

FNI developed hydraulic model runs for each Leonard WTP expansion to determine pumping recommendations. These scenarios are based on the projected daily water demands in **Section 5.2**. Each phased expansion utilized unique maximum and minimum water TSR water levels based on information provided in **Section 5.4**. The pumps were configured to supply the TSR within these bounds. Initially, multiple pump curves were evaluated for feasibility. **Section 6** includes figures displaying pump curves for different combinations of high head (large) and low head (small) pumps considered in this study as well as system curves at varying elevations of the LBCR. These will be revised during final design to reflect any modifications to the system and design.

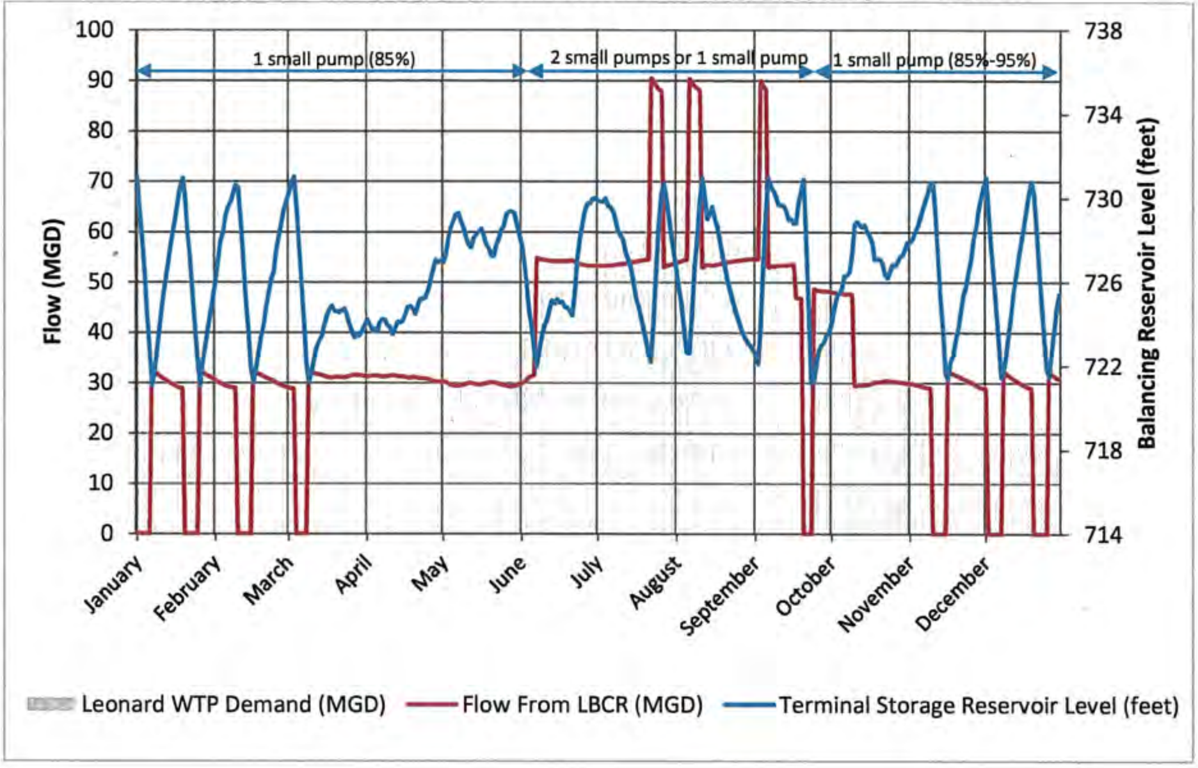
The figures on the following pages display model results utilizing pumps with adjustable frequency drives (AFD). The initial modeling effort used discrete speeds for the pumps and did not take advantage of the infinitely possible speed adjustments that can be made with the equipment. The goal of the analysis was to determine if AFDs are a required piece of equipment to facilitate simple operation of the LBCR pump station, TSR and Leonard WTP. One design parameter not explicitly included in the model results is that the NTMWD will prefer the water level of the TSR not fall or rise more than one foot per day in order to maintain consistent operations within the Leonard WTP. Use of AFDs will facilitate meeting this design criteria. These model results will be refined at later stages of the LBCR design phase.

5.5.1 Phase One – Leonard WTP Capacity of 70 MGD (2020-2025)

The initial phase was modeled using one small AFD pump operating between 85% and 95% speeds during lower demand months and two small pumps during higher demand months. The maximum and minimum WSL in the TSR used for this scenario were 731 and 720 feet MSL, respectively. **Figure 5-7** displays the modeled results for this scenario with projected water demands, proposed pumping, and the resulting TSR water surface level.

This scenario was developed with consideration of maintaining low cycling of the pumps. During the highest demand months, one small pump is insufficient to meet demands, requiring brief periods when two pumps are operating. During lower demand months, the TSR contains adequate storage when filled to 731 feet MSL to deliver water without pumping for periods of approximately one week.

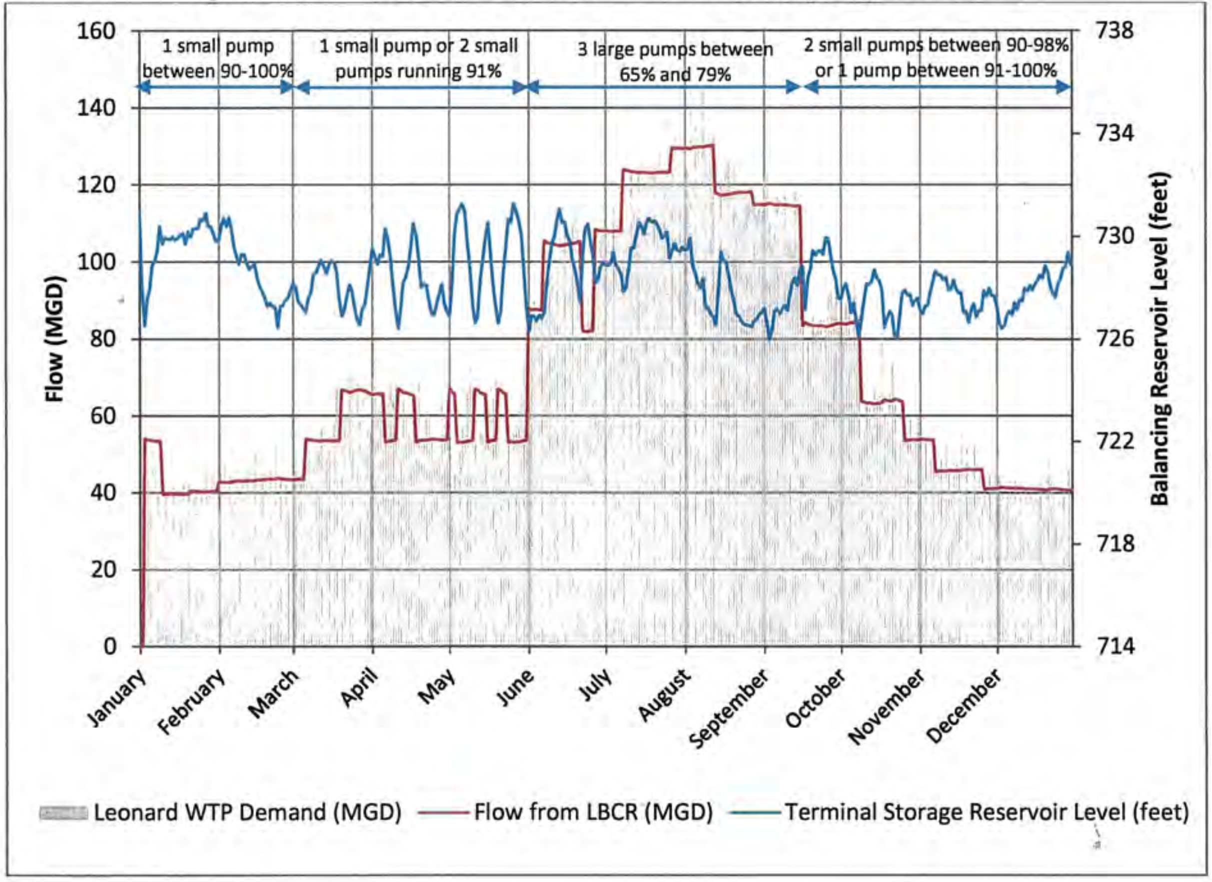
Figure 5-7 Modeled Results for Leonard WTP Capacity of 70 MGD



5.5.2 Phase Two – Leonard WTP Capacity of 140 MGD (2026-2031)

The second phase was analyzed with only one cell of the TSR in operation. This scenario was developed with consideration of maintaining pump speed with minimal changes. During high demand months, three large AFD pumps were modeled with a speed between 65% and 79% to meet projected daily demands. During lower demand months, one small AFD pump operating at a speed between 90% and 100% or two small AFD pumps operating at a speed of 91% were modeled to meet projected demands. The maximum and minimum WSL in the TSR used for this scenario were 731 and 726 feet MSL, respectively. **Figure 5-8** displays the modeled results for this scenario with projected water demands, pumping, and the TSR water surface level.

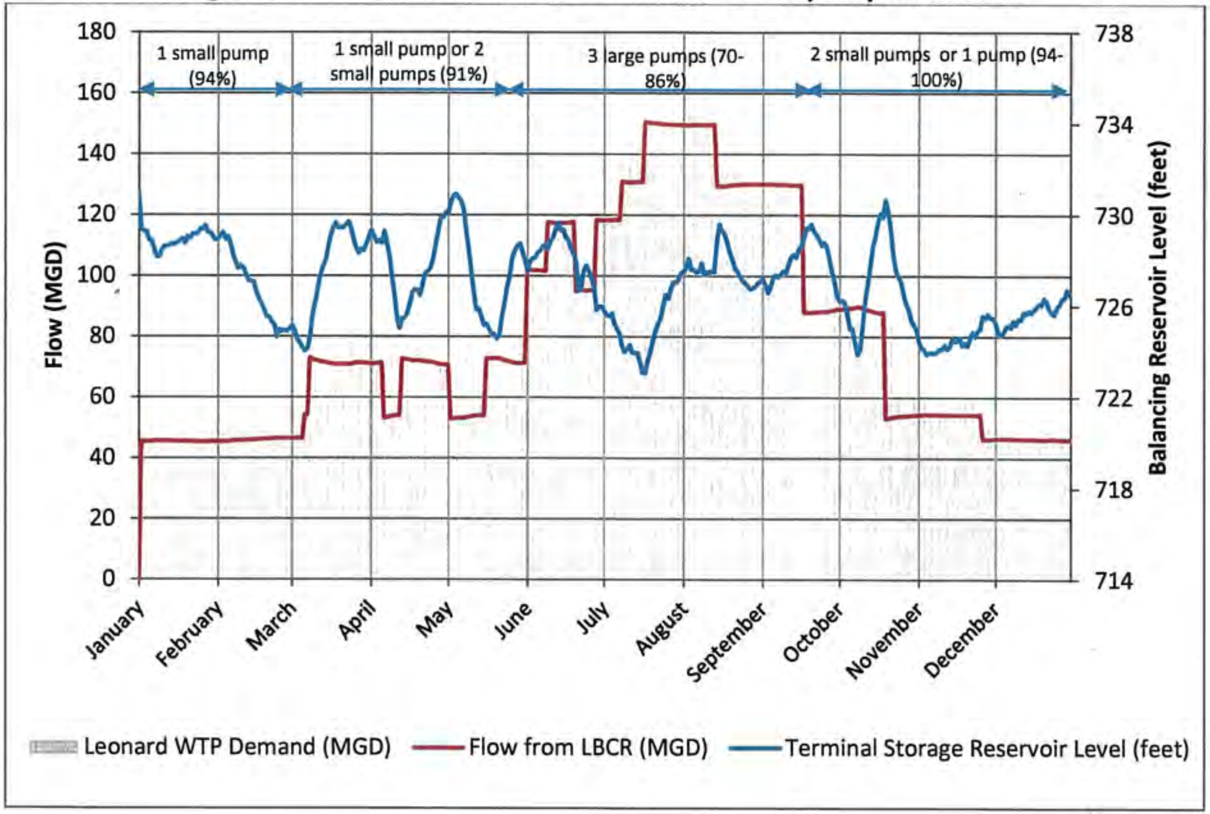
Figure 5-8 Modeled Results for Leonard WTP Capacity of 140 MGD



5.5.3 Phase Three – Leonard WTP Capacity of 210 MGD (2032-2035)

The third phase was modeled with consideration of maintaining pump speed with minimal changes. During this phase, one small AFD pump operating at a speed between 94% and 100% or two small pumps operating between 91% and 100% can meet projected water demands for low demand months. Three large AFD pumps operating at a speed between 70% and 86% can meet water demands for the higher demand months. The maximum and minimum WSL in the TSR used for this scenario were 731 and 723 feet MSL, respectively. **Figure 5-9** displays the modeled results for this scenario with projected water demands, pumping, and the TSR water surface level.

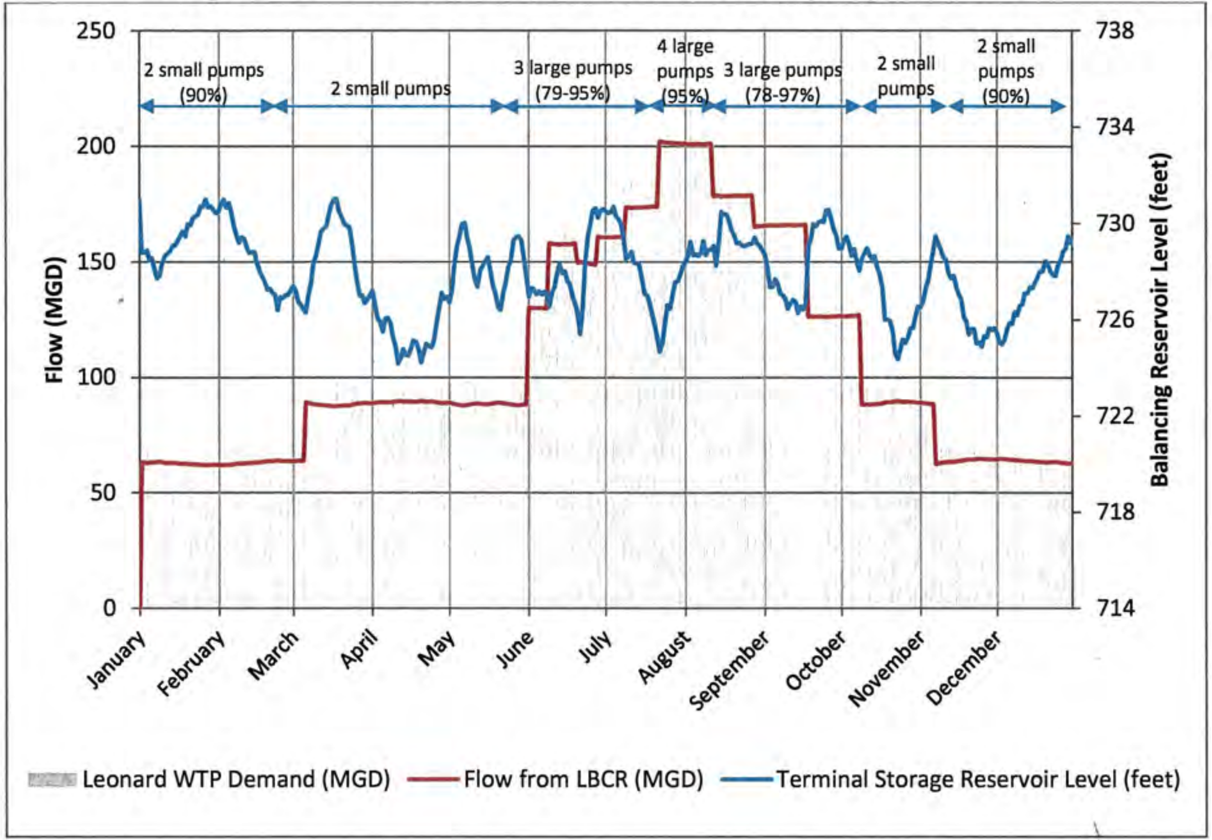
Figure 5-9 Modeled Results for Leonard WTP Capacity of 210 MGD



5.5.4 Phase Four – Leonard WTP Capacity of 280 MGD (Beyond 2035)

For the ultimate Leonard WTP capacity of 280 MGD, two small pumps were modeled operating between speeds of 90% and 100% to meet projected water demands during lower usage months while three large pumps operating between speeds of 78% and 97% were used to meet demands during higher usage months. During the months of July and August, four large pumps operating at 95% were utilized to meet projected daily water demands. The maximum and minimum WSL in the TSR used for this scenario were 731 and 723 feet MSL, respectively. **Figure 5-10** displays the modeled results for this scenario with demands, pumping, and the TSR water surface level.

Figure 5-10 Modeled Results for Leonard WTP Capacity of 280 MGD



5.6 RECOMMENDATIONS

Based on the results of the modeled scenarios, FNI recommends the following pump phases shown in **Table 5-3**.

Table 5-3 Pump Phasing Recommendations

Planning Period	Leonard WTP Capacity (MGD)	Average Annual Supply from LBCR (MGD)	Minimum Firm Capacity at LBCR (MGD)	Recommended Pump Additions
2021-2025	70	35	72	3 low head pumps with AFD
2026-2031	140	70	144	4 high head pumps with AFD
2032-2035	210	78(1)	144	-
Beyond 2035	280	105(1)	236	2 high head pumps with AFD(2)

(1)Assumes 75% supply from LBCR and 25% supply from Lake Texoma

(2)The sixth high head pump will be required to provide firm capacity up to 236

6.0 PUMP SELECTION

In the previous study documented with the May 2014 report "Lake Pump Station Alternative Analysis Report", horizontal split case pumps were selected as the preferred pump to be used for the design of the LBCR raw water pump station.

6.1 PUMP SIZES

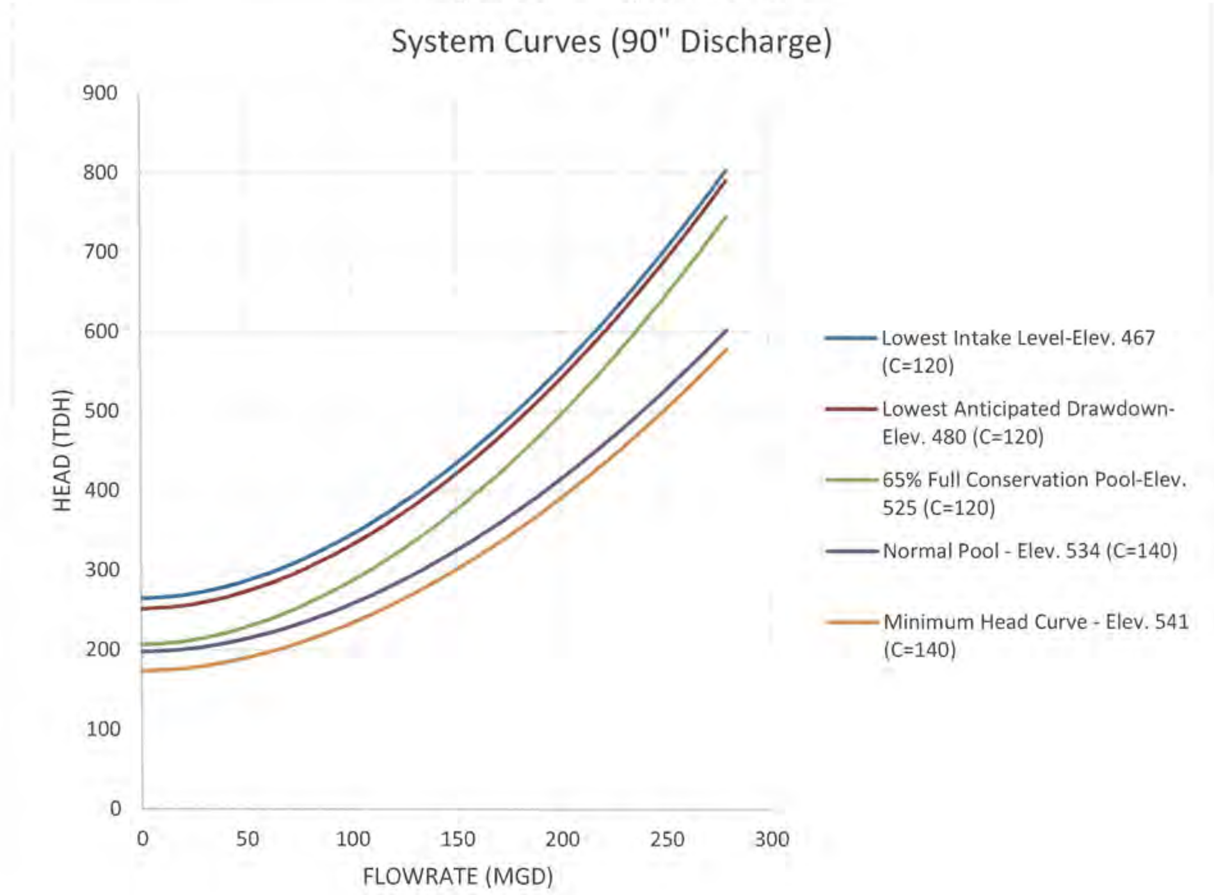
The LBCR pumps will pump into a 90-inch pipeline, approximately 35 miles to the TSR at the Leonard WTP. The ultimate firm capacity of the proposed raw water pump station will be 236 MGD. The design head was determined by preparing a system curve and hydraulic grade line (HGL) from the LBCR RWPS to the TSR for a range of flows between 0 MGD to 280 MGD. The centerline elevation of the 90-inch header in the RWPS will be 450.25 feet MSL. The wide range of potential static head (due to varying lake levels) affects the pump selection because the actual pump capacity of the station is relative to the lake level at which the capacity is established. The following assumptions were made when preparing the system curves shown in the proceeding figures:

- Elevation of the TSR at the Leonard WTP is 731 feet MSL
- Maximum Head: Lake Level at 467 feet MSL, Hazen Williams roughness C-factor of 120
- Lowest Anticipated Drawdown: Lake Level at 480 feet MSL, Hazen Williams roughness C-factor of 120
- 65% Conservation Pool: Lake Level at 525 feet MSL, Hazen Williams roughness C-factor of 120
- Normal Pool Elevation: Lake Level at 534 feet MSL, Hazen Williams roughness C-factor of 140
- Minimum Head (100-year flood elevation): Lake Level at 541 feet MSL, Hazen Williams roughness C-factor of 140

FNI selected a water level elevation of 525 feet MSL representing 65% of the full conservation pool to size and select the pumps. Firm capacity and the nominal rated point for the pumps will be relative to this elevation. All pumps intersect the system curve at lake elevations (467 feet MSL to 541 feet MSL) from the maximum head to the minimum head curve.

Multiple Hazen Williams roughness C-factors were used in the analysis to develop system curves. For the sake of simplicity on the following charts not all conditions are plotted. A Hazen Williams roughness C-factor of 120 would be expected for longer-term conditions on the raw water pipeline. However, during its initial service life, a higher Hazen Williams roughness C-factor of 140 may be expected on the pipeline. The minimum and normal pool system curves are shown with this higher roughness factor in order to evaluate and select pumps that will operated satisfactorily at the lower static and dynamic (friction) heads. The system curve is shown in **Figure 6-1**.

Figure 6-1 System Curves



Initially, demand to the treatment plant will fluctuate between 0 and 90 MGD as described in **Section 5.5**. The peak capacity for the pump station will be 236 MGD. Pumps were evaluated to meet all the pumping ranges necessary. FNI has received a pump curve that can meet the ultimate high head duty point and also be slowed down to meet the initial proposed operating condition, however pump selection for this scenario is likely to be extremely limited. A minimum of two pumps will need to operate at approximately

65% speed to meet the initial proposed operating conditions with pumps rated for the build out duty point.

Separate lower head pumps will be used to meet the initial demand to the treatment plant to provide station flexibility and simpler, more efficient operation. The lower head pumps can meet the initial demands with one pump running and can be used for pumping low flows when the demand fluctuates after the RWPS expands.

Both pump selections are based on the 65% conservation pool in LBCR. The low head pump has a full speed duty point of 50 MGD at 250' TDH and a reduced speed duty point of 30 MGD at 205' TDH. The high head pump has a full speed duty point of 47 MGD at 600 feet MSL TDH and a reduced speed duty point of 33 MGD at 295' TDH. Ultimately LBCR RWPS will have nine (9) pumps installed including one standby low head pump and one standby high head pump. The first three pumps installed will be the low head pumps and the subsequent six pumps will be the high head pumps. This may result in a lower capital cost by allowing the District to purchase only three low head pumps and associated equipment to meet the initial demand, however the inclusion of two standby units (one for high and low head sets of pumps) increases the total size of the structure. The District will also benefit from not having to run multiple high head pumps at very low speeds to meet initial demands and fluctuations in future demands.

6.2 PUMP SPECIFICATIONS

FNI's pump specification documents the requirements for the labor, materials, equipment and incidentals necessary to design, manufacture, fabricate, test, and deliver the horizontal centrifugal pumping units. Detailed development and review of the pump specification will occur during the final design phase. The following is a summary of the anticipated approach.

The materials of construction and requirements of the pump components must be suited to the frictional wear, corrosion, and chemical characteristics expected in the raw water. The following summary table designates the proposed materials of construction for the major pump components.

Table 6-1 Specification Material/Requirements

Pump Component	Material/Requirement
Pump Casing	Cast Steel or Ductile Iron
Impellers	Chrome-Nickel alloy stainless steel
Impeller and Casing Wear Rings	400 series stainless steel
Pump Shaft	410 or 416 stainless steel
Pump Shaft Sleeves	410 stainless steel
Seals	Mechanical, split type, stainless steel with filtered water flush
Bearings	Oil lubricated anti-friction ball type
Coupling	"FAST'S" flexible gear type, stainless steel
Pump and Motor Base	Fabricated steel
Pump Coatings	Interior: Ceramic epoxy Exterior: Match adjacent piping

The factory performance pump testing will be conducted to record the efficiency, capacity, horsepower, head, and NPSHR of the pump. The pump test will use a previously tested and accepted job motor operated at full speed. A review of testing capabilities of the pump manufacturers and possible test facilities for each has not been made. This review will be conducted during the process of vetting manufacturers to determine any critical limitations (capacity, pressure and/or power) of their test facilities.

The pump and motor manufacturers will be required to have a service representative at site before, during, and after installation and field testing. The pumps and motors will be specified with a one year warranty.

The expected delivery method with the CMAR will allow for evaluation of proposals from pump manufacturers based on price, qualifications and other factors. The pumps will be evaluated based on wire-to-water efficiency at selected duty points. The wire-to-water efficiency of the pumps at these points will be weighted with a dollar value to be used in evaluation of the proposals, such that initial costs and operating costs are both considered to aid in selecting a pumping unit that minimizes life-cycle costs.

6.3 PUMP MANUFACTURERS

FNI's has completed preliminary investigations and there appear to be six manufacturers of horizontal split case pumps that may be able to meet the design conditions of this system. These manufacturers are Flowserve, Xylem/Flygt, Patterson, Fairbanks Morse, Sulzer, and Hitachi. The NTMWD has experience with horizontal split case pumps manufactured by Flowserve, Xylem/Flygt, Patterson and Fairbanks Morse and these will be recommended for inclusion as acceptable manufacturers. FNI is currently reviewing additional information provided by Hitachi. To date, Sulzer has not provided additional information requested regarding service history and qualifications. FNI will continue to review other alternative manufacturers that may be presented between now and final design phase.

6.4 EVALUATION OF PUMPS

Two sets of pump selections are required for planning out the ultimate LBCR pump station configuration. The selections for low head pumps and high head pumps are described below. Acceptable pump selections will meet the required duty points within their AOR and ideally maximize the conditions where the pumps operate close to their best efficiency point at full speed and reduced speed.

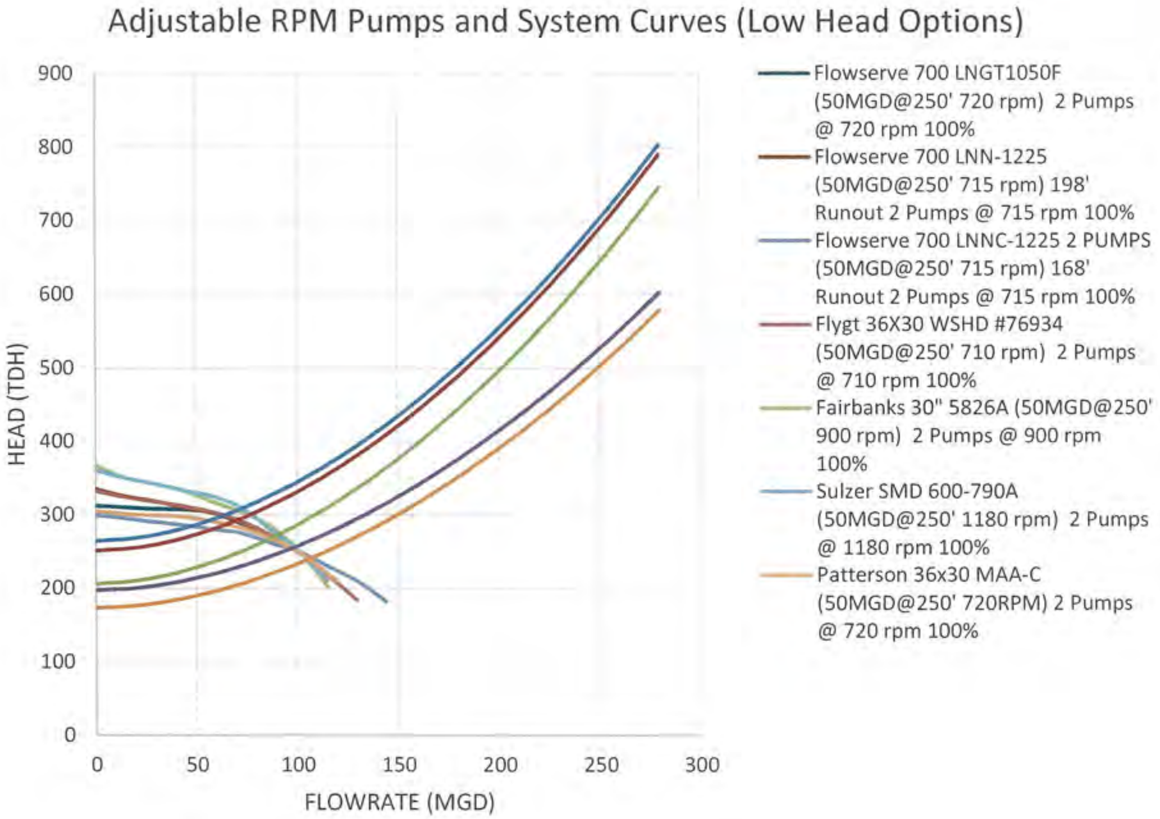
6.4.1 Low Head Pump Selection

The low head pump selections are intended to operate between 30 to 90 MGD and supply the Leonard WTP demands. Demands are within this range for the entirety of Phase 1 (70 MGD Leonard WTP) and about 70-percent of the time during ultimate Phase 4 (280 MGD Leonard WTP). Considering the expected run-time for these low head pumps, it becomes very important to achieve pumping at the highest efficiency possible.

Two initial duty points were set for discussions with pump manufacturers and development of pump selections. These will be reviewed further in final design prior to purchasing pumps. The rated point for full speed operation is 50 MGD (34,700 gpm) each at 250 feet TDH. This will allow at least 90 MGD to be supplied using these pumps at lake levels above the 65% conservation pool (525 feet MSL). The primary reduced speed duty point is 30 MGD each at 205 feet TDH. This point is intended to allow greater than 30 MGD at lake levels from normal pool to minimum drawdown.

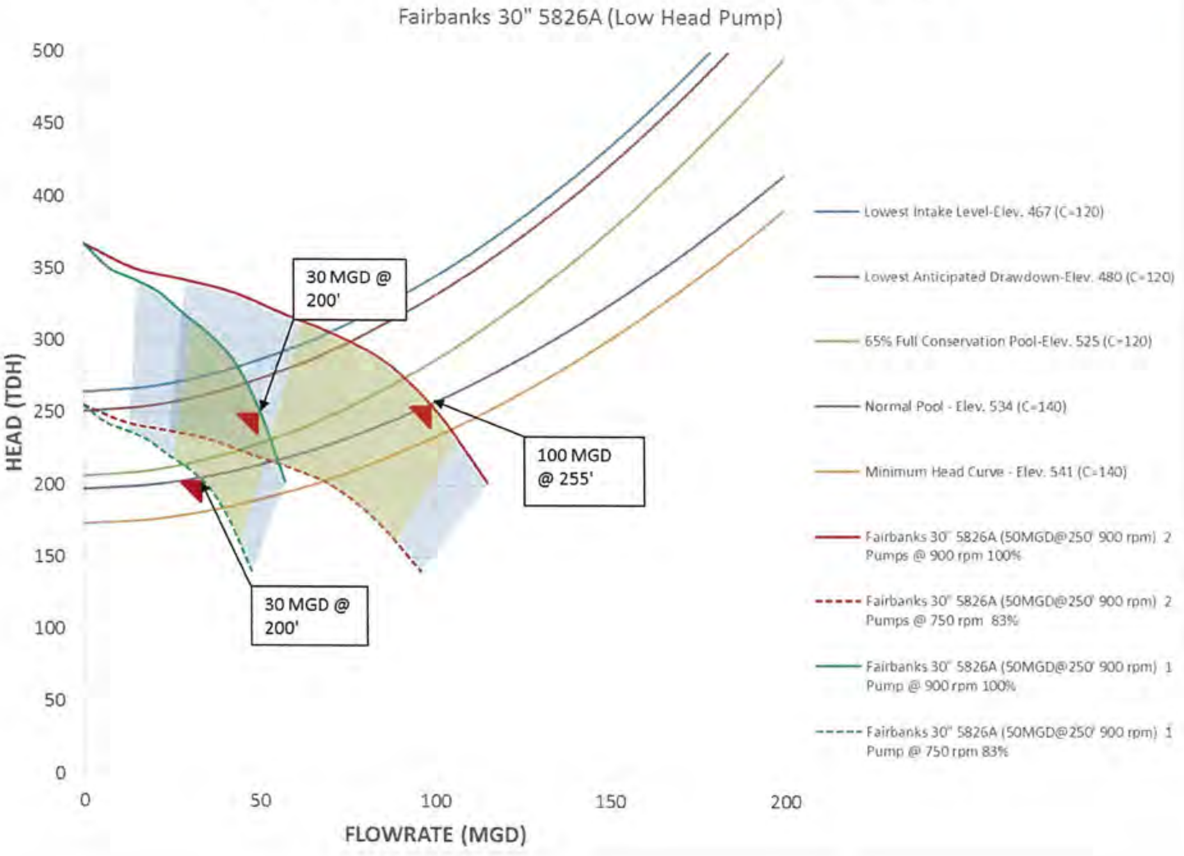
Low head pump selections were received from five manufacturers: Flowserve, Patterson, Fairbanks Morse (Pentair), Sulzer and Xylem/Flygt, with speeds ranging from 720 to 1200 rpm and motor horsepower ranging from 2750 to 3000HP. Flowserve provided three selections: one side suction pump from their Ingersoll-Dresser heritage line (LNN); a bottom suction pump option (LNNC); and a side suction pump from their Dutch (Hengelo) line (LNGT). The other manufacturers provided one "best-fit" selection. These selections are shown in **Figure 6-2** below.

Figure 6-2 Low Head Pump Selections, Full Speed, Two Pumps in Parallel



These pumps have generally similar hydraulic characteristics and will be considered for inclusion in the final specifications. These pumps were evaluated for reduced speed operation to confirm operations across the wide range of capacity needs and head variation due to changing lake levels. One example is shown in **Figure 6-3** below.

Figure 6-3 Low Head Pump, Reduced Speed Coverage



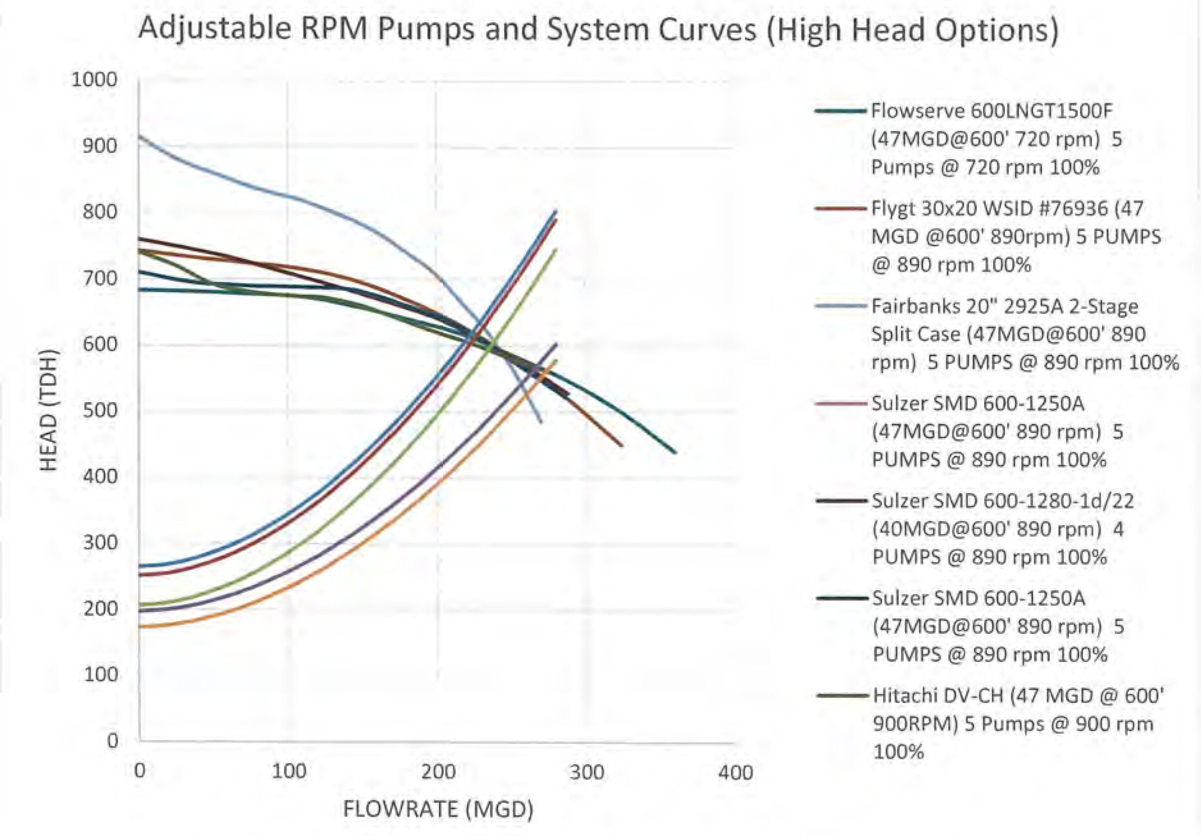
6.4.2 High Head Pump Selection

The high head pump selections are intended to operate between 90 to 236 MGD and supply the Leonard WTP demands. Demands are within this range for the beginning in Phase 2 (140 MGD Leonard WTP) and operating about 30-percent of the time through the future phases during high demand summer months. Additional pumps and higher speed operation will be used to meet growing demands as the systems is expanded. Although the run-time for these high head pumps is much shorter duration than the low head pumps, the capacity and pumping head require substantially greater power, therefore achieving high efficiency across the system operation range is a primary goal in pump selection.

Two initial duty points were set for discussions with pump manufacturers and development of pump selections. These will be reviewed further in final design prior to purchasing pumps. The rated point for full speed operation is 47 MGD (32,600 gpm) each at 600 feet TDH. This will allow up 236 MGD to be supplied using five pumps at lake levels above the 65% conservation pool (525 feet MSL). The primary reduced speed duty point is 33.3 MGD each at 295 feet TDH.

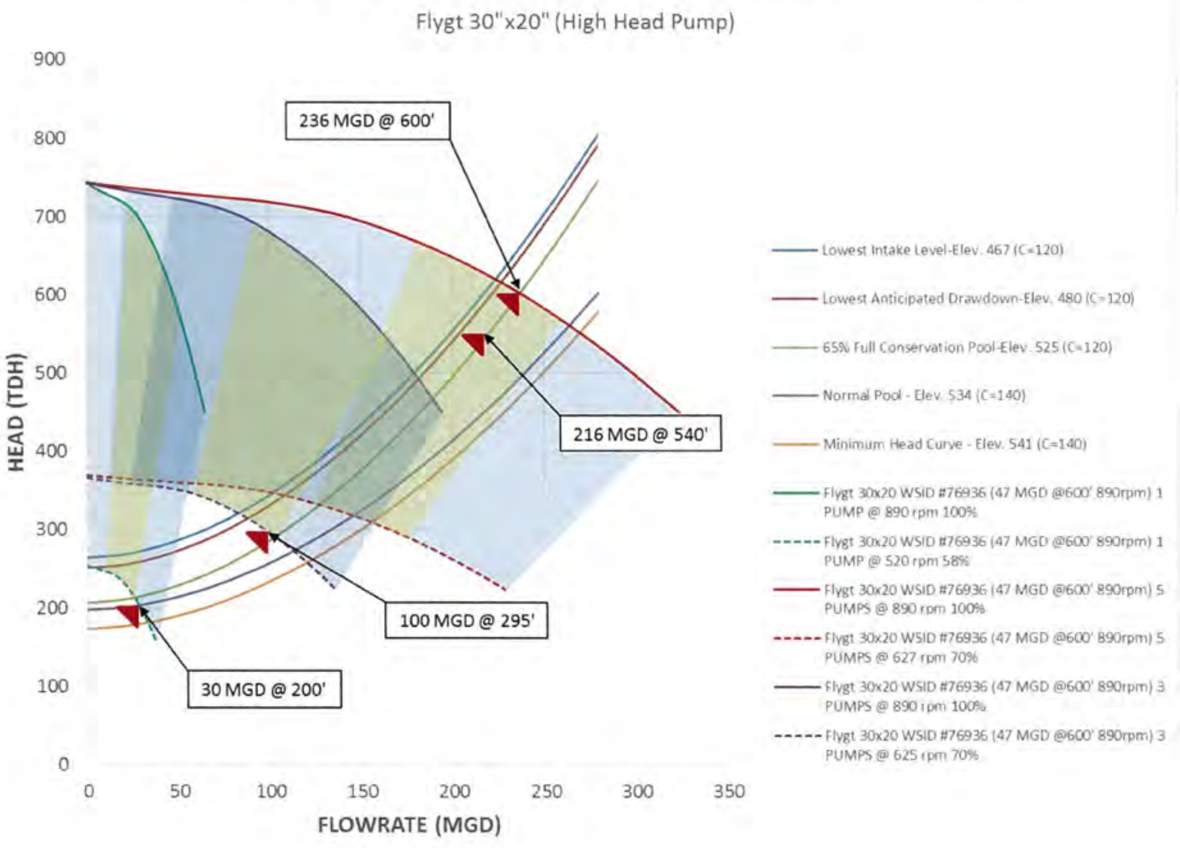
High head pump selections were received from five manufacturers: Flowserve, Fairbanks Morse (Pentair), Hitachi, Sulzer and Xylem/Flygt, with speeds ranging from 720 to 900 rpm and motor horsepower ranging from 6000 to 7400HP. There will be fewer options available from pump manufacturers that satisfy the capacity and head requirements. The Flowserve high head pump is from the Dutch (Hengelo) line of pumps. The Fairbanks Morse selection for the high head pump selection is a two-stage split case design. This type of pumps has substantially different characteristics and will not be recommended for inclusion in the project. Patterson did not have a pump capable of meeting the rated conditions and proposed two pumps in series. This configuration will not be recommended for inclusion in the project. The Hitachi and Sulzer pump selections are included, but the use of these pumps is still under review by FNI. FNI has past project experience with Hitachi for similar applications, however the NTMWD does not. Neither FNI nor NTMWD have past experience with Sulzer on similar large horizontal split-case pumps. Sulzer is relatively new to this pump application and selection received appears to be from the new design. FNI is working on getting information on pump service information within the United States and internationally. The Xylem/Flygt selection is from the Allis-Chalmers heritage line with a new impeller design. These selections are shown in **Figure 6-4** below.

Figure 6-4 High Head Pump Selections



These pumps have generally similar hydraulic characteristics and will be considered for inclusion in the final specifications, except for the two-stage option shown. The single-stage pumps were evaluated for reduced speed operation to confirm operations across the wide range of capacity needs and head variation due to changing lake levels. One example is shown in **Figure 6-5** below.

Figure 6-5 High Head Pump, AFD Coverage



6.5 RECOMMENDATIONS

FNI recommends a pump station design with spacing for nine pumps. Initially three low head pumps should be installed. As the water treatment plant expands, high head pumps will need to be added as shown in **Table 5-3** in Section 5.6.

At this time, FNI recommends soliciting proposals for pumps from Flowserve, Hitachi, Xylem/Flygt, Patterson (low head option only), and Fairbanks Morse (low head option only). The proposals should be evaluated based on the evaluation criteria outlined above. If other manufacturers are able to provide a selection that is able to meet the hydraulic requirements of the system as the design progresses, those pumps should also be evaluated. FNI is still reviewing selections from Sulzer and other interested manufacturers.

7.0 RAW WATER PUMP STATION DESIGN

7.1 RAW WATER PUMP STATION SITE DESIGN

7.1.1 Finished Floor Criteria

The finished floor for the LBCR raw water pump station will be 497 feet MSL. This elevation has been set above the PMF elevation of 496.3 feet MSL for Bois d'Arc Creek downstream of the proposed dam. The floor elevation provides almost 15 feet of freeboard above the 500-year flood elevation. Setting the building, electrical equipment and other components at the proposed floor elevation will protect from flooding.

7.1.2 Mass Grading

The site will be graded to freely drain in all directions from the pump station structure at slopes between 1% and 2% in the vicinity of the pump station. Drainage will be by sheet flow and swales draining to the diversion and spillway channels to the west, north and east. No localized storm drain collection system is anticipated. Where steeper grading is need to match finished or natural grades, this will be at maximum slopes of 4H:1V. The site will require approximately 54,300 cubic yards of cut (including the structure excavation) and 50,600 cubic yards of fill to construct the RWPS and elevate the finished floor and adjacent site above the PMF elevation.

7.1.3 Access Roadways

Access to the pump station site can be made from the east or west end of the dam. The roadway on the dam centerline will branch off near the west abutment of the service spillway bridge. This roadway will be shared for access to the road along the toe of the dam and the pump station. A driveway into the pump station site will have limited access for appropriate District staff. The roadway from the dam crest elevation to the pump station site elevation will be designed to limit the maximum grade at 7% to allow for maintenance and future construction vehicles.

Access roadways, driveways, and parking areas in the immediate vicinity of the pump station will be reinforced concrete. The pavement will have a minimum width of 22 feet, minimum thickness of 7 inches and be designed for mobile cranes and other heavy vehicles that may be needed for future maintenance of the pump station. Pavement design will require coordination with final geotechnical design recommendations for pavement above a large zone of backfill and address expected settlement of this material.

7.1.4 Site Fencing

A chain link fence that is 8 feet tall will be provided around the pump station site including electrical equipment. Motorized sliding gate(s) will be provided at driveway entry into the pump station site. No separate fence will be provided at the nearby flow meter site. Fencing at the electrical substation site will be provided by the utility to meet their own requirements.

7.2 RAW WATER PUMP STATION LAYOUT

The proposed LBCR RWPS site is located on the downstream side of the proposed LBCR dam embankment, between the dam and the service spillway. Apart from the pumps and associated mechanical equipment, the RWPS design will also include the discharge pipeline, flow meter site, reservoir release outlet valves and pipe, pump and electrical building, and other infrastructure to support the pump station. The proposed site layout is provided in **Figures 7.4** and **7.5** at the end of this section.

The RWPS will use side suction, horizontal split-case centrifugal pumps with suction from a pipe header (manifold) and discharge to a similar pipe header, located within a dry, below-grade pump room. The system will be designed in accordance with the ANSI Hydraulic Institute Rotodynamic Pumps standards as described in later section. Spatial allowances are made to accommodate work area around the pumps, motors, piping, valves and other equipment with needed operations and maintenance access. The ground level finished floor elevation will be set to 497 feet MSL and the pump room floor elevation will be set to 457 feet MSL. The proposed plan and section view are provided as **Figures 7.6** through **7.7** at the end of this section. Details regarding these elements are discussed in the following sections.

7.3 PUMP SUCTION

7.3.1 Sizing and Arrangement

The pump suction piping has been sized to accommodate maximum pumping capacity within the station. The 78-inch intake pipes enter the raw water pump station from the north through a pipe penetration in the wall and connect to a common suction header. One 78-inch butterfly valve is placed on each intake pipe and a third 78-inch butterfly valve is located between the intake pipes on the suction header. The butterfly valves will be used to isolate a side of the RWPS for maintenance, replacement, or installation of future equipment. These valves will also allow isolation of one intake tower cell and intake pipe and still maintain at least half of the pump station capacity in service. At the suction header, the flow splits to either side of the RWPS to pumps operating in parallel. Pumps one through five are located on the west side of the RWPS and pumps six through nine are on the east side. Each side of the RWPS contains three high head pumps, the west side of the RWPS includes two low head pumps, and the east side of the RWPS has one low head pump. The proximity of the RWPS to the service spillway excavation reduces the amount of pumps on the east side of the station.

The suction pipes to each pump were sized to meet HI 9.6.6-2009 Standard for Rotodynamic Pumps for Pump Piping. The pipe sizes accommodate the highest flows possible which typically occurs when a pump is operating by itself at full speed. The nominal design capacity of each half of the intake system was intended to allow supplying greater than 144 MGD, representing half of the Leonard WTP ultimate capacity. The parallel 78-inch diameter intake pipes are based on this nominal capacity to maintain low head loss between the intake tower and pump station and keep velocity under 8 fps. Due to the pump room layout, there is potential an operator could choose an unbalanced pumping scenario within the room. While not recommended for normal operation, there are potential scenarios due to operations and maintenance of the piping system or electrical feed system that may warrant this operation. The highest flow and velocity condition possible occurs if three (3) high head pumps running on one side of the pump station are at full speed and producing about 215 MGD. In this condition, the velocity in a single intake pipe and the initial section of the suction header would reach 10 fps. While this velocity is greater than desirable, it represents an extreme operating scenario. This will be reviewed during analysis of the planned physical model study to determine if a pipe size change or other flow conditioning approach is warranted to prevent uneven flow patterns at the pump suction flanges. In a more balanced operating scenario (three total running with two running on a single side) the maximum velocity through the 78-inch section of the header is under 8 fps.

After pumps five and six, the suction header is reduced to 72-inch to support two (2) high head pumps running full speed at 144 MGD and a velocity of 7.9 fps. After pumps two and seven the discharge header reduces to 60-inch to accommodate the flow of two low head pumps running full speed at 99 MGD. The velocity through this section of header is 7.8 fps.

The individual suction pipes will be a 54-inch for the high head pumps with a flow of 7.0 fps at full speed. The individual suction pipes for the low head pumps will be 48-inch so that the flow through the pipe with the pump at full speed is 7.5 fps. Eccentric reducers will be required upstream of each pump to mate up with the smaller pump suction flange. These reducers will be designed at a 4:1 reducing ratio to meet AWWA C208 standard as well as meeting HI 9.6.6 with required number of straight pipe length between the reducer and the pump suction flange. This straight section of pipe will include a harness and coupling to allow for disassembly and removal of the pump.

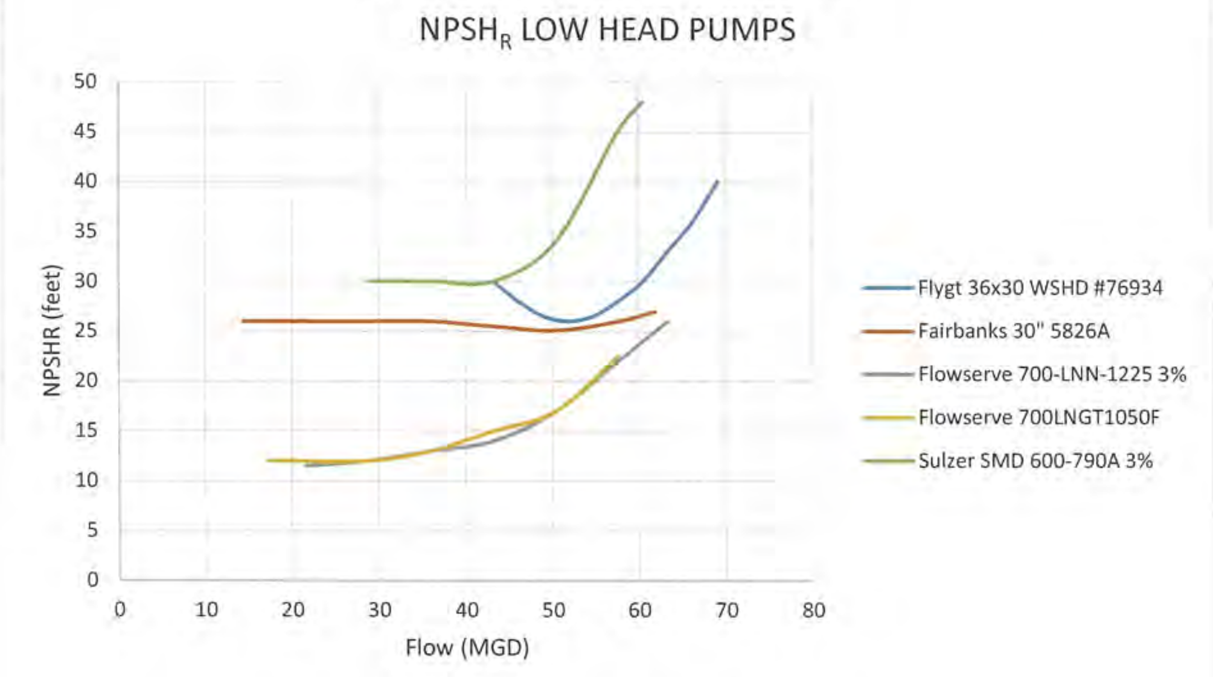
7.3.2 Side Suction and Bottom Suction

Horizontal split case pumps are available with side and bottom suction options. FNI conducted an initial review of the availability and feasibility of using both side and bottom suction pumps. There appeared to be limited availability of bottom suction pump designs for the sizes desired at the LBCR pump station. This could be overcome with additional engineering by the pump manufacturers during the design of the pumps to create new design and casting molds, but would add costs to the pump equipment. The other major disadvantage is the suction pipe layout beneath the station to accommodate bottom suction pumps requires a substantially deeper structure. While the floor area at the pump level may be decreased, the addition of another lower level for pipe and valve gallery would increase the total floor area required. Additional access and maintenance within the lower pipe gallery also raised concerns. The station design is based on a side suction horizontal split case pump for these reasons.

7.3.3 Pump NPSH and Submergence Analysis

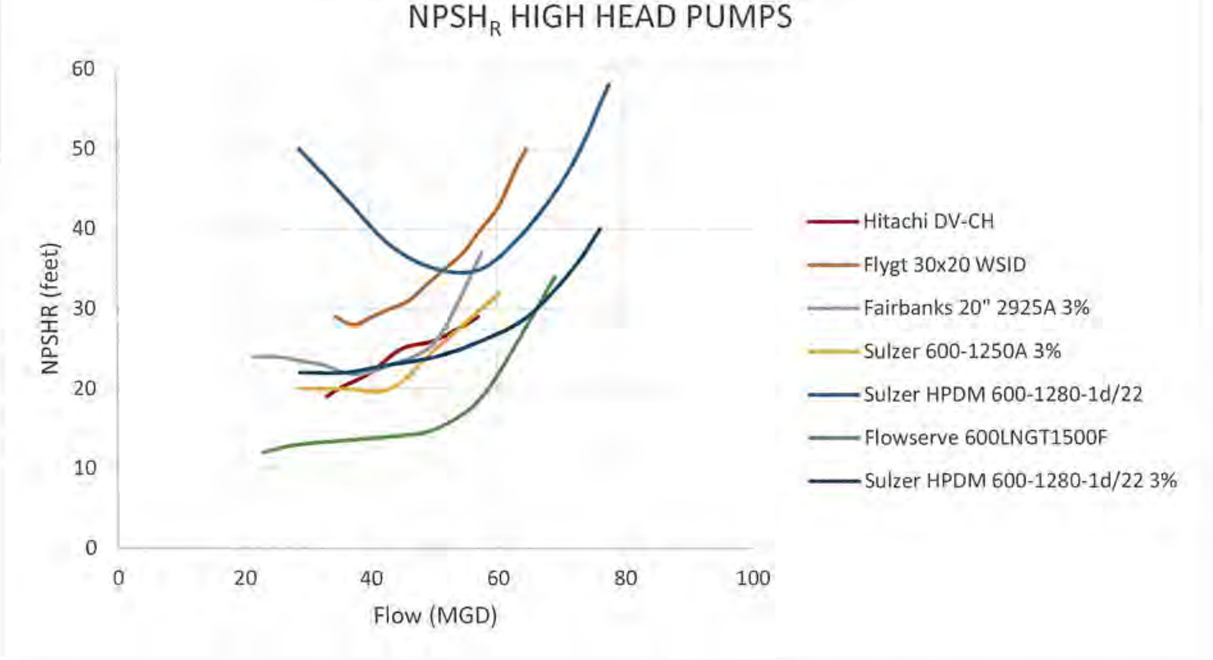
A net positive suction head (NPSH) analysis was performed for the LBCR raw water pump station for a low and high capacity pumping scenario. The low pumping scenario correlates to the initial 30 MGD flows that will be pumped from LBCR. A lake elevation of 470.25 is the lowest lake elevation that 30 MGD can be pumped while meeting the velocity requirements of 1fps through the intake screens. This condition is one small head pump running at approximately 90% speed. Friction and minor losses were calculated assuming 15 MGD will pass through each cell of the intake tower and intake pipe. A 5' margin was used based on HI Standard 9.6.1.4. The $NPSH_R$ of the low head pump curves not including the margin is shown in **Figure 7-1**.

Figure 7-1 NPSHR Low Head Pumps



The high pumping scenario analyzed was at the design capacity of 144 MGD with 10 cfs of environmental releases through one intake cell. In this analysis, 10 cfs of environmental releases was added to the capacity through the intake pipes to calculate losses through the system. A lake elevation of 500.5 is the lowest lake elevation that 144 MGD can be pumped out of one side of the intake tower while meeting the velocity requirements of 1 fps through the intake screens. There is not a case where a pump, operating at full speed, crosses the system curve at run out at lake elevations below 525 feet MSL. The NPSH$_R$ of the high head pump curves, neglecting the margin is shown in **Figure 7-2**.

Figure 7-2 NPSHR High Head Pumps

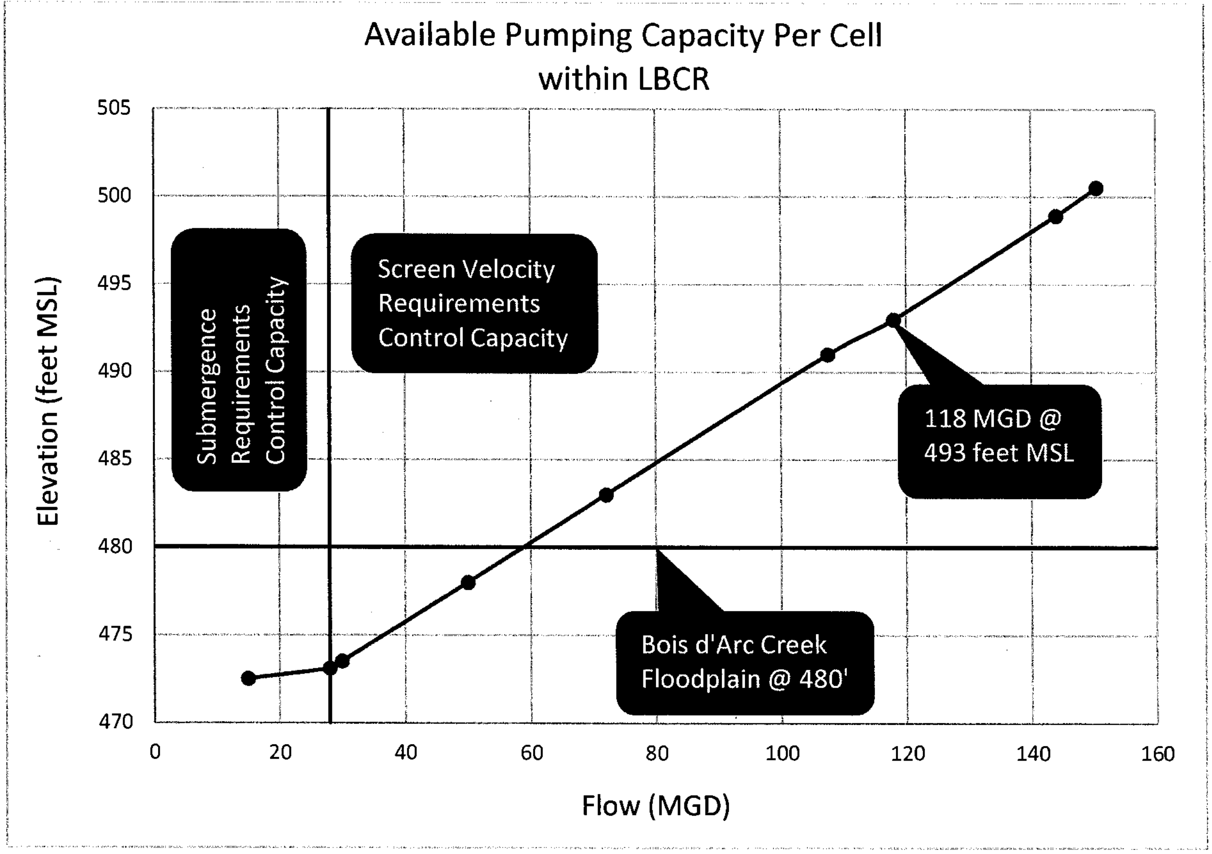


The highest NPSH$_R$ is three Flygt high head pumps running at approximately 90% speed for a total pumping capacity of 144 MGD. Three Sulzer pumps will need to run at 85% speed to meet these conditions and will have a lower NPSH$_R$.

It should be noted that the highest NPSH$_{rec}$ from Sulzer is approximately 22 feet higher than the NPSH$_{3\%}$ for the same pump. Depending on which pump is selected, NPSH$_A$ may be exceeded if a worst case scenario of one side of the station and intake operating at a capacity of 192 MGD and 20 cfs environmental releases at elevations below 483.5 feet MSL. It should be noted that according to **Figures 4-1** and **7-3**, the velocity requirements across the screen will control at this capacity and the lowest elevation the pump station should be operating at this capacity only using one cell is 511 feet MSL. If both sides of the intake tower are used, this capacity may be pumped at elevations 483.5 feet MSL with three pumps without exceeding the highest NPSH$_R$. The screen velocity requirements will allow pumping at this capacity at elevations above 477.6 feet MSL if both sides of the intake tower are used. If pumping is desired at this lower elevation, it is recommended that the District use four pumps to meet this capacity. The use of only three pumps will exceed the NPSH$_{rec}$ for the Sulzer and NPSH$_R$ for the Flygt pumps.

The intake pipe at the tower was raised to limit the amount of excavation required at the intake tower and minimize the total depth of construction. Submergence of the intake pipe will be the controlling factor in the capacity available to pump from LBCR at low lake elevations. Velocity across the screen will be the controlling factor for the capacity available to pump at elevations higher than 473.1 feet MSL and capacities of 28 MGD per cell and higher. **Figure 7-3** shows the available pumping capacities within LBCR assuming both intake cells are used.

Figure 7-3 Pumping Capacity Comparing Flow and Lake Elevation



Some of the intake submergence issues seen at low lake elevations where vortices could develop at the pipe inlet may resolve themselves within the long length of the intake pipe. An air release valve may be added on the downstream side of the intake system to allow any air to escape. CFD and physical modeling during further design of the intake and pump station will determine if any modifications to the design will be necessary and confirm if submergence will limit pumping capacity at low lake levels.

The finished floor of the pump room was set based on the $NPSH_R$ for the pump and submergence of the pump, while also considering reasonable elevations for equipment maintenance. The centerline of the suction side of the pump is set at 459.67 which meets the $NPSH_R$ requirements and also correlates to 1.15-foot submergence measured from the top of the pump casing. A 1 foot pump pad was assumed to support the pump base. A larger pump pad will increase the distance between the finished floor elevation and the pump equipment and appurtenances, making maintenance more difficult. As a result the RWPS pump room finished floor elevation will be 454.5 feet MSL.

7.3.4 CFD and Physical Modeling

Alden Research Laboratory Inc. will perform a CFD model of the proposed intake tower. The purpose of the CFD model will be to:

- Evaluate flow patterns from the Lower Bois d'Arc Creek Reservoir approaching the intake tower, within the intake tower, and within the intake pipe system;
- Evaluate the velocities at the intake screens; and
- Determine the extents of the physical model to be constructed.

At the conclusion of the CFD model, a physical model will be constructed of the raw water pump station. The purpose of the physical model will be to:

- Evaluate the hydraulic performance of the RWPS in terms of flow patterns in the pump suction piping for each pump drawing flow from a common manifold;
- Derive modifications to the piping, if necessary, to satisfy the HI 9.8-2012 and 9.6.6-2009 standards acceptance criteria in terms of swirl and velocity non-uniformities at the pumps; and

A separate CFD model will be constructed of the raw water discharge pipeline. The purpose of the model will be to:

- Evaluate flow patterns in the discharge piping leading to the planned flow meter in terms of swirl and velocity irregularities.

7.3.5 Connection to Intake Pipe

The intake pipe will be constructed concurrently with the dam and will be used to divert storm flows and make environmental releases during certain phases of the project. This will be completed before construction on the RWPS is complete. The section of intake pipe constructed with the dam will terminate just south of the proposed RWPS at the temporary diversion channel. The intake pipe will continue to be used to make environmental releases as the pump station is constructed. Once the pump station is constructed the intake pipe in service will be connected to the pump station suction piping. At that point in time, the environmental releases will be made through the pump station.

7.4 PUMP DISCHARGE

7.4.1 High Pressure Considerations

The highest pump shutoff head for designs provided to date is 760 feet. To accommodate this head, and the additional static pressure of 81 feet, the discharge piping between the pump and the control valve will be designed for a working pressure of at least 365 psig. A bypass pipe will be included to limit time at shut-off head conditions. The highest pressure expected downstream of the control valve will correlate to the pumping head at higher lake levels. The TDH of the pump at a lake elevation of 541 feet is 580. This results in a gauge pressure of 286 psig. The pipe and valves will be designed for a working pressure of 286 psi. Steel pipe can be designed for the pressures required and will be used for the pump discharge piping. These pressures will also require a different review of valve options available for this pump station and these considerations are discussed below in **Section 7.6**.

7.4.2 Discharge Pipe (from header to ground level)

The individual discharge piping was sized so that the max velocities through the pump control valves would be between 12 fps and 15 fps at pump run out conditions. A 42-inch pump control valve was selected for the high head pumps, which will allow a velocity of 11.6 fps at 72 MGD. A thrust harness is needed between the pump and control valve to allow disassembly of the pump, valve and piping. After the pump control valve, a 42-inch by 48-inch reducer and 48-inch pipe is used to keep the velocity at 8.9 fps at 72 MGD through the 48-inch isolation butterfly valve and the rest of the discharge pipe.

A 36-inch pump control valve was selected for the low head pumps, which will allow a velocity of 13.4 fps at 61 MGD. A thrust harness is needed between the pump and control valve to allow disassembly of the pump, valve and piping. After the pump control valve, a 36-inch by 48-inch reducer and 48-inch pipe is used to keep the velocity at 7.5 fps at 61 MGD through the 48-inch isolation butterfly valve and the rest of the discharge pipe.

Downstream of the isolation butterfly valve the discharge pipes will turn down under the floor slab. The pipe will be concrete encased and will connect to the common 90-inch discharge header. This buried discharge header allows clear walking access to each pump on the ground floor eliminating the need for access via mezzanine. The below floor approach is preferred in this application due to the pressure rating and diameter of the header. The discharge header will convey a maximum capacity of 236 MGD at a maximum velocity of 8.3 fps. The discharge header will have a 30-inch access manway at each end of the RWPS to allow for access and ventilation during entry. The 90-inch discharge pipe will exit the pump station on the northeast side below the floor and will generally follow the temporary excavation slope to a depth at the proposed grade providing about 6 feet of cover. Design of grading in the vicinity of the pump station and service spillway is incomplete and will affect the final pipe profile.

Other appurtenances for the discharge pipe include pressure gauges, pressure transmitters, pump control valve bypass, air valves, drain valves and water sample points.

7.4.3 Pipe Restraint near Pumps

The buried discharge header will result in the transfer of higher loadings to the pump machinery. FNI has had initial discussions with manufacturers and this layout may require reinforcement of the 90-degree bend above the foundation. The degree of the loading on the pump will also depend on the rigidity of the connection between the pump and the concrete foundation and the rigidity of the concrete foundation. The discharge thrust harness will be designed similar to the traditional Type RR harness in AWWA M-11, but with the additional goal of meeting the requirements in HI 9.6.6-2009 addressing expansion joints near pump nozzles to limit detrimental impact to the rotating elements of the pump. The goal will be designing a harness system matching the stiffness of the adjacent piping. The elongation in the harness rods at pump startup will be limited to an agreed upon acceptable amount by the pump manufacturers. Details will be addressed in later design phases after completing a pipe system flexibility analysis.

7.4.4 Thermal and Pressure Expansion

The pipe within the pump station that will be subject to thermal expansion is limited to the suction header and the individual discharge pipes. Assuming a temperature differential of 40 degrees the expected thermal expansion between the suction header and discharge pipe is approximately 0.19 inches. The need for expansion joint(s) on the suction header system will be reviewed in later design phases.

7.5 PIPE MATERIALS

7.5.1 Large Diameter

The suction pipe outside of the pump station will match the intake pipe material. This will be AWWA C301 Prestressed Concrete Cylinder Pipe, AWWA C200 Steel Pipe or ASTM D3262 Fiberglass Pipe. The suction piping inside the pump station will be AWWA C200 Steel Pipe designed to meet a minimum working pressure rating of 40 psi. Downstream of the pump, prior to the control valve, the discharge piping will be AWWA C200 Steel Pipe rated for 375 psi to match the shutoff pressure at the pump. Downstream of the control valve, the discharge piping will be AWWA C200 Steel Pipe rated for 300 psi which is the working pressure in the pipeline. All AWWA C200 Steel Pipe will be designed in accordance with AWWA Manual M11. The surge pressure is assumed to be 1.5 times the working pressure and these pressure ratings will be confirmed with a future transient analysis as discussed in **Section 7.7.3**.

7.5.2 Small Diameter

It is recommended that all piping 2 inches and smaller in diameter be copper, to prevent fouling by zebra mussels. Other small piping not susceptible to fouling will be PVC.

7.5.3 Coatings and Linings

All steel pipe within the pump station is recommended to have flexible linings and coatings. The lining system will be epoxy or polyurethane for all pipe within the RWPS. FNI does not recommend a cement mortar lining for the RWPS piping due to the potential for delaminating at the numerous points where the pipe interfaces with flanges, couplings, valves, etc. and there is a difference in the pipe and appurtenance inside diameter. Mortar lining also has potential for cracking during the greater thermal cycling (expansion and contraction) possible in exposed pipe. The pipe coating system will be an epoxy or urethane system intended for a highly corrosive environment such as the pump room where moisture and condensation are likely.

7.5.4 Corrosion Control

There are several cathodic protection systems available for the RWPS. An insulating kit will likely be used inside or near the pump station to isolate the station from the overall pipeline cathodic protection system. A qualified corrosion consultant will be added to the team during final design and will determine the appropriate corrosion control methods based on soil analysis and possible interference issues.

7.6 VALVES

7.6.1 Pump Control Valves

A. Control Valve

The pump control valve will be a slow opening and slow closing valve used to reduce surges during pump start-up and pump stop. The valves will also close at a slow speed during power failure. Typical normal opening and closing speeds range from 5 to 10 minutes and the power failure slow close speeds range from 10 to 15 minutes. These times will be verified by the surge analysis.

The pump control valves will be ball or cone valves rated for 365 psig as discussed in **Section 7.4.1**. These valves have a full open port, resulting in low head loss when fully open. Dezurik, Golden Anderson, and Rodney Hunt are the only manufacturers that can meet this pressure rating. Golden Anderson can supply a resilient seated, ductile iron ball valve with a maximum rated pressure of 500 psi. Dezurik and Rodney Hunt can supply cone valves that meet this pressure rating. Dezurik's cone valve is a monel seated, carbon steel valve rated to 720 psi. Rodney Hunt's cone valve is a monel seated, ductile iron valve rated to 525 psi.

B. Actuators

FNI investigated two different types of actuators for the pump control valves: hydraulic and Electro-hydraulic. Hydraulic actuators would have a centralized accumulator to distribute pressured hydraulic oil to individual control panels and actuators at each valve. This system will maintain sufficient pressure that during a power outage the actuators can bring the valves fully closed. The District has numerous pump stations with this type of system. The electro-hydraulic actuators will have a small motorized pump to control actuation of the valve. As a backup during power failure, the electro-hydraulic system will include a minimum of two oil-over-water tanks to provide an additional 3 full open or close actions for the valves. The District has at least one high service pump station with this type of system. Recent input from the District has presented their preference for REXA actuators. GA and Rodney Hunt may be unlikely to supply ball or cone valves if their actuator is not used. The SCUBA electro-hydraulic actuator is designed specifically for GA and Rodney Hunt valves and further review of this system with the District is recommended for the final design phase.

C. Pump Control Valve Bypass

A bypass will be installed around each pump control valve. The purpose is to relieve pressure on the pump during the slow opening and closing times when the valve is nearly closed and the pump is near shut off condition. The bypass will be sized for about 10% of the rated pump capacity and will be 10-inch diameter. The bypass will include gate valves for isolation, a diaphragm valve to act as a slow opening and closing check, and an orifice plate to restrict flow to design capacity. Pressure ratings will be matched with the pump control valve.

7.6.2 High Pressure Isolation Valves

A 48-inch motor operated butterfly valve will be installed downstream of the control valve to isolate the pump from the system and perform maintenance on the pump and appurtenances upstream. This valve will be a rubber seated, Class 250 butterfly valve with a ductile iron body. A 90-inch butterfly valve will be installed downstream of the flow meter vault. This will be used with the individual discharge isolation valves to isolate the flow meter. The 90-inch butterfly valve will also be a Class 250, rubber seated motor operated butterfly valve with a ductile iron body. The butterfly valves will be made for a working pressure of 300 psi. Crispin, Pratt, and Pentair have confirmed that they can manufacture valves at the required working pressure by increasing the shaft and body wall thickness.

7.6.3 Low Pressure Isolation Valves

In order to isolate one side of the RWPS and a cell of the intake tower, a 78-inch butterfly valve will be included on each intake pipe prior to the tee for the suction header. The 78-inch suction header will include a 78-inch butterfly valve between the two tees for the intake pipes. These butterfly valves will be rubber seated with an electric motor actuator.

The suction isolation valve is used to isolate the pump from the system for maintenance and repair. The 48-inch and 54-inch suction isolation valves will be motor operated, resilient wedge gate valves inside the pump station structure. The gate valve is a full port valve and is not considered to be a flow disturbance. There is an option to move the gate valve to the smaller side of the suction reducer, which will reduce the cost of the valve, and increases the clearances between the valve and the pump station structure.

7.6.4 Air Valves

An air valve will be installed on each pump discharge arrangement. The air valves will be located downstream of the pump assembly on the 90-degree vertical bend. A combination air and vacuum valve will be installed to vent air from the pipe system.

With the pumps located well below the lake level and with a continuous flooded suction, no air valve will be installed on top of the pump volute. A manual ball valve will be provided to allow venting the pump during filling of a pump lineup.

7.6.5 Dam Low Level Outlet Works and Release Valves

Flows for the dam low level outlet works will be routed through the pump station intake structure and suction header piping. The flows that will be routed through the low level outlet works include subsistence flows, freshet flows, and base flows. These will be controlled by valves and metered inside the pump station. The flows will be piped from the 78-inch suction header pipe inside the pump station. Two connections will be made to the header to allow use of the control valves if one side of the intake system is out of service. The release flow pipe will be routed along the pump station along the south wall, exit near the southwest corner and terminate at the diversion channel. There are design criteria for water quality, screening and uninterrupted service that are outlined in the separate LBCR Reservoir Preliminary Design Report and have been incorporated into the design. The release flows required by the Draft Water Use Permit are as shown in **Table 7-1** below. Base flows and subsistence flows will be released continuously. Pulse flows required when the lake elevation is above 516.4 feet MSL will be made through the service spillway outlet works and not pass through the intake and pump station system.

Table 7-1 Reservoir Environmental Release Requirements

Season	Subsistence Flow (480 < Lake Elev. < 516.4)	Freshet Flow (480 < Lake Elev. < 516.4)	Base Flow (Lake Elev. > 516.4)
Fall – Winter (Nov. – Feb.)	1 cfs	Peak: 20 cfs Volume: 69 acre-feet Duration: 3 days	3 cfs
Spring (Mar. – Jun.)	1 cfs	Peak: 20 cfs Volume: 69 acre-feet Duration: 3 days	10 cfs
Summer (Jul. – Oct.)	1 cfs	Peak: 20 cfs Volume: 69 acre-feet Duration: 3 days	3 cfs

The critical design considerations for these control valves will be the cavitation constant (σ) and the valve coefficient (Cv). These are summarized in **Table 7-2** below.

Table 7-2 Reservoir Release Valve Calculations

Lake Elevation (feet MSL)	Flow (cfs)	Differential Pressure (psi)	Cavitation Constant (σ)	Valve Coefficient (Cv)
534	3	26.01	0.71	264
534	10	25.79	0.72	884
516.4	1	18.41	0.99	105
516.4	3	18.39	1.00	314
516.4	10	18.17	1.02	1,053
516.4	20	17.50	1.10	2,146
480	1	2.65	6.91	276
480	20	1.74	11.06	6,808

The calculated values above will be verified based on final design pipe sizes, valve elevation and discharge elevation. Current design criteria are the use of a 30-inch pipe, valves at 461.5 feet MSL and discharge point at 471.0 feet MSL. The valve coefficient (Cv) is expected to vary as shown in the table. The range for continuous operations (base and subsistence flows) is from 105 to 1,053. The range for the intermittent freshet flows is from 2,146 to 6,808. It will be desirable to select two valves that can operate in parallel to meet the high freshet flow ranges and individually meet the low base and subsistence flow ranges.

Sleeve and piston globe valves were reviewed to determine ability to meet these service conditions. Based on the current information provided by valve manufacturers, it appears that two 16-inch piston valves can be more economically used than two sleeve valves. An alternative approach that may be used is one control valve and one ball valve (likely 12-inch diameter) where the control valve is used for continuous base and subsistence flows and the ball valve is used for intermittent freshet flows. This is likely a lower cost alternative, but sacrifices fine regulation of the flow rate. It also does not provide the redundancy of having two parallel control valves where one can be out of service for maintenance and still allow for releasing flows.

Release flows will be metered inside the pump room. The location of the flow meter will be on the run of pipe downstream of the control valves along the south wall of the pump station. This will be the longest straight-run of pipe where the best flow conditions can be found for metering. Other hydraulic conditions and sizing of the flow meter will be reviewed during final design. Control of the valve will be tied to the flow meter. The valves will be operated with electric motor actuators.

7.7 SURGE CONTROL

7.7.1 Pump and Pump Control Valve

Surge events occur when the velocity of the water is changed quickly. The magnitude of a surge can be reduced if the water's rate of acceleration (or deceleration) is reduced which can be successfully done by using appropriate pump control valves. Surge events can be controlled by choosing a slow opening and closing pump control valve for the pump start and stop sequence.

The largest magnitude of surges can occur during a power failure, when the motors de-energize very quickly. In this case, the water column comes to a stop and reverses direction. The pump control valves will be designed to close very slowly as the water column is allowed to reverse flow through the pumps and drain back into the sump. By slowly closing the pump control valves, the reverse flow of the water column is gently decelerated and the surges generated are small. The small surge pressures will dissipate in magnitude with each wave cycle due to friction in the piping system.

During a power failure, electrical power is not available; therefore, the pump control valves will be closed using air stored in a tank. The hydraulic controls allow the pump control valves to close at the emergency slow close speed, usually between 10 to 15 minutes.

Past experience with this type of surge control indicates the maximum surge pressures will be well below the standard allowable surge pressure rating of the pipeline. For pre-stressed concrete cylinder pipe (AWWA C301) and steel pipe (AWWA C200), the standard allowable surge pressure is 1.5 times the pipe pressure rating (maximum operating pressure).

This method of surge control has been used successfully on many similar projects. The surge analysis will verify that the method of surge control is acceptable, the normal opening and closing speeds of the pump control valves, and the emergency (power failure) closing speeds of the pump control valves required to keep the maximum surges within acceptable levels. This type of surge control offers several advantages over other methods of surge control as follows:

- The method is less expensive than large surge tanks or standpipes.
- The method does not require higher pressure rated pipe, thus reduces cost.
- The method is more reliable than surge relief valves or surge tanks since the pump control valve operation is verified every time the pump is started or stopped (the controls have frequent exercise). Surge tanks and surge relief valves must be relied on to operate properly on a very infrequent basis. These systems require frequent maintenance to verify proper operation.

7.7.2 Future Surge Analysis

A surge analysis will be performed by Foster Wheeler for the approximately 35 mile 90-inch pipeline from the raw water pump station to the terminal storage reservoir at the North Texas Water Treatment Plant. The system will be analyzed with a steady state flow rate of 236 MGD. Transient case simulations will be finalized at a later date but are anticipated to be:

- 100% power failure at the RWPS
- Partial power failure at the RWPS
- Normal start and stop of pump at RWPS

The purpose of this surge analysis will be to identify areas of concern within the proposed pipeline and RWPS and make recommendations to mitigate the transients.

7.8 PIPE DEWATERING

7.8.1 Intake Pipe & Dewatering Pump

Provisions have been established to dewater the intake structure and pipes for required inspections, maintenance and repair activity. When dewatering and entry into the intake is needed, the intake gates will be closed and stoplogs installed. The isolation valves at the suction header will be closed providing two valves between the active side of the header and the dewatered side. Water above elevation 471 MSL may be drained by gravity through the 30-inch environmental reservoir release pipe. Once the water level is no longer able to drain by gravity, a dewatering pump will be used to drain the intake and pipe. Directly inside the RWPS, 8-inch tangential outlets located on the 78-inch intake pipes are routed to a dewatering pump. The 1,000 gpm dewatering pump will drain the intake structure and pipes in approximately 4 hours.

7.8.2 Discharge Pipe

Blow off valves will be used to dewater the discharge pipeline on either side of the flow meter. The valve immediately downstream of the flow meter and the valves at the individual pumps will provide isolation of the pipe section. This may be necessary for maintenance or removal of the flow meter. The blow off valves will drain into the service and emergency spillway. Draining the discharge header at lowest point inside the pump station can be accomplished by installing a small drain line and valve routed to the sump pump system. However, complete draining will require the use of temporary submersible or self-priming pump installed through one of the access manways.

7.9 SUMP PUMPS

Duplex sump pumps will be used to keep the floor of the raw water pump station dry. These sump pumps will be located in the southeast and southwest corners of the RWPS, although the exact locations and routing of floor drains has not been determined during preliminary design. Drains from the pump piping and appurtenances will be routed to the sumps. The RWPS building will have perimeter finger drains that will also be routed to the RWPS sumps. Each set of sump pumps will operate based on level floats tied to the control panel.

7.10 ELEVATIONS AND BUILDING HEIGHT

The overall height of the pump vault is set based on the required pump elevation to meet the $NPSH_R$ requirements, and the finish floor elevation requirement to be above PMF. The clearance between the top of the motor and the bottom of the bridge crane is 483'. The height of the tallest motor selection received to date is 11'-9". The clearance in the station will allow for the motor to be lifted and moved directly to the area under the pump station access hatch for removal. The available clearance will allow the motor to be hoisted above other installed motors in the station if required.

ACAD Rel: 20.0s (LMS Tech)
Filename: N:\WTU\Drawings\PUMP STATION\CV-PST-PL-SITE01.dwg
Last Saved: 6/8/2015 8:54 AM Saved By: lmr

Plot Date: 6/8/2015 10:28 AM Plot By: lmr Filename: N:\WTU\Drawings\PUMP STATION\CV-PST-PL-SITE01.dwg

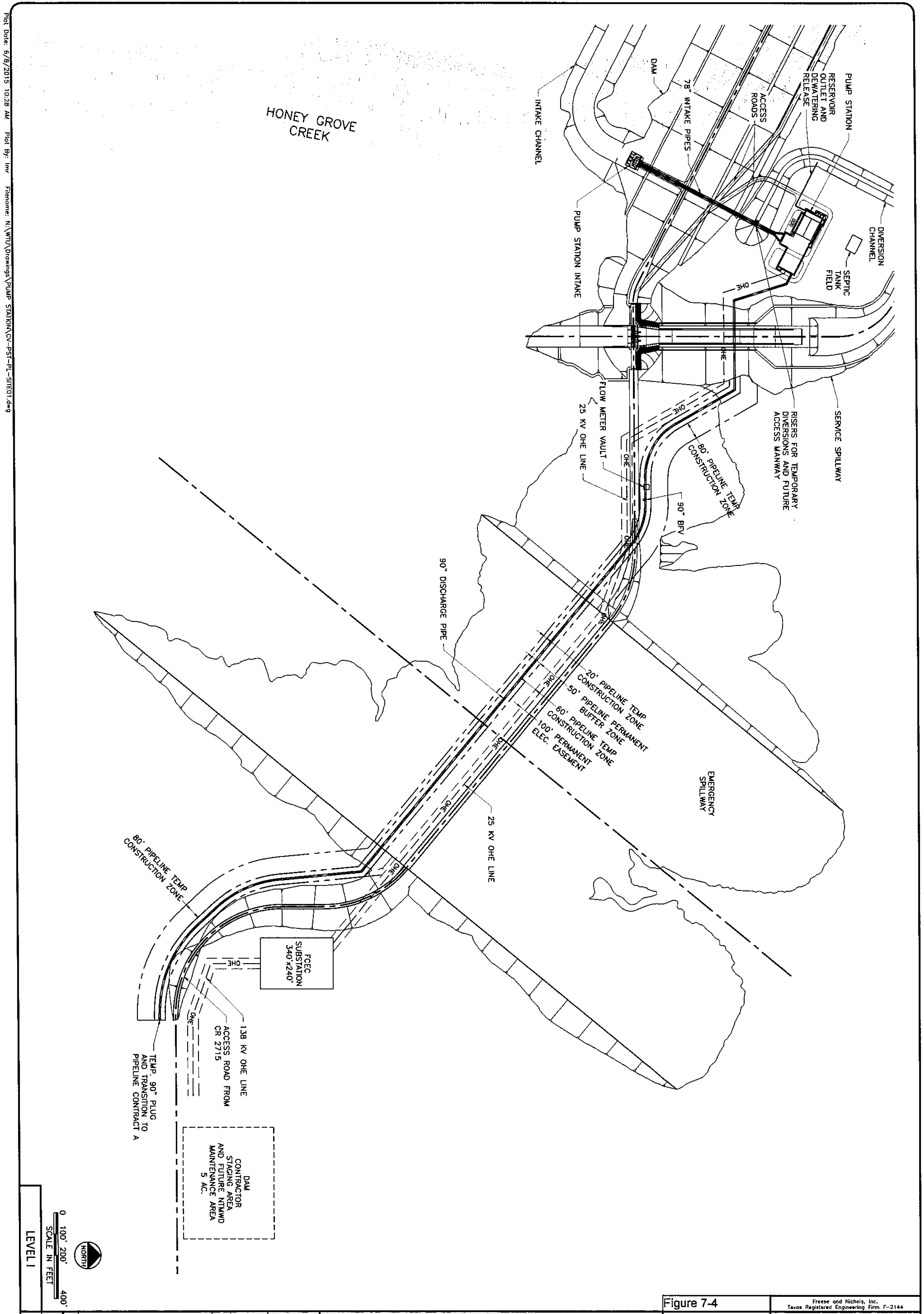


Figure 7-4

Freese and Nichols, Inc.
Texas Registered Engineering Firm F-2144

NO.	ISSUE	BY	DATE

VERIFY SCALE Bar is one inch on original drawing. If not one inch on this sheet, adjust scale.
0 1

F&N JOB NO.	NTD14295
DATE	MAY 2015
DESIGNED	ARP
DRAWN	RGM
REVISED	
CHECKED	SAM
FILE NAME	CV-PST-PL-SITE01.dwg

NORTH TEXAS MUNICIPAL WATER DISTRICT

LOWER BOIS D'ARC CREEK RESERVOIR
RAW WATER PUMP STATION

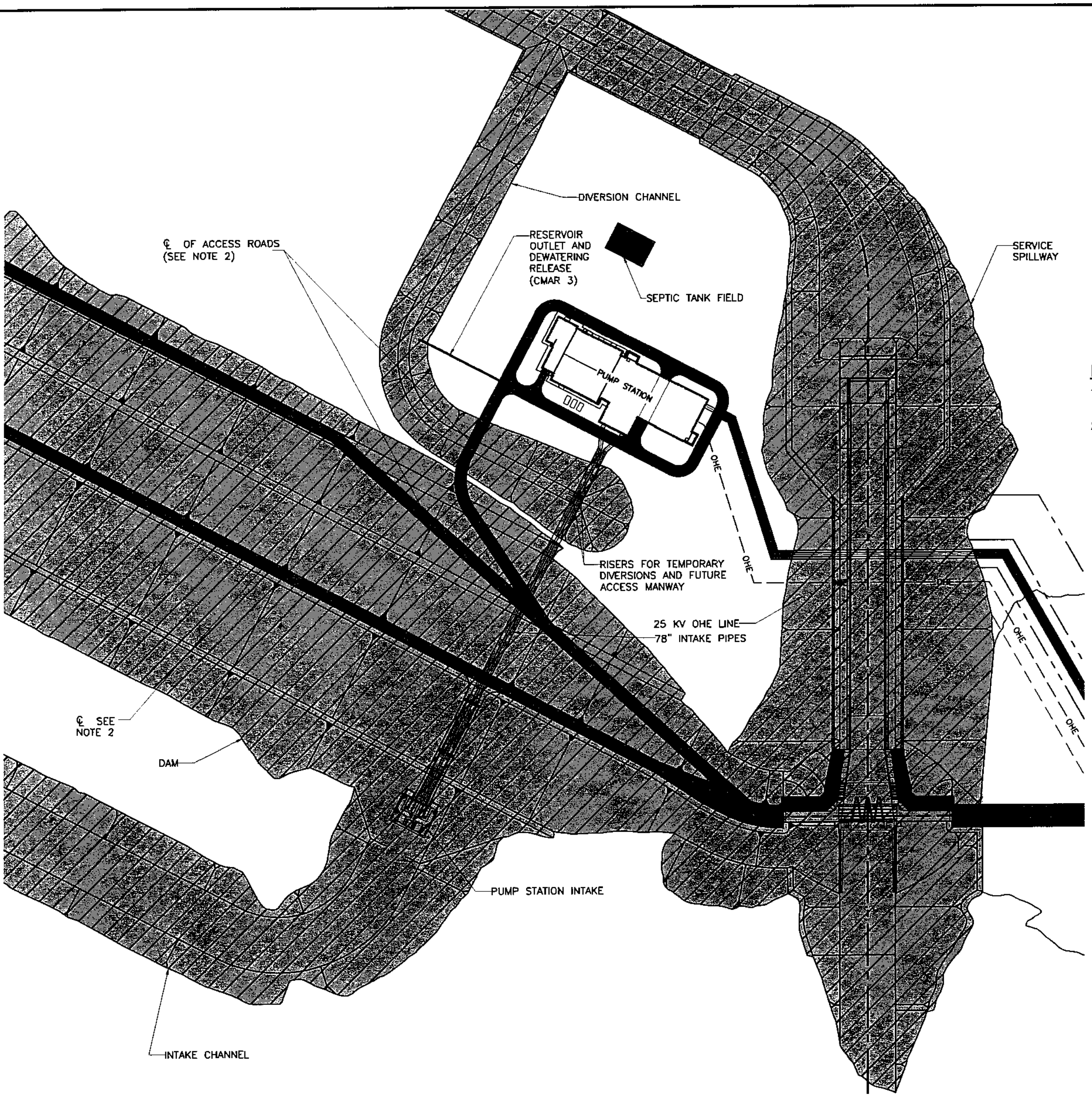
CIVIL

OVERALL SITE PLAN

FREESE AND NICHOLS
4055 International Plaza, Suite 200
Fort Worth, Texas 76109-4895
Phone – (817) 735-7300
Fax – (817) 735-7491
Web – www.freese.com

SHEET C-1
SEQ.

ACAD Rel: 20.0s (LMS Tech)
Filename: N:\WTU\Drawings\PUMP STATION\CV-PST-PL-SITE03.dwg
Last Saved: 6/3/2015 8:58 AM Saved By: lmr



NOTES

1. EARLY IMPROVEMENT SHALL DICTATE CMAR 1 FILLING IN TEMPORARY DIVERSION CHANNEL.
2. CMAR 1 SHALL ESTABLISH ROADWAY CENTERLINE, AND CONSTRUCT FLEXBASE ROADWAY WHERE SHOWN. AFTER SITE CONSTRUCTION IS COMPLETE, CMAR 3 SHALL PAVE ALL ROADWAYS FOR THE EXTENT OF LBCR SITE.

LEGEND

▨	CMAR 1
- - - -	℄ TO BE SET BY CMAR 1
■	CMAR 3

NORTH

0 100' 200'
SCALE IN FEET

LEVEL I

Freese and Nichols, Inc.
Texas Registered Engineering Firm F-2144

Figure 7-5

FREESE NICHOLS
4055 International Plaza, Suite 200
Fort Worth, Texas 76109-4895
Phone - (817) 735-7300
Fax - (817) 735-7491
Web - www.freese.com

NORTH TEXAS MUNICIPAL WATER DISTRICT
LOWER BOIS D'ARC CREEK RESERVOIR
RAW WATER PUMP STATION
CIVIL
CMAR DIVISION OF WORK

NO.	ISSUE	BY	DATE

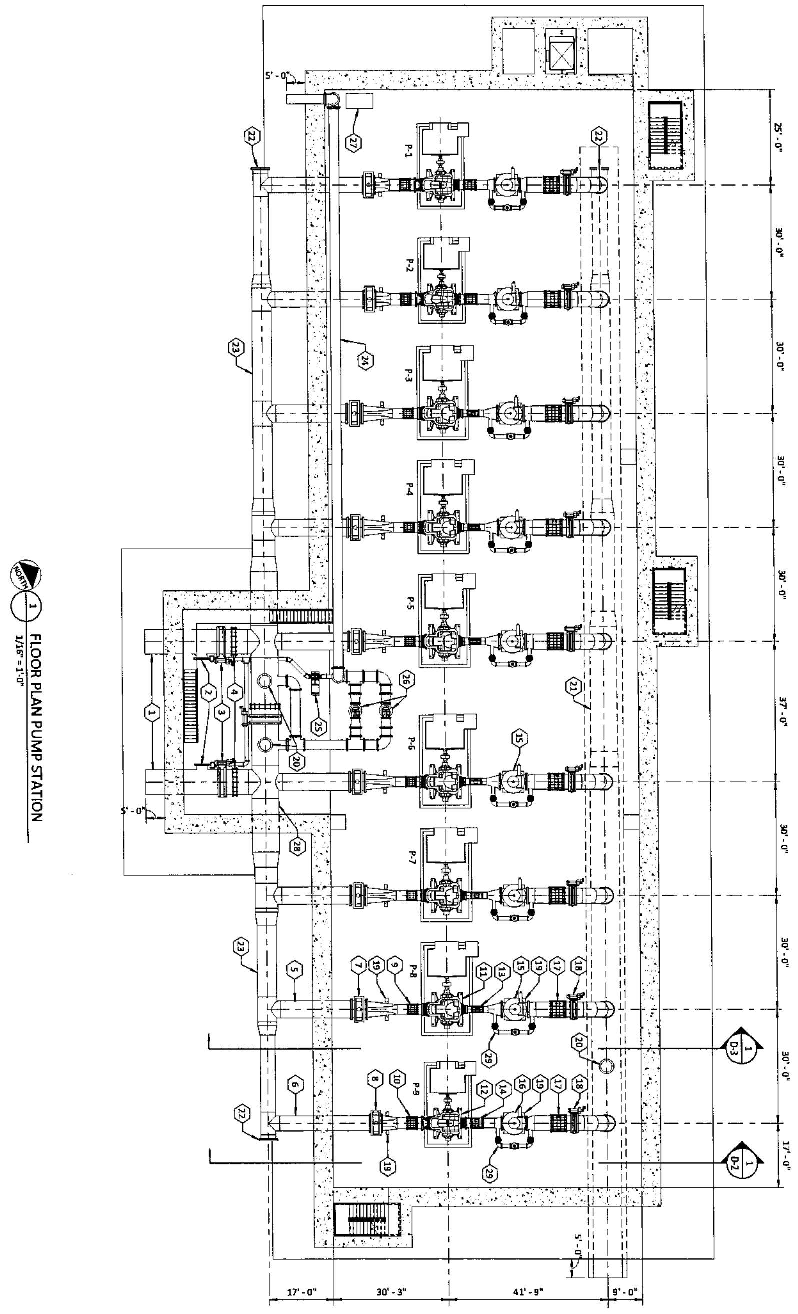
FN JOB NO.	NTD14295
DATE	MAY 2015
DESIGNED	ARP
DRAWN	RGM
REVISED	
CHECKED	SAM
FILE NAME	CV-PST-PL-SITE03.dwg

VERIFY SCALE 0 1 Bar is one inch on original drawing. If not one inch on this sheet, adjust scale.

SHEET C-2
SEQ. .

Plot Date: 6/8/2015 10:29 AM Plot By: lmr Filename: N:\WTU\Drawings\PUMP STATION\CV-PST-PL-SITE03.dwg

6/8/2015 9:42:11 AM



1 FLOOR PLAN PUMP STATION

1/16" = 1'-0"

NOTES BY SYMBOL "1"

1. 78" INTAKE PIPE.
2. 36" ACCESS MANWAY.
3. 78" BUTTERFLY VALVE.
4. 78" COUPLING.
5. 54" SUCTION PIPE (P-3 THROUGH P-8).
6. 48" SUCTION PIPE (P-1, P-2, P-9).
7. 54" GATE VALVE.
8. 48" GATE VALVE.
9. 30" THRUST HARNESS.
10. 36" THRUST HARNESS.
11. 50 MGD (7500 HP) PUMP (P-3 THROUGH P-8).
12. 47 MGD (3000 HP) PUMP (P-1, P-2, P-9).
13. 20" THRUST HARNESS.
14. 30" THRUST HARNESS.
15. 42" CONE VALVE (P-3 THROUGH P-8).
16. 36" CONE VALVE (P-1, P-2, P-9).
17. 48" THRUST HARNESS.
18. 48" BUTTERFLY VALVE.
19. VALVE / PIPE SUPPORTS.
20. 36" ACCESS MANWAY.
21. VARIABLE SIZED DISCHARGE HEADER.
22. 48" BLIND FLANGE.
23. VARIABLE SIZED SUCTION HEADER.
24. 30" RESERVOIR RELEASE PIPE.
25. DEWATERING PUMP.
26. 24" PISTON VALVE.
27. COOLING WATER/NPW FILTER SYSTEM.
28. 78" SUCTION PIPE.
29. CONTROL VALVE BYPASS.

LEVEL I

Figure 7-6

Freese and Nichols, Inc.
Texas Registered Engineering Firm F- 2144

NORTH TEXAS MUNICIPAL WATER DISTRICT
LOWER BOIS D'ARC CREEK RESERVOIR
RAW WATER PUMP STATION
PROCESS

FLOOR PLAN PUMP STATION

F&N JOB NO.	NTD14295
DATE	MAY 2015
DESIGNED	ARP
DRAWN	LMR
REVISED	.
CHECKED	SAM
FILE NAME	xx-ProjNumber.rvt

NO.	ISSUE	BY	DATE

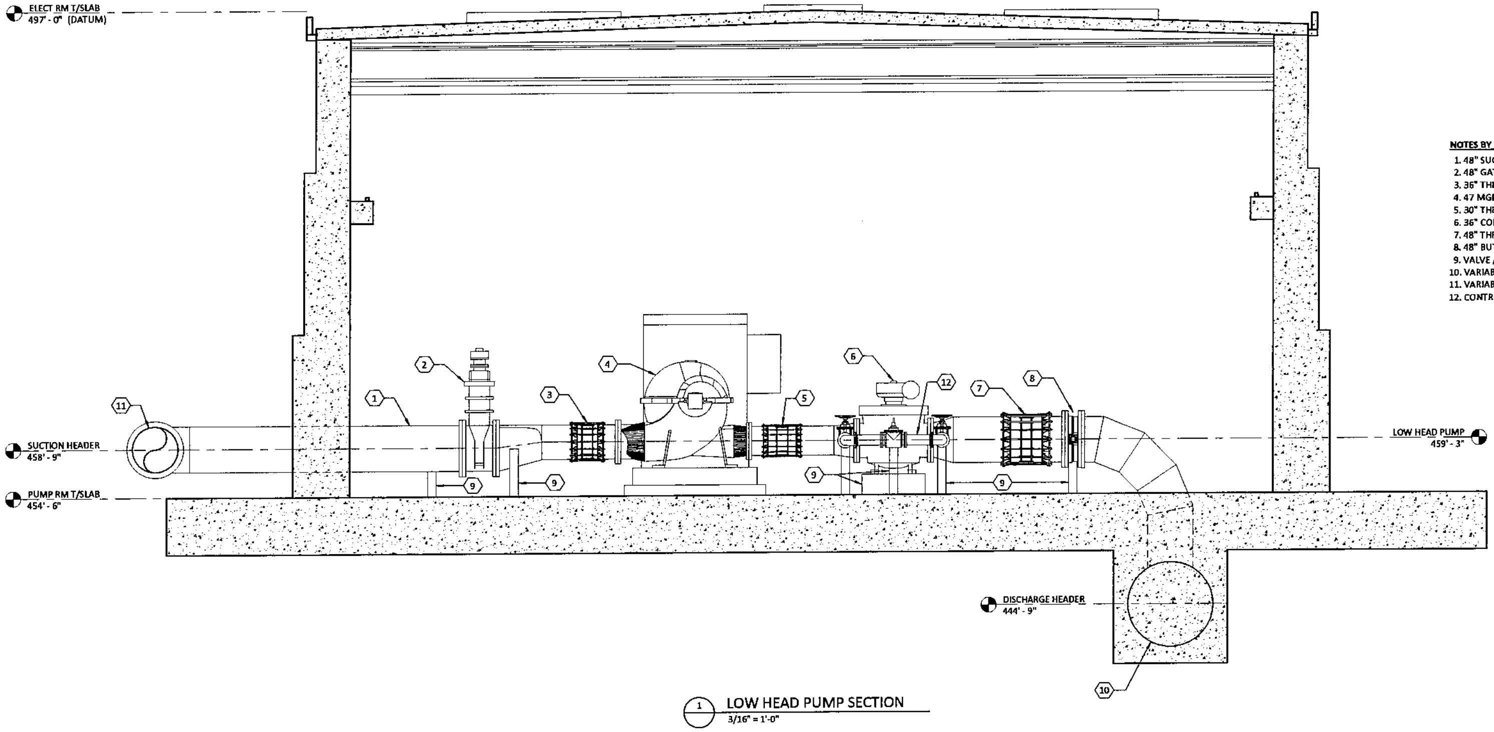
VERIFY SCALE 0 1 Bar is one inch on original drawing. If not one inch on this sheet, adjust scale.

SHEET D-1

SEQ .

FREESE AND NICHOLS
4055 International Plaza, Suite 200
Fort Worth, Texas 76109-4895
Phone - (817) 735-7300
Fax - (817) 735-7491

NOT FOR CONSTRUCTION
THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF INTERIM REVIEW UNDER THE AUTHORITY OF AMANDA R. POWERS P.E. TEXAS NO:110205 ON DATE: MAY 2015 IT IS NOT TO BE USED FOR CONSTRUCTION, BIDDING OR PERMIT PURPOSES.



1 LOW HEAD PUMP SECTION
3/16" = 1'-0"

NOTES BY SYMBOL "1"

1. 48" SUCTION PIPE.
2. 48" GATE VALVE.
3. 36" THRUST HARNESS.
4. 47 MGD (3000 HP) PUMP (P-1, P-2, P-9).
5. 30" THRUST HARNESS.
6. 36" CONE VALVE.
7. 48" THRUST HARNESS.
8. 48" BUTTERFLY VALVE.
9. VALVE / PIPE SUPPORTS.
10. VARIABLE SIZED DISCHARGE HEADER.
11. VARIABLE SIZED SUCTION HEADER.
12. CONTROL VALVE BYPASS.

Figure 7-7

Freese and Nichols, Inc.
Texas Registered Engineering Firm F- 2144

FREESE NICHOLS
4055 International Plaza, Suite 200
Fort Worth, Texas 76109-4895
Phone - (817) 735-7300
Fax - (817) 735-7491

NOT FOR CONSTRUCTION
THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF INTERIM REVIEW UNDER THE AUTHORITY OF AMANDA R. POWERS P.E. TEXAS NO:110205 ON DATE: MAY 2015
IT IS NOT TO BE USED FOR CONSTRUCTION, BIDDING OR PERMIT PURPOSES.

NORTH TEXAS MUNICIPAL WATER DISTRICT
LOWER BOIS D'ARC CREEK RESERVOIR
RAW WATER PUMP STATION
PROCESS
PUMP PIPING SECTION
PUMP STATION LOW HEAD

F&N JOB NO.	NTD14295
DATE	MAY 2015
DESIGNED	ARP
DRAWN	LMR
REVISED	
CHECKED	SAM
FILE NAME	xx-ProjNumber.rvt

NO.	ISSUE	BY	DATE

VERIFY SCALE
0 1
Bar is one inch on original drawing. If not one inch on this sheet, adjust scale.

SHEET
D-2
SEQ

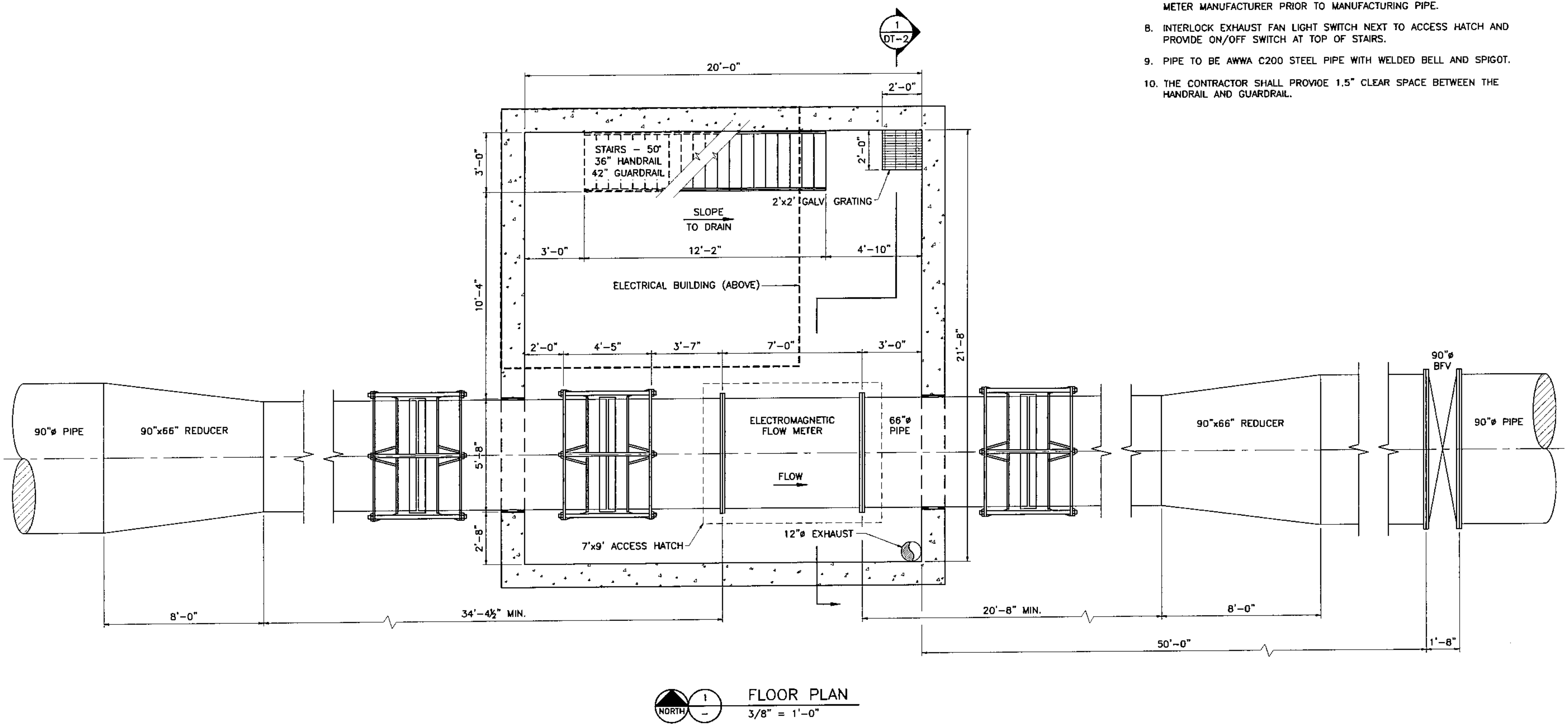
LEVEL I

6/8/2015 9:42:13 AM

ACAD Rel: 20.0s (LMS Tech)
Filename: N:\WTU\Drawings\DISCHARGE PIPELINE\CV-PPL-DT-VAULT01.dwg
Last Saved: 6/8/2015 10:01 AM Saved By: lmr

NOTES:

1. SPACING BETWEEN WALL AND FIRST FLANGE SHALL BE 3'-0".
2. THERE SHALL BE 6.25 UNOBSTRUCTED PIPE DIAMETERS PRIOR TO THE METER AND 3.75 UNOBSTRUCTED PIPE DIAMETERS DOWNSTREAM OF THE METER.
3. CONTRACTOR TO PROVIDE NTMWD WITH SPOOL PIECE IDENTICAL IN DIAMETER AND LENGTH TO THE METER FOR USE DURING MAINTENANCE.
4. EXPOSED PIPING TO HAVE MORTAR LINING AND EPOXY OR URETHANE COATING PER SPECIFICATION 09.47.16 – PIPELINE COATINGS AND LINING.
5. BURIED PIPING OUTSIDE OF VAULT TO HAVE MORTAR LINING AND POLYURETHANE COATING PER SPECIFICATION 09.97.16 – PIPELINE COATINGS AND LINING.
6. INSTALL DIELECTRIC FLANGE KIT ON FLOW METER FLANGE.
7. FLOW METER DIMENSIONS APPROXIMATE, COORDINATE WITH FLOW METER MANUFACTURER PRIOR TO MANUFACTURING PIPE.
8. INTERLOCK EXHAUST FAN LIGHT SWITCH NEXT TO ACCESS HATCH AND PROVIDE ON/OFF SWITCH AT TOP OF STAIRS.
9. PIPE TO BE AWWA C200 STEEL PIPE WITH WELDED BELL AND SPIGOT.
10. THE CONTRACTOR SHALL PROVIDE 1.5" CLEAR SPACE BETWEEN THE HANDRAIL AND GUARDRAIL.



NORTH
1
–
FLOOR PLAN
3/8" = 1'-0"

0 1' 2' 4'
3/8"=1'-0
LEVEL I

Figure 7-8

Freese and Nichols, Inc.
Texas Registered Engineering Firm F-2144

FREESE AND NICHOLS
4055 International Plaza, Suite 200
Fort Worth, Texas 76109-4895
Phone – (817) 735-7300
Fax – (817) 735-7491
Web – www.freese.com

NORTH TEXAS MUNICIPAL WATER DISTRICT
LOWER BOIS D'ARC CREEK RESERVOIR
RAW WATER PUMP STATION
DETAILS
FLOW METER VAULT
FLOOR PLAN

NO.	ISSUE	BY	DATE

F&N JOB NO.	NTD14295
DATE	MAY 2015
DESIGNED	ARP
DRAWN	RGM
REVISED	
CHECKED	SAM
FILE NAME	CV-PPL-DT-VAULT01.dwg

VERIFY SCALE 0 1 Bar is one inch on original drawing. If not one inch on this sheet, adjust scale.

SHEET DT-1
SEQ.

Plot Date: 6/8/2015 10:49 AM Plot By: lmr Filename: N:\WTU\Drawings\DISCHARGE PIPELINE\CV-PPL-DT-VAULT01.dwg

8.0 SYSTEM OPERATIONS

8.1 OPERATION OBJECTIVES

The system operation should meet the following objectives:

- Allow simple operation;
- Allow efficient pumping to the extent possible;
- Allow continuous delivery of water to the future WTP without interruptions;
- Control surge pressures in the pipelines to acceptable levels.

8.2 NORMAL OPERATING PROCEDURES

The normal operating procedures of the LBCR RWPS will be to supply the required water to the Leonard WTP. The pump station will be the only supply for the Leonard WTP for the initial phases of the facility. The treated water demand required by the North water system will have a significant diurnal pattern. However, there is intended to be sufficient storage within the treated water clearwells and the raw water terminal storage reservoir so the raw water pumping will not likely need to meet the same diurnal patterns. The use of the AFDs and the volume in the TSR will allow operators to select a target flow rate from the RWPS for a given period (one to several days). The operator will be able to select a certain combination of pumps and operating speed to achieve the highest efficiency pumping and minimize energy costs. An initial version of this operating scenario was modeled and is discussed in **Section 5** of this report. An alternative operating scenario to adjust pump speed using the AFDs to maintain a target water elevation in the TSR may also be considered.

8.3 CONTROL SYSTEM FEATURES

In the Remote mode, the pumps will be controlled remotely from the SCADA system via the Operator Interface Terminal (OIT) at the Pump Station or from NTMWD's central control station at the Wylie Plant. In the Local mode, the pumps will be controlled locally from the adjustable frequency drive (AFD) start/stop pushbuttons.

8.3.1 Start/Stop Sequence

The start sequence is initiated when the motor is called to start by either a start push button located on the AFD control panel or through a start signal from SCADA. The AFD will start the motor upon confirmation of all start permissive settings. The start sequence will ramp up the speed of the AFD slowly to a preset value (adjustable by programming). Upon reaching a certain pressure, a signal will be sent to the valve controller to begin opening the pump control valve. When the valve has reached the fully open position and confirmed by limit switches, control of speed of the AFD will be allowed by an operator or the PLC.

An emergency stop is initiated by any of the following:

- As a result of a power failure;
- When an emergency stop is called on by an E-stop pushbutton located on the motor starter or the E-stop pushbutton located near the motor or from SCADA; and
- Fault conditions in the AFDs and Motor Protection Relay.

An emergency stop will cause the motor to stop immediately.

The normal stop sequence is initiated when the motor is called on to stop by either a stop push button located at the AFD or through a stop signal from SCADA. The normal stop sequence will initiate closure of the pump control valve. When the valve reaches 95% closed position, the motor will be stopped and the valve will continue to close. An un-commanded normal stop is initiated by the detection of the motor winding RTDs exceeding the specified limits. Final design will confirm which shutdown functions will be latched and need to be manually reset.

8.3.2 Safety Features

Local automatic safety features will be provided for the following:

- Motor shutdown and warning protective features (temperature, overload, undercurrent, phase failure, ground fault, etc.);
- Automatic shutdown for fault conditions in the AFDs and Motor Protection Relay;
- Time-out for motor protection after emergency pump stop or power failure;
- Automatic shutdown for high water level in the pump room;
- Automatic shutdown for pump control valve failure (valve did not open within a given time);

- Pumps cannot start if the pump control valve is not closed;
- Time-out for surge dissipation after emergency pump stop or power failure; and
- Automatic shutdown for fault conditions in the AFDs and switchgear.

The following alarms will be reported back to SCADA:

- Pump room/electrical room door intrusion alarms
- Pump room high water level (flood) alarm
- Pump control valve failure
- High discharge pressure
- Transformer alarms
- Transformer protection relay trip
- AFD trip
- Motor protection relay trip
- Vibration alarm (pump and motor)
- Motor cooling system failure
- Reservoir release control valve failure
- Meter vault high water level

The following analog signals will be reported back to SCADA:

- PLC cabinet temperature
- Electrical room temperature
- Pump room temperature
- Motor cooling system flow rates
- Discharge pipeline flow rate
- Discharge header pressure
- Pump discharge pressure
- AFD speed
- Vibration signals (pump and motor)
- Lake elevation
- Reservoir release control valve position

- Reservoir release control valve pressure (upstream, downstream and/or differential)
- Reservoir release flow rate

The following discrete inputs will be reported back to SCADA:

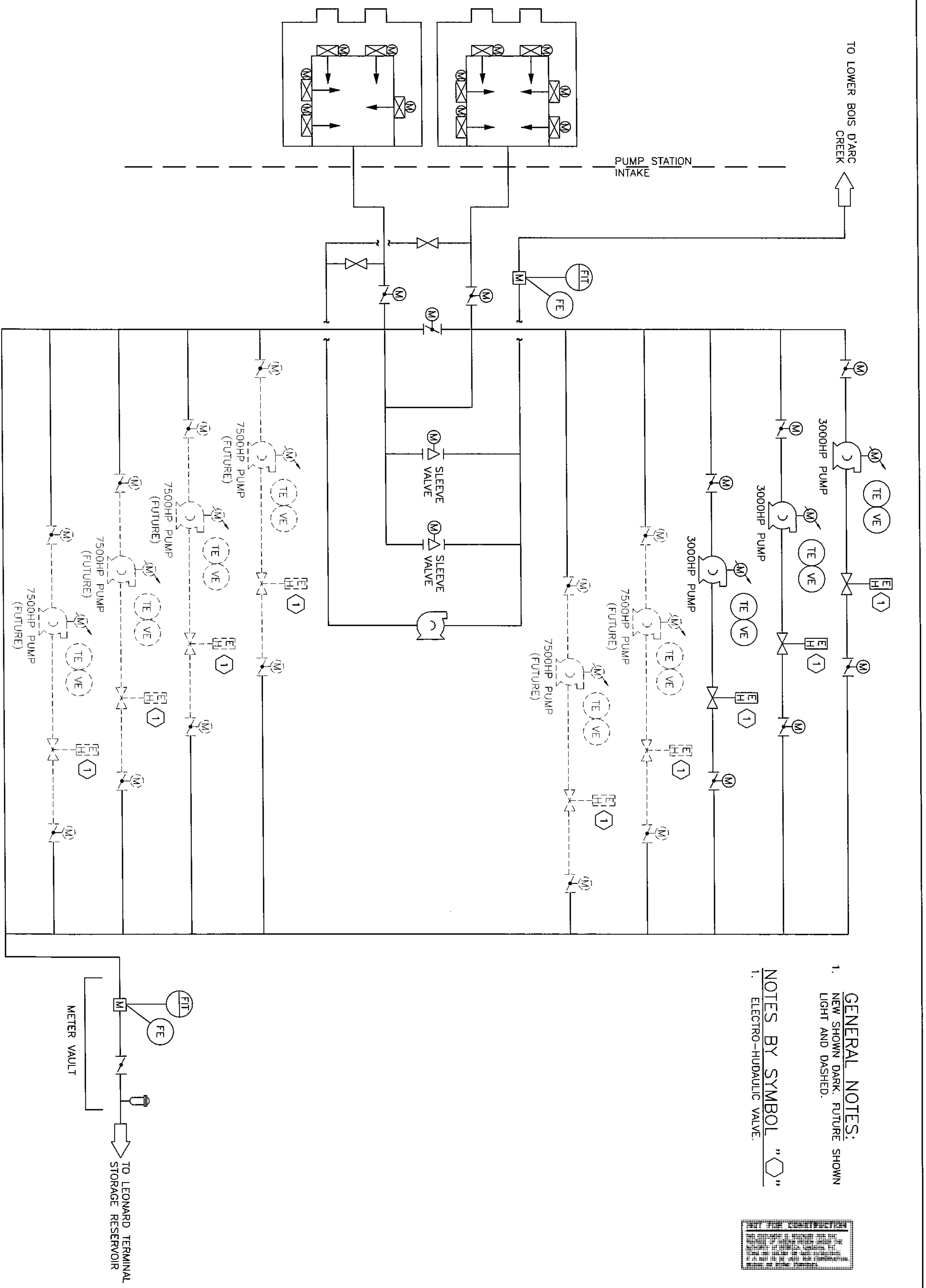
- SCADA cabinet doors open
- SCADA enable
- Pump status (running/stopped)
- Pump control valve status
- 6.9kV Switchgear Tie breaker open/close status
- Reservoir release control valve status

The following data highway signals will be reported back to SCADA:

- Each 6.9kV metal-clad switchgear main breaker and feeder protective relay
- Each motor starter (AFD) protective relay
- Each transformer protective relay

8.4 PROCESS AND INSTRUMENTATION DIAGRAM

An overall process and instrumentation diagram for the pump station is attached as **Figure 8-1**.



GENERAL NOTES:

1. NEW SHOWN DARK. FUTURE SHOWN LIGHT AND DASHED.

NOTES BY SYMBOL "⬡"

1. ELECTRO-HUDAULIC VALVE.

NOT FOR CONSTRUCTION

Freese and Nichols, Inc.
Texas Registered Engineering Firm F-2144

FREESE AND NICHOLS
2711 North Haskell Ave, Suite 3300
Dallas, Texas 75204
Phone - (214) 217-2200
Fax - (214) 217-2201

NORTH TEXAS MUNICIPAL WATER DISTRICT

LOWER BOIS D' ARC CREEK RESERVOIR

PROCESS AND INSTRUMENTATION

PROCESS DIAGRAM

F&N JOB NO NTD14295
DATE JUNE 2015
SCALE
DESIGNED RS
DRAFTED MRB
FILE PI-PST-DG-PI.dwg

FIGURE 8-1

9.0 ELECTRICAL SYSTEMS

9.1 UTILITY POWER SUPPLY

The pump station is served in a single transmission distribution service provider area that can only be served by Fannin County Electric Cooperative (FCEC). FCEC will provide a substation with two 25kV aerial feeders to the pump station. The two aerial feeders will be routed across the emergency and service spillways to the pump station. It is anticipated that the meter vault and intake structure will also have their own service drops from these same aerial feeders. More detailed information on the utility power will be determined after further coordination with the FCEC.

9.2 UTILITY SUBSTATION SITE REQUIREMENTS

In order to maintain ease of access FCEC has indicated that the substation needs to be on the east side of the emergency spillway. A preliminary location has been identified, however final determination of location, easements, size, site preparation and other requirements will need coordination with FCEC, NTMWD and CMAR for the dam project.

9.3 POWER DISTRIBUTION AT THE METER VAULT

The electric service to the meter vault will be 120/240V, 1-phase, 60-Hz supplied from a FCEC pole mounted transformer. The transformer will feed a 120/240V panelboard via a fused service entrance rated disconnect switch.

9.4 POWER DISTRIBUTION AT THE PUMP STATION

The electrical service to the pump station will be 6.9kV, 3-phase, 60-Hz supplied from FCEC from two loop connected aerial feeders in order to provide the required level of redundancy. That same level of redundancy will be carried through the electrical design from the 6.9kV metal clad switchgear to the 480V switchboard.

The two 25kV aerial feeders will be connected via several pole mounted reclosers located near the pump station. During the initial phase when only three pump motors are installed, one-6.9kV metal clad main-tie-main switchgear line-up will be provided at the site which will be fed by two unit transformers. The initial 6.9kV metal clad switchgear (SWGR-1) will also feed breakers for the three initial motor controllers, for the two pad mounted transformers for house loads and for two future motor controllers. The pad mounted transformers will feed a 480V switchboard that will include two main breakers, a tie breaker and circuit breakers for the feeder sections. During the second phase of the project when the larger pump motors are installed, a second 6.9kV metal clad main-tie-main switchgear (SWGR-2) line-up will be provided at the site that will be fed by two additional unit substation transformers. At this point the site will have a total of four unit substation transformers and each 6.9kV switchgear line-up will be kirk-key interlocked to allow a maximum of two unit substation transformers to operate in parallel at a time. The new 6.9kV metal clad switchgear will be similar in design to the one installed during phase one, in that it will also include main-tie-main circuit breakers and feeder breakers for each motor controller, and for a pad mounted transformer for house loads.

When SWGR-2 is installed one of the smaller pump motors and one of the pad mounted transformers will be disconnected from SWGR-1 and be refed from SWGR-2 in order to provide redundancy. **Figure 9-1** shows an overall one-line diagram of the pump station's electrical distribution system for the selected pump station layout for Phase I. **Figure 9-2** shows the ultimate overall one-line diagram with all 9 motors.

9.4.1 Design Voltage

A majority of NTMWD's facilities with high horsepower motors have the motors rated at 4.16kV or less. Due to the number and size of the motors anticipated at this site (3-3000HP and 6-7500HP motors), FNI is recommending that 25kV utility service be stepped down to 6.9kV for the utilization voltage at the pump station.

9.4.2 Power Factor Correction

FCEC is required by ERCOT to maintain a power factor of 97% or better, therefore FCEC is extending the same requirement to this site. Since adjustable frequency drives (AFD) can only correct the power factor at approximately 97% at 100% speed, power factor correction will be required regardless if AFDs are in use. Although power factor correction capacitors can be connected to the load side of the motor controller, it can only correct the power factor to approximately 95% without overexciting the motor. Therefore a switched capacitor bank(s) will be required off the main incoming electrical equipment in the pump station in order to correct the power factor to meet FCEC's requirements.

9.4.3 Motor Starting Requirements

FCEC has not indicated if there are any motor starting requirements for the site. Any requirements will need to be reviewed with the proposed AFDs and included in final specifications.

9.5 ADJUSTABLE FREQUENCY DRIVES

The AFDs will be Active-Front-End (AFE) using semiconductor switching to reduce line current harmonics to acceptable limits. The AFDs will be specified to control the motor speed throughout the entire operating range. The AFD will also include a bypass switch with an output contactor to allow the operator to choose to operate the pump motor either from the AFD or from the across-the-line starter. The motor will be able to operate while running using the across the line starter but will be limited to starting using the AFD due to motor starting restrictions.

The AFDs will be specified to have front access only but the room layout design will allow for rear access. In addition to the main medium voltage power, each AFD will have one external 480V, 3-phase source. The 480V, 3-Phase source will be used to power any cooling equipment (air or liquid cooled) as well as an internal control power transformer to power AFD boards, PLC, RTD interface module, AFD controls and other critical equipment. The AFD will include an operator interface which consists of a LCD display used for start-up, monitoring and troubleshooting. Each AFD has a power monitor for voltage, current and power monitoring.

AFD standard motor protective features are used for motor protection along with a remote mounted Schweitzer Motor Protection Relay that will be located near the pump motor. Motor protective features that are used are: overload, overvoltage, undervoltage, overcurrent, etc. Each AFD has a RTD interface module that interfaces with the motor winding and bearing RTDs to generate alarms and shut-downs.

AFDs will be specified to meet IEEE 519-1992 requirements for the total harmonic distortion limit. AFDs have 0.95 lagging power factor for speeds 60-100 percent, and might have leading power factor for speeds below 60 percent.

9.5.1 Liquid vs. Air Cooled

At the horsepower being considered for this project there is an option for the AFDs to be either liquid or air cooled. An AFD that is air-cooled will include built in redundant fans. The redundant fan comes on when the default fan fails. Additional external cooling will also be required to maintain an ambient temperature of 95 degrees F for the electrical room. Another option is for the AFD to be liquid-cooled which would include a closed loop system that would include a heat exchanger located outside the room to help remove the heat from the drive enclosure.

A. Availability:

At the ultimate 7500HP size there is a limited availability from several of the manufacturers to provide an air cooled option. For the most part a liquid cooled drive is the more readily available option at this horsepower. At the initial 3000HP there is a higher availability for an air cooled drive but there are some manufacturers who also offer a liquid cooled option.

B. External Cooling:

If the AFDs are air cooled the drives then during the initial phase each drive will have a heat loss of approximately 95kW/each. This will require very large HVAC units to cool the room in order to maintain an ambient temperature of 95 degrees F. The larger 7500HP drives will have a heat loss of approximately 184Kw/each.

It is our recommendation that the drives be liquid-cooled for both the small and larger horsepower pump motors.

9.6 MOTOR TYPE

9.6.1 Compare WP-1 vs. TEWAC

A Weather Protected I (WP-1) motor is an open type of motor that includes ventilation to minimize the entrance of some air-borne particles and is therefore suitable for a mild outdoor environment. NTMWD has several WP-1 motors located within their system.

A totally enclosed water to air cooled (TEWAC) motor is suitable for dirty locations where cooling water is available. NTMWD does not have any TEWAC motors located within their system. A TEWAC motor limits the amount of warm air that is discharged using a closed loop glycol system, a one or two tube cooler design or a U-Tube design. The water cooling design is determined by the motor manufacturer based on the specification requirements given. The cooling water used typically has a temperature of 86 degrees F, but if a higher temperature is present the motor manufacturer may be able to design around it by providing a larger cooling box. Discussion with the motor manufacturer has indicated that some Owners also choose to install additional accessories in order to monitor the system. These accessories would be installed by the Contractor (not the motor supplier) and could include water temperature meters, flow meters, a diverter system if the water temperature is too high, etc. Further coordination during design will be done to determine which accessories NTMWD would like to include.

A. Noise

The noise level on a WP1 motor can possibly be as low as 80dBA. The noise level output for a TEWAC motor is typically less than 80dBA.

B. Maintenance

The additional maintenance required for a TEWAC motor includes maintenance to the cooler box every 5 years. It is also recommended by the manufacturer to trend the motor temperature (from the winding RTDs). If it starts increasing, it could be indicative that maintenance needs to be done to the cooler box or that there is a leak in the system.

It is our recommendation that TEWAC motors be used for the small and larger motors at the pump station.

9.6.2 Vibration Monitoring

The motors will include motor vibration sensors. The vibration sensors will send a 4-20Ma signal to SCADA to be used for monitoring purposes only. The vibration signal will not automatically shut down the pump motors when a vibration warning or alarm set point is triggered.

9.7 MAJOR ELECTRICAL EQUIPMENT

The site will include two sets of unit substation transformers that will operate in parallel and feed a 6.9kV metal clad switchgear. Each 6.9kV switchgear line-up will consist of two (2) main breakers and a tie breaker that can be sub-fed from the other 6.9kV switchgear line-up. During the initial phase only one set of unit substation transformers and one 6.9kV metal clad switchgear will be installed. The switchgear will also include feeder breakers for the house load transformer and for the motor controllers. The pump motor loads will be split between the two line-ups. Each switchgear will include kirk-key interlocks to limit a maximum of any two transformers from running in parallel at any time.

The major electrical equipment located outside will consist of the following:

- Four (4) 12MVA/20MVA, 25kV to 6.9kV unit substation transformers (only two installed during phase one)
- Two (2) 750KVA, 6.9kV to 480V pad mounted transformers

The major electrical equipment in the Electrical Room will consist of the following:

- Two (2) 6.9kV metal clad main-tie-main-main switchgear (only one installed during phase one)
- AFDs with a run duty bypass for each pump (only three installed during phase one)
- Two (2) 6.9kV power factor correction switched banks (only one installed during phase one)
- 480V Switchboard with main-tie-main
- 208Y/120V panelboard

The switchgear bus and main/tie breakers will be sized for the ultimate pump station loads, but these breakers will have their trip settings reduced to a lower set point for the Initial loads. The current transformers (CT's) on the incoming main breakers will be sized for the ultimate loads as well.

The station electrical loads including unit heaters, A/C units, exhaust fans, and the 208Y/120V three phase panelboard will be fed from the 480V switchboard. The 208Y/120V panelboard will feed miscellaneous equipment in the pump station.

Figure 9-3 shows the pump station site plan. **Figure 9-4** shows a proposed layout of the electrical room with liquid cooled adjustable frequency drives.

The inclusion of equipment required for future phases of the pump station will require further discussion with the District. The one-line drawings and discussion above include the ultimate equipment required, however not all of this will be required to provide redundancy if the initial installation only includes the three low head pumps (3000 HP motors).

9.8 MISCELLANEOUS ELECTRICAL EQUIPMENT

Medium voltage cable (15kV) will be shielded type MV-105 rated for conduit runs with stress cones at the terminations. Low voltage wiring will be XHHW-2 rated for conduit runs. Conduit in concrete encased duct banks will be PVC schedule 40 and the minimum size conduit in a duct bank will be 2-inch diameter. All above grade conduit at the site will be aluminum or rigid galvanized steel (RGS).

Lightning protection will be provided on the pump station building.

9.8.1 Conduit and Cable Routing from Pump Level to the Electrical Room

Conduits and cable trays will be used for routing of 6.9kV, 480V power, control and instrumentation cable in the pump, control, storage and maintenance room, and electrical rooms. There will be separate cable trays for 15kV power, 480V power and control/instrumentation. The medium voltage cables from the adjustable frequency drives to the motors will be armored cable. These cables will be routed in cable trays from the electrical room to the storage and maintenance room where the cables will penetrate the floor along the west wall via conduit. Once on the lower level cables will continue to be routed in conduit and then transition to cable tray along the north wall. All cables routed from the cable trays to the pump motors, valves, and instrumentation will be routed exposed above grade and grouped together in order to avoid restricting maintenance access.

9.8.2 Conduit and Cable Routing from Transformers to the Electrical Room

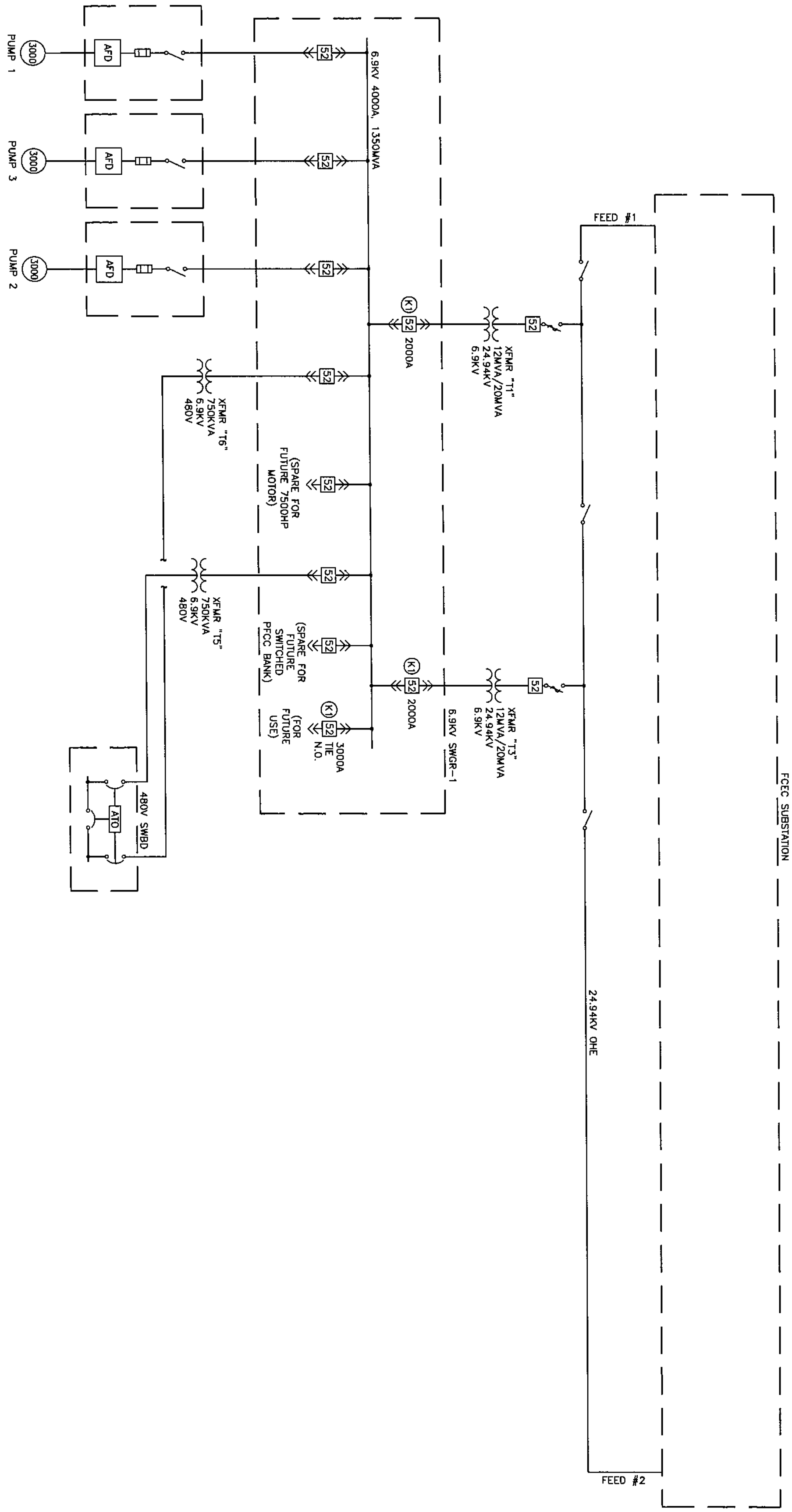
The incoming 6.9kV power cables will be routed to the unit substation transformers to accommodate the ultimate load. The feeders from each unit substation and pad mounted transformers to the 6.9Kv Switchgear can either be via conduits or cable trays. Due to the size of the service each service each group of feeders will need to be routed in its own separate cable tray. Conduits routed from the transformers to the electrical room will stub-up in a designated area along the east wall of the electrical room. Medium voltage cables from the unit substation and pad mounted transformers will be armored cable. Bus duct is not being considered due high cost/LF for the size of service combined with the significant amount of linear feet between the switchgear and the transformer.

9.9 LIGHTING

The pump room lighting will consist of LED fixtures with a luminance level of 35- to 40-foot-candles on average. Electrical room lighting will consist of LED fixtures with a luminance level of 40 to 50 foot-candles on average. Outdoor lighting will consist of wall mounted LED fixtures mounted off to the side of pedestrian doors and centered over truck doors. Light poles to will be used to illuminate the transformer area on top of the pump station and the driveway area immediately around the pump station. The outdoor lights will be controlled by a lighting contactor via a photocell. The lighting contactor will have a Hand-Off-Auto selector switch for manual override of the photocell. Emergency lights with battery back-up will be located throughout the pump and electrical rooms. The lighting will be designed in accordance with the International Energy Conservation Code.

Filename: N:\ELEC\Report\EL-PST-DG-ONEL.dwg
Last Saved: 6/29/2015 10:54 AM Saved By: rs

Plot Date: 6/29/2015 12:39 PM Plot By: rs Filename: N:\ELEC\Report\EL-PST-DG-ONEL.dwg



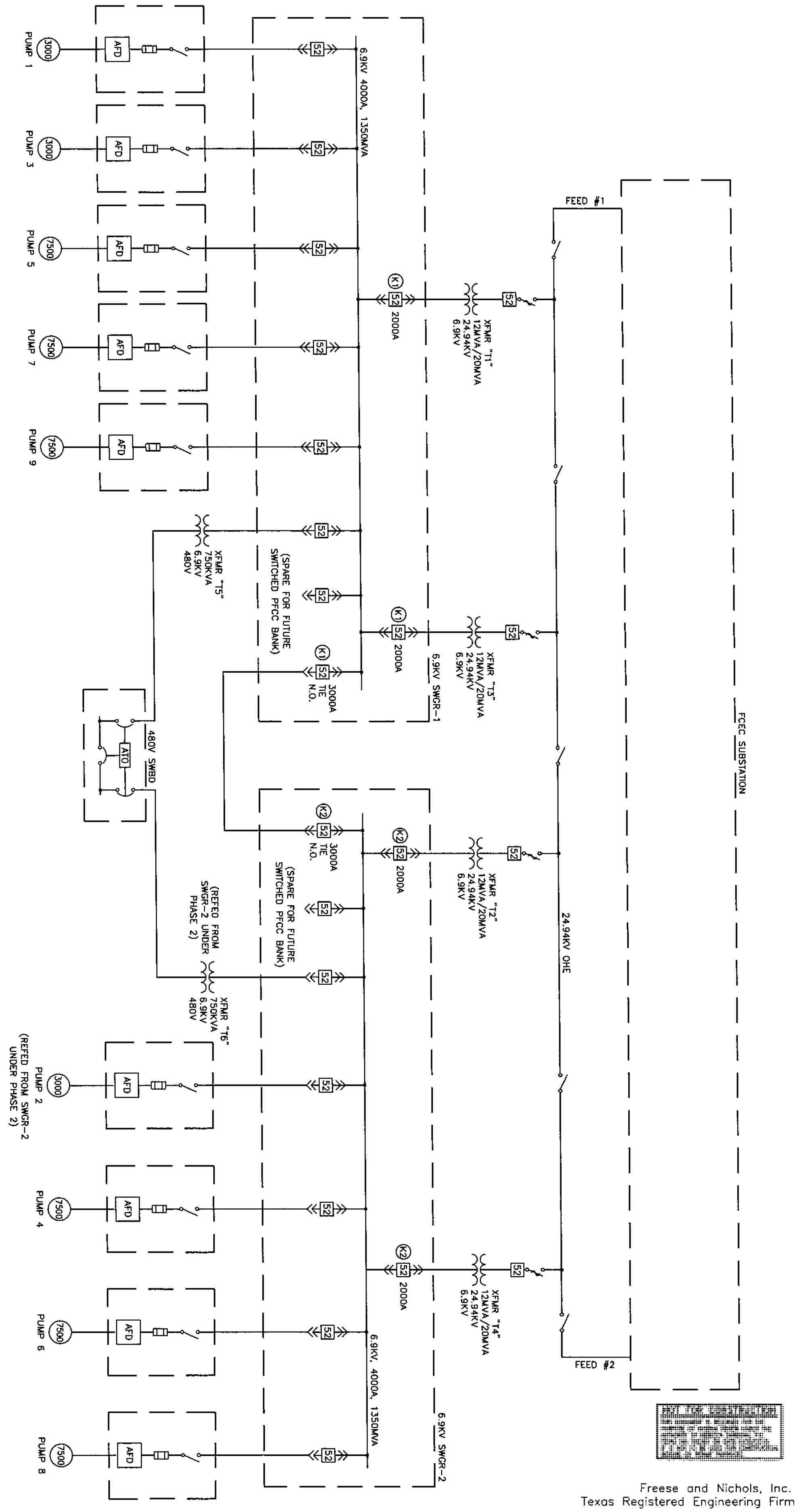
1
1
OVERALL ONE-LINE DIAGRAM (PHASE I)
NOT TO SCALE

NOT FOR CONSTRUCTION

Freese and Nichols, Inc.
Texas Registered Engineering Firm F-2144

FIGURE 9-1	FREESE AND NICHOLS 2711 North Haskell Ave. Suite 3300 Dallas, Texas 75204 Phone – (214) 217-2200 Fax – (214) 217-2201	NORTH TEXAS MUNICIPAL WATER DISTRICT LOWER BOIS D' ARC CREEK RESERVOIR ELETRICAL OVERALL ONE-LINE DIAGRAM (PHASE I)	F&N JOB NO NTD14295 DATE JUNE 2015 SCALE DESIGNED JNH DRAFTED TMG FILE EL-PST-DG-ONEL.dwg

Filename: N:\ELEC\Report\EL-PST-DG-ONEL2.dwg
Last Saved: 6/29/2015 12:25 PM Saved By: 02387



1
—
OVERALL ONE-LINE DIAGRAM
NOT TO SCALE

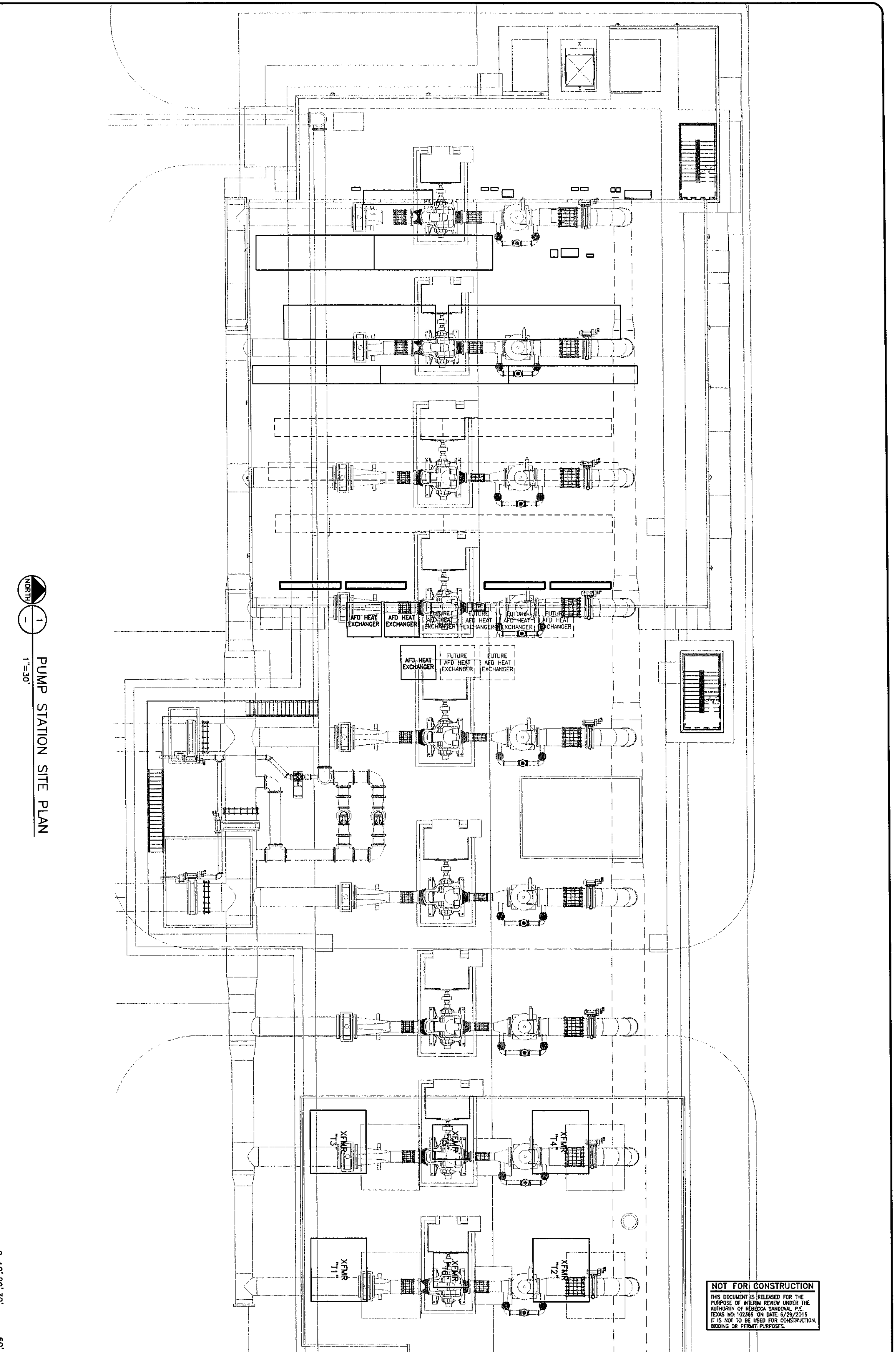
Freese and Nichols, Inc.
Texas Registered Engineering Firm F-2144

FREESE NICHOLS 2711 North Haskell Ave, Suite 3300 Dallas, Texas 75204 Phone – (214) 217-2200 Fax – (214) 217-2201	NORTH TEXAS MUNICIPAL WATER DISTRICT LOWER BOIS D' ARC CREEK RESERVOIR ELETRICAL OVERALL ONE-LINE DIAGRAM	F&N JOB NO NTD14295 DATE JUNE 2015 SCALE DESIGNED JNH DRAFTED TMG FILE EL-PST-DG-ONEL2.dwg

FIGURE
9-2

Filename: N:\ELEC\Report\EL-PST-PL-SITE.dwg
Last Saved: 6/29/2015 12:25 PM Saved By: 02387

Plot Date: 6/29/2015 12:40 PM Plot By: rs Filename: N:\ELEC\Report\EL-PST-PL-SITE.dwg



1
—
PUMP STATION SITE PLAN
1"=30'

NOT FOR CONSTRUCTION

THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF INTERIM REVIEW UNDER THE AUTHORITY OF REBECCA SANDOVAL P.E. TEXAS NO: 102369 ON DATE: 6/29/2015 IT IS NOT TO BE USED FOR CONSTRUCTION, BIDDING OR PERMIT PURPOSES.

Freese and Nichols, Inc.
Texas Registered Engineering Firm F-2144

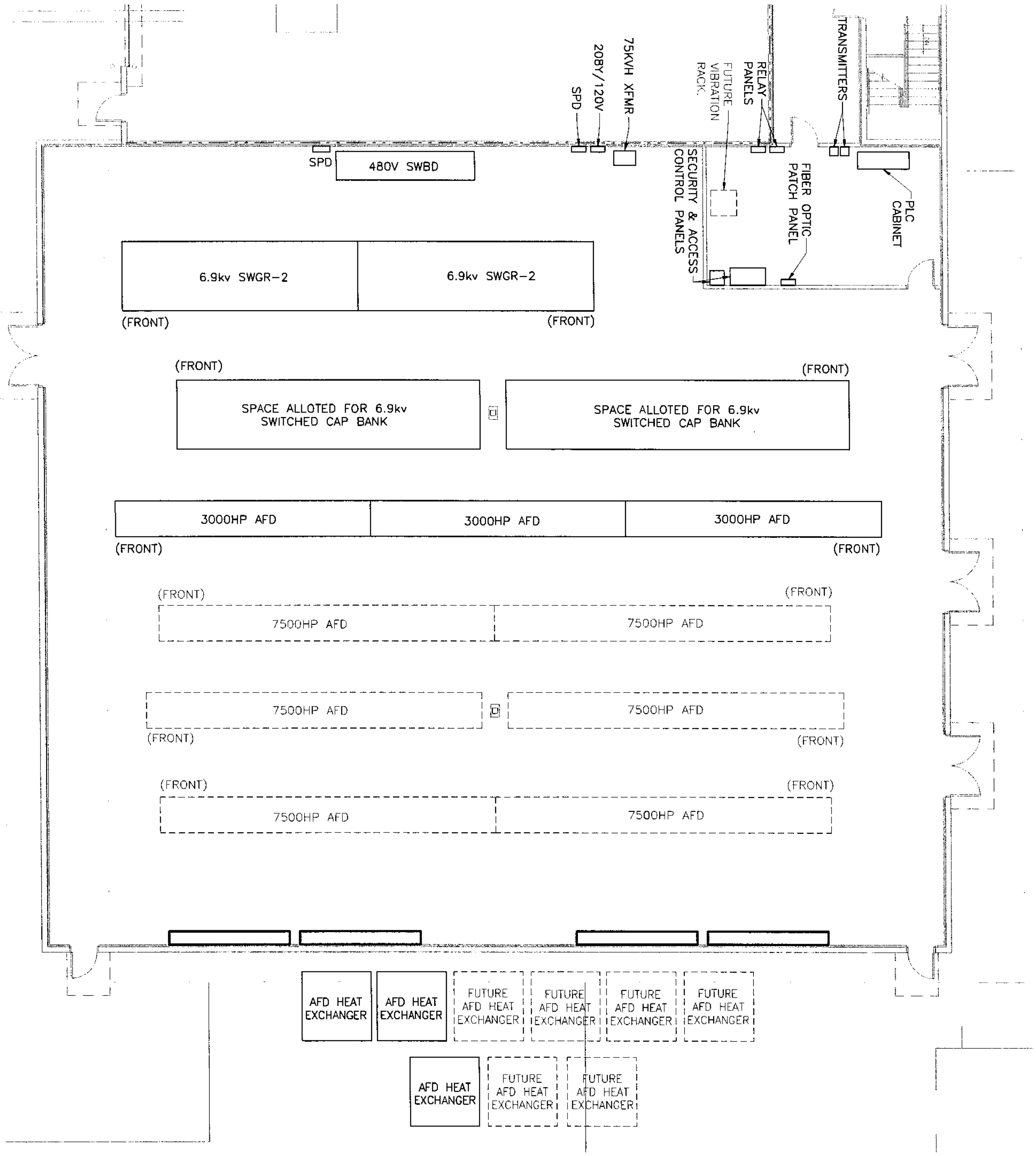
FIGURE
9-3

FREESE AND NICHOLS
2711 North Haskell Ave, Suite 3300
Dallas, Texas 75204
Phone - (214) 217-2200
Fax - (214) 217-2201

NORTH TEXAS MUNICIPAL WATER DISTRICT
LOWER BOIS D' ARC CREEK RESERVOIR
ELETRICAL
PUMP STATION SITE PLAN

F&N JOB NO. NTD14295
DATE JUNE 2015
SCALE
DESIGNED JNH
DRAFTED TMG
FILE EL-PST-PL-SITE.dwg

ACAD Rel: 19.1s (LMS Tech)
Filename: N:\ELEC\Report\EL-ELB-PL-BLDG.dwg
Last Saved: 6/29/2015 12:44 PM Saved By: rs



NORTH
1
-
ELECTRICAL BUILDING LAYOUT
1"=1'-0"

0 6" 1' 2'
1"=1'-0"

Freese and Nichols, Inc.
Texas Registered Engineering Firm F-2144

FIGURE 9-4

FREESE AND NICHOLS
2711 North Haskell Ave, Suite 3300
Dallas, Texas 75204
Phone - (214) 217-2200
Fax - (214) 217-2201

NORTH TEXAS MUNICIPAL WATER DISTRICT
LOWER BOIS D' ARC CREEK RESERVOIR
ELETRICAL
ELECTRICAL BUILDING LAYOUT

F&N JOB NO. NTD14295
DATE JUNE 2015
SCALE
DESIGNED JNH
DRAFTED TMG
FILE EL-ELB-PL-BLDG.dwg

10.0 INSTRUMENTATION, SECURITY AND SCADA

10.1 PUMP STATION INSTRUMENTATION

All field instrumentation and controls will be terminated in a programmable logic controller (PLC) cabinet located in the control room. Exact field instrumentation and controls will be determined after further coordination with the District. Refer to **Section 8.3** of this report for discussion of instrumentation required for control of the pump station. The pump station will include as a minimum a:

- Discharge pressure transmitter;
- Electrical room temperature transmitter;
- Level floats in the pump room for operation of the sump pump;
- A high level float in the pump room to indicate a pipe break; and
- Intrusion detectors at the pump room hatches and electrical building doors.

10.2 FLOW METER VAULT INSTRUMENTATION

All field instrumentation and controls at the meter vault will be terminated in a programmable logic controller (PLC) cabinet located above the meter vault. Exact field instrumentation and controls will be determined after further coordination with the NTMWD. The meter vault will include as a minimum a:

- Discharge pressure transmitter;
- A spool piece magnetic flow meter with remote transmitter;
- Level floats for operation of the sump pump;
- A high level float alarm; and
- Intrusion detectors to the building.

The meter vault will contain a sump pump, exhaust fan, lights, and receptacles.

10.3 SECURITY SYSTEMS

10.3.1 Access Control & Camera System

Security at the pump station will include intrusion alarms to SCADA for building doors and meter vault and pump room hatches. Security access will be provided to the electrical building and the exterior doors leading to the lower level pump room. Security access will be provided at the gate(s) into the pump station site.

Exterior mounted surveillance cameras will be provided to monitor the gate entrance and access to the building. Interior mounted cameras within the electrical room and pump room will also be provided and the exact locations will be determined after further coordination with NTMWD.

The surveillance cameras will be monitored locally. Local monitoring will include providing a control station at the pump station with a flat panel monitor and a DVR to store the video with communication link to the NTMWD's central SCADA system. The video surveillance system cameras will be tied to SCADA for remote monitoring via a Security Access Panel located in the Control Room.

10.4 COMMUNICATIONS SYSTEMS

10.4.1 Pump Station

Fiber optic cable will be the primary means of communication for the pump station. The fiber optic cable will be used for security, SCADA and telephone service. The pump station will either be controlled from/tied to the Wylie WTP or the Leonard WTP. Alternatively, NTMWD may decide to have the ability to control the pump station from both sites. Which site the pump station will be controlled from will be decided by NTMWD at a later date.

10.4.2 Dam and Other Facilities

Fiber optic lines will be installed along the dam from the intake tower, spillway, and pipeline flow meter vault and will be routed to the RWPS control room. The fiber optic cable will transmit security and SCADA information from the dam and other facilities to the RWPS.

10.4.3 Interconnection to Leonard WTP

A fiber optic line from the LBCR site to the Leonard WTP site will be constructed in parallel with the raw water pipeline.

10.4.4 Interconnection to Wylie WTP

A fiber optic line from the Leonard WTP site to the Texoma-Wylie pipeline will be constructed in parallel with the treated water pipeline to McKinney. These pipelines will intersect near Blue Ridge and a connection between fiber optic systems will be made. This connection will allow communication and control of the entire LBCR system to be made from the Wylie WTP if necessary.

10.4.5 Construction Phasing

A more detailed discussion of the construction plan will be required with the District since the communications system will cross over between multiple CMAR projects (dam, pump station and WTP, and pipeline).

10.5 SCADA

A new SCADA PLC cabinet will be installed in the Pump Station and Meter Vault Control Rooms. The pump station SCADA PLC cabinet will include a graphic user interface touchscreen that the operator will be able to use to monitor and control the pump station operations. The graphic user interface will be Modicon Magellis.

The SCADA PLC cabinet will include:

- A backup uninterruptible power supply;
- A managed Ethernet switch with expansion modules as required for the number of network connections;
- Cisco network switches and Cisco expansion modules;
- A switched light and receptacle; and
- Temperature sensor inside the cabinet.

10.6 NETWORK DIAGRAM

All power meters, feeder protection relays, motor protection relays, AFDs, and power factor correction capacitors will include an Ethernet data highway to SCADA. The metal clad switchgears and AFDs will each include an Ethernet Switch that will tie into the multiple data highway connections included in the electrical equipment. Where the manufacturer provides an Ethernet switch in the electrical equipment, the switch will follow NTMWD's standard (managed switch Cisco).

The signal from the flow meter will also include an Ethernet data highway to SCADA.

Information to be read over each of the data highways will be determined after further coordination with the NTMWD.

11.0 RAW WATER PUMP STATION BUILDING

11.1 GEOTECHNICAL DESIGN

11.1.1 Summary

FNI has selected locations and completed exploratory borings at the pump station site. The borings are currently being analyzed. Geotechnical analysis will be used to determine required foundation considerations for the pump station structure, electrical equipment pads, HVAC equipment pads, driveways, pipeline support, flow meter vault structure, and other miscellaneous facilities. A geotechnical report that presents boring locations, boring logs, and a discussion of subsurface conditions and their impact on design will be forthcoming.

11.1.2 Excavation for the RWPS and Interaction with Dam Facilities

Sloping for excavation of the RWPS will be determined based on the results of the geotechnical analysis at the pump station site. For site planning purposes a 3H:1V slope was used for locating the pump station based on the assumption the excavation will be opened for a lengthy period. The RWPS is located so that the excavation limits of the service spillway, diversion channel and the pump station excavation do not intersect.

11.2 STRUCTURAL DESIGN

11.2.1 Structural Design Criteria and Codes

The raw water pump station will consist of the pump station vault located below grade and servicing buildings founded on the RWPS vault roof slab which is at or near grade.

Below grade construction, the RWPS station vault, will be designed in accordance with the governing ACI 350 code. Above grade construction will be designed in accordance with IBC 2015, and the applicable ASCE 7, ACI 318, and AISC 360 codes and specifications. The live load design for the vault roof slab will not be less than 250 pounds per square foot or 16,000 pound wheel load. The roof slab, as applicable, will be designed for specific equipment loads (i.e., transformers, vehicle traffic, etc.).

The vault will be designed for applicable soil and hydrostatic loads as recommended by the forthcoming geotechnical report.

Buildings atop the vault will be designed for the applicable IBC and ASCE 7 dead, live, wind, and seismic loads with a Risk Category of III.

Normal weight concrete will be used in all construction. All steel framing will be hot-dipped galvanized in accordance with ASTM A123 and A153.

11.2.2 Raw Water Pump Station Vault

The RWPS vault will consist of a reinforced concrete structure buried in the ground to within approximately one foot of the existing ground surface. The structure/vault size is approximately 81 feet wide by 289 feet long by 42.5 feet deep.

The vault will be founded in limestone and backfilled with onsite materials for portions above the limestone and flowable fill for portions at and below the top of limestone surface. If onsite materials result in an inefficient, non-cost effective design approach, then imported materials will be provided around part or all of the vault.

11.2.3 Raw Water Pump Station Electrical and Storage Buildings

The electrical and storage buildings will be founded on the vault roof slab and will consist of precast concrete load bearing wall panels supporting roof framing. Interior columns will be provided as required to support the long spans for the electrical building roof.

Load bearing wall panels for the buildings will have a minimum structural thickness of not less than 5.5 inches. Final panel thicknesses will be determined based on building wall heights, loads, and architectural treatments.

Pad mounted HVAC equipment will be located out-of-doors on the backfill surrounding the RWPS. Depending on equipment size, ductwork flexibility, and equipment tolerance of differential settlement it may be necessary to provide drilled shafts for support of the HVAC equipment.

11.2.4 Bridge Crane Systems

A bridge crane is recommended to move pumps, motors, valves, and other equipment to a centralized staging area on the vault bottom slab when necessary for installation and maintenance. The centralized staging area will horizontally align with an opening in the vault roof slab overhead.

The bridge crane inside the vault will be underrunning and the supporting rails will be underhung from the roof slab girders. The size of the bridge crane is controlled by the maximum weight the crane must lift. The pump motors are approximately 60,000 pounds, requiring a 35-ton bridge crane.

A mobile crane will be required to retrieve items from the centralized area on the vault bottom slab – raising them up the roof slab and placing them on a truck bed or the top surface of the roof slab.

11.2.5 Equipment Pads

Equipment pads will be provided as required for support of pumps, transformers, electrical gear, and HVAC equipment. Additionally a secondary containment curb will be provided around the transformers.

11.3 ARCHITECTURAL DESIGN

11.3.1 Raw Water Pump Station Building

The raw water pump station will consist of an approximately 25,500-square foot concrete Pump Room vault with a concrete roof deck as shown in **Section 11.2**. Approximately 12,800 square feet of additional ancillary areas for the pump station will be located at grade above the pump room and consist of: an electrical room, control room, storage/maintenance, restroom, corridor, stairs, and an elevator with a controls room.

11.3.2 Architectural Design Criteria and Codes

The RWPS will be located in rural Fannin County outside of the jurisdiction of any local building code enforcement, and therefore, the State of Texas building codes would apply. The design will follow the current codes listed in **Section 2.2**.

11.3.3 Raw Water Pump Station Building Systems

A. Building Envelope:

Precast concrete panels are recommended for the walls of the above grade facilities - they are strong, durable and virtually maintenance free. Concrete panel walls are historically NTMWD's preferred wall system for pump stations. The structural wall panels will support a low-sloped steel frame roof structure consisting of a galvanized metal deck, rigid insulation, substrate board and membrane roofing.

An internal roof drain system will not be provided because of the danger internal drain lines present over electrical equipment and control areas if they were to leak. Roof drainage will be accomplished by through-parapet scuppers with conductor heads and downspouts.

To meet the Energy Code, all above grade building rooms that are air-conditioned (all rooms except the storage/maintenance and stairwells), will have continuous rigid insulation added to the interior face of the concrete wall panels. The insulation will be adhered to the panel face, covered with either metal wall panels, or gypsum board, and secured through the insulation to the concrete panels.

Daylighting will be provided in the electrical and storage/maintenance rooms and at the building entry via hurricane resistant glass block windows. These windows are non-operable and are virtually maintenance free. The windows will be mounted high on the walls just below the joists and above the electrical equipment and storage areas; this location will let natural light inside without providing views to the interior from the outside. These windows are assembled at the factory and installed much like traditional windows, and can have either heavy duty (thicker than normal) hollow glass blocks, or solid glass bricks, which are bullet resistant.

B. Room Functions:

The electrical and control rooms will be sized to accommodate the equipment they house. Oversized double doors at the north and south sides of the electrical room will allow loading and unloading of electrical equipment. Normal sized personnel doors on the east side of the electrical room will allow convenient access to the outdoor electrical equipment. All electrical room doors will be equipped with exit devices (panic bars) to meet National Electrical Code (NEC) requirements.

The storage/maintenance room will have an overhead coiling door on the south side, to allow access for trucks and other wheel based equipment. There will be enough room for storage and maintenance of valves and other pump related equipment. The room is not planned to be designed for vehicle storage which would require additional fire safety systems.

The restroom will be provided with Building Code required fixtures: One toilet, one lavatory, and a service sink (mop sink). The code also requires a drinking fountain which will be located just outside of the restroom.

The elevator functions are described in greater detail below. The requisite elevator controls room will be located on the ground floor level, adjacent to the elevator. Both the ground floor and the pump room level will have elevator vestibules, just outside the elevator. At the pump room level, the vestibule will have double doors with hold-open devices. These doors will be held open by magnets; if the smoke or fire alarms are activated, the magnets disengage and the doors close automatically, preventing smoke from traveling up the elevator shaft to the spaces at the ground floor. Even though the doors are closed, they can be always be operated manually.

Stairs from the pump room to ground level will be enclosed in stairwells to meet Building Code egress requirements, and spaced so that in the pump room, at least one exit stairwell will be within 200 feet of travel distance. The stairs will be constructed according to the Building Code, with requisite guardrails, handrails, closed risers, 1-inch nosings, etc. Ship's ladders will not be used, even though they would be OSHA (Occupational Safety and Health Administration) compliant, the more stringent Building Code requirements for stairs apply here.

11.3.4 Accessibility

The building will have to meet the current Texas Accessibility Standards (TAS). These standards apply only to the parking area, the restroom, and the control room. The other areas of the building are considered "machine rooms" and will not need to be accessible. TAS requires a designated accessible parking space (closest to the entry) with striping and signage. Because the site is not accessible by public transportation, an accessible sidewalk to the road with public transportation is not required. The project will have to be registered with the Texas Department of Licensing and Regulation (TDLR) by a Registered Accessibility Specialist (RAS), who will also review the drawings, and inspect the project.

11.3.5 Vertical Circulation

A. Elevator System:

The vertical distance from the ground level facilities to the pump room floor is approximately 50 feet, which makes it impractical to rely on stairs exclusively for vertical circulation. A single "building supported traction-type" service elevator will be provided. The elevator will have a 5,000 lb. load capacity, which will accommodate RWPS personnel, tools, welding equipment, and minor motor and pump parts. The footprint of the elevator will be large enough to transport a gurney, if needed. Loads greater than 5,000 lbs. will be accommodated via a crane through a hatch at ground level.

B. Stairs:

Three enclosed exit stairs are required by the Building Code and will be provided at each end and in the center of the pump room. The Building Code limits excess access to 200 feet or less. The center and east exit stairs will terminate at grade; and the west stair will terminate in the grade level corridor, near the building entrance.

C. Ladder to Roof:

A ladder up to a roof hatch will be provided in the west stairway to allow access to the rooftop HVAC equipment that will service the control room, corridor and restroom. (A separate HVAC system will service the Electrical Room – see **Section 11.4.**)

A. Catwalk:

A catwalk will be installed at the valve alcove, above the west intake pipe and suction header at approximately 12 feet above the pump room floor. The galvanized steel catwalk will be accessed by galvanized steel stairs with aluminum handrails. Stairs on either side of the catwalk will allow access to the piping and equipment at the pump room floor.

11.3.6 Sound Attenuation

Each of the pump motors at this facility generates approximately 82 dBA of noise at a 3-foot distance as measured on the equivalent A-weighted scale. The pumps and piping can also generate some level of hydraulic noise. OSHA allows employees to be exposed to 85 dBA for a maximum period of 8 hours. The noise reflecting off of the hard concrete walls, ceiling, and floor, together with the source noise could generate a condition known as constructive interference – where the sound wave compressions and rarefactions line up with each other to create a higher intensity noise. A sound consultant can be retained during the final design phase to determine the severity of interference in the Pump Room, and to recommend attenuation solutions. Generally, these solutions may include: 1) insulated, perforated metal panels that are bolted to the wall, and 2) cementitious spray applied insulation. The metal panels have stand-off attachment clips, allowing conduits to pass behind the panels. The spray-applied insulation cures rock-hard and is durable. Not all of the wall and ceiling surfaces will need attenuation. The initial assumptions for this scenario is that 30% of the pump room walls and ceiling will need to receive attenuation. The quantity and locations will be determined by the sound consultant during final design phase.

11.4 MECHANICAL (HVAC) DESIGN

11.4.1 Mechanical Design Criteria and Codes

A. The HVAC system for the buildings will be designed in accordance with:

- Applicable codes listed in this report
- ASHRAE 62.1-2010 – "Ventilation for Acceptable Indoor Air Quality"
- ASHRAE 90.1-2010 - "Energy Standard for Buildings"

B. The HVAC system will be sized based on summer and winter peak load calculations using the following design conditions:

Outdoor:

- Summer: 99.5°F DB / 74.6°F WB (ASHRAE 1%)
- Winter: 22.4°F DB (ASHRAE 99.6%)

Indoor:

- Electrical Room: 85°F DB / 50% RH
- Control Room: 75°F DB / 50% RH
- Pump Room: No more than 10°C DB above ambient outdoor temperature (Ventilation only)

11.4.2 Electrical Room Air Conditioning

The electrical room will be air conditioned by three grade-mounted packaged DX units sized to maintain n+1 redundancy such that if one of the units fails, the other two units will be capable of handling the entire heat load generated by the electrical equipment. The air conditioning units shall be controlled by wall mounted thermostats to maintain the design indoor conditions.

The capacity of the HVAC units will depend on the type of electrical equipment in the electrical room. If liquid-cooled AFD's are used, the heat load will be greatly reduced, and much smaller HVAC units can be used.

Air shall be distributed in the electrical room with horizontal ductwork to evenly distribute air. The supply air ductwork shall be mounted so that it stays clear of the space required for the electrical equipment and cable trays.

The electrical room will normally be unoccupied and hence does not require outside air ventilation for people. However, a minimal amount of outside air will be provided through the roof-mounted packaged DX units to slightly pressurize the spaces to prevent infiltration of unconditioned, unfiltered air. Since the space is unoccupied, the HVAC system serving the electrical room will be cooling-only and shall not have heating capability.

11.4.3 Pump Room Ventilation

The pump room will be ventilated and freeze-protected, but not air-conditioned. The ventilation system will be sized such that it does not allow the indoor conditions of the pump room to exceed more than 10°C above the outdoor ambient temperature. The ventilation system will be comprised one supply and one exhaust fan, both fans will be ducted to the finished floor level of the pump room. The operation of the fans will be controlled by a wall mounted thermostat. When the temperature in the pump room exceeds the designated set point, the fans will engage and ventilate the space. The design will depend on the type of pump motors used. Currently the pump motors will be water-cooled; if air-cooled motors are used, additional fans will need to be added to handle the ventilation requirements for the space.

Freeze protection will be provided for the pump room during low ambient conditions by electric unit heaters controlled by an integral thermostats.

11.4.4 Control Room Air Conditioning

The control room will be air conditioned by a wall-mounted packaged DX unit, controlled by a wall mounted thermostat to maintain design indoor conditions. Since the control room is occupied, it will be provided with outside air ventilation and heating.

11.4.5 Rest Room and Storage Room Ventilation

The restrooms and storage room will be provided with an exhaust fan interlocked with the light switch in order to provide ventilation to the space. Unit heaters will be provided for freeze-protection heating.

11.5 PLUMBING DESIGN

11.5.1 Plumbing Design Criteria and Codes

A. The plumbing system for the buildings will be designed in accordance with applicable codes listed in the report.

11.5.2 General Plumbing

A freeze protected non-freeze shower/eyewash will be provided on the exterior of the grade-level building. Non freeze hose bibbs will be provided along the exterior perimeter of the building not more than one-hundred feet apart.

11.5.3 Restroom Plumbing

There will be one restroom located adjacent to the control room. The restroom will be provided with a water closet, wall hung lavatory, floor-mounted service sink, floor drain and instantaneous water heater.

Hot and cold water piping will be purple CPVC with 1-inch thick insulation. The water source will be the discharge header from the pumps which will be under pressure. This line will be tapped off from in order to feed the building with non-potable water. The tap-off will be located on the top side of the discharge header so that sediment will not be drawn into the non-potable water line. The non-potable water line will be purple CPVC as an indicator that the water is non-potable. In addition, signage will be provided next to the mirror above the lavatory and around any hose bibbs warning occupants that the water is non-potable and is not suitable for drinking.

Any sanitary waste pipe will be cast iron above finished floor, DWV Schedule 40 PVC below finished floor and will extend five feet outside the building and continued by others. The vent pipe will be cast iron and one 4-inch vent will terminate above the roof to serve the restroom.

11.5.4 Pump Room Plumbing

An emergency shower/eyewash will be provided in the pump room. The intention is that when activated the water will drain to the sump pump systems.

11.6 SITE UTILITY DESIGN

11.6.1 Water Supply

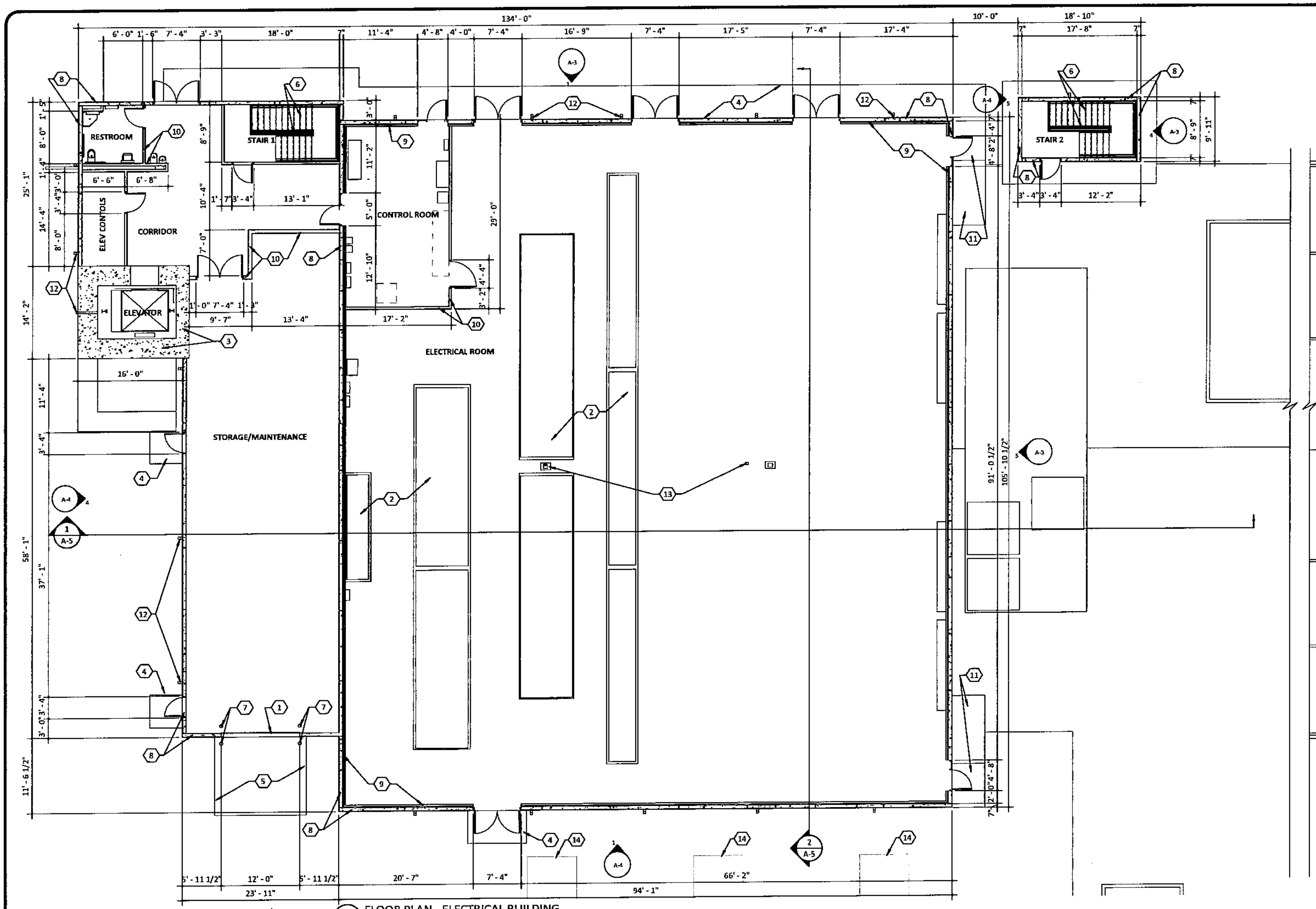
Water supply to the pump station facility will be required for latrine facilities, water cooled motors and fire protection systems. The potable domestic water demand is 50 GPM, and the non-potable water demand for the pump motor cooling system is 800 GPM (assuming five high-head pumps running). Single source options for water supply to the pump station are connecting to an existing 8-inch waterline, drilling water wells and chemically treating the well water, and treating the LBCR raw water. The closest potable water system with potential capacity is an 8-inch water line, owned by the Bois D'Arc Municipal Utility District (MUD), and is approximately 5 miles away. The approximate cost for this option is $1.25 million and the cost of the water will need to be negotiated between the owners. An estimated six drilled water wells will be necessary to meet the total water demand and will cost approximately $1.3 million. Treating the LBCR raw water will require a micro-strainer and a media cloth filter located at ground level within. This will likely be housed in the pump room. This option will cost approximately $625,000.

A more economical option to supply water to the pump station is to combine two water sources. The first combination is an approximately three mile, 2-inch water line extension from the MUD distribution system for potable water and raw water treatment for non-potable water use (e.g. motor cooling, wash down, etc.). The raw water treatment side will not require the media cloth filer system since it will be used for non-potable application. The reduced quantity of water to be treated will result in a smaller amount of treatment equipment which can be installed in the pump station room. The anticipated cost for this option is approximately $400,000. The advantage of this option is that the same domestic supply line can be used for dam maintenance facilities planned on the east side of the emergency spillway. A disadvantage of this option is that the water may only be used intimately and may require flushing to maintain water quality. A water well can also be installed in combination with raw water treatment to provide the necessary water to the pump station at an approximate cost of $450,000. FNI recommends using one of these combinations to provide water to the pump motors and station facilities.

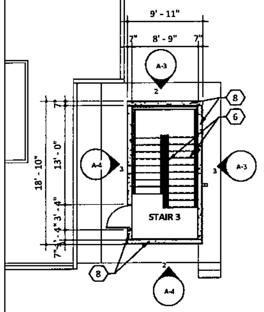
11.6.2 Septic System

Existing wastewater facilities are not within the project site. FNI recommends the design of an on-site septic tank system and leach field. Regular pumping of the tanks would be required, but would be on an annual or greater basis due to the limited use of the facilities. If an onsite perforated drain field is used, it will be located a minimum of 150 feet from any treated water pipeline or ground water well per TCEQ

Chapter 290 regulations. The drain field will also be located at least 150 feet from the pump station facility and raw water transmission line. Any additional storage facilities or offices that NTMWD plans to build in the future have not been included in the septic system analysis. Given the distance between the pump station site and the planned dam maintenance facilities, it is likely that separate septic systems at each facility will be more cost effective.



1 FLOOR PLAN - ELECTRICAL BUILDING
1/8" = 1'-0"



2 FLOOR PLAN STAIR 3
1/8" = 1'-0"

NOTES BY SYMBOL "⬡"

1. OVERHEAD COILING DOOR.
2. ELECTRICAL EQUIPMENT ON CONCRETE HOUSEKEEPING PADS, TYPICAL. RE: ELECTRICAL FOR THE EQUIPMENT AND STRUCTURAL FOR THE PADS.
3. CONCRETE ELEVATOR SHAFT, RE: STRUCTURAL.
4. CONCRETE LANDING AT DOORS, TYPICAL. RE: STRUCTURAL.
5. CONCRETE APPROACH APRON, RE: STRUCTURAL.
6. STAIRS AND RAILINGS, RE: SHEET A-_.
7. 6" DIA STEEL BOLLARDS, CENTERED ON THE JAMBS, 1'-0" AWAY FROM WALL OR COILING DOOR GUIDES. RE: STRUCTURAL.
8. PRE-CAST CONCRETE PANELS AT EXTERIOR WALLS, TYPICAL. RE: STRUCTURAL.
9. 2" RIGID INSULATION, 2 1/2" METAL STUD FRAMING AND 5/8" GYPSUM BOARD AT INSIDE FACE OF THIS CONCRETE PANEL WALL.
10. METAL STUD AND GYPSUM BOARD PARTITION, RE: PARTITION SCHEDULE, SHEET A-_.
11. CONCRETE LANDING AND RAMP, RE: STRUCTURAL.
12. PRE-FINISHED METAL DOWNSPOUT AND SCUPPER ABOVE, TYPICAL. RE: _/A-_.
13. STEEL COLUMN AND BASE PLATE, RE: STRUCTURAL.
14. HVAC EQUIPMENT, RE: MECHANICAL.

GENERAL NOTES

1. ALL DIMENSIONS ARE GIVEN TO:
   - A FACE OF CONCRETE OR MASONRY.
   - B CENTERLINE OF COLUMNS
   - C FACE OF FINISH.
   - D CONCRETE FLOOR LINE.
2. ALL INTERIOR FLOORS AND HOUSEKEEPING PADS ARE CONCRETE WITH CLEAR SEALER FINISH.

0 4' 8' 16'
1/8"=1'-0"

LEVEL I

Figure 11-1

Freese and Nichols, Inc.
Texas Registered Engineering Firm F-2144

NOT FOR CONSTRUCTION
THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF INTERIM REVIEW UNDER THE AUTHORITY OF PARRIS K. JONES TEXAS NO. 19268 ON 05/29/2015
NOT FOR REGULATORY APPROVAL, PERMITTING OR CONSTRUCTION.

FREESE NICHOLS
2711 North Haskell Ave. Suite 3300
Dallas, Texas 75204
Phone - 214-217-2200
Fax - 214-217-2201

NORTH TEXAS MUNICIPAL WATER DISTRICT
LOWER BOIS D'ARC PUMP STATION
ARCHITECTURE

ELECTRICAL BUILDING FLOOR PLAN

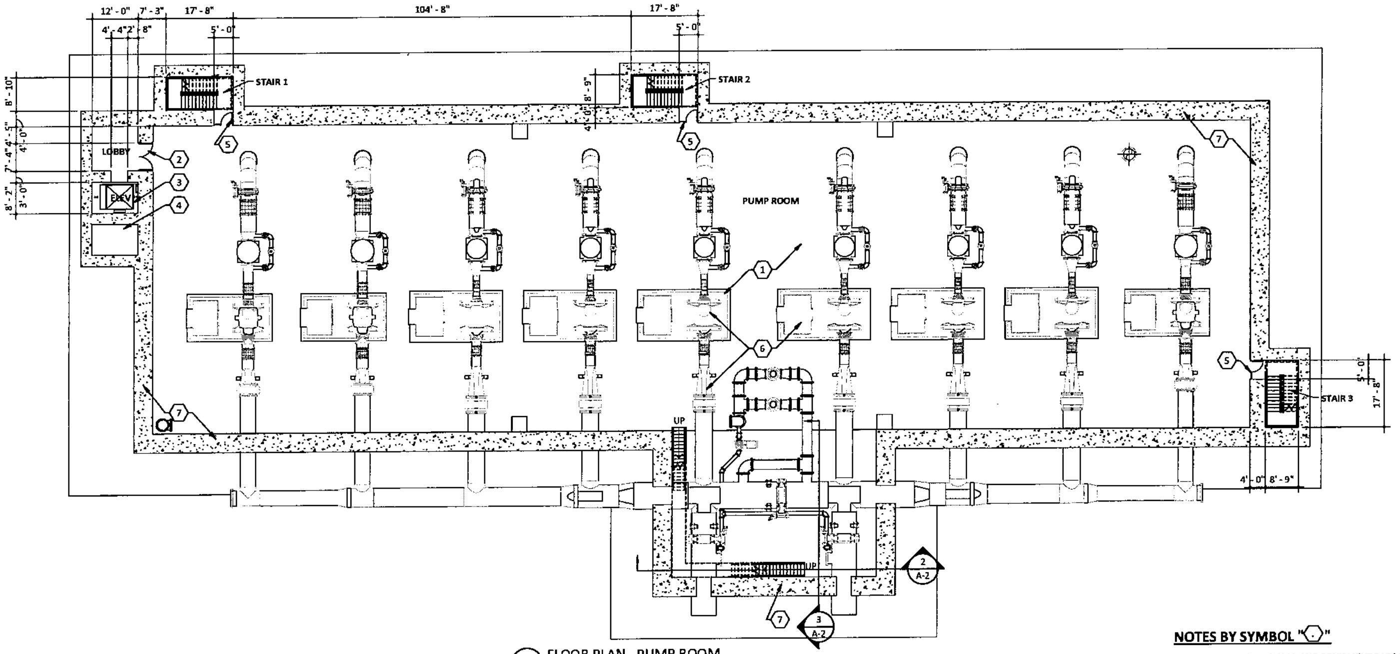
F&N JOB NO.	NTD14295
DATE	05/29/2015
DESIGNED	PKJ
DRAWN	NEL
REVISED	-
CHECKED	JWW
FILE NAME	C:\Users\nel\Documents\Arc-NTD14295_nel.rvt

NO.	ISSUE	BY	DATE

VERIFY SCALE Bar is one inch on original drawing. If not one inch on this sheet, adjust scale.

SHEET
A-1
SEQ

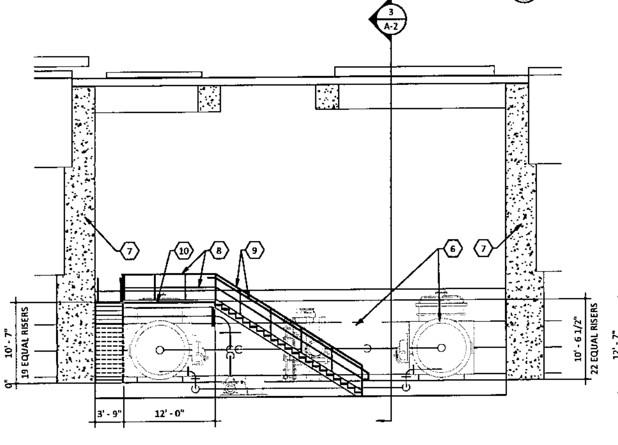
5/29/2015 2:23:31 PM



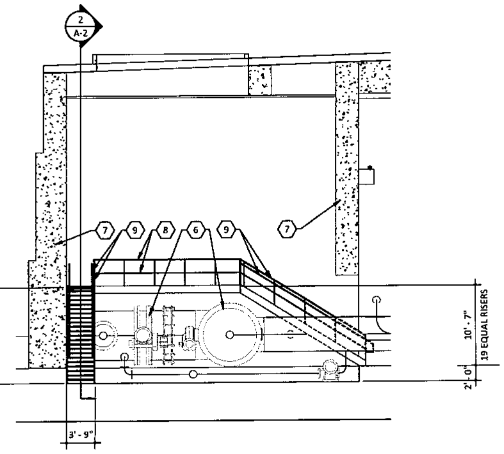
① **FLOOR PLAN - PUMP ROOM**
1/16" = 1'-0"

NOTES BY SYMBOL "⬡"

1 CONCRETE FLOOR SLAB AND EQUIPMENT PADS HAVE SMOOTH FINISH WITH CLEAR SEALER.
2 FIRE RATED DOUBLE DOORS AT ELEVATOR LOBBY WITH HOLD-OPEN DEVICES. (DOORS ARE NORMALLY HELD OPEN.)
3 5,000 LB. RATED SERVICE ELEVATOR WITH 4'-0" DOORS.
4 CONCRETE VENTILATION SHAFT, RE: STRUCTURAL AND MECHANICAL.
5 FIRE RATED DOOR WITH SIDE PANEL.
6 PUMPS, MOTORS, VALVES, PIPING AND APPURTENANCES, RE: PROCESS.
7 CONCRETE PUMP ROOM WALLS, RE: STRUCTURAL.
8 OSHA COMPLIANT GUARDRAIL, RE: SHEET A-_.
9 OSHA COMPLIANT GUARDRAIL AND HANDRAIL, RE: SHEET A-_.
10 STEEL FRAMED CATWALK.



② **CATWALK SECTION LOOKING NORTH**
1/8" = 1'-0"



③ **CATWALK SECTION LOOKING WEST**
1/8" = 1'-0"

0 4' 8' 16'
1/8" = 1'-0"
0 8' 16' 32'
1/16" = 1'-0"

LEVEL I

Freese and Nichols, Inc.
Texas Registered Engineering Firm F-2144

Figure 11-2

FREESE NICHOLS
2711 North Haskell Ave. Suite 3300
Dallas, Texas 75204
Phone - 214-217-2200
Fax - 214-217-2201

NOT FOR CONSTRUCTION
THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF INTERIM REVIEW UNDER THE AUTHORITY OF PARRIS K. JONES TEXAS NO. 19266 ON 05/29/2015 NOT FOR REGULATORY APPROVAL, PERMITTING OR CONSTRUCTION.

NORTH TEXAS MUNICIPAL WATER DISTRICT
LOWER BOIS D'ARC PUMP STATION
ARCHITECTURE

PUMP ROOM FLOOR PLAN

F&N JOB NO.	NTD14295
DATE	05/29/2015
DESIGNED	PKJ
DRAWN	NEL
REVISED	-
CHECKED	CK

NO.	ISSUE	BY	DATE

VERIFY SCALE Bar is one inch on origianl drawing. If not one inch on this sheet, adjust scale.
FILE NAME C:\Users\nel\Documents\Arc-NTD1 295_nel.rvt

SHEET
A-2
SEQ

5/29/2015 2:24:30 PM

12.0 INVASIVE SPECIES MANAGEMENT

The 2009 discovery of zebra mussels in Lake Texoma brought a new focus to evaluating the vulnerability of water system infrastructure to impacts caused by invasive species. The proposed LBCR will be a new reservoir and while there are currently no known findings of zebra mussels in Lower Bois d'Arc Creek a prudent step during the design of the new infrastructure is to consider the potential impact of invasive species and identify control strategies. The primary vulnerability evaluated as part of this project is fouling of and immediate impacts to the LBCR raw water intake and pump station systems. Control strategies identified may be implemented as part of the initial project or a future effort.

12.1 ZEBRA MUSSELS AND OTHER SPECIES

Zebra mussels are small freshwater mussels from the Dreissenid family classified as an invasive species. They reproduce abundantly and the free swimming larva will attach to any hard substrate.

Quagga mussels are a sister species to zebra mussels, but can thrive in colder environments, and are less selective with their food source. Zebra mussels prefer a warmer environment, rich with algae. Quagga mussels are primarily seen in the western United States and the Great Lakes region, and are not yet present in Texas. Management and prevention of both species is the same.

A third species called the Golden mussel is currently spreading in South America, slowly making its way north through Brazil. The Golden mussel prefers warm climates, and is more difficult to manage than the zebra or quagga mussels.

12.2 ENVIRONMENTAL REQUIREMENTS

The first step in reviewing the likelihood of zebra mussels at the proposed LBCR is consideration of their environmental requirements. **Table 12-1** below is a summary of water quality characteristics and likely survival of zebra mussels.

Table 12-1 Environmental Requirements Summary

Parameter	Adults do not survive long-term	Uncertainty of veliger survival	Moderate Infestation Level	High Infestation Level
Calcium (mg/L)	**<8 to <10**	**<15**	**16-24**	**≥24**
Alkalinity (mg CaCO3/L)	< 30	30-55	45-100	>90
Total Hardness (mg CaCO3/L)	<30	30-55	45-100	≥90
pH	**<7.0 or >9.5**	**7.1-7.5 or 9.0-9.5**	**7.5-8.0 or 8.8-9.0**	**8.2-8.8**
Mean Summer Temperature (°C)	<17 C	17-20 or >29 C	20-22 or 25-28	22-24
Dissolved Oxygen mg/L (% saturation)	<3 (25%)	5-7 (25-50%)	7-8 (50-75%)	≥8 (>75%)
Conductivity (µS/cm)	<30	<30-60	60-110	≥100
Salinity (mg/L) (ppt)	>10	8-10 (<0.01)	5-10 (0.005-0.01)	<5 (<0.005)
Secchi depth (m)	<0.1 >8	0.1-0.2 or >2.5	0.2-0.4	0.4-2.5
Chlorophyll a (µ/L)	<2.5 or >25	2.0-2.5 or 20-25	8-20	2.5-8
Total phosphorous (µg/L)	<5 or >50	5-10 or 30-50	15-25	25-35

The water quality parameters of primary concern are calcium content and pH. **Table 12-2** below is a matrix comparison of these parameters and the threshold values for survival of zebra mussels.

Table 12-2 Calcium Concentration and pH Threshold Values

	Calcium Concentration		
pH Level	Ca ≤ 12 mg/L	12 mg/L < Ca ≤ 15 mg/L	Ca > 15 mg/L
pH ≤ 7.3	unable	unable	unable
7.3 < pH ≤ 7.8	unable	potentially able	potentially able
pH > 7.8	unable	potentially able	able

Other characteristics such as temperature, dissolved oxygen, food, turbidity, and others become important if the calcium and pH are suitable. Water quality data for the proposed reservoir is obviously not available. However, water conditions in the reservoir are anticipated to be ideal living conditions for zebra mussels, based on estimated calcium, pH, temperatures, and dissolved oxygen from available knowledge of water in Lake Bonham and sampling programs within Bois d'Arc Creek. Other environmental factors that can mitigate zebra mussel development are lack of hard substrates, high temperatures, low dissolved oxygen, and high turbidity.

12.3 CONTROL STRATEGIES

The purpose of this analysis is to focus on possible strategies to protect the intake and raw water transmission systems from detrimental impact due to zebra mussels. Prevention is the first line of defense for invasive species control and monitoring is a key component. Frequent monitoring in order to detect presence or absence early on during the life of the reservoir using plankton nets and other methods is highly recommended. In the worst case, after an initial detection there can be sufficient time for implementation of planned control strategies. Sampling points, boat ramp controls, community education, and signage are all recommended for the reservoir. A wider analysis of sampling, monitoring, prevention and planning of control strategies for the reservoir as whole is beyond the scope of this report and is recommended to be undertaken as part of the overall LBCR program development. A unified effort between NTMWD, state agencies, federal agencies, and community stakeholders will be required.

12.4 INTAKE SYSTEM CONTROL STRATEGIES

The dual 78-inch intake pipe design allows the shutdown of one intake chamber and pipe at a time. The intake pipe taken out of service can be pigged without the need to dewater the pipe. Zebra mussels can be removed from the interior of the intake tower and pipe manually by power washing, or scraping and vacuuming. A concept to use pipeline pigging and the high pressure discharge of the pump station to clean the 700 foot long intake pipe was considered, but ultimately deemed not a viable option. A large space would be required in the pump room valve alcove to insert a pig upstream of the isolation valves. The debris from the operation would also be pushed back into the intake tower. The District has experience will manual cleaning of a similar size pipe from the Texoma Pump Station and has expressed some comfort with occasional manual cleaning of large diameter pipes. Access for this is provided both in the pump room at pipe manways and the intake tower through the removable grating. A self-contained breathing apparatus will be required for manual cleaning of the intake pipe and structure.

A spare set of screens can be included with the tower design to allow the complete removal and replacement of one set for easier cleaning. This will prevent the additional costs and risks associated with divers removing mussels by hand. The crane on top of the intake tower is sized to remove and maneuver screens onto a trailer for transport off of the intake structure. FNI recommends desiccation of the mussels by laying the screens on the ground in direct sunlight at the RWPS site or the planned dam maintenance facility. Mussels can take anywhere from two weeks to two months to die, after which they can be scraped off of the screens, and properly disposed of at a landfill. Screens should be pressure washed over the lake, because zebra mussels may be categorized as hazardous waste due to high levels of trace metals.

FNI is considering several different linings for the intake pipe and coatings for the screens including silicone, zinc, and copper. Zebra mussels do not attach to copper and zinc, but zinc coatings are only effective for one year or less. Once zinc develops a thin biofilm, the mussels will attach. A copper lining or sheeting is being considered, but may not be cost effective.

There are multiple silicone coating systems on the market that have been successfully used as foul-release coatings. FNI will only consider manufactured silicone coatings that have study periods greater than 18 months. The disadvantage of silicone coatings is that they are soft and are easily damaged during construction and cleaning. An initial silicone coating is recommended on the stainless steel screens, with periodic recoating. The mussels will still attach to the silicone coatings, but they will easily fall off once disturbed.

Pipe silicone linings may perform effectively for 10 years without recoating, but this will depend on frequency of cleaning and disturbance to the pipe lining. To reline the intake pipes, they will need to be completely drained and dehumidified, which is unlikely to be possible once the system is put into operation. Coatings inside the intake pipes are not proposed for this reason.

12.5 RAW WATER PUMP STATION CONTROL STRATEGIES

12.5.1 Large Diameter Pipe

Chemical injection on site, downstream of the 78-inch isolation valve on the intake pipes should be considered for zebra mussel control. Zequanox has greater than 80% mortality rate. Aquatic herbicides have shown promise – Bulab – chemical dosing approved for drinking water. Potash, pH above 6.9, 80 micron square filters and UV dosing have all proven effective. Space can be made available for chemical storage and feed pumps in the pump room and empty maintenance rooms on the ground level if chemical control is the preferred alternative.

Zebra mussels will not attach to submerged surfaces with velocities greater than 4.5 feet per second, however the shells will still clog up small orifices. Due to the variable demands from the Leonard WTP, maintaining velocity above this threshold will not be possible.

Oversized cranes and actuators are recommended to account for the additional weight due to fouling and resistance caused by shells. This will apply to equipment on the intake and valves within the pump station.

12.5.2 Small Diameter Pipe

All piping 2 inches in diameter and smaller will be copper to prevent zebra mussel attachment. Brass and bronze pipes are not as effective as copper in deterring zebra mussels.

12.5.3 Cooling Water Systems

Raw lake water will not be used in cooling water systems. **Section 11.6.1** of this report details the available sources for cooling water systems. Any raw water used for cooling water systems will be filtered and/or treated to eliminate zebra mussels and veligers to prevent fouling of piping, valves and motor cooling jackets.

12.6 PIPELINE CONTROL STRATEGIES

Similar to the discussion above for control of large diameter piping in the pump station, chemical control solutions should be investigated to maintain the 90-inch discharge pipeline. Unlike the pump station piping with numerous fittings and valves, the discharge pipeline can be designed for pigging. This would allow disposal of debris from the pipeline at the proposed TSR in Leonard. Detailed review of pigging for the pipeline should be reviewed as part of the pipeline preliminary design.

12.7 RECOMMENDATIONS

A Biobox monitoring system will be set up to provide early warning of zebra mussel biofouling similar to what was installed at the Sherman control valve and WTP. RNT Consulting will review the intake and RWPS facilities during final design and recommend alternatives for invasive species control and prevention.

13.0 FLOW METERING

13.1 FLOW METER LOCATION

The flow meter will be located approximately 1,350 LF downstream of the pump station, between the service spillway and emergency spillway as shown in **Figure 7.8**. This location was selected due to the limited area at the pump station site, the number of pipe bends near the pump station, and providing access from the adjacent dam crest road. There is adequate room to allow the manufacturers' recommended 5-pipe diameters upstream and 3-pipe diameters downstream of undisturbed flow, as well as an additional 25% for an additional factor of safety. At the planned location, approximately 6.25 pipe diameters of straight pipe can be provided upstream of the meter. A CFD model of the piping will allow for review of the flow conditions upstream of the meter and aid in determining flow conditioning improvements that may be required. FNI considered above ground and below ground options for the flow meter design, but ultimately the NTMWD preferred a below ground meter in a concrete vault for security and safety purposes.

13.2 FLOW METER AND INSTRUMENTATION

The flow meter and instrumentation selected for the LBCR RWPS will be consistent with the Meter Vault Standardization project (Project #338). An electro-magnetic flow meter will be used, due to its low maintenance and high accuracy. The two NTMWD approved manufacturers for these meters are Endress+Hauser and Siemens.

Based on the range of flows and range of allowable velocities through the meter, FNI has determined that a 66-inch flow meter is appropriate for the system. The minimum flow the system will see is 30 MGD and the maximum is 236 MGD. **Table 13-1** displays flows correlated to the velocity recommended by manufacturers 60, 66, and 72-inch meters. FNI recommends the 66-inch diameter flow meter to maintain appropriate velocity at low and high flow rates.

Table 13-1 Magnetic Flow Meter Sizing

Meter Size (in)	Low Allowable Flow @ 2 fps (MGD)	Optimum Flow @ 8 fps (MGD)	Recommended max flow @ 15 fps (MGD)	Allowable Max Flow @ 35 fps (MGD)
60	25.38	101.52	190.36	444.17
66	**30.71**	**122.84**	**230.33**	**537.44**
72	36.55	146.19	274.11	639.60

Additional instrumentation will include a pressure transmitter, collocated in the vault with the flow meter. SCADA and electrical instrumentation is discussed in more detail in Section 10.5 of this report.

13.3 FLOW METER LAYOUT

The Meter Vault Standardizations report (Project #338) was utilized for the preliminary design of the LBCR flow meter vault. The proposed flow meter vault will be approximately 14.5' deep, 20' long and 21'-8" wide. A stairway of minimum 30-inch width and 50-degree slope will be installed on one side of the vault for access. Lighting, ventilation and floor drainage will be designed per the NTMWD's standards. All electrical equipment and instrumentation will be located in a masonry building above the vault, with the same footprint as the vault foundation. A metal hatch will be located directly over the flow meter. A permanent monorail crane system to facilitate maintenance will be evaluated during final design. The raw water pump station storage room will include space for a 66-inch spool piece of pipe to be used during flow meter maintenance.

A 90-inch motor operated butterfly valve is proposed approximately 50 feet downstream of the vault for isolation purposes. The valve actuator will be housed in a separate 84-inch diameter manhole, with stiffener rings 4 feet on either side of the centerline of the valve to prevent deflection of the butterfly valve housing. This isolation valve, as well as the isolation valves on the discharge piping at the pump station will be closed when it is necessary to drain the line and pull the flow meter for maintenance. This portion of pipeline will be drained through a blow off valve located at the service spillway. A motor operator is included on this valve due to the susceptibility of flooding with the pump room from any major leak. This will allow remote closure of the valve after all pumps have stopped to limit water from the remainder of the pipeline from draining back through a leak.

13.4 FLOW METER PIPING ALTERNATIVES

The flow meter piping may not be the same material as the majority of the discharge pipeline and may transition to a different material inside of the vault walls. Acceptable pipe materials within the vault are urethane or epoxy coated steel pipe with a coating system suitable for a corrosive environment. The pipe will be mortar lined to match the rest of the discharge piping. Outside of the vault, the pipe material and coating will match the rest of the transmission pipeline.

14.0 TRANSMISSION PIPELINE

14.1 SUMMARY

FNI was tasked to design the initial section of the of transmission line that originates at the proposed raw water pump station and terminates just east of the emergency spillway. The end of this pipeline will then connect to the proposed LBCR transmission pipeline. The pipeline will be in a 50-foot wide raw water pipeline buffer zone, with a parallel 70-foot wide temporary construction zone, to match the easement width requirements of the main transmission line where it is located off NTMWD property. The pipeline will be 90-inch pipe based on the pipe diameter optimization as discussed in previous reports for the pipeline.

14.2 SERVICE SPILLWAY CROSSING

The 90-inch discharge pipeline crosses the service spillway at approximately STA 5+76 of the pipeline, 470 feet downstream of the dam centerline. FNI selected a location that would minimize the risk of future erosion. The service spillway crossing is upstream of the spillway basin and abutments, where the service spillway has a slope of -3.5%. The service spillway is comprised of 2-foot thick concrete, constructed directly on top of the existing rock. Locations downstream in the earthen channel were avoided due to erosion potential and the armoring they would require to protect the pipeline. The top of the discharge pipeline will be approximately 6 feet below the spillway concrete channel well within the existing rock. Construction sequencing of the dam and RWPS will require the spillway to be constructed prior to the discharge pipeline. To avoid future disturbance to the spillway, FNI recommends placing a portion of the pipeline in a concrete encasement under the spillway. The pipe will include a capped end on each side of the crossing. The discharge pipe will later be welded to the encased pipe as part of the RWPS construction. The minimal slope, concrete channel lining, existing rock and concrete encasement is expected to prevent any future disturbance to the transmission pipeline or spillway.

14.3 EMERGENCY SPILLWAY CROSSING

The 90-inch discharge pipeline crosses the emergency spillway at approximately STA 29+25 of the pipeline. The pipeline is located approximately 25 feet upstream of the emergency spillway crest and the site access road. The pipeline will have a minimum of 5 feet of cover at this location to protect against potential erosion from wave action during periods of time with high lake level. The proposed ground elevation at the selected location is approximately 540 feet MSL. During events greater than the 100-year storm when the spillway is engaged, velocities over the spillway crest will be lower on the upstream side than the downstream side of the crest. FNI has placed the transmission pipeline on the upstream side of the crest to limit erosion concerns with the pipeline cover. Additionally, FNI is considering a 20-foot wide swath of concrete or soil cement on top of the pipe to act as an erosion cap. It is anticipated that this section of the pipeline across the emergency spillway will be constructed with the rest of the transmission pipeline.

14.4 EASEMENTS AND WORK AREAS

The discharge pipeline is shown in a 50-foot wide raw water buffer zone, measured off of the upstream edge of the proposed dam road for the majority of the alignment. There will also be a 70-foot wide work area to serve as a temporary construction area, but no easements will be required as the project is on NTMWD property. These work areas match the proposed easements for the main transmission pipeline. It should be noted that a 100-foot wide electrical easement will be required for the Fannin County Electrical Cooperative's (FCEC) 138 kV overhead transmission lines and 25 kV overhead feeder lines, which will be located along the proposed 70-foot work area.

14.5 CONNECTION TO TRANSMISSION PIPELINE

The 90-inch transmission line included in the raw water pump station project will be plugged for a future connection to the LBCR transmission pipeline. This plug will allow hydrostatic testing of the pump station piping and the downstream transmission pipeline. The exact location of the transition from the pump station CMAR project to the pipeline CMAR project will be determined at a later date. For purposes of this design it is assumed to be immediately downstream of the meter vault and pipeline isolation valve.

14.6 PIPE MATERIALS

The pipeline will be constructed as either Polyurethane Coated Steel Pipe (AWWA C200) or Pre-Stressed Concrete Cylinder Pipe (AWWA C301) with mortar lining. All pipe joints for the pre-stressed pipe are to be a bell and spigot-type with rubber gaskets, and bonding clips for electrical continuity. Welded joints will be provided where required for thrust restraint. All pipe joints for the steel pipe will be the welded bell and spigot type. All materials will be specified to meet ANSI/NSF Standard 61.

14.7 TRENCHING AND EMBEDMENT

The pipeline embedment will be an imported granular embedment material compacted to 95% maximum density in accordance with ASTM D4253 measuring from the trench bottom to 70% of the pipe's outer diameter for steel pipe, and measuring 30% of the pipe's outer diameter for pre-stressed concrete cylinder pipe.

For polyurethane coated steel pipe, the pipeline embedment from the trench bottom to seven-tenths of the pipe's outer diameter will be an imported granular embedment material compacted to 95% maximum density in accordance with ASTM D4253. For polyurethane coated steel pipe, the granular embedment will continue to the top of the pipe zone, 12 inches above the top of the pipe. For pre-stressed concrete cylinder pipe, the remainder of the pipe zone above 30% of the pipe's outside diameter will be select material compacted to 95% Standard Proctor density in accordance with ASTM D698. Above the pipe zone, ordinary trench excavated material compacted to 95% of Standard Proctor density will be specified. The final 12 inches of the pipe trench will be topsoil. For depths of cover greater than 13 feet, flowable fill or concrete encasement will be used in the pipe zone for both pipe options. The pipeline crossing of the service spillway will be concrete encased.

Details of the pipeline embedment system will be further developed during preliminary design of the pipeline.

14.8 CORROSION CONTROL

Cathodic protection systems available for the transmission line are buried anodes and impressed-current systems. A qualified corrosion consultant will determine the appropriate corrosion control methods based on soil analysis and possible interference issues along the pipeline.

14.9 PIPELINE PIGGING

Provisions will be made to insert a pig downstream of the proposed flow meter and isolation valve. The approximately 1,350 LF of pipe between the pump station and the flow meter will need to be manually cleaned. A pig launching facility will be located along the proposed discharge pipeline near the LBCR site. A pig retrieving facility will be located near the TSR. Details of the pipeline pigging system will be further developed during preliminary design of the pipeline.

15.0 REGULATORY REQUIREMENTS

15.1 TCEQ

15.1.1 Public Water System Requirements

Public water system regulations are listed in Chapter 290 of the Texas Administrative Code (TAC) and are enforced by the TCEQ. The raw water intake, pump station and pipeline will be subject to these rules. Chapter 290.41.e.2 covers regulations for surface water intakes. Regulations include that raw water intakes have a 200-foot radius exclusion zone marked with buoys. Public boat launch facilities may not be located within 1,000 feet of the intake. The restricted zone (200-foot radius) around the intake shall be marked with signs in plain view and visible from all parts of the restricted area. Other requirements addressing access, multiple intake levels, screens and gates and location relative to sewage plants have already been discussed in this report. The TCEQ will perform an on-site assessment of the intake location prior to final design and also perform a design review of the pump station and pipeline plans to check for conformance with the requirements of TAC Chapter 290.

Chapter 290.41.e.3-5 address requirements of the raw water pump station. These include allowing operation during flood events, all-weather access roads, and a secure site with lockable building and intruder-resistant fencing.

Potable water line and groundwater well options will be designed to meet Chapter 290 rules and regulations. Any septic system will be designed to meet Chapter 285 rules and regulations.

Based upon past experience with TCEQ staff, they do not have specific regulations for raw water pipelines other than meeting the AWWA standards; however as the system connects directly to a surface water treatment plant they typically require plans and specifications to be submitted for review and approval. TCEQ has specific regulations for the raw water intake facilities including water quality, quantity and protection of the intake.

15.1.2 Dam Safety Requirements

The design of the intake, intake pipe through the dam, and the dam will comply with the TCEQ Chapter 299 requirements where applicable. These are addressed further in the LBCR Dam PDR.

15.2 ENVIRONMENTAL PERMITTING

Authorization to construct the pump station and pipeline will be approved in the Record of Decision for the Environmental Impact Statement prepared for the Lower Bois d'Arc Creek Project. Design considerations associated with the construction of the intake and pump station and pipeline are included in the following reports or memoranda.

- Proposed Lower Bois d'Arc Creek Reservoir, Fannin County, Texas, Mitigation Plan
- Report Supporting an Application for a Texas Water Right for Lower Bois d'Arc Creek Reservoir, 2 volumes
- Section 404 Permit Application and Jurisdictional Determination Report
- Environmental Report Supporting an Application for a 404 Permit for Lower Bois d'Arc Creek Reservoir.
- Supplemental Data Supporting and Application for a 404 Permit for Lower Bois d'Arc Creek Reservoir

16.0 OPERATION AND MAINTENANCE

16.1 MECHANICAL AND ELECTRICAL EQUIPMENT

The new LBCR water supply and transmission system will require an expanded operation and maintenance program by the NTMWD. The new pump station is over 80 miles away from the Wylie WTP, 45 miles from the proposed Leonard WTP and 25 miles from the Bonham WTP. Similar to other remote raw water supply stations for the District, these distance are a challenge for operators and maintenance staff to visit on a regular basis as needed. The whole of the LBCR transmission system will require some additional staffing of operators and maintenance staff and a determination of where this staff is based. The NTMWD will need to plan for this additional staffing as this system is designed and put into service between now and 2020. The following sections lists the anticipated general maintenance program requirements for the mechanical and electrical equipment at the LBCR RWPS and can be used as a guide for evaluating new staff necessary. A more detailed operation and maintenance program can be developed during later design and construction phases for the LBCR transmission system.

16.1.1 Pump Operational Checks and Minor Maintenance

The following recommended daily operational checks and minor maintenance at the pump station can reduce pump maintenance and downtime:

- Check flow and pressure
- Verify that check valves and control valves are working properly
- Verify that isolation valves are properly positioned
- Listen for any abnormal noises, vibrations or temperatures
- Check for leaks, mechanical seals should not leak. Packing boxes should have a slight leakage
- Check and clean all system strainers or filters
- Check for loose bolts, nuts and fittings
- Check drive shaft and coupling integrity
- Open and bleed air vents to remove any trapped air
- Report any abnormal conditions to maintenance

16.1.2 Motor Operational Checks and Minor Maintenance

The following recommended daily operational checks and minor maintenance can reduce motor maintenance and downtime:

- Check for abnormal noises or vibrations
- Check for excessive heat
- Clear dust and dirt from the motor and motor air vents
- Check for corrosion and condensation

If excessive heat from the motor is observed, verify that ambient conditions around the pump are within the manufacturer's specifications and that the cooling systems are intact and operating properly. Report any abnormal conditions to maintenance.

16.1.3 Electrical Equipment Preventive Maintenance

There are several basic categories that influence deterioration of electrical equipment including:

- The effect of foreign material (i.e. dust and dirt from environment)
- The effect of chemicals in the atmosphere
- Mechanical wear and fatigue on all moving parts
- Heat
- Loose joints and connections

Periodic PM activities should include monitoring these influences. Visual inspections should be made frequently of all electrical equipment. The following are some general recommendations for semi-annual mechanical and electrical inspections and tests:

- Check for general cleanliness, buildup of dust and dirt, and particularly for accumulation of foreign material on insulators. Thoroughly remove all dust and other accumulations.
- Check for any evidence of melting, discoloring, deterioration, etc. of wire and cable that would indicate excessive heat and insulation breakdown.
- Check isolation and disconnecting mechanisms.
- Inspect, clean and lubricate racking mechanisms and other moving parts.
- Measure resistance to ground and between phases using megger tests. Since definite limits cannot be given for satisfactory insulation resistance values, a record must be kept of the

reading. Weakening of the insulation from one maintenance period to the next can be recognized from the recorded readings.

- Check and tighten electrical connections.
- Check and clean air filters as applicable for outdoor equipment and equipment with cooling fans.

These recommendations and the following industry standards along with the original equipment manufacturers' recommendations should be considered when programming electrical equipment PM activities into MAXIMO. Other suggested references include:

- NFPA 70B (2010) – *Recommended Practice for Electrical Equipment Maintenance*
- IEEE Standard 3007.2 (2010) – *Recommended Practice for maintenance of Industrial and Commercial Power Systems*
- IEEE Standard P3007.3 (pending) – *Recommended Practice for Electrical Safety of Industrial and Commercial Power Systems*

17.0 CONSTRUCTION

17.1 PHASING WITH DAM CONSTRUCTION

The intake tower and dam will be the first items constructed at the LBCR site. The intake pipes will be constructed to the temporary section of the diversion channel. The current flows through Honey Grove Creek and Lower Bois D'Arc Creek will be directed through the dam until the intake tower and pipes are constructed. The intake tower and pipes will be used to convey the creek flows while the dam construction is completed. Special attention will need to be paid to maintaining these facilities at this time, particularly during storm events. The intake tower and pipes will only be used to make the required reservoir release flows once the dam construction is completed prior to the pump station commissioning.

The pump station construction will commence mid-way through the dam construction. The pump station suction piping will be constructed up to the location of the intake pipe release outlet. This suction piping will remain plugged until the pump station construction is completed and the reservoir release valves inside the station are operable. The plug will then be removed and the pipes will be connected.

The discharge pipe for the pump station will cross the service spillway encased in concrete. The section of discharge pipe that crosses the service spillway will be constructed with the service spillway construction. The concrete encasement for the pipe will also be poured at this time. This pipe will be plugged at either end until the remainder of the discharge pipe is constructed.

17.2 PHASING WITH PIPELINE AND LEONARD WTP CONSTRUCTION

Construction of the RWPS, Leonard WTP, and HSPS are all scheduled to commence in the fourth quarter of 2017. Construction of each facility is expected to span approximately 32 months. Construction of the raw water pipeline is expected to begin just prior to the fourth quarter of 2017 with completion in the first quarter of 2019. The raw water system, including the RWPS, electrical supply, pipeline, TSR and Leonard WTP are all to be completed by the second quarter in 2020. **Figure 18-1** displays the project schedule for the associated facilities.

17.3 STARTUP

The CMAR for RWPS and pipeline components will be consulted regarding the preferred method for testing facilities individually as they are commissioned. The RW pipeline will be completed prior to the RWPS and Leonard WTP completion. Filling and testing the RW pipeline without the RWPS and the TSR will need to be evaluated. The Leonard WTP and RWPS are scheduled to be completed within the same general timeframe. It is expected that the RWPS will provide the water necessary to commission the Leonard WTP. A detailed startup and commissioning plan will be developed during the final design and construction phases of the RWPS.

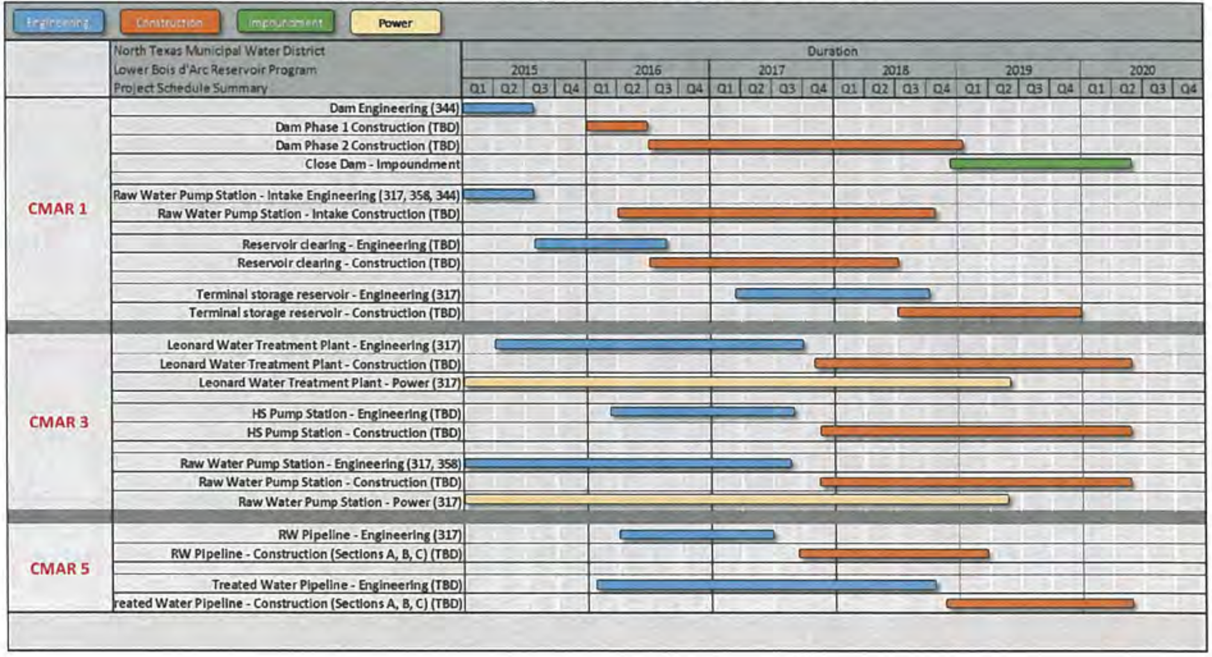
17.4 PROJECT DELIVERY METHOD

Construction Manager at Risk (CMAR) will be used for construction of the LBCR RWPS. This is the method proposed for all of the work associated with the LBCR program. The CMAR process allows the NTMWD to select a contractor or team based on qualifications and cost to provide pre-construction services and management of various sub-contractors during construction. The CMAR is selected early in the design process so that they can work closely with and serve as an advisor to the NTMWD and project designers. This provides the opportunity to tailor the design of the project to the details and suggested means and methods of the specific CMAR, thereby expediting the construction. The CMAR will provide other pre-construction services such as detailed schedule preparation and cost estimating. A total of five CMAR's will be used for the LBCR program. CMAR 1 will provide services for the dam and intake construction. CMAR 3 will provide services for the RWPS, Leonard WTP, and the High Service Pump Station (HSPS). CMAR 5 will provide services for the raw water pipeline. CMAR 1 was awarded at the end of March 2015 and CMAR 3 is expected to be awarded as early as the last quarter of 2015. CMAR 5 is not expected to be awarded until late 2016.

18.0 PROJECT SCHEDULE

Level 1 Intake plans were submitted in December 2014 and Level 2 Intake were submitted in March 2015 with the Level 2 Dam plans. The final intake design plans will be submitted in fall 2015 or as needed to meet the schedule for the dam and will be included with that project component from this point forward. Level 1 pump station and discharge pipeline design are submitted with this draft report. Preliminary design will conclude in winter 2015 with the completion of hydraulic modeling and transient modeling. Final engineering of the RWPS will commence in February of 2016 and conclude by July 2017. A key component in completing the pump station will be the power supply. The second quarter of 2019 has been identified as the preferred deadline for completion of the substation and transmission system required to support the RWPS and allow sufficient time for installation and testing of the electrical equipment at the RWPS. **Figure 18-1** below shows a more detailed schedule for the LBCR dam, intake and pump station design and construction. This schedule is current as of May 2015 and will continue to be updated as the program progresses.

Figure 18-1 Design and Construction Schedule



19.0 OPINION OF PROBABLE CONSTRUCTION COST

An OPCC has been prepared by FNI for the pump station preliminary design. The estimated construction cost of the RWPS is $54,800,000. This estimate was developed using a variety of tools, including actual bid data for some common elements, price quotes from vendors for equipment, discussions with specialty contractors, and other sources. This estimate is based on prices available in the spring of 2015 and does not include any escalation for inflation that is expected between now and project completion. A detailed OPCC can be found in **Appendix A**.

20.0 RECOMMENDATIONS

Recommendations section will be completed after further review of this draft report with the District. The summary of recommendations is constructing a new pump station with horizontal split-case pumps downstream of the dam. The pump station is to have ultimate firm capacity of 236 MGD. This will be met with three low head pumps to be installed during the initial phase to provide at least 72 MGD firm capacity along with required supporting infrastructure and equipment. Later phases will include six high head pumps and additional support equipment.

APPENDIX A
OPINION OF PROBABLE CONSTRUCTION COST

FREESE NICHOLS

LOWER BOIS D'ARC CREEK RESERVOIR
NORTH TEXAS MUNICIPAL WATER DISTRICT
RAW WATER PUMP STATION PRELIMINARY DESIGN

OPINION OF PROBABLE CONSTRUCTION COST, PHASE 1 June 30, 2015

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	PUMP STATION SITEWORK				**$1,626,400.00**
	EXCAVATION	54,400	CY	$10.00	$544,000.00
	BACKFILL	50,700	CY	$12.00	$608,400.00
	ACCESS ROAD AT PUMP STATION (12" Concrete @ 24' Width)	1,200	LF	$360.00	$432,000.00
	PUMP STATION SECURITY FENCING	1	LS	$32,000.00	$32,000.00
	SEPTIC DRAIN FIELD	1	LS	$10,000.00	$10,000.00
	SUBSTATION SITE GRADING AND PREP (Completed in Dam. CMAR No. 1)	1	LS	$0.00	$0.00
	ACCESS ROAD MAINT. & COMPLETION (Needs Coord with Dam. CMAR No. 1)	1	LS	$0.00	$0.00
	PUMP STATION MECHANICAL				**$10,277,211.45**
	78" SUCTION HEADER PIPING	122	LF	$1,510.00	$183,455.00
	72" SUCTION HEADER PIPING	10	LF	$1,110.00	$11,100.00
	60" SUCTION HEADER PIPING	63	LF	$860.00	$54,180.00
	LARGE DIAMETER FITTINGS FOR SUCTION HEADERS	1	LS	$100,000.00	$100,000.00
	54" SUCTION PIPING	108	LF	$920.00	$99,360.00
	48" SUCTION HEADER PIPING	113	LF	$500.00	$56,250.00
	78" BUTTERFLY VALVE	3	EA	$115,850.00	$347,550.00
	48" GATE VALVE	3	EA	$158,400.00	$475,200.00
	TEMPORARY 54" BLIND FLANGE	6	EA	$8,000.00	$48,000.00
	36" THRUST HARNESS (SUCTION SIDE)	3	EA	$19,530.00	$58,590.00
	LOW HEAD HORIZONTAL PUMP (3000 HP)	3	LF	$1,800,000.00	$5,400,000.00
	30" THRUST HARNESS (DISCHARGE SIDE)	3	EA	$17,630.60	$52,891.80
	48" THRUST HARNESS (DISCHARGE SIDE)	3	EA	$28,210.00	$84,630.00
	36" DISCHARGE PIPING	15	LF	$594.00	$8,910.00
	36" PUMP CONTROL CONE VALVE	3	EA	$434,500.00	$1,303,500.00
	PCV BYPASS & VALVES	3	LS	$35,100.00	$105,300.00
	48" BUTTERFLY VALVE (300 PSI)	3	EA	$51,480.00	$154,440.00
	TEMPORARY 48" BLIND FLANGE	6	EA	$9,230.00	$55,380.00
	48" DISCHARGE PIPING	109	LF	$768.00	$83,328.00
	60" DISCHARGE PIPING	57	LF	$1,332.00	$75,258.00
	72" DISCHARGE PIPING	26	LF	$1,578.00	$41,028.00
	84" DISCHARGE HEADER	33	LF	$2,052.00	$67,716.00
	90" DISCHARGE HEADER	135	LF	$1,188.00	$160,380.00
	LARGE DIAMETER FITTINGS FOR DISCHARGE HEADERS	1	LS	$100,000.00	$100,000.00
	PIPE SUPPORTS	1	LS	$50,000.00	$50,000.00
	SUCTION HEADER PIPE CONCRETE ENCASEMENT	432	CY	$425.00	$183,731.73
	DISCHARGE PIPE CONCRETE ENCASEMENT	361	CY	$500.00	$180,526.91
	30" ACCESS MANWAYS	3	EA	$2,500.00	$7,500.00
	SUMP PUMP	3	EA	$10,000.00	$30,000.00
	BRIDGE CRANE (35 TON)	1	EA	$138,996.00	$138,996.00
	MOTOR WATER COOLING EQUIPMENT	1	LS	$400,000.00	$400,000.00
	PAINTING PIPE AND EQUIPMENT	1	LS	$75,000.00	$75,000.00
	MISCELLANEOUS APPURTENANCES	1	LS	$85,000.00	$85,000.00
	INTAKE DEWATERING & RESERVOIR RELEASE				**$356,800.00**
	8" DEWATERING PIPING	100	LF	$80.00	$8,000.00
	DEWATERING PUMP	1	EA	$64,400.00	$64,400.00
	30" RESERVOIR RELEASE PIPING	530	LF	$300.00	$159,000.00
	24" RESERVOIR RELEASE PUMP CONTROL VALVE	1	EA	$125,400.00	$125,400.00
	6" RESERVOIR RELEASE PUMP CONTROL VALVE	1	EA	$19,800.00	$19,800.00
	YARD PIPING - PS TO METER VAULT SITE (STA 16+00)				**$1,626,539.47**
	90" TRANSMISSION PIPELINE	1,438	LF	$727.65	$1,046,360.70
	90" CONCRETE ENCASEMENT (Service Spillway)	102	CY	$500.00	$51,140.77
	90" BFV (MOTOR OPERATED, 300 PSI)	1	EA	$402,600.00	$402,600.00
	84" PRECAST MANHOLE (90" BFV Actuator)	1	EA	$30,000.00	$30,000.00
	84" PRECAST MANHOLE (90" BFV Access)	1	EA	$15,000.00	$15,000.00
	12" BOV WITH MANHOLE	1	EA	$28,000.00	$28,000.00
	8" CAV WITH MANHOLE	2	EA	$26,000.00	$52,000.00
	TRENCH SAFETY	1,438	LF	$1.00	$1,438.00
	FLOW METER VAULT				**$165,049.15**
	EXCAVATION (14.5 FT DEEP)	1,293	CY	$10.00	$12,930.00
	BACKFILL	606	CY	$12.00	$7,272.00
	ELEVATED SLAB	15	CY	$1,100.00	$16,296.30
	FOUNDATION	15	CY	$450.00	$6,666.67
	PRECAST BUILDING	1	LS	$25,000.00	$25,000.00
	VAULT WALLS	44	CY	$1,085.00	$47,760.19
	66" TRANSMISSION PIPELINE & APPURTENANCES	62	LF	$792.00	$49,104.00
	ARCHITECTURAL				**$2,982,800.00**
	ELECTRICAL & MAINT/STORAGE BUILDING	12,919	SF	$150.00	$1,937,850.00
	ELEVATOR	1	EA	$220,000.00	$220,000.00
	STAIRWELL	561	SF	$450.00	$252,450.00
	CATWALK AND LADDERS	225	SF	$100.00	$22,500.00
	HVAC	1	LS	$350,000.00	$350,000.00
	PLUMBING & COOLING	1	LS	$200,000.00	$200,000.00
	PUMP STATION STRUCTURAL				**$11,767,951.68**
	FOUNDATION	9,038	CY	$450.00	$4,067,100.00
	PUMP PAD	49	CY	$450.00	$22,126.68
	WALLS (below grade)	7,510	CY	$700.00	$5,257,000.00
	ELEVATED SLAB (concrete beams included)	1,875	CY	$1,000.00	$1,875,000.00
	PRECAST CONCRETE TxDOT Tx54 ROOF BEAMS (29 @ 81')	2,349	LF	$135.00	$317,115.00
	MISCELLANEOUS APPURTENANCES	1	LS	$200,000.00	$200,000.00
	18' x 30' ACCESS HATCH	540	SF	$30.00	$16,200.00
	15' x 25' ACCESS HATCH	375	SF	$30.00	$11,250.00
	6' x 12' ACCESS HATCH	72	SF	$30.00	$2,160.00
	ELECTRICAL AT PUMP STATION[1]				**$10,492,330.00**
	25kV RECLOSER	2	EA	$ 37,500.00	$ 75,000.00
	12MVA/20MVA UNIT SUBSTATION TRANSFORMER (25kV TO 6.9kV)	2	EA	$ 252,000.00	$ 504,000.00
	6.9kV METAL CLAD SWITCHGEAR (MAIN-TIE-MAIN)	1	EA	$ 1,918,000.00	$ 1,918,000.00
	3000HP, 6.9kV ADJUSTABLE FREQUENCY DRIVE WITH BYPASS, NEMA 1 ENCLOSURE	3	EA	$ 1,222,380.00	$ 3,667,140.00
	POWER FACTOR CORRECTION STEPPED BANK	1	EA	$ 1,050,000.00	$ 1,050,000.00
	750KVA PAD MOUNTED TRANSFORMER (6.9kV TO 480Y/277V)	2	EA	$ 31,920.00	$ 63,840.00
	480V SWITCHBOARD WITH MAIN-TIE-MAIN	1	EA	$ 203,000.00	$ 203,000.00
	75KVA TRANSFORMER (480-208Y/120V)	1	EA	$ 15,030.00	$ 15,030.00
	208Y/120V PANELBOARD (42 CIRCUIT, 200A MAIN BREAKER)	1	EA	$ 7,000.00	$ 7,000.00
	MISC. PANELS (LIGHTING CONTACTORS, SUMP PUMP PANEL, RELAY PANELS, ETC.)	1	LS	$ 23,400.00	$ 23,400.00
	MISC. ELECTRICAL (GROUNDING, LIGHTS, RECEPTACLES, ETC.)	1	LS	$ 75,000.00	$ 75,000.00
	LIGHTNING PROTECTION SYSTEM	1	LS	$ 35,000.00	$ 35,000.00
	VIDEO SURVEILLANCE AND ACCESS CONTROLS SYSTEM	1	LS	$ 200,000.00	$ 200,000.00
	ELECTRICAL MANHOLES	1	EA	$ 9,200.00	$ 9,200.00
	CABLE TRAY IN ELECTRICAL ROOM	1	LS	$ 222,330.00	$ 222,330.00
	CABLE TRAY IN PUMP ROOM	1	LS	$ 306,640.00	$ 306,640.00
	CABLE AND CONDUIT	1	LS	$ 1,772,650.00	$ 1,772,650.00
	FIBER OPTIC CABLE AND CONDUIT FROM INTAKE TO PUMP STATION	1	LS	$ 63,400.00	$ 63,400.00
	FIBER OPTIC CABLE AND CONDUIT FROM METER VAULT TO PUMP STATION	1	LS	$ 31,700.00	$ 31,700.00
	INSTRUMENTATION	1	LS	$ 50,000.00	$ 50,000.00
	SCADA	1	LS	$ 150,000.00	$ 150,000.00
	START-UP AND TESTING	1	LS	$ 50,000.00	$ 50,000.00
	ELECTRICAL AT METER VAULT[1]				**$154,840.00**
	ELECTROMAGNETIC SPOOL PIECE FLOW METER WITH REMOTE TRANSMITTER	1	EA	$ 39,540.00	$ 39,540.00
	100A, 120/240V SERVICE ENTRANCE FUSED DISCONNECT, NEMA 4X, 316 SS	1	LS	$ 5,100.00	$ 5,100.00
	120/240V PANELBOARD (24 CIRCUIT, 100A MAIN BREAKER)	1	LS	$ 5,500.00	$ 5,500.00
	MISC. ELECTRICAL (GROUNDING, LIGHTS, RECEPTACLES, ETC.)	1	LS	$ 15,000.00	$ 15,000.00
	LIGHTNING PROTECTION	1	LS	$ 5,000.00	$ 5,000.00
	VIDEO SURVEILLANCE AND ACCESS CONTROLS SYSTEM	1	LS	$ 15,000.00	$ 15,000.00
	CABLE AND CONDUIT	1	LS	$ 40,000.00	$ 40,000.00
	MISC. INSTRUMENTATION (PRESSURE, LEVEL FLOATS, INTRUSION DETECTORS ETC.)	1	LS	$ 4,500.00	$ 4,500.00
	SCADA	1	LS	$ 25,000.00	$ 25,000.00
		SUBTOTAL			$39,449,730
		CONTINGENCY		15%	$5,917,460
		SUBTOTAL			$45,367,190
		MOBILIZATION		5%	$2,268,360
		SUBTOTAL			$47,635,550
		OH & P		15%	$7,145,340
PROJECT TOTAL					**$54,780,900**

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	YARD PIPING - METER VAULT SITE (STA 16+00) TO EMERGENCY SPILLWAY - MOVE TO CMAR NO. 5 (PIPELINES)				**$3,867,496.61**
	90" TRANSMISSION PIPELINE	3,464	LF	$1,080.00	$3,741,120.00
	90" FLOWABLE FILL ENCASEMENT (Dam Crest Crossing)	409	CY	$100.00	$40,912.61
	12" BOV WITH MANHOLE	2	EA	$28,000.00	$56,000.00
	8" CAV WITH MANHOLE	1	EA	$26,000.00	$26,000.00
	TRENCH SAFETY	3,464	LF	$1.00	$3,464.00
		SUBTOTAL			$3,867,500
		CONTINGENCY		15%	$580,130
		SUBTOTAL			$4,447,630
		MOBILIZATION		5%	$222,390
		SUBTOTAL			$4,670,020
		OH & P		15%	$700,510
PROJECT TOTAL					**$5,370,600**

NOTES

[1] Does not include the cost for new electrical service from the FCEC Substation. Service at 25 kV from substation will be included in power supply project.

FREESE AND NICHOLS

LOWER BOIS D'ARC RESERVOIR
NORTH TEXAS MUNICIPAL WATER DISTRICT
PUMP STATION CONFIGURATION STUDY

OPINION OF PROBABLE CONSTRUCTION COST, PHASE 2

June 30, 2015

ESTIMATOR	CHECKED BY	ACCOUNT NO
ARP	SAM	NTD14295

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	PUMP STATION SITEWORK				**$0.00**
	PUMP STATION MECHANICAL				**$20,013,843.40**
	54" GATE VALVE	6	EA	$ 323,400.00	$ 1,940,400.00
	30" THRUST HARNESS (SUCTION SIDE)	6	EA	$ 17,630.60	$ 105,783.60
	HIGH HEAD HORIZONTAL PUMP (7400 HP)	6	EA	$ 2,350,000.00	$ 14,100,000.00
	20" THRUST HARNESS (DISCHARGE SIDE)	6	EA	$ 11,753.30	$ 70,519.80
	42" PUMP CONTROL CONE VALVE	6	EA	$ 539,000.00	$ 3,234,000.00
	48" THRUST HARNESS (DISCHARGE SIDE)	6	EA	$ 28,210.00	$ 169,260.00
	48" BUTTERFLY VALVE (300 PSI)	6	EA	$ 51,480.00	$ 308,880.00
	MISCELLANEOUS APPURTENANCES	1	LS	$ 85,000.00	$ 85,000.00
	ELECTRICAL				**$14,663,720.00**
	25kV RECLOSER	2	EA	$ 37,500.00	$ 75,000.00
	12MVA/20MVA UNIT SUBSTATION TRANSFORMER (25kV TO 6.9kV)	2	EA	$ 252,000.00	$ 504,000.00
	6.9 kV METAL CLAD SWITHCGEAR (MAIN TIE MAIN)	1	EA	$ 1,848,000.00	$ 1,848,000.00
	7500HP, 6.9kV ADJUSTABLE FREQUENCY DRIVE BYPASS, NEMA 1 ENCLOSRE	6	EA	$ 1,451,510.00	$ 8,709,060.00
	POWER FACTOR CORRECTION STEPPED BANK	1	EA	$ 1,050,000.00	$ 1,050,000.00
	750KVA PAD MOUNTED TRANSFORMER (6.9kV TO 480Y/277V)	1	EA	$ 31,920.00	$ 31,920.00
	MISC. ELECTRICAL (GROUNDING, ETC.)	1	LS	$ 7,500.00	$ 7,500.00
	CABLE AND CONDUIT	1	LS	$ 2,288,240.00	$ 2,288,240.00
	INSTRUMENTATION & CONTROL PANEL MODIFICATIONS	1	LS	$ 15,000.00	$ 15,000.00
	SCADA MODIFICATIONS	1	LS	$ 85,000.00	$ 85,000.00
	START UP AND TESTING	1	LS	$ 50,000.00	$ 50,000.00

SUBTOTAL:		$34,677,570
CONTINGENCY	15%	$5,201,640
SUBTOTAL:		$39,879,210
MOBILIZATION	5%	$1,993,970
SUBTOTAL:		$41,873,180
OH & P	18%	$7,537,180

PROJECT TOTAL	**$49,410,400**

NOTES:

PART D
#54

TECHNICAL MEMORANDUM

FREESE AND NICHOLS
Innovative approaches
Practical results
Outstanding service

4055 International Plaza, Suite 200 • Fort Worth, Texas 76109 • 817-735-7300 • fax 817-735-7491

TO:	Robert McCarthy, P.E. North Texas Municipal Water District
FROM	Jeff Payne, P.E. John Rutledge, P.E.
SUBJECT:	Project No. 317 (NTD13136) NWTP Terminal Storage Reservoir Site Analysis
DATE:	January 23, 2014
Cc:	

JOHN LEE RUTLEDGE
65045
1-23-14

FREESE AND NICHOLS, INC.
TEXAS REGISTERED
ENGINEERING FIRM
F – 2144

1.00 INTRODUCTION

This memorandum supersedes the previous version of the same name and dated August 2, 2013.

The previous version of this memo documents the site analyses for three potential reservoir sites: Sites 1, 2, and 3. The recommended site in that memorandum was Site 3. After that recommendation there were additional discussions with the NTMWD regarding their desire to explore additional sites. Sections 2.0 through 4.0 have been modified to not only include the analysis for the original three sites, but also the additional sites studied. Section 5.0 was added to further explore Site 1 and the summary and recommendations provided in Section 7.0 was updated to reflect the results of the new analysis.

As part of the Lower Bois d' Arc Creek Reservoir (LBCR) Final Pipeline Alignment Study project, FNI was tasked with analyzing potential Terminal Storage Reservoir (TSR) sites near the future North Water Treatment Plant (NWTP) in Leonard, Texas.

In previous studies, the ultimate reservoir capacity had been set at 560 MG. This represents approximately two days of storage at peak demands, given that the NWTP will ultimately be a 280 MGD plant. It has been assumed that the TSR will be constructed in two phases of 280 MGD each. The first phase would be constructed prior to commissioning of the NWTP and the second phase would be scheduled to coincide with future expansions of the NWTP. These previous studies were conceptual and no information on the NWTP layout or hydraulic profile was available. The approximate ground level of 700 feet-msl at the NWTP was assumed and no detailed hydraulic analysis was performed. This study updates and provides a greater level of detail now that the hydraulic information for the NWTP is available. The intent is to provide the information necessary for the NTMWD to identify and procure a TSR site.

In addition to a site analysis to determine feasibility of seven sites, this memorandum also discusses the ability to send future LBCR water from each TSR site to the Wylie Water Treatment Plant via the Texoma-Wylie pipeline (currently under construction) and the potential future connector pipeline between the Texoma-Wylie pipeline and the NWTP.

The analysis performed for this memorandum is based on conceptual information for the NWTP and the current raw water pipeline alignment. During preliminary and final design, the assumptions used in this analysis should be verified and final hydraulic calculations will determine the final layout of the TSR, piping, and operational characteristics.

The potential costs discussed in Section 4.0 of this memorandum are not intended to be the final Opinions of Probable Construction Cost (OPCC) as many of the related items, such as inlets, outlets, piping, security, and electrical items are not included as they would be similar at all sites and are not likely to be part of the key differential costs. Section 5.0 provides a detailed cost estimate for Site 1 which was developed during additional analysis of the site.

2.00 POTENTIAL TSR SITES

The location of the terminal storage reservoir was primarily based on proximity to the proposed water treatment plant and pipeline, existing development, and topography. A preliminary environmental desktop analysis was performed for each of the original three proposed TSR sites. The analysis included a review of aerial photographs, USGS 7.5-minute topographic maps, and the U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) data. According to the USFWS, the only endangered species listed for Fannin County is the least tern (Sterna antillarum). No impacts to this species or its habitat would be expected to occur as a result of constructing any of these TSR alternatives.

Three sites were initially chosen for the conceptual analysis of the TSR. Based on further discussion with NTMWD it was decided to look at additional TSR sites. A preliminary environmental desktop analysis was not performed for the additional TSR sites analyzed. The TSR sites included in the analysis are shown in **Figure 2.1**.

Site 1 is located just west of CR 4965 and north of CR 4945, within the Trinity River Basin. This site is located near both the proposed pipeline and the proposed treatment plant, just north of the proposed site for the water treatment plant. Site 1 is readily accessible via existing roadways, including US Highway 69. Site 1 is located entirely in the Trinity River Basin, however, can be designed to spill into the Red River Basin. This site appears to be located in an area dominated by agricultural fields. Although the USGS topo maps and NWI data do not indicate the presence of any streams, open waters, or wetlands, the aerial photos show that a drainage swale or ditch is located on the west side of the site. This feature was likely constructed in order to establish proper drainage of the site to maximize the area that could be cultivated. This feature appears to drain from east to west across the site eventually draining into an unnamed stream located west and outside of this TSR alternative. It is not possible to determine from a desktop level if this feature would be considered jurisdictional by the USACE and will require further on-site investigations to make that determination.

Site 2 is located north of the City of Leonard, near CR 4720 and FM 896. Site 2 is located predominantly in the Red River Basin and could be designed to spill directly into the Red River Basin. Although being located further away from the plant than Site 1, Site 2 provides better existing topography for the TSR, based on required minimum operating water surface elevations, which are discussed further in Section 3.00. Site 2 is located along the proposed pipeline and also is readily accessible via existing roadways. This site also appears to be dominated by agricultural fields. Although the USGS topo maps and NWI data do not indicate the presence of any streams, open waters, or wetlands, the aerial photos show that a pond is located within the west cell. This pond appears to be isolated and would likely not be considered jurisdictional by the USACE; however, further on-site investigations will be needed to make this determination. The NWI data and the aerials also indicate the presence of an additional pond located just outside but near the far southwest corner of the west cell. This feature appears to be isolated as well and it does not appear that it would be impacted by construction.

Site 3 is located northwest of the City of Leonard, near CR 4670 and CR 4665. Site 3 is located predominantly within the Trinity River Basin, however, based on the configuration, it could be designed as such that spill events would occur through the north cell, into the Red River Basin. Similar to Site 2, the existing topography at Site 3 provides a reasonable fit to the required minimum operating water surface elevations. Site 3 is also located along the proposed pipeline and is readily accessible via existing roadways, including US Highway 69. This site appears to be dominated by agricultural fields as well. Although the USGS topo maps and NWI data do not indicate the presence of any streams, open waters, or wetlands, the aerial photos show that a pond is located within the north cell. This pond appears to be isolated and would likely not be considered jurisdictional by the USACE; however, further on-site investigations will be needed to make this determination. The aerials also indicate that two drainage swales or ditches (one on the far northwest corner of the site and one located in the north cell behind the house to the south) are present. Again, these features were likely constructed in order to establish proper drainage of the site to maximize the area that could be cultivated. It is not possible to determine from a desktop level if these features would be considered jurisdictional by the USACE, and it will require further on-site investigations to make that determination.

Site 4 is located northeast of the City of Leonard, north of State Highway 78 and South of FC 4840. Site 4 is located predominantly in the Sulphur River Basin, however, can be designed to spill into the Red River Basin, from the north side of the TSR, which crosses into the Red River Basin. Site 4 is located along the proposed pipeline and has reasonable accessibility from State Highway 78. The existing topography at Site 4 is such that it will require substantial fill to construction the embankment based on the required minimum operating water surface elevations. Due to the distance from the NWTP, it would be necessary to have double pipelines to convey water from Site 4 to the NWTP with suitably low energy losses.

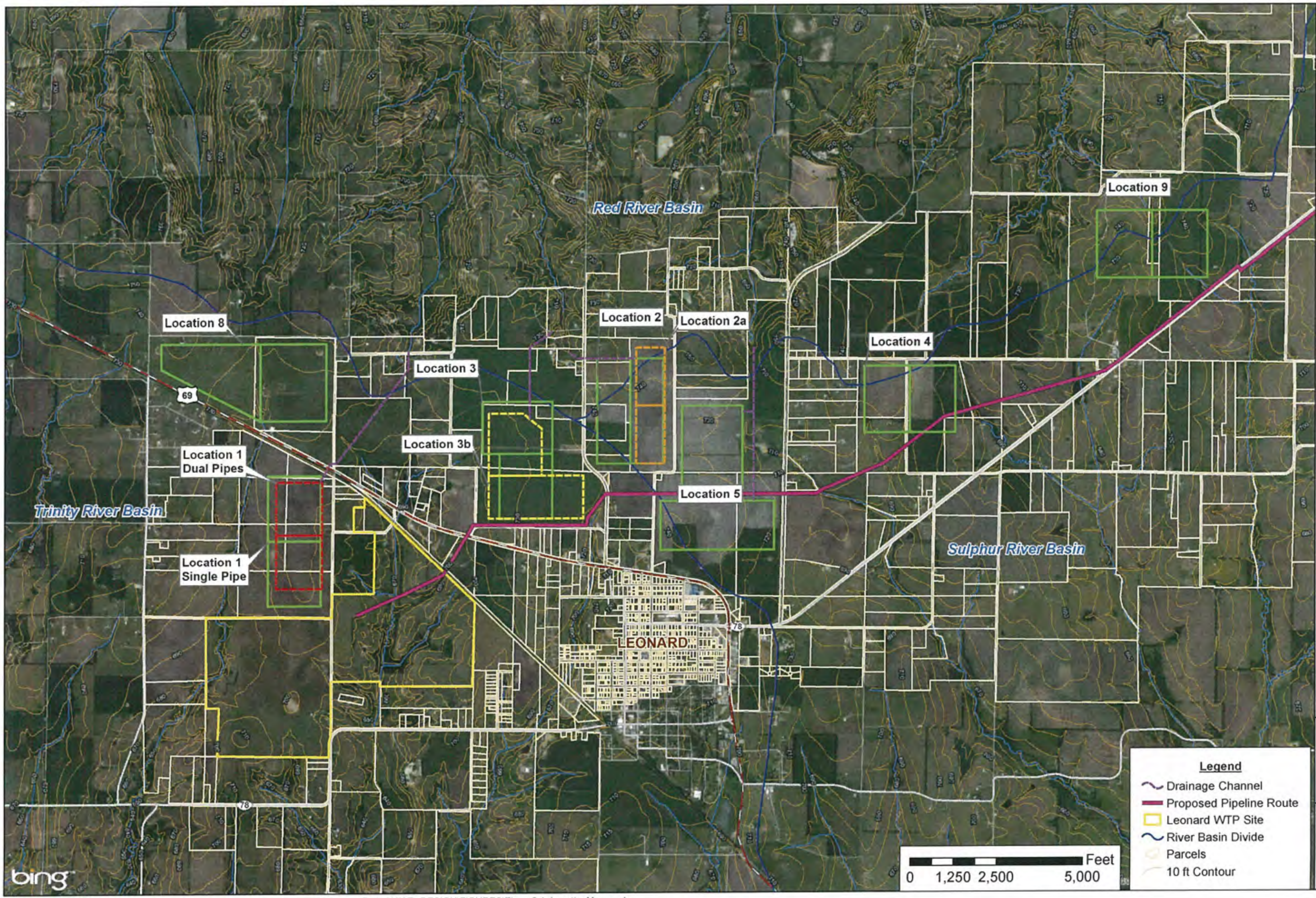
Site 5 is located north of the City of Leonard, partially within the ETJ for the City. It is located entirely in the Sulphur and Trinity River Basins. The construction of a pipe or channel would allow spill events to be conveyed north into the Red River Basin. Site 5 is located along the proposed pipeline and is readily accessible via FM1553 to the east and FC 4720 to the west. US Highway 69 is also located south of the proposed site. The existing topography is such that Site 5 provides a reasonable fit to the required minimum operating water surface elevations.

Site 8 is located northwest of the City of Leonard, north of US Highway 69. It is located entirely in the Trinity River Basin, however, can be designed to spill to the Red River Basin from the north portion of the TSR. Site 8 is readily accessible from the south via US Highway 69, from the east via County Road 4655 and from the west via County Road 4625; however, it is not located along the proposed pipeline. Existing topography allows for a reasonable fit for Site 8 based on the required minimum operating water surface elevations.

Site 9 is located northeast of the City of Leonard and is the furthest site east that was considered reasonably feasible for the TSR. Site 9 is located along the proposed pipeline and is fairly accessible from State Highway 78 to the south and FC 4810 which runs along the west portion of the site. Site 9 is located predominantly in the Sulphur River Basin; however half of the west cell is located in the Red

River Basin, therefore, allowing the site to be drained to the Red River Basin. Due to the distance from the NWTP, to maintain a reasonable minimum water surface elevation, it would be necessary to have double pipelines to convey water from Site 9 to the NWTP.

Sites 1, 2, 3, and 5 will require a significant drainage channel or pipe as well as an easement to effectively drain to the Red River Basin. These conceptual channels are also shown in **Figure 2.1**. During preliminary design the drainage channel and stream should be studied further to determine the extent of improvements required.



Date Saved: 12/2/2013 11:00:46 AM

Path: H:\WR_DESIGN\FIGURES\Figure2.1_LocationMap.mxd

FN PROJECT NO NTD13136
DATE CREATED Date 12/2/2013
DATUM & COORDINATE SYSTEM NAD83 State Plane (feet) Texas North Central
FILE NAME Name Figure2.1_LocationMap
PREPARED BY ERN

N
W E
S

LOWER BOIS D' ARC FINAL PL ALIGNMENT

Terminal Storage Reservoir

Location Map

FREESE NICHOLS

Freese and Nichols, Inc.
4055 International Plaza
Suite 200
Fort Worth, TX 76109
P: 817-735-7300

FIGURE

2.1

3.00 REQUIRED MINIMUM WSE

Under a separate task in this contract, a preliminary hydraulic profile for the future NWTP has been established. This profile is based on the ultimate plant capacity of 280 MGD and is considered worst-case because it uses conventional treatment technologies similar to what the NTWMD has at the Wylie and Tawakoni WTPs. This profile elevation at the beginning of the WTP processes is 711 feet above MSL. Even though this elevation in the WTP is considered worst-case from a treatment technology standpoint, the elevation cannot be higher than this so that the NTMWD maintains the flexibility to send Lake Texoma water to the NWTP under a future operational scenario that is not part of the LBCR.

Generally speaking, the further away the TSR site is from the NWTP, the higher the minimum WSE in the TSR must be. This is due to increased friction losses between the TSR and the headworks of the WTP. Friction losses are defined as major losses, while turbulence due to discontinuities is equated by minor losses. The pipeline major losses were calculated using the Hazen-Williams equation as seen below.

$$H_L = \frac{10.44\,L\,Q^{1.85}}{C^{1.85}D^{4.87}}$$

In this form of the equation, L is the pipeline length in feet, Q is the flow rate in gallons per minute, C is the Hazen-Williams coefficient, and D is the pipe diameter in inches. Values for the length varied for each potential TSR site and can be found in **Table 3.1**. These values were based on the pipeline alignment shown in **Figure 2.1** and include a 5 percent factor to account for increased length that may be added under the final pipeline routing. The maximum design flow between the TSR and NWTP is a peak of 236 MGD (The maximum withdrawal rate from LBCR), which was converted to GPM for use in the equation. A Hazen-Williams coefficient of 120 was used since it is the future value for concrete or mortar lined steel pipe which accounts for age and biofilm. Each reservoir site was analyzed for pipe sizes ranging from 90 inch to dual 108 inch pipes in order to determine the most efficient pipe size to transport water from the TSR to the WTP. The calculations summarized in the body of this memorandum are based on a 96 inch pipe, but major losses were also calculated for diameters of 90 inches, 102 inches, 108 inches, and dual pipes. These values can be found in **Appendix A**. The major losses calculated can be seen in **Table 3.1**. The conceptual sizes previously developed assumed a 90-inch pipeline between the TSR and the NWTP, but larger pipe capacities were required to be examined in order to ensure all reservoir sites are capable of operating at peak flow for low water surfaces elevations.

Table 3.1 – Minimum Water Surface Elevation (96-inch pipe)

TSR Site	Pipeline Length (ft)	Major Losses (ft)	Minor Losses (ft)	Minimum WSE (ft)
1	3500	5.12	4.68	721.65
2	12500	18.30	4.68	734.82
3	6500	9.51	4.68	726.04
4	6500	28.54	4.68	745.07
5	11500	16.83	4.68	733.36
8	9000	13.17	4.68	729.70
9	28500	41.72	4.68	758.24

Minor losses for the pipeline from the TSR to the WTP were associated with fittings, appurtenances, and the reservoir exit structure. Losses from fittings and appurtenances were calculated using the minor headloss equation below.

$$H_M = \sum K \frac{V^2}{2g}$$

For this calculation, ∑K is the summation of the minor loss coefficients of pipeline fittings and appurtenances, V is the velocity in feet per second, and g is the acceleration due to gravity, which is equal to 32.174 feet per second squared. K was calculated to be 5.7, or the summation of 0.25 for the rounded pipeline entrance from the reservoir exit structure, four 90° bends at 0.8 each, six 45° bends at 0.2 each, and three butterfly valves at 0.35 each. Velocity for a 96 inch pipe at a flow rate of 236 MGD was calculated to be 7.27 ft/s. The velocities and the minor losses calculated for all pipe diameters can be found in **Appendix A**. All of the TSR sites had the same minor losses due to the fact that the assumption regarding the number of fittings and minor loss coefficients remained constant regardless of the site option. In actuality, each site will have slightly different minor losses due to differences in the number and angle of horizontal and vertical bends. Since the pipeline alignment from the TSR sites to the WTP has not been finalized and to account for pipe routing inside the plant, the 10 bends were included as an estimate. Since good large diameter pipeline design practice is to limit the number of horizontal and vertical fittings so during the final alignment and final design, the number of fittings estimated is most likely conservative resulting in a decrease in minor losses.

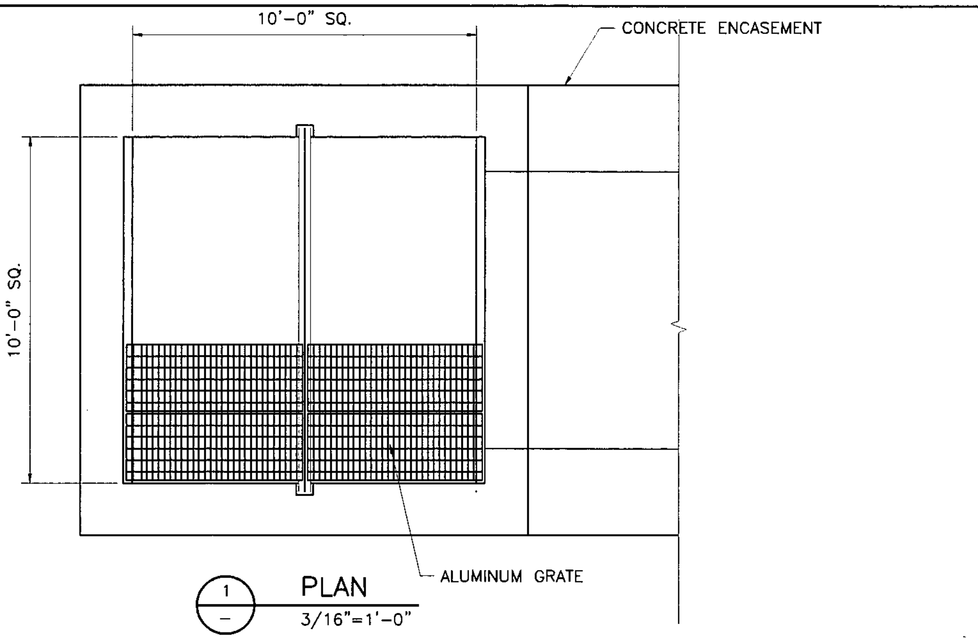
The minor losses of the reservoir exit structure were associated with the concrete structure and the aluminum grate. A conceptual level detail of this structure is shown in **Figure 3.1**. The minor loss equation from above was used to calculate the losses for both items, but they were calculated separately and then combined since the velocities through the grate and structure are different. The velocity as the water flows into the ten foot square concrete structure will be 3.65 ft/s. The K used for the projecting entrance was 0.8, and when input along with the velocity into the minor loss equation, the entrance losses for the concrete structure equaled 0.17 feet. The velocity of the water through the aluminum grate was calculated by first finding the open area of the grate. The grate was assumed to be 2 inches by 3/16 inches, bearing bars 13/16 inch center to center, and 3/16 inch rectangular cross bars 4 inch center to center. This resulted in an open area of 70 ft^2. The velocity was then calculated by taking the flow rate, 236 MGD converted to cfs, divided by 70 ft^2. The velocity was found to be 5.22 ft/s. The K used for the grate was 1.6, which is a typical value for a bar screen. When these values are input into the minor loss equation, the resulting headloss is 0.68 feet. This means the total headloss of the combined reservoir exit structure is equal to 0.85 feet. It is assumed that all of the TSR sites will have the same structure and therefore the same headloss. It has also been assumed that the aluminum grate will be cleaned on a regular basis and headloss values will remain approximately the same. The calculations for the outlet structure were also performed using general weir flow assumptions and these calculations showed that with approximately two feet of water over the top of the structure was sufficient to maintain adequate flow. Based on these calculations, to maintain a discharge of 236 MGD, it is recommended that the minimum water surface elevation is at least two feet above the top of the reservoir outlet structure.

The minimum water surface elevation of the TSR was calculated for each of the potential sites by combining the above headlosses and adding the total to the elevation of the WTP headworks. The WTP headworks elevation was assumed to be 711 feet-msl based on the hydraulic profile provided under a separate task. The calculated values for the minimum water surface elevation, assuming a 96-inch pipe between the TSR and the NWTP, of each of the potential TSR sites can be found in **Table 3.1**. The site closest to the WTP is Site 1, which has a required water surface elevation of approximately 722 feet-msl. The highest WSE required, 758.25 feet-msl, is at Site 9 since it is about 28,500 feet from the WTP. The full analysis of increasing the pipe diameter to 102 inches, 108 inches, or installing dual pipelines in order to decrease the headlosses from the TSR to the WTP can be found in **Appendix A**. The minimum WSE lowers by at least 2 feet and as much as 5 feet for the various sites when the pipe diameter is increased from 96 inches to 102 inches. And while the WSE continues to decrease for 108 inches, it is at a declining rate. The minimum WSE could also be lowered by increasing the size of the inlet structure or the effective area of the aluminum grate. Lowering the minimum WSE may allow a more efficient use of the terrain when constructing the reservoir.

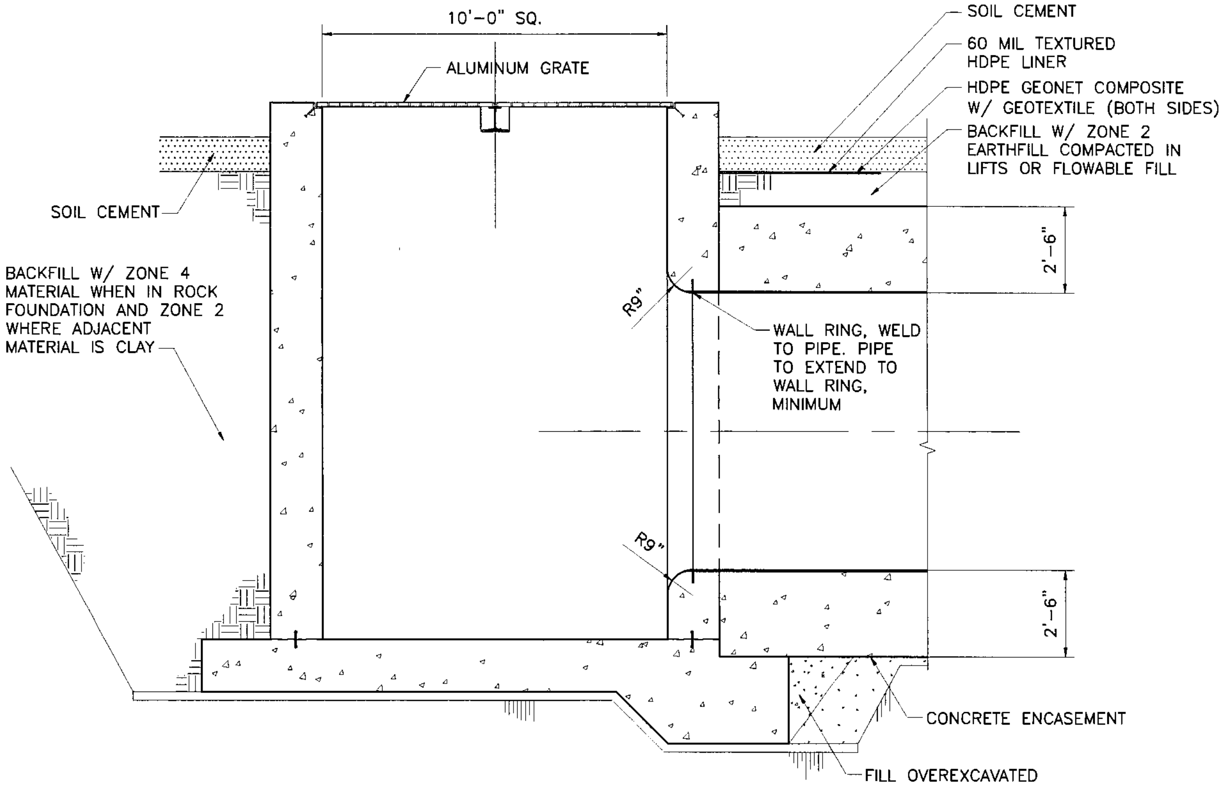
Based on ground elevation investigations and the reservoir layout design process described in Section 4.00, several pipe sizes were determined to be inadequate for various TSR locations. Location 1 was concluded to require dual 102 inch pipelines because of the similarity of elevations of the TSR and the WTP headworks. Location 4 and 9 were both determined to require dual 96 inch pipelines due to high headloss associated with the large distance between the TSR and the WTP. Location 5 would require a 102 inch pipeline because of low ground elevations at the TSR site and the headloss of the large length of pipeline from the TSR site to the WTP. Location 2, 3, and 8 were all identified to only require a single 96 inch pipeline to the WTP. All three had a high enough ground elevation to gravity flow from the TSR to the WTP, while maintaining a desirable minimum water surface elevation. T**able 3.2** below summarizes the calculations performed for the seven TSR locations using the optimal pipe size determined.

Table 3.2 – Minimum Water Surface Elevation (various pipe sizes)

TSR Site	Pipe Diameter (IN)	Pipeline Length (ft)	Major Losses (ft)	Minor Losses (ft)	Minimum WSE (ft)
1	Dual 102	3500	1.06	0.92	713.82
2	96	12500	18.30	4.68	734.82
3	96	6500	9.51	4.68	726.04
4	Dual 96	19500	7.92	1.17	720.93
5	102	11500	12.53	3.67	728.05
8	96	9000	13.17	4.68	729.70
9	Dual 96	28500	11.57	1.17	724.59



① PLAN
3/16"=1'–0"



DRAFT

THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF INTERIM REVIEW UNDER THE AUTHORITY OF JASON V. WARD P.E. TEXAS NO: 107836 ON DATE: 6/25/2013 IT IS NOT TO BE USED FOR CONSTRUCTION, BIDDING OR PERMIT PURPOSES.

② SECTION
3/16"=1'–0"

Freese and Nichols, Inc.
Texas Registered Engineering Firm F–2144

FREESE AND NICHOLS
4055 International Plaza, Suite 200
Fort Worth, Texas 76109–4895
Phone – (817) 735–7300
Fax – (817) 735–7491

NORTH TEXAS MUNICIPAL WATER DISTRICT
LOWER BOIS D' ARC TERMINAL
STORAGE RESERVOIR

OUTLET

F&N JOB NO.	NTD13136
DATE	JUNE 2013
SCALE	AS SHOWN
DESIGNED	EJE
DRAFTED	WFA
FILE	OUTLET.dwg

3.1
FIGURE

Date: Jun 25, 2013 – 3:36pm User: 02139
File: N:\util\EXHIBITS\OUTLET.dwg

4.00 CONCEPTUAL TSR LAYOUT

4.01 GENERAL PARAMETERS

The seven analyzed TSR sites are all based on a two phase construction, which will be in line with the phased expansion of the water treatment plant. The TSR is intended to provide a two day storage capacity at peak demands for the plant. At completion, both cells will provide 560 MG of storage, 280 MG in each cell. The phased construction of the TSR will require one cell to be completed prior to the construction of the second cell. The phased construction of the cells is discussed further for each site in the following discussion.

The TSR will consist of an earthen embankment with 4 horizontal to 1 vertical (4H:1V) interior and exterior slopes. The slope of the reservoir is based on available soil data and could be modified after geotechnical borings are drilled and data analyzed. The interior of the reservoir will be lined with 12 inches of soil cement and the exterior slope will have grass cover. For this analysis and costs provided, a combination of soil cement and HDPE liner is assumed on the interior slopes and bottom of the reservoir. The soil cement and HDPE liner may not be necessary on the reservoir bottom if a compacted clay bottom is feasible and a hard surface is not needed for maintenance. During final design, the use of soil cement on the floor of the reservoir should be analyzed and discussed with the NTMWD. The necessity of a soil cement bottom will be based on analysis of the geotechnical borings and cleanout requirements for the TSR There is a significant amount of soil cement associated with a reservoir this large, and hence a significant amount of capital cost. The operations and maintenance of the TSR should be discussed to determine if the soil cement floor is desired. The embankment will have a crest width of 20 feet, which will consist of an eight inch thick flexible road base for vehicular traffic.

A minimum of two feet above the outlet was determined to provide adequate hydraulics for the outlet structure. An additional one foot below the outlet structure was assumed for siltation. Therefore, the bottom elevation for the reservoir was three feet lower than the minimum operating elevation.

For clarification, the minimum operating elevation, in regard to the conceptual TSR analysis, is the elevation above which the capacity is used to meet the required 280 MG of storage per cell. For this analysis, this elevation is equivalent to or greater than the minimum elevation that is hydraulically required for gravity flow from the TSR to and through the water treatment plant. Capacity below this elevation is not used to compute the total 280 MG, however, will provide additional storage in the reservoir, in excess to the required 280 MG. The required pipe diameter for each site was provided in **Table 3.2** of Section 3.00

Freeboard between the operating elevation and the top of embankment was assumed to be seven feet. This freeboard, which was extrapolated based on reservoir size from the NTMWD Texoma Balancing Reservoir freeboard, will provide wave run-up protection for the reservoir.

4.02 SITE 1 – NEAR THE PROPOSED TREATMENT PLANT

Site 1 will consist of two cells of equal size, with a top of embankment footprint for each cell of 1,890 feet by 1,520 feet. This footprint is similar to the reservoir footprint determined for this location in 2011. Site 1 will have a proposed reservoir bottom elevation of 710 feet-msl. This elevation is based on the existing topography which is 11 feet lower than the required minimum water surface elevation. There will be significant storage capacity that will exist below the minimum water surface elevation of 721 feet-msl. The normal operating elevation will be 736 feet-msl and the top of embankment elevation will be 743 feet-msl. **Table 4.1** shows the elevation – area – capacity for Site 1. As shown in **Table 4.1**, there is 179 MG of storage below the minimum operating elevation that does not contribute to the required 280 MG capacity. This, in effect, means that Site 1 would be significantly over-sized to utilize the existing topography.

Due to the lower existing elevations at Site 1, minimal excavation will be possible. Therefore, the Site 1 TSR will be constructed primarily of fill that will be brought into the site. The estimated cost of Site 1 is shown in **Tables 4.2** and **4.3**. The combined total cost of both cells of the Site 1 TSR is approximately $58,387,000. This cost does not include required piping and inlet and outlet structures which would be considered equal for all sites and hence were not included in this analysis. Technical services and contingencies, as well as land acquisition costs have also not been included at this time.

While Site 1 is located entirely in the Trinity River Basin, it is feasible to design a morning glory-type spillway from the north cell which will convey any discharge to the Red River Basin via an approximately one mile long pipe.

Table 4.1 – Site 1 Elevation – Area – Capacity (One Cell)

Elevation (ft)	Area (acres)	Total Reservoir Capacity (MG)	Capacity Above Min. WSEL (MG)
710	46.88	0	
712	47.95	31	
714	49.02	63	
716	50.11	95	
718	51.21	128	
720	52.32	162	
721*	52.88	179	0
722	53.45	196	17
724	54.58	231	53
726	55.73	267	88
728	56.89	304	125
730	58.06	341	163
732	59.24	380	201
734	60.43	419	240
736**	61.64	458	280
738	62.86	499	320
740	64.08	540	362
742	65.33	582	404
743***	65.95	604	425

*Minimum required water surface elevation for 236 MGD to NWTP
**Normal operating elevation with 280 MG of storage above Min. WSE
***Top of embankment

Table 4.2 – Site 1 – South Cell Cost Estimate

Description	Quantity		Unit Cost	Cost
Excavation	26,522	CY	$5	$133,000
Compacted Fill	1,623,684	CY	$8	$12,989,000
Gravel	6,315	CY	$100	$631,000
Soil Cement	114,435	CY	$85	$9,727,000
Road base	3,368	CY	$90	$303,000
Liner	2,907,025	SF	$1.20	$3,488,000
Subtotal				$27,272,000
25% For Mobilization, Electrical, and Misc. Items				$6,818,000
Total				$34,090,000

Table 4.3 – Site 1 – North Cell Cost Estimate

Description	Quantity		Unit Cost	Cost
Excavation	166,056	CY	$5	$830,000
Compacted Fill	881,107	CY	$8	$7,049,000
Gravel	4,907	CY	$100	$491,000
Soil Cement	102,649	CY	$85	$8,725,000
Road base	2,617	CY	$90	$236,000
Liner	1,755,625	SF	$1.20	$2,107,000
Drainage Pipe	1	LS	$2,000,000	$2,000,000
Subtotal				$21,437,000
25% For Mobilization, Electrical, and Misc. Items				$5,359,000
Total				$26,797,000

4.03 SITE 2 – NORTH OF LEONARD

Site 2 will consist of two cells of equal size, with a top of embankment footprint for each cell of 965 feet by 3,050 feet. Site 2 will have a proposed reservoir bottom elevation of 732 feet-msl. This elevation is based on the existing topography which ranges from approximately 730 feet to 745 feet. A proposed bottom elevation of 732 feet-msl provided an approximate cut-fill balance. The normal operating elevation will be 750 feet-msl and the top of embankment elevation will be 757 feet-msl. **Table 4.4** shows the elevation – area – capacity for Site 2. As shown in **Table 4.4**, there is 50 MG of storage at the minimum operating elevation that does not contribute to the required 280 MG capacity. This storage is due to the three foot difference used for maintaining the outlet hydraulics and siltation. Unlike Site 1, the two cells for Site 2 will lay beside each other in an east-west direction instead of north-south. This was done to achieve an approximate cut-fill balance per cell, due to the phased construction of the TSR.

Site 2 has a reasonable cut-fill balance for each cell; however some imported fill will be needed for the west cell and some waste will occur at the east cell. The phasing of the construction will not alleviate the required imported fill or waste, and would likely result in increasing the imported fill required for construction of the Phase II cell. The estimated cost of Site 2 is shown in **Tables 4.5** and **4.6**. The combined total cost of the Site 2 TSR is approximately $44,846,000. This cost does not include required piping and inlet and outlet structures which would be considered equal for all sites. Technical services and contingencies, as well as land acquisition costs have also not been included at this time.

Table 4.4 – Site 2 Elevation – Area – Capacity (One Cell)

Elevation (ft)	Area (acres)	Total Reservoir Capacity (MG)	Capacity Above Min. WSEL (MG)
732	50.05	0	
734	51.39	33	
735*	52.06	50	0
736	52.73	67	17
738	54.09	102	52
740	55.46	137	88
742	56.84	174	124
744	58.23	212	162
746	59.63	250	200
748	61.05	289	239
750**	62.48	330	280
752	63.92	371	321
754	65.37	413	363
756	66.83	456	406
757***	67.57	478	428

*Minimum required water surface elevation for 236 MGD to NWTP
**Normal operating elevation with 280 MG of storage above Min. WSE
***Top of embankment

Site 2 is constrained on the east and west sides due to FM 896 and FC 4720. Also, there is one home that will be impacted by construction of the reservoir. Another home located north of the site would not currently be impacted by the reservoir. This property could potentially be avoided by slightly adjusting the reservoir footprint, or it could be purchased to provide additional buffer around the reservoir site for operations.

The majority of the TSR at Site 2 is located within the Red River Basin. The reservoir could be designed to spill and drain to the northwest to a creek west of FM 896. This concept is shown on **Figure 2.1**. Preliminary calculations for the drainage channel assumed a trapezoidal channel, with a bottom width of 8 feet, top width of 26 feet, depth of 3 feet, and 3H:1V side slopes. The channel would be lined with a 12 inch layer of riprap for erosion protection. This drainage channel, which would be required to spill into the Red River Basin, would cross FM 896 and would require a culvert and roadway improvements on FM 896. This is a potential drawback to Site 2.

Another potential drawback to Site 2 is maximum WSE of 750 feet-msl. In previous conceptual pipeline and pump station studies the average WSE of the TSR was assumed to be 700 feet-msl, and the controlling high point on the raw water pipeline HGL was an elevation of approximately 730 feet-msl. These elevations were assumed in the absence of any information on the NWTP process and resulting HGL. Now that there is a greater level of information available, these numbers are able to be refined. If the TSR were constructed at Site 2, it would raise the HGL for the raw water pipeline by approximately 20 feet. At a minimum this would result in additional energy costs for the NTMWD to pump to this higher elevation and may result in a portion of the raw water pipeline diameter increasing.

Table 4.5 – Site 2 – West Cell Cost Estimate

Description	Quantity		Unit Cost	Cost
Excavation	644,464	CY	$5	$3,222,000
Compacted Fill	633,280	CY	$3	$1,900,000
Gravel	7,435	CY	$100	$744,000
Soil Cement	111,664	CY	$85	$9,491,000
Road base	3,965	CY	$90	$357,000
Liner	4,030,057	SF	$1.20	$4,836,000
Drainage Channel	1	LS	$300,000	$300,000
Subtotal				$20,850,000
25% For Mobilization, Electrical, and Misc. Items				$5,213,000
Total				$26,063,000

Table 4.6 – Site 2 – East Cell Cost Estimate

Description	Quantity		Unit Cost	Cost
Excavation	543,303	CY	$5	$2,717,000
Compacted Fill	417,185	CY	$3	$1,252,000
Gravel	4,611	CY	$100	$461,000
Soil Cement	100,189	CY	$85	$8,516,000
Road base	2,459	CY	$90	$221,000
Liner	1,550,025	SF	$1.20	$1,860,000
Subtotal				$15,027,000
25% For Mobilization, Electrical, and Misc. Items				$4,859,000
Total				$18,783,000

Site 2 was re-analyzed to minimize the number of impacted property owners. As shown in **Figure 2.1**, Site 2a is reconfigured to fit entirely on one parcel, with the north cell constructed in Phase I and the south cell constructed in Phase II. To maintain a total combined storage of 560 MG, the normal operating level would be 775 feet-msl, which is an operating depth of 40 feet. This will require a significantly higher embankment elevation of 781 feet-msl. An operating elevation of 775 feet-msl is not feasible with for pipeline operations. The total combined cost for this option is $49,351,000. This cost does not include required piping and inlet and outlet structures which would be considered equal for all sites. Technical services and contingencies, as well as land acquisition costs have also not been included at this time. This option is not recommended.

Site 2a was also analyzed to determine the maximum storage feasible while maintaining a normal operating pool elevation 750 feet-msl which was 250 MG total between the two cells. This option had a total site cost of $25,486,000. This cost does not include required piping and inlet and outlet structures which would be considered equal for all sites. Technical services and contingencies, as well as land acquisition costs have also not been included at this time.

4.04 SITE 3 – NORTHWEST OF LEONARD

Site 3 will consist of two cells of different size and bottom elevation. The north cell will have a top of embankment footprint of 2,025 feet by 1,510 feet and a proposed reservoir bottom elevation of 725 feet-msl. The south cell will have a top of embankment footprint of 1,880 feet by 1,530 feet and a proposed reservoir bottom elevation of 724 feet-msl. These elevations are based on the existing topography which ranges from approximately 720 feet to 735 feet. The proposed bottom elevations provided an approximate cut-fill balance for each cell. The normal operating elevation will be 742 feet-msl and the top of embankment elevation will be 749 feet-msl. **Table 4.7** shows the elevation – area – capacity for Site 3. As shown in **Table 4.7**, there is storage of 55 MG in the north cell and 51 MG in south cell at the minimum operating elevation that does not contribute to the required 280 MG capacity. This storage is due to the three foot difference used for maintaining the outlet hydraulics and siltation. The varying size and bottom elevation for the north and south cells was done to achieve an approximate cut-fill balance per cell, due to the phased construction of the TSR.

Site 3 has a reasonable cut-fill balance for each cell; however some imported fill will be needed for the south cell and some waste will occur at the north cell. The phasing of the construction will not alleviate the required imported fill or waste, and would likely result in increasing the imported fill required for construction of the Phase II cell. The estimated cost of Site 3 is shown in **Tables 4.8** and **4.9**. The combined total cost of the Site 3 TSR is approximately $43,875,000. This cost does not include required piping and inlet and outlet structures which would be considered equal for all sites. Technical services and contingencies, as well as land acquisition costs have also not been included at this time.

Site 3 is constrained on the east and west sides due to CR 4665 and FM 896. Also, there are two homes nearby that could potentially be avoided by slightly adjusting the reservoir footprint. However, these two homes could be purchased to provide the NTMWD additional buffer and operating room. With the aforementioned constraints, Site 3 does provide flexibility in the footprint which could reduce required land acquisition.

Table 4.7 – Site 3 Elevation – Area – Capacity

North Cell				South Cell			
Elevation (ft)	Area (acres)	Total Reservoir Capacity (MG)	Capacity Above Min. WSEL (MG)	Elevation (ft)	Area (acres)	Total Reservoir Capacity (MG)	Capacity Above Min. WSEL (MG)
725	55.46	0		724	51.29	0	
726	56.04	18		726	52.41	34	
728*	57.21	55	0	727*	52.97	51	0
730	58.39	93	38	728	53.53	68	17
732	59.58	131	76	730	54.66	104	53
734	60.79	170	115	732	55.81	140	89
736	62.00	210	155	734	56.97	176	125
738	63.23	251	196	736	58.14	214	163
740	64.47	293	238	738	59.32	252	201
742**	65.72	335	280	740	60.52	291	240
744	66.99	379	323	742**	61.72	331	280
746	68.26	423	368	744	62.94	372	321
748	69.55	467	412	746	64.17	413	362
749***	70.20	490	435	748	65.41	455	404
				749***	66.03	477	426

*Minimum required water surface elevation for 236 MGD to NWTP
**Normal operating elevation with 280 MG of storage above Min. WSE
***Top of embankment

A small portion of the TSR at Site 3 is located within the Red River Basin. However, the reservoir could be designed to spill and drain to the north to a creek located on the west side of FM 896. This concept is shown on **Figure 2.1**. Preliminary calculations for the drainage channel assumed a trapezoidal channel, with a bottom width of 10 feet, top width of 28 feet, depth of 3 feet, and 3H:1V side slopes. The channel would be lined with a 12 inch layer of riprap for erosion protection. When the property for the reservoir is acquired, a drainage easement would also be required for construction of the drainage channel.

The maximum operating elevation of 742 feet-msl is 8 feet lower than Site 2. As discussed with Site 2, this is still higher than previously assumed controlling high points on the raw water pipeline and will result in higher pumping costs at a minimum. However, these costs are less than Site 2.

Table 4.8 – Site 3 – North Cell Cost Estimate

Description	Quantity		Unit Cost	Cost
Excavation	582,710	CY	$5	$2,914,000
Compacted Fill	537,100	CY	$3	$1,611,000
Gravel	6,546	CY	$100	$655,000
Soil Cement	115,990	CY	$85	$9,859,000
Road base	3,491	CY	$90	$314,000
Liner	3,124,056	SF	$1.20	$3,749,000
Drainage Channel	1	LS	$300,000	$300,000
Subtotal				$19,402,000
25% For Mobilization, Electrical, and Misc. Items				$4,850,000
Total				$24,252,000

Table 4.9 – Site 3 – South Cell Cost Estimate

Description	Quantity		Unit Cost	Cost
Excavation	553,496	CY	$5	$2,767,000
Compacted Fill	451,390	CY	$3	$1,354,000
Gravel	4,898	CY	$100	$490,000
Soil Cement	102,975	CY	$85	$8,753,000
Road base	2,612	CY	$90	$235,000
Liner	1,749,006	SF	$1.20	$2,099,000
Subtotal				$15,698,000
25% For Mobilization, Electrical, and Misc. Items				$3,925,000
Total				$19,623,000

Site 3 was re-configured to avoid a house located on the east portion of the proposed reservoir site. This configuration, Site 3b shown in **Figure 2.1**, creates an L-shaped reservoir, impacting only two properties. This configuration decreases the normal operating elevation of 742 feet-msl, which decreases the total combined capacity to 528 MG. A drainage channel would still be necessary to drain Site 3 to the Red River Basin. This drainage channel would be longer for Site 3b than the original Site 3 footprint. The total cost for Site 3b is $48,232,000. This cost does not include required piping and inlet and outlet structures which would be considered equal for all sites. Technical services and contingencies, as well as land acquisition costs have also not been included at this time.

4.05 SITE 4 – NORTHEAST OF LEONARD

Upon direction from the NTMWD, three additional sites were considered east of Leonard (Sites 4, 5, and 9) and one site located northwest of Leonard (Site 8).

Site 4 will consist of two cells of equal size, with a top of embankment footprint for each cell of 1,320 feet by 1,920 feet. Site 4 will have a proposed reservoir bottom elevation of 719 feet-msl, based on the existing topography which ranges from approximately 710 feet to 735 feet. A cut-fill balance is not feasible due to the low-lying areas in the south and east portions of Site 4. The normal operating elevation will be 740 feet-msl with a total combined capacity of 560 MG. The top of embankment elevation will be 747 feet-msl. The estimated cost of Site 4 is shown in **Tables 4.10** and **4.11**. The combined total cost of the Site 4 TSR is approximately $39,978,000. This cost does not include required piping, which will be greater due to required dual 96-inch pipes. The inlet and outlet structures were also not included as they would be considered equal for all sites. Technical services and contingencies, as well as land acquisition cost have also not been included at this time.

Table 4.10 – Site 4 – East Cell Cost Estimate

Description	Quantity		Unit Cost	Cost
Excavation	153,836	CY	$5	$769,000
Compacted Fill	870,898	CY	$7	$6,096,000
Gravel	6,000	CY	$100	$600,000
Soil Cement	96,301	CY	$85	$8,186,000
Road base	3,200	CY	$90	$288,000
Liner	2,624,400	SF	$1.20	$3,149,000
Subtotal				$19,088,000
25% For Mobilization, Electrical, and Misc. Items				$4,772,000
Total				$23,860,000

Table 4.11 – Site 4 – West Cell Cost Estimate

Description	Quantity		Unit Cost	Cost
Excavation	453,868	CY	$5	$2,269,000
Compacted Fill	366,959	CY	$3	$1,101,000
Gravel	4,222	CY	$100	$422,000
Soil Cement	86,348	CY	$85	$7,340,000
Road base	2,252	CY	$90	$203,000
Liner	1,299,600	SF	$1.20	$1,560,000
Subtotal				$12,894,000
25% For Mobilization, Electrical, and Misc. Items				$3,224,000
Total				$16,118,000

Site 4 is not highly restricted due to existing roadways, however, will impact four properties. While no homes appear to be present within the reservoir footprint, there several homes located nearby along the west portion of the proposed TSR. A small draw already exists just north of the proposed site which drains directly to the Red River Basin which could be used to convey any spill events from the TSR.

Due to the distance from the NWTP, approximately 1.2 miles upstream, dual 96 inch pipes will be necessary to covey water to the treatment plant. This distance and the increased cost of using dual conduits is a potential drawback to Site 4.

4.06 SITE 5 – NORTH OF LEONARD

Site 5 will consist of two cells of different size and bottom elevations that will be separated by approximately 370 feet to allow sufficient space for the construction of the embankment and pipeline to run between the two cells. The north cell which would be constructed in Phase I will have a top of embankment footprint of 2,400 feet by 1,750 feet and a proposed bottom elevation of 727 feet-msl. The south cell which would be constructed in Phase II will have a top of embankment footprint of 1,415 feet by 3,300 feet and a proposed bottom elevation of 728 feet-msl. These elevations are based on the existing topography which ranges from approximately 720 feet to 735 feet. The proposed bottom elevations provided an approximate cut-fill balance for each cell. The normal operating elevation will be 740 feet-msl, with a total combined capacity of 560 MG. The top of embankment elevation will be 747 feet-msl. The estimated cost of Site 5 is shown in **Table 4.12** and **4.13**. The combined total cost of the Site 5 TSR is approximately $66,821,000. This cost does not include required piping, and inlet and outlet structures as they would be considered equal for all sites. Technical services and contingencies, as well as land acquisition cost have also not been included at this time.

Table 4.13 – Site 5 – North Cell Cost Estimate

Description	Quantity		Unit Cost	Cost
Excavation	448,286	CY	$5	$2,241,000
Compacted Fill	554,313	CY	$5	$2,772,000
Gravel	7,694	CY	$100	$769,000
Soil Cement	156,297	CY	$85	$13,285,000
Road base	4,104	CY	$90	$369,000
Liner	4,316,006	SF	$1.20	$5,179,000
Subtotal				$24,616,000
25% For Mobilization, Electrical, and Misc. Items				$6,154,000
Total				$30,770,000

Table 4.13 - Site 5 - South Cell Cost Estimate

Description	Quantity		Unit Cost	Cost
Excavation	838,995	CY	$5	$4,195,000
Compacted Fill	606,996	CY	$3	$1,821,000
Gravel	8,731	CY	$100	$873,000
Soil Cement	174,861	CY	$85	$14,863,000
Road base	4,657	CY	$90	$419,000
Liner	5,557,807	SF	$1.20	$6,669,000
Subtotal				$28,841,000
25% For Mobilization, Electrical, and Misc. Items				$7,210,000
Total				$36,051,000

Site 5 is partially located within the ETJ of the City of Leonard and is restricted to the south, east, and west due to US Highway 69, FM 1553 and FC 4720. No homes appear to be present within the reservoir footprint; however, the athletic fields for the City are located approximately 230 feet east of the proposed south cell. Site 5 is located primarily in the Sulphur River Basin. A morning glory – type spillway and discharge pipe would be required to convey any discharge due to a spill event to the Red River Basin. The approximate location of the discharge conduit is shown in **Figure 2.1**. The cost for this drainage conduit has not been included in the cost estimate for the site. The additional cost for the discharge structure to the Red River Basin is a potential drawback of Site 5.

4.07 SITES 6 AND 7 – NORTH OF LEONARD

Site 6 was located north of Leonard and north of proposed Site 3. It is restricted to the north and west by CR 4665, with existing development located east of the site. Site 7 was also located north of Leonard and west of proposed Site 3. It was located north of US Highway 69 and restricted on the north, east, and west by CR 4660, CR 4665, and CR 4655, respectively. Both Sites 6 and 7 were eliminated early in the preliminary site selection due to site restrictions in regard to the size of the TSR. A much smaller footprint was required at these two sites which would have required a higher operating water surface elevation than would be feasible with the pipeline operations.

4.08 SITE 8 – NORTHWEST OF LEONARD

Site 8 is located northwest of the NWTP and is the furthest west that was a feasible site for the TSR. Site 8 will consist of two cells of different size and same bottom elevation. The west cell, which would be constructed in Phase I, is a trapezoidal shape with a total top of embankment length of 9,054 feet. The east cell, constructed in Phase II, will have a top of embankment length of 2,220 feet by 1,895 feet. The proposed reservoir bottom elevation would be 728 feet. This elevation was based on the existing topography which ranges from approximately 720 feet to 740 feet. The proposed bottom elevation provided an approximate cut-fill balance for each cell. The normal operating elevation will be 741 feet-msl with a total combined capacity of 560 MG. The top of embankment elevation will be 748 feet-msl. The estimated cost of Site 8 is shown in T**able 4.14** and **4.15**. The combined total cost of the Site 8 TSR is approximately $60,395,000. This cost does not include required piping, and inlet and outlet structures as they would be considered equal for all sites. Technical services and contingencies, as well as land acquisition cost have also not been included at this time.

Table 4.14 – Site 8 – West Cell Cost Estimate

Description	Quantity		Unit Cost	Cost
Excavation	799,094	CY	$5	$3,995,000
Compacted Fill	618,782	CY	$3	$1,856,000
Gravel	8,383	CY	$100	$838,000
Soil Cement	159,600	CY	$85	$13,566,000
Road base	4,471	CY	$90	$402,000
Liner	5,123,125	SF	$1.20	$6,148,000
Subtotal				$26,806,000
25% For Mobilization, Electrical, and Misc. Items				$6,702,000
Total				$33,508,000

Table 4.15 – Site 8 – East Cell Cost Estimate

Description	Quantity		Unit Cost	Cost
Excavation	713,339	CY	$5	$3,567,000
Compacted Fill	521,170	CY	$3	$1,564,000
Gravel	5,565	CY	$100	$556,000
Soil Cement	151,140	CY	$85	$12,847,000
Road base	2,968	CY	$90	$267,000
Liner	2,257,507	SF	$1.20	$2,709,000
Subtotal				$21,510,000
25% For Mobilization, Electrical, and Misc. Items				$5,377,000
Total				$26,887,000

Site 8 is constricted to the north, south, east, and west by CR 4640, US Highway 69, CR 4625, and CR 4655. No homes appear to be present within the reservoir footprint Site 8 is located entirely in the

Trinity River Basin; however, the north portion of the site could be designed to spill to the Red River Basin. An existing draw already exists which could be used to convey flows to the north.

4.09 SITE 9 – NORTHEAST OF LEONARD

Site 9 will consist of two cells of equal size, with a top of embankment footprint for each cell of 1,950 feet by 1,600 feet. Site 9 will have a proposed reservoir bottom elevation of 723 feet-msl, based on the existing topography which ranges from approximately 715 feet to 740 feet. A reasonable cut-fill balance is achieved with the proposed bottom elevation. The normal operating elevation will be 740 feet-msl with a total combined capacity of 560 MG. The top of embankment elevation will be 747 feet-msl. The estimated cost of Site 9 is shown in **Table 4.16** and **4.17**. The combined total cost of the Site 9 TSR is approximately $43,088,000. This cost does not include required piping, which will be greater due to required dual 96-inch pipes. The inlet and outlet structures were also not included as they would be considered equal for all sites. Technical services and contingencies, as well as land acquisition cost have also not been included at this time.

Table 4.16 – Site 9 – West Cell Cost Estimate

Description	Quantity		Unit Cost	Cost
Excavation	350,291	CY	$5	$1,751,000
Compacted Fill	585,826	CY	$5	$2,929,000
Gravel	6,574	CY	$100	$657,000
Soil Cement	116,619	CY	$85	$9,913,000
Road base	3,506	CY	$90	$316,000
Liner	3,150,624	SF	$1.20	$3,781,000
Subtotal				$19,347,000
25% For Mobilization, Electrical, and Misc. Items				$4,837,000
Total				$24,184,000

Table 4.17 – Site 9 – East Cell Cost Estimate

Description	Quantity		Unit Cost	Cost
Excavation	389,271	CY	$5	$1,946,000
Compacted Fill	397,653	CY	$3	$1,193,000
Gravel	4,769	CY	$100	$477,000
Soil Cement	109,286	CY	$85	$9,289,000
Road base	2,543	CY	$90	$229,000
Liner	1,657,657	SF	$1.20	$1,989,000
Subtotal				$15,124,000
25% For Mobilization, Electrical, and Misc. Items				$3,781,000
Total				$18,904,000

Site 9 is not highly restricted due to existing roadways, however, will impact three properties. No homes appear to be present within the reservoir footprint. The north portion of the west cell is located within the Red River Basin and thus can spill to the Red River without the construction of an additional drainage channel.

Due to the distance from the NWTP, approximately 5.4 miles upstream, dual 96 inch pipes will be necessary to covey water to the treatment plant. This distance and the increased cost of using dual conduits is a potential drawback to Site 9.

4.10 SUMMARY OF RESULTS

Table 4.18 summarizes the results of the TSR analyses.

Table 4.18 – Site Summary

Site	Minimum/ Maximum WSE (feet-msl)	Phase 1 Analysis Cost	Phase 2 Analysis Cost	Drawbacks
1	721/736	$34,090,000	$24,297,000	• Large amount of imported embankment fill required • Topography results in inefficient layout resulting in oversized reservoir to achieve required storage • Requires drainage channel/pipe and easement required to drain to Red River Basin
2	735/750	$26,063,000	$18,783,000	• 20 feet higher maximum WSE results in higher pumping costs and potential raw water pipeline upsize • Requires a drainage channel and easement to spill to the Red River Basin • Requires an improved culvert crossing of FM 896 • Footprint restricted due to site constraints
2a	735/775	$24,635,000	$24,716,000	• 45 feet higher maximum WSE results in higher pumping costs and potential raw water pipeline upsize • Requires a drainage channel and

Site	Minimum/ Maximum WSE (feet-msl)	Phase 1 Analysis Cost	Phase 2 Analysis Cost	Drawbacks
				easement to spill to the Red River Basin • Requires an improved culvert crossing of FM 896 • Footprint restricted due to site constraints
3	North: 728/742 South: 727/742	$24,252,000	$19,623,000	• 12 feet higher maximum WSE results in higher pumping costs and potential raw water pipeline upsize • Requires a drainage channel and easement to spill to the Red River Basin • Unwilling landowners
3b	728/742	$29,868,000	$18,364,000	• 12 feet higher maximum WSE results in higher pumping costs and potential raw water pipeline upsize • Requires a drainage channel and easement to spill to the Red River Basin • Less than 560 MG of combined storage • Unwilling landowners
4	722/740	$23,860,000	$16,118,000	• Significant distance from NWTP • Dual pipes required to NWTP • Large amount of imported embankment fill required
5	North: 730/740 South: 731/740	$30,770,000	$36,051,000	• Requires drainage channel/pipe and easement required to drain to Red River Basin • Partially located within Leonard ETJ • Potential unwilling landowners
8	731/741	$33,508,000	$26,887,000	• Not along proposed pipeline alignment • Approximately 2 miles northwest of NWTP
9	726/740	$24,184,000	$18,904,000	• Significant distance from NWTP • Dual pipes required to NWTP

5.00 TSR ANALYSIS – SITE 1 REANALYZED

Site 1 was re-analyzed assuming dual 102 inch pipes between the TSR and NWTP. This pipe configuration significantly lowered the minimum required water surface elevation which made Site 1 a more feasible location due to its proximity to the NWTP and accessibility. In addition, the land would be available from a willing seller with minimal impact to homeowners in the area. These factors and adjustments led to Site 1 becoming the preferred site, so further, more detailed analysis of the site was performed. During the re-analysis of Site 1, it was also determined by the NTMWD that a full capacity of 560 MG was not necessary. At their direction, Site 1 was re-analyzed for 210 MG per cell for a total storage capacity of 420 MG. A storage volume of 420 MG represents two days of storage of LBCR water. The additional 140 MG of raw water will come from other potential sources and hence was removed from the storage calculations. With dual – 102 inch pipes connecting the TSR to the NWTP, the minimum required water surface elevation was decreased further, to 714 feet-msl, and the normal operating elevation to 731 feet-msl. The top of embankment will be 738 feet-msl. The lower storage capacity of 210 MG also allowed for a slightly smaller TSR footprint and decreased the normal operating water surface elevation. The two cells will be of equal size, with a top of embankment footprint of 1,545 feet by 1,320 feet. Lower existing elevations at the site will require a large amount of imported fill since minimal excavation will be possible. While Site 1 is located entirely in the Trinity River Basin, it is feasible to design a morning glory-type spillway from the north cell which will convey any discharge to the Red River Basin via an approximately one mile long drainage pipe. Since this will be needed from the start of operations, the phasing of the cells was modified to construct the north cell in Phase I which will include the construction of the drainage structure to the Red River Basin. It should also be noted that while both 102 inch pipes will not be required in the Phase I construction of the reservoir, the second 102 inch pipe will need to be in service when the plant expands to a 140 MG capacity.

As the recommended site, a more detailed cost estimate was developed for Phase I (north cell) and Phase II (south cell) for the revised Site 1 footprint, which is show in **Tables 5.1** and **5.2**.

Table 5.1 – Site 1 – Phase I (North Cell)

Detailed Cost Estimate (210 MG)

Description	Quantity		Unit Cost	Cost
Excavation	139,409	CY	$5	$697,000
Compacted Fill	724,018	CY	$8	$5,792,000
Gravel Drain	5,306	CY	$100	$531,000
Soil Cement (1 foot)	76,528	CY	$85	$6,505,000
Flex Road Base (8 inches)	2,830	CY	$90	$255,000
HDPE Liner	2,052,056	SF	$1.20	$2,462,000
Outlet to the Red River Basin	1	LS	$2,000,000	$2,000,000
Inlet and Outlet Structures	1	LS	$1,500,000	$1,500,000
Electrical Building and Controls	1	LS	$1,500,000	$1,500,000
Mobilization – 5%				$1,062,000
Subtotal				**$22,304,000**
Contingency – 20%				$4,461,000
Engineering, Surveying, Permitting – 8%				$2,141,000
Land and Easement Acquisition				$1,500,000
Construction Inspection – 1%				$268,000
Total				**$30,674,000**

Table 5.2– Site 1 – Phase II (South Cell)

Detailed Cost Estimate (210 MG)

Description	Quantity		Unit Cost	Cost
Excavation	17,150	CY	$5	$86,000
Compacted Fill	735,512	CY	$8	$5,884,000
Gravel Drain	4,083	CY	$100	$408,000
Soil Cement (1 foot)	72,579	CY	$85	$6,169,000
Flex Road Base (8 inches)	2,178	CY	$90	$196,000
HDPE Liner	1,215,506	SF	$1.20	$1,459,000
Inlet and Outlet Structures	1	LS	$1,500,000	$1,500,000
90 inch Pipeline	500	LF	$650	$325,000
102 inch Pipeline	4,225	LF	$1,230	$5,197,000
102 inch Butterfly Valve	1	EA	$225,000	$225,000
Mobilization – 5%				$1,072,000
Subtotal				**$22,521,000**
Contingency – 20%				$4,504,000
Engineering, Surveying, Permitting – 8%				$2,162,000
Construction Inspection – 1%				$270,000
Total				**$29,457,000**

6.00 FUTURE OPERATION ANALYSIS

Although not anticipated for initial operation of the LBCR/NWTP systems, the TSR potentially provides additional flexibility to NTMWD raw water operations. If the NTMWD were to connect the Texoma-Wylie raw water pipeline to the NWTP in the future, this project would also provide a conduit that could be used to bring LBCR water to the Wylie WTP. Based on previous hydraulic analyses, it is possible to pump directly from the LBCR to the Wylie WTP while sending water to the North WTP or bypassing the North WTP. This scenario would require the TSR to be bypassed.

The proposed TSR sites provide the ability to pump from the LBCR to the TSR and then gravity flow from the TSR to both the NWTP and the Wylie WTP. **Figure 6.1** displays hydraulic grade lines for the proposed TSR sites based on low WSELs and sending 70 MGD to the North WTP. TSR Site 1 has the ability to gravity flow 121 MGD to the Wylie WTP in addition to sending 70 MGD to the North WTP based on the low WSEL. TSR Site 2 has the ability to gravity flow 128 MGD to the Wylie WTP in addition to sending 70 MGD to the North WTP. TSR Site 3 has the ability to send 126 MGD to the Wylie WTP in addition to 70 MGD to the North WTP. This analysis assumes a single 96-inch pipeline from the TSR site to the North WTP and an 84-inch pipeline from the TSR to the Texoma pipeline (Connector Pipeline). Previous conceptual analysis conducted during the design of the Lake Texoma Outfall to Wylie Water Treatment Plant Raw Water Pipeline showed this connector pipeline as a 72-inch diameter pipeline. However, after the conceptual level HGL was developed for the NWTP, analyses showed that an 84-inch connector pipeline provides the most flexibility in sending 70-80 MGD from the Lake Texoma balancing reservoir to the NWTP based on the minimum Texoma balancing reservoir WSE of 821 feet-msl. **Figure 6.2** shows the hydraulic grade line from the Texoma Balancing Reservoir to the NWTP with an 84-inch connector pipeline. **Figure 6.3** displays the hydraulic grade line from TSR Site 1 to the NWTP with dual 102-inch pipes.

The hydraulic analysis conducted indicates that each site is approximately equal with regards to operational flexibility. The hydraulic analysis does not include sending water from Lake Chapman, the Texoma Balancing Reservoir or Tawakoni/East Fork to the Wylie WTP while sending water from the North WTP TSR. It is impossible to gravity flow from the Texoma balancing reservoir and TSR to Wylie WTP simultaneously due to the Texoma balancing reservoir higher water surface elevation of 812 to 832 feet. A flow control valve can be installed on the proposed Texoma pipeline upstream of the North WTP pipeline connection to break head along the Texoma line and send raw water from Lake Texoma and the TSR to Wylie WTP at the same time. These scenarios could be studied at a future date.

Figure 6.1
Gravity Flow from LBCR TSR Locations to Wylie WTP

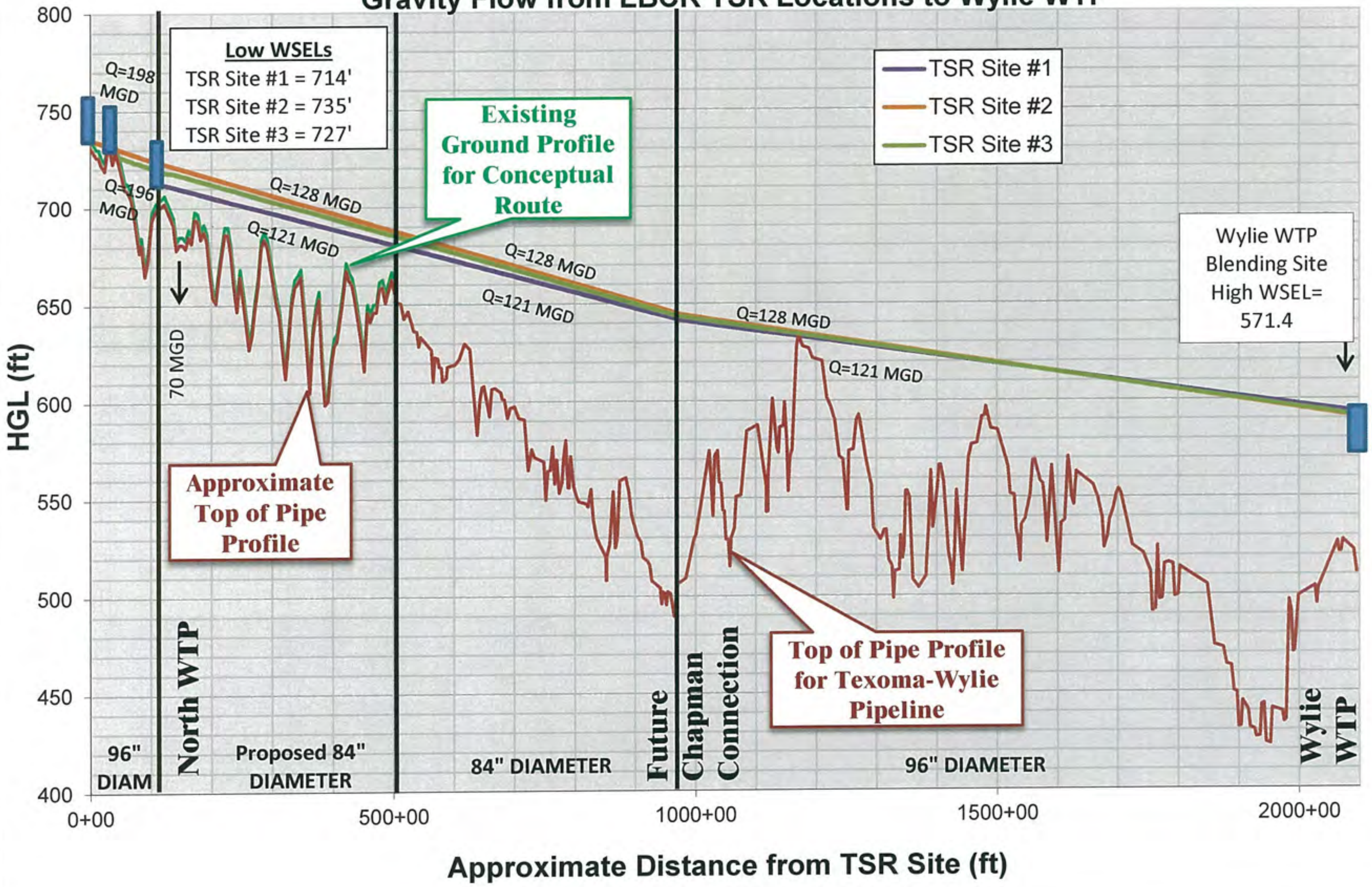


Figure 6.2
Gravity Flow from Texoma Balancing Reservoir to North WTP

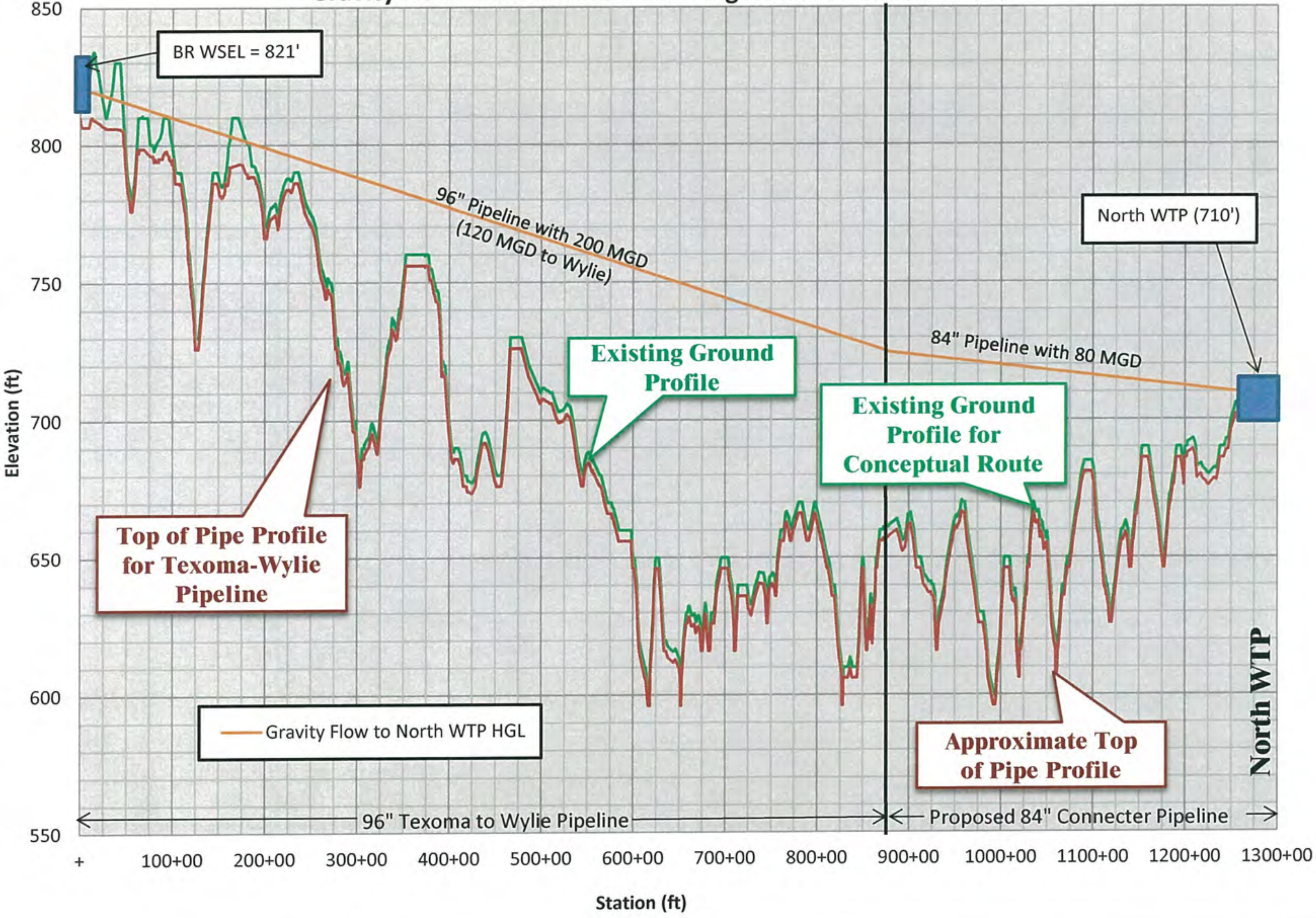
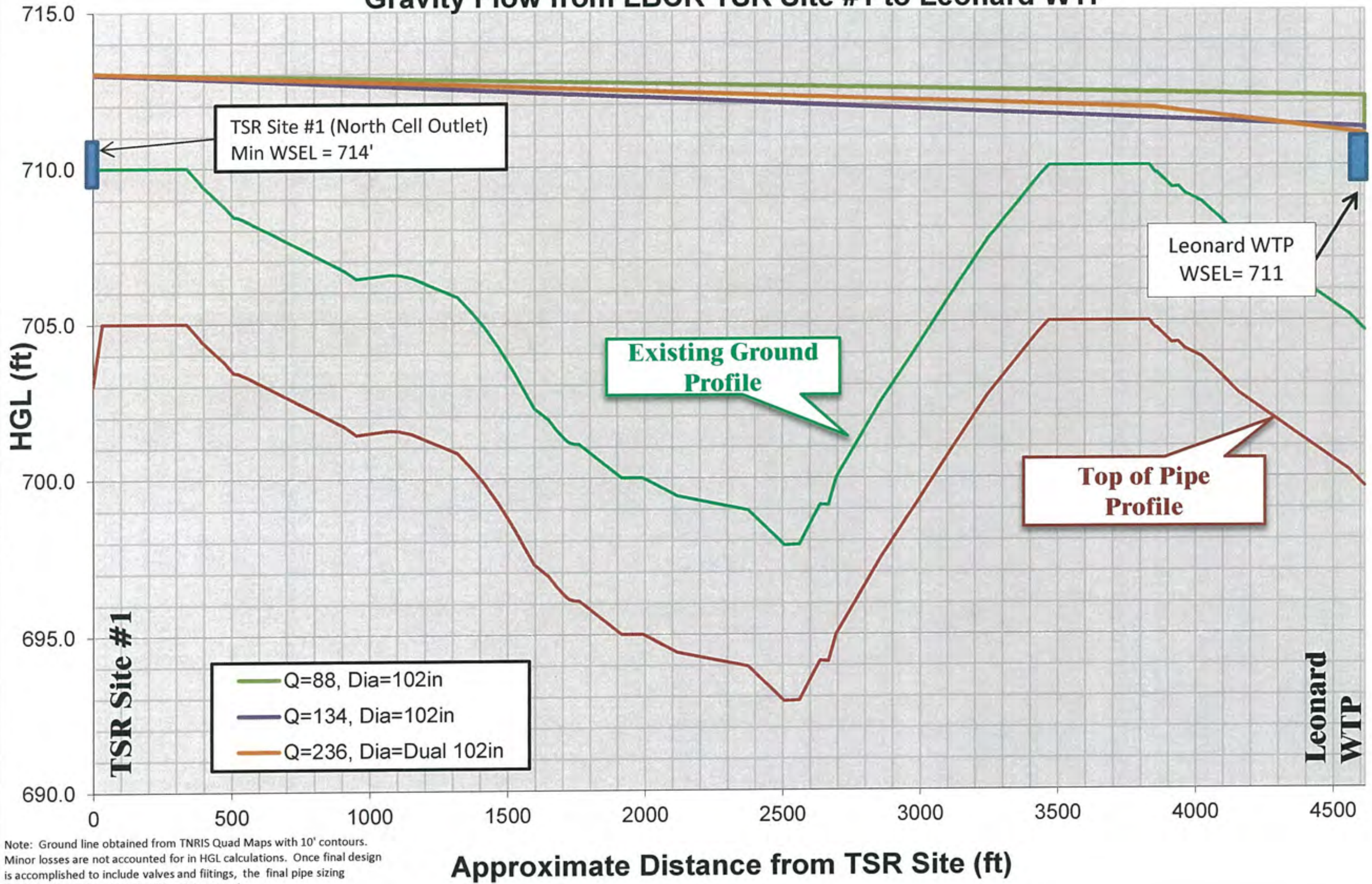


Figure 6.3
Gravity Flow from LBCR TSR Site #1 to Leonard WTP



Note: Ground line obtained from TNRIS Quad Maps with 10' contours. Minor losses are not accounted for in HGL calculations. Once final design is accomplished to include valves and fiitings, the final pipe sizing between the TSR and WTP will be determined.

7.00 SUMMARY AND RECOMMENDATION

Based on the conceptual analysis, the smaller Site 1 alternative (420 MG) is the most favorable and recommended site. With the dual pipes connecting Site 1 to the NWTP, a reasonable minimum and maximum operating elevation was achieved. This site is close to the NWTP site and is readily accessible via US Highway 69 to the north and CR 4965 to the east. The decreased storage requirement also allowed for a smaller footprint and lower top of embankment elevation, both of which helped to reduce the site cost. Willing landowners in the area also make land acquisition less of a concern as it would be with some of the other sites.

A detailed cost estimate for Phase I construction of the Site 1 TSR was developed. A total cost of Phase I would be $30,674,000. A significant portion of the cost is attributed to the large volume of soil cement required for a reservoir of this size. The necessity of a soil cement bottom will be based on analysis of the geotechnical borings and cleanout requirements for the TSR. This will be determined in final design. This includes the inlet and outlet structures, Red River drainage outlet, electrical building and controls and the estimated pipe and valves that would be needed at the TSR. This estimate also includes technical services and contingency. This estimate does not include the cost of construction for Phase II, the south cell, which would be $29,457,000.

APPENDIX A
PIPELINE LOSSES

A.1 LOCATION 1:

Table A.1 – Pipeline Parameters

Flow from TSR (Q) =	236	MGD
Length of Pipe from TSR to WTP (L) =	4650	FT
Hazen Williams Coefficient (C) =	120	
Pipe Diameter (D) =	96	IN
WTP Elevation =	711	FT

Table A.2 – Pipeline Elbows

Pipeline Elbows (K)	
90° Bends =	0.80
45° Bends =	0.20
4-90° + 6-45° Bends =	4.4

Table A.3 – Grate Losses

Grate Losses (FT)		
Effective Area =	70.00	FT^2
Velocity thru Grate =	5.22	FT/S
Friction Coefficient (K) =	1.60	
Grate Losses =	0.68	FT

Table A.4 – Reservoir Exit Structure Losses

Reservoir Exit Structure Losses (FT)		
Entrance: Projecting =	0.80	
Velocity at Entrance =	3.65	FT/S
Grate Losses =	0.68	FT
Entrance Structure Losses =	0.84	FT

Table A.5 – TSR to NWTP Losses

Entrance Losses =	0.84	FT
Major Losses =	6.81	FT
Velocity in Pipe =	7.27	FT/S
Pipeline Entrance (K) =	0.25	
10 Pipeline Elbows (K) =	4.4	
3 Butterfly Valves (K) =	1.05	
Minor Losses =	4.68	FT
Total Headloss =	12.33	FT
TSR Elevation =	723.33	FT

Table A.6 – Dual Pipe Lengths for Headloss Calculations

For Dual Pipes the Distances are:		
3850	FT	Dual Pipes to tee for combined pipe
800	FT	Single Combined pipe to WTP
4650	FT	Total Length

Table A.7 – TSR to NWTP Losses for Varying Pipe Diameters at Peak Flow

Flow from TSR = 236 MGD					
Pipe Diameter (IN)	Velocity in Pipe (FT/S)	Entrance Losses (FT)	Major Losses (FT)	Minor Losses (FT)	WSE Required (FT)
90	8.27	0.84	9.32	6.06	727.23
96	7.27	0.84	6.81	4.68	723.33
102	6.44	0.84	5.07	3.67	720.58
108	5.74	0.84	3.84	2.92	718.60
Dual 90	4.14	0.84	3.74	1.52	717.10
Dual 96	3.64	0.84	2.73	1.17	715.75
Dual 102	3.22	0.84	2.04	0.92	714.80
Dual 108	2.87	0.84	1.54	0.73	714.12

Table A.8 – TSR to NWTP Losses for Varying Pipe Diameters at Minimum Flow

Flow from TSR = 53 MGD					
Pipe Diameter (IN)	Velocity in Pipe (FT/S)	Entrance Losses (FT)	Major Losses (FT)	Minor Losses (FT)	WSE Required (FT)
90	1.86	0.04	0.59	0.31	711.94
96	1.63	0.04	0.43	0.24	711.71
102	1.45	0.04	0.32	0.19	711.55
108	1.29	0.04	0.24	0.15	711.43

*The values for **Table A.6** and **A.7** follow the same calculation process as the values shown in **Table A.1, A.2, A.3, A.4,** and **A.5** with changes only occurring due to the change in pipeline diameter.*

A.2 LOCATION 2:

Table A.1 – Pipeline Parameters

Flow from TSR (Q) =	236	MGD
Length of Pipe from TSR to WTP (L) =	12500	FT
Hazen Williams Coefficient (C) =	120	
Pipe Diameter (D) =	96	IN
WTP Elevation =	711	FT

Table A.2 – Pipeline Elbows

Pipeline Elbows (K)	
90° Bends =	0.80
45° Bends =	0.20
4-90° + 6-45° Bends =	4.4

Table A.3 – Grate Losses

Grate Losses (FT)		
Effective Area =	70.00	FT^2
Velocity thru Grate =	5.22	FT/S
Friction Coefficient (K) =	1.60	
Grate Losses =	0.68	FT

Table A.4 – Reservoir Exit Structure Losses

Reservoir Exit Structure Losses (FT)		
Entrance: Projecting =	0.80	
Velocity at Entrance =	3.65	FT/S
Grate Losses =	0.68	FT
Entrance Structure Losses =	0.84	FT

Table A.5 – TSR to NWTP Losses

Entrance Losses =	0.84	FT
Major Losses =	18.30	FT
Velocity in Pipe =	7.27	FT/S
Pipeline Entrance (K) =	0.25	
10 Pipeline Elbows (K) =	4.4	
3 Butterfly Valves (K) =	1.05	
Minor Losses =	4.68	FT
Total Headloss =	23.82	FT
TSR Elevation =	734.82	FT

Table A.6 – TSR to NWTP Losses for Varying Pipe Diameters at Peak Flow

Flow from TSR = 236 MGD						
Pipe Diameter (IN)		Velocity in Pipe (FT/S)	Entrance Losses (FT)	Major Losses (FT)	Minor Losses (FT)	WSE Required (FT)
90		8.27	0.84	25.05	6.06	742.96
96		7.27	0.84	18.30	4.68	734.82
102		6.44	0.84	13.62	3.67	729.14
108		5.74	0.84	10.31	2.92	725.08
Dual	90	4.14	0.84	6.95	1.52	720.31
Dual	96	3.64	0.84	5.08	1.17	718.09
Dual	102	3.22	0.84	3.78	0.92	716.54
Dual	108	2.87	0.84	2.86	0.73	715.43

Table A.7 – TSR to NWTP Losses for Varying Pipe Diameters at Minimum Flow

Flow from TSR = 53 MGD					
Pipe Diameter (IN)	Velocity in Pipe (FT/S)	Entrance Losses (FT)	Major Losses (FT)	Minor Losses (FT)	WSE Required (FT)
90	1.86	0.04	1.58	0.31	712.93
96	1.63	0.04	1.15	0.24	712.43
102	1.45	0.04	0.86	0.19	712.09
108	1.29	0.04	0.65	0.15	711.84

*The values for **Table A.6** and **A.7** follow the same calculation process as the values shown in **Table A.1**, **A.2**, **A.3**, **A.4**, and **A.5** with changes only occurring due to the change in pipeline diameter.*

A.3 LOCATION 3:

Table A.1 – Pipeline Parameters

Flow from TSR (Q) =	236	MGD
Length of Pipe from TSR to WTP (L) =	6500	FT
Hazen Williams Coefficient (C) =	120	
Pipe Diameter (D) =	96	IN
WTP Elevation =	711	FT

Table A.2 – Pipeline Elbows

Pipeline Elbows (K)	
90° Bends =	0.80
45° Bends =	0.20
4-90° + 6-45° Bends =	4.4

Table A.3 – Grate Losses

Grate Losses (FT)		
Effective Area =	70.00	FT^2
Velocity thru Grate =	5.22	FT/S
Friction Coefficient (K) =	1.60	
Grate Losses =	0.68	FT

Table A.4 – Reservoir Exit Structure Losses

Reservoir Exit Structure Losses (FT)		
Entrance: Projecting =	0.80	
Velocity at Entrance =	3.65	FT/S
Grate Losses =	0.68	FT
Entrance Structure Losses =	0.84	FT

Table A.5 – TSR to NWTP Losses

Entrance Losses =	0.84	FT
Major Losses =	9.51	FT
Velocity in Pipe =	7.27	FT/S
Pipeline Entrance (K) =	0.25	
10 Pipeline Elbows (K) =	4.4	
3 Butterfly Valves (K) =	1.05	
Minor Losses =	4.68	FT
Total Headloss =	15.04	FT
TSR Elevation =	726.04	FT

Table A.6 – TSR to NWTP Losses for Varying Pipe Diameters at Peak Flow

Flow from TSR = 236 MGD					
Pipe Diameter (IN)	Velocity in Pipe (FT/S)	Entrance Losses (FT)	Major Losses (FT)	Minor Losses (FT)	WSE Required (FT)
90	8.27	0.84	13.03	6.06	730.93
96	7.27	0.84	9.51	4.68	726.04
102	6.44	0.84	7.08	3.67	722.60
108	5.74	0.84	5.36	2.92	720.13
Dual 90	4.14	0.84	3.61	1.52	716.97
Dual 96	3.64	0.84	2.64	1.17	715.65
Dual 102	3.22	0.84	1.96	0.92	714.73
Dual 108	2.87	0.84	1.49	0.73	714.06

Table A.7 – TSR to NWTP Losses for Varying Pipe Diameters at Minimum Flow

Flow from TSR = 53 MGD					
Pipe Diameter (IN)	Velocity in Pipe (FT/S)	Entrance Losses (FT)	Major Losses (FT)	Minor Losses (FT)	WSE Required (FT)
90	1.86	0.04	0.82	0.31	712.17
96	1.63	0.04	0.60	0.24	711.88
102	1.45	0.04	0.45	0.19	711.67
108	1.29	0.04	0.34	0.15	711.53

*The values for **Table A.6** and **A.7** follow the same calculation process as the values shown in **Table A.1, A.2, A.3, A.4,** and **A.5** with changes only occurring due to the change in pipeline diameter.*

A.4 LOCATION 4:

Table A.1 – Pipeline Parameters

Flow from TSR (Q) =	236	MGD
Length of Pipe from TSR to WTP (L) =	19500	FT
Hazen Williams Coefficient (C) =	120	
Pipe Diameter (D) =	96	IN
WTP Elevation =	711	FT

Table A.2 – Pipeline Elbows

Pipeline Elbows (K)	
90° Bends =	0.80
45° Bends =	0.20
4-90° + 6-45° Bends =	4.4

Table A.3 – Grate Losses

Grate Losses (FT)		
Effective Area =	70.00	FT^2
Velocity thru Grate =	5.22	FT/S
Friction Coefficient (K) =	1.60	
Grate Losses =	0.68	FT

Table A.4 – Reservoir Exit Structure Losses

Reservoir Exit Structure Losses (FT)		
Entrance: Projecting =	0.80	
Velocity at Entrance =	3.65	FT/S
Grate Losses =	0.68	FT
Entrance Structure Losses =	0.84	FT

Table A.5 – TSR to NWTP Losses

Entrance Losses =	0.84	FT
Major Losses =	28.54	FT
Velocity in Pipe =	7.27	FT/S
Pipeline Entrance (K) =	0.25	
10 Pipeline Elbows (K) =	4.4	
3 Butterfly Valves (K) =	1.05	
Minor Losses =	4.68	FT
Total Headloss =	34.07	FT
TSR Elevation =	745.07	FT

Table A.6 – TSR to NWTP Losses for Varying Pipe Diameters at Peak Flow

Flow from TSR = 236 MGD						
Pipe Diameter (IN)		Velocity in Pipe (FT/S)	Entrance Losses (FT)	Major Losses (FT)	Minor Losses (FT)	WSE Required (FT)
90		8.27	0.84	39.08	6.06	756.99
96		7.27	0.84	28.54	4.68	745.07
102		6.44	0.84	21.25	3.67	736.76
108		5.74	0.84	16.08	2.92	730.85
Dual	90	4.14	0.84	10.84	1.52	724.20
Dual	96	3.64	0.84	7.92	1.17	720.93
Dual	102	3.22	0.84	5.89	0.92	718.66
Dual	108	2.87	0.84	4.46	0.73	717.04

Table A.7 – TSR to NWTP Losses for Varying Pipe Diameters at Minimum Flow

Flow from TSR = 53 MGD					
Pipe Diameter (IN)	Velocity in Pipe (FT/S)	Entrance Losses (FT)	Major Losses (FT)	Minor Losses (FT)	WSE Required (FT)
90	1.86	0.04	2.47	0.31	713.81
96	1.63	0.04	1.80	0.24	713.08
102	1.45	0.04	1.34	0.19	712.57
108	1.29	0.04	1.01	0.15	712.20

*The values for **Table A.6** and **A.7** follow the same calculation process as the values shown in **Table A.1, A.2, A.3, A.4,** and **A.5** with changes only occurring due to the change in pipeline diameter.*

A.5 LOCATION 5:

Table A.1 – Pipeline Parameters

Flow from TSR (Q) =	236	MGD
Length of Pipe from TSR to WTP (L) =	11500	FT
Hazen Williams Coefficient (C) =	120	
Pipe Diameter (D) =	96	IN
WTP Elevation =	711	FT

Table A.2 – Pipeline Elbows

Pipeline Elbows (K)	
90° Bends =	0.80
45° Bends =	0.20
4-90° + 6-45° Bends =	4.4

Table A.3 – Grate Losses

Grate Losses (FT)		
Effective Area =	70.00	FT^2
Velocity thru Grate =	5.22	FT/S
Friction Coefficient (K) =	1.60	
Grate Losses =	0.68	FT

Table A.4 – Reservoir Exit Structure Losses

Reservoir Exit Structure Losses (FT)		
Entrance: Projecting =	0.80	
Velocity at Entrance =	3.65	FT/S
Grate Losses =	0.68	FT
Entrance Structure Losses =	0.84	FT

Table A.5 – TSR to NWTP Losses

Entrance Losses =	0.84	FT
Major Losses =	16.83	FT
Velocity in Pipe =	7.27	FT/S
Pipeline Entrance (K) =	0.25	
10 Pipeline Elbows (K) =	4.4	
3 Butterfly Valves (K) =	1.05	
Minor Losses =	4.68	FT
Total Headloss =	22.36	FT
TSR Elevation =	733.36	FT

Table A.6 – TSR to NWTP Losses for Varying Pipe Diameters at Peak Flow

Flow from TSR = 236 MGD						
Pipe Diameter (IN)		Velocity in Pipe (FT/S)	Entrance Losses (FT)	Major Losses (FT)	Minor Losses (FT)	WSE Required (FT)
90		8.27	0.84	23.05	6.06	740.96
96		7.27	0.84	16.83	4.68	733.36
102		6.44	0.84	12.53	3.67	728.05
108		5.74	0.84	9.49	2.92	724.25
Dual	90	4.14	0.84	6.39	1.52	719.75
Dual	96	3.64	0.84	4.67	1.17	717.68
Dual	102	3.22	0.84	3.48	0.92	716.24
Dual	108	2.87	0.84	2.63	0.73	715.21

Table A.7 – TSR to NWTP Losses for Varying Pipe Diameters at Minimum Flow

Flow from TSR = 53 MGD					
Pipe Diameter (IN)	Velocity in Pipe (FT/S)	Entrance Losses (FT)	Major Losses (FT)	Minor Losses (FT)	WSE Required (FT)
90	1.86	0.04	1.45	0.31	712.80
96	1.63	0.04	1.06	0.24	712.34
102	1.45	0.04	0.79	0.19	712.02
108	1.29	0.04	0.60	0.15	711.79

*The values for **Table A.6** and **A.7** follow the same calculation process as the values shown in **Table A.1, A.2, A.3, A.4,** and **A.5** with changes only occurring due to the change in pipeline diameter.*

A.6 LOCATION 8:

Table A.1 – Pipeline Parameters

Flow from TSR (Q) =	236	MGD
Length of Pipe from TSR to WTP (L) =	9000	FT
Hazen Williams Coefficient (C) =	120	
Pipe Diameter (D) =	96	IN
WTP Elevation =	711	FT

Table A.2 – Pipeline Elbows

Pipeline Elbows (K)	
90° Bends =	0.80
45° Bends =	0.20
4-90° + 6-45° Bends =	4.4

Table A.3 – Grate Losses

Grate Losses (FT)		
Effective Area =	70.00	FT^2
Velocity thru Grate =	5.22	FT/S
Friction Coefficient (K) =	1.60	
Grate Losses =	0.68	FT

Table A.4 – Reservoir Exit Structure Losses

Reservoir Exit Structure Losses (FT)		
Entrance: Projecting =	0.80	
Velocity at Entrance =	3.65	FT/S
Grate Losses =	0.68	FT
Entrance Structure Losses =	0.84	FT

Table A.5 – TSR to NWTP Losses

Entrance Losses =	0.84	FT
Major Losses =	13.17	FT
Velocity in Pipe =	7.27	FT/S
Pipeline Entrance (K) =	0.25	
10 Pipeline Elbows (K) =	4.4	
3 Butterfly Valves (K) =	1.05	
Minor Losses =	4.68	FT
Total Headloss =	18.70	FT
TSR Elevation =	729.70	FT

Table A.6 – TSR to NWTP Losses for Varying Pipe Diameters at Peak Flow

Flow from TSR = 236 MGD					
Pipe Diameter (IN)	Velocity in Pipe (FT/S)	Entrance Losses (FT)	Major Losses (FT)	Minor Losses (FT)	WSE Required (FT)
90	8.27	0.84	18.04	6.06	735.94
96	7.27	0.84	13.17	4.68	729.70
102	6.44	0.84	9.81	3.67	725.32
108	5.74	0.84	7.42	2.92	722.19
Dual 90	4.14	0.84	5.00	1.52	718.36
Dual 96	3.64	0.84	3.65	1.17	716.67
Dual 102	3.22	0.84	2.72	0.92	715.48
Dual 108	2.87	0.84	2.06	0.73	714.63

Table A.7 – TSR to NWTP Losses for Varying Pipe Diameters at Minimum Flow

Flow from TSR = 53 MGD					
Pipe Diameter (IN)	Velocity in Pipe (FT/S)	Entrance Losses (FT)	Major Losses (FT)	Minor Losses (FT)	WSE Required (FT)
90	1.86	0.04	1.14	0.31	712.49
96	1.63	0.04	0.83	0.24	712.11
102	1.45	0.04	0.62	0.19	711.85
108	1.29	0.04	0.47	0.15	711.66

*The values for **Table A.6** and **A.7** follow the same calculation process as the values shown in **Table A.1, A.2, A.3, A.4,** and **A.5** with changes only occurring due to the change in pipeline diameter.*

A.7 LOCATION 9:

Table A.1 – Pipeline Parameters

Flow from TSR (Q) =	236	MGD
Length of Pipe from TSR to WTP (L) =	28500	FT
Hazen Williams Coefficient (C) =	120	
Pipe Diameter (D) =	96	IN
WTP Elevation =	711	FT

Table A.2 – Pipeline Elbows

Pipeline Elbows (K)	
90° Bends =	0.80
45° Bends =	0.20
4-90° + 6-45° Bends =	4.4

Table A.3 – Grate Losses

Grate Losses (FT)		
Effective Area =	70.00	FT^2
Velocity thru Grate =	5.22	FT/S
Friction Coefficient (K) =	1.60	
Grate Losses =	0.68	FT

Table A.4 – Reservoir Exit Structure Losses

Reservoir Exit Structure Losses (FT)		
Entrance: Projecting =	0.80	
Velocity at Entrance =	3.65	FT/S
Grate Losses =	0.68	FT
Entrance Structure Losses =	0.84	FT

Table A.5 – TSR to NWTP Losses

Entrance Losses =	0.84	FT
Major Losses =	41.72	FT
Velocity in Pipe =	7.27	FT/S
Pipeline Entrance (K) =	0.25	
10 Pipeline Elbows (K) =	4.4	
3 Butterfly Valves (K) =	1.05	
Minor Losses =	4.68	FT
Total Headloss =	47.24	FT
TSR Elevation =	758.24	FT

Table A.6 – TSR to NWTP Losses for Varying Pipe Diameters at Peak Flow

Flow from TSR = 236 MGD					
Pipe Diameter (IN)	Velocity in Pipe (FT/S)	Entrance Losses (FT)	Major Losses (FT)	Minor Losses (FT)	WSE Required (FT)
90	8.27	0.84	57.12	6.06	775.03
96	7.27	0.84	41.72	4.68	758.24
102	6.44	0.84	31.05	3.67	746.57
108	5.74	0.84	23.51	2.92	738.27
Dual 90	4.14	0.84	15.85	1.52	729.20
Dual 96	3.64	0.84	11.57	1.17	724.59
Dual 102	3.22	0.84	8.61	0.92	721.38
Dual 108	2.87	0.84	6.52	0.73	719.10

Table A.7 – TSR to NWTP Losses for Varying Pipe Diameters at Minimum Flow

Flow from TSR = 53 MGD					
Pipe Diameter (IN)	Velocity in Pipe (FT/S)	Entrance Losses (FT)	Major Losses (FT)	Minor Losses (FT)	WSE Required (FT)
90	1.12	0.02	1.42	0.11	712.54
96	0.99	0.02	1.04	0.09	712.14
102	0.87	0.02	0.77	0.07	711.85
108	0.78	0.02	0.58	0.05	711.65

*The values for **Table A.6** and **A.7** follow the same calculation process as the values shown in **Table A.1, A.2, A.3, A.4,** and **A.5** with changes only occurring due to the change in pipeline diameter.*

PART D
#54
LEONARD WTP TECH MEMOS

ALAN PLUMMER
ASSOCIATES, INC.
ENVIRONMENTAL
ENGINEERS AND SCIENTISTS

TECHNICAL MEMORANDUM

TECHNICAL MEMORANDUM
NTMWD Leonard WTP Preliminary Design Services
Sludge Treatment Evaluation

ALAN E. DAVIS
89254
6-9-16

PHILLIP LINTEREUR
114390
6/9/16

Project No.:	0587-013-01
Date:	June 9, 2016
Prepared For:	CH2M and NTMWD
Prepared By:	Alan Davis, APAI, Texas (P.E. No. 89254) Phillip Lintereur, APAI, Ph.D., Texas (P.E. No. 114390) Kyle Nelson, APAI, E.I.T.

1. INTRODUCTION

The purpose of this technical memorandum is to evaluate sludge treatment options for the North Texas Municipal Water District (NTMWD) Leonard Water Treatment Plant (WTP). Sludge treatment stages considered for the sludge treatment evaluation included thickening, storage, dewatering, extended dewatering, transport, and disposal. Sludge treatment options which consisted of various methods and technologies that could be categorized as one of the sludge treatment stages were also assessed during the evaluation. Capital and O&M costs were developed for each sludge treatment option. Different combinations of sludge treatment stages and options were arranged to create complete sludge treatment systems (referred to as sludge treatment alternatives in this technical memorandum). A life cycle cost analysis was performed to compare the long-term costs of each sludge treatment alternative. The viable sludge treatment alternatives developed from the evaluation are listed below.

Baseline:	Gravity Thickening → Sludge Lagoons → Land Application
Alternative 1:	Gravity Thickening → Tank Storage → Land Application
Alternative 2:	Gravity Thickening → Tank Storage → Centrifuge → Land Application
Alternative 3:	Gravity Thickening → Tank Storage → Centrifuge → Solar Drying → Monofill (Nearby Location)
Alternative 4:	Gravity Thickening → Tank Storage → Centrifuge → Solar Drying → Monofill (Distant Location)
Alternative 5:	Gravity Thickening → Tank Storage → Pump to Offsite Dewatering Facility → Tank Storage → Centrifuge → Solar Drying → Monofill (Nearby Dewatering Facility)

The sections included in this technical memorandum include:

- *Background*
- *2012 Wylie WTP – Sludge Treatment Evaluation*
- *Phased Expansions for Leonard WTP*
- *Sludge Characterization*
- *Sludge Treatment Stages*
- *Sludge Treatment Options*
- *Sludge Treatment Alternatives*
- *Comparison of Sludge Treatment Alternatives*
- *Discussion*

2. BACKGROUND

The NTMWD is in the preliminary design stage for a new water treatment plant in Leonard, Texas. The Leonard WTP will have an initial capacity of 70 MGD with an ultimate capacity of 280 MGD. The water sources for the plant will be from Lower Bois d'Arc Creek Reservoir (210 MGD) and Lake Texoma (70 MGD). In the initial 70 MGD phase, the water source will be exclusively from the Lower Bois d'Arc Creek Reservoir. It is anticipated that the WTP process will include pre-oxidation, coagulation/flocculation/sedimentation, ozonation, biologically active filtration, pH adjustment, chlorination, chloramination, and fluoridation.

3. 2012 WYLIE WTP - SLUDGE TREATMENT EVALUATION

An evaluation of sludge handling alternatives for the Wylie WTP was completed in 2012 and documented in the technical memorandum, "Wylie Water Treatment Plant – Water Plant Residuals Handling Conceptual Design: Long-Term Options and Screening Analysis". The purpose of this technical memorandum was to evaluate long-term sludge disposal options/scenarios at the Wylie WTP, and provide sludge handling recommendations. The lessons learned in the Wylie WTP sludge evaluation were considered in the sludge treatment evaluation for the Leonard WTP. The 2012 Wylie WTP technical memorandum evaluated several alternatives that included a combination of some of the same sludge treatment options evaluated for this project. The Wylie WTP evaluation recommended a phased approach in sludge management and outline below.

Phase 1 – Present Condition: Land Application;
Phase 2 – Addition of gravity thickeners;
Phase 3 – Pipeline transport and geotube monofill disposal;

Phase 4 – Mechanical dewatering and monofill disposal;
Phase 5 – Extended dewatering and monofill disposal.

4. PHASED EXPANSIONS FOR LEONARD WTP

The Leonard WTP will be built in a series of expansions. The liquid treatment and sludge treatment processes will be planned in accordance with this series of expansions. The anticipated schedule for these expansions is provided below.

- Phase I: 2020 – 70 MGD
- Phase II: 2025 – 140 MGD
- Phase III: 2030 – 210 MGD
- Phase IV: 2035 – 280 MGD

5. SLUDGE CHARACTERIZATION

The raw water and sludge characteristics shown in Table 1 were developed during the liquid treatment evaluation phase of this project which was conducted by CH2M. These values were used for preliminary sizing of components associated with the sludge treatment options. Maximum conditions (which were assumed to be sustained over a 3 month period) were used to size sludge treatment units, while average conditions were used to estimate annual average operation and maintenance requirements. It was assumed that ferric sulfate in combination with a polymer would be dosed at the Leonard WTP.

Table 1: Sludge Characteristics

Parameter	Value
Raw Water Characteristics	
Average	
Turbidity	12 NTU
Ferric Dose	12 mg/L as Fe
Maximum	
Turbidity	26 NTU
Ferric Dose	20 mg/L as Fe
Sludge Characteristics	
Settled Solids Concentration	0.40%
Specific Gravity of Solids	2.3
Sludge Production Conversion Factors	
Turbidity	1.5 lb-Sludge / NTU
Ferric Dose	2.9 lb-Sludge / lb-Fe

6. TERMINOLOGY

The labeling of processes/unit operation categories making up the different sludge treatment systems evaluated in this technical memorandum follow a systematic naming convention. "Alternatives", which represent the complete sludge treatment system, are made up of a combination of different "Stages", which are made up of individual "Options". A diagram which illustrates this naming convention and lists the different "Stages" and "Options" considered for the sludge treatment evaluation is shown as Figure 1.

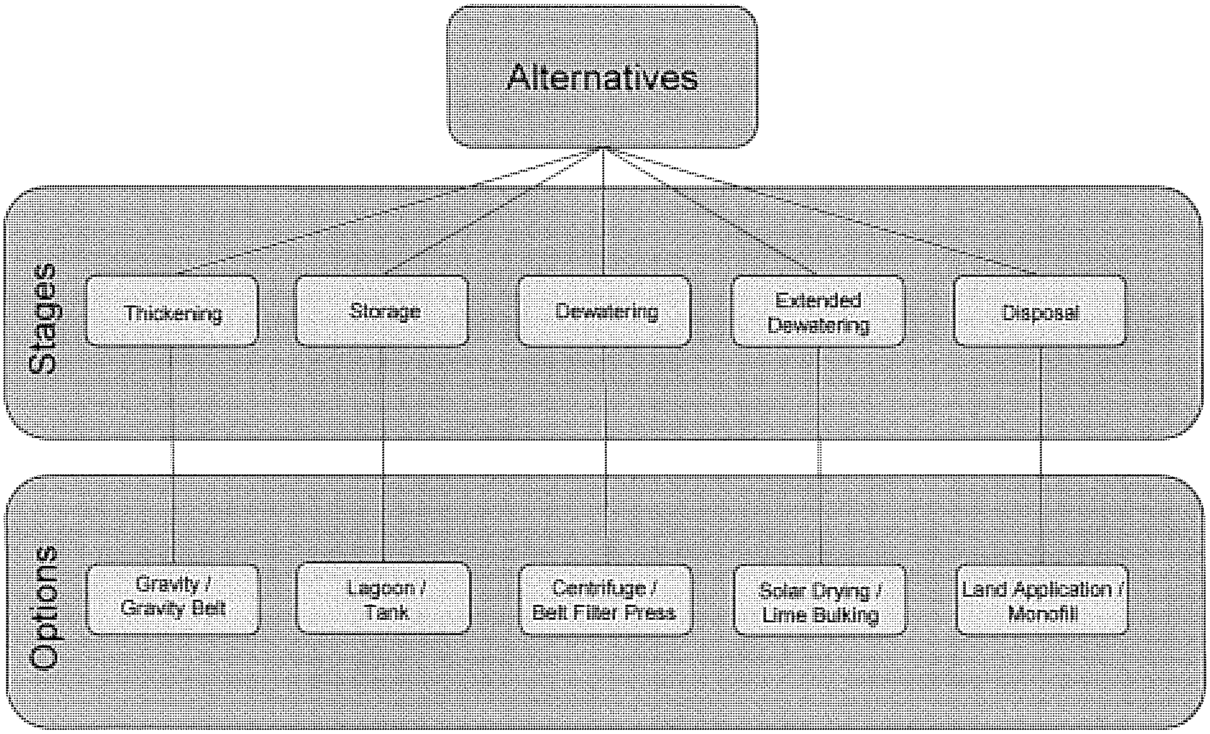


Figure 1: Sludge Treatment Evaluation - Terminology

7. SLUDGE TREATMENT STAGES

The sludge treatment system was divided into the following stages for the evaluation:

- Storage
- Thickening
- Dewatering
- Extended Dewatering
- Transport
- Disposal

Multiple methods and technologies capable of meeting the design objectives may be feasible for each stage. The possible methods and technologies will be referred to as sludge treatment options (or simply as "options") in this technical memorandum.

The sludge storage stage can be used to hold sludge while downstream units are offline, or to serve as an equalization point in the sludge treatment system which allows the downstream units to operate under more steady conditions. Sludge holding tanks and sludge lagoons were both considered as storage units for the sludge treatment evaluation. Sludge holding tanks sized for a detention time of 3 days would be used during normal operating conditions to hold sludge from the sedimentation basins (only for the gravity belt thickening options), and to hold thickened sludge. Sludge lagoons would serve as a backup storage option to be used in the event the sludge treatment system was taken out of service.

Thickening was considered for reducing the volume of sludge directly from the sedimentation basin. Gravity thickeners and gravity belt thickeners, which represent the most common methods for thickening sludge, were included in the sludge treatment evaluation. Use of these thickening methods can typically reduce the volume of sludge by approximately 80-90 percent. In a gravity thickener, sludge is allowed to settle via gravity. Settled sludge is collected in the underflow, while the supernatant overflows into a collection trough. For a gravity belt thickener, sludge is fed onto a slow moving belt to separate solids from the liquid by gravity drainage. Gravity belt thickening can generally produce thicker sludge than gravity thickening. For the purposes of the sludge treatment evaluation, a thickened solids concentration of 2 percent was applied for the gravity thickening option, while a thickened solids concentration of 3 percent was applied for the gravity belt thickening option. It was assumed that both thickening options would use polymer.

The dewatering stage follows the thickening stage of the sludge treatment system. The dewatering stage further reduces the volume of thickened sludge by about 90 percent. Belt filter presses, centrifuges, three-belt presses, sludge lagoons, and geotubes are possible methods for dewatering sludge. In a belt filter press, sludge is initially fed into a gravity drainage zone to remove free water, and then enters a zone where high pressure is generated by a series of serpentine rollers to press out additional water. Centrifugal dewatering is a high speed process that uses centrifugal forces to separate solids from water in the sludge. Centrifuges require smaller footprints compared to other dewatering alternatives and can handle higher design loadings than belt filter presses. Three-belt presses are similar to belt filter presses, but unlike the typical belt filter press, the gravity and pressure zones of a three-belt press run independently of each other. Three-belt presses essentially combine the thickening and dewatering stages into a single unit, and therefore don't require a separate upstream thickening stage. Geotubes are large tubes made of a geotextile material. Sludge is pumped into the geotube container, where water is drained through small pores in the geotextile via gravity and evaporation.

Sludge lagoons and geotubes were evaluated during a preliminary screening phase of the sludge treatment evaluation, but were ultimately eliminated as feasibility options for dewatering. Both options would not be expected to reliably dewater to the same level as a belt filter press, centrifuge, or three-belt press. Furthermore, the amount of time required to dewater under these options would be too long to support steady operation of a downstream extended dewatering stage. The belt filter press and centrifuge options were considered for the sludge treatment evaluation. For the purposes of the evaluation, a dewatered solids concentration of 25 percent was applied for both options. It was assumed that polymer would be added ahead of the dewatering options. The three-belt press was found to be cost competitive with the belt filter press and centrifuge options, but was ultimately not included in the evaluation since there is less flexible with phasing the thickening and dewatering stages. If the stages were to be phased, then purchase of the dewatering stage during the later phase would be without competition since the equipment selection would be limited to the manufacturer of the thickener stage. If the NTMWD decides to forego phasing and instead implement the thickening and dewatering stages at the same time, then three-belt presses should be reconsidered.

Extended dewatering is a process utilized to further increase the solids content of dewatered sludge. For the purposes of this project, extended dewatering would be required to improve the stability of sludge such that the final product could be stacked in a monofill while being capable of supporting heavy machinery loads. Processes available for extended dewatering include windrowing, drying beds, solar drying, and the addition of a bulking agent. Windrowing is a method in which sludge is deposited in rows and allowed to dry from evaporation. Sludge drying beds utilize a sand pit where sludge is placed and dewatered by gravity separation and evaporation. Solar drying utilizes an enclosed area that functions similarly to a greenhouse. Sludge is regularly tilled in the enclosed area by an automated control system that also regulates the air exchange using fans. The addition of a bulking agent increases the solids content by directly adding more solids (such as lime or fly ash) to the sludge.

Sludge drying beds and windrowing were eliminated as feasible extended dewatering options. Mainly due to the historical rainfall near the site, neither of these options is expected to consistently produce sludge with a high enough solids content that would allow disposal in a monofill. It was assumed that the final solids content would need to be at least 70 percent to be considered stable enough for stacking in a monofill. Both solar drying and lime bulking are capable of reliably producing this solids content, and, as such, were considered for the sludge treatment evaluation.

The sludge treatment evaluation assessed the benefits of operating an onsite versus offsite dewatering facility. For the offsite dewatering facility, thickened sludge would be transported from the Leonard WTP to the dewatering facility. The options considered for transporting the thickened sludge were hauling and pumping.

The sludge disposal methods considered for the sludge treatment evaluation were land application and operation of a monofill. It was assumed that sludge with a solids content as low as that of thickened sludge could be land applied. Disposal in a monofill would require extended dewatering of sludge beforehand.

A more detailed description of the sludge treatment options mentioned in this section are provided in Appendix A.

8. SLUDGE TREATMENT OPTIONS

Capital and O&M costs were developed for the different stages of the sludge treatment system. Costs were estimated for different options within each stage of the sludge treatment system. The viable options included:

- Sludge lagoons and sludge holding tanks for the storage stage;
- Gravity thickeners and gravity belt thickeners for thickening;
- Belt filter presses and centrifuges for dewatering;
- Solar drying and lime bulking for extended dewatering;
- Pumping and hauling for transport;
- Land application and monofill operation for disposal.

These options will be combined in various arrangements to define potential sludge treatment alternatives and described in Section 8. The following section provides a description of the components associated with each option as defined for the purposes of developing a preliminary scope of supply and ultimately estimating a capital and O&M cost. The capital and O&M costs for the different options within each stage are included in the following section as well. Costs presented in this section represent the estimated cost for the Phase I plant capacity of 35 MGD (average)/ 70 MGD (maximum).

8.1 General Assumptions

A list of general assumptions that applied to the capital and O&M cost estimates for each sludge treatment option is provided in Table 2. Life cycle costs prepared for this technical memorandum assumed an interest rate of 3 percent.

Table 2: General Cost Assumptions

Cost Item	Value
Capital Costs	
Contingency	35% of Construction Sub-Total
Mobilization	5% of Construction Sub-Total with Contingency
Contractor Overhead and Profit	20% of Construction Sub-Total with Contingency and Mobilization
Equipment Installation	20% of Equipment Cost
Dewatering Buildings	$200 per square foot
General Equipment Buildings	$100 per square foot
Canopy	$50 per square foot
Concrete	
Slab	$450 per cubic yard
Walls	$550 per cubic yard
Specialty Form-Work	$700 per cubic yard
Annual O&M Costs	
Electrical	$0.06 per kW-hr
Maintenance	2% of Equipment Cost
Labor	$24 per hour
Polymer	
Dose	10 lbs per Dry Ton
Unit Cost	$0.94 per lb

8.2 Storage

Sludge lagoons and sludge holding tanks were considered as options for the storage stage of the sludge treatment system. The components and costs associated with the sludge lagoon and sludge holding tank storage options are provided below.

8.2.1 Sludge Lagoons

It was assumed that two (2) sludge lagoons would serve as backup storage in the event the sludge treatment system was taken offline. During such an event, sludge would be conveyed to one of the sludge lagoons and eventually removed during clean-out of the sludge lagoon. Once one sludge lagoon is filled to capacity, the plant would start sending sludge to the other sludge lagoon and repeat the cycle. Sludge stored in the sludge lagoons would settle out while supernatant would be decanted and drained to the backwash waste equalization basin. The sludge lagoons were sized to operate in 12 month cycles at the annual average sludge production rate. A summary of the characteristics of the sludge lagoons is shown in Table 3. The capital and O&M costs for the sludge lagoons are shown in Table 4. It should be noted that the O&M cost represents normal operation of the sludge lagoons as backup units. As backup units, it is assumed the sludge lagoons will remain in standby mode, and therefore not be used.

Table 3: Summary of Characteristics (Phase I) - Sludge Lagoons

Parameter	Value
Quantity	2 Units
Geometry	Rectangular
Side Slopes	5:1
Length (at Normal WSE)	1,007 feet
Width (at Normal WSE)	336 feet
Normal Side Water Depth	8 feet
Freeboard	3 feet
Liner	Clay; 2 feet thick
Decant	2 Units per Sludge Lagoon

Table 4: Opinion of Capital and Annual O&M Costs (Phase I) – Sludge Lagoons

Item	Cost
OPCC	
Sitework	$ 4,672,600
Structural	$ 134,800
Equipment	$ 192,000
Mechanical	$ 627,200
Electrical/Instrumentation	N/A
Contingency	$ 1,969,400
Mobilization	$ 379,800
Overhead and Profit	$ 1,595,200
Total OPCC	$ 9,571,000
Annual O&M	
Power	N/A
Chemical	N/A
Maintenance	$ 83,200
Labor	N/A
Total O&M	$ 83,200

8.2.2 Sludge Holding Tanks

The size and placement of sludge holding tanks within the sludge treatment system depended on the type of thickening used and the location of the dewatering facility. For alternatives with gravity thickening, the sludge holding tanks would be placed directly downstream of the thickening units, while none would be placed upstream. In contrast, sludge holding tanks for alternatives with gravity belt thickeners would be placed both directly upstream and downstream of the thickening units. For alternatives with offsite dewatering facilities, sludge holding tanks would also be placed, in addition to those previously mentioned, upstream of the dewatering units at the offsite dewatering facility. Figure 1 illustrates the relative position of the sludge holding tanks for the different thickening and dewatering facility location options. The sludge holding tanks were sized for the maximum sludge production rate. A summary of the characteristics of the sludge holding tanks is shown in Table 5. The capital and O&M costs for the sludge holding tanks are shown in Table 6.

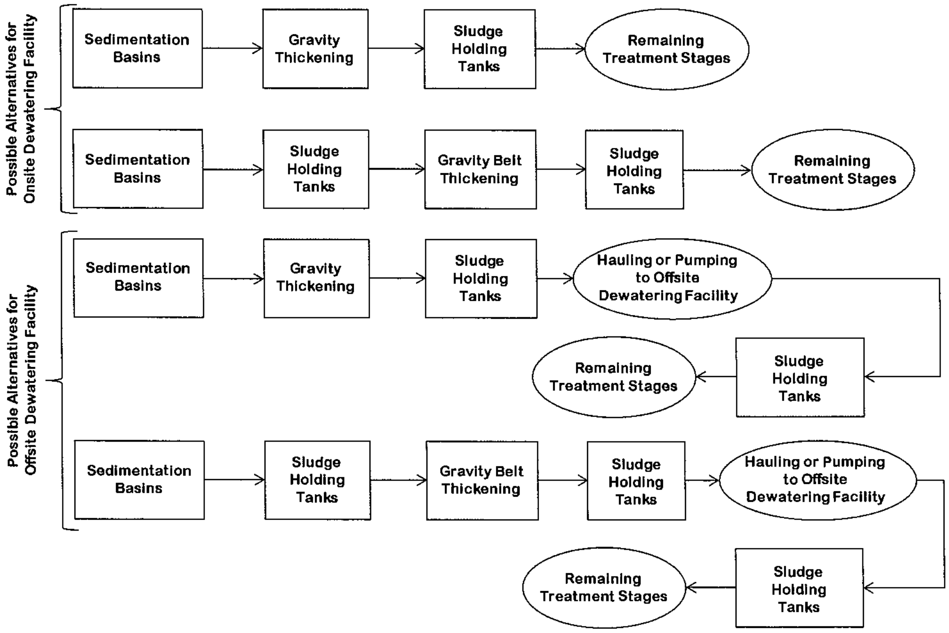


Figure 2: Sludge Storage Configurations

Table 5: Summary of Characteristics (Phase I) - Sludge Holding Tanks

Parameter	Gravity Thickening		Gravity Belt Thickening	
	Upstream	Downstream	Upstream	Downstream
Quantity[1]	N/A	2 onsite; 2 offsite	2 onsite	2 onsite; 2 offsite
Geometry	N/A	Circular	Circular	Circular
Diameter	N/A	70'-0"	156'-0"	57'-0"
Side Water Depth	N/A	18'-0"	18'-0"	18'-0"
Freeboard	N/A	2'-0"	2'-0"	2'-0"
Compressed Gas Mixing System – Air Compressor	N/A	2 × 15-hp Units	2 × 60-hp Units	2 × 15-hp Units
Building Area (Mixing System)	N/A	20' × 15'	20' × 15'	20' × 15'

Table 6: Opinion of Capital and Annual O&M Costs (Phase I) – Sludge Holding Tanks

Item	Gravity Thickening		Gravity Belt Thickening	
	Upstream	Downstream	Upstream	Downstream
OPCC				
Sitework	N/A	$ 56,500	$ 199,600	$ 42,300
Structural	N/A	$ 666,900	$ 2,091,700	$ 517,400
Equipment	N/A	$ 474,000	$ 1,320,000	$ 402,000
Mechanical	N/A	$ 120,300	$ 300,100	$ 105,000
Electrical/Instrumentation	N/A	$ 300,000	$ 610,000	$ 300,000
Contingency	N/A	$ 566,200	$ 1,582,500	$ 478,400
Mobilization	N/A	$ 109,200	$ 305,200	$ 92,300
Overhead and Profit	N/A	$ 458,700	$ 1,281,900	$ 387,500
Total OPCC	N/A	$ 2,751,800	$ 7,691,000	$ 2,324,900
Annual O&M				
Power	N/A	$ 5,900	$ 23,600	$ 5,900
Chemical	N/A	N/A	N/A	N/A
Maintenance	N/A	$ 7,900	$ 22,000	$ 6,700
Labor	N/A	$ 12,800	$ 12,800	$ 12,800
Total O&M	N/A	$ 26,600	$ 58,400	$ 25,400

---

[1] Offsite sludge holding tanks are only applicable for alternatives with an offsite dewatering facility. Note that each alternative includes a set of onsite sludge holding tanks downstream of the thickening stage, regardless of the location of the dewatering facility.

8.2.3 Storage Option Evaluation

The sludge lagoons were included in the initial phase as a backup storage option for each sludge treatment alternative. However, additional sludge lagoons were not included during the expansion phases. In contrast, the sludge holding tanks were included in each expansion phase.

8.3 Thickening

Gravity thickeners and gravity belt thickeners were considered as options for the thickening stage of the sludge treatment system. The components and costs associated with the gravity thickening and gravity belt thickening options are provided below.

8.3.1 Gravity Thickening

The gravity thickeners were sized to receive the maximum sludge production rate directly from the sedimentation basins at a continuous pace. Thickened sludge from the gravity thickeners would be pumped to a downstream sludge holding tank, while overflow would drain by gravity to the backwash waste equalization basin. The thickened sludge pump station was sized to operate in accordance with the dewatering schedule (assumed to be 5 days per week; 8 hours per day). A summary of the characteristics of the gravity thickening option is shown in Table 7. The capital and O&M costs for the gravity thickening option are shown in Table 8.

Table 7: Summary of Characteristics (Phase I) – Gravity Thickening

Parameter	Value
Quantity	2 Duty + 0 Standby
Geometry	Circular
Diameter	95 feet
Side Water Depth	10 feet
Polymer Feed System	1 Duty + 1 Standby
Thickened Sludge Pumps	2 Duty + 1 Standby (500 gpm each)
Building Area (Thickened Sludge Pumps)	24’ × 20’

Table 8: Opinion of Capital and Annual O&M Costs (Phase I) – Gravity Thickening

Item	Value
OPCC	
Sitework	$ 90,200
Structural	$ 697,400
Equipment	$ 588,600
Mechanical	$ 249,300
Electrical/Instrumentation	$ 370,000
Contingency	$ 698,500
Mobilization	$ 134,700
Overhead and Profit	$ 565,800
Total OPCC	$ 3,394,500
Annual O&M	
Power	$ 6,400
Chemical	$ 26,500
Maintenance	$ 9,900
Labor	$ 21,400
Total O&M	$ 64,200

8.3.2 Gravity Belt Thickening

The gravity belt thickeners were sized to receive the maximum sludge production rate while operating on a schedule of 5 days per week and 8 hours per day. Thickened sludge from the gravity belt thickeners would be pumped to a downstream sludge holding tank, while filtrate would drain by gravity to the backwash waste equalization basin. A summary of the characteristics of the gravity belt thickening option is shown in Table 9. The capital and O&M costs for the gravity thickening option are shown in Table 10.

Table 9: Summary of Characteristics (Phase I) – Gravity Belt Thickening

Parameter	Value
Quantity	10 Duty + 1 Standby
Belt Width	2 meters
Polymer Feed System	1 System (1 Pump per Thickener)
Feed Pumps	1 per Unit (495 gpm each)
Thickened Sludge Pumps	1 per Unit (150 gpm each)
Building Area	200’ × 101’

Table 10: Opinion of Capital and Annual O&M Costs (Phase I) – Gravity Belt Thickening

Item	Gravity Belt Thickening	
OPCC		
Sitework	$	56,600
Structural	$	4,681,400
Equipment	$	4,550,700
Mechanical	$	431,800
Electrical/Instrumentation	$	960,000
Contingency	$	3,738,200
Mobilization	$	721,000
Overhead and Profit	$	3,028,000
Total OPCC	$	18,167,700
Annual O&M		
Power	$	19,700
Chemical	$	26,500
Maintenance	$	74,900
Labor	$	122,900
Total O&M	$	244,000

8.3.3 Thickening Option Evaluation

The capital and O&M costs developed for the thickening options show that the gravity thickening option is less expensive to build and operate. However, these costs alone do not necessarily suggest that the gravity thickening option is more cost effective than the gravity belt thickening option. A fair cost comparison of the thickening options must take into account, not only the cost of the thickening system, but also the costs of the upstream and downstream stages. This is because the sizing of the sludge treatment stages directly upstream and downstream of the thickening stage are dependent on the type of thickening process. Alternatives with the gravity belt thickening option utilize upstream sludge holding tanks, whereas alternatives with gravity thickening do not. Dewatering systems downstream of the gravity belt thickening option were sized to receive thickened sludge with a solids concentration of 3 percent, whereas dewatering systems downstream of the gravity thickening options were sized for 2 percent solids. Furthermore, for sludge treatment alternatives that require hauling or pumping of thickened sludge, the difference in solids concentration will favor the thickening option with the more concentrated thickened sludge. Since some sludge treatment stages are dependent on the type of thickening option, a direct cost comparison between gravity thickening and gravity belt thickener needs to consider the total cost of the complete sludge treatment alternative. A comparison of the costs for the sludge treatment alternatives is provided later in this technical memorandum. The issue of identifying the more cost effective thickening option will be addressed in the alternative evaluations.

8.4 Dewatering

Belt filter presses and centrifuges were considered as options for the dewatering stage of the sludge treatment system. The components and costs associated with the belt filter press and centrifuge options are provided below.

8.4.1 Belt Filter Press

The belt filter press layout was sized to receive thickened sludge at the maximum sludge production rate while operating on a schedule of 5 days per week and 8 hours per day. Dewatered sludge from the belt filter presses would fall onto a conveyor belt that would send the sludge to a dumpster, while pressate would drain by gravity to the backwash waste equalization basin. The number of belt filter press units was controlled by the hydraulic loading rate as opposed to the solids loading rate. As such, the number of belt filter press units depended on the thickened solids concentration, and thus depended on the type of thickening option upstream of the dewatering stage. A summary of the characteristics of the belt filter press option is shown in Table 11. The capital and O&M costs for the belt filter press option are shown in Table 12.

Table 11: Summary of Characteristics (Phase I) – Belt Filter Press

Parameter	**Upstream Thickening Option**	
	Gravity Thickening	**Gravity Belt Thickening**
Quantity	8 Duty + 1 Standby	5 Duty + 1 Standby
Belt Width	2 meters	
Polymer Feed System	1 System (1 Pump per Belt Filter Press)	
Feed Pumps	1 per Unit (140 gpm each)	
Building Area	175' × 99'	115' × 99'
Canopy Area	99' × 40'	

Table 12: Opinion of Capital and Annual O&M Costs (Phase I) – Belt Filter Press

Item	Upstream Thickening Option	
	Gravity Thickening	Gravity Belt Thickening
OPCC		
Sitework	$ 49,700	$ 35,200
Structural	$ 4,306,400	$ 2,942,900
Equipment	$ 4,111,000	$ 2,753,200
Mechanical	$ 151,200	$ 120,000
Electrical/Instrumentation	$ 770,000	$ 770,000
Contingency	$ 3,286,000	$ 2,317,500
Mobilization	$ 633,800	$ 447,000
Overhead and Profit	$ 2,661,700	$ 1,877,200
Total OPCC	$ 15,969,800	$ 11,263,000
Annual O&M		
Power	$ 3,700	$ 2,900
Chemical	$ 26,500	$ 26,500
Maintenance	$ 67,800	$ 45,400
Labor	$ 55,600	$ 38,300
Total O&M	$ 153,600	$ 113,100

8.4.2 Centrifuge

The centrifuge layout was sized to receive thickened sludge at the maximum sludge production rate while operating on a schedule of 5 days per week and 8 hours per day. Dewatered sludge from the centrifuges would fall onto a conveyor belt that would send the sludge to a dumpster, while centrate would drain by gravity to the backwash waste equalization basin. The number of centrifuge units was controlled by the solids loading rate as opposed to the hydraulic loading rate. As such, the number of centrifuge units depended only on the solids load from the thickening stage. Since the solids load from the thickening stage was assumed to equivalent for each thickening option, the number centrifuge units did not depend on the type of thickening option upstream of the dewatering stage. A summary of the characteristics of the centrifuge option is shown in Table 13. The capital and O&M costs for the centrifuge option are shown in Table 14.

Table 13: Summary of Characteristics (Phase I) – Centrifuge

Parameter	Value
Quantity	3 Duty + 1 Standby
Bowl Diameter	30 inches
Polymer Feed System	1 System (1 Pump per Centrifuge)
Feed Pumps	1 per Unit (400 gpm each)
Building Area	72' × 65'
Canopy Area	72' × 40'

Table 14: Opinion of Capital and Annual O&M Costs (Phase I) – Centrifuge

Item	Cost
OPCC	
Sitework	$ 18,200
Structural	$ 1,327,600
Equipment	$ 3,367,000
Mechanical	$ 100,600
Electrical/Instrumentation	$ 770,000
Contingency	$ 1,954,200
Mobilization	$ 376,900
Overhead and Profit	$ 1,582,900
Total OPCC	$ 9,497,400
Annual O&M	
Power	$ 32,800
Chemical	$ 26,500
Maintenance	$ 55,900
Labor	$ 27,400
Total O&M	$ 142,600

8.4.3 Dewatering Option Evaluation

The costs developed for the dewatering options show that the centrifuge option requires the least capital investment. The savings during Phase I compared to the belt filter press option are about $6.5 million for the gravity thickening option and $1.8 million for the gravity belt thickening option. The annual O&M costs are relatively similar between the dewatering options. However, since the O&M cost for the centrifuge is not the least expensive, a life cycle analysis must be conducted to evaluate whether the centrifuge is the most cost effective dewatering option. Unlike the thickening options, the dewatering options as defined in this technical memorandum will not impact the downstream stage differently. As such, the life cycle analysis can be isolated to the capital and O&M costs of the dewatering components themselves, as opposed to comparing the total costs for the complete sludge treatment alternatives. The net present worth for the dewatering options over a 20 year life cycle are shown in Table 15. The life cycle analysis suggests that the centrifuge is the more cost effective dewatering option.

Table 15: 20 year Life Cycle Cost Analysis (Phase I) – Dewatering Options

Item	Belt Filter Press Option		Centrifuge Option
	Gravity Thickening	Gravity Belt Thickening	
OPCC	$ 15,969,800	$ 11,263,000	$ 9,497,400
Annual O&M	$ 153,600	$ 113,100	$ 142,600
Net Present Worth	$ 18,255,000	$ 12,946,000	$11,619,000

8.5 Extended Dewatering

Solar drying and lime bulking were considered as options for the extended dewatering stage of the sludge treatment system. The components and costs associated with the solar drying and lime bulking options are provided below. The extended dewatering stage would be applied for sludge treatment alternatives that utilize a monofill as the method of disposal. The extended dewatering stage is intended to provide a final sludge product with a high enough solids content suitable for stacking in a monofill. The final sludge product from the extended dewatering stage should be capable of supporting the full load of heavy machinery regardless of the depth of the monofill. For the purposes of estimating a cost for each extended dewatering option, it was assumed that a final solids content of 70 percent would be suitable to provide the necessary sludge stability. However, it should be noted that this concentration will need to be confirmed through geotechnical analysis for both extended dewatering options prior to making a final selection. The components and costs associated with the solar drying and lime bulking options are provided below.

8.5.1 Solar Drying

The solar drying system was sized to receive dewatered sludge at the maximum sludge production rate over a 7 day per week filling cycle. Processed sludge from the solar drying units would be disposed of in a monofill, while the water removed from the sludge would evaporate. The total area required for the solar drying units depends on the drying time needed to increase the initial solids concentration to the designated solids content (assumed to be 70 percent). The drying time is dependent on both the initial solids concentration and ambient temperature. Drying times are lower during the warmer summer months, and higher during the cooler winter months. A summary of the characteristics of the solar drying option is shown in Table 16. The capital and O&M costs for the solar drying option are shown in Table 17.

Table 16: Summary of Characteristics (Phase I) – Solar Drying

Parameter	Value
Quantity	15 Duty + 0 Standby
Dimensions per Unit	432' × 42'
Sludge Depth	6 inches
Summer Drying Time	27 days
Winter Drying Time	45 days

Table 17: Opinion of Capital and Annual O&M Costs (Phase I) – Solar Drying

Item	Cost
OPCC	
Sitework	$ 534,100
Structural	$ 5,646,700
Equipment	$13,254,600
Electrical/Instrumentation	$ 1,500,000
Contingency	$ 7,327,400
Mobilization	$ 1,413,200
Overhead and Profit	$ 5,935,200
Total OPCC	$35,611,200
Annual O&M	
Power	$ 13,100
Chemical	N/A
Maintenance	$ 15,000
Labor	$ 5,500
Total O&M	$ 33,600

8.5.2 Lime Bulking

The lime bulking system was sized to dose the maximum sludge production rate at a continuous pace. The lime bulking option would involve the mixing of lime to dewatered sludge. Following lime bulking, bulked sludge would be disposed of in a monofill. It should be noted that the design lime dosage would need to be determined through laboratory testing. For the purposes of the cost evaluation, a lime dosage of 6 pounds of lime per pound of dry sludge was applied. This dose represents the amount of lime required to increase the solids content of the dewatered sludge to 70 percent. In addition to the lime dosage, the minimum final solids content suitable for disposal in a monofill will also need to be determined through laboratory testing. The dose applied for the cost evaluation assumes that 100 percent of the lime added contributes to the solids content of the sludge, and that no reaction occurs between lime and water. In reality, some portion of the lime will react with water to further reduce the water content. Lime addition not only has the advantage of directly reducing the water content through this reaction, lime addition also forms a cement-like product from the reaction which strengthens the bearing capacity of the sludge. A summary of the characteristics of the lime bulking option is shown in Table 18. The capital and O&M costs for the lime bulking option are shown in Table 19.

Table 18: Summary of Characteristics (Phase I) – Lime Bulking

Parameter	Value
Mixer and Conveyor Units	4 Duty + 0 Standby
Lime Storage Silos	9 × 200-Ton Units

Table 19: Opinion of Capital and Annual O&M Costs (Phase I) – Lime Bulking

Item	Cost
OPCC	
Sitework	$ 183,400
Structural	$ 90,000
Equipment	$ 4,980,000
Electrical/Instrumentation	$ 200,000
Contingency	$ 1,908,700
Mobilization	$ 368,200
Overhead and Profit	$ 1,546,100
Total OPCC	$ 9,276,400
Annual O&M	
Power	$ 50,000
Chemical[2]	$ 2,987,200
Maintenance	$ 10,000
Labor	$ 12,500
Total O&M	$ 3,059,700

8.5.3 Extended Dewatering Option Evaluation

The costs developed for the extended dewatering options show that the lime bulking option requires the least capital investment. The savings compared to the solar drying option is about $26.3 million during Phase I. However, there is a comparatively significant disadvantage with operating under the lime bulking option. Largely due to the chemical cost associated with purchasing lime, the annual O&M cost for the lime bulking option is about $3.0 million greater than that of the solar drying option. Since the amount of sludge generated differs between the two extended dewatering options (due to the fact that lime addition increases the total of sludge), a life cycle cost comparison of the two extended dewatering option needs to consider the total cost of the complete sludge treatment alternative. A comparison of the costs for the sludge treatment alternatives is provided later in this technical memorandum. The issue of identifying the more cost effective extended dewatering option will be addressed in the alternative evaluations.

---

[2] Lime Cost = $177 per ton

8.6 Transport

Alternatives were developed that considered both an onsite and offsite dewatering facility. An onsite facility would require the final processed sludge product to be hauled for either land application or disposal in a monofill. For alternatives utilizing a monofill, an offsite dewatering facility located adjacent to the monofill was considered. Both hauling and pumping were considered as options for transporting thickened sludge to the offsite dewatering facility. The components and costs associated with the hauling and pumping options are provided below.

8.6.1 Hauling

It was assumed that the overall hauling cost would amount to $20 per cubic yard of sludge hauled.

8.6.2 Pumping

It was assumed that the pipeline length would be 30 miles. Booster pump stations would be spaced every 8 miles. The pumping system was sized to pump the maximum sludge production rate at a continuous pace. A summary of the characteristics of the pumping option is shown in Table 20. The capital and O&M costs for the pumping option are shown in Table 21.

Table 20: Summary of Characteristics (Phase I) – Thickened Sludge Pumping

Parameter	Value
Pipeline Distance	30 miles
Pipeline Diameter	6 inches
Booster Pump Stations	4 Units
Pumps per Booster Pump Station	1 Duty + 1 Standby
Capacity per Pump	236 gpm (Gravity Thickening) 214 gpm (Gravity Belt Thickening)
Working Horsepower per Pump	38 hp

Table 21: Opinion of Capital and Annual O&M Costs (Phase I) – Thickened Sludge Pumping

Item	**Upstream Thickening Option**	
	Gravity Thickening	**Gravity Belt Thickening**
OPCC		
Sitework	$ 6,064,500	$ 6,064,500
Structural	$ 174,600	$ 174,600
Equipment	$ 229,300	$ 229,300
Mechanical	$ 2,974,900	$ 2,974,900
Electrical/Instrumentation	$ 880,000	$ 880,000
Contingency	$ 3,613,200	$ 3,613,200
Mobilization	$ 696,900	$ 696,900
Overhead and Profit	$ 2,926,700	$ 2,926,700
Total OPCC	$ 17,560,100	$ 17,560,100
Annual O&M		
Power	$ 16,300	$ 12,000
Chemical	N/A	N/A
Maintenance	$ 3,900	$ 3,900
Labor	$ 10,000	$ 10,000
Total O&M	$ 30,200	$ 25,900

8.6.3 Transport Option Evaluation

A 20 year life cycle cost analysis was performed for the transport options to evaluate the cost effectiveness of hauling versus pumping thickened sludge. The net present worth for the transport options over a 20 year life cycle at an interest rate of 3 percent is shown in Table 22. In addition to the costs for the transport options, the life cycle cost analysis also includes the life cycle cost for the sludge holding tanks located at the offsite dewatering facility. The life cycle cost analysis cost shows that pumping is significantly more cost effective to transport both gravity thickened and gravity belt thickened sludge. While the pumping option is initially more expensive because of the substantial capital cost, the option will eventually become more cost effective than the hauling option. The payback period for the pumping option is about 6 years for the gravity thickening option and 9 years for the gravity belt thickening option.

Table 22: 20 year Life Cycle Cost Analysis (Phase I) – Sludge Transport Options

Transport Option	**Thickening Option**	**Net Present Worth**
Hauling	Gravity Thickening	$ 52,428,000
	Gravity Belt Thickening	$ 35,443,000
Pumping	Gravity Thickening	$ 21,157,000
	Gravity Belt Thickening	$ 20,649,000

8.7 Disposal

Land application and a monofill were considered as options for the disposal. The cost used in the cost evaluation for hauling and land applying sludge was $20 per cubic yard. It was assumed that the monofill would be designed for an operating life of 40 years at the plant build-out capacity of 280 MGD. The construction cost was estimated to be $9.25 per cubic yard of storage space in the monofill. The capital cost of the monofill for build-out of the solar drying and lime bulking options is $4.3 million and $26.2 million, respectively. The annual O&M cost used in the evaluation represents 3 percent of the monofill capital cost. A cost comparison between the two disposal options needs to include the total cost of the complete sludge treatment alternative. A comparison of these total costs is provided later in this technical memorandum.

9. SLUDGE TREATMENT ALTERNATIVES

This section identifies the sludge treatment stages making up each sludge treatment alternative, and provides the corresponding combined opinions of capital and O&M costs. The costs presented in this section represent the cost over a 20 year period from 2020 to 2040. The costs include the additional capital and O&M costs at each expansion phase. For the purposes of this technical memorandum, it was assumed that the sludge treatment system would undergo the expansions shown in Table 23. The following section evaluates the sludge treatment alternatives through each of the expansion phases.

Table 23: Treatment Capacity for each Expansion Phase

Expansion Phase	Year	Treatment Plant Capacity (Average / Maximum)	Sludge Treatment System Capacity (Average / Maximum)
Phase I	2020 (Start-up)	35 MGD / 70 MGD	35 MGD / 70 MGD
Phase II	2025	70 MGD / 140 MGD	70 MGD / 140 MGD
Phase III	2030	105 MGD / 210 MGD	140 MGD / 280 MGD
Phase IV	2035 (Build-out)	140 MGD / 280 MGD	Same as 2030

9.1 Baseline Alternative (Thickening and Sludge Lagoons with Land Application)

The Baseline Alternative consists of wasting sludge from the sedimentation basins to gravity thickeners and followed by sludge lagoons. A schematic of the treatment stages for the Baseline Alternative is shown in Figure 2. Although the sludge treatment system could feasibly operate without gravity thickening (i.e. rely solely on sludge lagoons), gravity thickening is included to improve the water quality of the solids recycle stream. Water quality of supernatant in a sludge lagoon typically deteriorates because the sludge in a lagoon is held under anaerobic conditions at a relatively long detention time.

Such conditions can elevate the levels of manganese, iron, algae, TOC, MIB, and geosmin in the supernatant which is ultimately returned to the plant. By placing gravity thickeners ahead of the sludge lagoons, the volume of water sent to the sludge lagoons is reduced by about 80 percent. As such, the volume of poor quality supernatant returned to the plant from the sludge lagoons is reduced by about 80 percent, thereby improving the overall water quality of the solids recycle stream.

The Baseline Alternative relies on full-time operation of the sludge lagoons. The function of the sludge lagoon for the other alternatives is to serve as a back-up storage unit during events when the sludge treatment system is offline. Whereas the sludge lagoons are not expanded for these other sludge treatment alternatives, the sludge lagoons must be expanded for the Baseline Alternative (the gravity thickening system is expanded as well). It was assumed that the sludge lagoons would operate under a 12 month fill/clean-out cycle. On any given day, half of the sludge lagoons would be receiving sludge, while the other half would be offline as part of the clean-out cycle. Every 12 months the sludge lagoons would alternate between being filled and cleaned out. For the purposes of the cost evaluation, it was assumed that sludge lagoons would be cleaned out by a contractor at a unit cost of $99.75 per ton of dry solids[3]. A summary of the OPCC, annual O&M, and 20 year cumulative costs for the Baseline Alternative are shown in Table 24. The cost of implementing the Baseline Alternative without gravity thickening is also provided in Table 24 to show the cost impact of gravity thickening. The cumulative net present worth of the Baseline Alternative is shown in Figure 3.

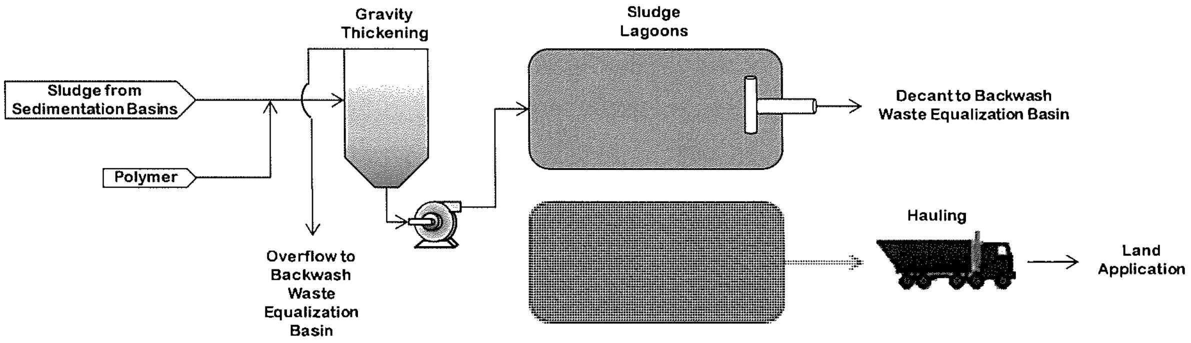


Figure 3: Process Flow Schematic – Baseline Alternative

---

[3] The unit cost for cleaning out the sludge in the sludge lagoons is based on the September 2015 bid proposal from the NTMWD Wylie WTP Removal and Disposal of Water Treatment Residuals (Project No. ENG 15-6).

Table 24: Cost Summary ($ Million) – Baseline Alternative (Sludge Lagoons / Land Application with and without Gravity Thickening)

Phase	(Does not include Gravity Thickening)			(Includes Gravity Thickening)		
	OPCC	Annual O&M	20-Year Interest-Adjusted Cumulative Cost (2016 Dollars)	OPCC	Annual O&M	20-Year Interest-Adjusted Cumulative Cost (2016 Dollars)
I	$ 9.6	$ 0.4	$ 9.7	$ 13.0	$ 0.4	$ 12.9
II	$ 9.6	$ 0.7	$ 19.4	$ 13.0	$ 0.9	$ 25.6
III	$ 19.1	$ 1.5	$ 40.7	$ 25.9	$ 1.7	$ 53.0

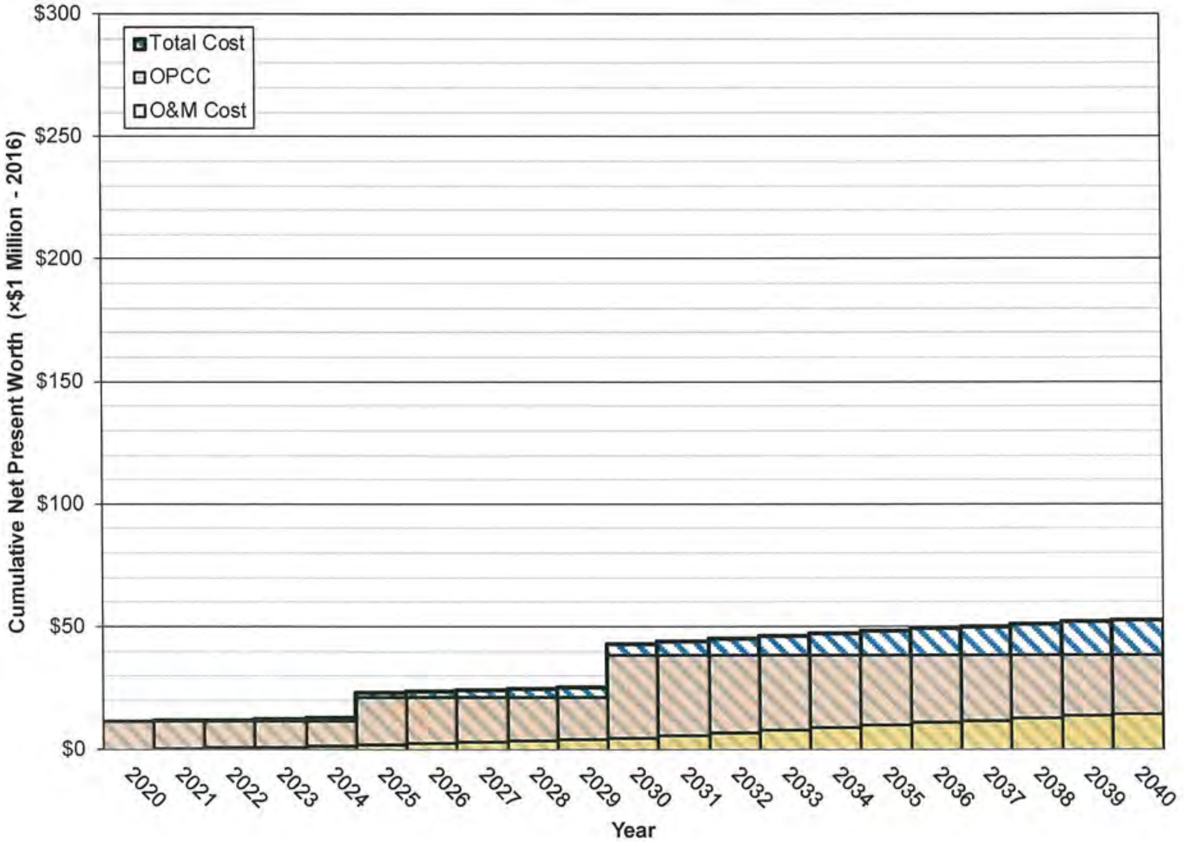


Figure 4: Cumulative 20 Year Life Cycle Cost – Baseline Alternative (Gravity Thickening / Sludge Lagoons / Land Application)

9.2 Alternative 1 (Thickening/Tank Storage with Land Application)

The treatment stages making up Alternative 1 are thickening, storage, and disposal of thickened sludge through land application. A comparison of the 20 year life cycle cost between the gravity thickening and gravity belt thickening options indicated that implementing gravity thickening was the more cost effective option. Gravity thickening is about $36.1 million less than the gravity belt thickening option over the first 20 years of operation. A summary of the OPCC, annual O&M, and 20 year cumulative costs for the gravity thickening and gravity belt thickening options of Alternative 1 are shown in Table 25. A schematic of the treatment stages for Alternative 1 is shown in Figure 4. The cumulative net present worth of Alternative 1 is shown in Figure 5.

Table 25: Cost Summary ($ Million) – Alternative 1 (Gravity Thickening and Gravity Belt Thickening Options)

Phase	Gravity Thickening			Gravity Belt Thickening		
	OPCC	Annual O&M	20-Year Interest-Adjusted Cumulative Cost (2016 Dollars)	OPCC	Annual O&M	20-Year Interest-Adjusted Cumulative Cost (2016 Dollars)
I	$ 15.7	$ 3.5	$ 25.6	$ 37.8	$ 2.6	$ 42.3
II	$ 6.1	$ 6.9	$ 52.7	$ 28.2	$ 5.2	$ 80.7
III	$ 12.3	$ 13.8	$ 143.3	$ 56.4	$ 10.3	$ 179.4

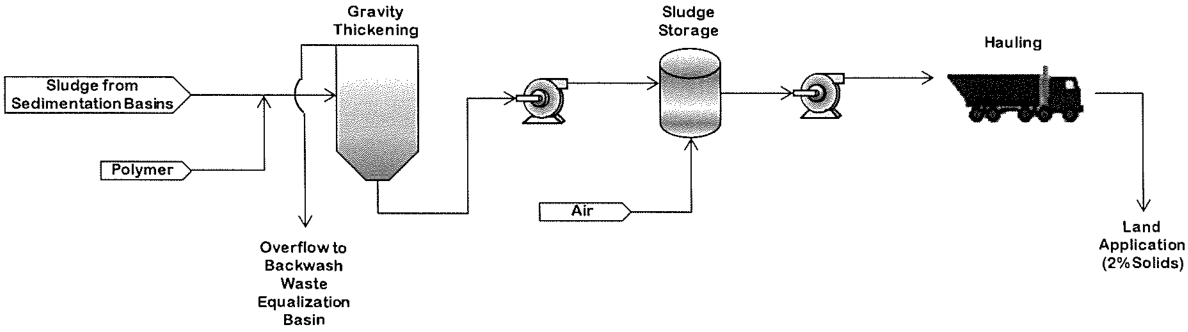


Figure 5: Process Flow Schematic – Alternative 1

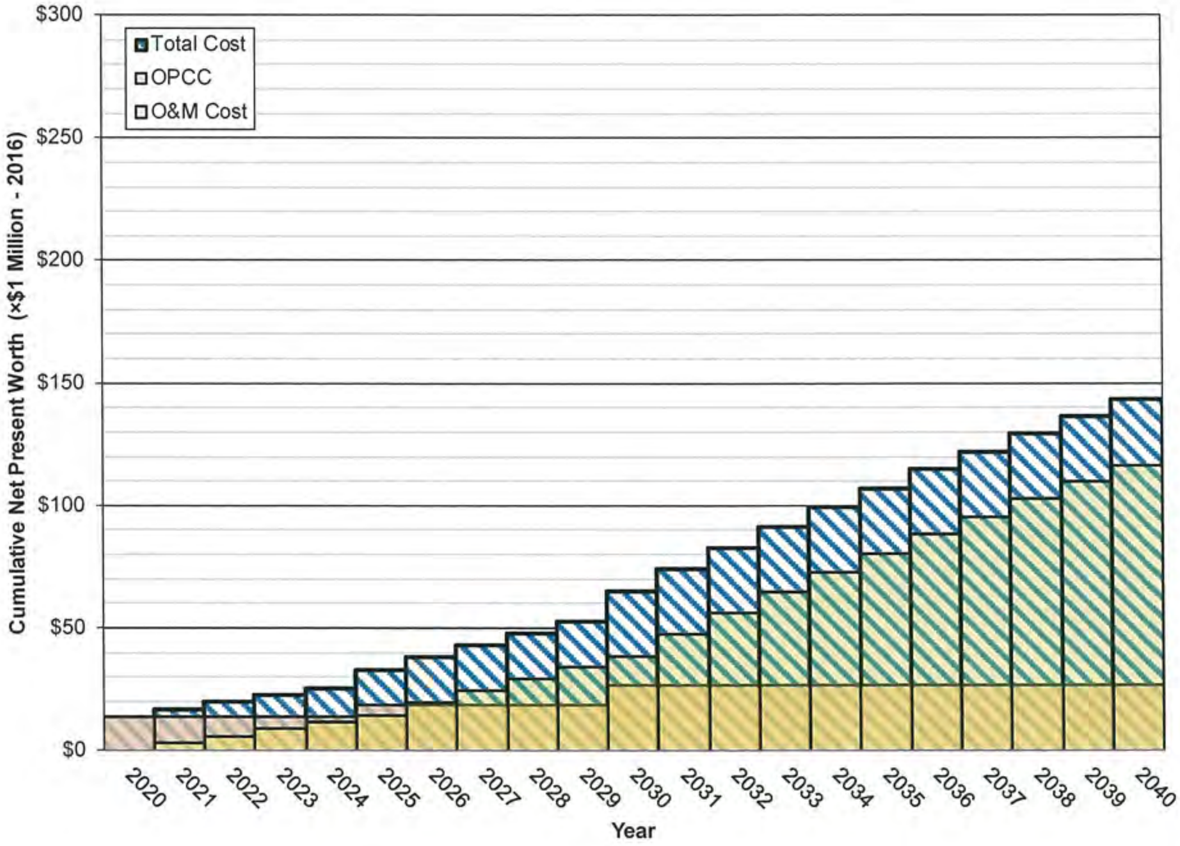


Figure 6: Cumulative 20 Year Life Cycle Cost – Alternative 1 (Gravity Thickening / Land Application)

9.3 Alternative 2 (Thickening/Tank Storage and Dewatering with Land Application)

The treatment stages making up Alternative 2 are thickening, storage, dewatering, and disposal of dewatered sludge through land application. It was determined from Section 7 *Sludge Treatment Options* that the centrifuge option is the more cost effective dewatering option when compared to a belt filter press. From the cost evaluation of Alternative 1, it was determined that the gravity thickening option is more cost effective than the gravity belt thickening option. As such, the thickening and dewatering options selected for Alternative 2 included gravity thickening and centrifuges. A summary of the OPCC, annual O&M, and 20 year cumulative costs for Alternative 2 are shown in Table 26. A schematic of the treatment stages for Alternative 2 is shown in Figure 6. The cumulative net present worth of Alternative 2 is shown in Figure 7.

Table 26: Cost Summary ($ Million) – Alternative 2 (Centrifuge Option)

Phase	OPCC	Annual O&M	20-Year Interest-Adjusted Cumulative Cost (2016 Dollars)
I	$ 25.2	$ 0.5	$ 24.2
II	$ 15.6	$ 1.0	$ 39.5
III	$ 31.3	$ 1.9	$ 71.7

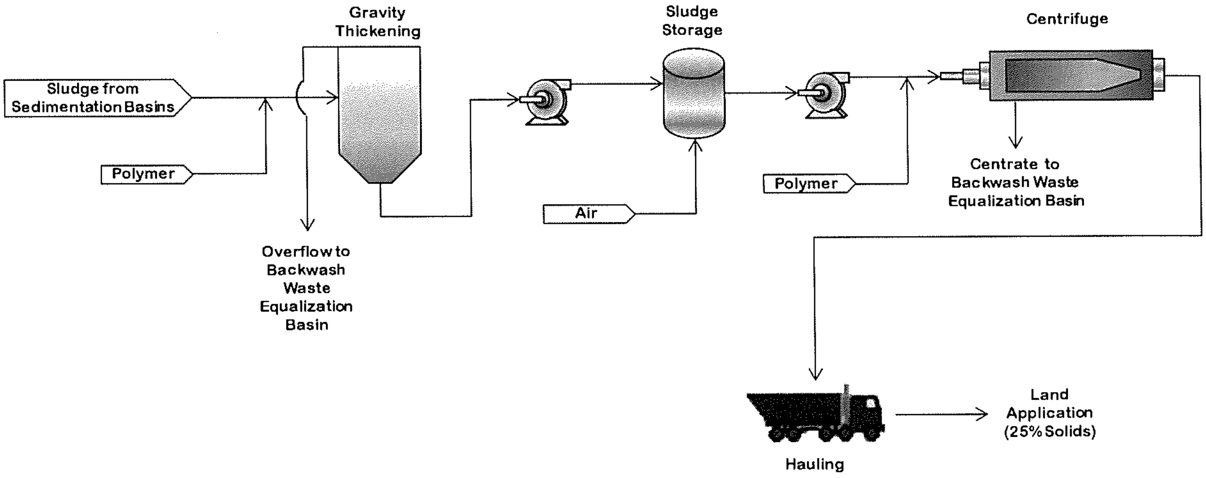


Figure 7: Process Flow Schematic – Alternative 2

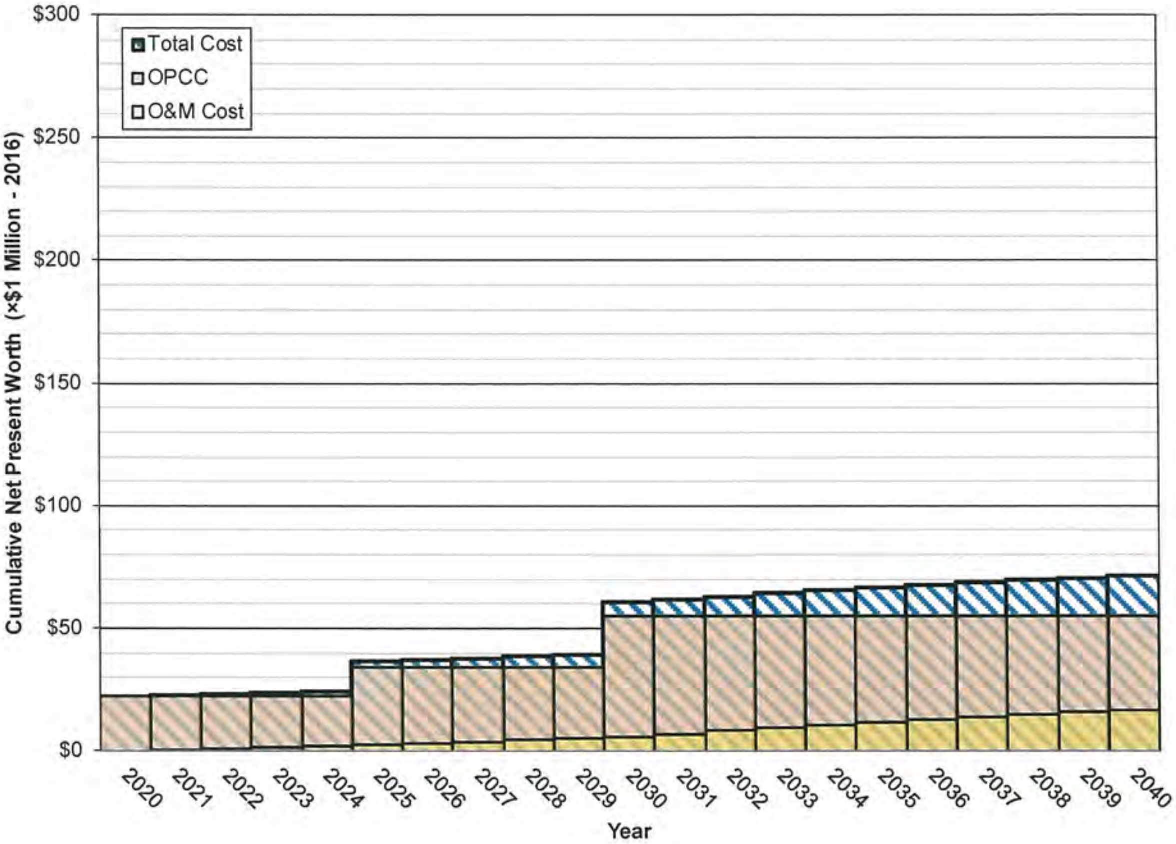


Figure 8: Cumulative 20 Year Life Cycle Cost – Alternative 2 (Gravity Thickening / Centrifuge / Land Application)

9.4 Alternative 3 (Thickening/Tank Storage, Dewatering, and Extended Dewatering with Nearby Monofill)

Alternative 3 included monofill for sludge disposal. The monofill disposal must include an extended dewatering stage to increase the solids content beyond the limit of traditional dewatering systems such as belt filter presses and centrifuges. Sludge from the sedimentation basins would be thickened, stored, dewatered, processed in an extended dewatering stage, and then disposed of in a monofill. It was determined from the 20 year life cycle costs of Alternatives 2 that the gravity thickening and centrifuges options are the most cost effective thickening and dewatering options.

A 20 year life cycle cost was determined for both the solar drying and lime bulking options. Solar drying is more cost effective over 20 years with a savings of about $48.5 million. A summary of the OPCC, annual O&M, and 20 year cumulative costs for the solar drying and lime bulking options of Alternative 3 are shown in Table 27. Although the solar drying option is more cost effective, it should be noted that the payback period is about 12 years. The comparison of solar drying and lime bulking is significantly dependent on the lime dosage. The more conservative lime dosage of 6 pounds per pound of dry solids was used for the cost evaluation. However, it's possible that a lime dosage as low as 3 pounds per pound of dry solids could be sufficient. In which case, lime bulking would be more cost effective over 20 years with a savings of about $19.7 million. Given the sensitively of the life cycle analysis to the lime dosage, it is critical that laboratory testing be conducted to determine the optimum lime dosage before selecting the type of extended dewatering system. A schematic of the treatment stages for Alternative 3 is shown in Figure 8. The cumulative net present worth of Alternative 3 is shown in Figure 9. The cost evaluation assumes that the monofill is adjacent to the Leonard WTP, and that the effort required to haul is within the O&M budget of the monofill (the annual O&M budget for the monofill represents 3 percent of the monofill capital cost).

Table 27: Cost Summary ($ Million) – Alternative 3 (Solar Drying and Lime Bulking Options)

Phase	Solar Drying			Lime Bulking		
	OPCC	Annual O&M	20-Year Interest-Adjusted Cumulative Cost (2016 Dollars)	OPCC	Annual O&M	20-Year Interest-Adjusted Cumulative Cost (2016 Dollars)
I	$ 65.1	$ 0.4	$ 59.1	$ 60.7	$ 3.6	$ 65.8
II	$ 51.3	$ 0.7	$ 100.6	$ 24.9	$ 7.1	$ 107.7
III	$ 102.5	$ 1.3	$ 176.0	$ 49.8	$ 14.0	$ 224.5

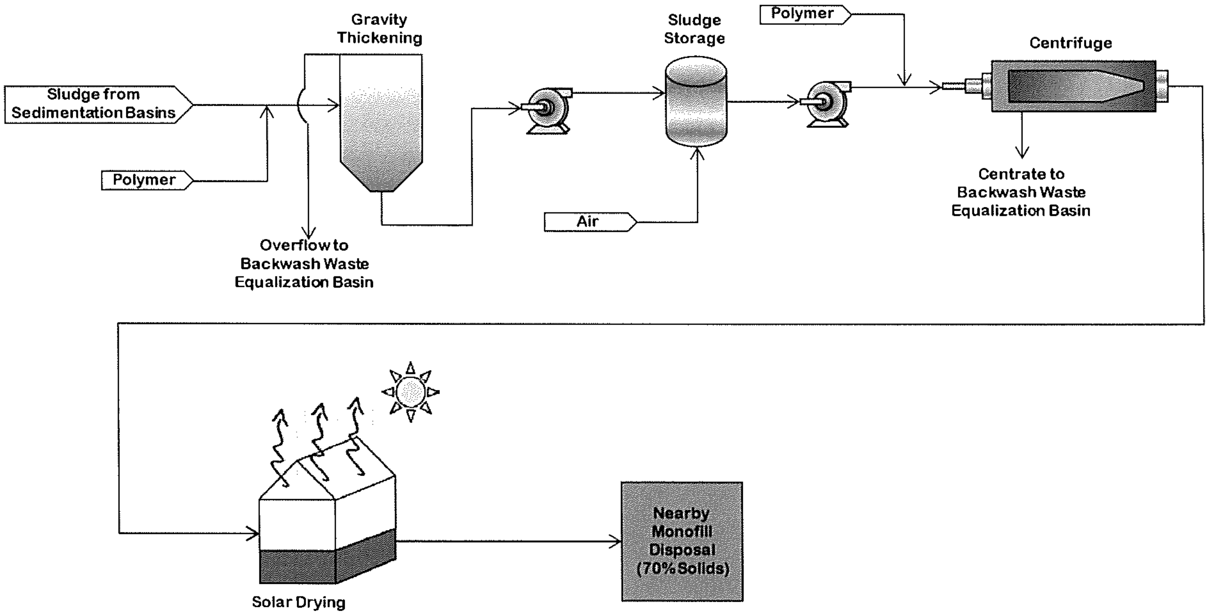


Figure 9: Process Flow Schematic – Alternative 3

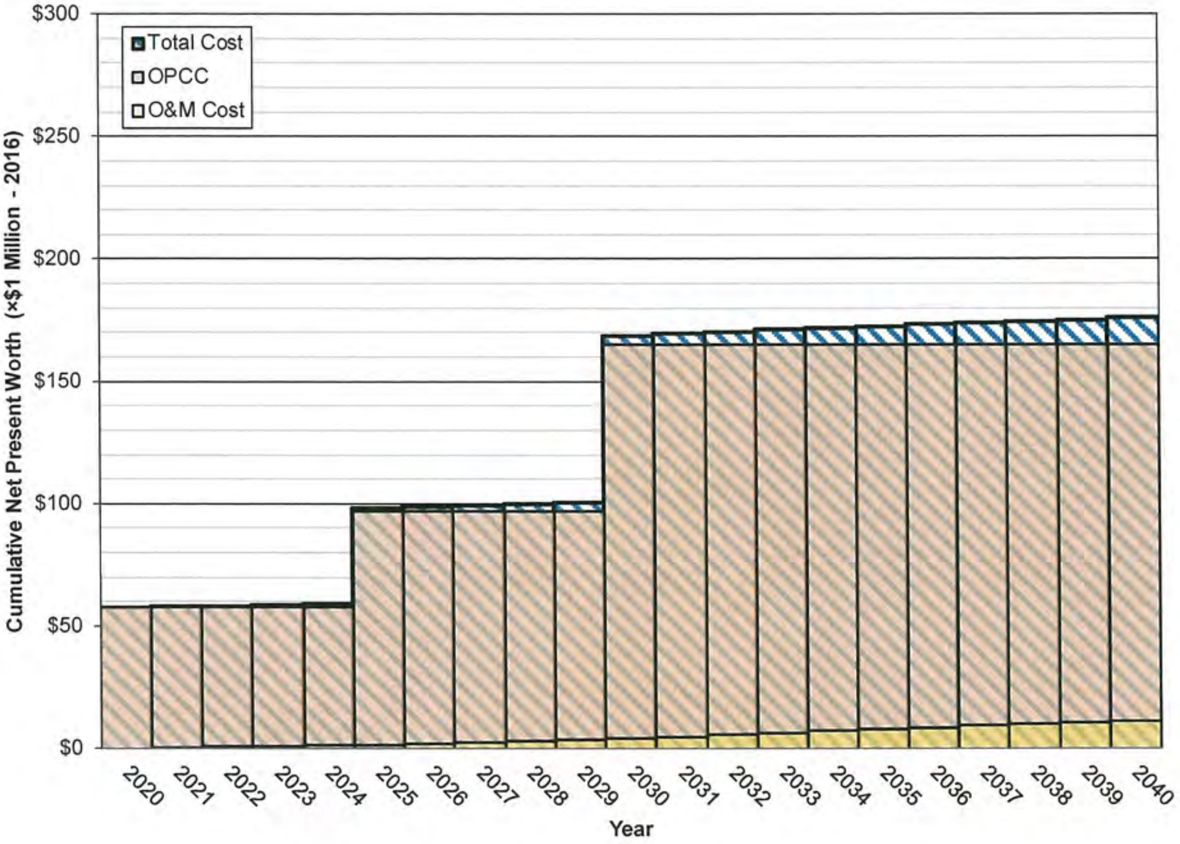


Figure 10: Cumulative 20 Year Life Cycle Cost – Alternative 3 (Gravity Thickening / Centrifuge / Solar Drying / Monofill)

9.5 Alternative 4 (Onsite Thickening/Tank Storage/Dewatering/Extended Dewatering with Hauling to Distant Monofill)

Alternative 4 is similar to Alternative 3, except the monofill is assumed to be located approximately 30 miles from the site rather than adjacent to the Leonard WTP. A summary of the OPCC, annual O&M, and 20 year cumulative costs for the solar drying and lime bulking options of Alternative 4 are shown in Table 28. Comparing the costs between Alternatives 3 and 4, the increase in total cost due to hauling processed sludge over the 20 year life cycle is about $2.0 million for solar drying and $12.0 million for lime bulking at a lime dosage of 6 pounds per pound of dry solids ($9.8 million at 3 pounds per pound of dry solids). A schematic of the treatment stages for Alternative 4 is shown in Figure 10. The cumulative net present worth of Alternative 4 is shown in Figure 11.

Table 28: Cost Summary ($ Million) – Alternative 4 (Solar Drying and Lime Bulking Options)

Phase	Solar Drying			Lime Bulking		
	OPCC	Annual O&M	20-Year Interest-Adjusted Cumulative Cost (2016 Dollars)	OPCC	Annual O&M	20-Year Interest-Adjusted Cumulative Cost (2016 Dollars)
I	$ 65.1	$ 0.4	$ 59.3	$ 60.7	$ 3.9	$ 66.9
II	$ 51.3	$ 0.8	$ 101.2	$ 24.9	$ 7.8	$ 111.2
III	$ 102.5	$ 1.5	$ 178.0	$ 49.8	$ 15.5	$ 236.5

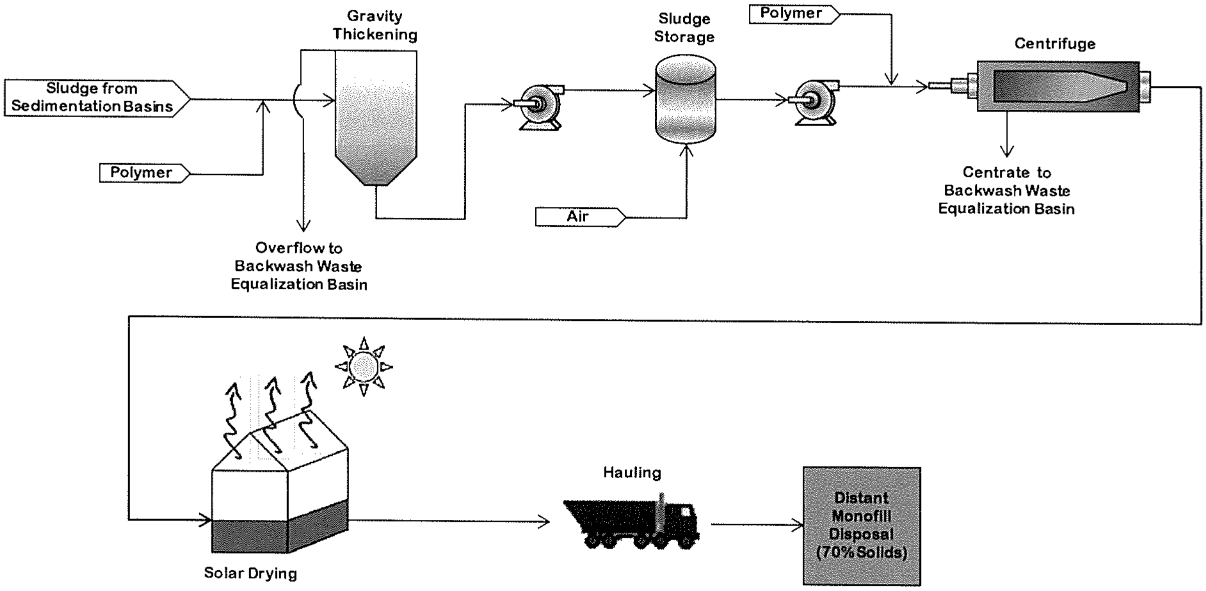


Figure 11: Process Flow Schematic – Alternative 4

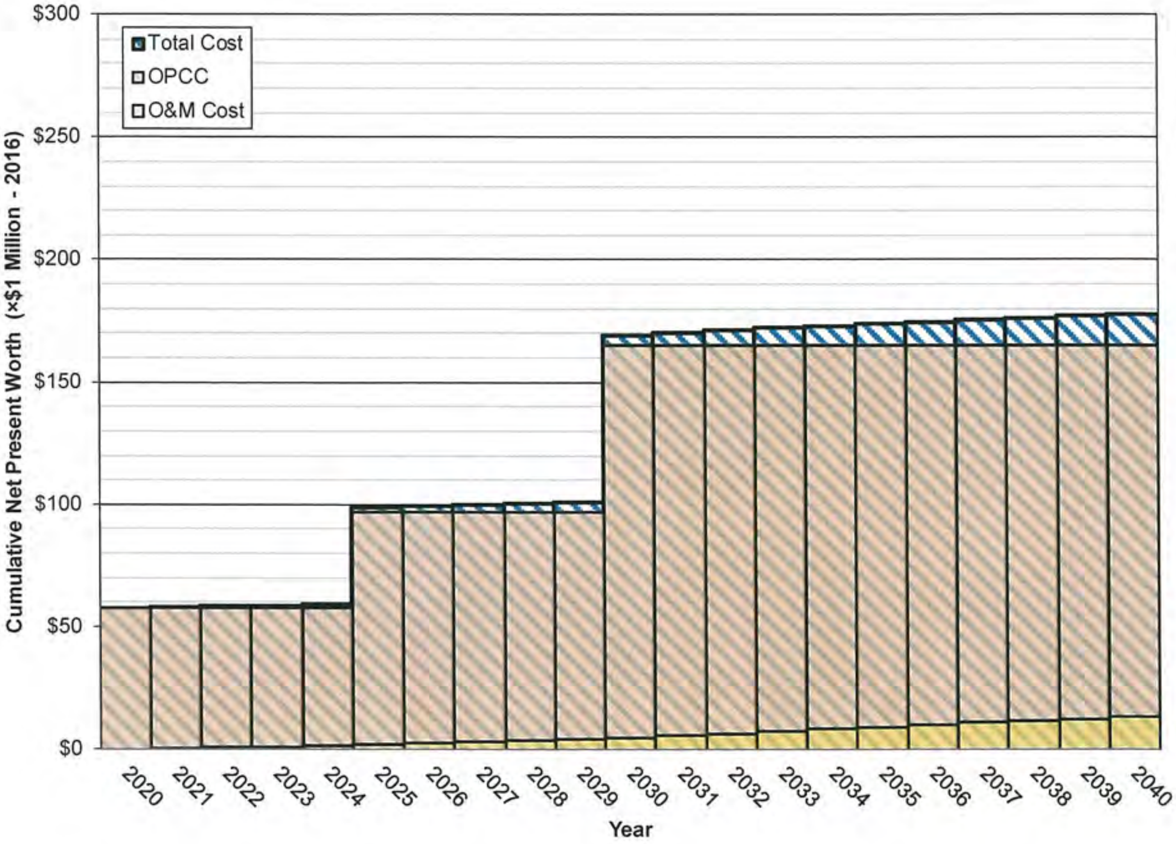


Figure 12: Cumulative 20 Year Life Cycle Cost – Alternative 4 (Gravity Thickening / Centrifuge / Solar Drying / Hauling to Distant Monofill)

9.6 Alternative 5 (Pumping Thickened Sludge to Offsite Dewatering Facility/Monofill)

Sludge from the sedimentation basins would be thickened, stored, pumped to the offsite dewatering facility where it would be stored, dewatered, processed in an extended dewatering stage, and then disposed of in a monofill. Alternative 5 is similar to Alternative 3 except both the dewatering facility and monofill are assumed to be located offsite. It was determined from Section 7.6.3 *Transport Option Evaluation* that pumping thickened sludge was more cost effective than hauling thickened sludge. As such, the pumping option was evaluated for Alternative 5 while applying the same thickening, dewatering, and extended dewatering options selected for Alternative 3. Since the O&M cost for pumping gravity belt thickened sludge is slightly less than that of gravity thickened sludge, both thickening options were evaluated in a 20 life cycle cost analysis of Alternative 5. The life cycle cost indicated that gravity thickening is significantly more cost effective than gravity belt thickener for this alternative. The savings over the 20 year period is about $72.2 million. A summary of the OPCC, annual O&M, and 20 year cumulative costs for the gravity thickening and gravity belt thickening options of Alternative 5 are shown in

Table 29. A schematic of the treatment stages for Alternative 5 is shown in Figure 12. The cumulative net present worth of Alternative 5 is shown in Figure 13.

Table 29: Cost Summary ($ Million) – Alternative 5 (Gravity Thickening and Gravity Belt Thickening Options)

Phase	Gravity Thickening			Gravity Belt Thickening		
	OPCC	Annual O&M	20-Year Interest-Adjusted Cumulative Cost (2016 Dollars)	OPCC	Annual O&M	20-Year Interest-Adjusted Cumulative Cost (2016 Dollars)
I	$ 85.4	$ 0.4	$ 77.3	$ 107.0	$ 0.7	$ 97.3
II	$ 71.6	$ 0.8	$ 134.8	$ 93.2	$ 1.3	$ 172.8
III	$ 143.1	$ 1.5	$ 238.4	$ 186.4	$ 2.4	$ 310.6

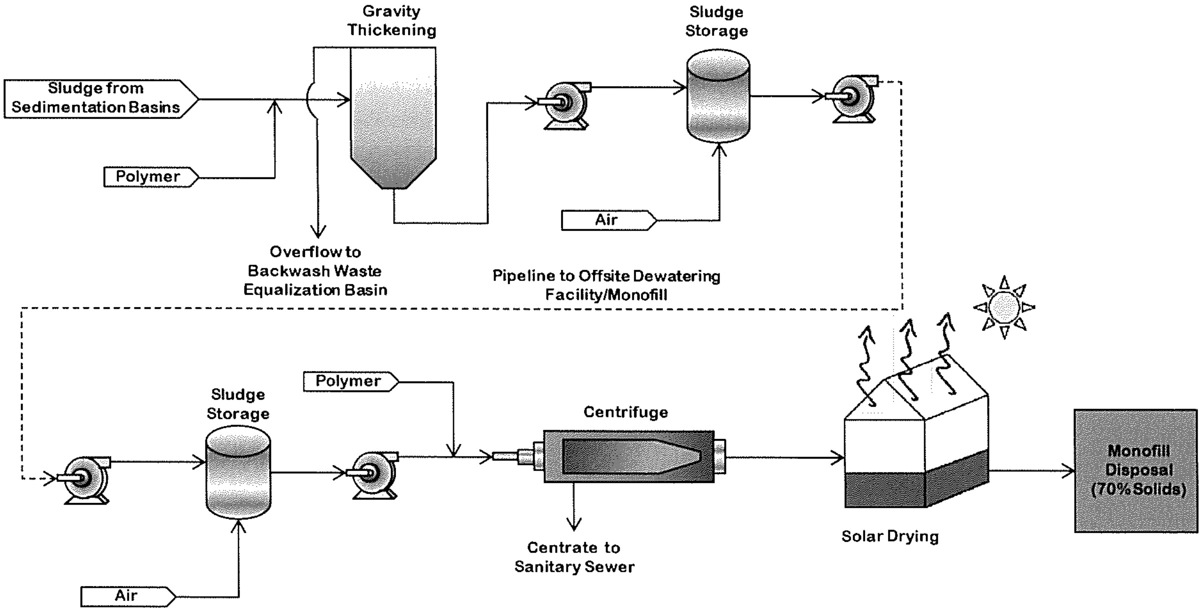


Figure 13: Process Flow Schematic – Alternative 5

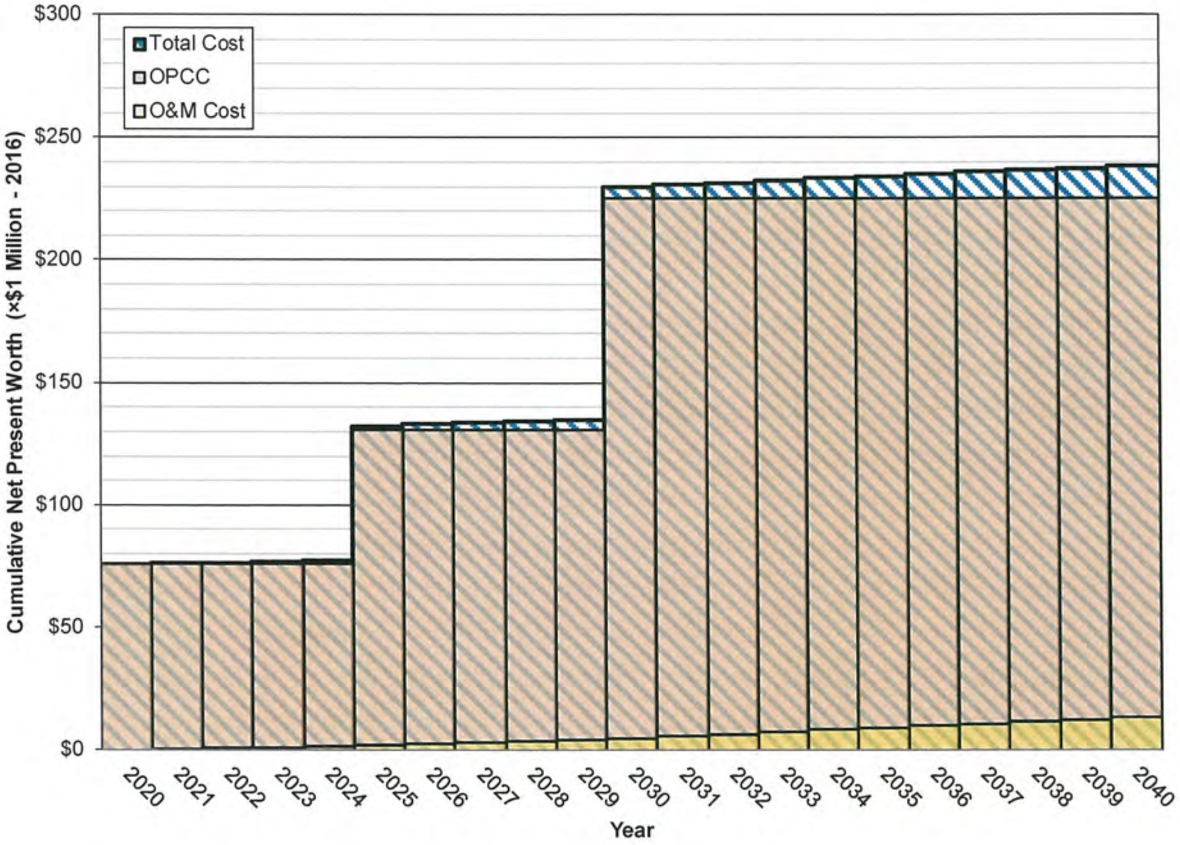


Figure 14: Cumulative 20 Year Life Cycle Cost – Alternative 5 (Gravity Thickening / Pump to Offsite Dewatering Facility / Centrifuge / Solar Drying / Monofill)

10. COMPARISON OF SLUDGE TREATMENT ALTERNATIVES

A comprehensive summary of the OPCC, annual O&M, and 20 year cumulative costs for the sludge treatment alternatives developed for the Leonard WTP are shown in Table 30. The 20 year life cycle cost show that the baseline alternatives are the least expensive alternatives. The baseline alternatives were intended to represent the current and proposed methods of sludge handling at the NTMWD Wylie WTP. Currently the Wylie WTP sends sludge from the sedimentation basins to sludge lagoons which are periodically cleaned out by a contractor. The proposed sludge handling method at the Wylie WTP utilizes gravity thickeners prior to sending sludge to the sludge lagoons. A tradeoff between water quality and capital costs is reflected in the costs of the alternatives. Although the baseline alternatives are the least expensive, they have the disadvantage of producing the poorest quality recycle stream of the alternatives. This is because the baseline alternatives, unlike the other alternatives, utilize sludge lagoons during normal operation which produce poor quality supernatant. The addition of a gravity thickening system to the sludge lagoon operation would improve the overall water quality of the solids recycle stream by reducing the volume of water sent to the sludge lagoons. However, if water quality is a primary concern for selecting the sludge treatment system, then the baseline alternatives should be eliminated from consideration in favor of alternatives that do not utilize sludge lagoons under normal operation such as Alternatives 1 thru 5.

Table 30: Cost Summary ($ Million) – Sludge Treatment Alternatives

Disposal Method	Alternative	Interest-Adjusted Cumulative OPCC (2016 Dollars)	Annual O&M (Phase I)[4]	20-Year Interest-Adjusted Net Present Worth (2016 Dollars)
Land Application	Baseline (w/o Thickening)	$ 28.5	$ 0.36	$ 40.7
	Baseline (Gravity Thickening/Sludge Lagoons/Disposal)	$ 38.6	$ 0.43	$ 53.0
	1 (Gravity Thickening/Tank Storage/Disposal)	$ 26.8	$ 3.51	$ 143.3
	2 (Gravity Thickening/Tank Storage/Centrifuge/Disposal)	$ 55.1	$ 0.55	$ 71.7
Monofill	3 (Gravity Thickening/Tank Storage/Centrifuge/ Solar Drying/Nearby Disposal)	$ 164.9	$ 0.38	$ 176.0
	4 (Gravity Thickening/Tank Storage/Centrifuge/Solar Drying/Distant Disposal)	$ 164.9	$ 0.44	$ 178.0
	5 (Gravity Thickening/Tank Storage/Thickened Sludge Pumping to Offsite Dewatering Facility/Centrifuge/Solar Drying/Disposal	$ 225.4	$ 0.44	$ 238.4

---

[4] The O&M cost for Phase II is 2 × Phase I; Phase III is 4 × Phase I.

Comparison of the disposal methods in Table 30 shows that land application is more cost effective than monofill disposal over a 20 year life cycle. Comparing the most expensive land application alternative (Alternative 1) with the least expensive monofill alternative (Alternative 3) suggests that the hauling cost would have to be increased from $20.00 to $25.80 per cubic yard for the monofill to be more cost effective. Similarly, when comparing Alternative 2 with Alternative 3, the hauling cost would have to be increased from $20.00 to $290.00 per cubic yard.

Alternative 2, which represents land application of dewatered sludge from a centrifuge system, is the most cost effective alternative over a 20 year life cycle when comparing alternatives that do not use sludge lagoons during normal operation (i.e. Alternatives 1 thru 5). Alternative 2 has the disadvantage of requiring a substantial initial capital investment. The initial capital investment for Alternative 2 is about $9.5 million more expensive than Alternative 1 (which represents land application of gravity thickened sludge) which has the lowest initial capital investment of Alternatives 1 thru 5. The payback period for implementing Alternative 2 is about 6 years after initial startup.

Comparison of the sludge treatment alternatives using a monofill for disposal suggests that operating an onsite dewatering facility would be more cost effective than an offsite dewatering facility. This is illustrated by comparing the 20 year life cycle costs of Alternatives 4 and 5 which are similar with the exception of the cost required to transport sludge to an offsite dewatering facility. Alternative 4 represents the operation of an onsite dewatering facility/offsite monofill, and Alternative 5 represents the operation of an offsite dewatering facility adjacent to the monofill. The hauling cost applied to the final sludge product for Alternative 4 would have to be increased from $20.00 to $643.00 per cubic yard for Alternative 5 to be more cost effective.

11. SUMMARY OF ANALYSIS

A summary of the key points drawn from the evaluation of the sludge treatment alternatives is provided below.

- Any decision to implement sludge lagoons must take into consideration not only costs, but also the impacts of the poor water quality of the sludge lagoon supernatant on the solids recycle streams.
- The cost evaluation suggests that land application is more cost effective than implementing a monofill when hauling/disposal costs are less than $25.80.
- Other than the Baseline Alternative (which represents gravity thickening, sludge lagoon storage, and land application), Alternative 2 (which represents gravity thickening, centrifuge dewatering,

and land application of dewatered sludge) offers the greatest long-term cost savings of the alternatives evaluated as suggested by the 20-year net present worth.

- Even though land application is more cost effective than implementing a monofill, non-cost factors may drive the decision to implement a monofill. These non-cost factors include:
  a. Availability/reliability of land application sites.
  b. Requirements imposed by new regulations.
  c. Client preference of disposal method.
- Below are possible scenarios which represent phased approaches for implementing the sludge treatment system. The OPCC, annual O&M, and 20 year life cycle costs for each scenario are provided in Table 31.

Scenario 1:
Phase I (2020): Alternative 1 – Gravity Thickening / Land Application
Phase II (2025): Same as Phase I
Phase III (2030): Alternative 3 – Gravity Thickening / Centrifuge / Solar Drying / Monofill

Scenario 2:
Phase I (2020): Alternative 2 – Gravity Thickening / Centrifuge / Land Application
Phase II (2025): Same as Phase I
Phase III (2030): Alternative 3 – Gravity Thickening / Centrifuge / Solar Drying / Monofill

Scenario 3:
Phase I (2020): Alternative 1 – Gravity Thickening / Land Application
Phase II (2025): Alternative 2 – Gravity Thickening / Centrifuge / Land Application
Phase III (2030): Alternative 3 – Gravity Thickening / Centrifuge / Solar Drying / Monofill

Table 31: Cost Summary ($ Million) – Phasing of Alternatives

Phase	OPCC	Annual O&M	20-Year Interest-Adjusted Cumulative Cost (2016 Dollars)
Alternative 1 / 1 / 3 (Phase I/II/III)			
I	$ 15.7	$ 3.5	$ 25.6
II	$ 6.1	$ 6.9	$ 52.7
III	$ 197.0	$ 1.3	$ 194.8
Alternative 2 / 2 / 3 (Phase I/II/III)			
I	$ 25.2	$ 0.5	$ 24.2
II	$ 15.6	$ 1.0	$ 39.5
III	$ 178.0	$ 1.3	$ 165.0
Alternative 1 / 2 / 3 (Phase I/II/III)			
I	$ 15.7	$ 3.5	$ 25.6
II	$ 25.1	$ 1.0	$ 50.4
III	$ 178.0	$ 1.3	$ 176.0

12. IMPLEMENTATION PLAN

A progress meeting was held with the District on March 10, 2016 during which the design team and the District discussed the sludge treatment alternatives evaluated in this technical memorandum. Based on the outcome of the discussion, APAI recommends implementing the Baseline Alternative (gravity thickening and sludge lagoons with land application) for the first phase of construction of the Leonard WTP. APAI also recommends that a third lagoon be installed in the first Phase based on input from the District and the project team during the meeting. The Baseline Alternative was selected because of the advantages in capital cost and its operational similarities to the Wylie WTP.

In addition to the implementation of the Baseline Alternative, APAI recommends that the following tasks be included in the Phase I project:

1. A sludge settleability test using Wylie WTP sludge to provide additional data for sizing the sludge thickeners at Leonard WTP.
2. Geotech testing using Wylie WTP sludge to determine the optimum solids content that would allow supporting of heavy machinery loads at a monofill. Geotech tests should analyze both air dried sludge to represent the product from a solar drying unit, and sludge dosed with lime to represent the product from lime bulking. Sludge should be dewatered to a solids content of 25 percent prior to air drying or adding lime.
3. A bulking agent pilot study using thickened Wylie WTP sludge to provide the District with data regarding the amount of lime required for improving the extended dewatering of ferric sludge.
4. A site evaluation for locating a sludge monofill near the Leonard WTP site.

APPENDIX A

NTMWD Leonard WTP Preliminary Design Services
Sludge Treatment Evaluation

ALAN PLUMMER
ASSOCIATES, INC.
ENVIRONMENTAL
ENGINEERS AND SCIENTISTS

TECHNICAL MEMORANDUM

TECHNICAL MEMORANDUM – APPENDIX A
NTMWD Leonard WTP Preliminary Design Services
Sludge Treatment Evaluation

Project No.:	0587-013-01
Date:	June 8, 2016
Prepared For:	CH2M Hill
Prepared By:	Alan Davis, APAI, Texas (P.E. No. 89254) Phillip Lintereur, APAI, Texas (P.E. No. 114390) Kyle Nelson, APAI, E.I.T.

1.1 Sludge Treatment Options

The sludge treatment system was divided into six stages for the evaluation which were labeled storage, thickening, dewatering, extended dewatering, transport, and disposal. The stages were further sub-divided into sludge treatment options which represented the different methods and technologies capable of meeting the design objectives of a given stage. A general description of the methods and technologies for each sludge treatment option considered during the evaluation are described in this appendix.

1.2 Storage

Sludge lagoons and sludge holding tanks were considered as options for the storage stage of the evaluation. Sludge lagoons are commonly used at water treatment facilities as a means for storage and dewatering of sludge. Sludge from the sedimentation basins can be sent directly to the lagoons or thickened beforehand. Once in the sludge lagoons, solids from the sludge settle out to form distinct layers of compacted solids and liquid (supernatant). Supernatant can be decanted and conveyed out of the sludge lagoon to make space for additional sludge. Once the volume of solids in the compacted solids layer of the sludge lagoon is filled to capacity, solids must be removed from the sludge lagoon (referred to as the clean-out cycle). Multiple sludge lagoons are typically built to allow operations to continue while a sludge lagoon is out-of-service for solids removal/cleaning. The filling and clean-out cycles can range from several months to years, depending on the size of the sludge lagoons and climate. The relatively long detention times for sludge lagoons present a disadvantage to maintaining favorable water quality in the solids recycle stream. Under the anaerobic conditions of the compacted solids layer, and during the long detention time, solids can deteriorate the quality of the supernatant layer through the release of such constituents as manganese, iron, and TOC. Furthermore, the environmental conditions in the sludge lagoon can promote the formation of algae, MIB, and geosmin.

Sludge holding tanks are typically used to store sludge for relatively short periods of time. Detention times are usually no more than a few days. Sludge holding tanks can be used to store thickened and unthickened sludge, but are generally considered inappropriate for storing sludge with a solids content greater than about 4 percent. When placed ahead of a thickening or dewatering process, sludge holding tanks allow the downstream process to operate more easily at a steady flow. Sludge holding tanks include some method of regular mixing such as mechanical or aeration mixing.

1.3 Thickening

Gravity thickening and gravity belt thickening were considered as options for the thickening stage of the evaluation. After removal from the sedimentation basin, sludge can be thickened to reduce the volume by approximately 80 to 90 percent.

Gravity thickeners are the most common type of thickening process used at water treatment facilities. There are two types of gravity thickener systems: continuous flow and batch “fill-and-draw” systems. Continuous flow thickeners operate similar to a settling tank. Residuals enter near the center of the basin and are distributed radially. The settled sludge is collected in the underflow, while the supernatant exits over a peripheral weir or trough. Gravity thickeners are typically equipped with a sludge mechanism to promote sludge movement down to a draw-off pipe near the bottom in the center of the tank. The solids are allowed to settle and compact, and the thickened sludge is withdrawn from the bottom of the tank. Batch thickeners are equipped with sloped hoppers where the sludge collects. Sludge flows into the tank until full. The sludge is allowed to settle, and a telescoping decant pipe is used to remove the supernatant. This pipe may be lowered until the desired solids concentration is reached. Sludge settling in gravity thickeners may be enhanced by the addition of a polymer. Polymers are used to enhance the coagulation of particles through promoting floc formation by bridging particles together. This bridging effect improves solids compacting, and increases the hydraulic throughput capacity in gravity thickeners.

Gravity belt thickeners are typically used to thicken sludge prior to mechanical dewatering. A basic schematic of a gravity belt thickener is shown in Figure 1. Feed sludge is dosed with a polymer and flows on to a filter belt. Water is separated from the sludge by gravity and flows through the traveling filter belt. The remaining sludge is moved by the belt and is collected at the end of the horizontal belt as a pumpable thickened sludge. Gravity belt thickeners offer a lower footprint than gravity thickeners, and they can generally produce higher thickened solids concentrations.

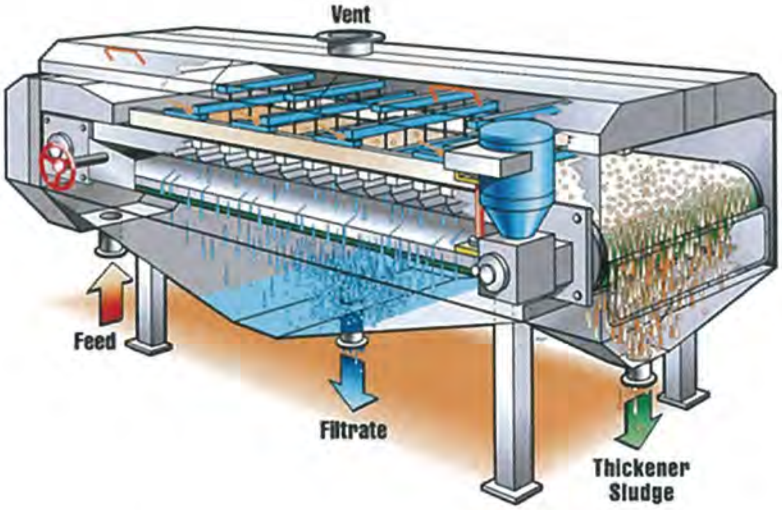


Figure 1: Gravity Belt Thickener (courtesy of BDP Industries)

1.4 Dewatering

Belt filter presses, centrifuges, three-belt presses, and geotubes were considered for this evaluation. Each dewatering option would include the addition of a polymer to increase the efficiency of the process.

Belt filter presses are common for dewatering water treatment sludge. An example of a belt filter press is shown in Figure 2. Belt filter presses use a combination of gravity draining and mechanical pressure to dewater the sludge. After the solids are conditioned with a polymer, the sludge enters a gravity drainage stage similar to a gravity belt thickener. The gravity zone transitions directly onto another belt for generating pressure. The partially dewatered solids are sandwiched between two tensioned porous belts that travel in an S-shaped path over and under rollers of various diameters. The S-shaped path creates shear forces that assist in the dewatering process. Increased pressure is created as the belt passes over rollers which decrease in diameter. The compressive and shear forces working on the sludge increase with the length of the belt.

Figure 2: Belt Filter Press (courtesy of Ashbrook)

Centrifugal dewatering is a high speed process that uses centrifugal forces to separate solids from liquid. A schematic of a centrifuge is shown in Figure 3. Sludge is continuously fed into the middle of the centrifuge where the centrifugal force of the rotary shaft draws the solids up the walls and to one end of the centrifuge. Clarified water gravity drains over weirs on the opposite side of the centrifuge. Centrifuges require a smaller floor space relative to other dewatering methods, and can handle higher design loadings than belt filter presses. However, centrifuges have high power consumption.

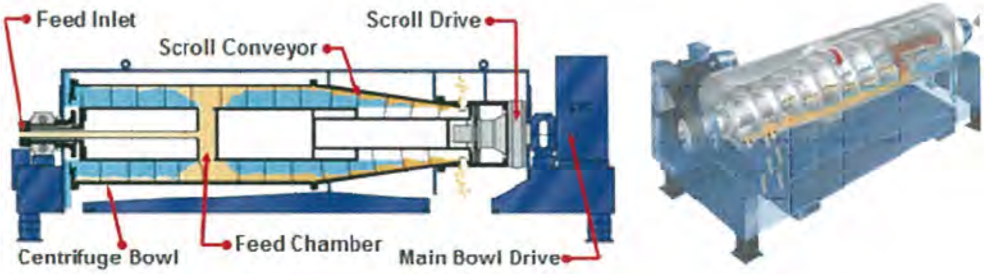


Figure 3: Centrifuge (courtesy of Hiller)

A three-belt press is similar to a belt filter press, but unlike the typical belt press, the gravity and pressure zones of a three-belt press run independently of each other. A photograph of a three-belt press system is shown in Figure 4. The gravity deck has the ability to run at different speeds than the pressure zone, which allows for less concentrated sludge to be fed to the unit at high hydraulic feed rates. The three-belt press is optimized to dewater feed solids at less than 1.5 percent. This design eliminates the need for a separate thickening process prior to mechanical dewatering and utilizes one polymer feed instead of separate polymer feeds for thickening and dewatering.

Figure 4: Three-Belt Press (courtesy of BDP)

Geotubes are large tubes made of polypropylene or polyester cloth geotextile. A photograph of a series of geotubes is provided in Figure 5. Sludge is pumped into the geotube container along with a polymer. Filtrate water drains from the geotube through small pores in the textile, and from evaporation when solar energy is absorbed by the fabric. This volume reduction allows for repeated filling until the residuals have reached their maximum practical dryness. When full, the geotubes container and contents can be left on site, deposited at a landfill, or the solids can be removed and disposed. Filtrate is collected in channels or perforated tubes, and disposed of in a stormwater holding pond. Captured water would need to be treated prior to discharge or returned to the head of the plant.

Figure 5: Geotubes (courtesy of TenCate)

1.5 Extended Dewatering

Extended dewatering is employed as an additional step following other dewatering methods described in the prior section. In this evaluation, extended dewatering is achieved through non-mechanical methods such as solar drying and the addition of bulking agents. The main purpose of the extended dewatering system is to increase the solids concentration near the plastic limit such that the final product is suitable for stacking in a monofill. The extended dewatering process should render a product that is structurally stable when piled up and capable of supporting the loads from heavy machinery.

The main technologies available on the market for solar drying systems are supplied by two manufacturers (Parkson and Infilco-Degremont). The basic elements between the two systems are similar, with the major difference being the tilling method. Evaporation is the primary mechanism of dewatering in both systems. Sludge is pumped into and stored in a translucent building that allows solar energy to pass through and drive off moisture from the sludge. A mechanical mixer turns, spreads, and aerates the sludge to improve the drying efficiency. The manufacturers utilize differing methods for mixing the sludge. Parkson uses a robotic "mole" (shown in Figure 6) that travels around the drying chamber while simultaneously tilling the sludge. The Infilco-Degremont system uses an auger (shown in Figure 7) that travels along the length of the chamber to till the sludge. Both systems utilize a ventilation system consisting of fans and vents that serve to circulate and exchange air from inside-to-outside of the chamber.

Figure 6: Mole-Type Solar Drying System (courtesy of Parkson)

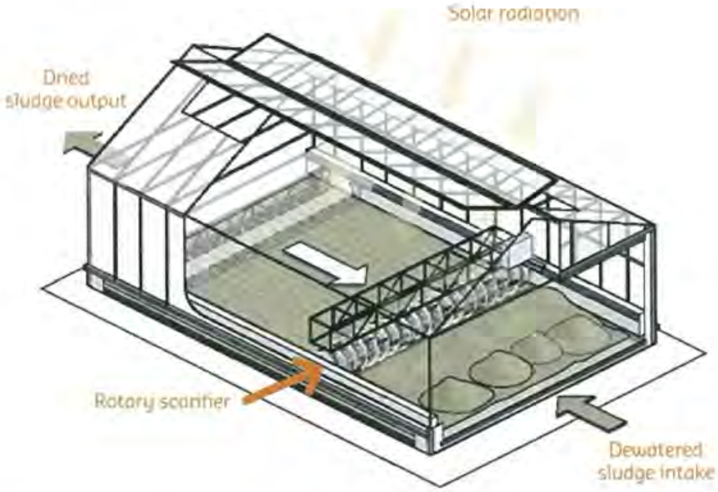


Figure 7: Auger-Type Solar Drying (courtesy of Infilco-Degremont)

Bulking agents can be added to the sludge to help scavenge additional moisture and/or directly add more solids to the sludge. Lime, fly ash, earth, compost, and woodchips are bulking agents that can be used for water treatment sludge. Some bulking agents such as wood chips and earth may help promote evaporation and prevent excessive compaction of the substrate by providing the structural support to create interparticle voids. The agent is fed into a sludge stream and blended together in a tank or pugmill. The main disadvantage to using bulking agents is the cost of the raw material and the addition of solids to the final sludge product, which can significantly increase the volume of sludge for disposal.

1.6 Transportation

Hauling and pumping of thickened sludge were considered for the transport stages of the evaluation. Truck hauling would allow for thickening, dewatering, and extended dewatering to take place onsite at the Leonard WTP. The District could either purchase hauling trucks, or contract hauling services to an outside company. High solids content would reduce transportation costs by reducing the total volume of sludge loaded onto trucks.

A pipeline could be utilized when the dewatering and extended dewatering stages are located offsite of the Leonard WTP at a monofill site. Thickened sludge could be pumped to a monofill site where the dewatering and extended dewatering unit processes would be located. Facilities would need to be located at the monofill site to treat or return the captured filtrate.

1.7 Disposal

Two options for final sludge disposal were considered: land application and disposal in a monofill.

Land application can occur either on land owned by the District, or a third-party contract could be bid out to land apply WTP residuals. Sludge can be dry or wet for land application. Denali Water Solutions noted that from their experience land owners who receive sludge are typically not concerned with the percent solids; they find the additional water from less concentrated sludge to be beneficial. Additionally, Denali stated ferric sludge is not particularly difficult to work with. Disposal of residuals treated in sludge lagoons at the Wylie WTP are currently contracted out to a company that has ultimate responsibility to obtain agreements with land owners for application. All permitting and regulatory record keeping would be maintained by the contractor. One issue encountered with the sludge in the Wylie WTP lagoons occurs when the percent solids is unusually high (24-26%). During such cases, water needs to be added to help create a slurry that can be pumped out. However, this is not a common issue encountered by Denali.

The District currently owns a monofill site about 32 miles south of the Leonard WTP in Farmersville, Texas. A secondary monofill site could be investigated and obtained by the District that would be closer to the Leonard WTP. If disposing residuals in a monofill is selected, the physical properties of the sludge would need to be determined to calculate the structural stability of the sludge. HVJ Engineering has been selected to test the material strength of the Wylie WTP sludge. HVJ plans to determine the plastic and liquid limit of the sludge, which would indicate the extent of dewatering required for monofill disposal. The ultimate goal is to be able to drive heavy machinery over sludge disposed of in a monofill for compaction. A permit issued by TCEQ would be required for disposal in a monofill.

APPENDIX B

NTMWD Leonard WTP Preliminary Design Services Sludge Treatment Evaluation

ALAN PLUMMER
ASSOCIATES, INC.
ENVIRONMENTAL
ENGINEERS AND SCIENTISTS

TECHNICAL MEMORANDUM

TECHNICAL MEMORANDUM – APPENDIX B
NTMWD Leonard WTP Preliminary Design Services
Sludge Treatment Evaluation

Project No.:	0587-013-01
Date:	June 8, 2016
Prepared For:	CH2M Hill
Prepared By:	Alan Davis, APAI, Texas (P.E. No. 89254) Phillip Lintereur, APAI, Texas (P.E. No. 114390) Kyle Nelson, APAI, E.I.T.

1. DESIGN CRITERIA

Sludge treatment alternatives evaluated in this technical memorandum consisted of various combinations of sludge treatment stages which included storage, thickening, dewatering, extended dewatering, transport, and disposal. These sludge treatment stages were made up of processes/unit operations referred to as sludge treatment options. The sludge treatment options consisted of sludge lagoons and sludge holding tanks for the storage stage, gravity thickening and gravity belt thickening for the thickening stage, belt filter press and centrifuge units for the dewatering stage, hauling and pumping for the sludge transport stage, and land application and a monofill for the disposal stage. The components and conceptual layouts associated with each sludge treatment option were defined by size and quantity while applying the design criteria described in this appendix. The size and quantity of the components associated with the sludge treatment options were then used to develop capital and O&M costs. The following section provides the design criteria applied to the sludge treatment options considered for the development and cost evaluation of the sludge treatment alternatives.

1.1 Storage

The storage options considered for the cost evaluation consisted of sludge lagoons and sludge holding tanks. The design criteria for each of the storage options are provided in the following sections.

1.1.1 Sludge Lagoons

It was assumed that when used for backup storage, sludge lagoons would be constructed for the Phase I plant capacity, but not for Phases II, III, and IV. When the sludge lagoon layout was considered for the baseline alternative (i.e. the sludge treatment alternative would use sludge lagoons during normal operation instead of as backup storage), the sludge lagoon system was sized for each plant expansion phase. The sludge lagoons would alternate between 12 month fill and 12 month clean-out cycles. During normal operation half of the sludge lagoons would be operating in the fill cycle, while the other half would be in the clean-out cycle. The average annual sludge production rate was applied to size the sludge lagoons. The design criteria applied to the sludge lagoons is shown in Table 1.

Table 1: Design Criteria – Sludge Lagoons

Parameter	Value
[1]Maximum Solids Loading Limit	16.4 lb/ft^2 as Dry Solids
Duration of Fill/Clean-Out Cycles	12 months, each
Side Water Depth	8 feet
Freeboard	3 feet

1.1.2 Sludge Holding Tanks

It was assumed that sludge would be stored in circular concrete tanks and mixed with an intermittent-release compressed air mixing system. The compressed air mixing system consists of air compressors that pressurize a series of receiver tanks. Short bursts of compressed air originating from the receiver tank are released through nozzles mounted to the floor of the sludge holding tanks. The bursts are automatically controlled by a series of actuated valves. The sludge holding tanks were sized for the maximum sludge production rate. The design criteria for the sludge storage tanks are shown in Table 2.

Table 2: Design Criteria – Sludge Storage Tanks

Parameter	Value
Detention Time	3 days
Side Water Depth	18 feet
Freeboard	2 feet

1.2 Thickening

The thickening options considered for the cost evaluation consisted of gravity thickening and gravity belt thickening. The design criteria for each of the thickening options are provided in the following sections.

1.2.1 Gravity Thickening

The gravity thickening units were sized based on a maximum solids loading criteria. The units were sized to meet the criteria at the maximum sludge production rate while assuming continuous/steady blowdown

---

[1] Crittenden, John C., et al. *MWH's Water Treatment: Principles and Design*. John Wiley & Sons, 2012.

of sludge from the sedimentation basins. The design criteria for the gravity thickening units are shown in Table 3.

Table 3: Design Criteria – Gravity Thickening

Parameter	Value
Maximum Solids Loading Rate[2]	4.0 lb/d/ft^2 as Dry Solids
Thickened Solids Concentration	2%
Side Water Depth	10 feet

1.2.2 Gravity Belt Thickening

The gravity belt thickening system was sized for units with belt widths of 2-meters. The operating schedule was assumed to follow a weekly routine of 5 days per week and 8 hours for each day of operation. The gravity belt thickener system was sized for the maximum sludge production rate. The design criteria for the gravity belt thickening units are shown in Table 4.

Table 4: Design Criteria – Gravity Belt Thickening

Parameter	Value
Maximum Solids Loading Rate[3]	1,250 lb/hr/m
Maximum Hydraulic Loading Rate[4]	250 gpm/m
Thickened Solids Concentration	3%

1.3 Dewatering

The dewatering options considered for the cost evaluation consisted of belt filter press and centrifuge units. The design criteria for each of the dewatering options are provided in the following sections.

1.3.1 Belt Filter Press

The belt filter press system was sized for units with belt widths of 2-meters. The operating schedule was assumed to follow a weekly routine of 5 days per week and 8 hours for each day of operation. The belt filter press system was sized for the maximum sludge production rate. The design criteria for the belt filter press units are shown in Table 5.

---

[2] Cornwell, David A. "Water treatment plant residuals management." *Water Quality and Treatment: A Handbook of Community Water Supplies* 5 (1999).

[3] TCEQ §217.248.e.2.A

[4] TCEQ §217.248.e.2.B

Table 5: Design Criteria – Belt Filter Press

Parameter[5]	Value
Maximum Solids Loading Rate	1,000 lb/hr/m
Maximum Hydraulic Loading Rate	70 gpm/m
Dewatered Solids Concentration	25%

1.3.2 Centrifuge

The centrifuge system was sized for units with a bowl diameter of 30-inches. The operating schedule was assumed to follow a weekly routine of 5 days per week and 8 hours for each day of operation. The centrifuge system was sized to handle the maximum sludge production rate. The design criteria for the centrifuge units are shown in Table 6.

Table 6: Design Criteria – Centrifuge

Parameter[6]	Value
Maximum Solids Loading Rate	3,500 lb/hr
Maximum Hydraulic Loading Rate	400 gpm
Dewatered Solids Concentration	25%

1.4 Extended Dewatering

The extended dewatering options considered for the cost evaluation consisted of solar drying and lime bulking. The design criteria for each of the extended dewatering options are provided in the following sections.

1.4.1 Solar Drying

It was assumed that the solar drying units (which consist of "chambers" resembling greenhouses) would operate on a fill cycle of 7 days. The solar drying system was sized to handle the maximum sludge production rate at the summer drying time, and the average sludge production rate at the winter drying time. The design criteria for the solar drying units are shown in Table 7.

---

[5] Based on recommendations from Ashbrook for the Klampress model.

[6] Based on recommendations from Ashbrook for the G3-125 model.

Table 7: Design Criteria – Solar Drying

Parameter[7]	**Value**
Width per Chamber	42 feet
Length per Chamber	432 feet
Sludge Depth	6 inches
Drying Time (with Initial Solids at 25%)	
Summer	27 days
Winter	45 days
Fill Cycle	7 days
Dried Solids Concentration	70%

1.4.2 Lime Bulking

The lime bulking option consisted of a mixing/conveyor system with lime storage silos that would operate to mix lime with dewatered sludge. The lime bulking system was sized to handle the maximum sludge production rate. The design criteria for the lime bulking system are shown in Table 8.

Table 8: Design Criteria – Lime Bulking

Parameter[8]	**Value**
Lime Dosage	6 lbs per 1 lb of Dry Solids
Lime Storage	10 days
Silo Storage Capacity	200 tons
Lime Density	200 lbs/ft^3
Bulked Solids Concentration	70%

1.5 Transport

Both hauling and pumping were considered as sludge transport options to transport thickened sludge for sludge treatment alternatives with offsite dewatering facilities. Truck hauling costs represented the Engineer's opinion based on past experience. Costs for the sludge pumping option were estimated from applying the design criteria shown in Table 9.

---

[7] Based on recommendation from Parkson for the Thermo-System model.
[8] Based on recommendations from RDP Technologies.

Table 9: Design Criteria – Sludge Transport

Parameter	**Value**
Sludge Pumping	
Booster Pump Station Maximum Spacing	8 miles
Pipeline Length	32 miles
Capacity	Maximum Sludge Production Rate (Pumped Continuously)
Total Static Head	150 feet
Average Fitting Spacing	500 feet
Hazen-Williams Coefficient	120
Sludge Headloss Correction Factor	1.5 (2% Thickened Solids) 2.0 (3% Thickened Solids)
Average Minor Headloss Coefficient	0.3
Pipeline Velocity	2-3 ft/sec
Pump Wire-to-Water Efficiency	65%

1.6 Disposal

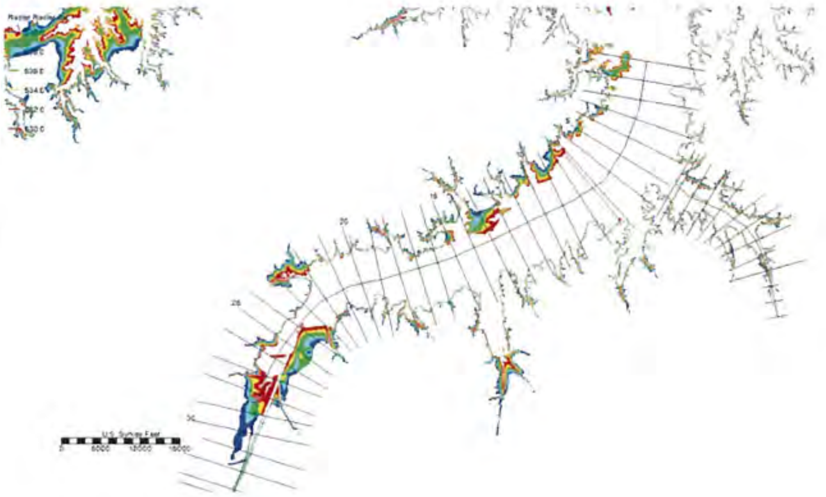
Land application and a monofill were both considered as the disposal methods for the cost evaluation. It was assumed that the monofill would be sized to receive dried sludge from the extended dewatering stage for a period of 40 years. The monofill was sized for the average sludge production rate corresponding to the ultimate plant capacity of 280 MGD. The solids content of the final sludge product would need to have sufficient bearing capacity to support heavy machinery at the monofill. It was assumed that a solids content of 70 percent would be sufficient to meet these criteria.

REPORT

Bois d’Arc Reservoir Water Quality Model

Prepared for

North Texas
Municipal Water
District



September 2015

ch2m

Executive Summary

Water quality in the future Bois d'Arc Reservoir will significantly impact operations at the Leonard Water Treatment Plant (LWTP). Design of LWTP needs to anticipate raw water quality. Management of the reservoir necessary to optimize treatment at the LWTP depends fundamentally on an understanding of raw water quality in the reservoir. CE-QUAL-W2 modeling of the reservoir provides this understanding.

CE-QUAL-W2 is probably the most commonly used hydrodynamic and water quality model for reservoirs world-wide. It is a two-dimensional model along the reservoir longitudinally and vertically, divided into rectangular segments running from the reservoir top to bottom. It laterally averages water quality along the length of a river run or reservoir. It models flow through the reservoir, wind action on the reservoir, reservoir physics along a vertical profile, water chemistry, and algae growth.

All reservoir models need calibration from reservoir data to be accurate. CE-QUAL-W2 is a precise virtual model of a Bois d'Arc Reservoir that does not yet exist. Therefore, most results are preliminary projections of water quality.

Building confidence in a virtual model starts with geometry (reservoir bathymetry), water balance, and climate data. The model closely matches the existing water balance (stage elevation) model of Bois d'Arc Reservoir. With inputs from weather data, the model then creates virtual lake physics, principally a heat budget which provides the thermal structure of the lake upon which most of the rest of the model directly or indirectly depends.

Model confidence then relies on comparison, in place of calibration, to other reservoirs in North Texas. A screening analysis of all major reservoirs in North Texas identified two that most closely resemble Bois d'Arc Reservoir physically (depth and size) and that have vertical profile data sets that enable comparison of model results: Lake Ray Roberts and Lake Fork Reservoir.

Water quality results from the Bois d'Arc Reservoir model are similar to the comparison reservoirs with regard to vertical distribution of temperature and dissolved oxygen (DO). These parameter are fundamentally important to water quality. Water quality data from Bois d'Arc Creek and stormwater quality guidelines provide a firm foundation for nutrient inputs to Bois d'Arc Reservoir.

Fifteen-year simulations using these data inputs and model strengths approximate future water quality conditions in Bois d'Arc Reservoir (Figures ES-1 and ES-2):

- Thermal stratification will be strong (Figure ES-3). Because Bois d'Arc Reservoir runs east-west and prevailing winds are north-south; the degree of thermal stratification is more intense than in comparison reservoirs. Because of such a low fetch, there is little natural mixing energy. Bottom summer temperatures in the reservoir may be less than 10 degrees Centigrade (50 degrees Fahrenheit) if the future climate is similar to model run meteorological data.
- Bottom waters (hypolimnion) will be anoxic (Figure ES-4). Strong thermal stratification cuts off the hypolimion from the atmosphere. A high organic load from algae settling to the bottom and decomposing will strip out oxygen from May into October.
- A strong inference from the model is that the hypolimnion will have high iron and manganese concentrations, but there is insufficient data to provide probable concentrations.
- The reservoir will be hypereutrophic. Bois d'Arc Creek and anticipated stormwater quality will consistently load the reservoir with a total phosphorus (TP) concentration in excess of 100 micrograms per liter (μg/L). Left unmanaged, reservoir surface TP concentrations will eventually exceed 200 μg/L.
- Strong algae blooms will occur from spring to fall as a consequence of high TP concentrations.

- Algae blooms will create pH values greater than 9 late spring to early fall.
- The reservoir will be alkaline. Model results suggest peak alkalinity values exceeding 200 milligrams per liter (mg/L) as calcium carbonate ($CaCO_3$) in many years. The model does not have a means of alkalinity loss as a consequence of formation of insoluble $CaCO_3$ precipitates under high pH conditions. Thus model alkalinity results may be artificially high.
- Total organic carbon concentrations will exceed 1 mg/L.

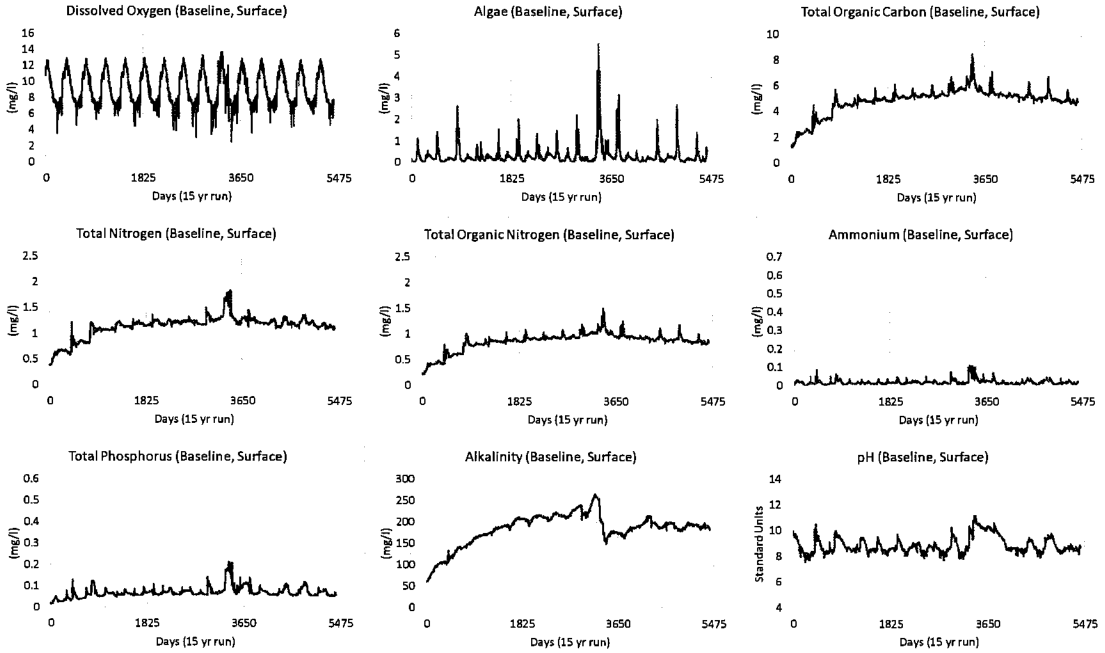


Figure ES-1. Baseline 15-year Simulation, Surface Water Quality near Dam

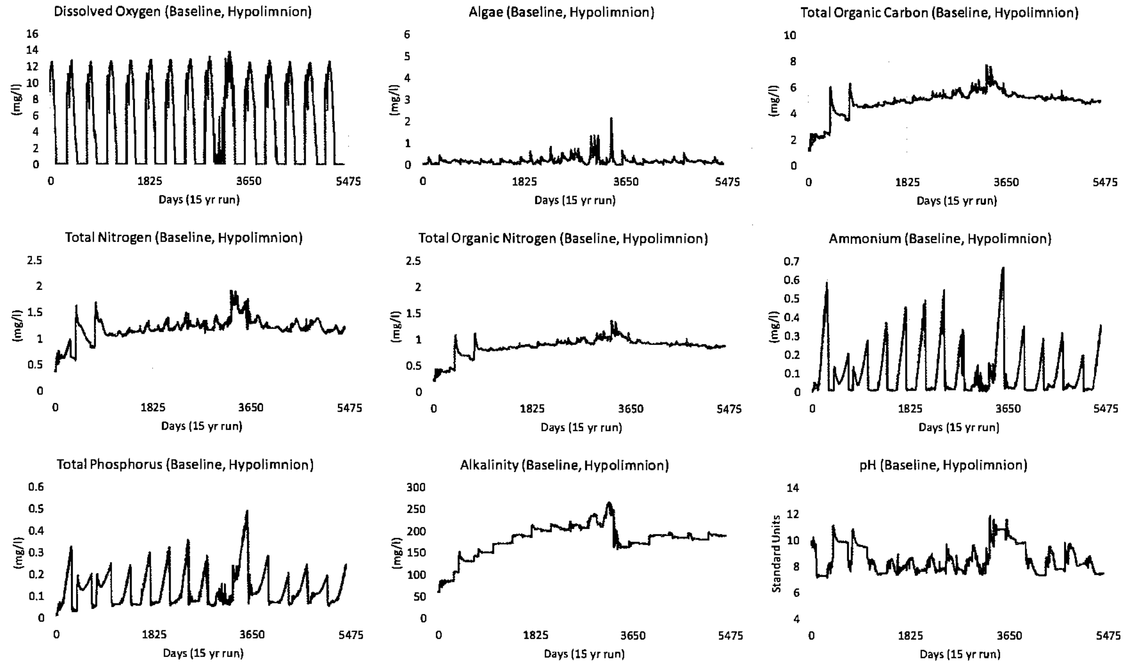


Figure ES-2. Baseline 15-year Simulation, Hypolimnion Water Quality near Dam

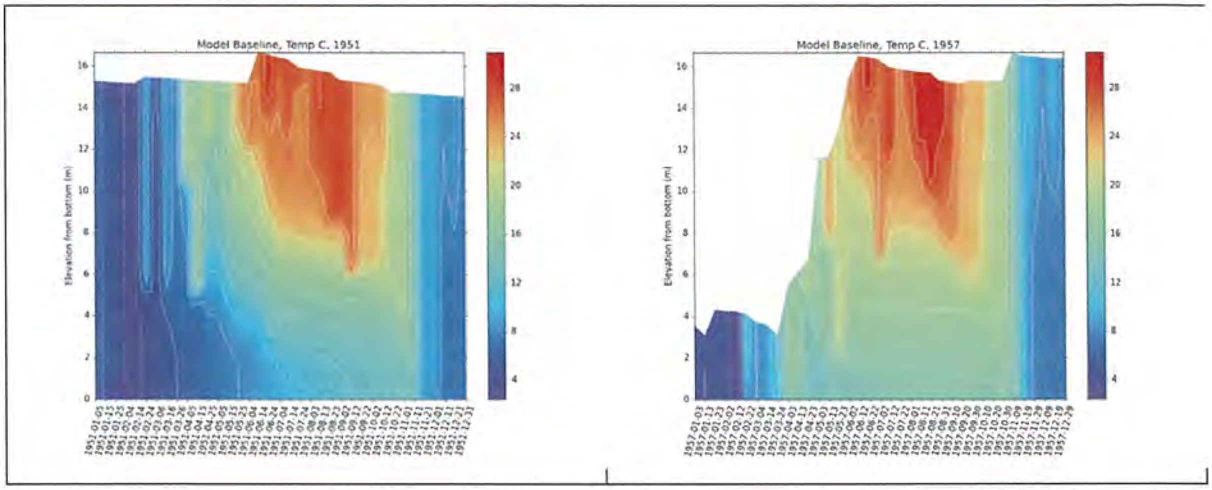


Figure ES-3. Annual Temperature Isopleths (January – December) for Bois d'Arc Model in High Stage Elevation Meteorological Year 1951 or Model Year 4 (left) and Low Stage Elevation Meteorological Year 1957 or Model Year 10 (right) Conditions

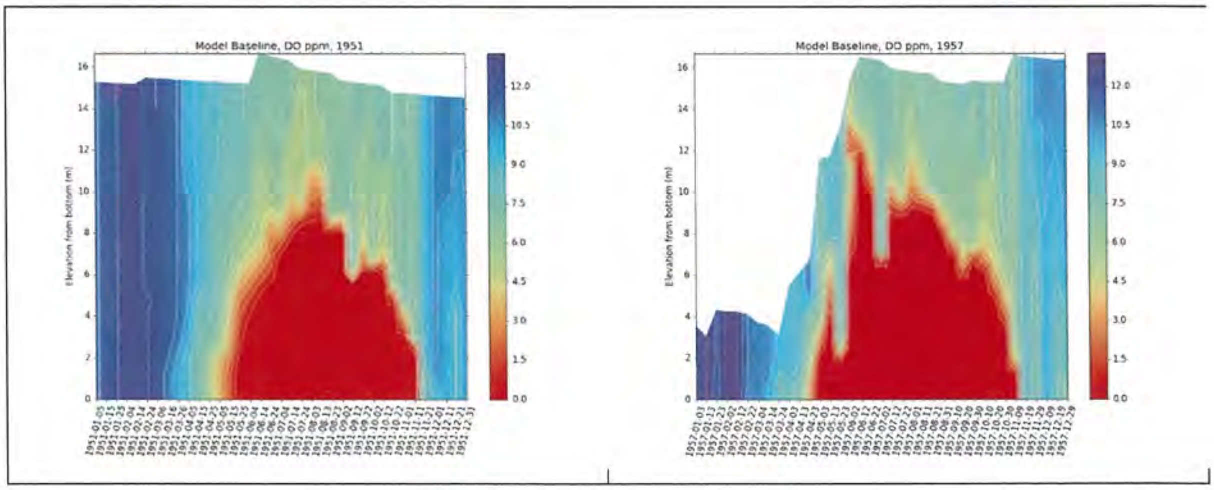


Figure ES-4. Annual Dissolved Oxygen Isopleths (January – December) for Bois d'Arc Model in High Stage Elevation Meteorological Year 1951 or Model Year 4 (left) and Low Stage Elevation Meteorological Year 1957 or Model Year 10 (right) Conditions

Water quality in the reservoir and thus raw water quality to LWTP will be poor May through October, dominated by algae blooms and anoxic conditions in the hypolimnion. Water quality will be worse at low stage elevation than at full stage. Improvement of water quality in the reservoir, if desired, will require active management. Based on model results and experience with management of reservoirs, a two-part management method is recommended.

1. Watershed: Although outside of the scope of this analysis, an analysis of watershed nutrient loading sources should be done to determine to what extent external nutrient loading can be abated
2. Reservoir:
    - Inject ferric chloride at the reservoir inlet. This method strips phosphate from inflows. Bois d'Arc Creek has TP concentrations near 150 µg/L as do stormwater inflows. Mass load reduction of phosphate into Bois d'Arc reservoir will improve water quality.

- Construct a hypolimnetic oxygenation system. Keeping DO high in the reservoir bottom waters (hypolimnion) will largely eliminate mobilization of phosphorus from sediments and keep ferric-bound phosphate from solubilizing. A ferric chloride injection system integrated into the hypolimnetic oxygenation system further strips phosphorus from the water column and improves water quality.

This proven management solution to this problem comes from Saint Paul Regional Water Services – SPRWS (Minnesota), which pumps 50 to 100 MGD from the Mississippi River through a chain of lakes (off line reservoirs) to improve raw water quality. With no control over TP inputs, water quality in SPRWS reservoirs was consistently poor. A two-fold solution emerged:

1. Dosing Mississippi water with ferric chloride. The target dosing rate seeks a nominal iron concentration of 0.5 mg/L in water pumped to the reservoirs.
2. Hypolimnetic aeration, later replaced with hypolimnetic oxygenation plus injection of ferric chloride.

In the final SRPWS reservoir this management method reduced median surface TP from 61 µg/L (maximum 300 µg/L) to 22 µg/L (maximum 37 µg/L). There was a cascade of water quality improvements as consequence of high DO concentrations in the hypolimion, including minimization of hypolimnion manganese, iron, and ammonium (NH_4^+) and increase in water transparency. Appendix C provides more details of this case study.

Model runs emulating this management method showed significant improvements to water quality (Figures ES-5 and ES-6).

Recommended future actions to create high water quality in the reservoir are as follows:

1. Calibrate the model to water quality in the reservoir during the first 2 years of fill
2. Conduct a high-level study for ferric injection into Bois d'Arc Creek at the reservoir inlet
3. Conduct a high-level study for a hypolimnetic oxygenation system with ferric injection
4. Finalize cost estimates and feasibility study using the calibrated model

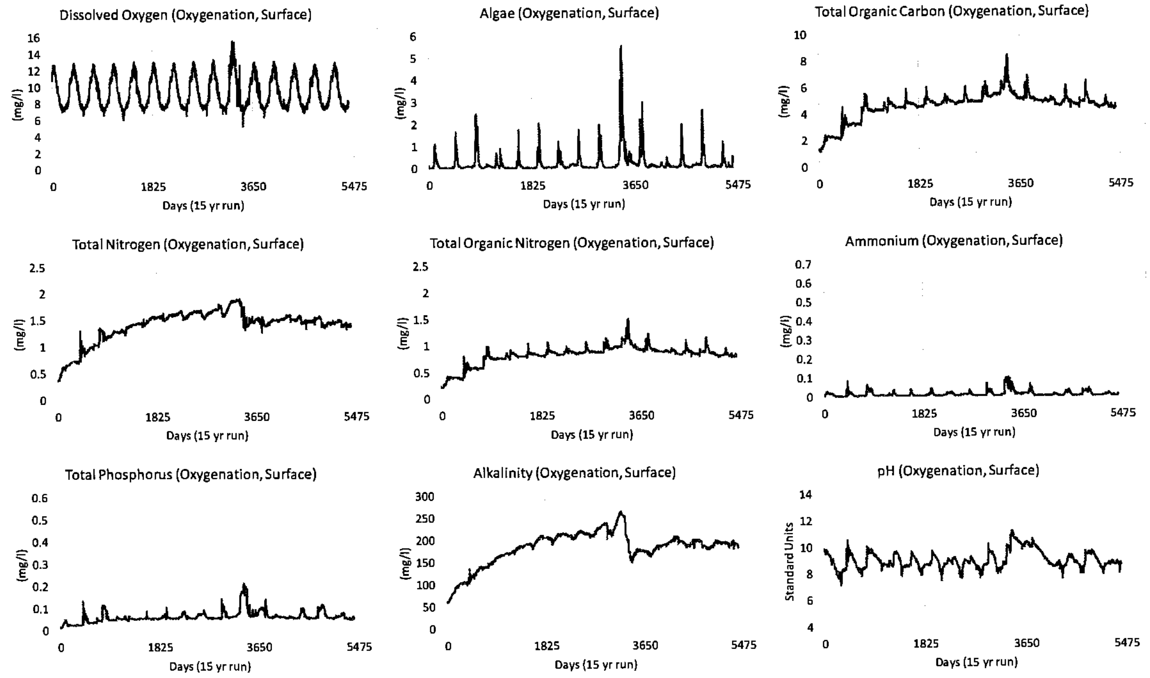


Figure ES-5. Oxygenation 15-year Simulation, Surface Water Quality near Dam

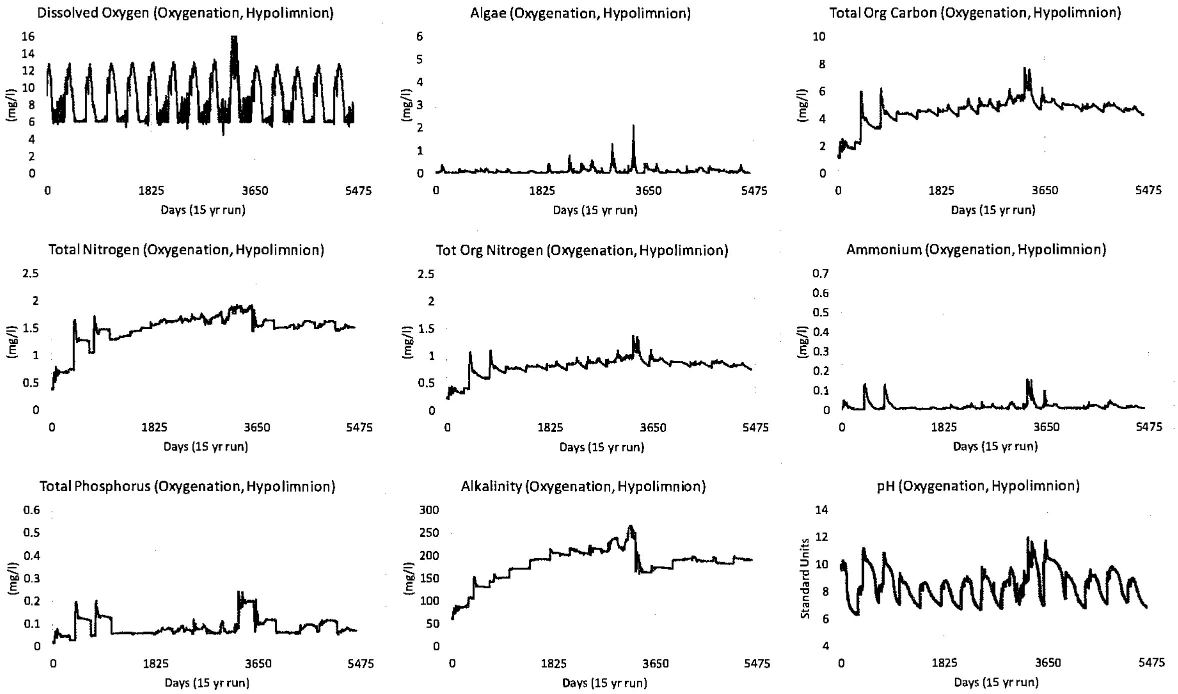


Figure ES-6. Oxygenation 15-year Simulation, Hypolimnion Water Quality near Dam (Segment 23)

Contents

Section Page

Appendixes

Tables

Section Page

Figures

Section Page

Acronyms and Abbreviations

$CaCO_3$	calcium carbonate
CO_2	carbon dioxide
DEM	digital elevation model
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
FMP	Flood Modeler Pro
ft^3/sec	cubic feet per second
GHCN	Global Historical Climatology Network
kg O^2/day	kilograms of oxygen per day
LBCR	Lower Bois d 'Arc Creek Reservoir
LDOM	labile dissolved organic matter
LWTP	Leonard Water Treatment Plant
mg/L	milligrams per liter
mgd	million gallons per day
NH_4^+	ammonium
NTMWD	North Texas Municipal Water District
PO_4	phosphate
SOD	sediment oxygen demand
TCEQ	Texas Commission on Environmental Quality
TDS	total dissolved solids
TOC	total organic carbon
TP	total phosphorus
USGS	U.S. Geological Survey
µg/L	micrograms per liter
mg/L	milligrams per liter

SECTION 1

Background and Purpose

Water Quality Model Used to Predict Future Reservoir Dynamics

North Texas Municipal Water District (NTMWD) is in process of implementing the Bois d'Arc Reservoir project. This project includes the construction of a dam on the Lower Bois d 'Arc Creek which will form the Lower Bois d 'Arc Creek Reservoir (LBCR) as shown on Figure 1-1 and the Leonard Water Treatment Plant (LWTP). The initial capacity of the LWTP will be 70 million gallons per day (mgd) in 2021 and treat water exclusively from LBCR. Future plans for the LWTP include expansion up to 280 mgd and blending water from Lake Texoma with LBCR.

The design of the LWTP must take into account the water quality of the LBCR which will not be constructed until 2017. In addition there are multiple reservoir management techniques that required investigation to optimize the LBCR water quality. Thus there are four objectives for the lake water quality model:

1. Provide the range of expected water quality parameters in the LCBR that directly affect drinking water treatment including (total organic carbon [TOC], iron, manganese, alkalinity, pH, total dissolved solids [TDS], nitrate, and ammonia). Total phosphorus (TP) and chlorophyll-*a* indirectly, but strongly, impact raw water quality by influencing reservoir dynamics of parameters with direct impacts.
2. Assess impacts of water quality on harmful algae blooms.
3. Assess the potential of reservoir invasion by zebra and quagga mussel.
4. Determine how reservoir water quality may be improved by a proven method.

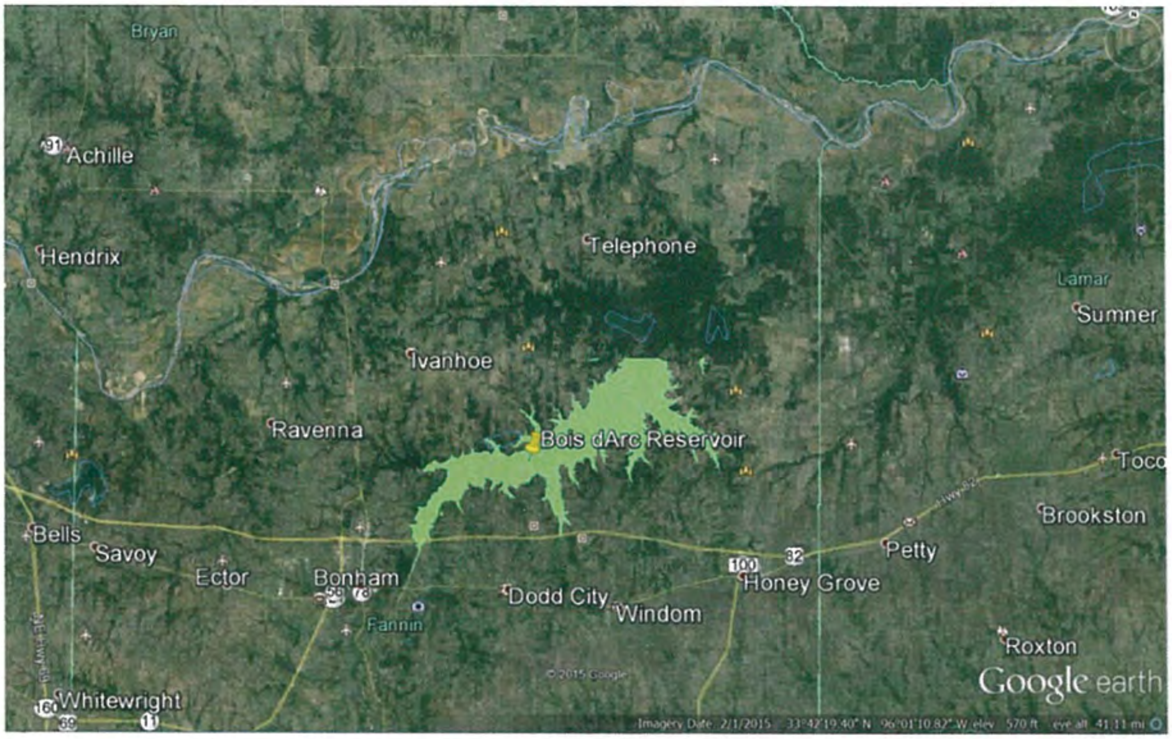


Figure 1-1 Location of Proposed Lower Bois d'Arc Reservoir (shaded at 534-foot elevation)

SECTION 2

Model Development

CE-QUAL-W2 was selected as the modeling platform for the water quality investigations, based on its applicability to the physical system, its recognized status in the modeling community, its availability to the general public, and project staff familiarity with the model.

CE-QUAL-W2 is a two-dimensional water quality and hydrodynamic model for rivers, estuaries, lakes, reservoirs, and river basin systems. Model dimensions are longitudinal and vertical. As discussed in Section 2.1, the model creates a longitudinal section of the reservoir. This section is then divided in to rectangular segments in layers from top to bottom. Hydrodynamic and water quality calculations are solved within each segment. Solutions within a segment are initial conditions for adjacent segments.

CE-QUAL-W2 models basic reservoir physics, water chemistry, and eutrophication processes such as flow through the reservoir, water balance, temperature, pH, sedimentation, dissolved oxygen (DO), nutrient dynamics, algae growth, organic matter fate and transport, and basic sediment-water relationships.

CE-QUAL-W2 is widely used by the U.S. Army Corps of Engineers, U.S. Environmental Protection Agency (EPA), utilities, universities, state regulatory agencies, and the consulting community. First developed in 1975, several versions have been released to the public since 1986; there are 2,378 reported applications worldwide, with 738 in the United States. Version is 3.72 was used for the models (Portland State University, 2015).

Model construction and calibration have several elements:

- Meteorological data, preferably from meteorological stations on site
- Reservoir bathymetry (digital elevation maps)
- Hydrologic inputs
- Vertical profile data (temperature, pH, DO, conductivity) and water quality data from the reservoir modeled

As discussed in this section, not all these elements are available. Meteorological data are not from the reservoir location. Large reservoirs create local wind effects that affect reservoir physics. Data from the site would not improve the quality of meteorological data, because the reservoir has yet to be constructed. There are, of course, no water quality calibration data for Bois d'Arc Reservoir available either. Nevertheless, there are many reservoirs in North Texas that allow comparison of model results in lieu of calibration data.

The hydrologic data and reservoir bathymetry developed for reservoir design are the most critical elements for model construction. Given the long, open-source history of the model, there is a high degree of confidence in model physics with these inputs in conjunction with data. Because reservoir physics (e.g., vertical temperature distribution and hydrodynamics) largely determine all water quality parameters, modelling of a reservoir net yet constructed can be done also with a high level of confidence in the realism of model results. Final calibration of the model is advised once the reservoir fills.

2.1 Model Construction

A digital elevation model (DEM) was obtained from the U.S. Geological Survey (USGS) Web site to assist in the development of the bathymetric grid for the Bois d'Arc CE-QUAL model. The 1/3 arc-second (32-kilometer grid) elevation data were downloaded for the region surrounding the reservoir from the

USGS National Map Viewer tool. The DEM was loaded into CH2M's Flood Modeler Pro (FMP) software, which assists in the development of cross sections. The FMP software generated a table of points along each cross section; these points were imported into Excel to calculate segment widths for use in CE-QUAL-W2. A storage volume-elevation curve was generated from the segments and compared to a baseline curve provided in the firm yield analysis developed by Freese and Nichols (2015). Minor adjustments were made to the segment widths to improve agreement between provided volume-elevation curve and that developed from the model grid.

The model reservoir has two longitudinal branches, one along the main reservoir body and another along Honey Springs Creek (Figure 2-1). Final segmentation of the CE-QUAL-W2 grid starts with Segment 2 representing the upstream end of the main reservoir branch and Segment 29 representing the dam at the downstream end (Figure 2-2).

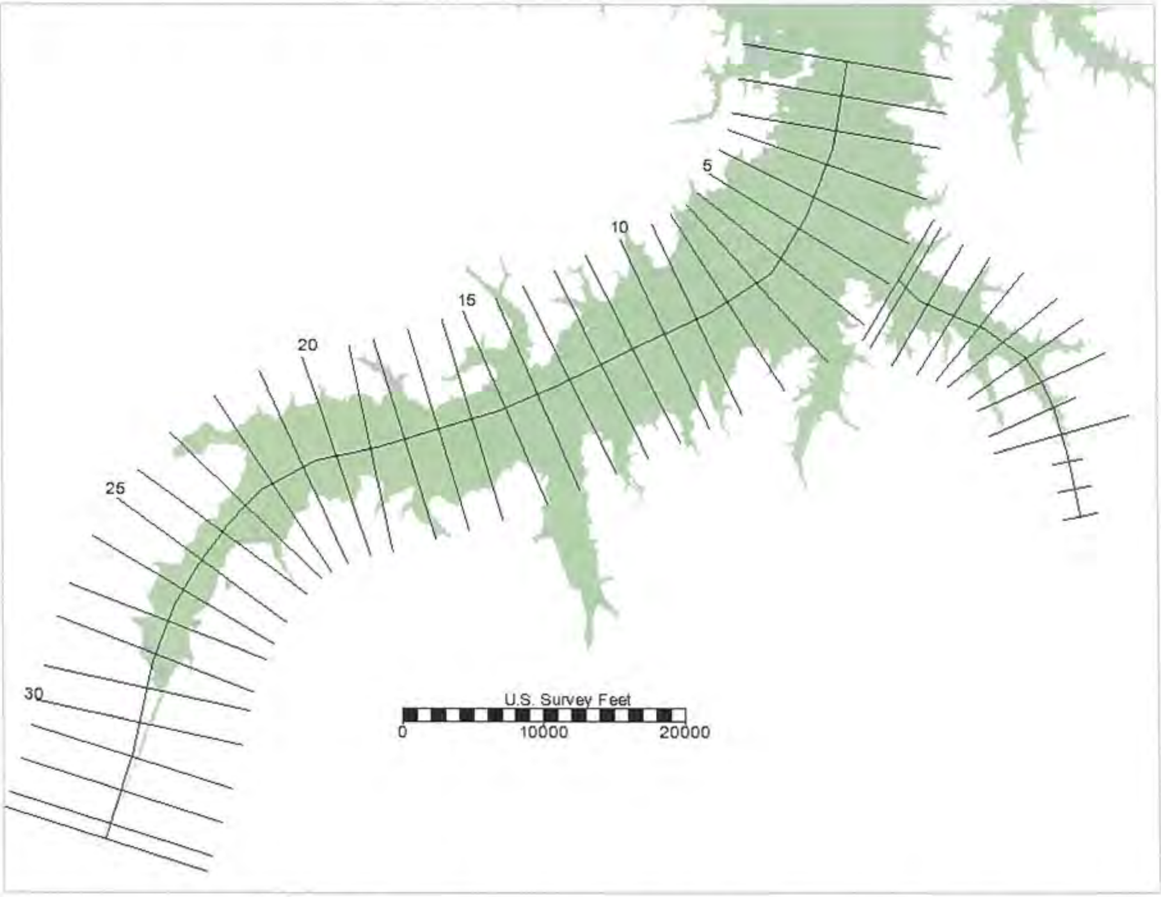


Figure 2-1. DEM with Elevations at 540 Feet and Lower Shaded; Channel Centerline, and Cross Section Locations

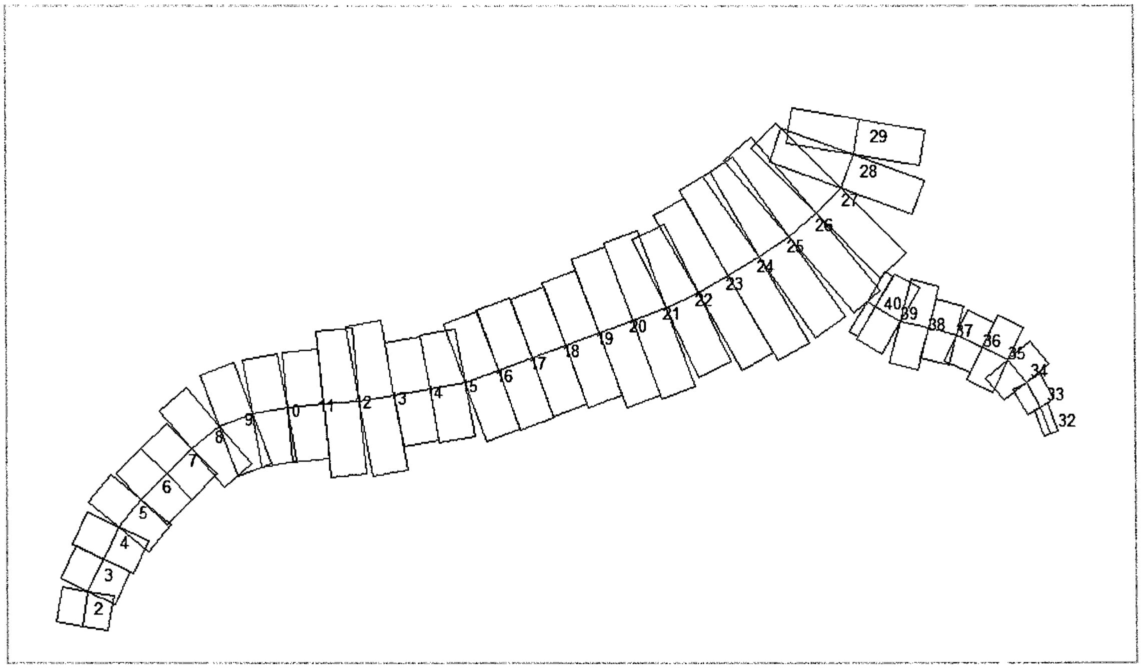


Figure 2-2. CE-QUAL-W2 Model Segments

2.2 Model Boundary Conditions

CE-QUAL-W2 requires input data describing external influences on the water body, including meteorological data (temperature and rainfall), inflows, outflows, withdrawals, and constituent inflow concentrations. This section describes the data used to specify all necessary boundary conditions in the model.

2.2.1 Meteorological Data

Meteorological data required for CE-QUAL model simulations includes daily total precipitation, dew point, average temperature, wind speed and direction, and percent cloud coverage over the model geometry. Daily data from Global Historical Climatology Network (GHCN) Station USW00053914 McKinney Municipal Airport northeast of Dallas, Texas (approximately 50 miles southwest of the reservoir site) was obtained from the National Climatic Data Center (2015). Daily average temperature, dew point, wind speed and direction for periods January 2012 through May 2015 were input into an Excel database for analysis. Data from 2014 were chosen to be representative of an average, recent meteorological year and was applied as an annual repeating pattern for model simulations. Cloud cover data were not available from the McKinney Airport Station, so data from GHCN Station 13960 (Dallas FAA Airport) was downloaded and reviewed. Data were available for 1965 through 1972; 1967 was found to depict an average year and daily cloud cover for 1967 was input into the model as an annual repeating pattern.

Daily total precipitation from August 1st, 1939 through May 31st, 2015 was obtained from station GHCN USW00013960 Dallas FAA Airport (approximately 80 miles southwest of the reservoir site). Long-term precipitation data were input into the model to capture significant storm and drought events and to provide an accurate representation of actual inflows into the reservoir. Figure 2-3 presents a 50-year record of annual rainfall in millimeters, with the average of 921 millimeters (36.3 inches) shown in red. While the model is set up to run 50-year simulations, analysis of model results discussed in this report was performed for a representative 15-year simulation that included wet and drought years. Wind directional data are represented in the wind rose shown on Note: Note that prevailing winds are from the north.

Figure 2-4. Winds out of the north dominate the annual wind patterns at the proposed reservoir site, with southerly winds representing the next largest direction. The majority of the winds are perpendicular to the main axis of the reservoir, which reduces vertical mixing and favors thermal stratification in the reservoir. Predicted temperature profiles discussed below are colder than in other local reservoirs; this can be explained by the predominant wind orientation.

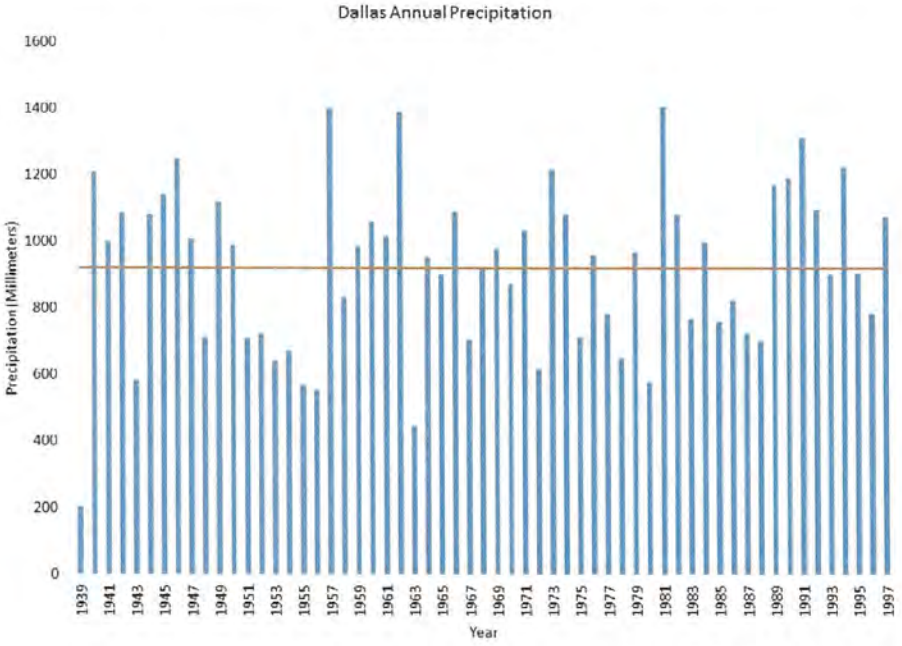
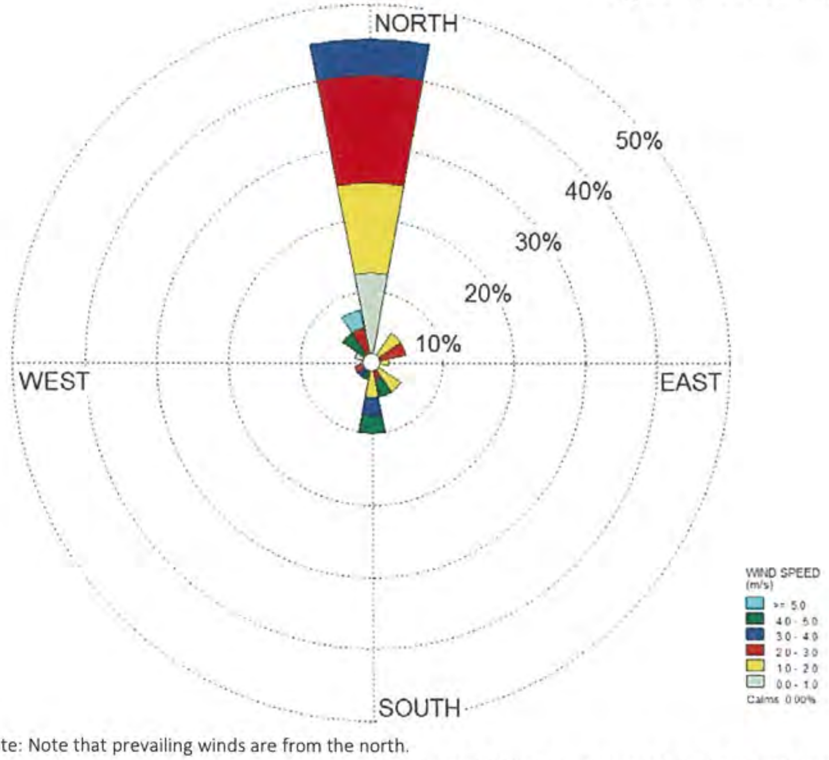


Figure 2-3. Annual Precipitation at Dallas Airport Station



Note: Note that prevailing winds are from the north.

Figure 2-4 Wind Rose Data for 12-month Period at McKinney Municipal Airport

2.2.2 Inflows, Outflows, and Mass Balance

The water balance for the proposed reservoir includes stormwater inflows in Lower Bois d'Arc Creek, and 1,449 acre-feet per year pass through from the Bonham Wastewater Treatment Plant, a 120,000 acre-foot annual diversion for the proposed water treatment facility, direct precipitation, and evaporation. The pass-through flow, equal to 2 cubic feet per second (ft^3/sec), is released from an upstream reservoir and will pass through Bois d'Arc Reservoir such that the minimum daily average outflow is 2 ft^3/sec. Data prescribing the inflows, outflows, and withdrawals from the proposed reservoir were obtained from the Firm Yield Analysis developed by Freese and Nichols (2015), which was developed with a 50-year historic hydrologic record spanning 1948 to 1998 that is assumed to be representative of future conditions. Daily evaporation values were also provided in the firm yield analysis. The Freese and Nichols analysis of water surface includes two significant drought events during the 50-year period (Figure 2-5). No precipitation data were provided in the firm yield analysis.

Daily time series for reservoir inflows, outflows, and withdrawals were taken directly from the firm yield analysis and applied to the model. Precipitation data from the National Climatic Data Center (2015) were used. Evaporation is calculated by the model and is influenced by wind speed and temperature. For purposes of model stability, a number of high-inflow events were smoothed by distributing high single day flows over a 3-day period without altering the total inflow volume. A comparison of the water surface elevation generated by the CE-QUAL-W2 model with that developed by Freese and Nichols (2015) is presented in Section 3.

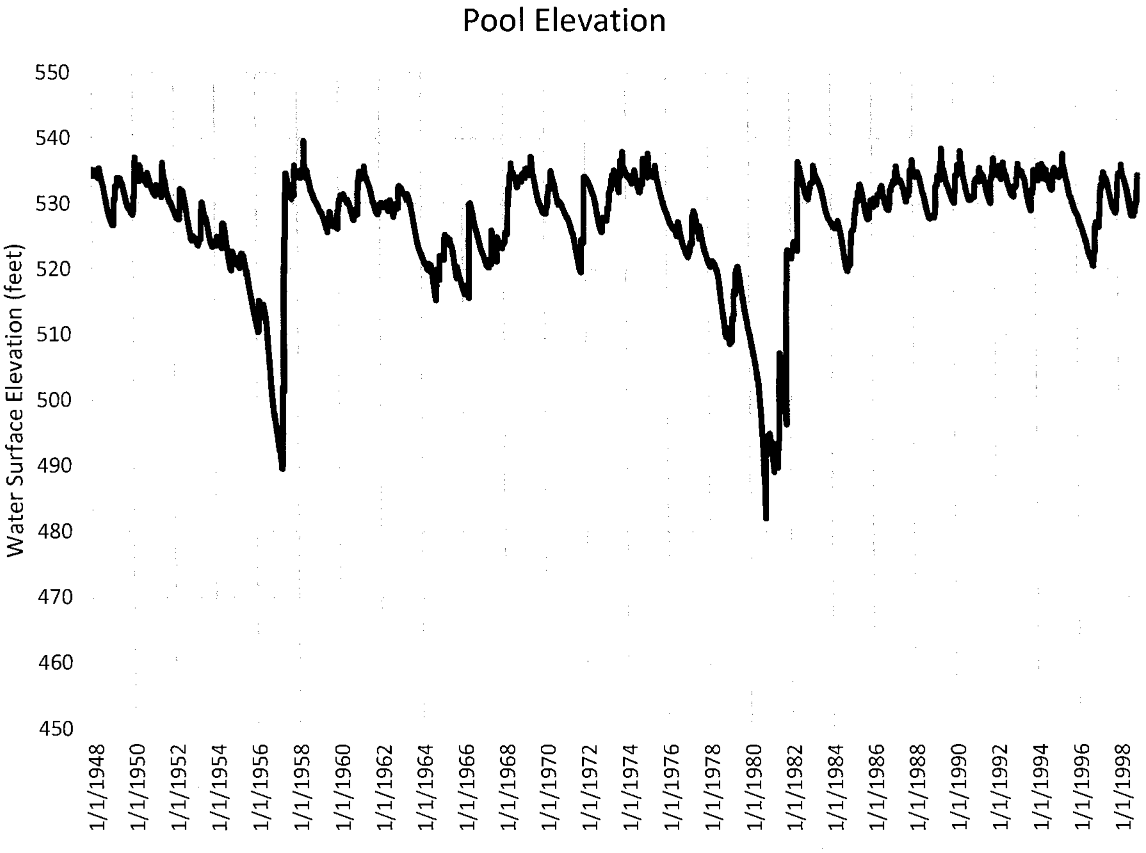


Figure 2-5. Water Surface Elevation Time History for 50-year Representative Hydrology

The water treatment plant withdrawal of 120,000 acre-feet per year at the dam was included in the Bois d'Arc CE-QUAL-W2 model to accurately represent the hydraulic effects on the reservoir water quality. The withdrawal was inserted in Segment 29, the location of the dam. An elevation of 155 meters (approximately 508.5 feet) was indicated as the withdrawal centerline, slightly below the minimum elevation the reservoir is expected to reach from year to year, with the exception of extreme low drought elevations (Figure 2-5). A maximum withdrawal top elevation as well as a minimum bottom elevation were designated in the model to portray the variation in withdrawal gate elevations from the proposed reservoir pump station design. The maximum elevation for withdrawal in the model is located at layer 10, an elevation of approximately 159 meters (522 feet). The minimum withdrawal elevation is located at layer 20, an elevation of approximately 153.5 meters (503 feet).

2.2.3 Inflow Concentrations

The Texas Commission on Environmental Quality (TCEQ) maintains an online database of water quality data collected by various agencies at river and stream stations throughout the state (TCEQ, 2015). There are seven stations on Lower Bois d'Arc Creek (Segment 0202A) in the vicinity of the proposed reservoir site (Figure 2-6). Station 21028 is closest to the upstream end of the site, and Station 20167 is adjacent to the proposed location of the dam. Water quality data for these stations were obtained from TCEQ (2015) and analyzed for use in setting constituent concentrations for various parameters in the reservoir inflows.

Figure 2-6. Sampling Station Locations

Water quality data were analyzed to determine the degree annual variability as well as seasonal patterns. In several cases, no discernable patterns were evident and inflow concentrations were set as constant for the year. This was done for TDS, calcium, inorganic suspended solids, phosphate, ammonia, nitrate, dissolved organic matter, and alkalinity. Parameters with time-varying inflow concentrations included algae, DO, total inorganic carbon, and particulate organic matter. Data were not sufficient to develop any relationship between flow and water quality at the sampling stations. Therefore, the model either uses a seasonal variation of inputs or constant, depending on the observed variability of the parameter.

Inflow constituent concentrations were set primarily based on review of available water quality data at the two closest locations to the proposed reservoir, namely Stations 21028 and 20167. Data at the upstream station (21028) consists of 32 samples over a 3-year period (2011-2014). Of these, only three were taken with measurable flow in the river. At the downstream station (20167), the available dataset consists of 51 samples taken over a 7-year period (2007 to 2014) of which 24 were taken with measurable flow in the river greater than 1 ft^3/sec. Thus, the available datasets are primarily reflective of stagnant or very low river flow conditions, and measured concentrations may not be representative of inflow concentrations expected during stormwater runoff events.

In general, there are no distinct seasonal patterns in the available datasets for primary nutrients, including phosphorus, ammonia, and nitrate-nitrite. Figure 2-7, Figure 2-8, and Figure 2-9 show the seasonal variation of total phosphorus (TP), ammonia, and nitrate + nitrite from the water quality sampling stations upstream and downstream from the proposed reservoir, with plots presented on a Julian day basis to visualize seasonal trends. No discernable seasonal trends are evident in the figures; therefore, the inflow concentrations were set at constant values representative of annual average concentrations. Section 4.4 discusses the limitation of not having sufficient data to assign flow-based concentrations to account for increased concentrations during storm runoff events.

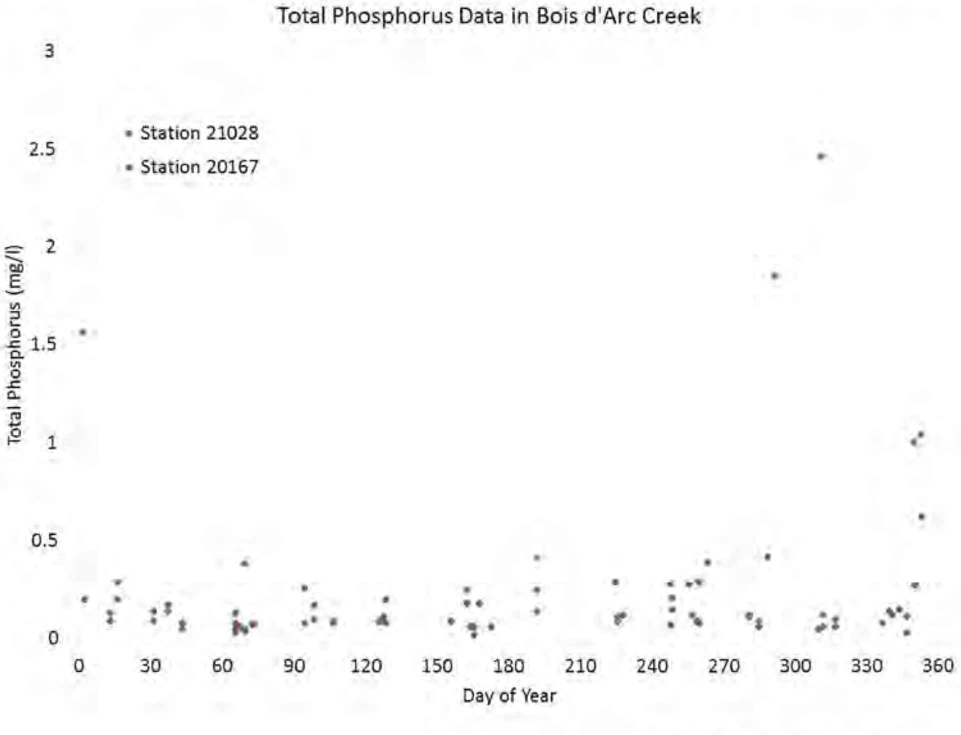


Figure 2-7 Total Phosphorus Data for Bois d'Arc Creek

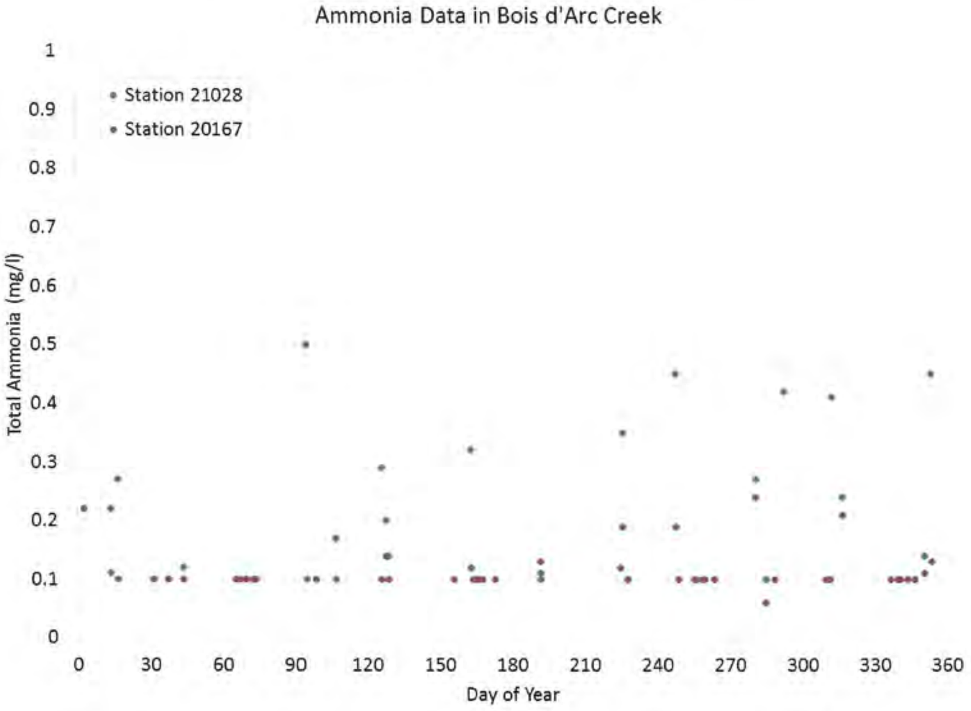


Figure 2-8 Ammonia Data for Bois d'Arc Creek

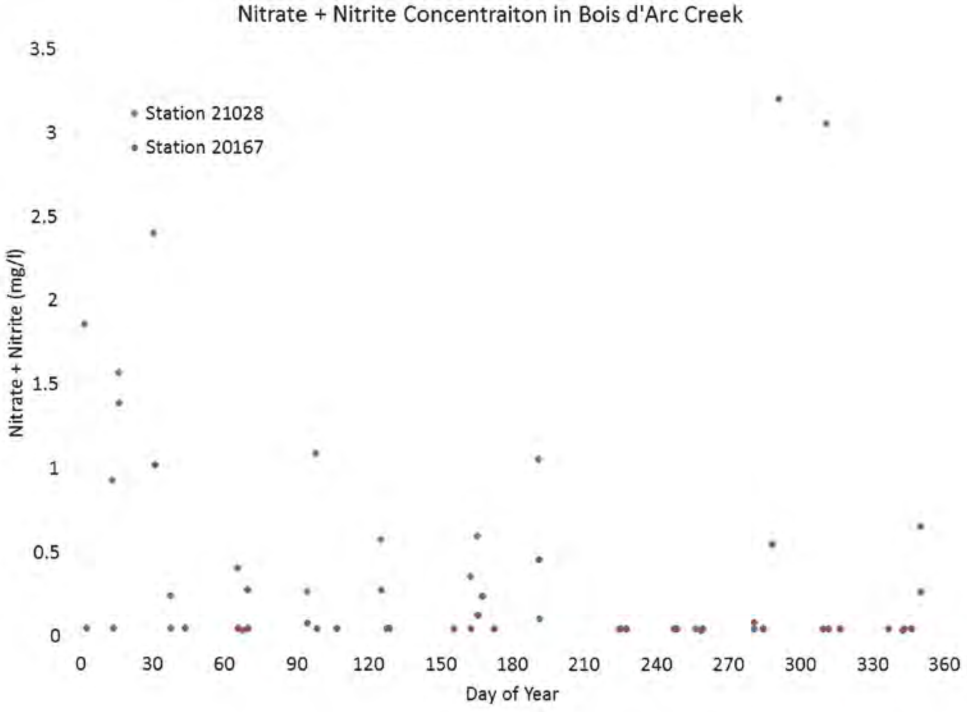


Figure 2-9 Nitrate + Nitrite Data for Bois d'Arc Creek

In addition to these parameters, concentrations of TOC, dissolved organic matter, TDS, inorganic suspended solids, alkalinity, and calcium showed no clear seasonal trends. Table 2-1 summarizes the inflow constituent concentrations that were set as constant based on a lack of seasonal variation in the available field data. For these parameters, the annual average concentration was specified as a constant concentration for the duration of the simulation. For phosphorus, limited data were available for both orthophosphate and TP; since CE-QUAL-W2 requires inputs in inorganic phosphorus, the ratio derived from the limited dataset (orthophosphate/TP = 0.6) was applied to the more extensive TP dataset to develop the inflow concentration for use in the CE-QUAL-W2 model.

Table 2-1. Summary of Constituents with Constant Inflow Concentrations in Bois d'Arc CE-QUAL-W2 Model

Parameter	Constant Concentration (mg/L)
Inorganic Phosphorus (phosphate)	0.15
Ammonium	0.15
Nitrate + Nitrite	0.45
DOM	16.4
Inorganic Suspended Solids	20
Total Dissolved Solids	283
Calcium	80
Alkalinity	165 as $CaCO_3$

Note:

DOM = dissolved organic matter

Certain water quality parameters exhibit significant seasonal variation in the data from Bois d'Arc Creek. The best example of this is DO, which decreases in the summer, with increased temperature and algal biomass. Inflow concentrations of DO are shown on Figure 2-10. Other parameters with time variable concentrations in inflows to Lower Bois d'Arc Reservoir include iron, algae (derived from chlorophyll-a), particulate organic matter, and total inorganic carbon. Table 2-2 summarizes the annual repeating concentrations for these parameters.

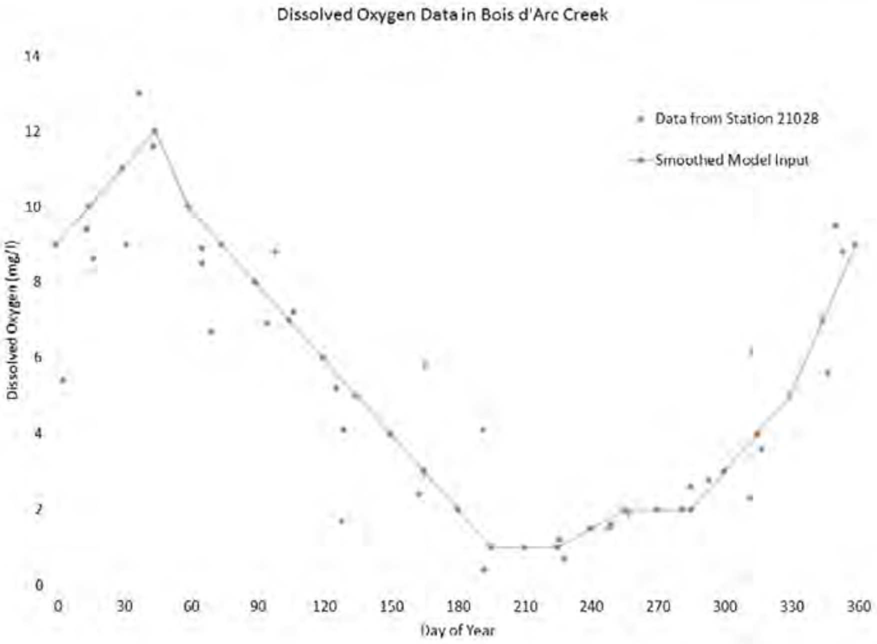


Figure 2-10 Seasonal Variation in Dissolved Oxygen Data in Bois d'Arc Creek

Table 2-2 Annual Repeating Patterns for Time Variable Constituent Concentrations in Inflow to Bois d'Arc Reservoir

JDAY	FE	LPOM	ALG	DO	TIC
1	0.6	0.9	0.36	9	12.29
15	0.6	0.4	0.36	10	13.14
30	0.6	0	0.36	11	19.92
45	0.55	0	0.36	12	5.42
60	0.5	0.4	0.36	10	17.58
75	0.5	0.2	0.36	9	14.11
90	0.5	0.2	0.36	8	8.58
105	0.5	0.2	0.36	7	9.8
120	0.443	0.3	0.3	6	11.91
135	0.7	0.2	0.15	5	21.03
150	0.9	0.2	0.12	4	7.61
165	1.2	0.2	0.09	3	25.2
180	1.4	0.7	0.3	2	12.37
195	1.275	0.7	0.45	1	8.66
210	1.15	0.8	0.6	1	9.83
225	1	0.9	0.75	1	2.42
240	0.9	0	0.9	1.5	10.39
255	0.9	0	1.05	2	7.25
270	0.9	0.4	1.05	2	8
285	0.9	1.6	1.05	2	9.13
300	0.84	0.9	1.05	3	7.23
315	0.84	0.7	1.05	4	8.22
330	0.9	0.7	0.9	5	13.4
345	0.9	0.2	0.6	7	14.07
360	0.8	0.2	0.45	9	17.78

Notes:

JDAY = Julian Day

FE = iron

LPOM = labile particulate organic matter

ALG = algae

Several parameters are important to raw water quality at the treatment plant as compounds that are directly regulated by the EPA (i.e., nitrate/nitrite, iron, manganese), will react with the various treatment process to produce regulated compounds (i.e., TOC and bromide) or have the potential to affect the treatment process (i.e., alkalinity or ammonia). Water quality data were available to incorporate into the model most parameters of interest to water treatment. Manganese and bromide were not available and thus were not modeled. These parameters could readily be incorporated into the model when data become available. .

Model Validation

In a standard water quality model application, the model would demonstrate the ability to represent a set of known conditions in a reservoir. This process is termed model calibration. The typical calibration process for a CE-QUAL-W2 model involves adjusting model parameters to optimize the agreement between model results and field data. The effort progresses through various parameters with increasing levels of influence on results. For example, temperature is often calibrated before nutrients or algae since the thermal regime has significant influence on the nutrient and algal kinetics. Because the Lower Bois d'Arc reservoir has not been constructed, field data does not exist to perform a robust calibration of the CE-QUAL-W2 model. To demonstrate the reasonableness of model results, a quasi-calibration effort was performed in which model results were compared to field data at similar regional reservoirs.

To select reservoirs for use in calibrating the model, we analyzed basic morphological data and the availability of water quality data for 10 reservoirs in the surrounding area (Table 3-1). The lakes were first screened to confirm that water quality data were publically available through the TCEQ surface water reporting tool. The assessment of morphological features revealed that two reservoirs were good candidates for model calibration. Lake Ray Roberts has similar area and volume to Bois d'Arc; it also provides a robust dataset for calibrating the lake temperature, DO, and pH. Lake Ray Roberts is also the only reservoir with vertical profile data available for several key water quality parameters (alkalinity, ammonia, nitrate, phosphate, iron, manganese). Additional comparisons were made with data from Lake Fork Reservoir.

Table 3-1. Reservoirs Analyzed for Comparison to Model Results

	Bois d'Arc	**Texoma**	**Ray Roberts**	**Lewisville**	**Lavon**	**Ray Hubbard**	**Tawakoni**	**Fork**	**Chapman**	**Mayse**	**Hugo**
Data Available in TCEQ?	NA	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No
Area (thousand acres)	16.5	89.0	29.3	29.9	21.4	22.7	37.3	26.9	19.3	5.9	13.2
Volume (thousand acre-feet)	368	2,536	788	555	275	490	872	637			158
Depth (feet)	60	100	90	67	38	40	70	59	55	55	

Validation for the Bois d'Arc CE-QUAL-W2 model is a multistep process. First, the mass balance of all inflows and outflows is validated against the projected variation of reservoir water surface elevation through time. Next, the thermal regime of the reservoir is validated. Efforts then extend to water quality parameters, with focus on DO, nutrients, and algae. A detailed discussion of the validation of the physical and water quality parameters is provided in Section 3.1.

3.1 Physical Parameter Validation

Model validation for CE-QUAL-W2 Bois D'Arc Reservoir application was a multistep process. The first step focused on the water balance. For the Bois d'Arc Reservoir, a daily time series of water levels was provided in the Firm Yield Analysis developed by Freese and Nichols. Model predictions were compared to this time series to determine appropriate application of inflows, outflows, withdrawals, precipitation inputs, and evaporation. Minor discrepancies are expected between CE-QUAL-W2 model results and those provided by the Firm Yield Analysis, because the CE-QUAL-W2 model likely used different precipitation, temperature, and wind inputs, which influences evaporation. Given the nature of localized storm events, it is expected that precipitation can vary considerably over relatively short distances. Thus, the water balance is not expected to match perfectly. Results indicate good general agreement in the time series of water levels, with an average absolute error of 9 inches (Figure 3-1).

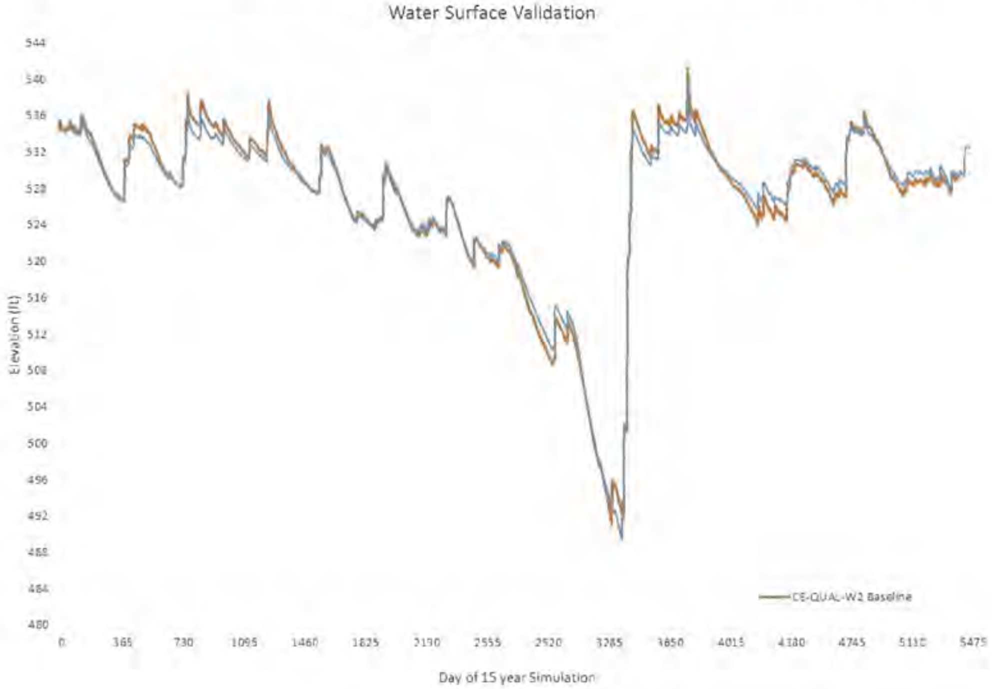


Figure 3-1. Comparison of CE-QUAL-W2 and Firm Yield Analysis Results of Water Level

After the water level verification, the quasi-calibration effort focused on the thermal structure in the reservoir. Several model parameters influence the thermals structure in the reservoir, including the applied wind scaling and the coefficients applied to relate wind speed to heat exchange.

Measured winds applied to the model were obtained from McKinney Municipal Airport northeast of Dallas, Texas (approximately 50 miles southwest of the reservoir site). The wind data were part of the full meteorological dataset used in the model. The model allows a user-defined coefficient to be applied to each model segment that is used to scale the applied wind. While this is generally used to represent sheltering of a portion of the reservoir from wind, it can also be used to increase the wind speed to reflect topographic funneling of the wind or just as a recognition of differences in the local wind and the measured wind, which may be a significant distance from the site. For this application, the wind sheltering coefficients were increased to 1.15 to increase the thermal mixing in the reservoir, because results from initial simulations yielded thermal stratification considerably stronger than in other local reservoirs. Sensitivity studies were also conducted with wind sheltering coefficients of 1.0 and 1.25 to quantify the sensitivity of the model to this parameter.

Datasets from Lake Ray Roberts and Lake Fork Reservoir were plotted for comparison to predicted vertical temperature profiles in July. Profiles from the end of July were extracted from the Baseline CE-QUAL-W2 simulation for nine consecutive years (Figure 3-2). Model results indicate a stronger stratification at Bois d'Arc than at either Lake Ray Roberts or Lake Fork Reservoir. This could be associated with the shape of the reservoirs, with two distinct branches of approximately equal size that could allow winds from a large range of directions to impart energy sufficient to mix the lakes. Lower Bois d'Arc Reservoir, on the other hand, is primarily one single branch, and only wind aligned with the long axis of the reservoir would impart energy to mix the thermal profiles. Bois d'Arc Reservoir is aligned largely in an east-west axis, whereas prevailing winds flow along a north-south axis. These results are very sensitive to wind as indicated by several sensitivity simulations; near bottom temperatures could be increased by over 4 degrees C with a 10 percent increase in the wind sheltering coefficient.

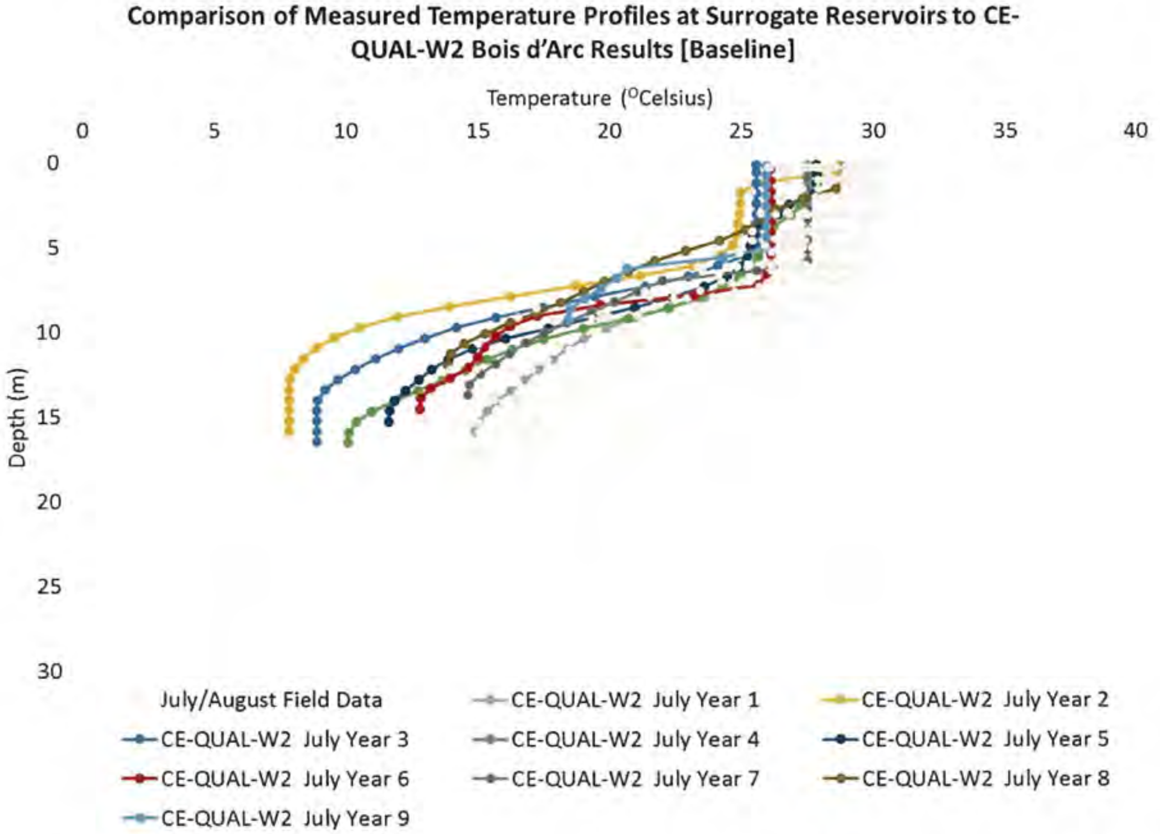


Figure 3-2. Comparison of Temperature Profiles in July of 9 Years to Similar Measurements in Lake Ray Roberts and Lake Fork Reservoir

Year-round temperature data for the calibration lakes were also used to confirm that the model thermal stratification matches the observed data under high- and low-stage conditions (Figure 3-3, Figure 3-4, and Figure 3-5). Year-round DO data were used to confirm that the summer anoxic conditions predicted in the model match observed data under high- and low-stage conditions in the calibration reservoirs (Figure 3-6, Figure 3-7, and Figure 3-8).

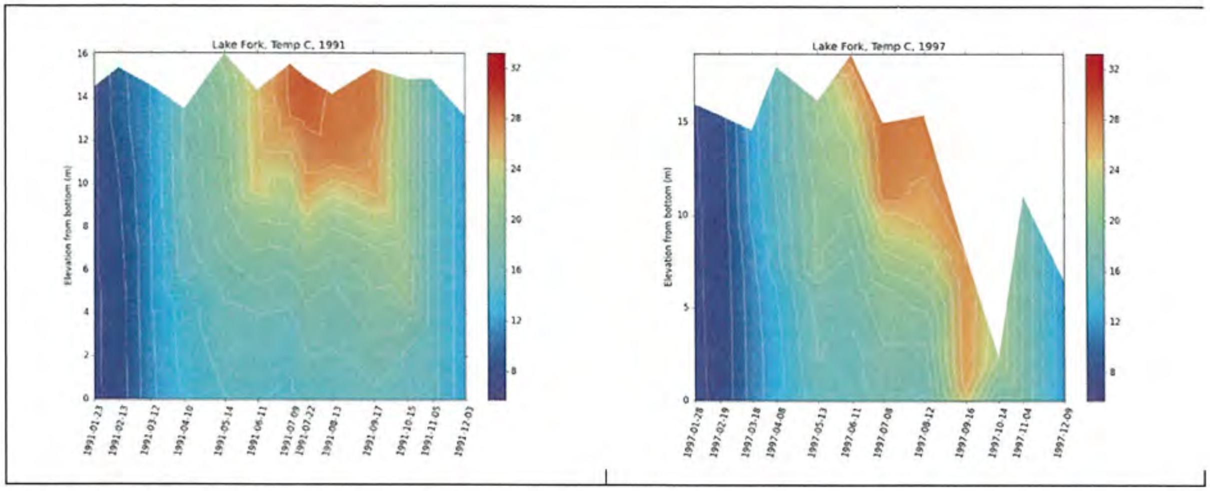


Figure 3-3. Annual Temperature Isopleths (January – December) for Lake Fork Reservoir in High-stage Elevation (left) and Low-stage Elevation (right) Conditions

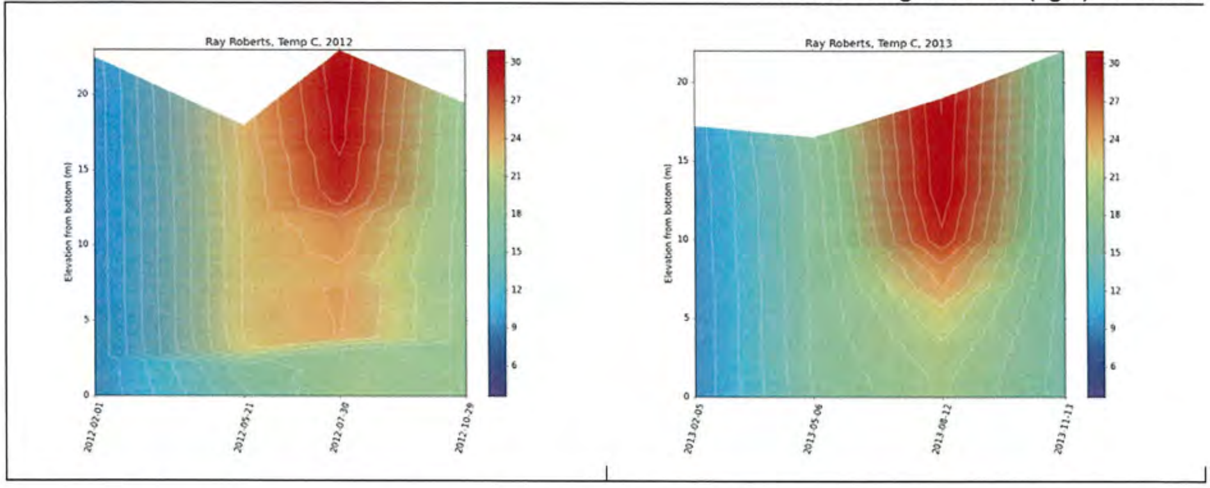


Figure 3-4. Annual Temperature Isopleths (January – December) for Lake Ray Roberts in High-stage Elevation (left) and Low-stage Elevation (right) Conditions

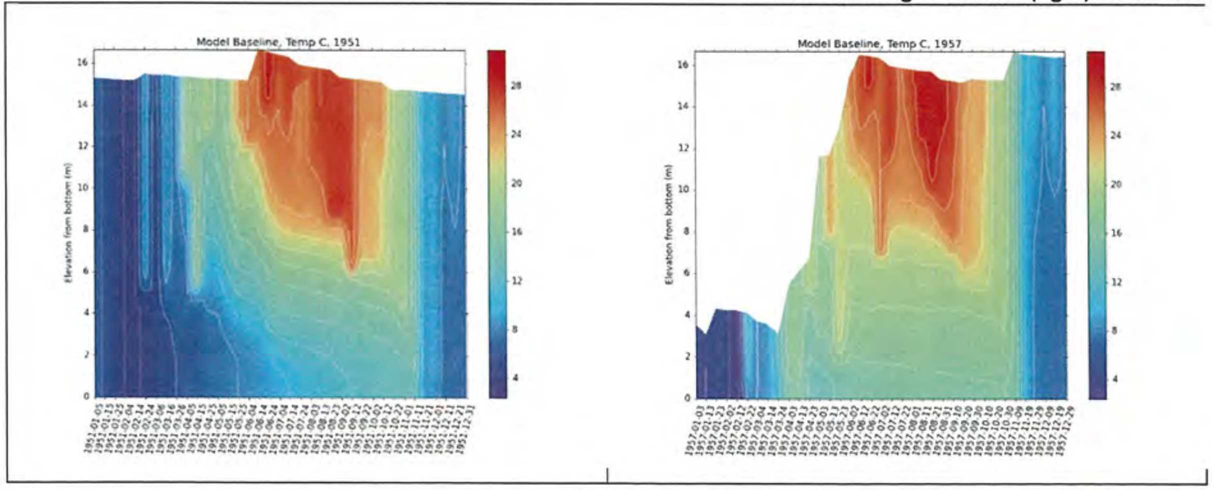


Figure 3-5. Annual Temperature Isopleths (January – December) for Bois d'Arc Model in High-stage Elevation Meteorological Year 1951 or Model Year 4 (left) and Low-stage Elevation Meteorological Year 1957 or Model Year 10 (right) Conditions

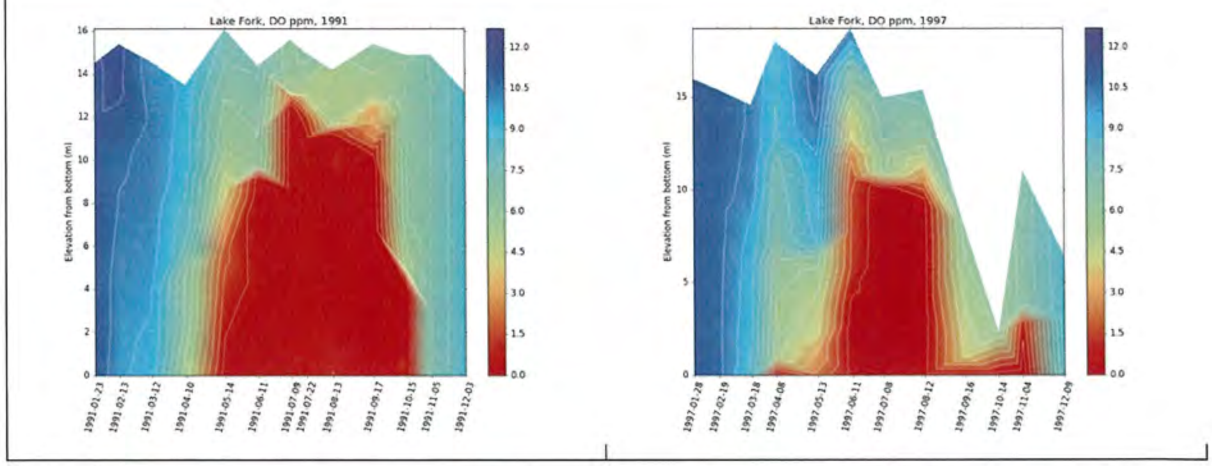


Figure 3-6. Annual Dissolved Oxygen Isopleths (January – December) for Lake Fork Reservoir in High-stage Elevation (left) and Low-stage Elevation (right) Conditions

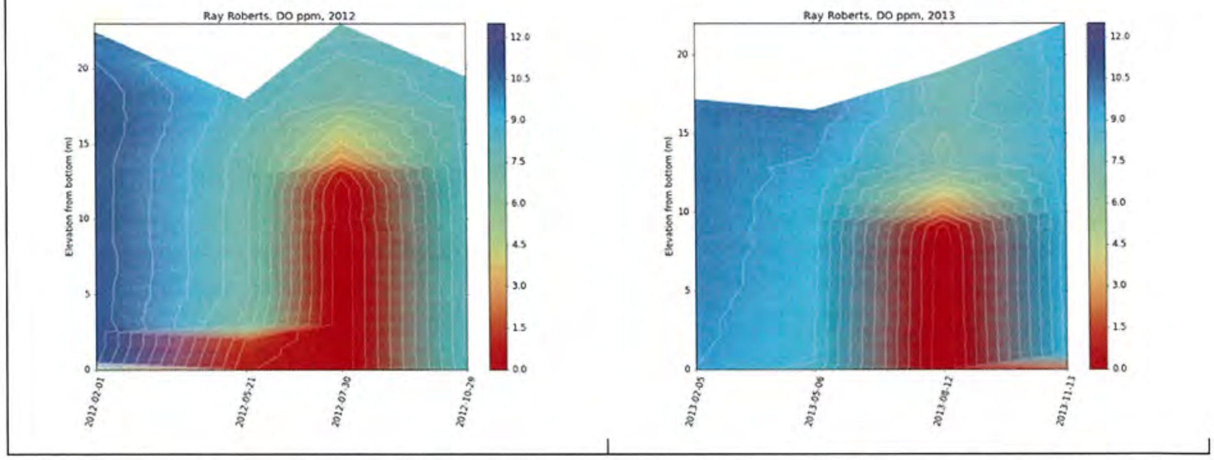


Figure 3-7. Annual Dissolved Oxygen Isopleths (January – December) for Lake Ray Roberts in High-stage Elevation (left) and Low-stage Elevation (right) Conditions

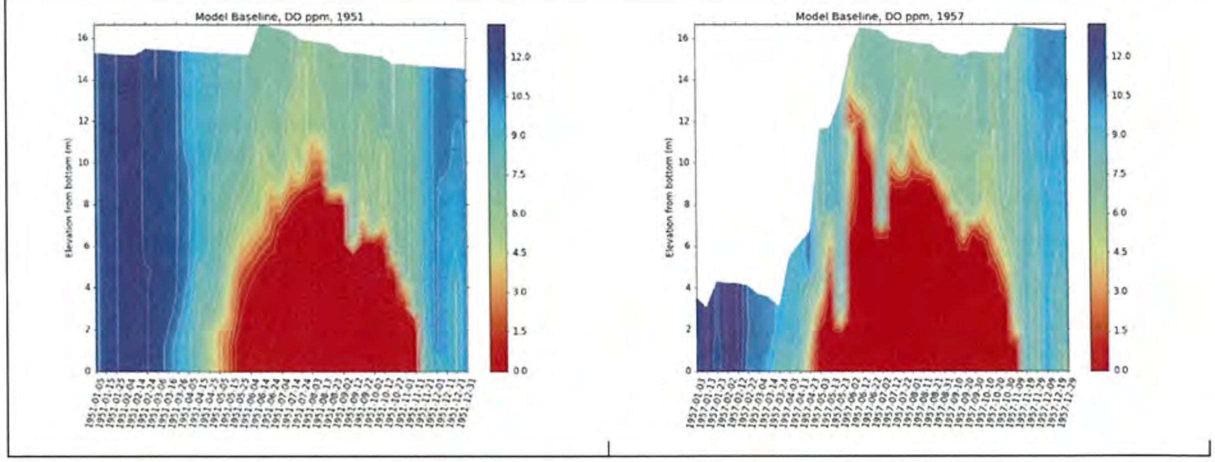


Figure 3-8. Annual Dissolved Oxygen Isopleths (January – December) for Bois d'Arc Model in High-stage Elevation Meteorological Year 1951 or Model Year 4 (left) and Low-stage Elevation Meteorological Year 1957 or Model Year 10 (right) Conditions

3.2 Water Quality Parameter Validation

This section provides a discussion of adjustments made to water quality parameters during the model validation process and graphical comparisons of predicted water quality constituents and measured field data from similar local reservoirs. The interrelated nature of nutrients, algae, DO, and pH required an iterative approach to the adjustment of governing kinetic rates and parameters to yield water quality results representative of conditions at other local reservoirs.

Following the discussion of parameter adjustments, figures are presented comparing profiles in the proposed reservoir to water quality data obtained primarily from Lake Ray Roberts, but in select cases at multiple reservoirs. The profile plots are presented to two seasonal extremes, one in February and one in July. The lack of available data to compare and validate the prediction of the CE-QUAL-W2 model is evident in several plots.

3.2.1 pH, Algae, and Nutrient Kinetic Coefficients Adjustments

The pH is modeled in CE-QUAL-W2 as a basic function of the carbonate-bicarbonate equilibrium reaction (Appendix B equations B-54 and B-55 in Cole and Wells, 2015):

$HCO_3^- \longleftrightarrow CO_3^{-2} + H^+$

$H_2O \longleftrightarrow H^+ + OH^-$

Equilibrium constants and carbonate species concentrations are a function of temperature, TDS, alkalinity and carbon dioxide (CO_2), and TIC. Along with the oversimplification of alkalinity compromising accuracy in pH results, CE-QUAL-W2 does not differentiate magnesium and calcium carbonates, both of which can also influence pH differently. The hydrogen concentrations are derived in part from nitrification, with the release of hydrogen ions as ammonia converts to nitrate. Calibration efforts for pH were focused on adjusting constituent kinetic coefficients that directly affect pH. These are provided in Table 3-2 and the following discussion.

CO_2 is a key parameter for its influence on pH and has numerous coefficients that were adjusted to control its reactions. Algae extract CO_2 from the environment for use in photosynthetic processes, which can lead to an increase in pH due to the shifting forms of alkalinity from bicarbonates to carbonates, and eventually to hydroxide. Initial model runs with default or sample kinetic coefficients resulted in unreasonably high algal blooms deeper into the reservoir than would be expected for a turbid reservoir. These initial results also had unreasonably high pH vertical profile values, which is expected with the occurrence of high-density algal blooms. A sensitivity study was then performed on the influence of algal processes on pH in the Bois d'Arc model. Results showed only slightly lowered pH during high bloom seasons (summer and winter) when all algal processes were turned off. The focus of the calibration then shifted to minor adjustments in the first 10 coefficients in Table 3-2 to decrease algal blooms to a reasonable range, with a sensitivity analysis of sediment release rates and their influence on pH.

Table 3-2 Kinetic Coefficients Adjusted for Water Quality Calibration

Kinetic Coefficient	Initial Value	Default Value	Final Value
Maximum Algal Growth Rate	2 day^{-1}	2 day^{-1}	1.5 day^{-1}
Stoichiometric Equivalent between Algal Biomass and Phosphorus (fraction)	0.005	0.005	0.015
Ratio of Algal Biomass and Chlorophyll-*a*	0.065 mg algae/µg Chl-*a*	0.05 mg algae/µg Chl-*a*	0.05 mg algae/µg Chl-*a*

Table 3-2 Kinetic Coefficients Adjusted for Water Quality Calibration

Kinetic Coefficient	Initial Value	Default Value	Final Value
Light Extinction for Pure Water	0.45 m^{-1}	0.25 m^{-1}	0.25 m^{-1}
Light Extinction Due to Inorganic Suspended Solids	0.01 $m^{-1}/g/m^3$	0.15 $m^{-1}/g/m^3$	0.15 $m^{-1}/g/m^3$
Light Extinction Due to Organic Suspended Solids	0.2 $m^{-1}/g/m^3$	0.1 $m^{-1}/g/m^3$	0.15 $m^{-1}/g/m^3$
Fraction of Incident Solar Radiation Absorbed at Water Surface	0.45	0.45	0.8
Sediment Phosphorous Release Rate	0.015	0.001	0.0025
Phosphorous Sorption onto Inorganic Suspended Solids	1.2	0	0
Sediment Release Rate of Ammonium	0.15 NH_4-N/m^2/day	0.001 NH_4-N/m^2/day	0.005 NH_4-N/m^2/day
Ammonium Decay Rate	0.05 day^{-1}	0.12 day^{-1}	0.25 day^{-1}
Sediment CO_2 Release Rate	0.1 day^{-1}	1.2 day^{-1}	0.5 day^{-1}
Sediment Oxygen Demand Rate	0.3-1.9 grams O_2/m^2/day	-	1-2 grams O_2/m^2/day
Labile DOM Decay Rate	0.3 day^{-1}	0.1 day^{-1}	0.1 day^{-1}

Notes:

mg algae/µg Chl-*a* = milligram of algae per microgram of chlorophyll-*a*

NH_4-N/m^2/day = ammonium per square meter per day

O_2/m^2/day = oxygen per square meter per day

3.2.1.1 Algal Kinetic Coefficients

Bois d'Arc reservoir will be a highly turbid system due to algae growth. Light is expected to be a limiting factor for algae during periods of peak algae growth. To represent this in the model, the two light extinction and solar radiation coefficients shown in Table 3-2 were increased to a reasonable range for a turbid system. Other kinetic coefficients that were adjusted lowered to reasonable ranges based on suggestions from the CE-QUAL-W2 manual and EPA guidance (1985) for a mixed algae species population include the ratio of algal biomass and chlorophyll-*a* and maximum algal growth rate coefficient. The biomass to chlorophyll-*a* ratio was decreased from 0.065 to 0.05, with algae in milligrams and chlorophyll-*a* in micrograms (1 milligram algae = 20 micrograms of chlorophyll-*a*). The maximum algal growth rate was lowered slightly by a reasonable degree from 2 to 1.5 day^{-1}. These changes brought the maximum algae concentration down by 50 percent during the summer.

The stoichiometric equivalent between algal biomass and phosphorus fraction was assessed after phosphate (PO_4) values were noticed to be impractically high. Recommended EPA (1985) values range from 0.008 to 0.033 for green and blue green algae; the initial value was lower, at 0.005. The parameter was adjusted to 0.015 and predicted PO_4 and TP values were much more reasonable.

Labile dissolved organic matter (LDOM) in CE-QUAL represents the partition of DOM that decays at a higher rate (up to two orders of magnitude greater) than refractory DOM, and typically consists of compounds found in early products of algal decay. The LDOM decay rate primarily affects nitrogen and phosphorus constituent concentrations, providing substrate for algae growth. Suggested LDOM rates from the manual range from 0.01 to 0.64 day^{-1}, with a default value of 0.1 day^{-1}. The default value was chosen with limited data for comparison.

3.2.1.2 Sediment Oxygen Demand Nutrient Release Rates

Sediment release rates for ammonia and phosphate are defined in CE-QUAL-W2 as a fraction of the sediment oxygen demand (SOD). With little information on the chemical composition of sediments at the proposed reservoir site, a SOD range of 1 to 2 O_2/m^2/day was specified based on engineering judgement and previous experience with CE-QUAL-W2. This range was distributed low to high from the upstream end to the downstream to reflect increased settling of organic matter, low velocities, and high residence times in the deeper sections of the reservoir. Furthermore, the shallow segments will be exposed to air more often when the water surface elevation is low. Anoxic conditions are expected to occur from June through September, based on data from surrogate reservoirs. The influence of model parameters on the duration of seasonal anoxia is discussed below.

Sediment release of phosphorous was analyzed first as a part of the effort to reduce algal blooms. This parameter is highly variable amongst different soil compositions. The CE-QUAL-W2 manual recommends using a default value of 0.1 percent of SOD rates unless soil chemical composition is well understood for the model site. For these SOD rates, this equates to a release of 10 to 20 grams pf phosphate per square meter per day. Initial model results with this release rate did not yield reasonable results in that there was little vertical variation in TP as expected. The release rate of phosphorus was subsequently increased to 0.25 percent. The manual also recommends turning off the process of dissolved phosphorus sorption onto inorganic suspended solids unless it is known this will occur in the reservoir; that feature was turned off.

Following the effort of reducing algal blooms to a reasonable range, a sensitivity study was performed on the sediment CO_2 release rate to better understand its influences on CO_2 concentrations throughout the reservoir and pH. The sediment CO_2 release rate was set to 50, 100, and 125 percent SOD in three separate model runs, with no other changes made to the model. The pH results, as expected, showed substantial influence of sediment CO_2 release rates on pH. For runs with a sediment CO_2 release rate of 50, 100, and 125 percent, the pH ranged from approximately 7.2 to 9.6, 6.8 to 9.4, and 6.7 to 9.3 in the first year of each run, respectively. The value of 125 percent SOD was selected as the most feasible sediment CO_2 release rate, because these results produced pH values within the target range.

As previously mentioned, ammonia is another parameter known to affect pH levels in natural water systems. Model runs with the initial ammonia kinetic coefficients shown in Table 3-2 inaccurately resulted in no change of concentration with depth. Sediment release rate of ammonia was increased from 5 to 25 percent of the SOD rate. Ammonia increased with depth at a rate comparable to the surrogate reservoirs, as seen in the vertical profile comparison with Lake Ray Roberts data presented below. In addition, the decay rate of ammonia was increased to reduce elevated pH values.

3.2.1.3 Discussion of Water Quality Model Calibration Graphics

Figure 3-9 through Figure 3-24 present model results for DO, TP, ammonia, pH, TOC, chlorophyll-*a*, alkalinity, and iron in the form of vertical profiles at the water intake location (Segment 29, near the dam). For each parameter, two plots are presented, one showing the range in late winter (February) conditions for 9 consecutive years ending with the large drawdown event and the other showing conditions in July. In each plot, data from other local comparable reservoirs are shown to demonstrate the reasonableness of the CE-QUAL-W2 Bois d'Arc model results.

Figure 3-9 and Figure 3-10 compare model predictions of DO to water quality data in other comparable or surrogate reservoirs. In February, conditions are generally well mixed with DO levels between 12 and 13 mg/L. Results are slightly higher than the mean of the water quality data, but are not within the measured data range. Stratification is clearly visible in July with near surface values between 6 and 8 mg/L, which agrees well with the observed dataset. Anoxic conditions are well represented in the water quality database of comparable lakes. The duration of projected anoxia generally extends from May through October. The lack of wind mixing may contribute to the extended anoxic conditions in the proposed reservoir. However, it is possible that sediment oxygen demand is set at too high a value, contributing to the extended anoxic conditions. Site-specific data will allow for improved model calibration of DO.

Figure 3-11 and Figure 3-12 present model predictions for TP as well as field data for comparison. Wintertime TP profiles are generally well mixed after the first 2 years of the model simulation; these early results should be interpreted with caution because of the influence of initial conditions on model results until the lake has achieved dynamic equilibrium with the inflows. Profiles from July demonstrate increased TP in the hypolimnion of up to 0.2 mg/L. This is in line with available field data. Total phosphorus values were sensitive to phosphate release rates from the sediments as well as the percent phosphorus specified in algal biomass.

Predicted ammonia concentrations are compared to field data on Figure 3-13 and Figure 3-14. Ammonia is predicted to be well mixed during the winter after the first 2 years of the simulation. Concentrations are less than 0.03 mg/L throughout the water column. During summer, ammonia release from the sediment during anoxic conditions in the hypolimnion yield an increase in concentration with depth that matches very well with field data. The user-defined sediment release rate of ammonia was adjusted to obtain this match.

Figure 3-15 and Figure 3-16 present winter and summer pH predictions along with the full range of field data for comparison. Predicted pH is slightly above the field data range in February. Results from the first 3 years of the model should be disregarded until the model spins up and equilibrates to inflow conditions. In July, predicted profiles demonstrate the expected decrease with depth, with surface values between 8 and 9.5 and bottom values near 7.5. Model results agree well with available water quality data.

Predicted TOC results are presented on Figure 3-17 and Figure 3-18. There is a lack of field data against which to compare model results for this parameter. Results indicate a generally well mixed distribution of TOC that can vary considerably year to year. Maximum predicted concentrations are near 5 mg/L in the winter and near 6 mg/L in the summer.

Figure 3-19 and Figure 3-20 present model predictions for chlorophyll-*a* and all available field data which are, unfortunately, limited to surface samples. Results indicate well mixed conditions in February with a concentration around 5 µg/l; field data show are large range of results up to 25 µg/l for the winter season. In the summer months, peak chlorophyll concentrations in July reach 15 µg/l at roughly half depth, well within the range of field data. A more complete review of chlorophyll results demonstrates that algal blooms occur more in the center of the reservoir, not near the dam. Furthermore, they tend to peak in April or May.

Alkalinity is a measurement of carbonate species in water that provide a buffering capacity for variation in pH. Although alkalinity is generally dominated by bicarbonate and carbonate, in some systems constituents such as calcium, ammonia, organic matter, phosphoric acid, silicic acid, and boric acid can have acidic/buffering properties (USGS, 2013) that are unaccounted for in the CE-QUAL-W2 model. CE-QUAL-W2 also does not model the reactions and effects of carbonate precipitations nor carbonate being released from the sediment in anoxic zones. This oversimplification of alkaline properties in these constituents leads to alkalinity results that do not accurately reflect internal reactions of these constituents and carbonate species. Rather, CE-QUAL treats alkalinity as a conservative constituent that is solely a function of its concentration in the inflows.

With these caveats in mind, alkalinity inflow and initial concentrations were the primary focus during the calibration. With an initial concentration set to 60 mg/L as $CaCO_3$ and inflow concentration set to 165 mg/L as $CaCO_3$, alkalinity as a conservative constituent increases over time from 60 to 240 mg/L in winter and 220 mg/L in summer. Results presented on Figure 3-21 and Figure 3-22 show alkalinity ranging from 40 to 90 mg/L higher than surrogate reservoirs indicate. It is expected that the model results for alkalinity overestimate expected conditions in the reservoir; it is advised that alkalinity results, as well as the constituents it influences such as pH, are interpreted with caution given the limitations in CE-QUAL.

CE-QUAL-W2 has a simplistic representation of iron in the model, with sources from inflows and a user-prescribed sediment release rate, and losses through settling back to the sediments. The model is very sensitive to the sediment release rate and settling velocity. The sediment release rate controls how quickly iron builds in the hypolimnion during anoxic events, and the settling velocity controls how long this iron remains in the water column. Model simulations used default values for these two parameters. Model predicted profiles in February of 9 consecutive years are presented on Figure 3-23; results indicate no iron in the water column. Any iron released from the sediment during the previous summer has settled out of suspension by February. Figure 3-24 presents results for July in 9 consecutive model years. Increases in iron concentration with depth are associated with sediment release during anoxic conditions. Iron concentrations of up to 50 mg/L are predicted when using the default release rate of 0.5 times the sediment oxygen demand, which equates to a release rate of 0.5 to 1.0 milligrams per square meter per day. Near bottom concentrations are approximately 10 times higher than water quality data from comparable reservoirs, indicating the default release rate may be high. The availability of site-specific water quality data would allow for improved calibration of iron in the CE-QUAL-W2 model.

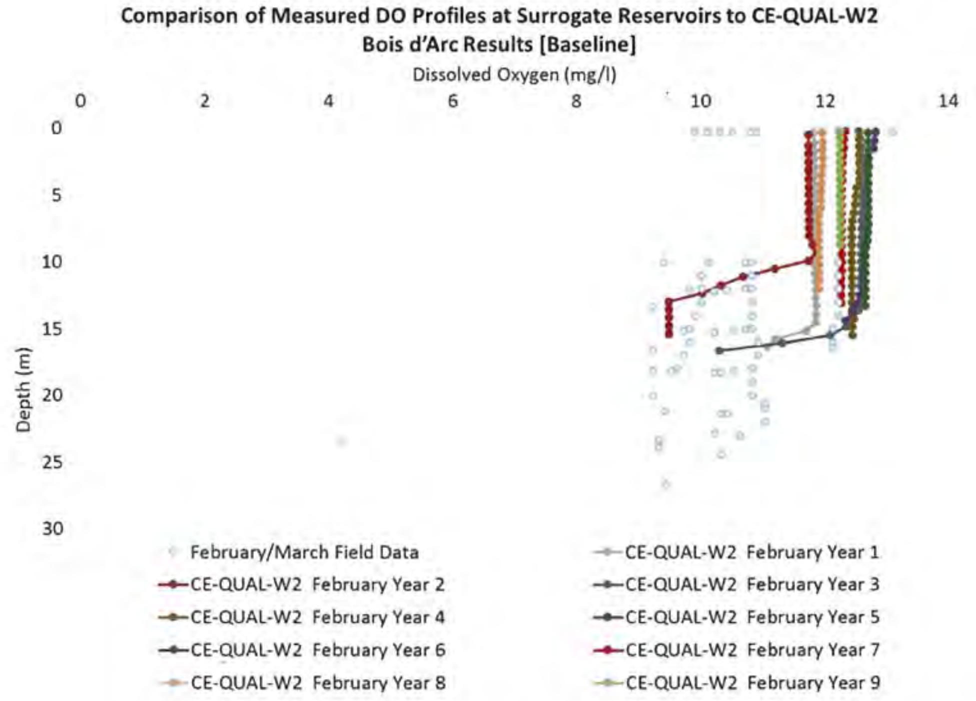


Figure 3-9. Comparison of Measured February DO Profiles to Baseline Bois d'Arc Reservoir

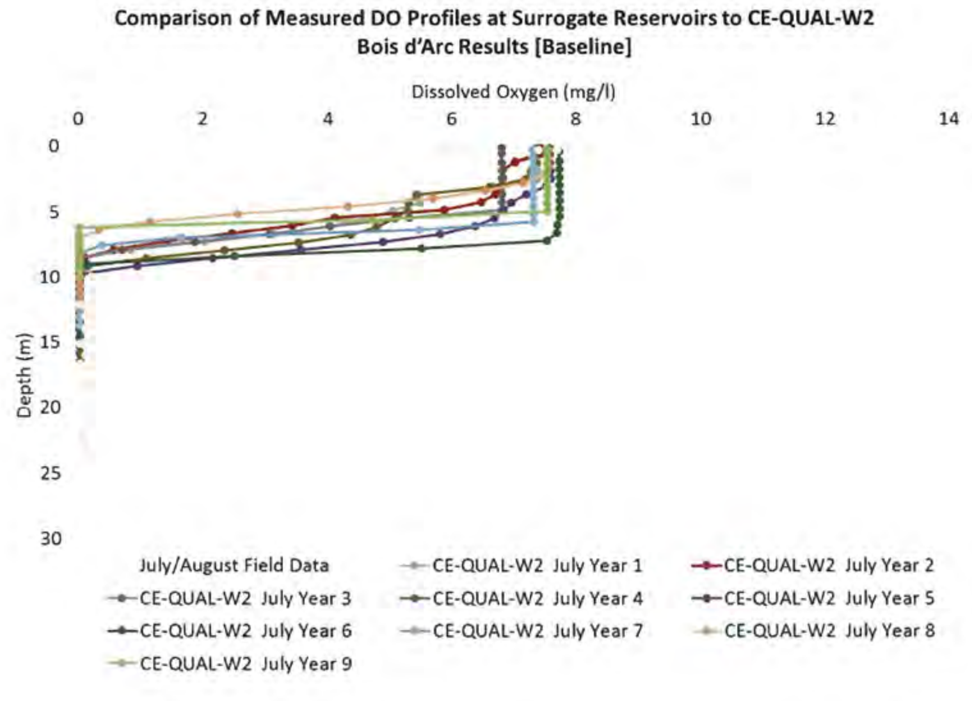


Figure 3-10. Comparison of Measured July DO Profiles to Baseline Bois d'Arc Reservoir

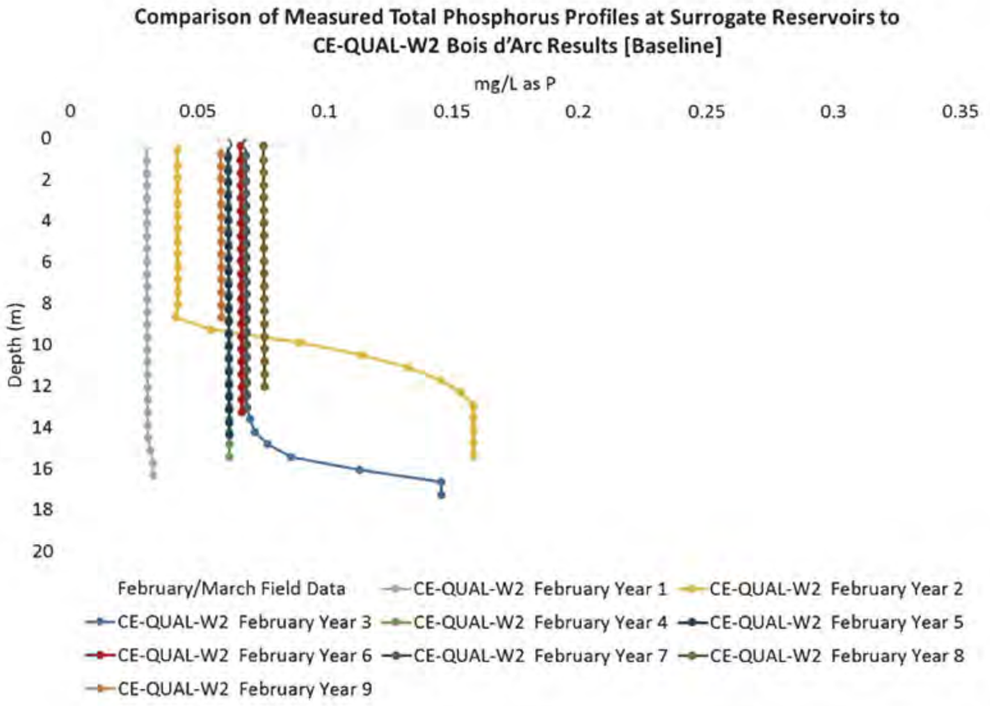


Figure 3-11. Comparison of Measured February Total Phosphorus Profiles to Baseline Bois d'Arc Reservoir

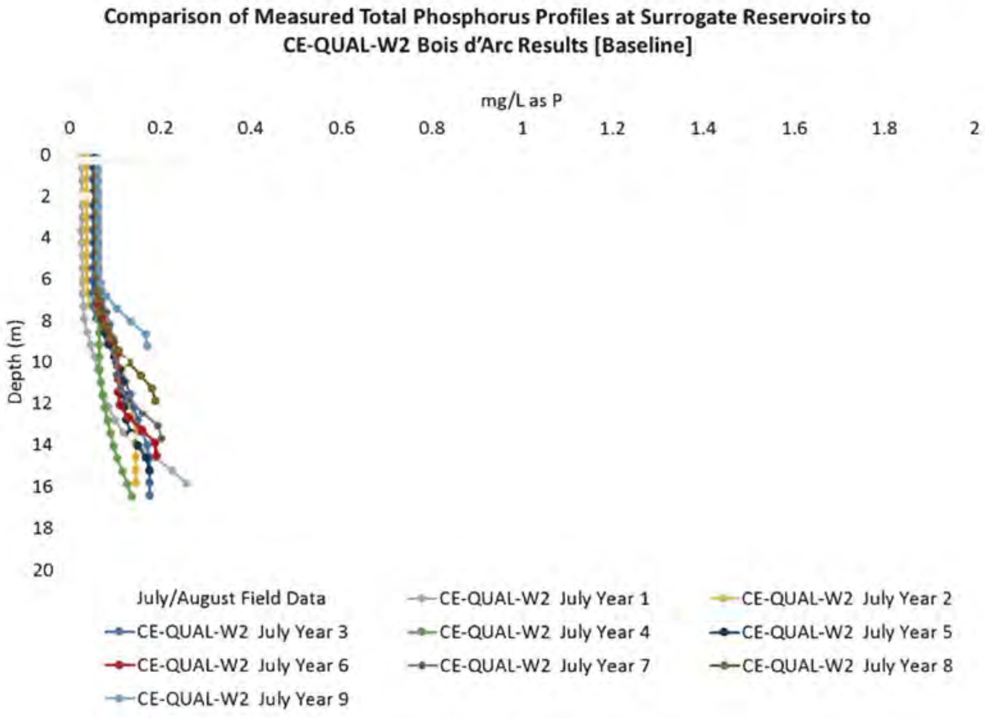


Figure 3-12. Comparison of Measured July Total Phosphorus Profiles to Baseline Bois d'Arc Reservoir

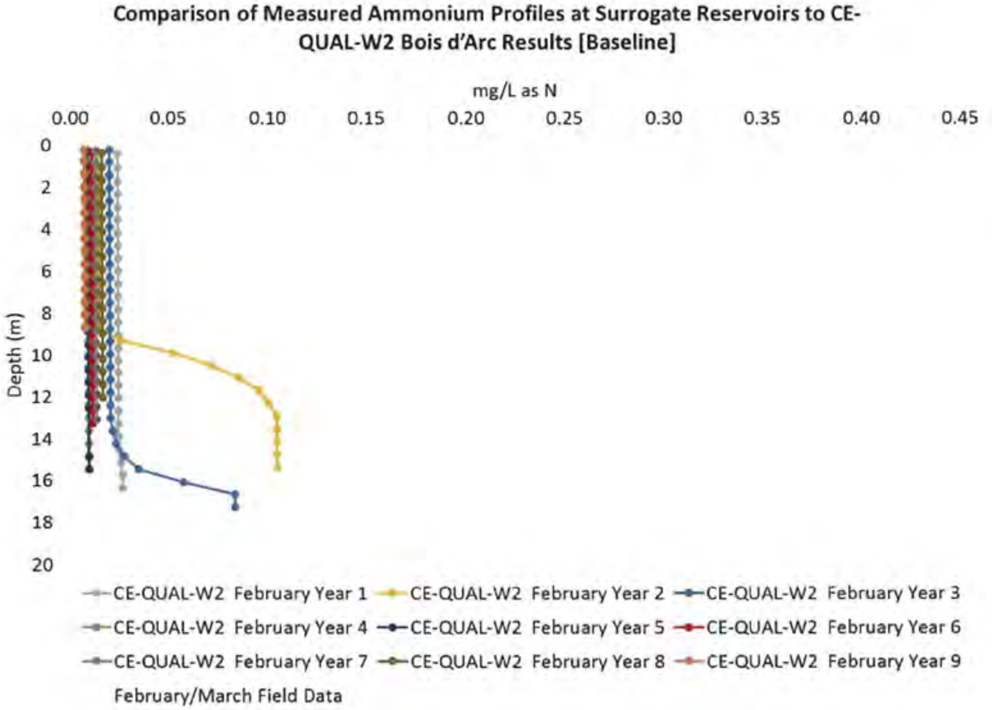


Figure 3-13. Comparison of Measured February Ammonium Profiles to Baseline Bois d'Arc Reservoir

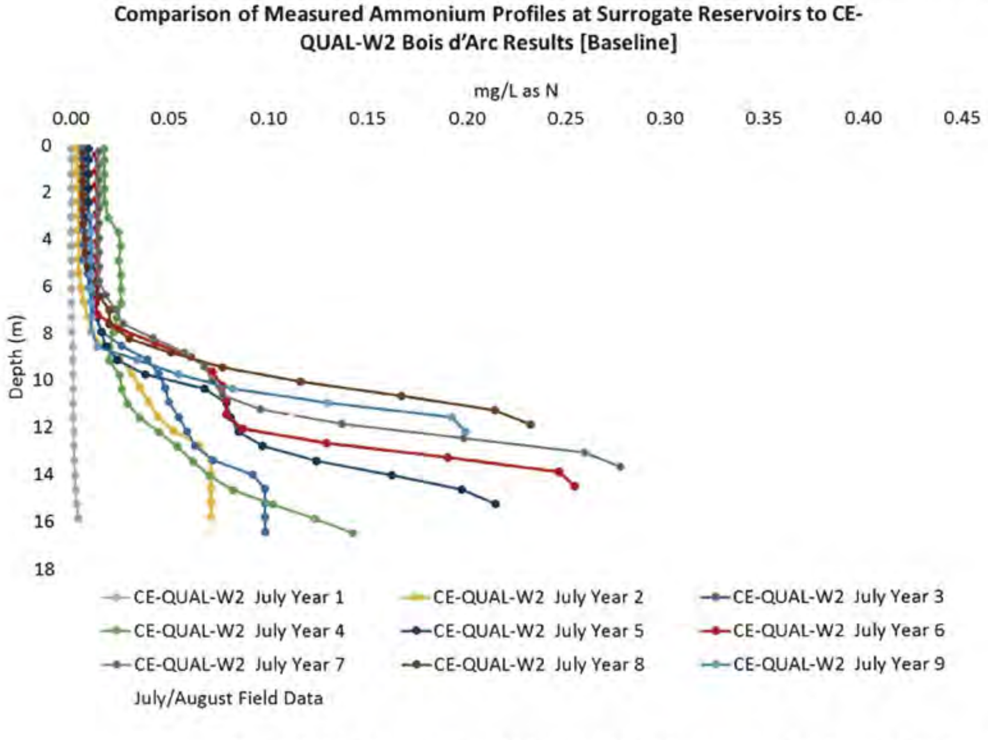


Figure 3-14. Comparison of Measured July Ammonium Profiles to Baseline Bois d'Arc Reservoir

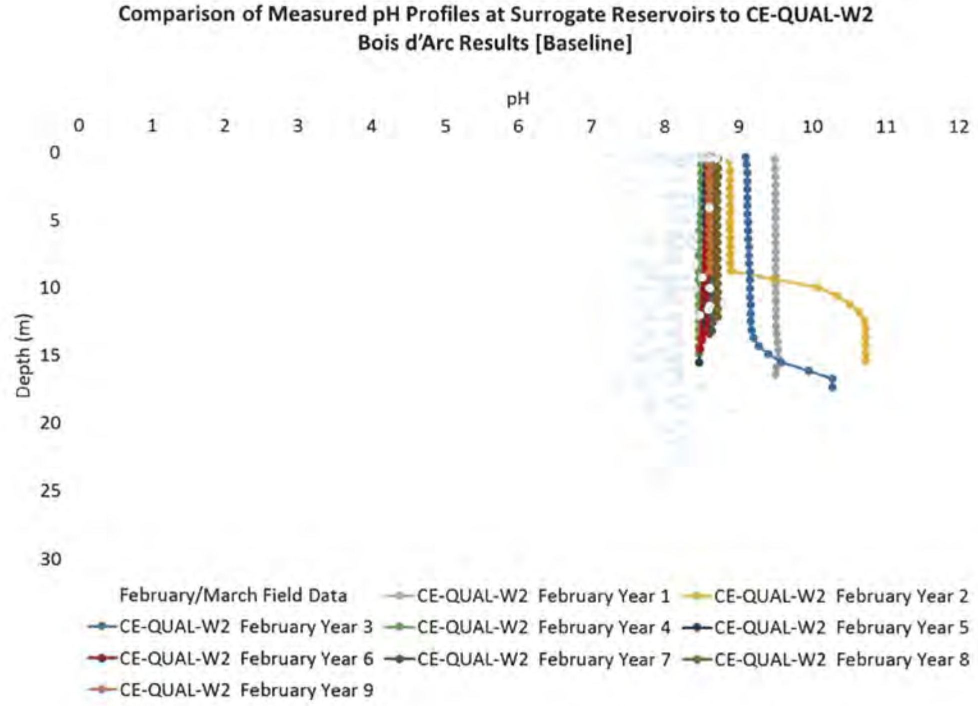


Figure 3-15. Comparison of Measured February pH Profiles to Baseline Bois d'Arc Reservoir

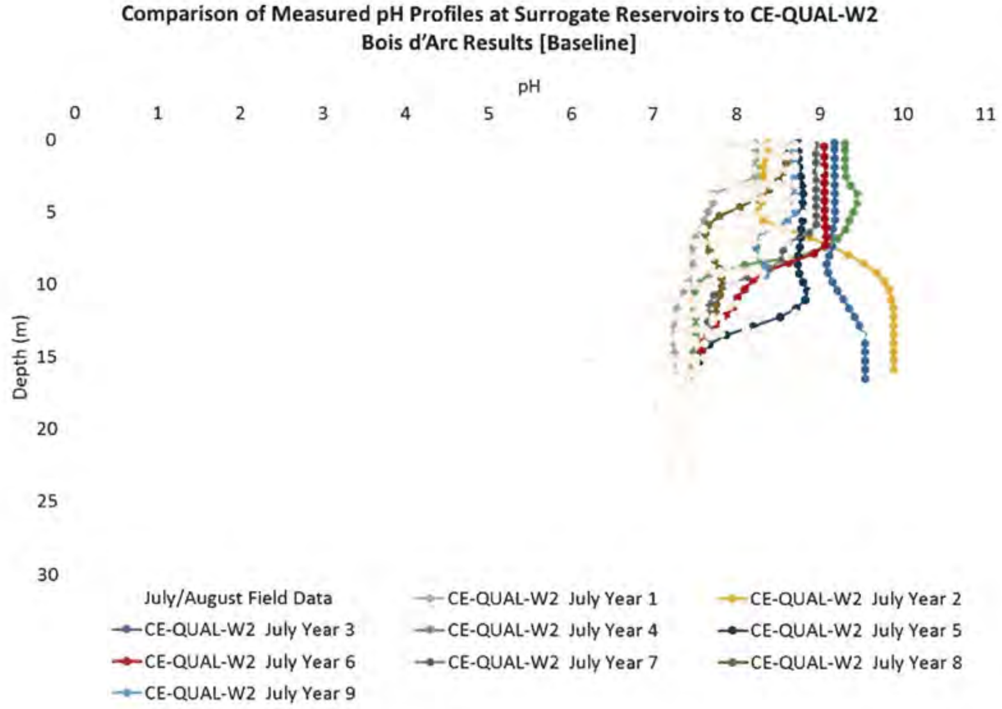


Figure 3-16. Comparison of Measured July pH Profiles to Baseline Bois d'Arc Reservoir

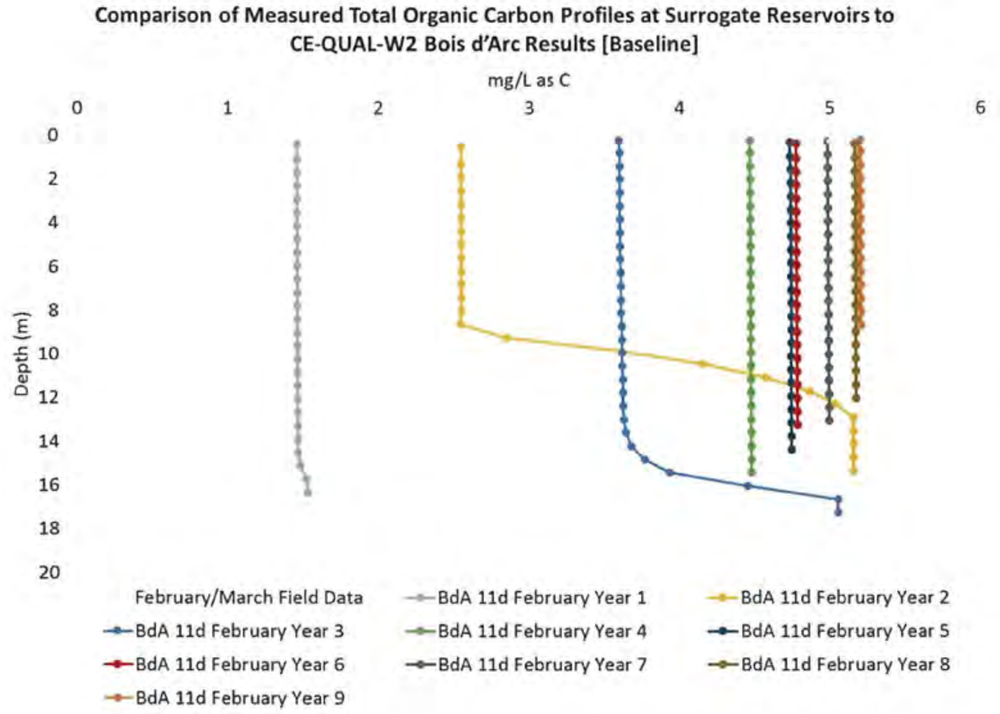


Figure 3-17. Comparison of Measured February TOC Profiles to Baseline Bois d'Arc Reservoir

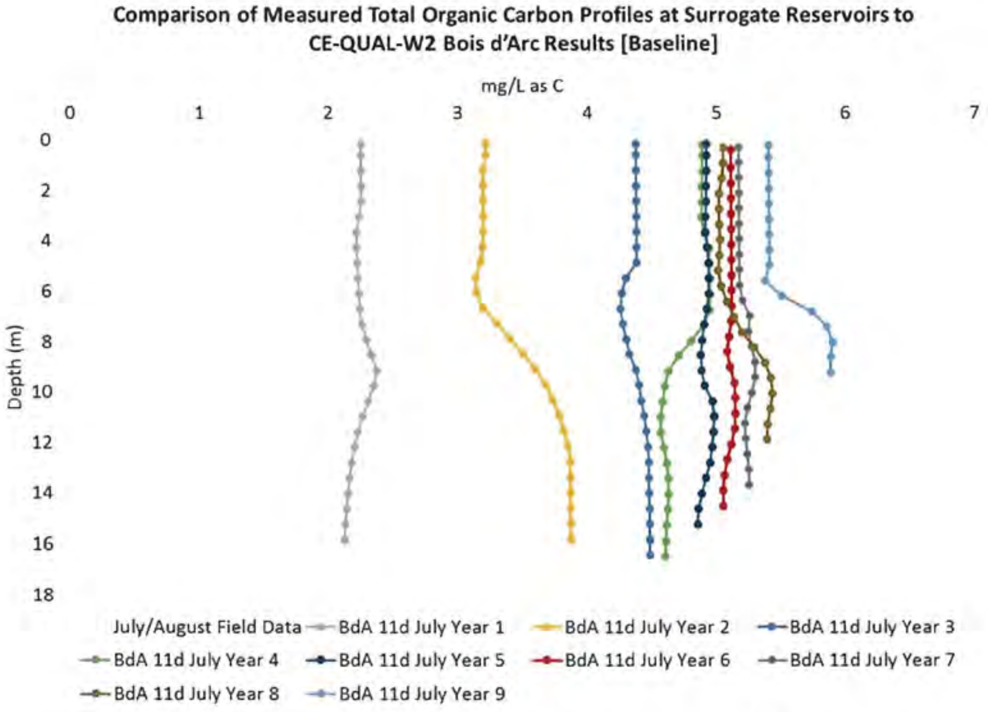


Figure 3-18. Comparison of Measured July TOC Profiles to Baseline Bois d'Arc Reservoir

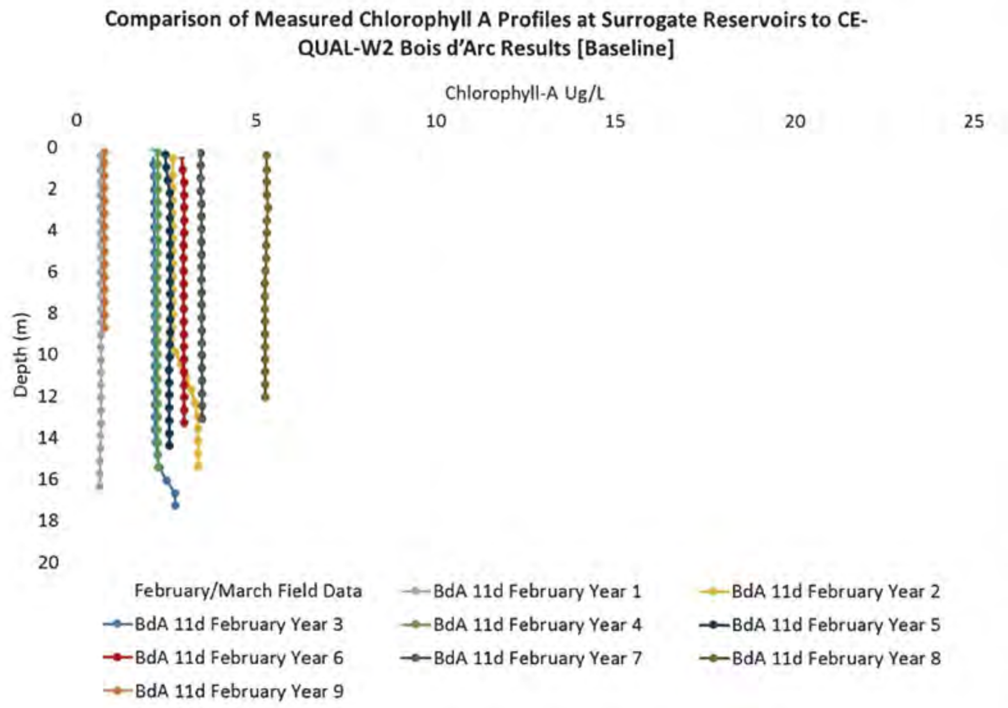


Figure 3-19. Comparison of Measured February Chlorophyll-*a* Profiles to Baseline Bois d'Arc Reservoir

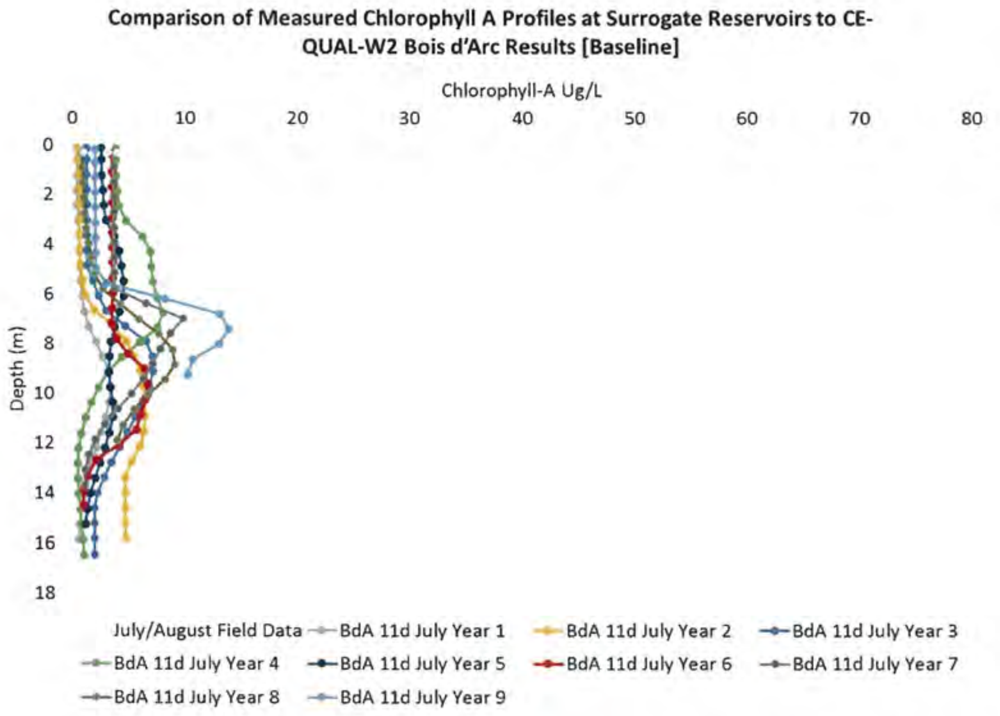


Figure 3-20. Comparison of Measured July Chlorophyll-*a* Profiles to Baseline Bois d'Arc Reservoir

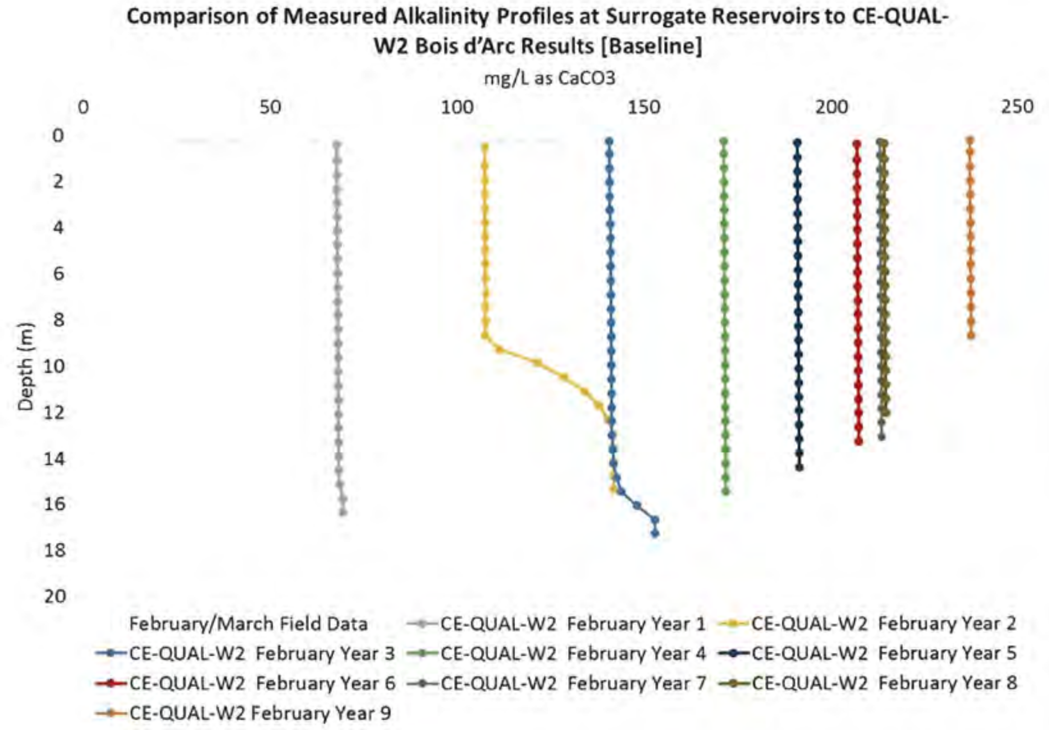


Figure 3-21. Comparison of Measured February Alkalinity Profiles to Baseline Bois d'Arc Reservoir

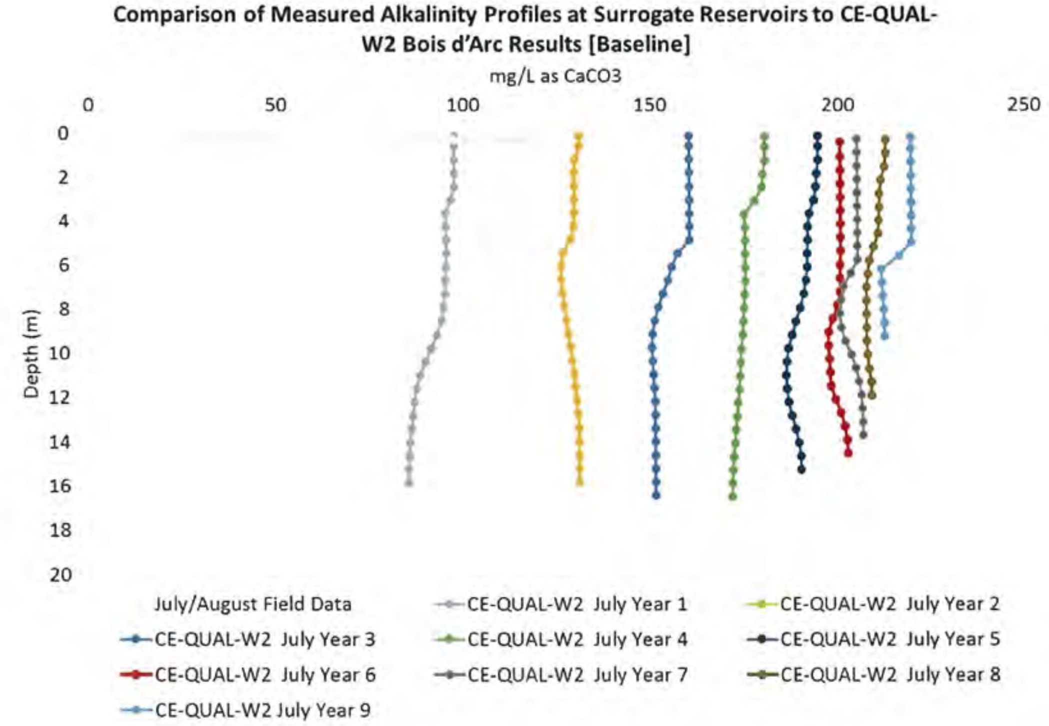


Figure 3-22. Comparison of Measured July Alkalinity Profiles to Baseline Bois d'Arc Reservoir

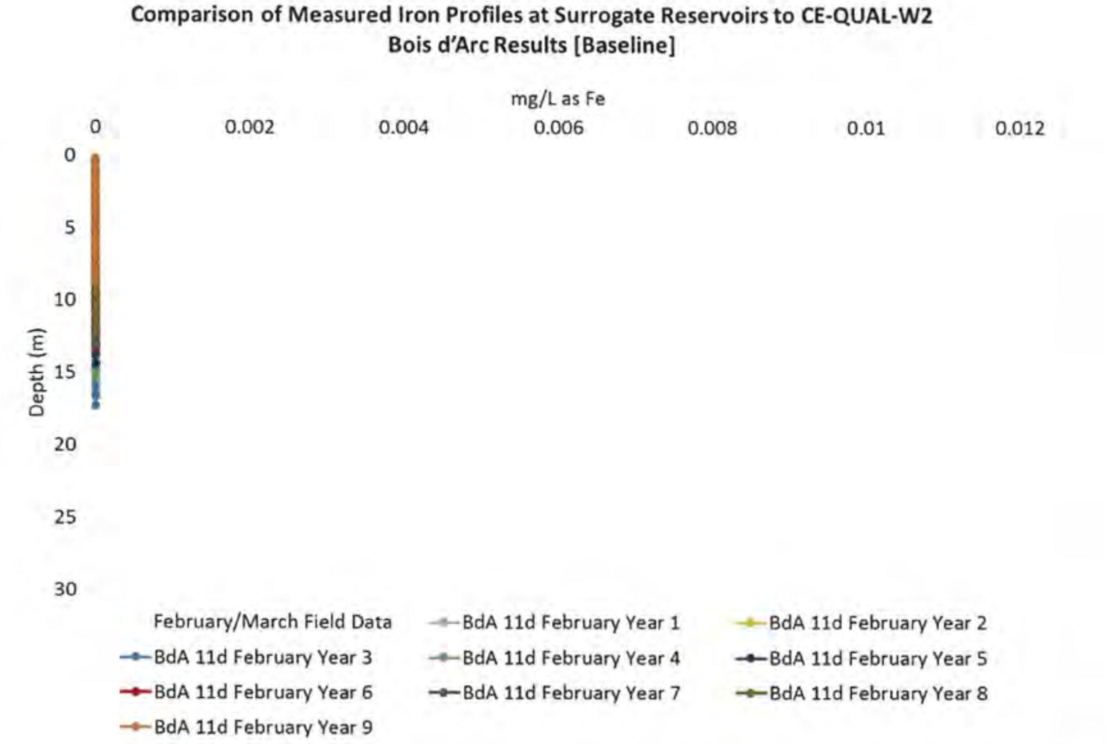


Figure 3-23. Comparison of Measured February Iron Profiles to Baseline Bois d'Arc Reservoir

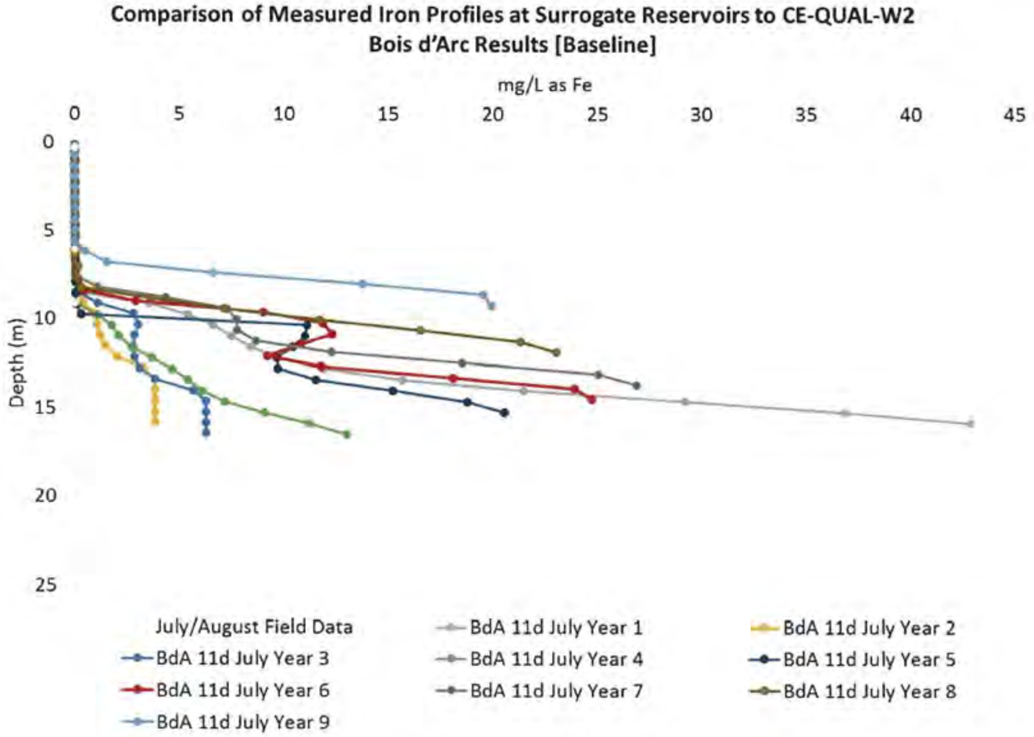


Figure 3-24. Comparison of Measured July Iron Profiles to Baseline Bois d'Arc Reservoir

3.2.1.4 Variation in Profiles with Time through Year (Year 7)

This section provides a discussion of the variation in water quality parameters with time. Monthly profile plots as well as time series plots are presented and explained. Profile plots (Figure 3-25 through 3-32) are provided for DO, chlorophyll a, ammonium, nitrate/nitrite, total nitrogen, total organic nitrogen, phosphate, and pH. Profile plots are presented as constituent concentrations through time of the vertical profile at the dam. Figures were constructed with output every 10 days and reflect conditions in Year 7 of the model simulation, which is considered representative of average conditions.

Thermal stratification will induce anoxia in the hypolimnion from May through October, approximately half of the year (Figure 3-25). Anoxia creates a cascade of poor water quality results including eutrophication; cyanobacteria blooms; high manganese, iron, and NH_4^+ in the hypolimnion; and poor cool-water fishery habitat.

Model results indicate peak algae blooms in April (Figure 3-26). Sedimentation of algae from this peak bloom contributes to hypolimnetic anoxia in May.

Settled algae have a high organic nitrogen content. Decomposition of algae yields ammonium. In an anoxic hypolimion there will be no oxidation of ammonium, causing an accumulation of ammonium (Figure 3-27). There will be some oxidation of ammonium to nitrate/nitrite as the hypolimnion transitions from aerobic to anoxic, but there will be steady loss of nitrate/nitrate in the hypolimnion during summer (Figure 3-28). Aerobic conditions November to March will contribute to nitrate in surface waters. Total nitrogen profile large follow ammonium dynamics (Figure 3-29), but is governed by organic nitrogen dynamics (Figure 3-30). Organic nitrogen tends to have an irreducible background concentration near 0.8 mg/L. This unreactive fraction thus influences overall TN dynamics.

Hypolimnetic anoxia causes iron-bound phosphate in sediments to solubilize (Figure 3-31). Advective, turbulent mixing in the summer from wind will enrich surface water with this hypolimnetic phosphate during the summer. In Bois d'Arc Reservoir, the lack of a long fetch will reduce this hypolimnion-epilimnion transfer of phosphorus. At turnover, the hypolimnetic phosphate enriches the entire water column. Without phosphorus inputs from stormwater, fall turnover enrichment of the hypolimnion can stimulate spring algae blooms.

The pH in Bois d'Arc Reservoir will probably be over 8 consistently (Figure 3-32). High pH is a consequence of high primary productivity and high alkalinity. Drops in pH in the hypolimion are a consequence of lack of photosynthesis and fermentation of sediments in anoxic conditions.

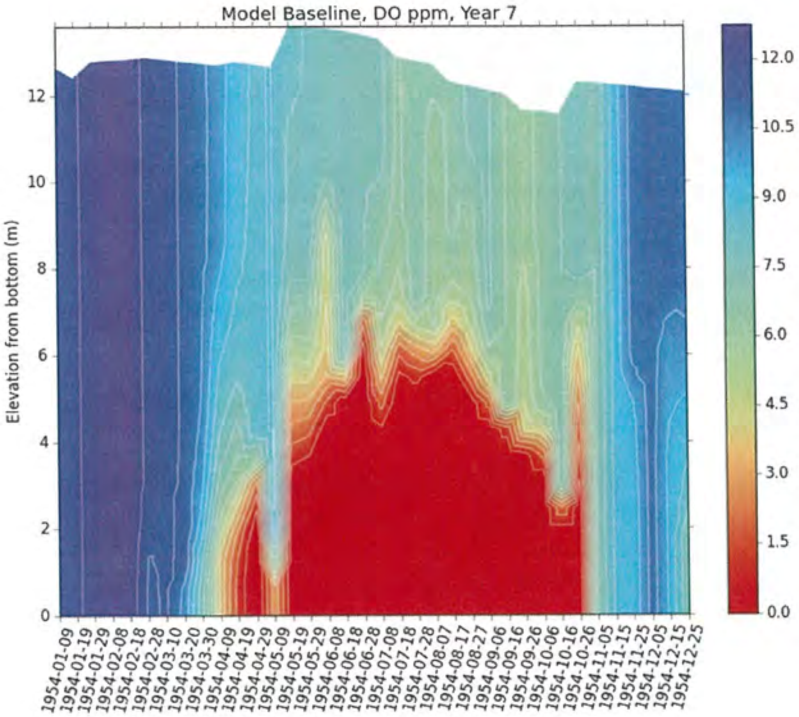


Figure 3-25. Monthly Dissolved Oxygen Profiles in Year 7 (mg/L)

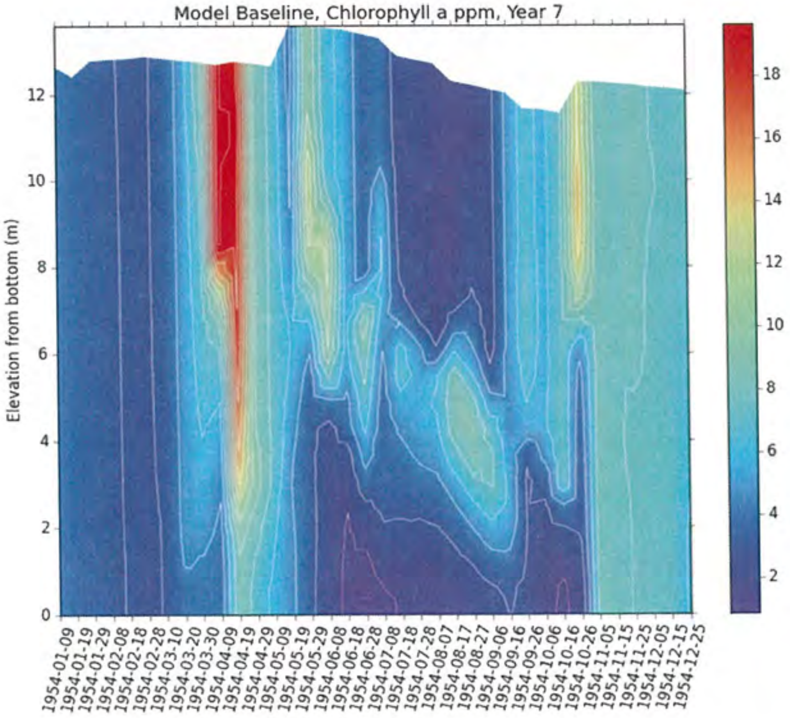


Figure 3-26. Monthly Chlorophyll-*a* Profiles in Year 7 (µg/L)

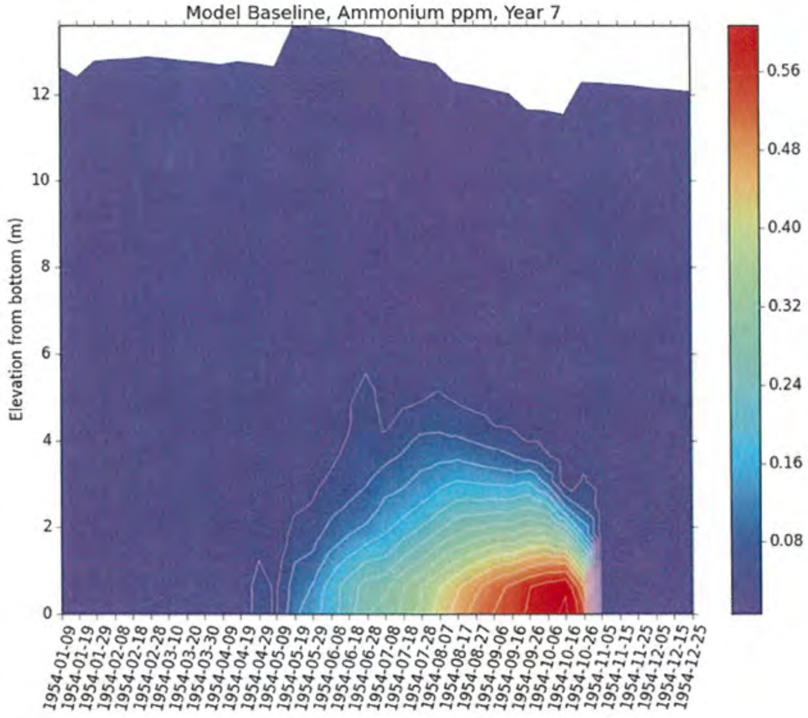


Figure 3-27. Monthly Ammonium Profiles in Year 7 (mg/L)

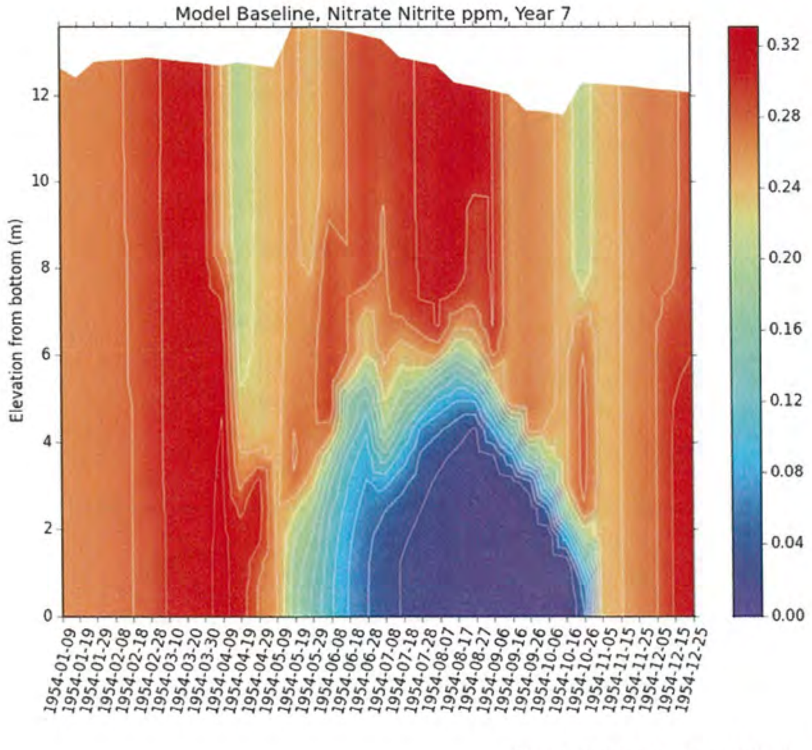


Figure 3-28. Monthly Nitrate + Nitrite Profiles in Year 7 (mg/L)

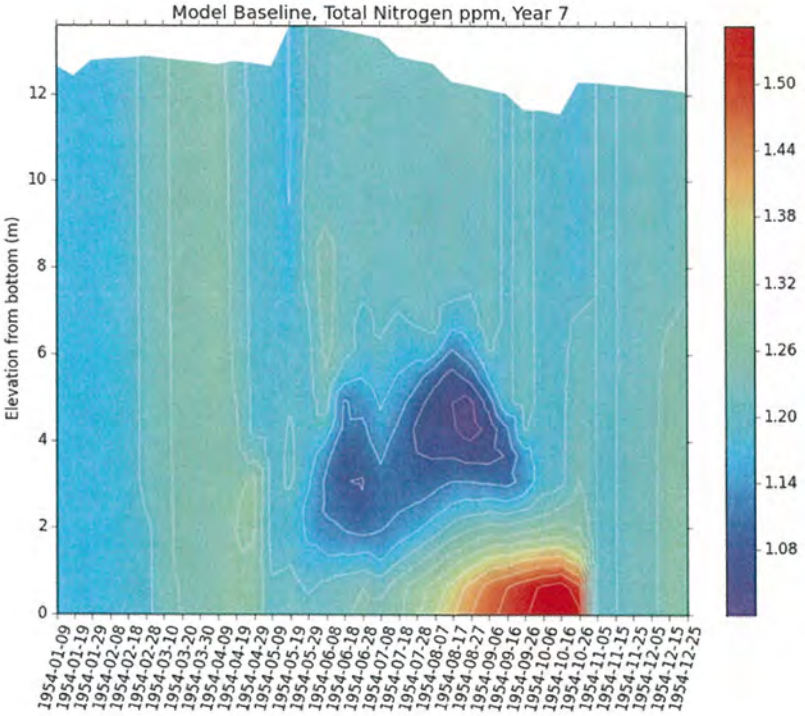


Figure 3-29. Monthly Total Nitrogen Profiles in Year 7 (mg/L)

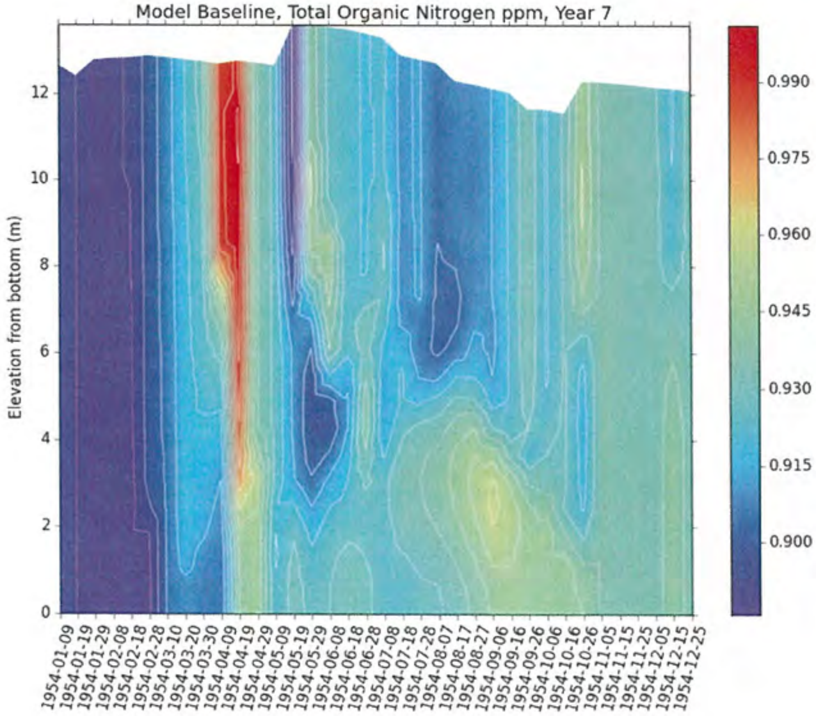


Figure 3-30. Monthly Total Organic Nitrogen Profiles in Year 7 (mg/L)

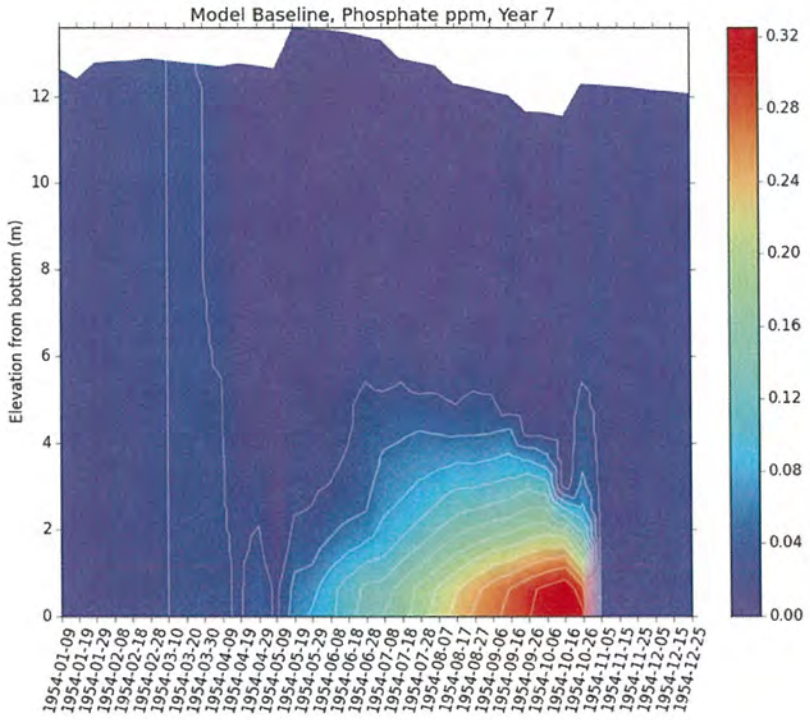


Figure 3-31. Monthly Phosphate Profiles in Year 7 (mg/L)

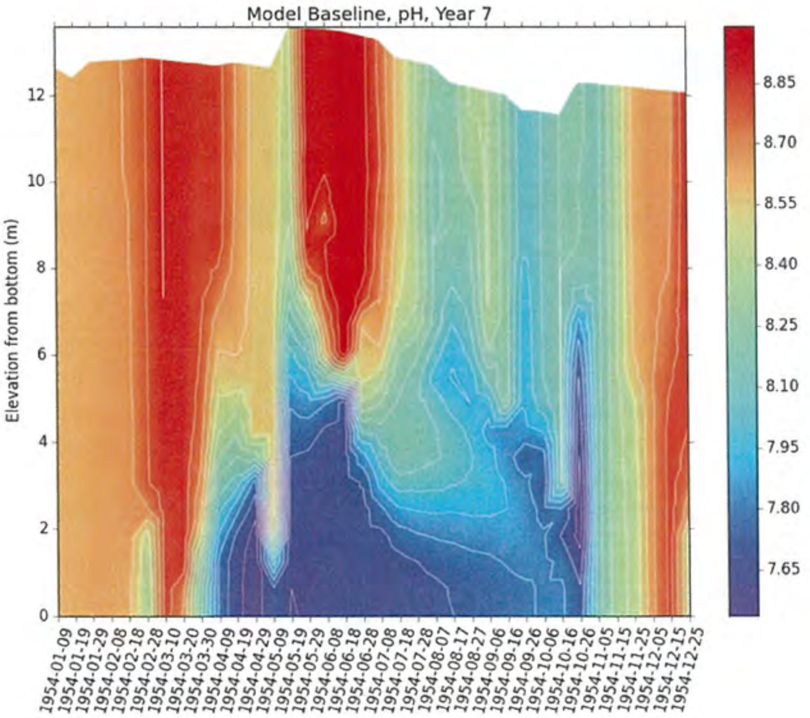


Figure 3-32. Monthly pH Profiles in Year 7

Figure 3-33 and Figure 3-34 present time series plots of key water quality parameters at the surface and at the bottom. Surface results were extracted from model Segment 29 at the dam; bottom results were extracted at model Segment 23. The time series plots reflect results for a 15-year model simulation, including the extreme drawdown event in Year 9 and rapid recovery in Year 10, as shown on Figure 2-5.

Dissolved oxygen is predicted to follow standard annual cycles for eutrophic lakes in the surface and bottom waters. The surface DO reached 12 mg/L during winter and drops to 6 mg/L or lower during the summer. In the hypolimnion, DO varies from 12 mg/L in the winter months to anoxic during the late spring to early fall. In general, there are anoxic conditions are during May through the end of October. The model estimation of anoxia is directly related to user specified sediment oxygen demand rates. The predicted duration of anoxia can be improved with site-specific data after construction of the reservoir.

Predicted algal concentrations in the surface water reach 1 to 2 mg/L algae (dry weight), which equates to 20 to 40 µg/L chlorophyll-*a* assuming a 5 percent algal biomass (in mg/L) to chlorophyll (in µg/L) as used in the model. During the drought event, the algal bloom reaches over 5 mg/L in the spring bloom. In the near bottom waters, low light conditions retard algal growth and peak concentrations during spring blooms rarely exceed 1 mg/L, and then only in drought years when the water is relatively shallow. Predicted algal concentrations are sensitive to assumed growth rates, which can vary considerably from species to species. Algal concentrations can be fine-tuned when site specific data are available.

Total organic carbon shows little variation through the water column. TOC concentrations reach a dynamic equilibrium between 5 and 6 mg/L a few years into the simulation. During drought conditions, the TOC approaches 8 mg/L. Several other parameters exhibit a similar pattern, where dynamic equilibrium is achieved a few years into the simulation and only upset by drought conditions where the inflow concentrations become significantly more influential because of the reduced lake volume.

Total nitrogen and total organic nitrogen exhibit similar patterns in both the surface and bottom waters. Dynamic equilibrium for total nitrogen is around 1.25 mg/L; for organic nitrogen it is slightly lower, at 1 mg/L. The total nitrogen in the system is influenced by the organic material inflows during storm events. Ammonium concentrations in the surface water are generally less than 0.05 mg/L. In the bottom water, release of ammonium from the sediments raises the concentration from the onset of anoxia in May until the lake turns over in October or early November. Peak near bottom concentrations of ammonia can reach 0.65 mg/L. These predicted concentrations are directly related to user-prescribed release rates of ammonia from the sediments. Model results are sensitive to these rates and the decay rate of ammonia to nitrate.

Total phosphorus concentrations were highly variable through a range of sensitivity simulations. In the final simulations, surface water TP concentrations reach a dynamic equilibrium below 0.1 mg/L, and bottom concentrations receive contributions from sediment releases during anoxic conditions that raise TP concentrations to above 0.2 mg/L in average years and up to 0.5 mg/L in drought years. Reductions in TP to less than 0.1 mg/L in the surface water were brought about by increasing the stoichiometric composition of algae from 0.5 percent phosphorus by weight to 1.5 percent by weight. Site-specific field data post construction will enable improved phosphorus predictions in the water quality model.

Alkalinity, which is treated as conservative by the model and thus expected to be lower than that predicted by the model, exhibits a similar pattern to other nutrients that reach a dynamic equilibrium related to the inflow concentration. Alkalinity is predicted to concentrate in the reservoir up to 250 mg/L during drought conditions. There is little vertical variation in predicted alkalinity.

Predicted pH levels show annual variations between 8 and 10, with occasional spikes in pH during high inflow periods when the alkalinity in the lake is diluted by stormwater runoff. pH levels in the bottom water show a slight increase in range and lower minimum pH levels than the surface water, as expected.

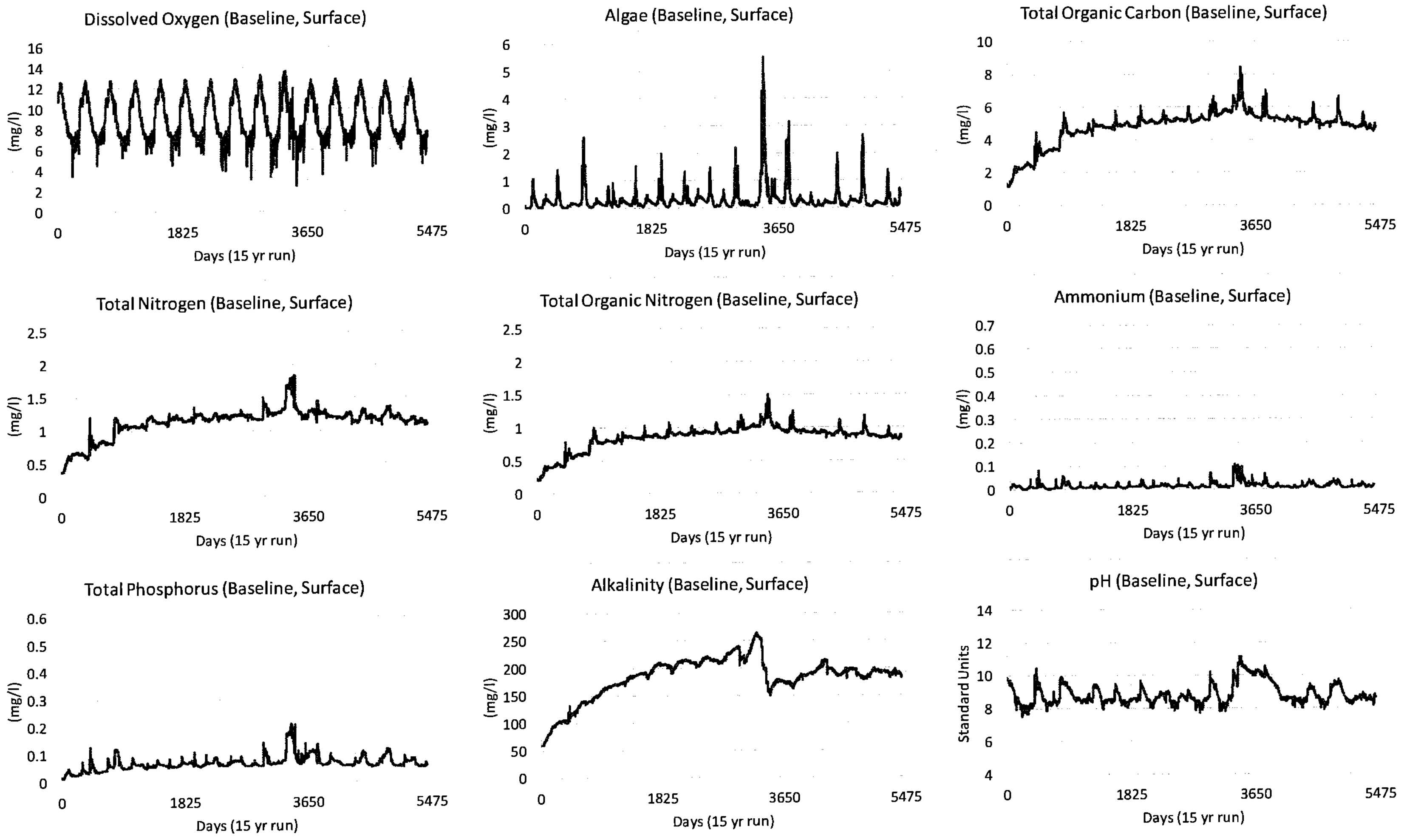


Figure 3-33. Baseline Simulation, Surface Water Quality near Dam

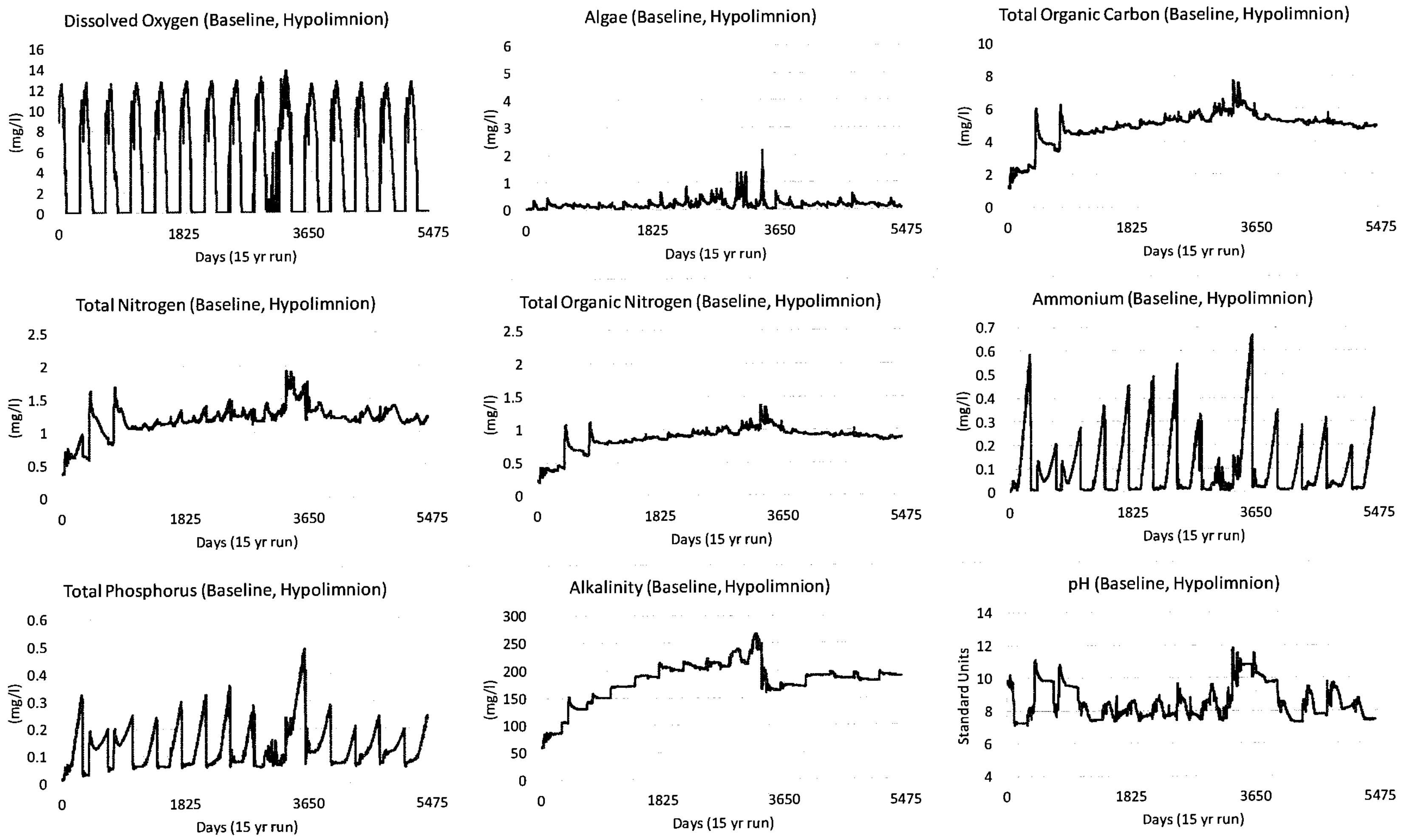


Figure 3-34. Baseline Simulation, Hypolimnion Water Quality near Dam

SECTION 4

Discussion

Model results outline in detail probable water quality in Bois d'Arc Reservoir. Results are as expected. Water quality results are similar to other reservoirs in the region of similar depth and size. The comparison procedure used instead of calibration did not demand significant adjustment of model parameters. CE-QUAL-W2 is notably strong with regard to temperature and DO profiles, which strongly influence other parameters.

Water quality of Bois d'Arc Reservoir is the raw water quality for Leonard Water Treatment Plant. Because water quality parameters also have implications for reservoir ecology that do not necessary impact LWTP, the two categories are discussed in separate sections below even through there is substantial bridging between the categories for many parameters.

As clearly shown in model results, water quality in Bois d'Arc Reservoir will be poor. An immediate question, therefore, is what can be done to improve reservoir water quality? As discussed in the following sections, the model investigated this question using proven technology that is widely used in drinking water reservoirs: hypolimnetic oxygenation. Model simulations also informed model results because responses of similar reservoirs to hypolimnetic oxygenation are well known. The choice of key parameters know ranges for algae growth, algae settling, and phosphorus solubilization were finalized by observing model responses to injections of oxygen into the hypolimnion.

4.1 Reservoir Water Quality

The two largest drivers of water quality in Bois d'Arc Reservoir are predicted to be the high phosphorus load and hypolimnetic anoxia. Confidence in this prediction is high.

Bois d'Arc Creek has a TP concentration of approximately 150 µg/L. Stormwater soluble phosphorus concentrations are typically within the same range (EPA, 1983). Reservoirs with this TP concentration in surface waters are considered hypereutrophic (Wetzel, 2001). As shown in the model results, surface TP concentrations are dynamic with seasonal fluctuations. It is likely that mean surface TP concentrations will equilibrate at concentrations less than 100 µg/L, indicating eutrophic conditions with occasional higher spikes into the hypereutrophic range.

Significant algae growth is predicted to be a feature of Bois d'Arc Reservoir. Settling of algae into the hypolimnion creates a high oxygen demand that rapidly creates anoxic conditions at the onset of thermal stratification in the spring. The mode does not predict a "grace period" at reservoir start up. Rather the model predicts that anoxia will begin within the first year of fill.

A common dynamic of algae growth in reservoir is to have diatoms in the winter, followed by green, algae, then followed by dominance of cyanobacteria (Wetzel, 2001). Although algae dynamics are complex, this pattern is largely driven by thermal stratification. Diatoms are silica-limited and tend to outcompete green algae and cyanobacteria growth. Diatoms settle out of the water column. When there is no thermal stratification reservoir turnover replenishes silica in surface waters. Thermal stratification traps silica in bottom waters, allowing green algae to dominate primary productivity. Green algae also settle out. Faster growing than cyanobacteria, green algae tend to strip bio-available phosphorus out of surface waters. Cyanobacteria do not necessarily thrive in nutrient poor water. Rather, most cyanobacteria regulate buoyancy. They obtain ample nutrients in the hypolimnion while burning carbohydrates accumulated during growth in the photic zone, and then float back to the surface. This cycle resets at reservoir turnover, often with large diatom blooms that dominate throughout the winter.

Harmful algae blooms are a likely consequence of the fertility of Bois d'Arc Reservoir and the successional dynamics of diatoms, green algae, and cyanobacteria. Appendix A details harmful algae bloom dynamics and known concerns in Texas reservoirs.

Bois d'Arc Reservoir low DO will limit fisheries habitat. Strong hypolimnetic anoxia from May through October preclude a cool water fishery. Only warm water fish tolerant of eutrophic conditions will thrive in Bois d'Arc Reservoir.

Algae growth will impair water clarity in Bois d'Arc Reservoir. Although not explicitly modeled, relationships between TP and Secchi disk depth are well known (Carlson, 1977). During summer, Secchi disk depths will be less than 0.5 meter. Maximum Secchi disk depths during the winter will be less than 2.0 meters.

A concern for all drinking water reservoirs is the potential for invasion by zebra and Quagga mussels. Model water quality results indicate an overall high water threat of invasion by both mussel types in Bois d'Arc Reservoir, as detailed in Appendix B. Strong anoxia in the hypolimnion limits deep water habitat, but relief from anoxia is a potential management goal. If a mussel invasion occurs, it may be necessary to temporarily suspend oxygenation of the reservoir, as discussed in Section 4.2.

4.2 Raw Water Quality

Algae directly and indirectly dominate raw water quality. Direct impacts are those imparted by algae biomass. Indirect impacts come from anoxic conditions induced by algae decay.

Excessive algae growth has a direct impact on raw water quality in several ways:

- **Taste and odor:** A wide variety of algae and cyanobacteria genera release compounds while living and when they die (mthylisoborneol [MIB] and geosmin) that strongly affect the taste and odor of the water, even at concentrations measured in nanogram(s) per liter (Paerl et al., 2001).
- **Cyanotoxins:** Many genera of cyanobacteria generate cyanotoxins (Appendix A)
- **TOC:** Increase in TOC is directly in proportion to algae biomass.
- **Biomass:** Some algae species create blooms of high concentrations of gelatinous biomass that clogs filters and affect plant operations.
- **High pH:** Surface waters peaking over a pH of 9 in summer and possibly over 10 during the most intense algae blooms.

Model results indicate algae biomass peaking yearly to over 10 mg/L and spiking over 50 mg/L. These algae bloom spikes, which include cyanobacteria blooms, are sufficient to drive all of these direct impacts, depending on the successional dynamics of algae growth.

The following are indirect impacts of algae blooms on other parameters:

- **Increased TOC:** This is also an indirect effect due to growth of bacteria on settle algae biomass.
- **Spikes in iron and manganese:** Prolonged hypolimnetic anoxia reduces insoluble iron and manganese oxides to soluble forms. Data are limited for iron and unavailable for manganese.
- **Increased ozone demand:** Caused by ammonium, sulfide, soluble iron, soluble manganese, and TOC (primary productivity and secondary productivity [bacteria growth] from decomposing algae).

The combined impact of algae on LWTP operations will likely include increased operating expense (labor and material) to meet treatment demands during periods of peak algae growth (April through October). Many drinking water reservoirs actively manage water quality through such methods as hypolimnetic oxygenation, hypolimnetic aeration, or destratification and phosphorus sequestration through injection of ferric chloride or alum to improve raw water quality (Cooke et al., 2005; Singleton and Little, 2006;

Gantzer et al., 2009). Therefore, the model investigated the potential for these methods to improve Bois d'Arc Reservoir water quality.

4.3 Water Quality Management

This section describes the mechanical hypolimnetic oxygenation system simulated in the Bois d'Arc Reservoir CE-QUAL-W2 model. In the model, pure oxygen was added to the reservoir to enhance the water quality below the thermocline, prior to the water treatment plant intake. Adding oxygen below the thermocline improves mineralization from the sediments, reduces dissolution of phosphate and nitrogen from the sediments, and improves habitat.

Hypolimnetic oxygenation was chosen because the scale of Bois d'Arc Reservoir is too large for hypolimnetic aeration and too deep for destratification. The only proven method of anoxic relief at the project scale is hypolimnetic oxygenation.

A long-term case study of hypolimnetic aeration, hypolimnetic oxygenation, and ferric injection is presented in Appendix C. The case study contains data from 1984 in two reservoirs near Saint Paul, Minnesota. Data were collected by Saint Paul Regional Water Services. The water source is the Mississippi River pumped to a chain of lakes that serve as off-line reservoirs that improve water quality prior to treatment. The case study is germane to Bois d'Arc Reservoir because of the high TP concentrations in the Mississippi River and strong thermal stratification in the reservoirs.

The CE-QUAL-W2 model does not model the physical dynamics of a bubble plume (pure oxygen in this case). It will only deliver additional oxygen to user-specified sections of the system (Table 4-1). A DO target of 4 to 6 mg/L (approximately half-saturation) was set for development of the oxygenation system to remove anoxic conditions and allow for viable habitat conditions. The probes allow real-time model control of the addition of oxygen based on local DO conditions in the reservoir. The user defines an upper and lower DO trigger at each probe location. To avoid anoxic conditions, the aerators turn on when the DO concentration is equal to or below 4 mg/L; to avoid over-saturation of DO and minimize the loading rate, the aerators shut off when the DO exceeds 6 mg/L.

Oxygenation does not physically operate as in the model. Physically, the oxygen flow rate of the bubble plume is turned up or down gradually to meet DO targets in the hypolimnion. Although oxygenation preserves thermal stratification, it does induce slow circulation of oxygenated water throughout the hypolimnion.

Oxygen was added to nine separate segments, every other segment starting at the dam (Segment 29) and extending upstream approximately 13 kilometers (8 miles). The systems were placed to cover the extent of the summer anoxic zone as shown on Figure 4-1. In each of nine model segments, two or three separate oxygenation systems were deployed in order to vary the oxygen loading rate in different levels of the water column. Separate injection points were necessary to avoid model-predicted hyper-saturation of oxygen in the near bottom waters which have less volume than the hypolimnetic waters closer to the thermocline. For most segments, two systems were deployed: the upper and lower systems. Each system added oxygen at a user-defined rate determined after multiple trial simulations. A middle layer was created for two segments to provide additional resolution necessary to reach the half-saturation DO target. Figure 4-1 summarizes the segment location, layer span, and mass loading rate for 19 individual systems. A schematic of the deployed systems is shown on Figure 4-2. Results of the oxygenation systems on mid-summer DO are shown on Figure 4-3, which can be contrasted with results on Figure 4-1 to see the improvement in anoxic conditions.

The placement of oxygenation infrastructure in the reservoir to reduce anoxic conditions would likely involve one or more parallel pipe systems oriented along the main axis of the reservoir. The CE-QUAl-W2 model, however, allows for oxygenation systems to be applied on a segment-by-segment basis and also for the user to define the number of vertical layers over which the oxygen is distributed. The oxygenation feature in the model is designed to allow the user to determine the amount of oxygen required to raise oxygen concentrations in the hypolimnion to acceptable levels. The model is limited in that it doesn't model the additional mixing dynamics associated with a bubble diffuser. It cannot model additional circulation patterns in the hypolimnion associated with rising currents imparted by the bubbles and any associated return currents.

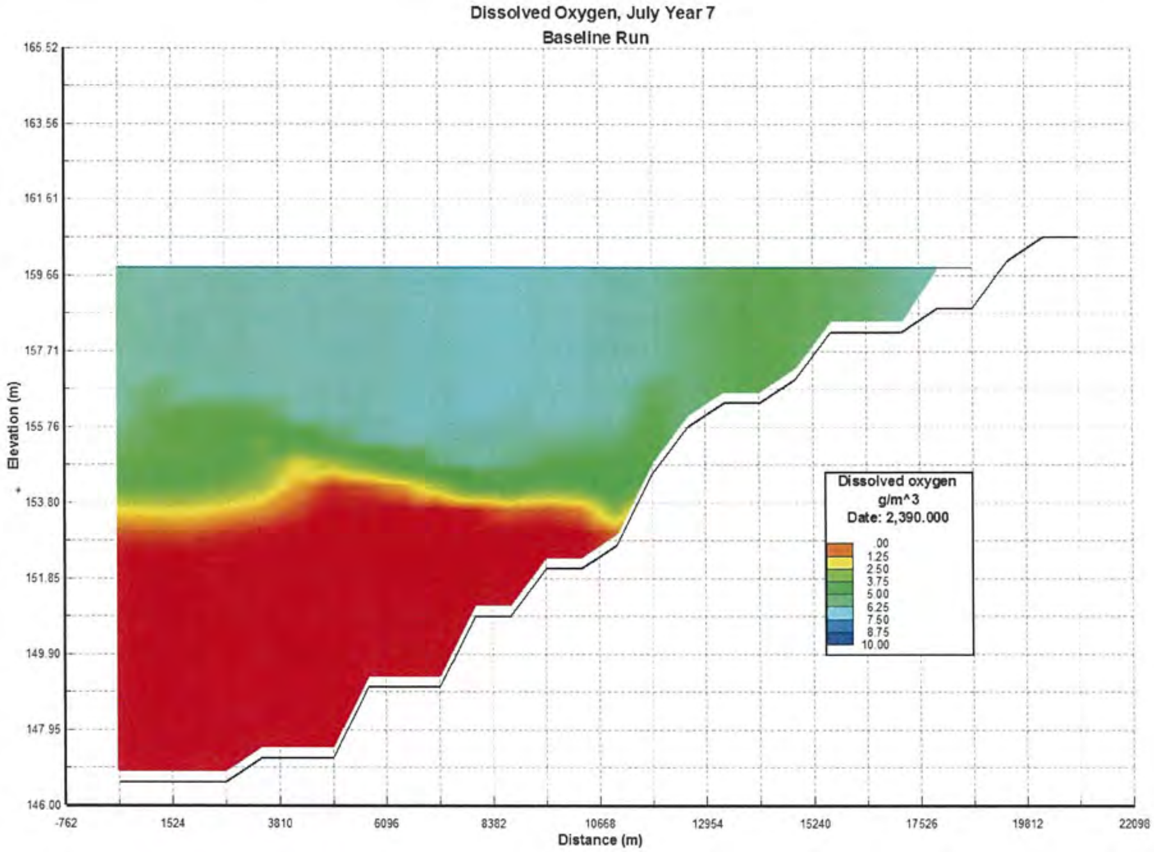


Figure 4-1. Contour Plot of Dissolved Oxygen Concentration in Bois d'Arc Baseline Model Simulation (Day 2,390; mid-July, Year 7).

Table 4-1. Simulated Aerator Descriptions

Number	Segment	Section	Top Layer	Bottom Layer	Mass Loading Rate (kg O_2/day)
1	29	Upper	26	30	4,000
2	29	Lower	15	25	3,000
3	27	Upper	26	30	4,000
4	27	Lower	15	25	3,000
5	25	Upper	27	29	3,600
6	25	Middle	25	26	2,400
7	25	Lower	15	24	10,000
8	23	Upper	27	29	3,600
9	23	Middle	25	26	2,400
10	23	Lower	15	24	6,000
11	21	Upper	22	26	3,000
12	21	Lower	15	21	6,000
13	19	Upper	19	23	10,000
14	19	Lower	14	18	3,000
15	17	Upper	17	21	5,000
16	17	Lower	12	16	3,000
17	15	Upper	16	20	3,000
18	15	Lower	11	15	10,000
19	13	—	11	15	6,000

Note:

kg O_2/day = kilograms of oxygen per day

— = Only one system in Segment 13

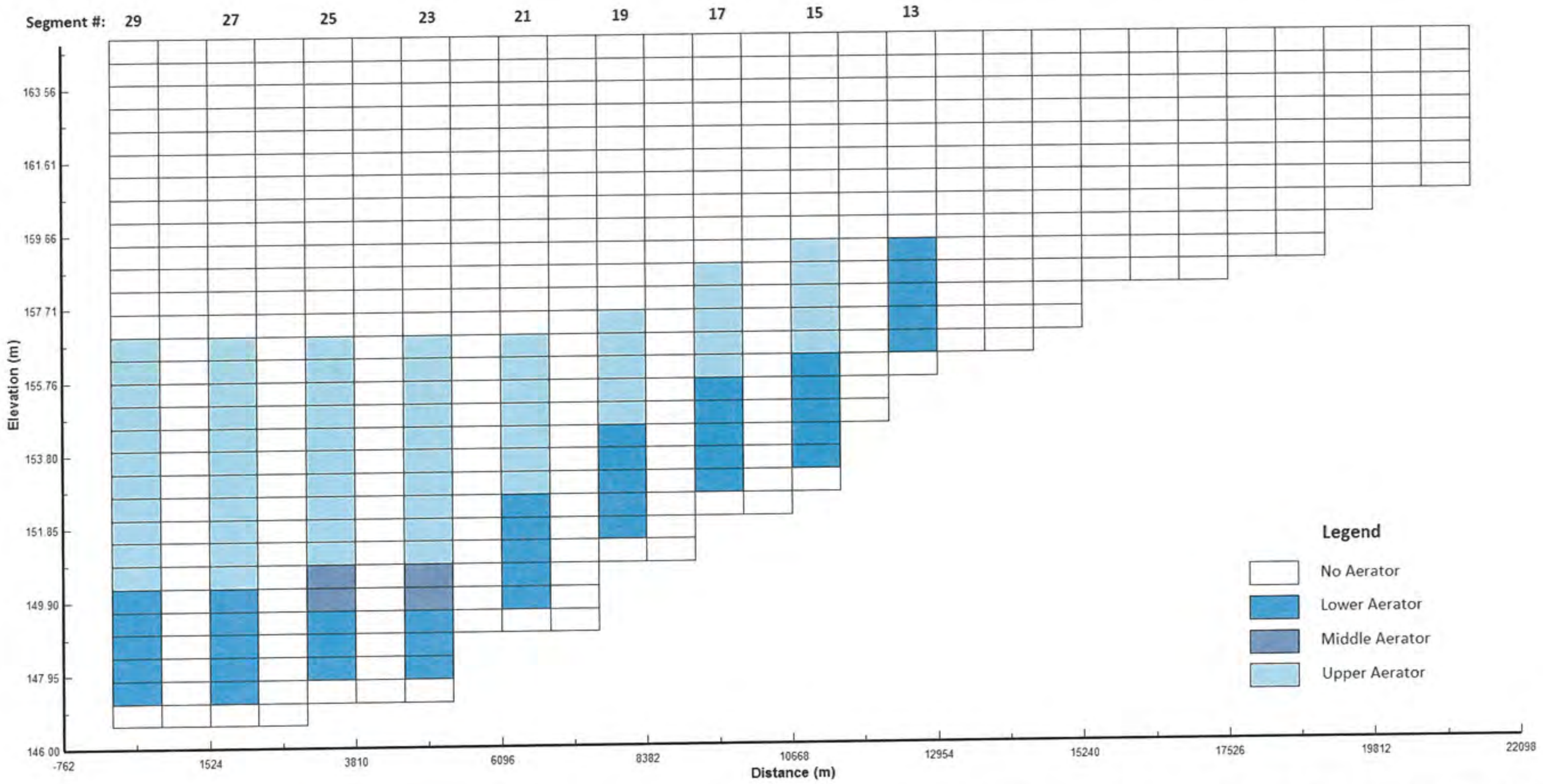


Figure 4-2. Locations of Simulated Aerators in Bois d'Arc Reservoir Model

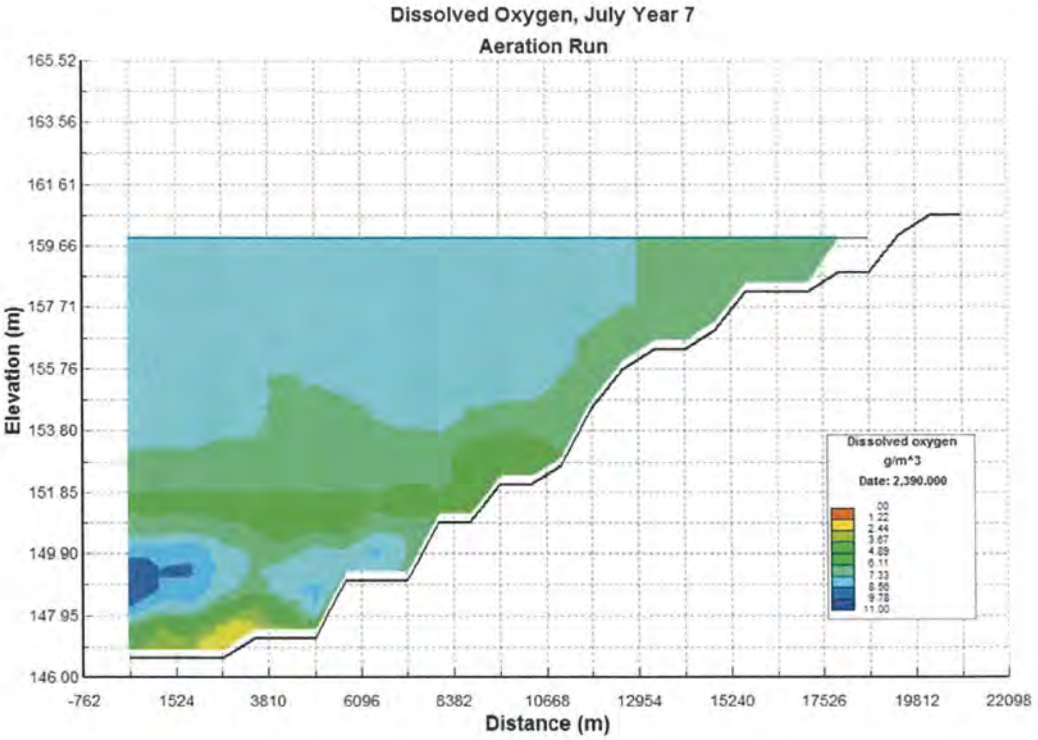


Figure 4-3. Contour Plot of Dissolved Oxygen Concentration in Bois d'Arc Model with Oxygenation (Day 2390; mid-July, Year 7).

The 19 oxygenation systems were individually modeled with a maximum combined loading rate of 91,000 kg O^2/day. The use of virtual DO probes in the CE-QUAL-W2 model to control the application of oxygen yields average application rates significantly less than the maximum rates specified in Table 4-1 for each of the individual systems. Model output provides a measure of the daily oxygen applied for each of the individual systems, as controlled by the virtual DO probes. Figure 4-4 provides a summary of the monthly average oxygen load. Although details are available for each individual system, the monthly use depicted on Figure 4-4 is the sum of all systems averaged over the month. During the months of June, July, and August the systems load an average of 16,000 kg O^2/day into the reservoir. The usage can vary considerably from year to year, as shown on Figure 4-5, with oxygen requirements considerably higher during low-storage years.

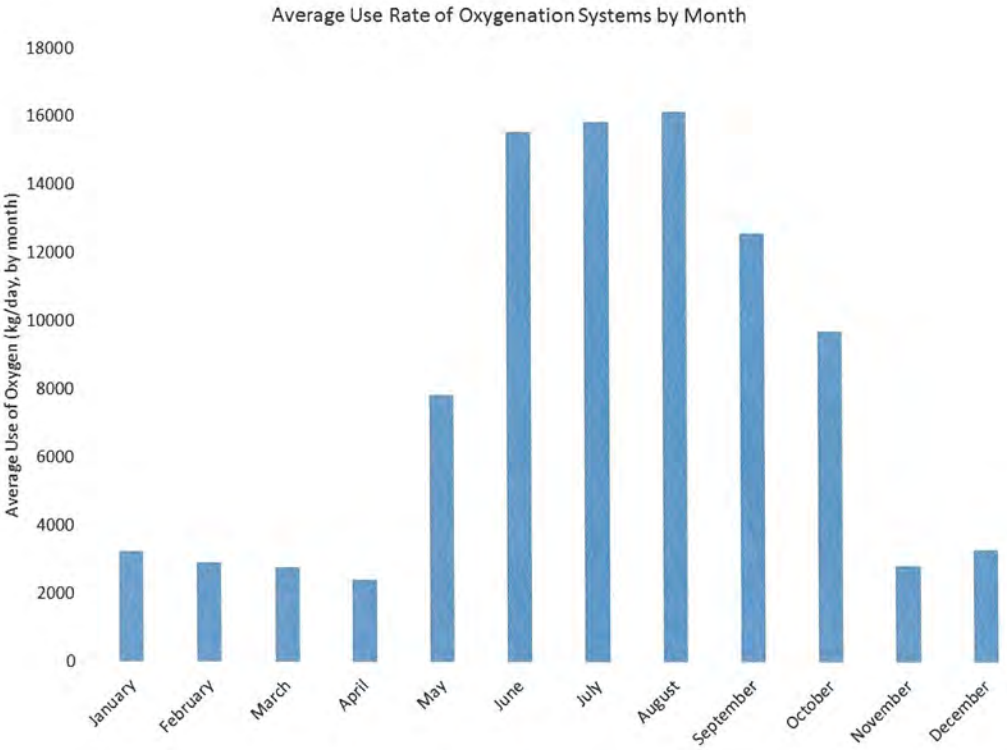


Figure 4-4. Average Monthly Use of Oxygenation Systems.

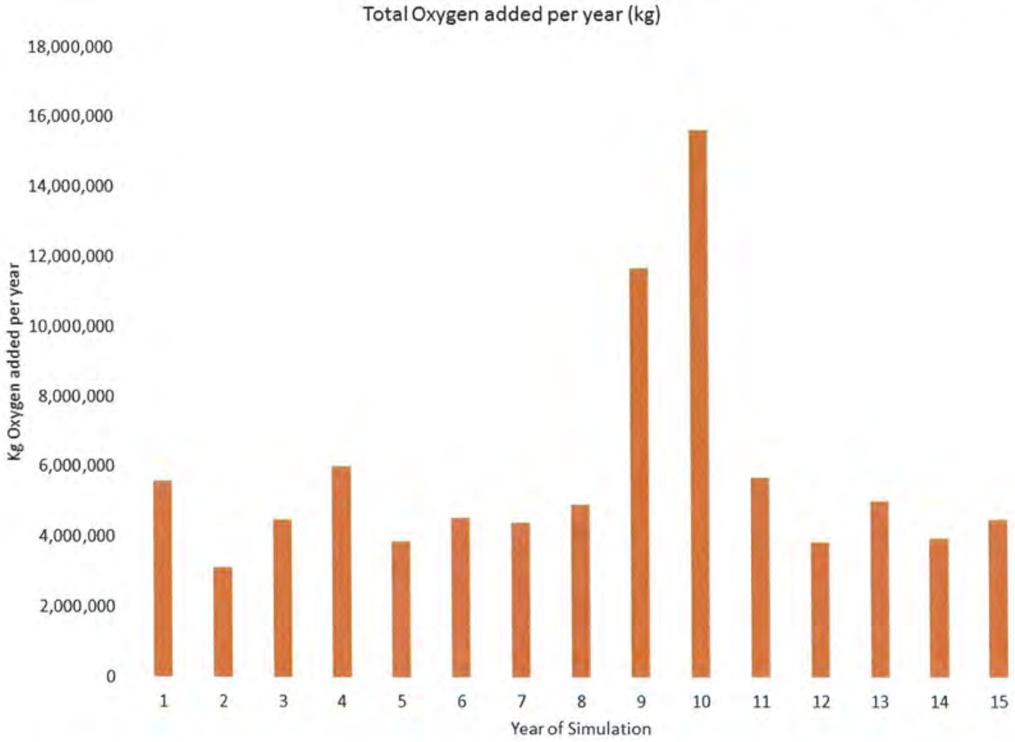


Figure 4-5 Annual Variation in Total Oxygen Required to Maintain Desirable Hypolimnetic Dissolved Oxygen Levels

4.3.1.1 Key Model Parameters with and Without Oxygenation

Figure 4-6 through Figure 4-13 present contour plots of average summertime conditions for several key parameters for both Baseline and With Oxygenation simulations. Contour plots are presented for mid-July conditions in Year 7 of the simulation, which is considered representative of average summertime conditions in the proposed reservoir. Results are presented for phosphate, ammonium, nitrate-nitrite, and algae. All units in the nutrient and algae plots are in mg/L. Plots showing the improvement in hypolimnetic oxygen concentrations were presented on Figures 4-1 and 4-3. Plots of DO demonstrate the largest change with the addition of the oxygenation systems, as expected. The oxygenation systems successfully remove anoxic conditions in the hypolimnion during the summer and fall.

There is a considerable reduction in hypolimnetic phosphate concertation with oxygenation (Figure 4-7) compared to the Baseline (Figure 4-6). The anoxic release of inorganic phosphorus in the Baseline simulation is reduced to near zero in the alternative simulation. These contours reflect conditions in July; therefore, the peak phosphate concentrations shown on Figure 4-6 will continue to build when anoxic conditions persist.

Predicted algal concentrations are presented on Figure 4-8 for baseline conditions and on Figure 4-9 for the oxygenation simulation. There is a reduction in algae concentration with oxygenation throughout the entire water column. This reduction is likely associated with reduced nutrient availability as the oxygenated hypolimnion prevents release of phosphorus and ammonia from the sediments.

As with the phosphorus, the prevention of anoxic conditions in the hypolimnion with targeted oxygenation reduced the hypolimnetic ammonia concentrations considerably from baseline values. On Figure 4-10, near bottom ammonia concentrations exceed 0.30 mg/L in July, but the aeration simulation (Figure 4-11) does not show concentrations higher than 0.05 mg/L.

The significant change in ammonia concentration in the hypolimnion also affects nitrate/nitrite concentrations. On Figure 4-12, baseline results indicate nitrate/nitrite concentrations generally below 0.2 mg/L. In the oxygenation simulation (Figure 4-13), the presence of oxygen in the hypolimnion allows for the formation of nitrate/nitrite from the available ammonia.

Time series plots of water quality conditions with oxygenation are presented on Figure 4-14 for surface water conditions near the dam (Segment 29) and on Figure 4-15 for bottom conditions (Segment 23). The most noticeable changes to the time series plots presented in Section 3 are the reduction of anoxic conditions in the sediment and the reduction of phosphorus and ammonia released during anoxic events into the hypolimnetic waters. With the oxygenation system, near bottom DO concentrations are generally above 6 mg/L, as prescribed by the operation rules for the oxygenation systems.

Total nitrogen is slightly higher with the oxygenation system; near bottom ammonia concentration is significantly lower and shows little variation from surface values.

Surface water TP concentrations are similar between the Baseline and With Oxygenation simulations; near bottom TP is considerably lower in the oxygenation system because there is no sediment release when hypolimnetic waters contain oxygen.

Data from the Saint Paul Regional Water Services show strong differences in surface TP concentration as a consequence of hypolimnetic aeration or oxygenation and ferric chloride injection (Appendix C). The critical difference with the model is that experience with reservoir operations determined final ferric dosing criteria and design rationale for upgrade from hypolimnetic aeration to oxygenation. Fine tuning of the model to simulate these operationally determined management actions (ferric dosing and oxygen mass flux rates) is certainly possible, but is not good practice. The benefits of oxygenation should be revisited after the reservoir has been construction and can provide actual data.

There is very little difference between the baseline and the oxygenation simulations TOC, and alkalinity.

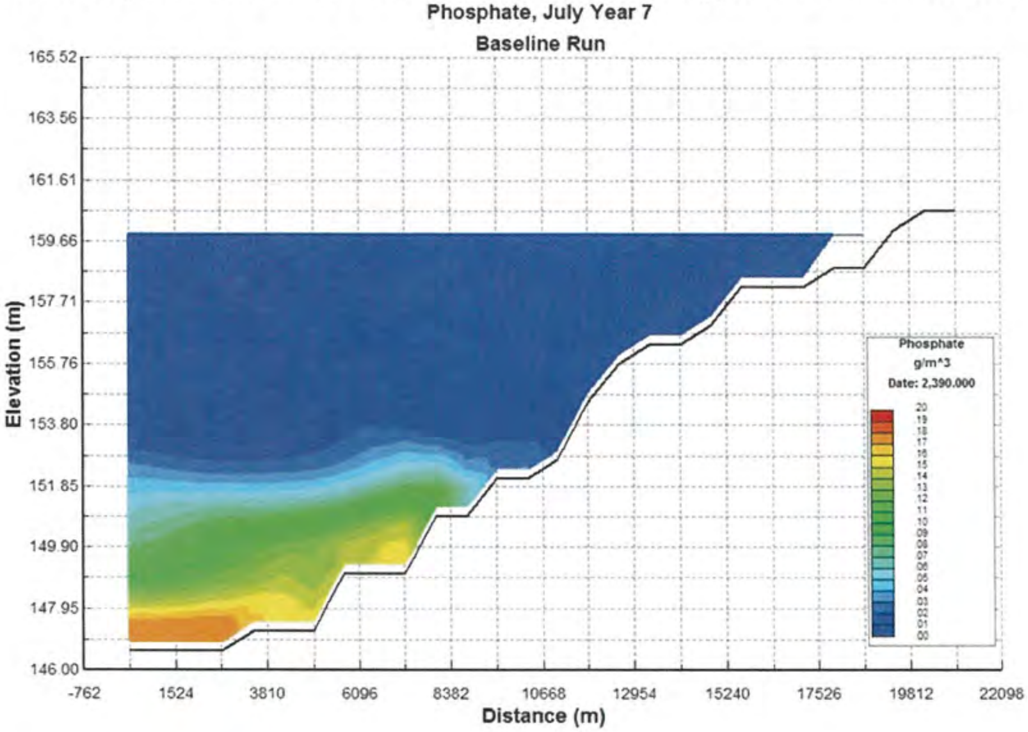


Figure 4-6 Contour Plot of Phosphate Concentration in Bois d'Arc Baseline Model Simulation (mid-July, Year 7).

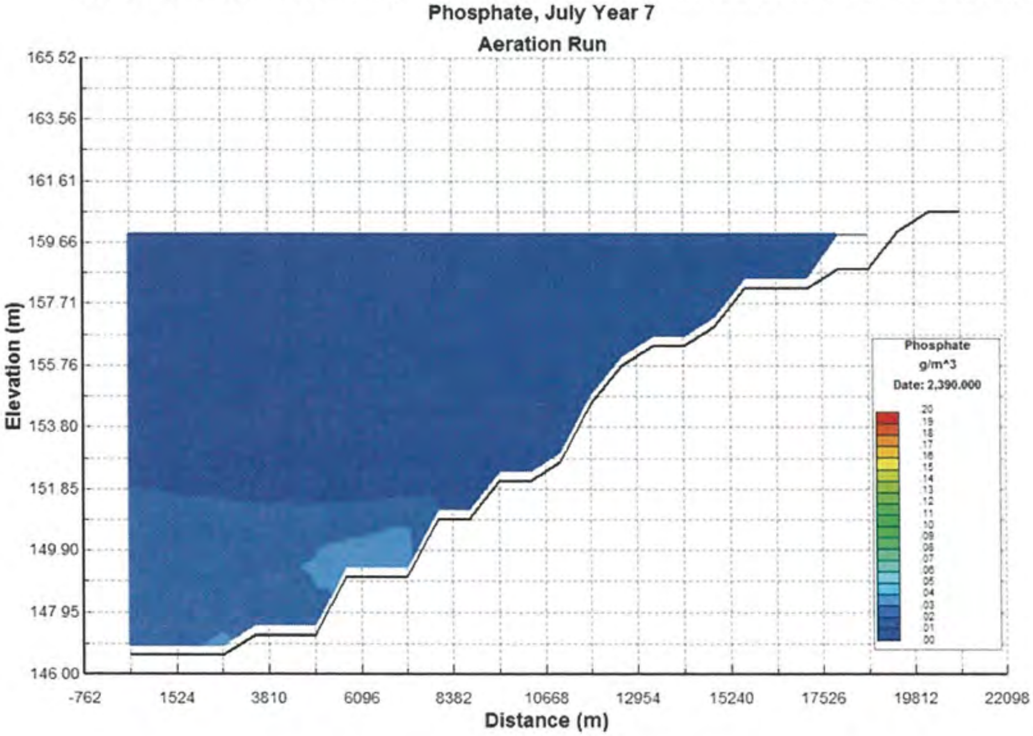


Figure 4-7 Contour Plot of Phosphate Concentration in Bois d'Arc Model with Oxygenation (mid-July, Year 7)

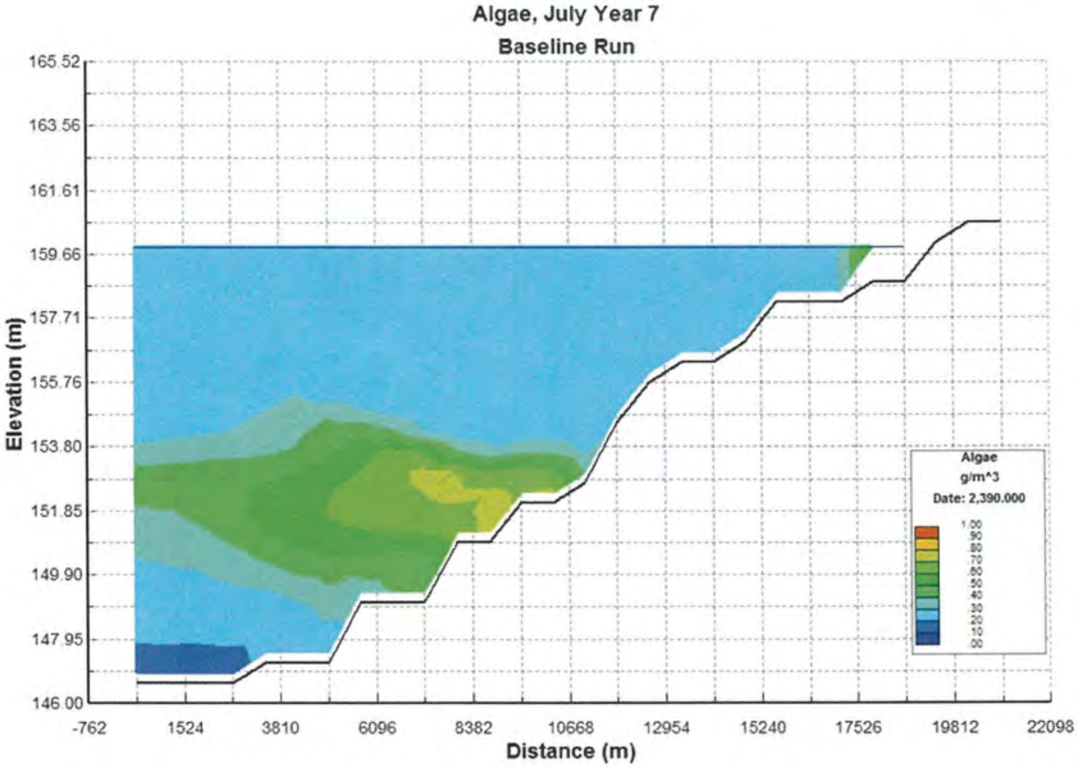


Figure 4-8 Contour Plot of Algae Concentration in Bois d'Arc Baseline Model Simulation (mid-July, Year 7).

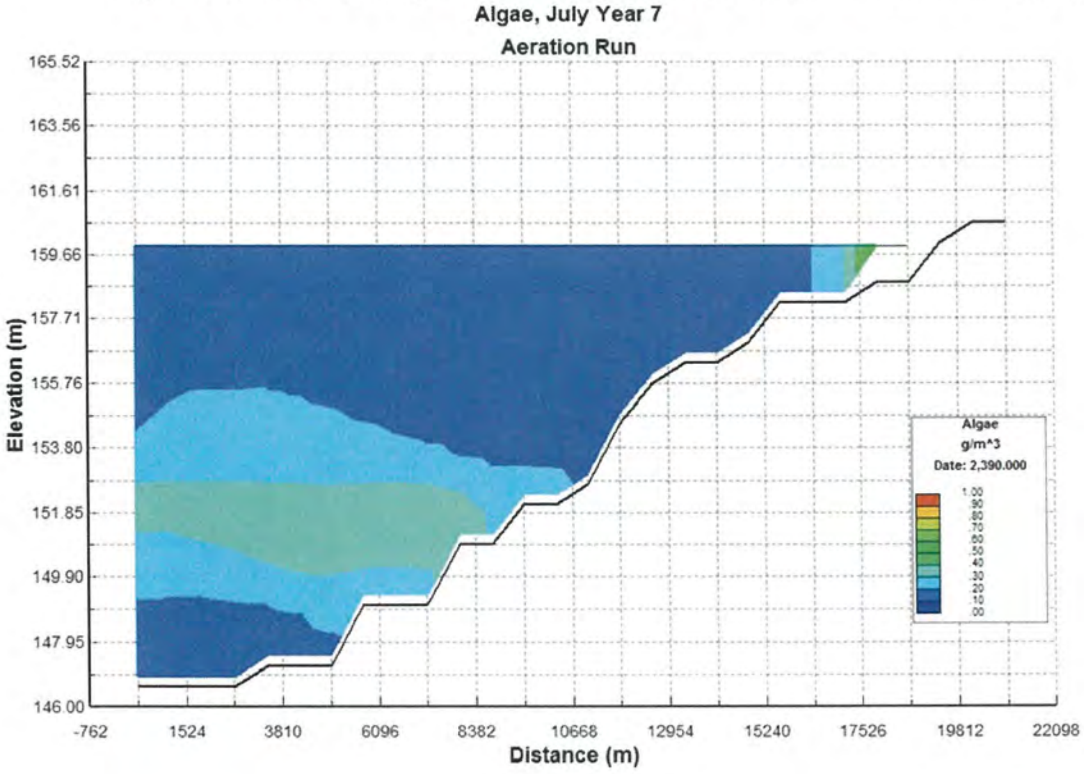


Figure 4-9 Contour Plot of Algae Concentration in Bois d'Arc Model with Oxygenation (mid-July, Year 7)

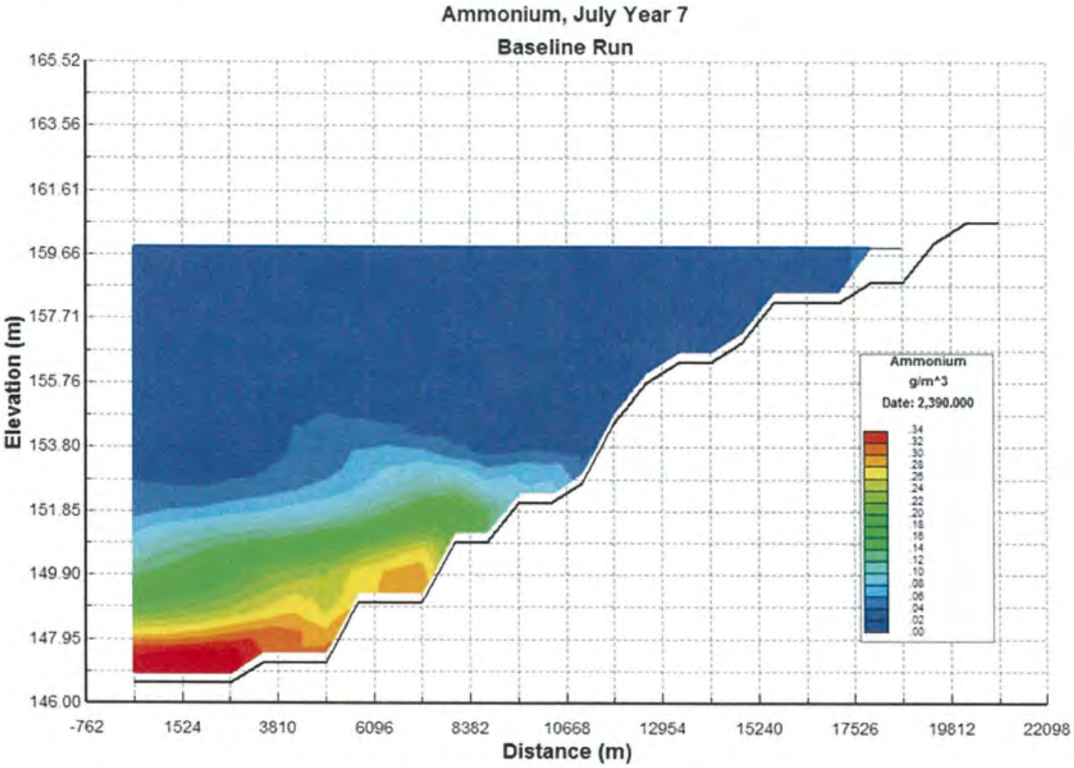


Figure 4-10 Contour plot of Ammonium Concentration in Bois d'Arc Baseline Model Simulation (mid-July, year 7).

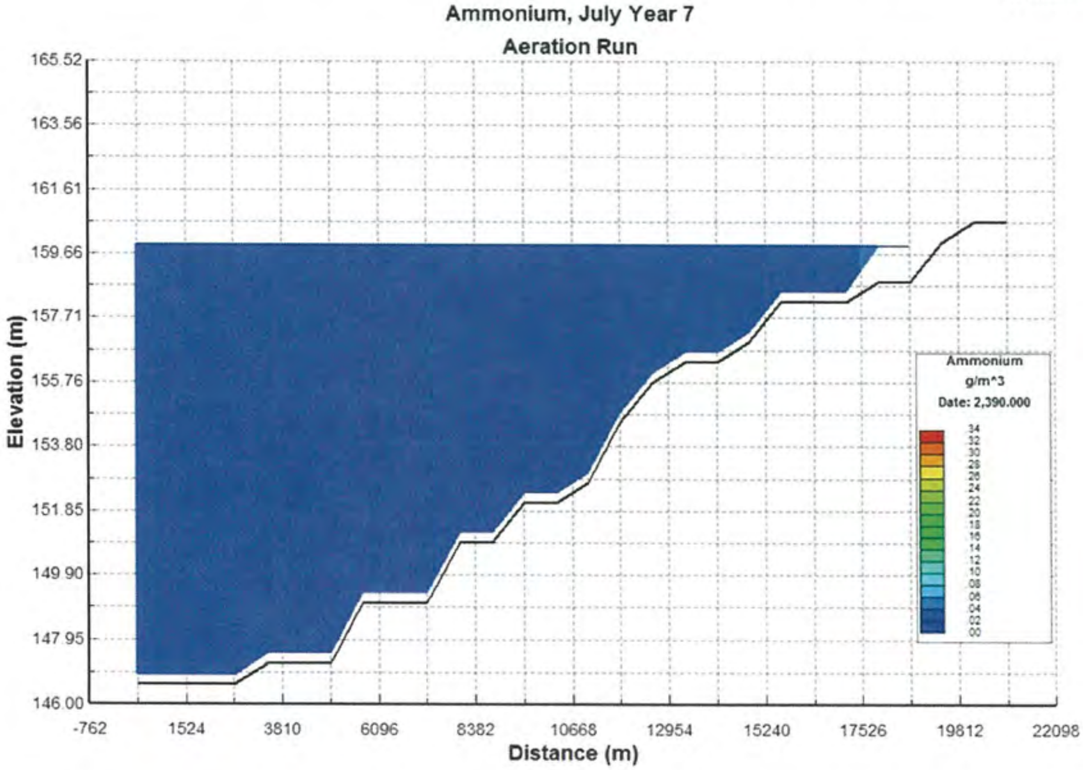


Figure 4-11 Contour Plot of Ammonium Concentration in Bois d'Arc Model with Oxygenation (mid-July, Year 7)

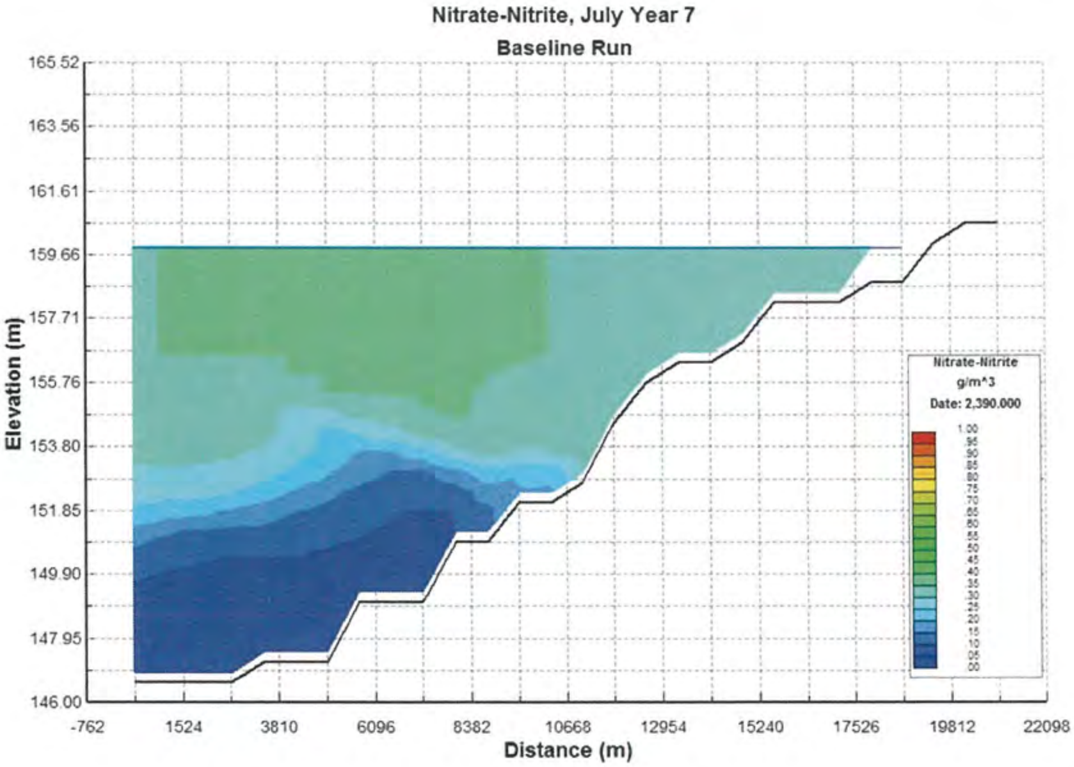


Figure 4-12 Contour Plot of Nitrate/Nitrite Concentration in Bois d'Arc Baseline Model Simulation (mid-July, Year 7).

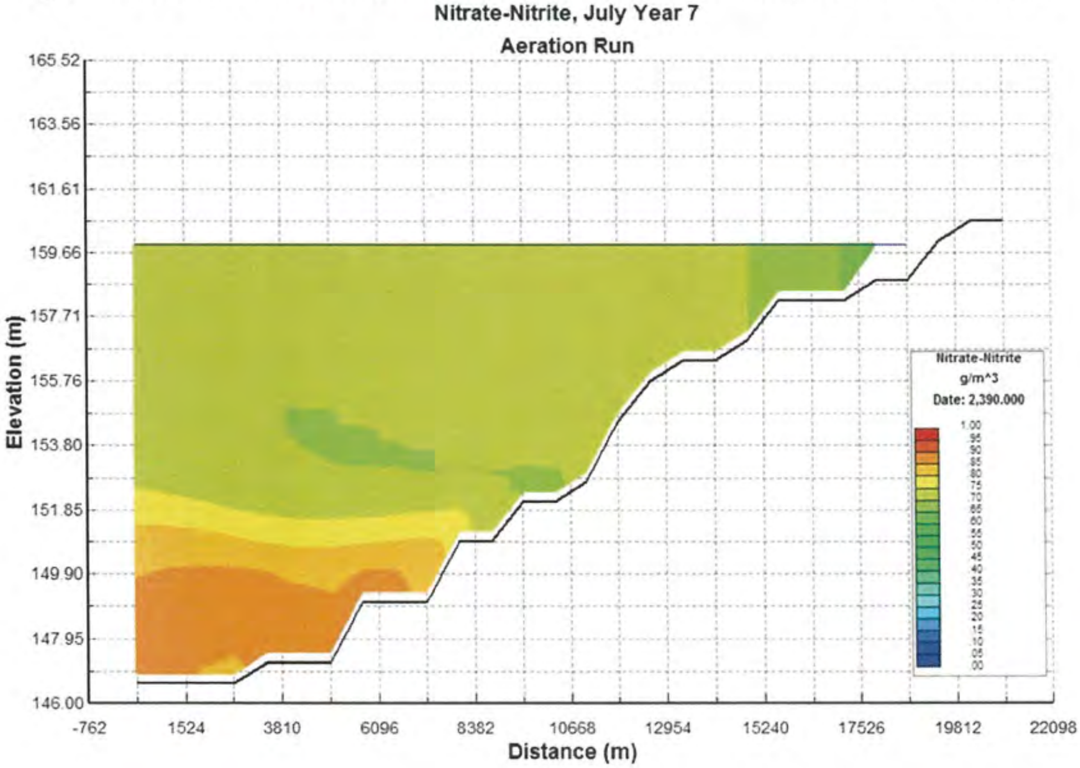


Figure 4-13 Contour Plot of Nitrate/Nitrite Concentration in Bois d'Arc Model with Oxygenation (mid-July, Year 7)

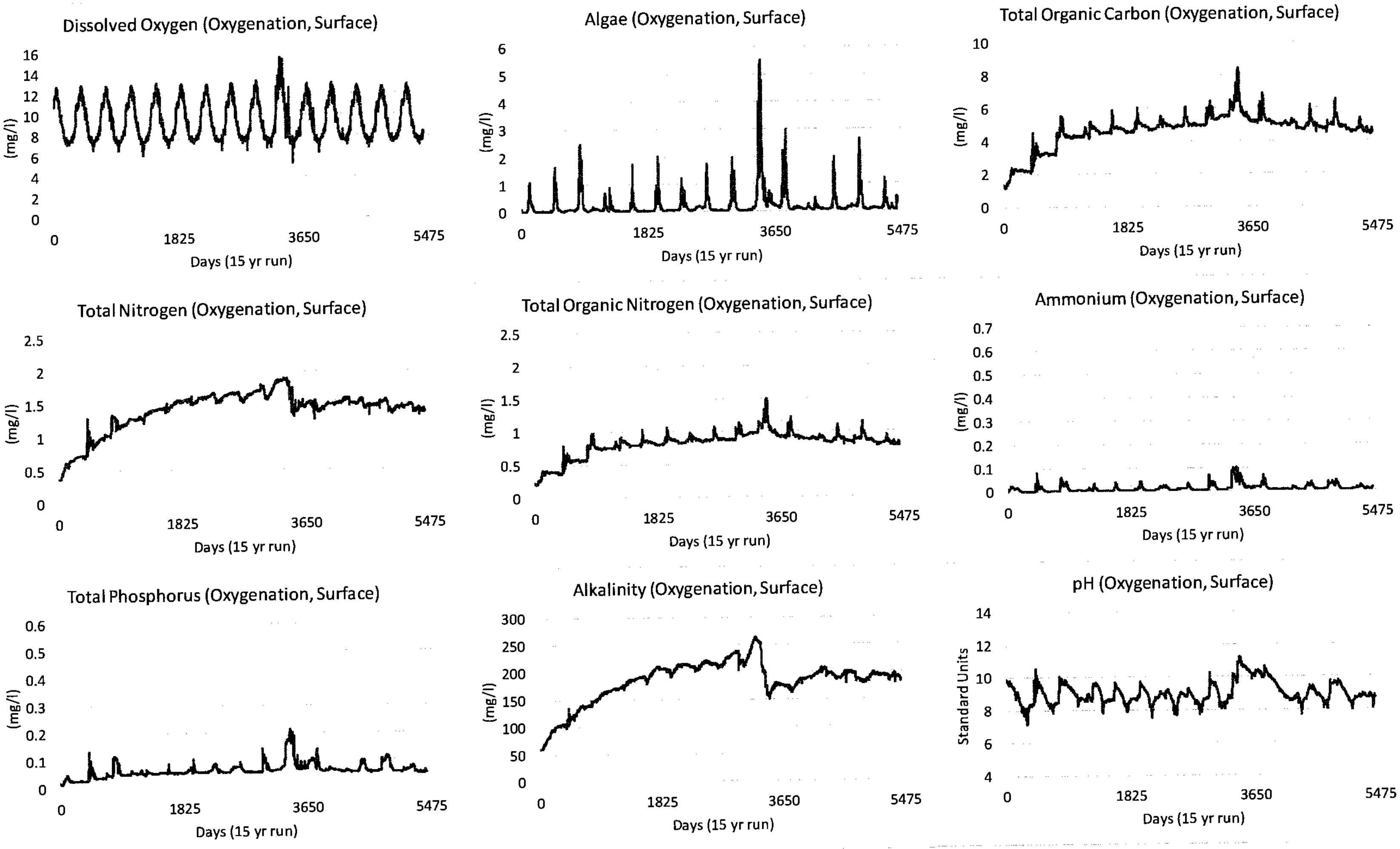
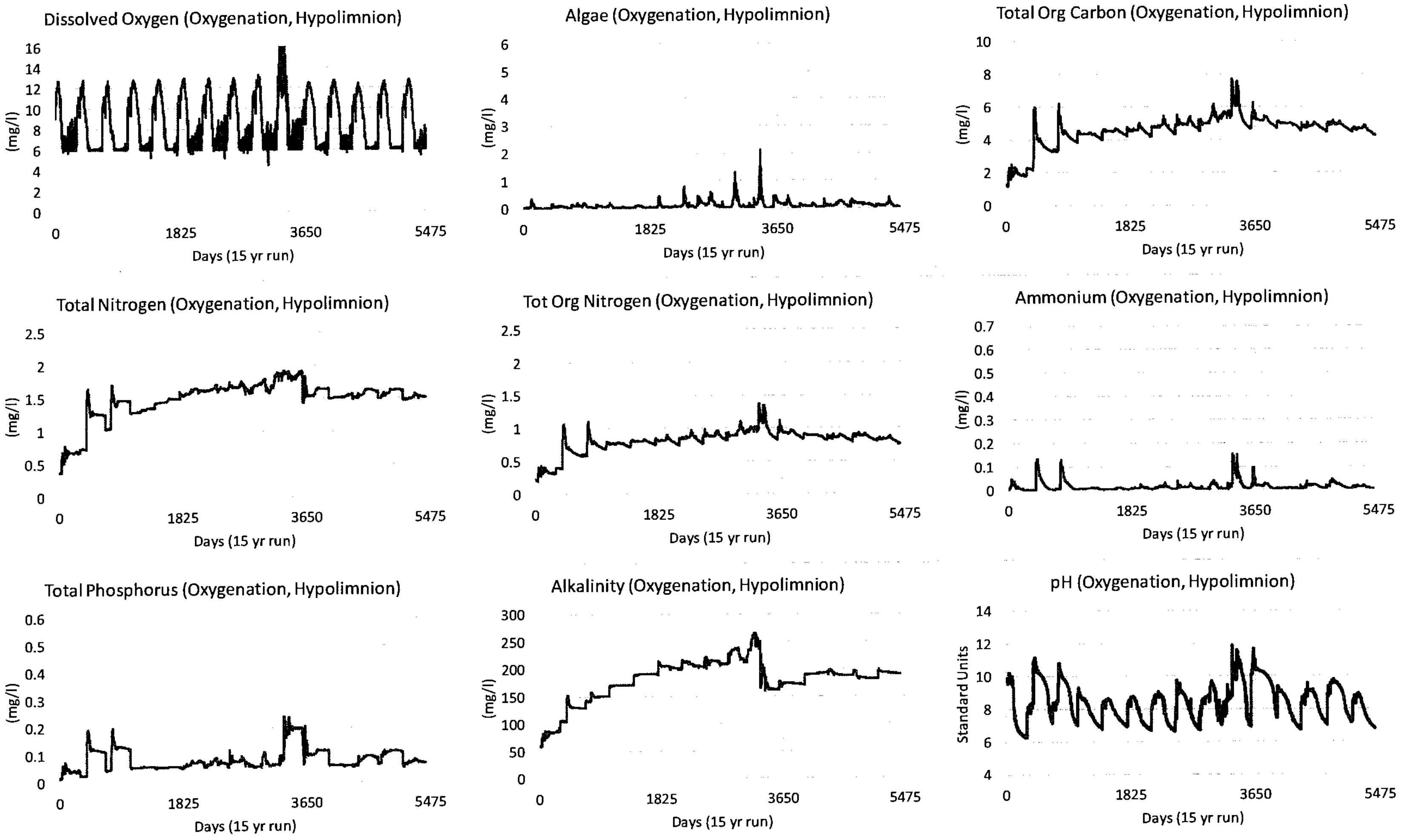


Figure 4-14. Oxygenation Simulation, Surface Water Quality near Dam


Dissolved Oxygen (Oxygenation, Hypolimnion)

Algae (Oxygenation, Hypolimnion)

Total Org Carbon (Oxygenation, Hypolimnion)

Total Nitrogen (Oxygenation, Hypolimnion)

Tot Org Nitrogen (Oxygenation, Hypolimnion)

Ammonium (Oxygenation, Hypolimnion)

Total Phosphorus (Oxygenation, Hypolimnion)

Alkalinity (Oxygenation, Hypolimnion)

pH (Oxygenation, Hypolimnion)

Figure 4-15. Oxygenation Simulation, Bottom Water Quality near Dam (Segment 23)

4.4 Model Limitations and Known Issues

Alkalinity is treated as conservative in the model. During prolonged drought events, alkalinity increases and then when the reservoir quickly refills, alkalinity drops significantly (inflow is set at 165), yielding a rise in pH to unrealistic levels above 10. The model does not simulate the interaction between calcium and alkalinity, because calcium is also treated as a conservative substance.

Constituent inflow concentrations were developed based on a review of available data obtained from the TCEQ online database at various stations along Bois d'Arc Creek, as discussed in Section 2.2. The nature of streamflow in Bois d'Arc Creek coupled with the scarcity of sampling data, which appears to be at a monthly resolution at best, yields a dataset in which the majority of the samples were taken during periods of negligible or even zero flow in the creek. Available data do not indicate much seasonal variation in many parameters. Including phosphorus, ammonia, nitrate, nitrite, total organic matter, alkalinity, and calcium. Furthermore, the low-flow data did not allow for development of any flow variable loadings. Thus, the model is severely limited by the inflow dataset with basically no knowledge of how key parameters might increase or decrease in concentration during high-flow events. This could lead to a significant overloading of nutrients in the model.

Water quality kinetics can be highly sensitive to minor changes in coefficients, kinetic rates, and constants. For example, TP was reduced by 80 percent by simply changing the assumed algal composition from 0.5 to 1.5 percent phosphorus, although literature values support a range twice as large as this increase. Thus, the calibration is limited to a rough comparison with local surrogate reservoirs until there is a sufficient water quality database for the Lower Bois d'Arc Reservoir against which to calibrate the water quality model.

SECTION 5

Conclusions

Bois d'Arc Reservoir will be a eutrophic to hypereutrophic basin. This result is expected because of the high nutrient content of sources waters. Nevertheless, reservoir water quality will impose an operational burden on the Leonard Water Treatment Plant.

The CE-QUAL-W2 model approximates water quality in Bois d'Arc, but is likely to have overshot or undershot future water quality parameter values. Without calibration to the reservoir, this caveat is essential, but water quality will be dominated by high growth rates for algae and hypolimnetic anoxia. Harmful algae blooms of some type are inevitable as the reservoir matures. There is a moderate to high probability that zebra or quagga mussel invasion will occur. The model, therefore, provides useful insights into trends and patterns of water quality dynamics in the actual reservoir.

Impacts of water quality in Bois d'Arc Reservoir to will be sufficiently adverse on LWTR raw water quality to motivate calibration of the model as soon as the reservoir begins to fill. Calibration of the model to the first 1 to 3 years of operation will anchor subsequent trends and patterns. Thus, a monitoring program for the reservoir should include model parameters and the additional parameters of interest not modeled: bromide and manganese. Vertical profile data (temperature, conductivity, DO, and pH) near the dam will be especially important.

Model results indicate that water quality will be substantially better in the first 3 years of fill than in the following years. This latent period is in reality difficult to predict because it depends to a large extent on future weather patterns that may be different than past weather patterns used to predict reservoir hydrology and dynamics.

Active management of water quality in Bois d'Arc Reservoir is needed. Model results of oxygenation demonstrate improved raw water quality and overall reservoir water quality. Project experience with reservoir management fully supports these results and suggest that water quality benefits of hypolimnetic oxygenation may be underestimated. A model calibrated to actual reservoir conditions can better estimate these benefits.

Form a practical perspective, it is highly likely that effective management of reservoir water quality will entail hypolimnetic oxygenation combined with low-concentration ferric chloride injection into the hypolimnion and at the reservoir inlet. Construction of such a system occurs after or during reservoir fill. Thus, a final decision can wait for reservoir data to inform conceptual design criteria, including estimates for capital and operating expenses. A 16-metric-ton-per-day hypolimnetic oxygenation system is well within the range of currently operating hypolimnetic oxygenation systems. However, reservoir data may indicate that the real design oxygen demand is 10 or 20 tons per day. It is important to match design to known demands, using the model to predict future variability based on known initial conditions.

SECTION 6

References

Carlson, R. 1977. "A trophic index for lakes." *Limnology and Oceanography*. 22(2): 361–369.

Cole, Thomas M. and Scott A. Wells, 2015. *CD-QUAL-W2: A Two-Dimensional, Laterally Average, Hydrodynamic and Water Quality Model, Version 3.72*. Portland State University, Department of Civil and Environmental Engineering. March.

Cooke, G.D., E.B. Welch, S.A. Peterson, and S.A. Nichols. 2005. *Restoration and Management of Lake and Reservoirs, 3rd Edition*. New York, New York. Taylor & Francis.

Freese and Nichols. 2015. Firm Yield Study calculations in Excel file delivered via email.

Gantzer, P.A., L.D. Bryant, and J.C. Little. 2009. "Controlling soluble iron and manganese in a water-supply reservoir using hypolimnetic oxygenation." Water Research. 43:1285–1294.

HDR Engineering, Inc., Freese and Nichols, Inc., and R.J. Brandes Company. 2006. *Reservoir Site Protection Study*. Draft. Prepared for Texas Water Development Board. December.

National Climatic Data Center. 2015. Web site information.

Paerl, H.W., R.S. Fulton, P.H. Moisander, and J. Dyble. 2001. "Harmful freshwater algal blooms, with an emphasis on cyanobacteria." *The Scientific World Journal*. 1:76–113.

Portland State University. 2015. *CE-QUAL-W2 Hydrodynamic and Water Quality Model*. Version 4.0. Water Quality Research Group. http://www.ce.pdx.edu/w2/. September 15.

Singleton, V.L. and J.C. Little (2006). "Designing Hypolimnetic Aeration and Oxygenation Systems – A Review." *Environmental Science & Technology*. 40(24):7512–7520.

Texas Commission on Environmental Quality. 2015. Online database. http://www80.tceq.texas.gov/SwqmisWeb/public/crpmap.html.

U.S. Environmental Protection Agency (EPA). 1985. *Rates, Constants, and Kinetics Formulations in Surface Water quality Modeling*. Second edition. EPA/600/3-85/040. June.

U.S. Environmental Protection Agency (EPA0. 1983. *Results of the Nationwide Urban Runoff Program: Volume I – Final Report*. Water Planning Division. Washington, DC.

U.S. Geological Survey (USGS). 2013. http://pubs.usgs.gov/sir/2013/5016/section5.html

Wetzel, R.G. 2001. *Limnology: Lake and River Ecosystems*. Amsterdam, The Netherlands. Elsevier Science.

Appendix A
Harmful Algae Blooms: Potential Threats to Bois d'Arc Reservoir

Appendix A

Harmful Algae Blooms: Potential Threats to Bois d'Arc Reservoir

Harmful algal blooms (HAB) are becoming an increasingly common phenomenon in freshwater systems, including reservoirs that store raw water for drinking water supply (Leigh, et al. 2010). The issue of freshwater HABs has received more attention outside the United States in the past, but is of growing national concern as most U.S. states now experience freshwater HABs. Some of the key drivers behind the global expansion of HABs are believed to be anthropogenic modifications to the environment including nutrient enrichment, hydrologic alterations, introduced algal species, and altered weather and precipitation patterns induced by climate change (Paerl and Otten 2013). HABs are typically comprised of algal species that either produce toxins and/or cause the deterioration of water quality through the build-up of high biomass, which degrades aesthetic, ecological, and recreational values (Lopez et al. 2008). Freshwater HAB toxins can have significant negative impacts on humans, animals and aquatic ecosystems, and pose a particular threat if they occur in drinking water sources. In drinking water supply reservoirs, HABs can be prime agents of water quality deterioration, causing taste and odor problems, hypoxia or anoxia induced by algal biomass decomposition, toxicity, food web alterations and fish kills (Paerl et al. 2001).

This technical memorandum reviews some of the common HAB threats, with an emphasis on some established and emerging HAB threats in lakes and reservoirs within Texas.

Common Freshwater Harmful Algal Bloom (HAB) Types

Various genera of freshwater algae are capable of forming HABs. Some examples include eukaryotic algae such as chlorophytes, dinoflagellates, cryptophytes, and chrysophytes; however, the prokaryotic blue-green algae (cyanobacteria) are by far the most notorious bloom formers, and cause the majority of the freshwater HAB problems reported in the United States and worldwide (Paerl, et al. 2001).

Cyanobacterial blooms are of particular concern in reservoirs in Texas and the factors driving cyanobacterial bloom dynamics are discussed in the following sections in this TM. Another section of this TM focuses on the cyanobacterium, *Cylindrospermopsis raciborskii*, that has spread aggressively throughout many regions of the world, including the United States, and has the potential to colonize Texas reservoirs. The golden alga, *Prymnesium parvum*, is found in reservoirs of several river basins in Texas and could pose a potential threat to the Bois d'Arc reservoir. Due to its potential toxicity to gilled aquatic animals and presence in several Texas reservoirs, the environmental factors driving the dynamics of the golden alga are discussed in this TM.

Table 1. Harmful Algal Blooms and Impacts

HAB Phylum	Representative Genera	Adverse Impacts
Prokaryotes		
Cyanobacteria (Blue-Green Algae)	*Anabaena, Aphanizomenon, Cylindrospermopsis, Gleotrichia, Nodularia, Microcystis, Oscillatoria, Gomphosphaeria, Aphanocapsa, Lyngbya, Synechococcus, Nostoc, Planktothrix, Phormidium*	Produce a variety of toxins that adverse human and animal health impacts. Cause taste and odor problems in drinking water and in aquaculture operations, discoloration of water, unsightly and foul-smelling blooms, hypoxia from high biomass build-up.
Eukaryotes		
Chlorophyta (Green Algae)	*Botryococcus, Chlorococcus, Sphaerocystis, Volvox, Pandorina, Cladophora*	Some species can produce toxins that affect aquatic animals (e.g., *Botryococcus*). Cause discoloration of water and localized hypoxia. Some blooms cause unsightly and foul smelling mats that can harbor human pathogens (e.g., *Cladophora*).
Pyrrhophyta (Dinoflagellates and Cryptomonads)	Class Dinophyceae (dinoflagellates): *Peridinium, Ceratium, Heterocapsa, Prorocentrum.* Class Cryptophyceae (Cryptomonads): *Cryptomonas, Rhodomonas*	Some species like *Peridinium polonicum* are known to produce toxins that cause fish kills. Although most species are not normally thought to be nuisance causing, bloom conditions can occasionally cause discoloration of water, local hypoxia, foul taste and odors and loss of aesthetic and recreational value of affected waters.
Chrysophyta (Golden Algae)	*Prymnesium, Chrysochromulina, Chromulina Dinobryon, Mallomonas,*	Some species, including *Prymnesium* are known to produce toxins that can affect gill-bearing organisms (fish and molluscs). Dense blooms can foul shorelines and cause local hypoxia.
Euglenophyta	*Euglena sanguinea*	Under certain conditions can produce fish toxins that cause fish kills. Discoloration of water under bloom conditions.

Source: Paerl et al. (2001); Lopez et al. (2008)

Cyanobacterial Harmful Algal Blooms (C-HABs)

The frequency and geographic distribution of documented C-HABs has increased dramatically in recent decades in the United States and globally due to anthropogenic activities such as eutrophication and climate-induced environmental change. C-HABs have also been identified as a significant issue in Texas freshwater systems (Texas Parks and Wildlife (TPWD) website), and could be a potential threat to the

Bois d'Arc Reservoir once it is constructed and functional. In particular, two genera of cyanobacteria commonly found under bloom conditions in Texas, *Anabaena* and *Microcystis*, are known to produce substances that cause taste and odor problems in water supplies, and a suite of toxins that are harmful to human health, fish and wildlife. Fish kills have occurred in private stock ponds in Texas as a result of C-HABs and there have been a few reports of livestock dying from drinking water contaminated with cyanobacterial toxins (Texas Parks and Wildlife (TPWD) website).

A cyanobacterial species, *Cylindrospermopsis raciborskii*, has also been the focus of recent concern due to its presence in Lake Texoma (Teel et al., 2013). Over the past few decades, this filamentous and potentially toxigenic diazotroph (nitrogen-fixer) has greatly expanded its global geographical range (Sinha et al. 2012). It is now found in reservoirs, lakes and rivers in the United States (Paerl and Otten 2013). *C. raciborskii* has notably spread aggressively in freshwater lakes and rivers in central and northeast Florida (Paerl et al. 2001). Bloom characteristics and global proliferation patterns of *C. raciborskii* suggest a strong link to eutrophication and global warming (Fuentes et al; 2010; Sinha et al. 2012; Paerl and Otten 2013; Wood et al. 2014; Chislock et al. 2014). Further details on *C. raciborskii* are provided in a separate section below.

Addressing C-HAB threats in reservoir systems, including the Bois D'Arc Reservoir, requires an understanding of environmental conditions that favor bloom formation. Cyanobacterial blooms can occur when complex interactions between physical, chemical and biotic factors provide conditions that are optimal for growth. Under optimal growth conditions, harmful cyanobacteria can outcompete other beneficial algae and if consumption cannot keep pace with production, excess cyanobacteria accumulate, leading to bloom conditions. Key environmental factors influencing C-HAB formation in reservoir and lakes are summarized below (Paerl et al. 2001; Paerl and Otten 2013).

Physical Factors

Key physical factors that drive the dynamics of C-HAB bloom formation and persistence include water temperature, light, turbulence and mixing, and water residence time. Each factor is summarized below.

Water Temperature

In general, warmer water temperatures favor surface bloom forming cyanobacteria and many genera have maximal growth rates that occur at temperatures in excess of 25 ^{0}C. Summer and late-summer blooms of cyanobacteria are thus common in many lakes and reservoirs where surface water temperatures stay in excess of 20 ^{0}C over prolonged periods of time. Warm surface waters are also prone to vertical stratification. Many cyanobacteria can exploit such thermally-stratified conditions by forming gas vesicles that provide buoyancy and help maintain their position in the warm surface waters.

Light

Many C-HAB forming genera prefer high light conditions and can even tolerate high UV radiation. Cellular adaptations such as gas vesicles allow cyanobacteria to maintain their position with the euphotic phone near the surface, where increased rates of photosynthesis can lead to high primary productivity. However, there are some low-light adapted cyanobacteria such as *Oscillatoria, Synechocystis, Lyngbya,* and notably, *C. raciborskii* that can flourish below the euphotic zone.

Turbulence and Mixing

Low turbulence and poorly mixed conditions are preferred by most bloom forming cyanobacteria genera. Cyanobacteria are particularly sensitive to water column stability and vertical stratification. Surface blooms typically form during summer stratification events when the water body is poorly mixed, and turbulence-induced shear stresses that can cause disaggregation of growth-promoting mutually-beneficial cyanobacterial/bacterial associations, cell/filament breakage and cellular death, are relatively low.

Water Residence Time

Long water residence times are preferred by all cyanobacterial genera.

Chemical Factors

Primary chemical factors that drive C-HAB bloom formation and persistence include the availability of nutrients (nitrogen and phosphorus), micronutrients (trace metals), dissolved inorganic and organic carbon, and salinity.

Nutrients (N and P)

In aquatic systems, nutrients such as N and P are typically in short supply relative to cyanobacterial growth requirements. Enrichment of natural waters with one or both of these essential nutrients could trigger cyanobacterial blooms and eutrophication events. In freshwater systems, excessive P-loading can shift molar N:P ratios to levels (< 15) that generally favor blooms of N_2-fixing cyanobacteria (e.g., *Anabaena, Aphanizomenon, Cylindrospermopsis, Gloeotrichia, Nodularia*). This loading can be external and/or internal via release of P from the sediment during anoxic conditions. However, highly eutrophic freshwaters where both N and P loadings are very high can favor blooms of non-N_2-fixing cyanobacteria (e.g., *Microcystis, Oscillatoria, Gomphosphaeria* and *Lyngbya*). Moderately N- and P-enriched waters frequently support mixed blooms of N_2- and non-N_2-fixing cyanobacteria.

Micronutrients

Trace metals such as iron, manganese, cobalt, copper, molybdenum and zinc are required by cyanobacteria for photosynthesis, N_2-fixation and a variety of other metabolic functions. In most freshwater systems, availability of these trace metals meets cyanobacterial growth requirements and trace metal limitation is likely not a modulator of bloom conditions. There is, however, evidence that iron (Fe) could be limiting in some freshwater systems, and could play a secondary role (to N and P) in determining the distributions and magnitudes of cyanobacterial blooms (Molot 2014).

Dissolved Carbon

Dissolved inorganic carbon (DIC) can limit the growth of eukaryotic algae, but cyanobacteria have an environmental adaption known as a CO_2 concentrating mechanism (CCM) that evolved to improve photosynthetic performance, particularly under CO_2-limiting conditions (Price 2011). When DIC levels are limiting, the CCM functions to provide an elevated intracellular CO_2 concentration to facilitate the photosynthetic production of carbohydrates, providing competitive advantages to bloom forming cyanobacteria. Many cyanobacterial bloom taxa are also capable of utilizing dissolved organic carbon (DOC), and blooms often flourish in DOC-enriched waters.

Salinity

Salinization of freshwater systems due to human activities and climate change has increased worldwide. The use of freshwater for agricultural irrigation and hydrological alterations can increase saline runoff into source waters. Salinization can also occur when more intense and prolonged summer droughts induced by climate change increase the evaporative loss of water from lakes and reservoirs due to warmer temperatures, while reducing freshwater inputs into these systems (EPA 2013). Several bloom-forming cyanobacterial genera that are common in freshwater systems are tolerant of a wide range of salinities, and could potentially outcompete eukaryotic algae when salinities increase. Examples include toxin-producing N_2-fixing genera such as *Anabaena, Anabaenopsis, Nodularia, and Lyngbya*, and non-N_2 fixing genera such as *Microcystis* and *Oscillatoria*. Further, temporary salinity variations could potentially trigger the release of cyanobacterial toxins into the water due to leakage of salt-stressed cells (EPA 2013). Increases in salinity in freshwater lakes and reservoirs during drought conditions can also create favorable conditions for the invasion of cyanobacteria that are adapted to brackish water and marine conditions. This is occurring in southwestern and south central US lakes where the brackish/marine alga, *Prymnesium parvum* (golden algae), has been increasing since 2000, causing significant fish kills in inland waters (EPA 2013).

Biotic Factors

While the physical and chemical factors described above primarily drive cyanobacterial bloom formation in freshwater systems, biotic factors such as grazing, microbial interactions and symbiotic relationships can also play a key role in modulating C-HAB dynamics.

Grazing

Selective grazing by zooplankton and benthic organisms (e.g., bivalve molluscs) can have the effect of favoring large inedible filamentous and colonial forms of cyanobacteria, as well as genera that are toxic to grazers. Selective grazing, in certain cases, can effectively remove competing algae from the system, and tip the balance towards blooms of unpalatable cyanobacteria (Vanderploeg, et al. 2001).

Microbial Interactions

Bloom-forming cyanobacteria form close associations with other microorganisms including heterotrophic bacteria, eukaryotic algae, and protozoans. These associations may provide mutual benefits to both organisms via synergistic exchange of metabolites and growth factors. Consortial cyanobacterial-bacterial interactions are known to promote cyanobacterial growth and may likely play a role in C-HAB formation and persistence.

Symbiotic Relationships

Cyanobacteria also form symbiotic relationships with higher plants and animals, thriving as epiphytes attached to aquatic plants and as epizoites attached to aquatic animals. Cyanobacterial endosymbiosis (living within host cells) with algae, ferns and vascular plants has also been reported; often these relationships are obligate and involve N_2-fixing cyanobacteria.

Cylindrospermopsis raciborskii: A Potential C-HAB Threat?

C. raciborskii is an invasive filamentous, bloom forming cyanobacterium that has a wide global distribution (Antunes et al. 2015). Initially considered to a tropical species, this cyanobacterium species is now found throughout many temperate regions, including the United States. *C. raciborskii* can produce hepatoxins (cylindrospermopsin) and neurotoxins (saxitoxin) which can affect both humans and animals. It was first detected in the United States in 1955, and has since been reported in Florida, Indiana, Louisiana, Michigan, Minnesota, Texas, and Wisconsin (Fuentes, et al. 2010). Late summer and fall blooms of *C. raciborskii* have been of major concern in Florida and recent concern has also been noted due to the presence of this species in some reservoirs in Texas (Teel et al. 2013).

Strain-Related Toxicity of *C. raciborskii*

The type of toxin produced by *C. raciborskii* appears to be strain-dependent. Australian, New Zealand and east- and southeast Asian strains produce cylindrospermopsin, whereas South American strains are the only known ones that produce saxitoxins (Sinha et al. 2012; Antunes et al. 2015). It is also important to note that not all strains of *C. raciborskii* produce toxins and the presence of this cyanobacterium does not necessarily mean that its toxins will also be present in the water (Teel et al. 2013; Antunes et al. 2015). Rather, there is relatively recent evidence that the strains of *C. raciborskii* found in lakes and rivers in the United States (and in Europe) do not produce toxins (Yilmaz and Phlips 2011; Antunes et al. 2015) and may not pose a direct health threat to animals and humans. More research on strain-related toxicity and its triggers is, however, warranted (Sinha et al.; Teel et al. 2013). Research indicates that in U.S. waters, the toxin cylindrospermopsin is produced by other cyanobacteria (e.g., *Aphanizomenon ovalisporum*), but not by existing *C. raciborskii* strains (Teel et al. 2013). Regardless, this species remains of immediate concern in the United States (and in Texas) due to its physiological adaptability that allows it to persist and form bloom conditions that are less than optimal for other phytoplankton (Sinha et al. 2012). Under unfavorable conditions, *C. raciborskii* forms specialized cells called akinetes that can remain dormant in the sediment for prolonged periods of time and germinate when favorable conditions return.

Environmental Conditions Favoring *C. raciborskii* Blooms

Environmental factors such as water temperature, light intensity, vertical stratification and lake mixis, nitrogen, phosphorus, salinity and pH play a role in the dynamics of *C. raciborskii* in lake and reservoir systems, and are summarized below.

Water Temperature

C. raciborskii can tolerate a wide range of water temperatures, but blooms occur only at warm temperatures (Wood et al. 2014). The process of akinete formation and germination is closely linked to water temperature, and may be a key strategy that has allowed *C. raciborskii* to colonize temperate regions globally. Akinete production increases under cooler temperatures and may allow this species to remain dormant through the winter. Akinetes germinate when water temperatures exceed 22 °C, and blooms typically occur at water temperatures of 25-32 °C (Fuentes et al. 2010; Antunes et al. 2015). There are likely several strains or ecotypes of *C. raciborskii* that are adapted to different temperatures. Rather, the expansion of this cyanobacterium to temperate climates may be the result of selection of clones with lower critical temperature for akinete germination, compared to its tropical counterparts (Antunes et al. 2015). It has also been demonstrated that temperate strains produce more akinetes than their tropical counterparts, further illustrating the adaptation of strains to different climates (Antunes et al. 2015).

Light and Vertical Stratification

C. raciborskii is tolerant of, and can grow under a wide range of light intensities (Wood et al. 2014; Antunes et al. 2015). It is a shade-adapted species and can form blooms under low light conditions, allowing it to thrive in systems with high levels of suspended solids and turbidity, or under light limited conditions created by surface algal blooms that can limit other phytoplankton. Unlike many other cyanobacteria in lakes and reservoirs, *C. raciborskii* can thrive under stratified, as well as well-mixed conditions, due to its neutral buoyancy which favors it either directly by maintaining it in the water column during mixis, or indirectly via circulating cells to lower light environments where primary production is increased (Wood et al. 2014).

Nutrients (Nitrogen and Phosphorus)

C. raciborskii is flexible in its use of nitrogen, and can maintain high growth rates under diazotrophic and non-diazotrophic conditions, utilizing dissolved inorganic nitrogen (DIN) when concentrations are sufficient and nitrogen fixation when DIN is depleted (Wood et al. 2014). The ability of this species to alternate between DIN assimilation and N2-fixation based on availability of DIN, likely contributes to its ability to colonize and dominate systems with highly variable seasonal DIN concentrations (Antunes et al. 2015).

C. raciborskii can dominate in waters with very low dissolved inorganic phosphorus (DIP) due to its high P-uptake and P-storage capacity, and can also use different sources of organic P to support its growth when there is P-limitation in its environment (Wood et al. 2014; Antunes et al. 2015). Physiological adaptations to overcome P-limitation include its ability to regulate metabolism and increase alkaline phosphatase, an enzyme used in P-metabolism, when DIP concentrations are low (Antunes et al. 2015). *C. raciborskii* is known to outcompete other bloom-forming cyanobacteria such as *Microcystis aeruginosa* and *Aphanizomenon flos-aquae* in its ability for P-uptake and use (Antunes et al. 2015). A recent study in a eutrophic area has also shown that *C. raciborskii* tends to dominate in lakes with either very low or very high N:P ratios (Chislock et al. 2014). This flexible and opportunistic nutrient strategy (N and P uptake and use) likely confers *C. raciborskii* an advantage over other cyanobacterial species in colonizing systems with highly variable nutrient concentrations.

Salinity and pH

C. raciborskii is essentially a freshwater species, with a preference for low salinity conditions, but is capable of growing in slightly brackish waters (up to 3.5 ppt). Although higher salinities can be limiting to this species, nitrogen enrichment enables *C. raciborskii* to better withstand elevated salinities (Calandrino and Paerl 2011). *C. raciborskii* can tolerate a wide range of pH and is known to grow in lakes with pH between 5.49 and 9.91, although it has a preference for waters with high pH between 8.1 and 9.4 (Antunes et al. 2015).

The Golden Alga: *Pyymnesium parvum*

Colonization of Texas Waters by *Prymnesium parvum*

The golden alga, *Prymnesium parvum*, is primarily a marine/estuarine species that is also known to inhabit inland freshwater systems. Under certain conditions, GA can produce toxins that are lethal to gilled aquatic animals, and toxic GA blooms are known to cause significant ecological and economic damage (Graneli et al. 2012). The colonization and dispersal of GA within Texas has been summarized by Patino et al. (2014), based on multiple previous studies. GA was first reported in 1985 in the Pecos River within the Rio Grande Basin in Texas, where it caused a massive fish kill. Sporadic GA bloom events were subsequently observed between 1985 and 2001 in isolated stream reaches within the Brazos River and the Colorado River Basins. In 2001, a marked range expansion of highly toxic GA blooms was observed into previously unaffected waterbodies of the Brazos River, Colorado River, and Red River basins, including several large reservoirs in Texas. Toxic blooms of GA are now a common occurrence in five river basins in west, central and north-central Texas, as well as in 22 other US states.

The rapid expansion of GA in Texas and other states over the past decade is believed to be the result of initial novel introductions of GA into systems with pre-existing favorable habitat followed quickly by toxic GA bloom formation. Another explanation for this rapid expansion includes initial introductions of GA into systems with unfavorable habitat, where natural or anthropogenic changes in water quality led to the gradual development of conditions that eventually favored toxic bloom formation. The existence of several reservoirs in Texas that contain GA but have not yet experienced toxic blooms supports this second scenario (Patino et al. 2014).

Conditions that Favor Toxic Blooms of *Prymnesium parvum*

Role of Mixotrophy and Allelopathy in Toxic Bloom Dynamics

Mixotrophy and allelopathy are two ecophysiological adaptations that, along with water quality, play an important role in the formation and dynamics of toxic GA blooms (Graneli et al. 2012). GA is a mixotrophic species, that is, it can photosynthesize as well as consume organic materials such as dissolved organic matter (DOM) or bacteria/algae as sources of nutrition. Mixotrophy gains GA a competitive advantage over other algae when inorganic nutrients (N and P) are scarce or when light is too limiting for photosynthesis. While there is an energetic cost involved with switching from autotrophy to heterotrophy, this extra energy cost is more than compensated for through competitive gains over other algae (Stoecker et al., 2006).

Allelopathy refers to the ability of GA to produce and release toxic chemicals that can inhibit growth and kill other organisms, including phytoplankton competitors and zooplankton grazers. There is some evidence that allelochemicals, toxins and grazer deterrents are all the same chemical compounds (Graneli et al. 2012). These toxic chemicals are typically produced and released under conditions that are stressful for GA, such as when light, temperature, pH, N:P ratios, and salinity are sub-optimal for growth (Baker et al 2007; Graneli et al. 2012; Patino et al. 2014). Under such conditions, GA release allelochemicals to deter zooplankton predators and also kill prey that they can consume.

Light

Stress induced by low light conditions (such as in highly turbid waters) can increase GA toxicity. This appears to be a mechanism to compensate for decrease in photosynthetic activity by producing toxins to kill and ingest prey. As such, low light appears to be one of several environmental triggers under which GA switches to mixotrophy (Graneli, et al. 2012).

Water Temperature

Optimum temperatures for GA growth are between 25 and 30 °C. However, it has been shown that toxicity of GA is higher under sub-optimal temperatures for growth (10-15 °C), although extremely high temperatures (> 30 °C) are also known to enhance toxicity (Graneli et al. 2012). Toxic blooms of GA in Texas are known to typically occur during the winter or early spring.

pH

Toxicity of GA is also pH dependent. In laboratory and field experiments, GA toxicity was reported to be consistently higher at pH 8.5 than at pH 6.5 or 7.5, likely due to pH-mediated shifts in ionization states of prymnesin toxins (Valenti et al. 2010). Studies indicate that not only are more toxins produced by GA under bloom conditions, but there is also an increase in toxin potency due to an increase in pH during photosynthetic activity.

Nutrients

GA toxicity is influenced by N and P deficiencies and imbalances in N:P ratios (Graneli et al. 2012). GA toxicity was reduced with addition of N and P into nutrient deficient cultures or into mesocosms placed in lakes with nutrient imbalances (Graneli et al. 2012). GA toxicity has also been observed to be greater during P deficiency than N deficiency in laboratory cultures, as well as large scale lake studies where toxicity was reduced within days after the addition of excess P to pond water (Graneli et al. 2012). In general, GA toxicity is enhanced when N:P ratios are very low (< 12, N deficiency) or very high (> 20, P deficiency).

Salinity

Salinity is an important factor defining GA habitat, and a key predictor of toxic GA bloom potential in Texas reservoirs (Patino et al. 2014). Minimum estimated salinities for toxic GA bloom formations were reported to be 0.59 and 1.02 psu for Brazos and Colorado River reservoirs, respectively, indicating that specific salinity threshold values may differ across and within basins and that water quality traits other than salinity may also be influencing GA spread and bloom occurrence in Texas reservoirs.

Sulfate

Sulfate, in particular, with intrinsic properties beyond its contribution to salinity, deserves closer attention as a potential factor influencing GA bloom formation (Patino et al., 2014). Sulfate is an important source of sulfur for marine and freshwater phytoplankton, and is likely a limiting nutrient in eutrophic systems that are not under N and P limitation. GA is known to have invaded primarily eutrophic or highly eutrophic reservoirs in Texas with levels of sulfate that were approximately 8 times higher than in reservoirs that did not experience GA blooms. This indicates that sulfate, in addition to contributing to overall salinity and thus indirectly enhancing the colonization potential of GA, may also be necessary as a nutrient to support GA growth (Patino et al., 2014).

References

Antunes, J. T., P. N. Leao, V. M. Vasconselos. 2015. *Cylindrospermopsis raciborskii*: review of the distribution, phylogeography, and ecophysiology of a global invasive species. Frontiers in Microbiology 6. Article 473. doi: 10.3389/fmicb.2015.00473.

Baker, J. W., J. P. Grover, B. W. Brooks, F. Urena-Boeck, D. L. Roelke, R. Errera, and R. L. Kiesling. 2007. Growth and toxicity of *Prymnesium parvum* (Haptophyta) as a function of salinity, light, and temperature. Journal of Phycology 43: 219:227.

Calandrino, E. S., and Paerl, H. W. 2011. Determining the potential for the proliferation of the harmful cyanobacterium *Cylindrospermopsis raciborskii* in Currituck Sound, North Carolina. Harmful Algae 11: 1–9. doi:10.1016/j.hal. 2011.04.003.

Chislock, M. F., K. L. Sharp, and A. Wilson. 2014. *Cylindrospermopsis raciborskii* dominates under very low and high nitrogen-to-phosphorus ratios. Water Research 49: 207-214.

EPA. 2013. Impacts of climate change on the occurrence of Harmful Algal Blooms. EPA 820-S-13-001.

Fuentes, M. S., J. J. Rick, K. H. Hasenstein. 2010. Occurrence of a *Cylindrospermopsis* bloom in Louisiana. Journal of Great Lakes Research. 36: 458-464.

Granéli, E., B. Edvardsen, D. L. Roelke, J. A. Hagström. 2012. The ecophysiology and bloom dynamics of Prymnesium spp. Harmful Algae 14: 260-270.

Holland, D. P., A. Pantorno, P. T. Orr, S. Stojkovic, and J. Beardall. 2012. The impacts of high CO_2 environment on a bicarbonate user: The cyanobacterium *Cylindrospermopsis raciborskii*. Water Research 46: 1430-1437.

Leigh, C., M. A. Burford, D. T. Roberts, and J. W. Udy. 2010. Predicting the vulnerability of reservoirs to poor water quality and cyanobacterial blooms. Water Research 44: 4487-4496.

Lopez, C.B., Jewett, E.B., Dortch, Q., Walton, B.T., Hudnell, H.K. 2008. Scientific Assessment of Freshwater Harmful Algal Blooms. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC.

Molot, L.A., S. B. Watson, I. F. Creed, C.G. Trick, S. K. McCabe, M. J. Verschoor, R. J. Sorichetti, C. Powe, J. J. Venkiteswaran, and S. L. Schiff. 2014. A novel model for cyanobacteria bloom formation: the critical role of anoxia and ferrous iron. Freshwater Biology, doi: 10.1111/fwb.12334.

Paerl, H. W., and T. G. Otten. 2013. Harmful cyanobacterial blooms: Causes, consequences, and controls. Environmental Microbiology (online): DOI 10.1007/s00248-012-0159-y. Springer Publishers.

Appendix B

Dreissenid Mussel Infestation Risk in the Lower Bois D'Arc Creek Reservoir: An Assessment Based on Water Quality Modeling

Appendix B

Dreissenid Mussel Infestation Risk in the Lower Bois D'Arc Creek Reservoir: An Assessment Based on Water Quality Modeling

Introduction

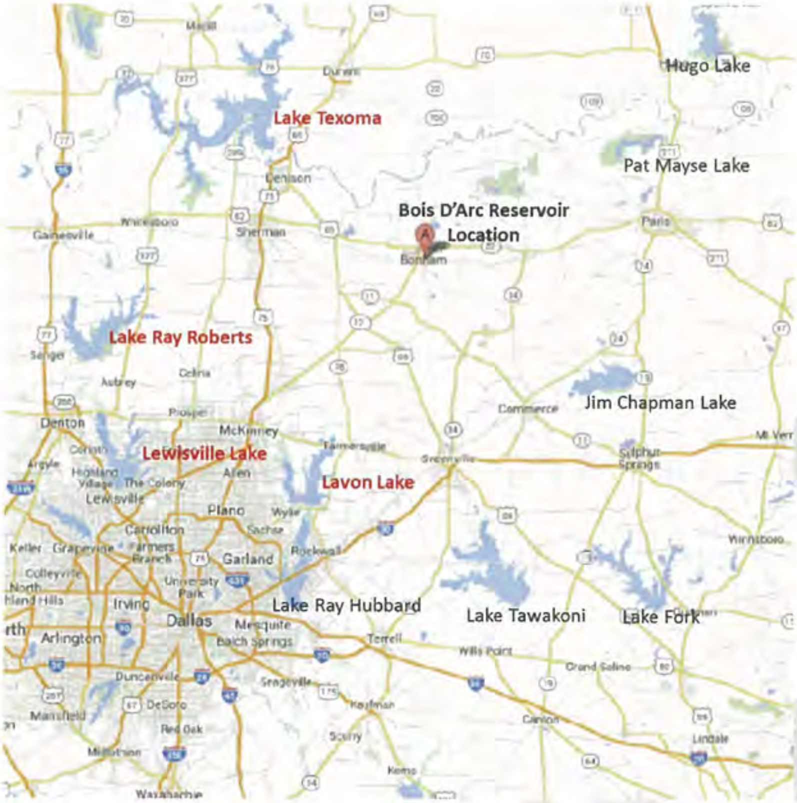
The North Texas Municipal Water District (NTMWD) serves water to customers over eight counties in north central Texas, and is currently pursuing the development of a new reservoir, the Lower Bois d'Arc Creek Reservoir (BDAR) in the Red River Basin. The BDAR will provide approximately 126,200 acre-feet/year (113 mgd) of new raw water supply for NTMWD. The nearest major demand center is the Dallas-Fort Worth area, which is located approximately 60 miles southwest of the reservoir site. The purpose of this technical memorandum (TM) is to evaluate the potential risk of infestation of the BDAR by zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena bugensis*), both highly invasive mollusk species (collectively called dreissenid mussels) that have caused widespread ecological and economic damage elsewhere in the United States.

The first Texas infestation of zebra mussels was found in Lake Texoma in 2009. As of 2015, viable zebra mussel populations have been documented in lakes Belton, Bridgeport, Lavon, Lewisville, Ray Roberts, Texoma and Waco. Several of these reservoirs are in relatively close proximity to the BDAR (Figure 1) which increases its risk of becoming infested with mussels, most likely via inadvertent transport by recreational boating activities between reservoirs. Zebra mussel DNA has also been documented in several additional water bodies in Texas, but to date no adults or veligers have been found to verify their presence (TPWD 2015). While there have been no reports of infestations of quagga mussels in Texas waters, the risk of quagga mussel infestation in the BDAR is also imminent due to the similar life histories and habitat preferences of these two mussel species.

This TM focuses on an assessment of projected water quality conditions in the BDAR to evaluate the risk of infestation by dreissenid mussels. A separate water quality modeling study has been undertaken to estimate projected water quality conditions in the BDAR (this report). These projected water quality parameters were used to estimate mussel infestation risk potential in the BDAR.

Figure 1. Map of Proposed Location of BDAR and Area Reservoirs

Red type indicates reservoirs with known presence of dreissenid mussels



Methods

The risk and level of infestation by dreissenid mussels in the BDAR will depend on specific water quality parameters that are the basis of the physiological and ecological requirements and tolerances of these mussel species. These water quality parameters, as such, define the key physical, chemical and biological requirements that regulate the survival and establishment of dreissenid mussels once the mussels are introduced into a body of water. The parameters can be grouped into chalk variables, nutrient variables and physical variables (Table 1), and together will determine the level of mussel infestation at a particular site.

TABLE 1.
Water Quality Variables for Assessing Potential Levels of Infestation by Dreissenid Mussels
Mackie and Claudi (2010)

Chalk Variables	**Nutrient Variables**	**Physical Variables**
Calcium (mg Ca/L)	Dissolved Oxygen (mg/L)	Water Temperature (^{0}C)
pH	Chlorophyll a (ug/L)	Conductivity (uS/cm)*
Total Alkalinity (mg CaCO3/L)	Total Phosphorus (ug/L)	Total Dissolved Solids (mg/L)
Total Hardness (mg CaCO3/L) *	Total Nitrogen (ug/L)	Turbidity (NTU)*
	Secchi Depth (m) *	Total Suspended Solids (mg/L)

* Variable information was not available for analysis of mussel infestation risk potential in this study.

Chalk Variables

For dreissenid mussels (as for all mollusks), the group of chalk variables consisting of calcium, alkalinity, pH, and total hardness are key chemical variables that are most likely to determine survival of dreissenid mussels (Mackie and Claudi 2010). Of these interdependent variables, the key variable is calcium content, followed by pH and alkalinity that define the availability of calcium to mussels. In water, calcium mainly exists as calcium carbonate and calcium bicarbonate, depending on the pH. Mussels can use calcium only in its soluble bicarbonate form. The non-soluble carbonate form of calcium precipitates out of the water column and is not available to mussels. Total alkalinity consists of bicarbonate alkalinity (HCO_3) and carbonate alkalinity (CO_3). At pH values below 8.2, all the calcium is available in the soluble HCO_3 form and at pH values above 8.2, calcium is increasingly present in the non-available CO_3 form (Mackie and Claudi 2010).

Nutrient Variables

The nutrient parameters including dissolved oxygen, chlorophyll *a*, nutrients (total phosphorus and total nitrogen) and Secchi depth are collectively known as "trophic indicators" as they collectively define the algal food levels for mussels in a body of water. Since dreissenid mussels feed on algae, the values of these trophic indicators are important criteria for predicting the levels of mussel infestations in a body of water (Mackie and Claudi 2010). The higher the values of the nutrients, the greater the biomasses of algae and hence of chlorophyll *"a"*, and dissolved oxygen (as a by-product of photosynthesis), and the lower the Secchi depth values as the water gets more turbid with algal biomass (Claudi and Prescott 2009). However, Secchi depth measures vary with depth-related light penetration that drives levels of algal photosysthesis. Dissolved oxygen is also critically important in the metabolism of mussels and may become limiting to mussels during certain portions of the year and at certain depths in the reservoir.

Physical Variables

Important physical variables pertinent to BDAR are water temperature, conductivity (or total dissolved solids), turbidity and total suspended solids. Depending on the season, water temperatures may be limiting to the reproduction and survival of mussels and could determine the levels of infestation. Conductivity is related to the total dissolved solids content in the water, and is an electrical surrogate measure of all the cations (e.g., calcium, magnesium) and anions (e.g., chloride, nitrate, phosphate) dissolved in the water. Total dissolved solids (TDS) can thus be used as an alternate measure in case conductivity data is not available, as was done in this study. Dreissenid mussels have lower and upper threshold levels for TDS. Below the low TDS threshold levels, water with too few ions such as calcium will be unable to support the growth and reproduction of mussels. The upper TDS threshold level is defined as the salinity threshold level for mussels which typically occurs at salinities in excess of 5 g/l (ppt) where the risk of infestation rapidly declines, to 10 g/l (ppt) above which there is no risk of infestation (Mackie and Claudi 2010).

Modeling Data on Water Quality Parameters

Specific water quality parameters that define the habitat conditions for dreissenid mussels were estimated using a water quality model described in this report. Model output estimates daily values of these parameters, which were then used to derive monthly averages for each parameter over a 12 year period. This 12-yr period was chosen to encompass a major drought event in the reservoir. The water quality data in this TM is presented as monthly averages, which are sufficient for evaluating mussel infestation risk potential. These monthly averages of water quality parameters were compared to known physiological requirements and ecological tolerances of zebra and quagga mussels in order to assess invasion risk and define potential levels of mussel infestations that could occur at those sites (see section below on Defining Mussel Infestation Risk Potential).

Infestation risk potential was estimated in this manner for two locations in the BDAR (Figure 2); the middle of the reservoir and near the dam. For each location, the model was further used to estimate surface and bottom water quality data to estimate depth-related mussel infestation risk.

Figure 2. Locations of sites used for modeling water quality for mussel infestation risk analysis

Water quality data on total hardness, secchi depth, conductivity and turbidity was not available (Table 1) and thus not used in the analysis. Lack of this information was judged to not be critical to this analysis, as available information on the remaining water quality parameters provided a robust framework for assessing mussel infestation risk in the BDAR.

Defining Mussel Infestation Risk Potential

Four potential levels of infestation risk based on known ecological and physiological tolerances of mussels (Mackie and Claudi 2010) were defined for the BDAR:

1. No potential for adult mussel survival (N): The water quality variables are in ranges that will not support the survival of adult mussels. Since larval stages have relatively stringent water quality requirements, it also follows that larval stages of mussels will not be able to survive these conditions. Under these water quality ranges, there is no risk of developing nuisance levels of mussel infestation.
2. Little potential for larval mussel development (L): The water quality variables are in ranges that can likely support adult mussels, but have little potential for supporting larval development. There is thus little potential for developing nuisance levels of mussel infestations under these water quality conditions.
3. Moderate potential for nuisance infestations (M): Water quality variables are in ranges that can support the survival, growth and development of all stages of mussels, but are not at levels that can likely support massive infestations. Under these conditions, there is moderate potential for developing nuisance infestations.
4. High potential for massive infestations (H): Water quality variables are in ranges that are ideal for the growth and survival of larval and adult mussels and there is high potential for developing massive infestations under these conditions.

Tables 2 and 3 categorize the infestation risk potential based on known physiological and ecological tolerances of zebra mussels and quagga mussels, respectively. Using time series of averages of a suite of chalk, nutrient and physical water quality variables that define the habitat of zebra and quagga mussels, insights were gained into potential levels of dreissenid mussel infestation risk at each BDAR site.

TABLE 2
Water Quality Criteria and Potential Levels of Infestations for Zebra Mussels

Parameter	No Potential for Adult Survival and Nuisance Infestations	Little Potential for Larval Development and Nuisance Infestations	Moderate Potential for Nuisance Infestations	High Potential for Massive Infestations
		Chalk Variables		
Calcium (mg Ca^{2+}/L)	<8	8-15	15-30	30-80
pH	<7.0, >9.5	7.0-7.8, 9.0-9.5	7.8-8.2, 8.8-9.0	8.2-8.8
Total Alkalinity (mg $CaCO_3$/L)	<30	30-55	55-100	100-280
		Nutrient Variables		
Dissolved Oxygen (mg/L) (% saturation)	<3 (<25%)	3-7 (25-50%)	7-8 (50-75%)	≥8 (>75%)
Chlorophyll *a* (µg/L)	<2.0 or >25	2.0-2.5 or 20-25	8-20	2.5-8
Total Phosphorus (µg/L)	<5 or >50	5-10 or 35-50	10-25	25-35
Total Nitrogen (µg/L)	<75 or >750	75-150 or 525-750	150-375	375-525
		Physical Variables		
Temperature (°C)	<10,>32	26-32	10-20	20-26
Total Dissolved Solids (mg/L)	<20	20-40	40-70	>70
Total Suspended Solids (mg/L)	>96	28-96	8-28	<8

Water Quality Criteria Source: Mackie and Claudi (2010)

TABLE 3
Water Quality Criteria and Potential Levels of Infestation for Quagga Mussels

Parameter	No Potential for Adult Survival and Nuisance Infestations	Little Potential for Larval Development and Nuisance Infestations	Moderate Potential for Nuisance Infestations	High Potential for Massive Infestations
		Chalk Variables		
Calcium (mg Ca^{2+}/L)	<10	10-12	12-30	30-120
pH	<7.0, >9.5	7.0-7.8, 9.0-9.5	7.8-8.2, 8.8-9.0	8.2-8.8
Total Alkalinity (mg $CaCO_3$/L)	<35	35-42	42-100	100-420
		Nutrient Variables		
Dissolved Oxygen (mg/L) (% saturation)	<4 (<25%)	4-7 (25-50%)	7-8 (50-75%)	≥8 (>75%)
Chlorophyll *a* (µg/L)	<2.0 or >25	2.0-2.5 or 20-25	8-20	2.5-8
Total Phosphorus (µg/L)	<5 or >50	5-10 or 35-50	10-25	25-35
Total Nitrogen (µg/L)	<75 or >750	75-150 or 525-750	150-375	375-525
		Physical Variables		
Temperature (°C)	<2, >30	2-10 or >28	10-16 or 24-28	16-24
Total Dissolved Solids (mg/L)	<20	20-40	40-70	>70
Total Suspended Solids (mg/L)	>96	28-96	8-28	<8

Water Quality Criteria Source: Mackie and Claudi (2010)

Results and Discussion

Mussel Infestation Potential Based on Chalk Variables

This section describes the infestation potential for dreissenid mussels in the BDAR based on the chalk water quality variables, calcium, pH and total alkalinity, which are modeled for the mid-lake and near dam locations in the proposed reservoir.

Calcium

Calcium is an essential element for metabolic function and shell growth, and low availability of calcium is considered to be a key limiting factor for dreissenid mussels (Whittier et al. 2008; Mackie and Claudi 2010).

Typically, water bodies with calcium levels below 8-10 mg/L will not support dreissenid mussels. A minimum of 12-15 mg/L of calcium is required for mussel establishment and even at this concentration, development of veligers (larval stages) may be limited (Table 2 [Zebra Mussels] and Table 3 [Quagga Mussels]). There is moderate potential for nuisance infestations of dreissenid mussels to develop at calcium levels of 12-30 mg/L, and a high potential for massive infestation to occur above 30 mg Ca/L (Tables 2 and 3).

Monthly average surface calcium concentrations range from 27.6 to 125.7 mg/L with an overall average concentration of 92.4 mg Ca/L at the Mid-Lake Site, and from 76.3 to 125.9 mg/L and overall average of 95.2 mg/L at the Near Dam site (Table 4). While there are expected intra-annual and inter-annual variations in surface calcium concentrations over the 12-year period, calcium levels are consistently in a range that can support massive infestations of both species of dreissenid mussels (Figure 3).

TABLE 4

Surface and Bottom Water Quality Averages and Ranges Modelled at Two Sites for the Bois D'Arc Reservoir over a 12-Year Period

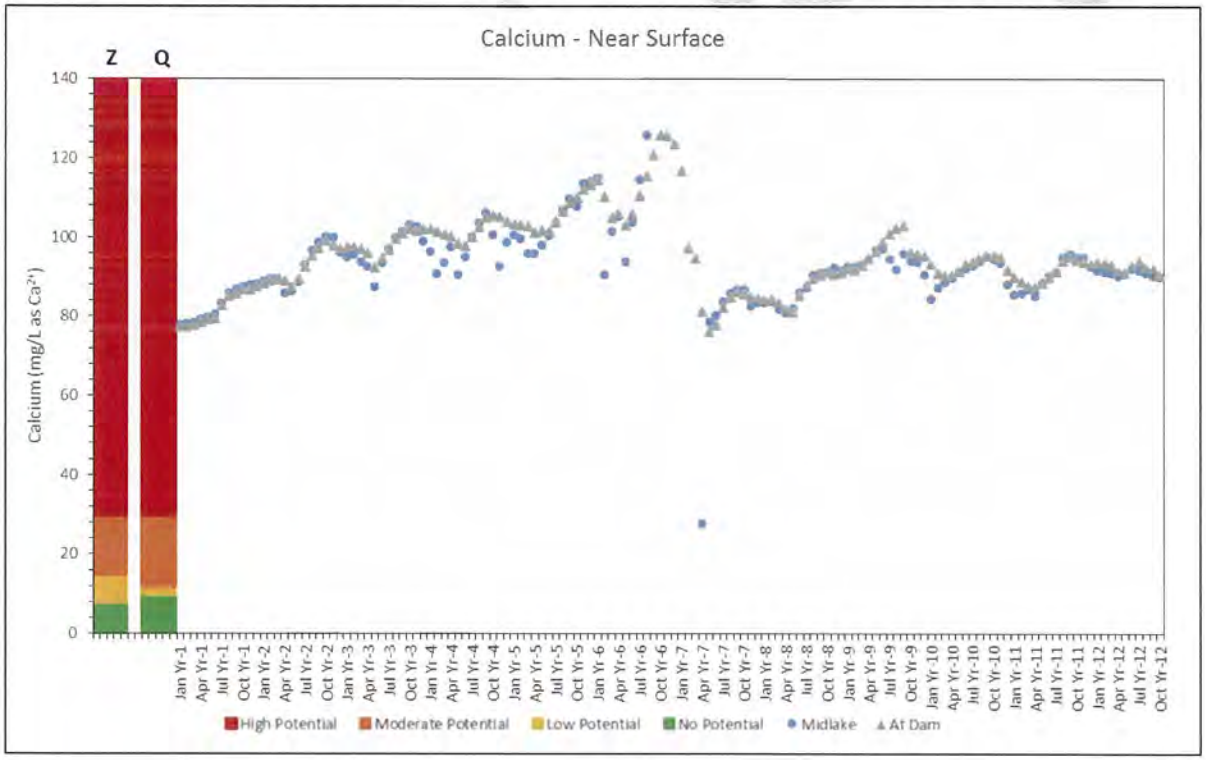
Parameter	**Mid-Lake Site - Surface Average (Range)**	**Mid-Lake Site - Bottom Average (Range)**	**Near Dam Site - Surface Average (Range)**	**Near Dam Site - Bottom Average (Range)**
		Chalk Variables		
Calcium (mg Ca^{2+}/L)	92.4 (27.6 – 125.7)	92.2 (77.8 – 115.0)	95.2 (76.3 – 125.9)	92.7 (40.0 – 125.9)
pH	9.2 (8.0 - 11.0)	8.9 (7.4 - 11.2)	8.9 (8.1 – 11.0)	8.5 (7.3 – 10.9)
Alkalinity, total (mg $CaCO_3$/L)	192.5 (57.0 – 260.4)	192.3 (162.4 – 238.7)	198.5 (157.4 – 260.8)	193.5 (82.6 – 260.8)
		Nutrient Variables		
Dissolved Oxygen (mg/L)	9.1 (2.4 - 12.9)	5.7 (0 - 12.9)	9.1 (6.4 - 12.6)	5.6 (0 - 12.5)
Chlorophyll *a* (µg/L)	12.9 (0.9 – 87.8)	9.3 (0.9 – 33.1)	9.3 (1.7 - 61.3)	4.5 (0.3 – 25.0)
Total Phosphorus (µg/L)	223.4 (184.4 – 286.2)	228.8 (184.3 – 267.1)	225.4 (183.8 – 290.2)	235.3 (184.0 – 290.2)
Total Nitrogen (µg/L)	1,105.4 (859.2 - 1,820.8)	1,121.5 (859.7 - 1,804.8)	1,014.3 (853.5 - 1,699.3)	1,069.0 (854.5 – 1750.6)
		Physical Variables		
Temperature (°C)	17.5 (2.9 - 28.1)	14.3 (3.0 - 27.3)	17.5 (3.5 – 28.0)	11.2 (3.6 - 26.4)

TABLE 4

Surface and Bottom Water Quality Averages and Ranges Modelled at Two Sites for the Bois D'Arc Reservoir over a 12-Year Period

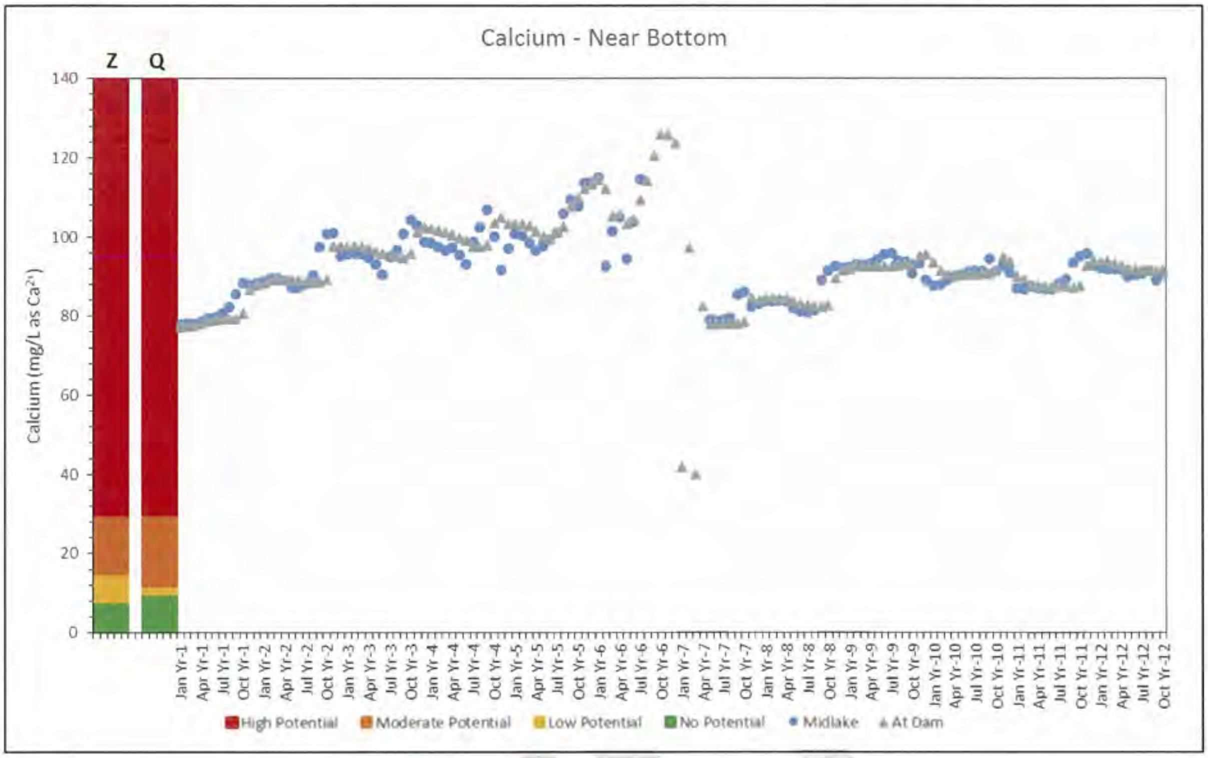
Parameter	Mid-Lake Site - Surface Average (Range)	Mid-Lake Site - Bottom Average (Range)	Near Dam Site - Surface Average (Range)	Near Dam Site - Bottom Average (Range)
TDS (mg/L)	328.5 (97.7 – 445.6)	328.0 (278.6 – 408.1)	338.6 (270.0 – 446.4)	329.9 (141.6 – 446.3)
TSS (mg/L)	1.0 (0.1 – 5.5)	1.0 (0.1 – 6.6)	0.6 (0.1 – 4.1)	0.5 (0.1 – 2.8)

Figure 3. Surface Calcium Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR



Monthly average bottom calcium concentrations range from 77.8 to 115.0 mg/L with an overall average concentration of 92.2 mg Ca/L at the Mid-Lake Site, and from 40.0 to 125.9 mg/L and overall average of 92.7 mg/L at the Near Dam site (Table 4). Over the 12-year period, reservoir bottom calcium levels at both these sites are consistently in a range that can support massive infestations of both species of dreissenid mussels (Figure 4).

Figure 4. Bottom Calcium Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR

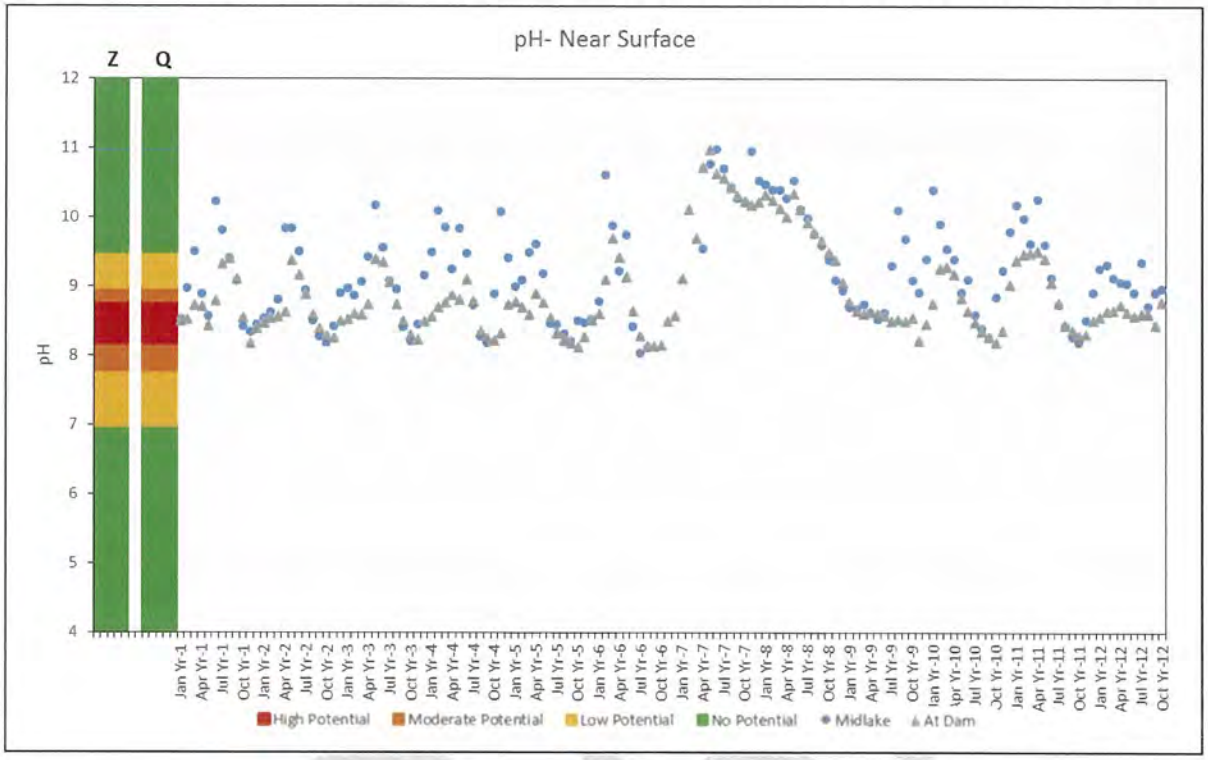


pH

In fresh water lakes and reservoirs, the pH determines the form of calcium present in the water and governs whether calcium is present mainly in the soluble bicarbonate form which is readily available to mussels, or the insoluble carbonate form which largely precipitates out and is unavailable to mussels (Mackie and Claudi 2010). Therefore, pH is an important chalk variable to consider when evaluating mussel infestation risk at particular site. Typically, water bodies with pH levels below 7.8 and above 9.0 have little to no potential for supporting the development of zebra or quagga mussel veligers (Tables 2 and 3). Moderate potential for nuisance levels of mussel infestations exists at pH levels of 7.8-8.2 and 8.8-9.0, with a high potential for heavy infestations in a pH range of 8.2-8.8 (Tables 2 and 3).

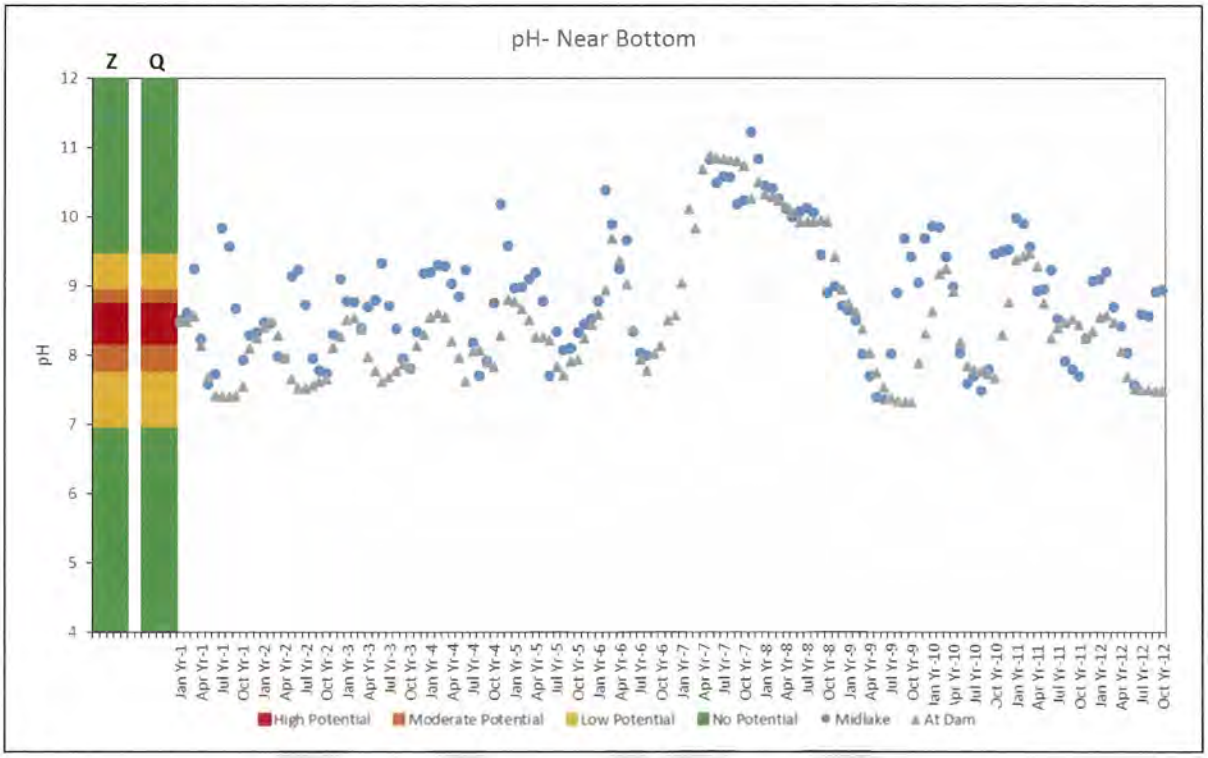
Monthly average surface pH ranges from 8.0 to 11.0 with an overall average pH of 9.2 at the Mid-Lake Site, and from 8.1 to 11.0 and overall average pH of 8.9 at the Near Dam site (Table 4). While there are expected intra-annual and inter-annual variations in surface pH levels over the 12-year period, surface pH levels are generally in a range that would support infestations of both species of dreissenid mussels (Figure 5). The overall risk of mussel infestation of surface waters at both sites would be moderate, due to pH exceeding the upper tolerance limit of 9.5 for both species on several occasions, and especially during the drought period (year 7-8).

Figure 5. Surface pH Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR



Monthly average bottom pH range from 7.4 to 11.2 with an overall average pH of 8.9 at the Mid-Lake Site, and from 7.3 to 10.9 and overall average pH of 8.5 at the Near Dam site (Table 4). Over the 12-year period, bottom pH levels are generally in a range that would support infestations of both species of dreissenid mussels (Figure 6). The overall risk of mussel infestation of bottom waters at both sites would be moderate, due to pH exceeding the upper tolerance limit of 9.5 for both species on several occasions, especially during the drought period (year 7-8).

Figure 6. Bottom pH Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR

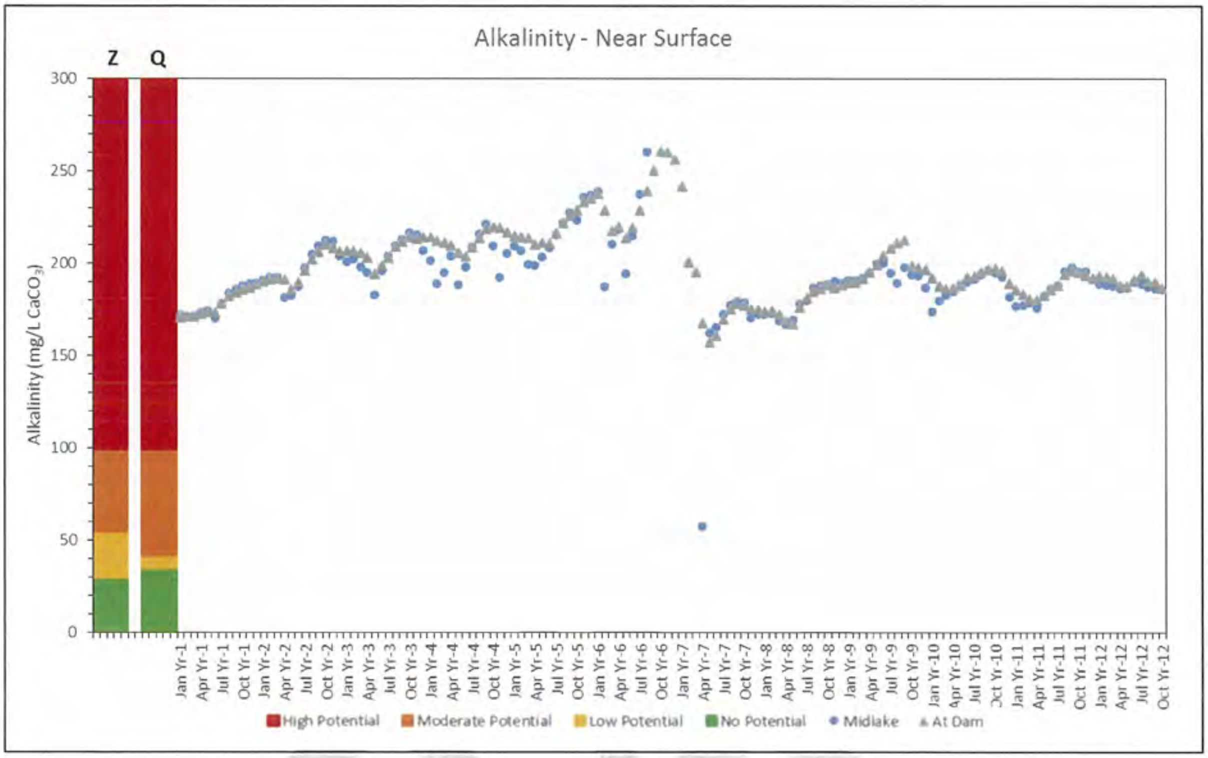


Alkalinity

Alkalinity is a measure of the buffering capacity of water and is important in determining the reservoir water's ability to resist a change in pH. The buffering materials that primarily contribute to total alkalinity are bicarbonate (HCO_3) and carbonate anions (CO_3), and occasionally, hydroxide ions among others. Since calcium is primarily found in water as bio-available calcium bicarbonate or non-available calcium carbonate (based on pH), total alkalinity provides insights into the pool of calcium potentially available to dreissenid mussels. Alkalinity criteria differ slightly for zebra and quagga mussels (Tables 2 and 3), but generally, water bodies with alkalinity levels below 30-35 mg $CaCO_3$/L have no potential for infestations by either species, and little potential for larval development and nuisance infestations when alkalinity ranges from 35-55 mg $CaCO_3$/L. Moderate potential for development of nuisance mussel infestations exists at alkalinity levels up to 100 mg CaCO3/L, above which there is high risk for heavy mussel infestations (Tables 2 and 3).

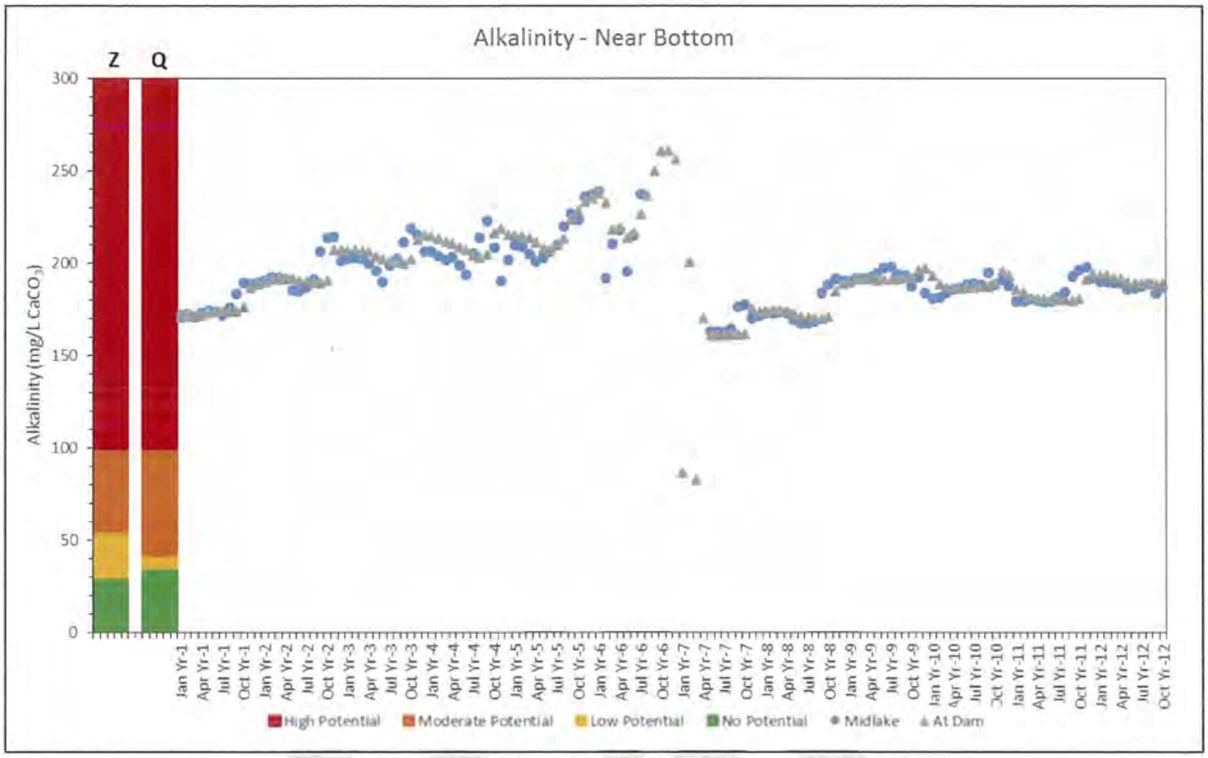
Monthly average total alkalinity at the surface ranges from 57.0 to 260.4 mg/L with an overall average total alkalinity of 192.5 mg/L at the Mid-Lake Site, and from 157.4 to 260.8 mg/L and overall average of 198.5 mg/L at the Near Dam site (Table 4). While there are expected intra-annual and inter-annual variations in surface total alkanility over the 12-year period, these levels are consistently in a range that can support massive infestations of both species of dreissenid mussels (Figure 7).

Figure 7. Surface Total Alkalinity Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR



Monthly average total alkalinity at the bottom ranges from 162.4 to 238.7 mg/L with an overall average concentration of 192.3 mg Ca/L at the Mid-Lake Site, and from 82.6 to 260.8 mg/L and overall average of 193.5 mg/L at the Near Dam site (Table 4). Over the 12-year period, reservoir bottom total alkalinity levels at both these sites are consistently in a range that can support massive infestations of both species of dreissenid mussels (Figure 8).

Figure 8. Bottom Total Alkalinity Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR



Mussel Infestation Potential Based on Nutrient Variables

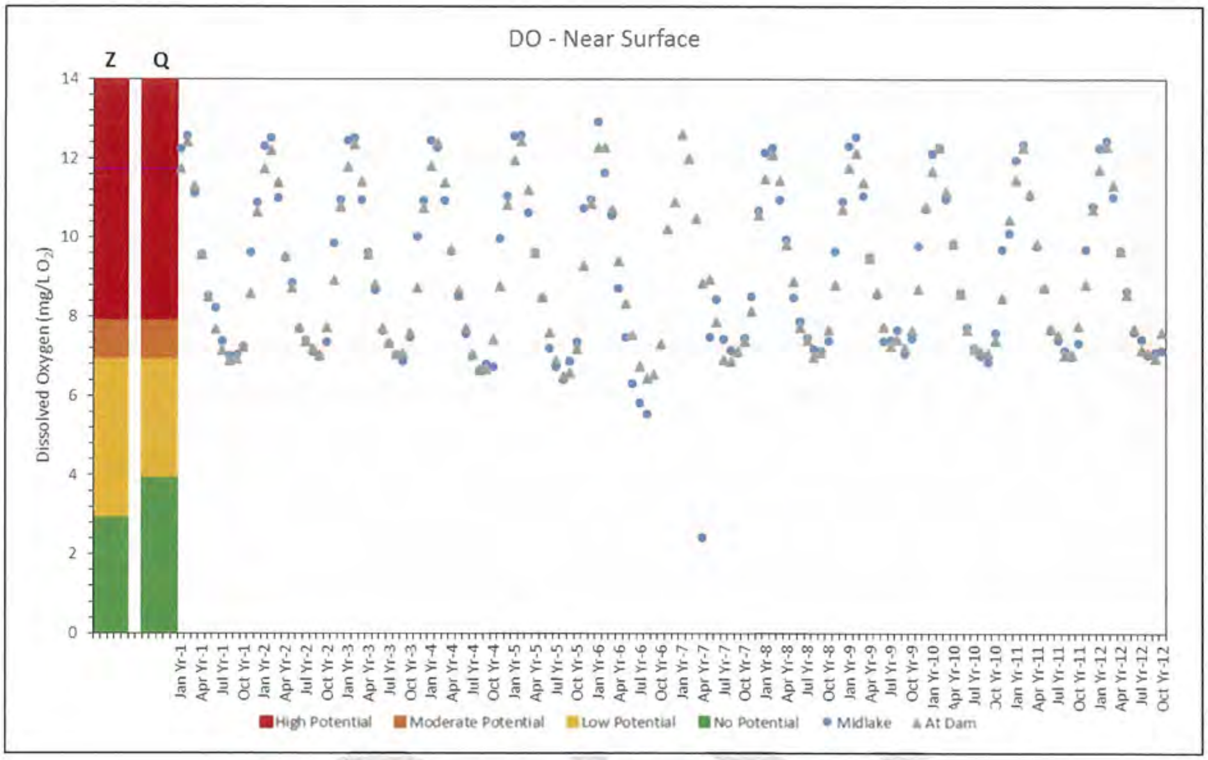
This section describes the infestation potential for dreissenid mussels in the BDAR based the nutrient water quality variables such as dissolved oxygen, chlorophyll a, total phosphorus and total nitrogen that are modeled for the Mid-Lake and Near Dam locations in the proposed reservoir.

Dissolved Oxygen

Dreissenid mussels, and particularly the veliger (larval) stages of these mussels, are relatively intolerant to hypoxia or anoxia. Tolerance to low (or no) dissolved oxygen (DO) condition increases with mussel size (McMahon 1996; Mackie and Claudi 2010). DO criteria differ slightly for zebra and quagga mussels (Tables 2 and 3), but generally, water bodies with DO levels below 3-4 mg/L over any prolonged period of time cannot sustain either species of mussels. Moderate levels of mussel infestations can establish at DO levels between 7-8 mg/L, and a high risk for heavy mussel infestations exists above 8 mg/L DO (Tables 2 and 3).

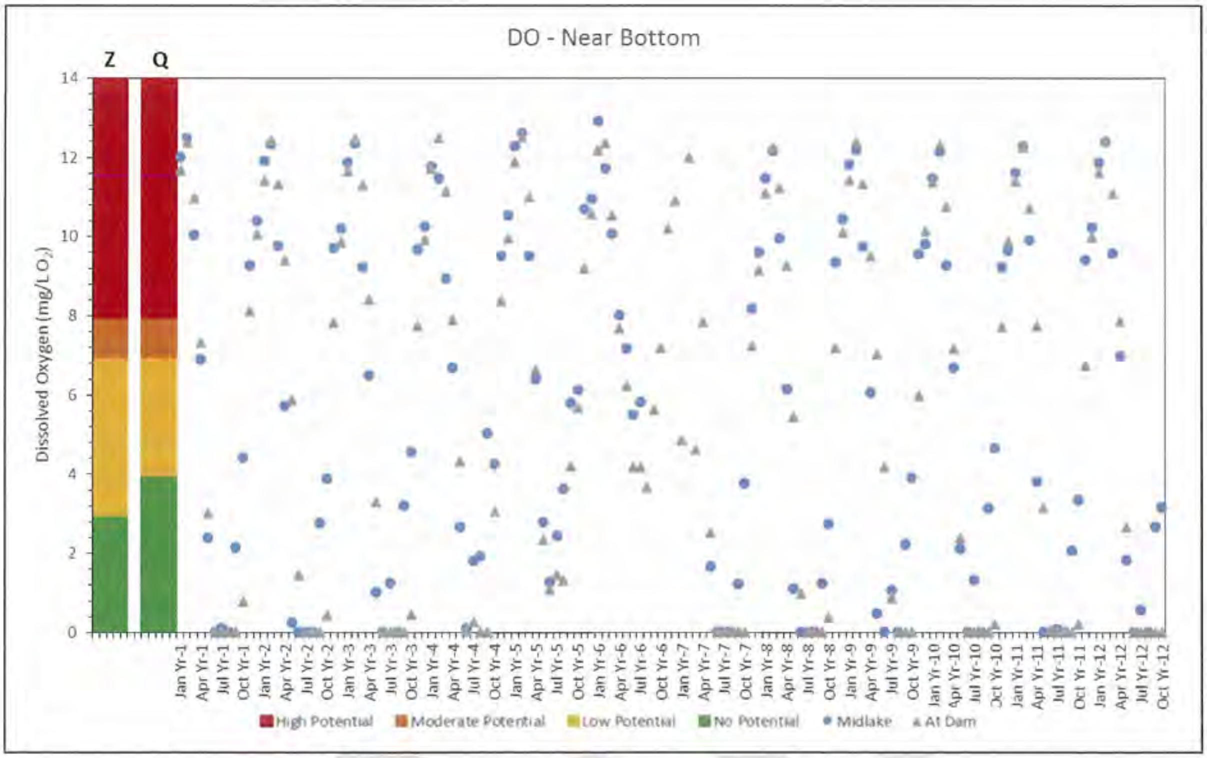
Monthly average surface DO ranges from 2.4 to 12.9 mg/L with an overall average DO of 9.1 mg/L at the Mid-Lake Site, and from 6.4 to 12.6 mg/L and overall average of 9.1 mg/L at the Near Dam site (Table 4). Over the 12-year period, these levels are mostly in a range that have moderate to high potential for supporting nuisance infestations of both species of dreissenid mussels, although peak summer time DO could drop to levels that are stressful for development larval stages (Figure 9).

Figure 9. Surface Dissolved Oxygen Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR



Monthly average bottom DO ranges from 0 to 12.9 mg/L with an overall average DO of 5.7 mg/L at the Mid-Lake Site, and from 0 to 12.5 mg/L and overall average of 5.6 mg/L at the Near Dam site (Table 4). Under these conditions, DO levels near the bottom are expected to be frequently limiting to development of larval mussels and also for support of adult mussel populations, mostly during the summer when larval densities peak due to increased spawning activity (Figure 10). Bottom DO conditions overall could be limiting and will likely restrict both species of mussels to shallower depths in the reservoir.

Figure 10. Bottom Dissolved Oxygen Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR



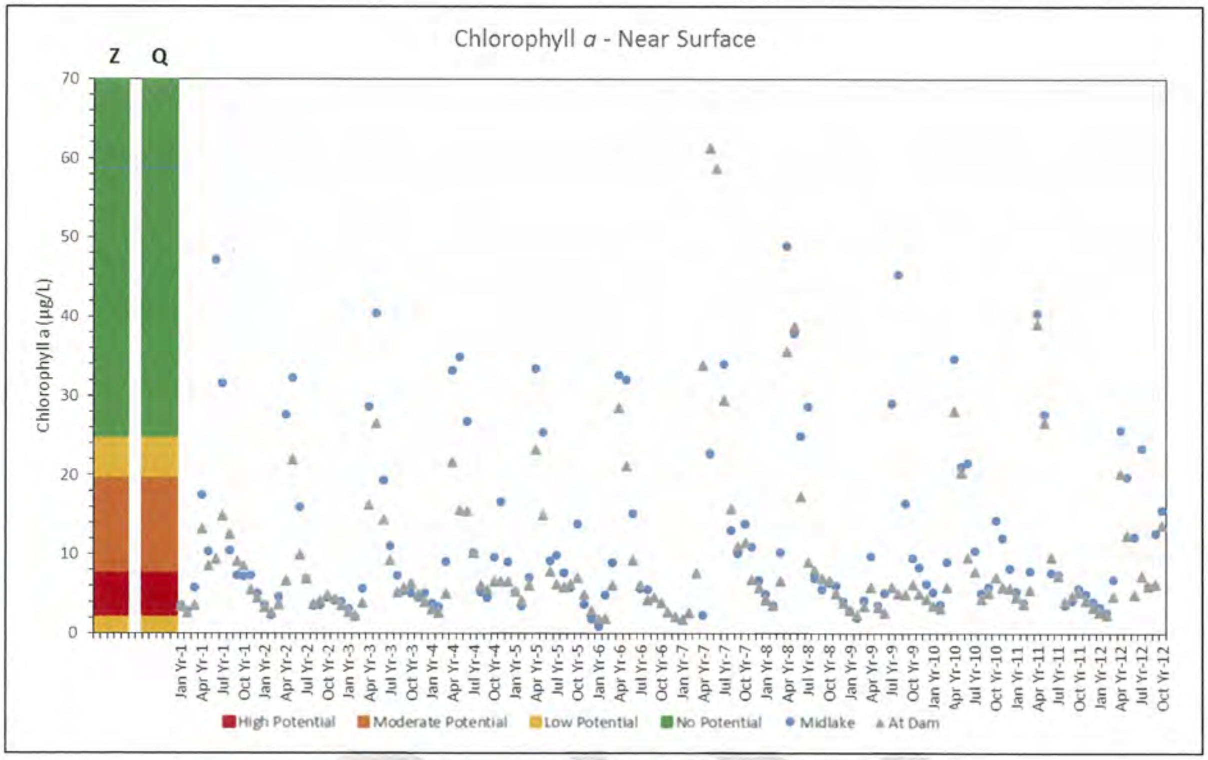
Chlorophyll *a*

The trophic status of surface waters often dictates the presence and abundance of dreissenid mussels (Mackie and Claudi 2010). Chlorophyll *a* levels are indicative of the algal biomass (and hence food source for the mussels) present in a body of water and can thus be used to assess its trophic status. Exceedingly high or exceedingly low trophic states or levels of chlorophyll *a* (food) can potentially limit dreissenid mussel survival and establishment in a body of water, because of insufficient food levels or very high algal food densities that can clog the mussel's gills, respectively (Mackie and Claudi 2010). Chlorophyll *a* levels are driven by spring levels of nutrients such as total phosphorus (in phosphorus limited systems) or total nitrogen (in nitrogen limited systems).

Chlorophyll *a* criteria for assessing the infestation risk of a body of water are the same for zebra and quagga mussels (Tables 2 and 3). There is no likelihood of long term survival of mussels in oligotrophic (< 2.5 µg/L chlorophyll *a*) or highly eutrophic (> 25 µg/L chlorophyll *a*) waters. Mussel larvae have little potential for development in oligo-mesotrophic waters (2.0-2.5 µg/L chlorophyll *a*) and slightly eutrophic waters (20-25 µg/L chlorophyll *a*), consequently preventing mussel populations from reaching nuisance levels. Moderate potential for nuisance infestations exists at chlorophyll *a* levels of 8 and 20 µg/L, and high potential for heavy infestation occurs between chlorophyll *a* levels of 2.5 and 8 µg/L (Mackie and Claudi 2010, Tables 2 and 3).

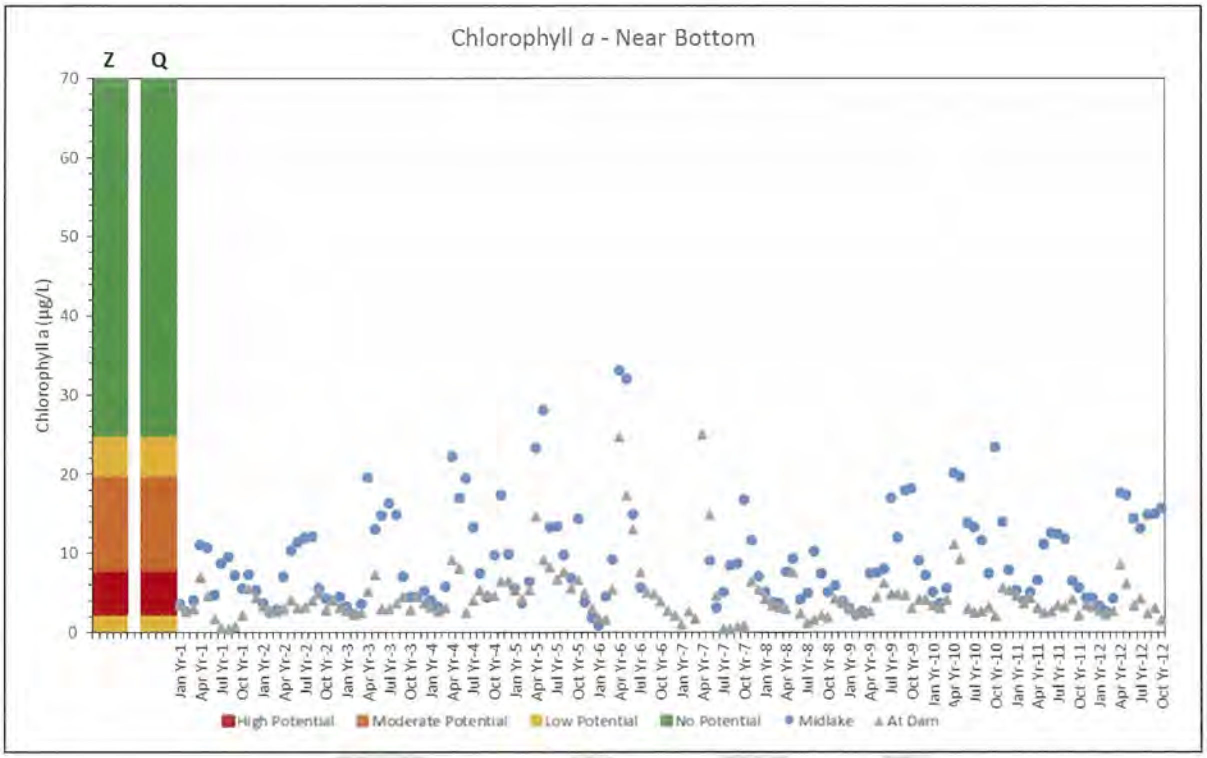
Monthly average chlorophyll *a* at the surface ranges from 0.9 to 87.8 mg/L with an overall average of 12.9 mg/L at the Mid-Lake Site, and from 1.7 to 61.3 mg/L and overall average of 9.3 mg/L at the Near Dam site (Table 4). Over the 12-year period, these levels are mostly in a range that have moderate to high potential for supporting nuisance infestations of both species of dreissenid mussels (Figure 11). However, the reservoir surface frequently switches to a eutrophic or highly eutrophic state during the summer when very high levels of algae could negatively affect mussel populations (Figure 11).

Figure 11. Surface Chlorophyll *a* Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR



Monthly average bottom chlorophyll *a* ranges from 0.9 to 33.1 mg/L with an overall average of 9.3 mg/L at the Mid-Lake Site, and from 0.3 to 25.0 mg/L and overall average of 4.5 mg/L at the Near Dam site (Table 4). Over the 12-year period, reservoir bottom levels of chlorophyll *a* are mostly in a range that have moderate to high potential for supporting nuisance infestations of both species of dreissenid mussels (Figure 12). However, the reservoir bottom occasionally switches to a eutrophic or highly eutrophic state that could negatively affect mussel populations (Figure 12).

Figure 12. Bottom Chlorophyll *a* Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR



Total Phosphorus

If the system is phosphorus-limited, total phosphorus (TP) concentrations can influence algae levels in the water, with greater biomasses of algae occurring at higher total P. Because dreissenid mussels feed on certain types of algae, TP can be used as a criterion for predicting mussel presence and abundance (Mackie and Claudi, 2010), especially when chlolorphyll *a* data is not available. Chlorophyll *a* data, when available, should be used as the primary direct indicator of the trophic status of a water body, with nutrients such as TP only as supporting data.

Exceedingly high or exceedingly low trophic levels of algae can potentially limit dreissenid mussel survival and establishment in a body of water (see section on chlorophyll *a*), and there are lower and upper threshold levels for TP (and related algal production) that affect mussel survival. As such, the TP criteria for assessing the risk of infestation in lakes and reservoirs are the same for zebra and quagga mussels (Tables 2 and 3). There is no likelihood of long term survival of mussels in very low (< 5 µg/L) or very high (> 50 µg/L) TP environments. Low potential for larval development and nuisance infestations exists for waters with 5-10 µg/L and 35-50 µg/L of TP, moderate potential for nuisance mussel infestations exists between TP levels of 10 and 25 µg/L, and high potential for heavy infestation occurs between TP levels of 25 and 35 µg/L (Mackie and Claudi 2010, Tables 2 and 3).

Modelled TP levels at the surface and bottom indicate consistently hypereutrophic conditions in the BDAR (Figures 13 and 14). Monthly average TP at the surface ranges from 184.4 to 286.2 µg/L with an overall average of 223.4 µg/L TP at the Mid-Lake Site, and from 183.8 to 290.2 µg/L and overall average of 225.4 µg/L TP at the Near Dam site (Table 4). Monthly average bottom TP ranges from 184.3 to 267.1 µg/L with an overall average of 228.8 µg/L TP at the Mid-Lake Site, and from 184.0 to 290.2 µg/L and overall average of 235.3 µg/L TP at the Near Dam site (Table 4). Hypereutrophic levels of surface and bottom TP indicate that there is no potential for mussel survival and nuisance mussel infestations to develop in the BDAR (Figure 13 and 14). However, chlorophyll-a data indicate that such high TP levels do not always translate into prohibitively high algal levels for mussels in the BDAR, and actual trophic conditions may be more suitable for mussels than the TP data indicates.

Figure 13. Surface Total Phosphorus Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR

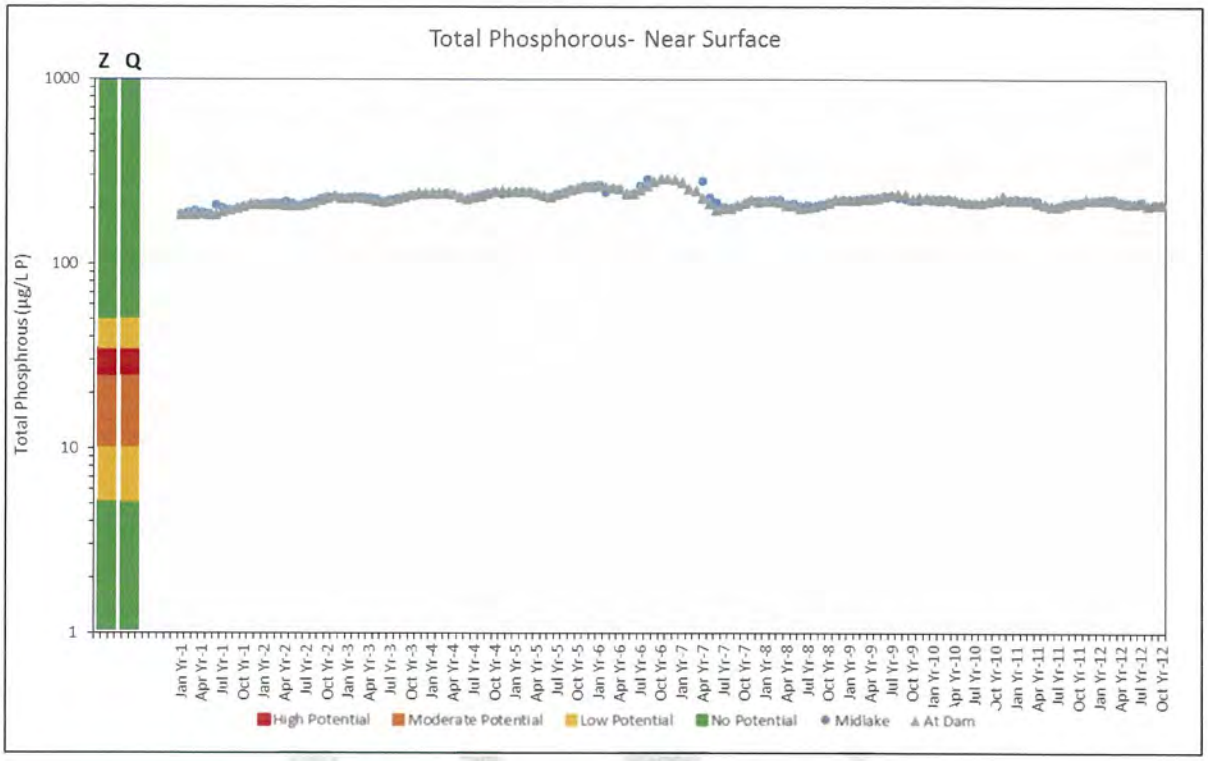
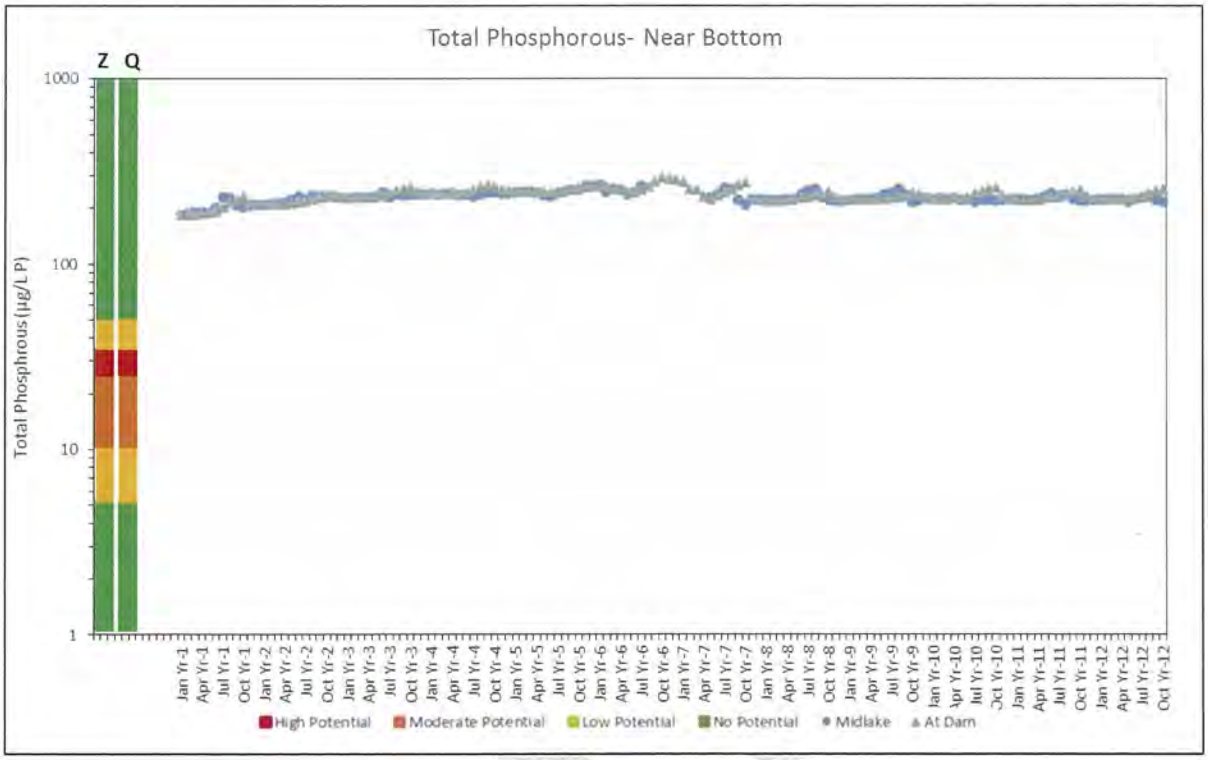


Figure 14. Bottom Total Phosphorus Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR



Total Nitrogen

If the system is nitrogen-limited, total nitrogen (TN) levels can influence algae levels in the water, with greater biomasses of algae occurring at higher total N. Because dreissenid mussels feed on algae, TN can also be used as a criterion for predicting mussel presence and abundance (Mackie and Claudi, 2010), especially when chlolorphyll *a* data is not available. Chlorophyll *a* data, when available, should however be used as the primary indicator of the trophic status of a water body, with TN only as supporting data.

As with TP, exceedingly high or exceedingly low trophic levels of algae driven by TN levels can potentially limit dreissenid mussel survival and establishment in a body of water (see section on chlorophyll *a*), and there are lower and upper threshold levels for TN (and related algal production) that affect mussel survival. The TN criteria for assessing the infestation potential of a body of water are the same for zebra and quagga mussels. Habitats with TN concentrations less than 75 µg/L or greater than 750 µg/L will have no potential for mussel colonization. Waterbodies with TN concentrations between 75 to 150 µg/L or 525 to 750 µg/L will have low infestation potential. Waterbodies with TN concentrations between 150 to 375 µg/L will have moderate infestation potential, and with concentrations between 375 to 525 µg/L will have high infestation potential.

Modelled TN levels at the surface and bottom indicate consistently hypereutrophic conditions in the BDAR (Figures 15 and 16). Monthly average TN at the surface ranges from 859.2 to 1,820.8 µg/L with an overall average of 1,105.4 µg/L TN at the Mid-Lake Site, and from 853.5 to 1,699.3 µg/L and overall average of 1,014.3 µg/L TN at the Near Dam site (Table 4). Monthly average bottom TN ranges from 859.7 to 1,804.8 µg/L with an overall average of 1,121.5 µg/L TN at the Mid-Lake Site, and from 854.5 to 1,750.6 µg/L and overall average of 1,069.0 µg/L TN at the Near Dam site (Table 4). Hypereutrophic levels of surface and bottom TN indicate that there is no potential for mussel survival and nuisance mussel infestations to develop in the BDAR (Figure 15 and 16). However, chlorophyll-a data indicate that such high TN levels do not always translate into prohibitively high algal levels for mussels in the BDAR, and actual trophic conditions may be more suitable for mussels than the TN data indicates.

Figure 15. Surface Total Nitrogen Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR

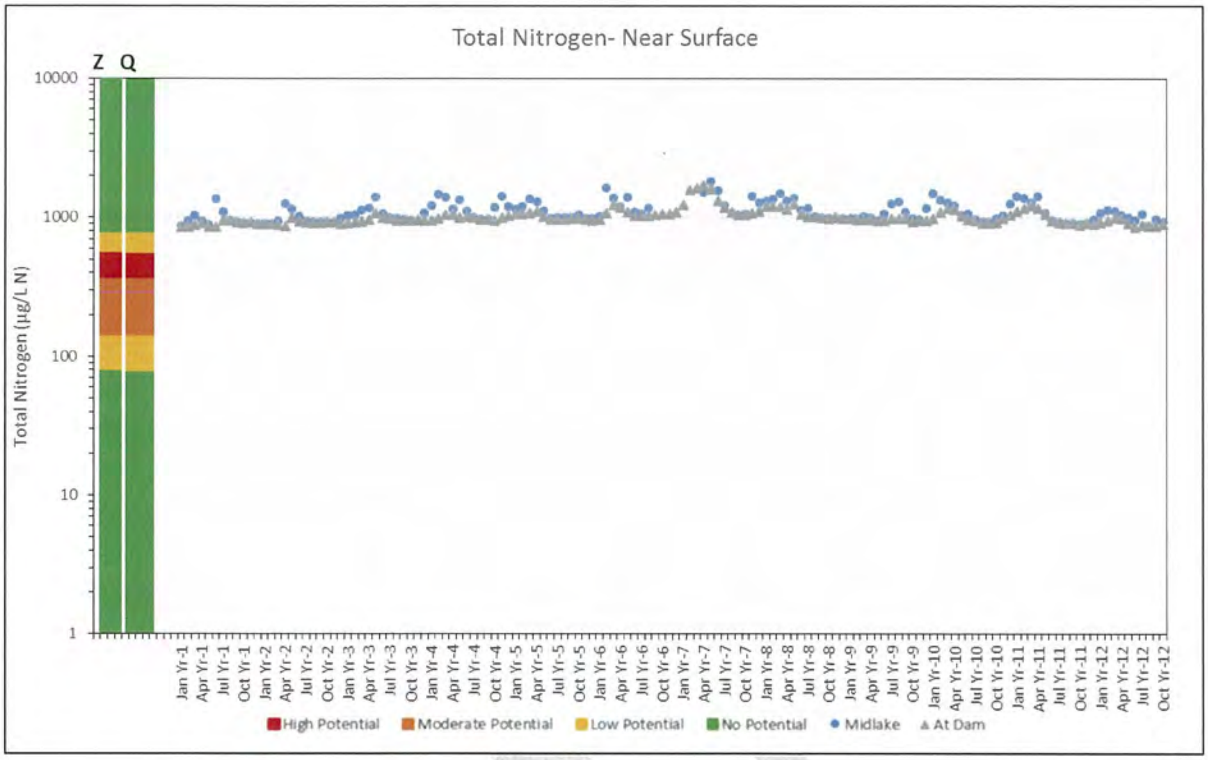
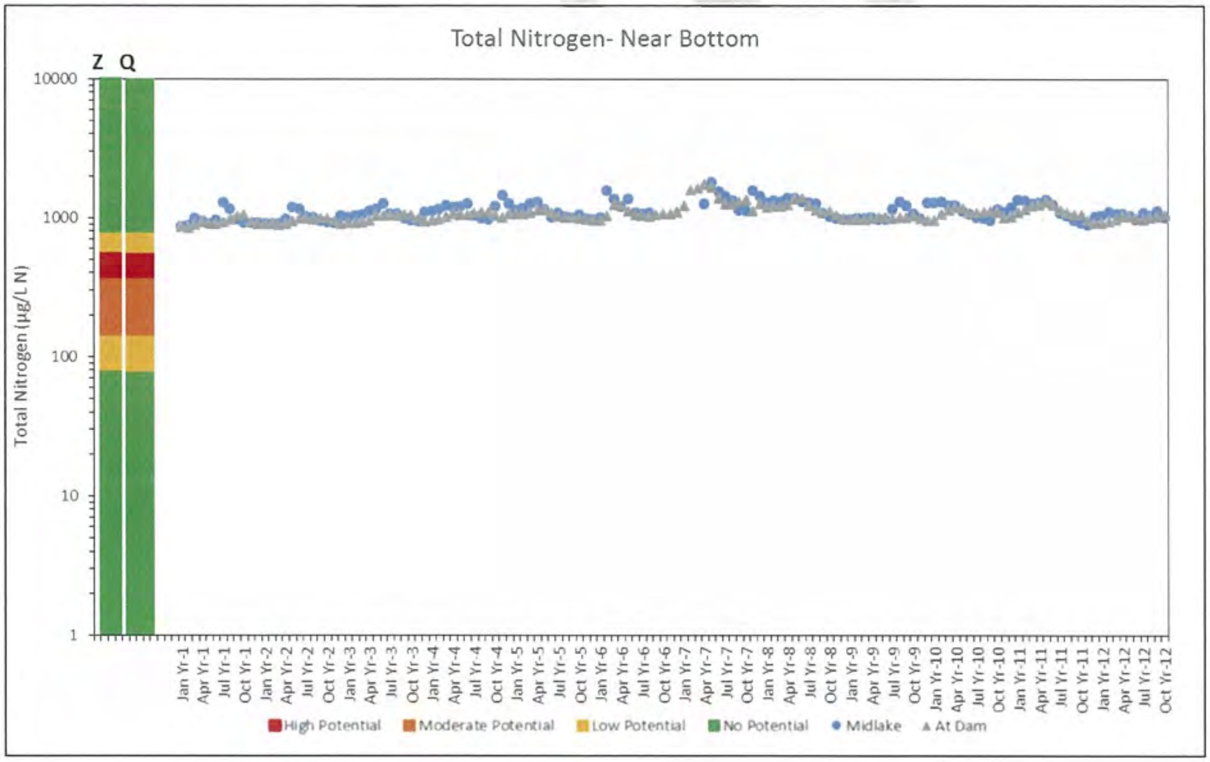


Figure 16. Bottom Total Nitrogen Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR



Mussel Infestation Potential Based on Physical Variables

This section describes the infestation potential for dreissenid mussels in the BDAR based physical water quality variables such as water temperature, total dissolved solids, and total suspended solids that are modeled for the Mid-Lake and Near Dam locations in the proposed reservoir.

Water Temperature

Dreissenid mussels have a wide range of water temperature tolerances, but like all mollusks, quagga and zebra mussels have upper and lower lethal temperature limits. While dreissenid mussels (and especially quagga mussels) can live at temperatures approaching freezing, production of gametes, and hence spawning, stops below 10°C for zebra mussels. Although quagga mussels are known to spawn at temperatures down to 4-5°C, production of veligers is relatively low at these temperatures. Reduced veliger production and growth at low temperatures reduces the IP of dreissenid mussels. Similarly, infestation risk is greatly reduced as water temperatures approach the upper lethal limits for zebra mussels (26-32°C, depending on acclimation temperatures) and quagga mussels (> 28 °C). Infestation risk is generally moderate to high between 10°C and 26°C for zebra mussels and 10°C and 28°C for quagga mussels (Tables 2 and 3).

It should be noted that mussels acclimated to warmer seasonal temperatures within lakes and reservoirs in Texas could have slightly higher upper tolerance limits for water temperatures. For example, studies conducted by UT Arlington researchers (Dr. Robert McMahon's team) on zebra mussels in Lake Texoma indicated that the mussels appeared to spawn and settle in the spring of 2011 after water temperatures rose above 18-20°C, and ceased settlement after temperatures reached 28°C. However, mussels have been shown to be adaptive to higher temperatures and have been seen to spawn and settle at temperatures as high as 32°C in Lake Texoma.

Water temperatures varied seasonally and spatially in the BDAR over the 12-yr period (Figures 17 and 18). Average surface water temperature was 17.5 °C at both sites in the BDAR and well within the lower and upper temperature limits that would favor growth and reproduction. Based on modelled water temperatures, peak seasons for growth and reproduction are likely to be limited to spring, summer and fall in the BDAR. IP at the BMD site varied between moderate to high, depending on seasonal water temperatures. Summer water temperatures are not expected to be limiting to mussel colonization in the BDAR.

Figure 17. Surface Water Temperature Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR

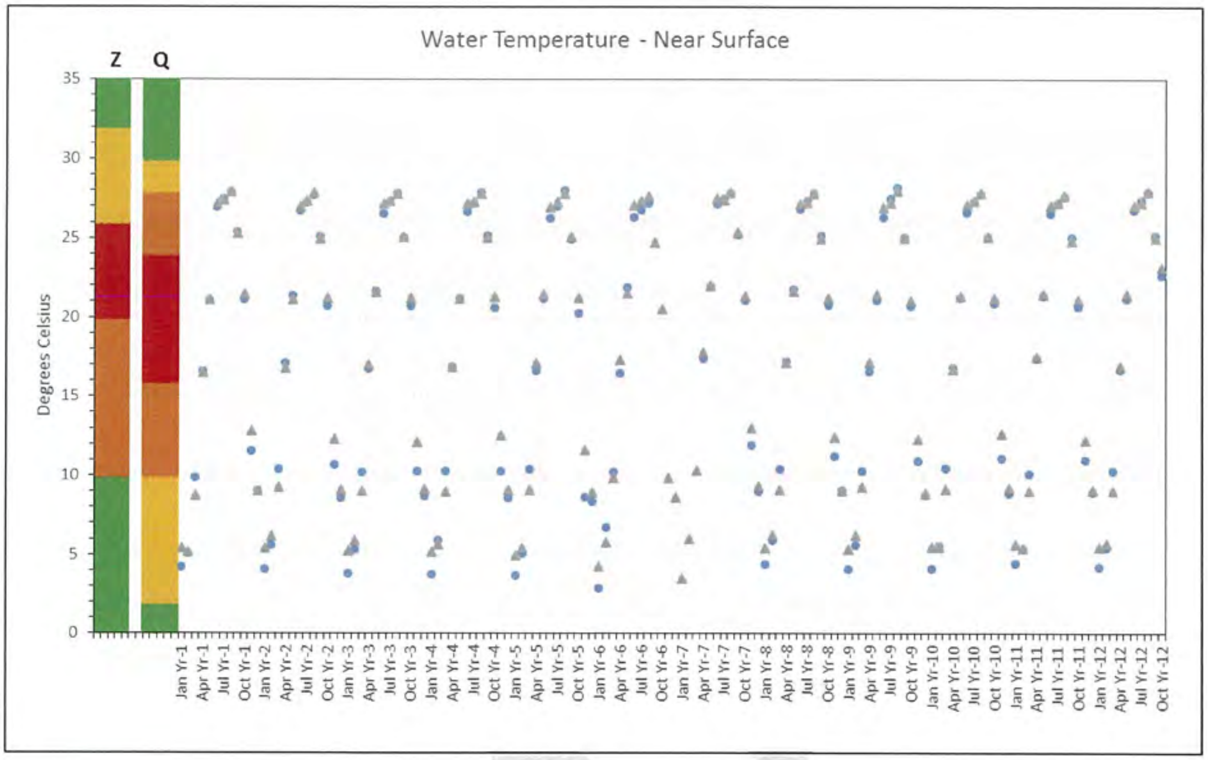
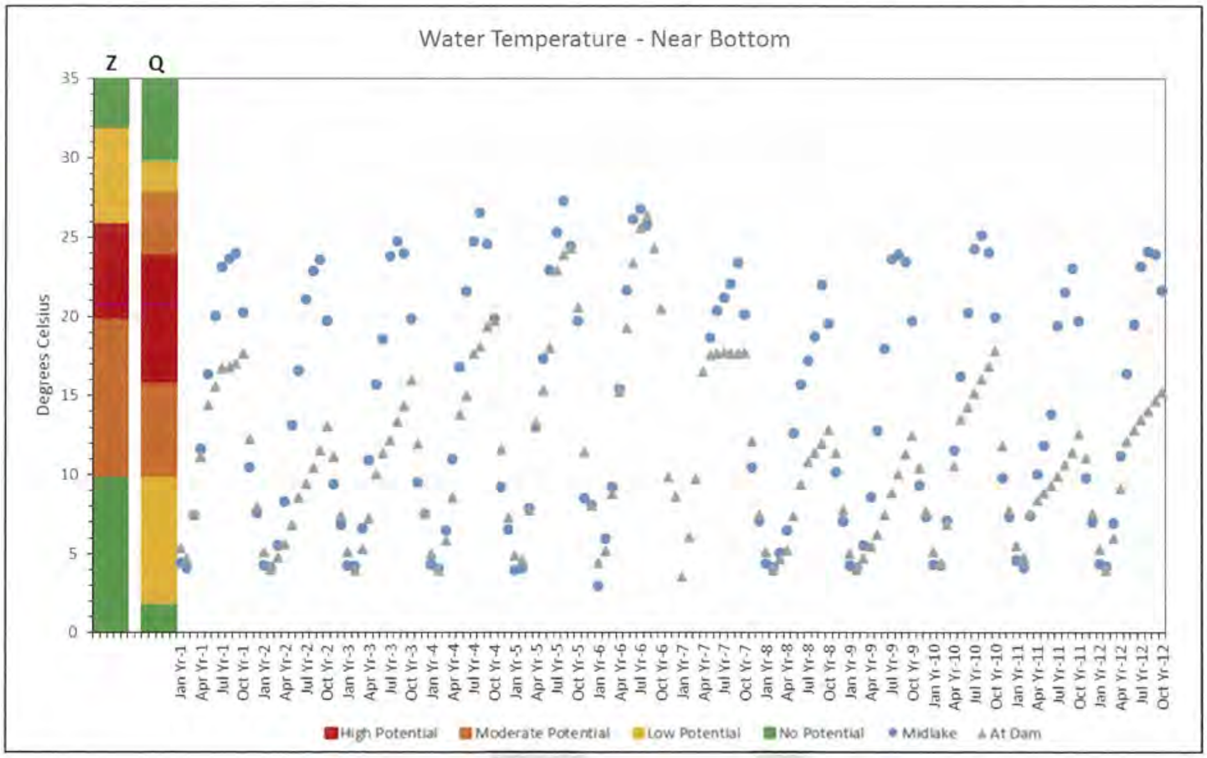


Figure 18. Bottom Water Temperature Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR



Total Dissolved Solids

Total dissolved solids (TDS) is a measure of the total concentration of cations and anions dissolved in water. As such, TDS serves as a surrogate measure for the salinity of water bodies. Dreissenid mussels are essentially known as freshwater organisms, but can tolerate brackish water with TDS levels up to 5,000 mg/L fairly well. Above this TDS level, spawning becomes increasingly unlikely. Generally, habitats with high potential for massive infestations will have TDS ranging from 70 up to 5,000 mg/L. Water bodies with TDS ranging from 5,000 to 8,000 mg/L will have moderate potential for nuisance infestations, whereas habitats with TDS ranging from 8,000 to 10,000 mg/L will have little potential for larval development and infestation. Water bodies with TDS exceeding 10,000 mg/L have no potential for mussel infestations.

Habitats with very low TDS levels (< 70 mg/L) can also be detrimental to mussels due to the lack of essential cations and anions in the water that are needed by the mussels for various metabolic processes and growth. At low TDS ranges, habitats with moderate potential for massive infestations will have TDS ranging from 40 to 70 mg/L. Water bodies with TDS ranging from 20 to 40 mg/L will have little potential for larval development and infestation, and with TDS below 20 mg/L will have no potential for mussel infestations.

Monthly TDS levels at the surface and bottom at both sites in the BDAR are consistently in a range (97.7 to 466.4 mg/L) that would indicate high potential for massive mussel infestation (Table 4; Figures 19 and 20).

Figure 19. Surface Total Dissolved Solids Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR

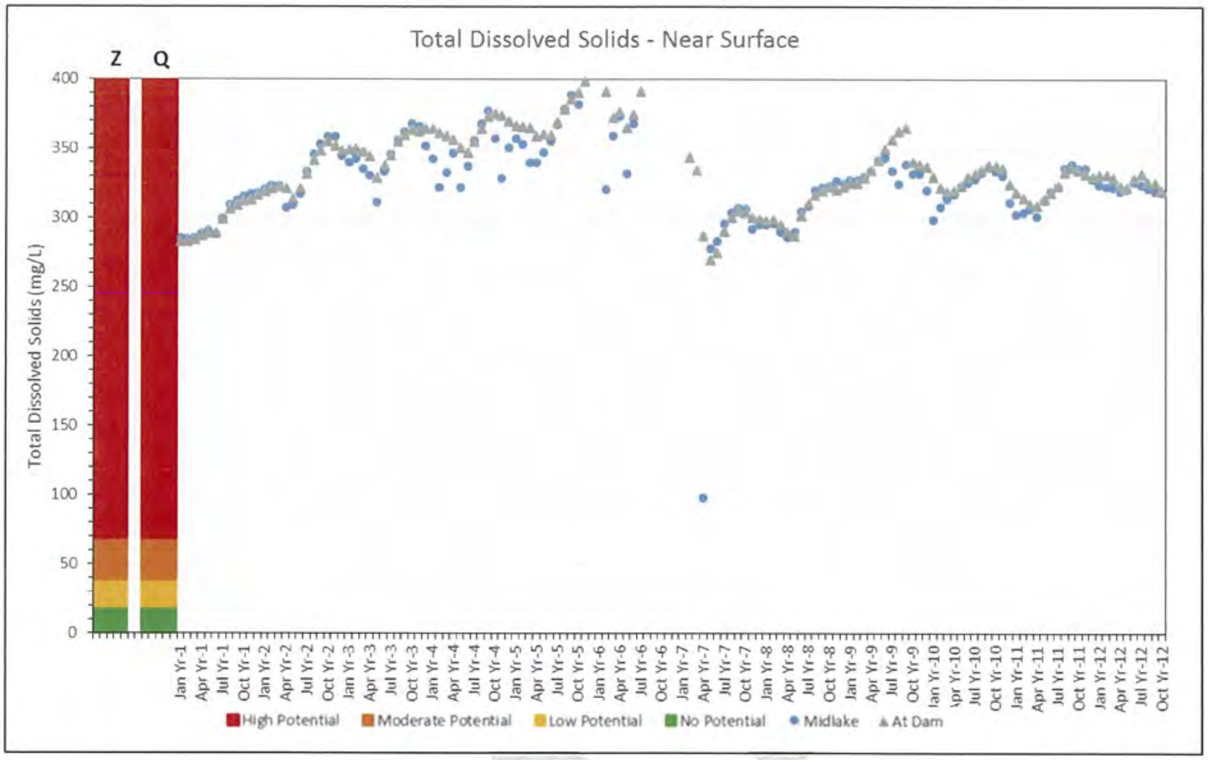
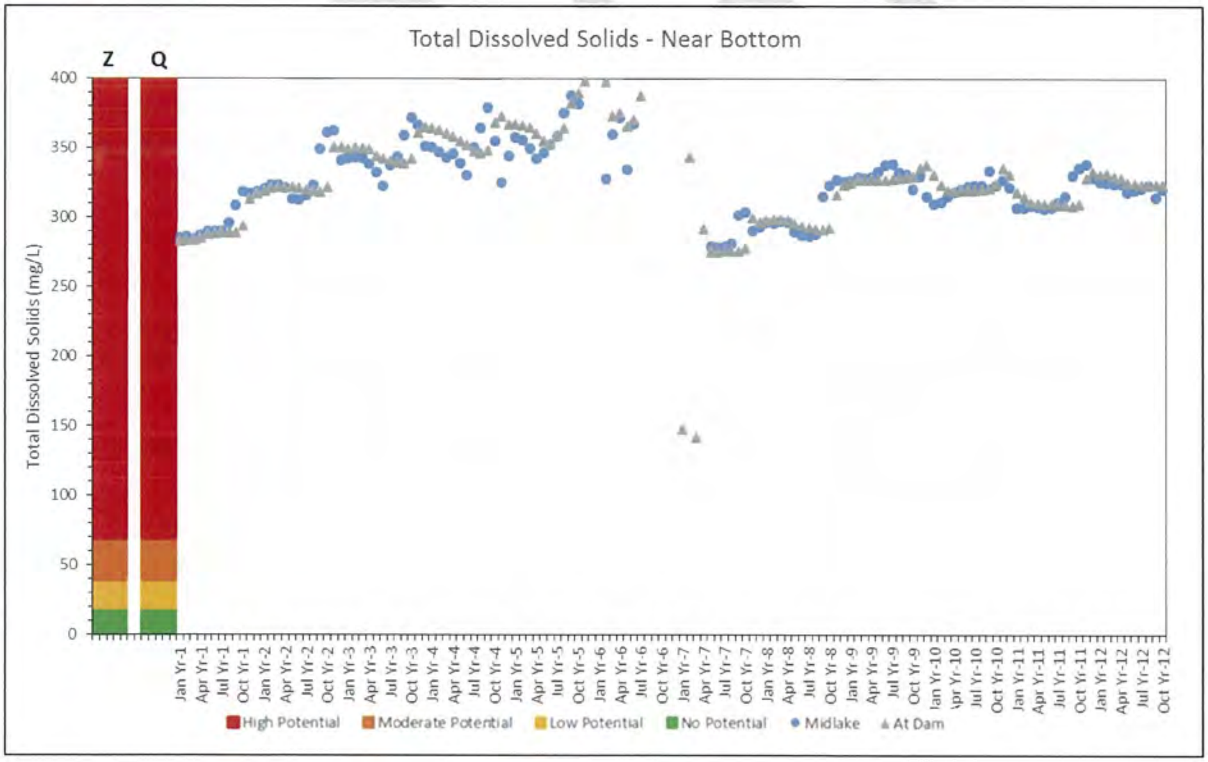


Figure 20. Bottom Total Dissolved Solids Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR



Total Suspended Solids

Total suspended solids (TSS) contribute directly to the turbidity of water and as such, TSS and turbidity are closely related variables. Madon et al. (1998) have reported that the particle clearance, food ingestion, food assimilation rates and growth potential of zebra mussels are all greatly reduced at high loads of suspended sediment (a component of TSS). Dreissenid mussels cannot establish and survive in waters where TSS levels exceed 96 mg/L (Tables 2 and 3). Water bodies with TSS levels of 28-96 mg/L typically have low risk of infestation, at TSS levels of 8-28 mg/L have moderate infestation risk, and below 8 mg/L have high infestation risk (Tables 2 and 3).

Monthly TSS levels at the surface and bottom at both sites in the BDAR are consistently in a range (0.1 to 6.6 mg/L) that would indicate high potential for massive mussel infestation (Table 4; Figures 21 and 22).

Figure 21. Surface Total Suspended Solids Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR

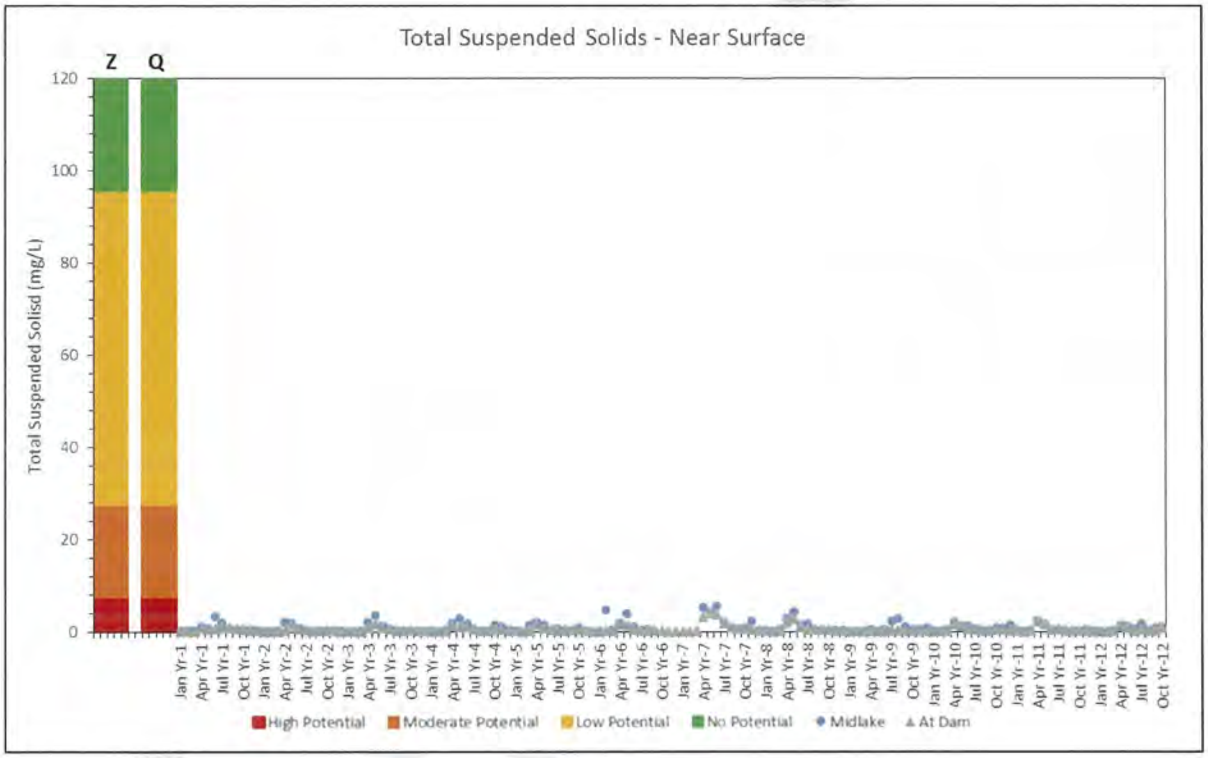
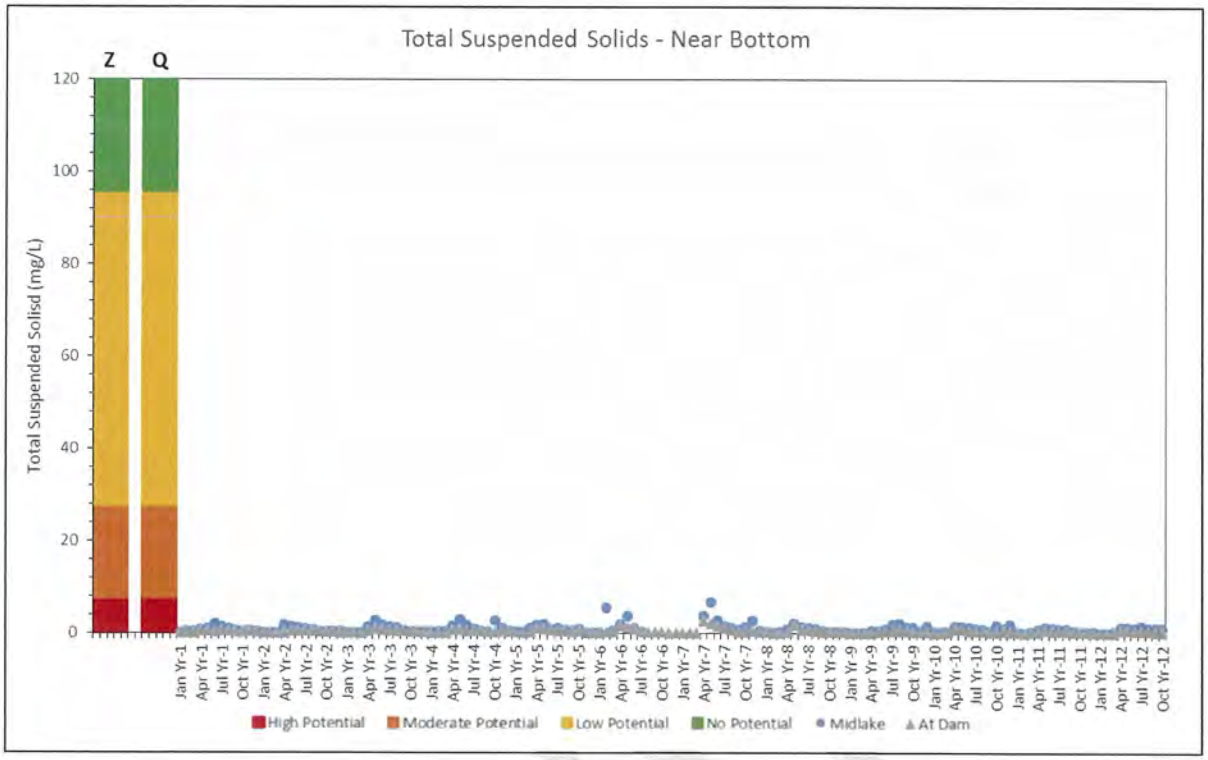


Figure 22. Bottom Total Suspended Solids Levels and Potential Levels of Infestation of Zebra Mussels (Z) and Quagga Mussels (Q) in the BDAR



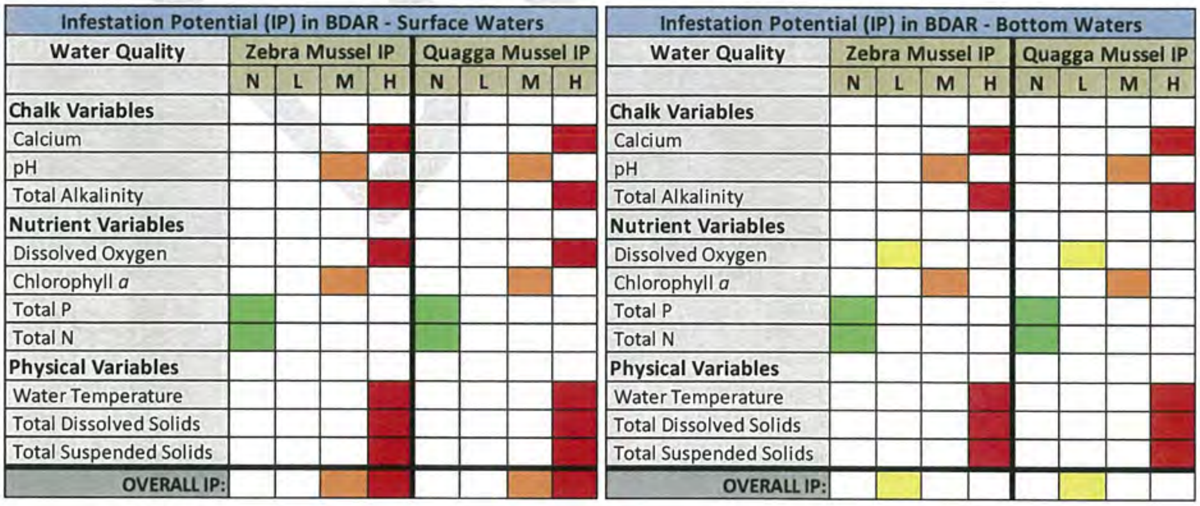
Conclusions

Summary of Mussel Infestation Risk Potential in the Bois D'Arc Reservoir

Based on water quality modeling for the two sites in the BDAR, the risk of infestation of surface waters ranges from moderate to high, with little risk of infestation in bottom waters (Figure 23).

Figure 23. Mussel infestation risk potential in surface (left) and bottom (right) waters of the BDAR

Combined for both sites due to similar infestation risk.



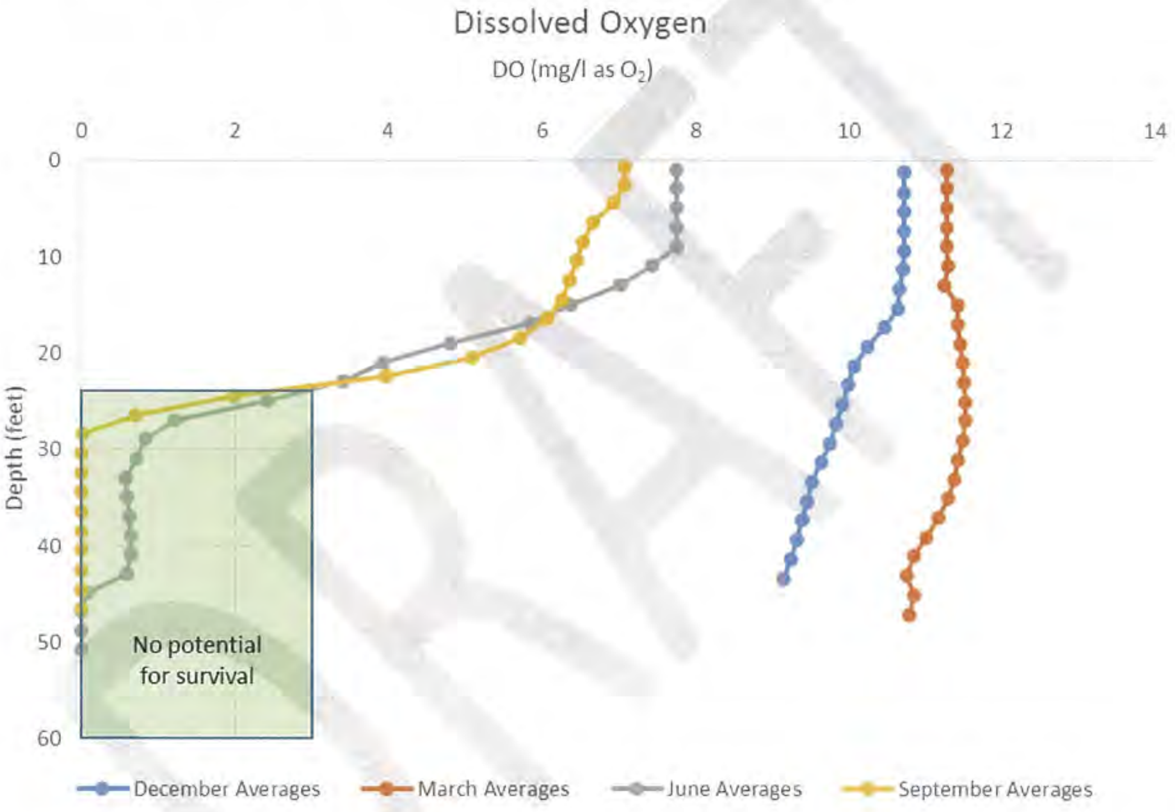
Infestation Potential (IP) in BDAR - Surface Waters								
Water Quality	**Zebra Mussel IP**				**Quagga Mussel IP**			
	N	**L**	**M**	**H**	**N**	**L**	**M**	**H**
Chalk Variables								
Calcium				🟥				🟥
pH			🟧				🟧	
Total Alkalinity				🟥				🟥
Nutrient Variables								
Dissolved Oxygen				🟥				🟥
Chlorophyll *a*			🟧				🟧	
Total P	🟩				🟩			
Total N	🟩				🟩			
Physical Variables								
Water Temperature				🟥				🟥
Total Dissolved Solids				🟥				🟥
Total Suspended Solids				🟥				🟥
OVERALL IP:			🟧	🟥			🟧	🟥

Infestation Potential (IP) in BDAR - Bottom Waters								
Water Quality	**Zebra Mussel IP**				**Quagga Mussel IP**			
	N	**L**	**M**	**H**	**N**	**L**	**M**	**H**
Chalk Variables								
Calcium				🟥				🟥
pH			🟧				🟧	
Total Alkalinity				🟥				🟥
Nutrient Variables								
Dissolved Oxygen		🟨				🟨		
Chlorophyll *a*			🟧				🟧	
Total P	🟩				🟩			
Total N	🟩				🟩			
Physical Variables								
Water Temperature				🟥				🟥
Total Dissolved Solids				🟥				🟥
Total Suspended Solids				🟥				🟥
OVERALL IP:		🟨				🟨		

Of all the water quality parameters evaluated for surface waters, only total P and total N were identified as being very limiting to zebra and quagga mussels at both sites, in ranges high enough to potentially cause high levels of algal production that could limit filter feeding by mussels. However, a more direct estimate of algal production, chlorophyll-a, indicated algal food levels in ranges sufficient to adequately support mussel infestations. All other surface water quality parameters are at levels at which the risk of mussel infestation is high.

Bottom waters will have little risk of mussel infestation primarily because dissolved oxygen levels are frequently limiting at deeper depths in the BDAR. Even though all other physical and chalk variables, and chlorophyll-a levels are in ranges that will support mussel infestations, low dissolved oxygen (< 3 mg/L) throughout the summer months at depths in excess of approximately 25 feet (Figure 24) will limit mussel infestations to shallower depths in the reservoir.

Figure 24. Seasonal vertical profiles of dissolved oxygen in the BDAR



In summary, based on the water quality modeling, the BDAR is susceptible to infestation and colonization by invasive zebra and quagga mussels. Proactive measures to limit the translocation of mussels from other infested water bodies in Texas to the BDAR, along with a monitoring program for early identification of any potential infestations would serve as an important first step in an overall strategy for managing invasive species in this reservoir.

References

Claudi, R., and T. Prescott. 2009. Assessment of the Potential Impact of Invasive Mussels on Water System Facilities and Structures and Recommendations on Control – Pueblo Reservoir, Fryingpan-Arkansas Project. Report Prepared for the Eastern Colorado Area Office, USBR. February 23, 2009.

Mackie, G. L. and R. Claudi. 2010. Monitoring and Control of Macrofouling Mollusks in Fresh Water Systems. CRC Press. 508 p.

Madon, S. P., D. W. Schneider, J. A. Stoeckel, and R. E. Sparks. 1998. Effects of inorganic sediment and food concentrations on energetic processes of the zebra mussel, *Dreissena polymorpha*: Implications for growth in turbid rivers. Canadian Journal of Fisheries and Aquatic Sciences 55: 401-413.

McMahon, R. F. 1996. The physiological ecology of zebra mussel, *Dreissena polymorpha*, in North America and Europe. American Zoologist 36: 339-363.

Texas Parks and Wildlife Department (TPWD). 2015. The zebra mussel threat. Online article.

Whittier, T. R., P. L. Ringold, A. T. Herlihy, and S. M. Pierson. 2008. "A Calcium-based Invasion Risk Assessment for Zebra and Quagga Mussels (*Dreissena spp).*" *Frontiers in Ecology and the Environment 6*, doi: 10.1890/070073.

Appendix C
Saint Paul Regional Water Services Case Study: Management of Water Quality in Vadnais Lake and Pleasant Lake Reservoirs

Appendix C

Saint Paul Regional Water Services Case Study: Management of Water Quality in Vadnais Lake and Pleasant Lake Reservoirs

Saint Paul Regional Water Services (SPRWS) serves a population of approximately 415,000 people located in the City of Saint Paul and neighboring communities. The distribution system serving these areas consists of about 1,100 miles of water mains, 130 MG of water storage, 10 booster stations, and 5 pressure zones. Annual average water use is about 45 mgd. Peak daily demand is around 80 mgd.

The SPRWS obtains most of its source water from the Mississippi River, which is pumped from the Fridley Pump Station and travels through a chain of lakes located about 6 miles north of St. Paul. The major lakes in the chain include Lake Charles, Pleasant Lake, Sucker Lake, and Lake Vadnais. The chain of lakes has a combined watershed area of approximately 29 square miles, a water surface of about 1,600 acres, a total volume of 8 billion gallons and an available supply of 3.6 billion gallons. In addition, Centerville Lake and 10 groundwater wells provide a back-up water source.

All water is treated at the McCarrons Water Treatment Plant (WTP) located in the City of Maplewood. The treatment process includes lime softening, recarbonation, granular activated carbon (GAC) and sand filtration, and chlorine/chloramines for disinfection. Finished water is pumped into the distribution system from a pump station located at McCarrons water plant. The water plant was constructed in 1920–22 and has been enlarged and modernized over the years. Recent upgrades include enhanced security, updated plant automation, new office facilities, upgraded chemical feed systems, expanded sludge dewatering, new lake aeration systems, and new GAC filter media in existing filters.

Water quality management has been active since 1986 to Mississippi River water pumped to the chain of lakes, drainage to the lakes, and to two reservoirs: Pleasant Lake and Vadnais Lake (Table 1). The detailed chronology has several milestones. In summary, there been substantial improvements to reservoir raw water quality as consequence of ferric injection to Mississippi River water transfer to the chain of lakes and to drainages, hypolimnetic aeration and oxygenation, and ferric injection to aeration/oxygenation systems. The purpose of reservoir water quality improvements is to improve raw water quality reaching the treatment plant.

Based on the dates above the water quality data for Vadnais and Pleasant have been compared by the different treatment regimes. All data analysis is based on June-September Data. Surface samples are form samples collected from zero to three meters in depth. Hypolimnion samples are ones collected ten meters or below.

In documenting the effect of water quality improvement actions, it is important to understand although Mississippi River phosphate-P concentrations dropped since reservoir monitoring began in 1984, the drop would not be significant to reservoir water quality (Figure 1).

Statistical comparison of water quality between various phases of management strategy reveals large, successive improvements with regard to chlorophyll-a, surface TP, hypolimnion TP, hypolimion Mn, and hypolimnion Fe from 1984-2015 at each water quality management milestone (Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, Figure 7, and Figure 8). Note that the Pleasant Lake hypolimnetic aeration system ceased to function in 2007 and was replaced with hypolimnetic oxygenation in late 2013.

Table 1.
Key Dates For SPRWS Lake Improvements

Date	Project	Comments
1984	Beginning of Data collection No treatment on any lake	
November 1986	Aeration System installed at Vadnais	Problems with compressors and flexible fabric caused system replacement 2 ½ years
April 1987	Initiation of Ferric Chloride Feed at Mississippi River Intake	
1998	Ferric Feed piloted on Vadnais Lake	10 metric tons dosed into the lake in the first year.
1990	Aeration towers replaced in Vadnais Lake	
August 1994	Aeration System Installed on Pleasant Lake	Need to look into winter operation. May not have been operated year round for more than 1 year
2007	Pleasant Lake Aeration system ceased operations based on blower data logs	
Summer 2011	Aeration System removed from both Pleasant and Vadnais	
Fall 2011	Oxygenation system installed in Vadnais Lake	
Fall 2013	Oxygenation system installed in Pleasant Lake	

Table 1.

Key Dates For SPRWS Lake Improvements

Date	Project	Comments

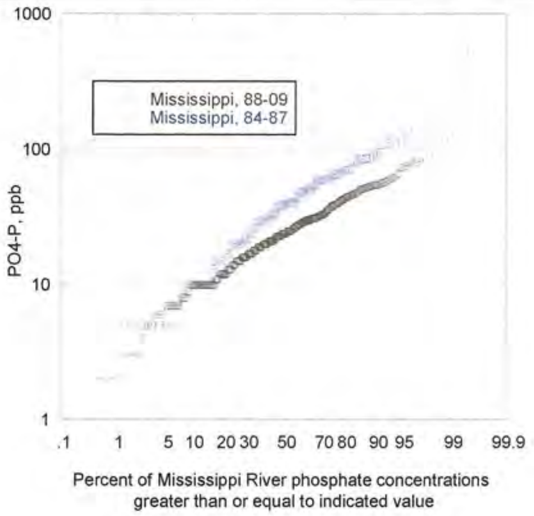


Figure 1. Historic frequency distribution of Mississippi River phosphate-P 1984-2009 as measured at the pump station

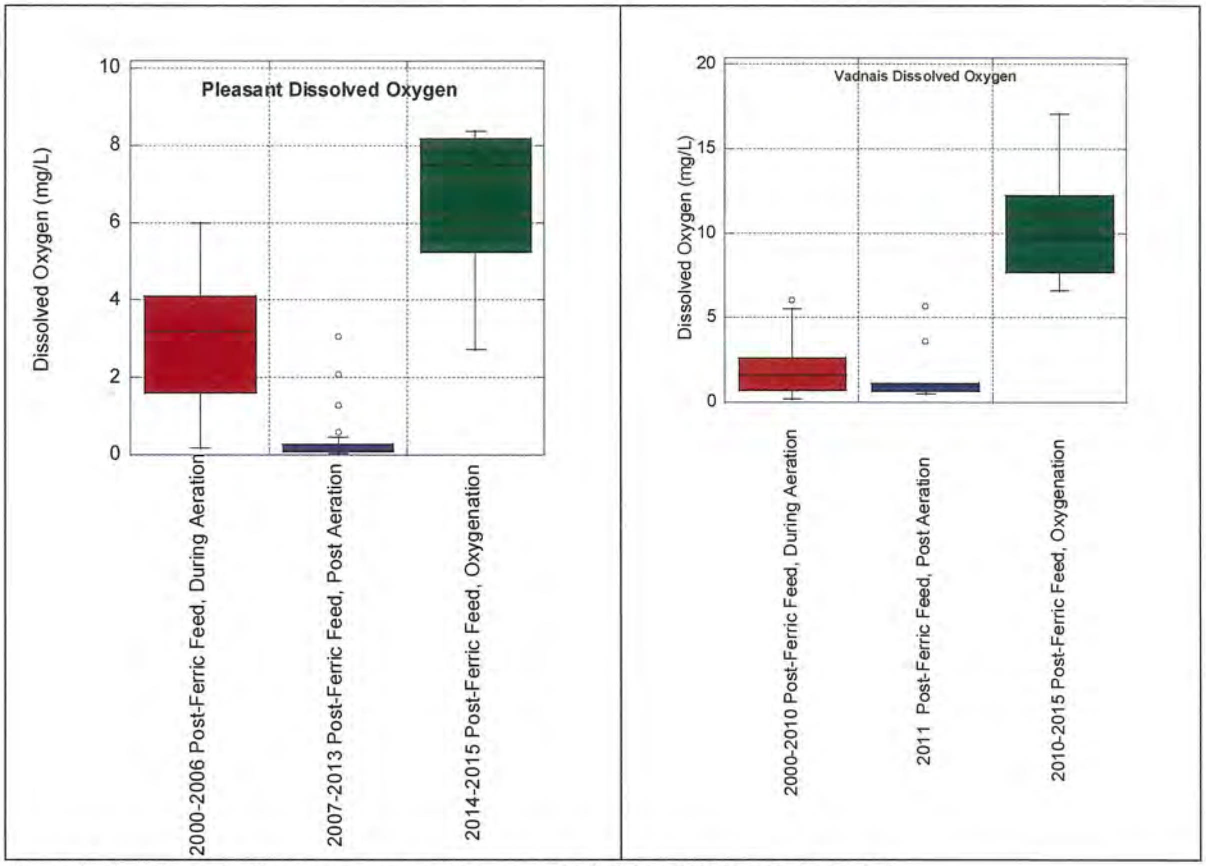


Figure 2. Hypolimnetic dissolved oxygen in Pleasant Lake (left) and Vadnais Lake (right).

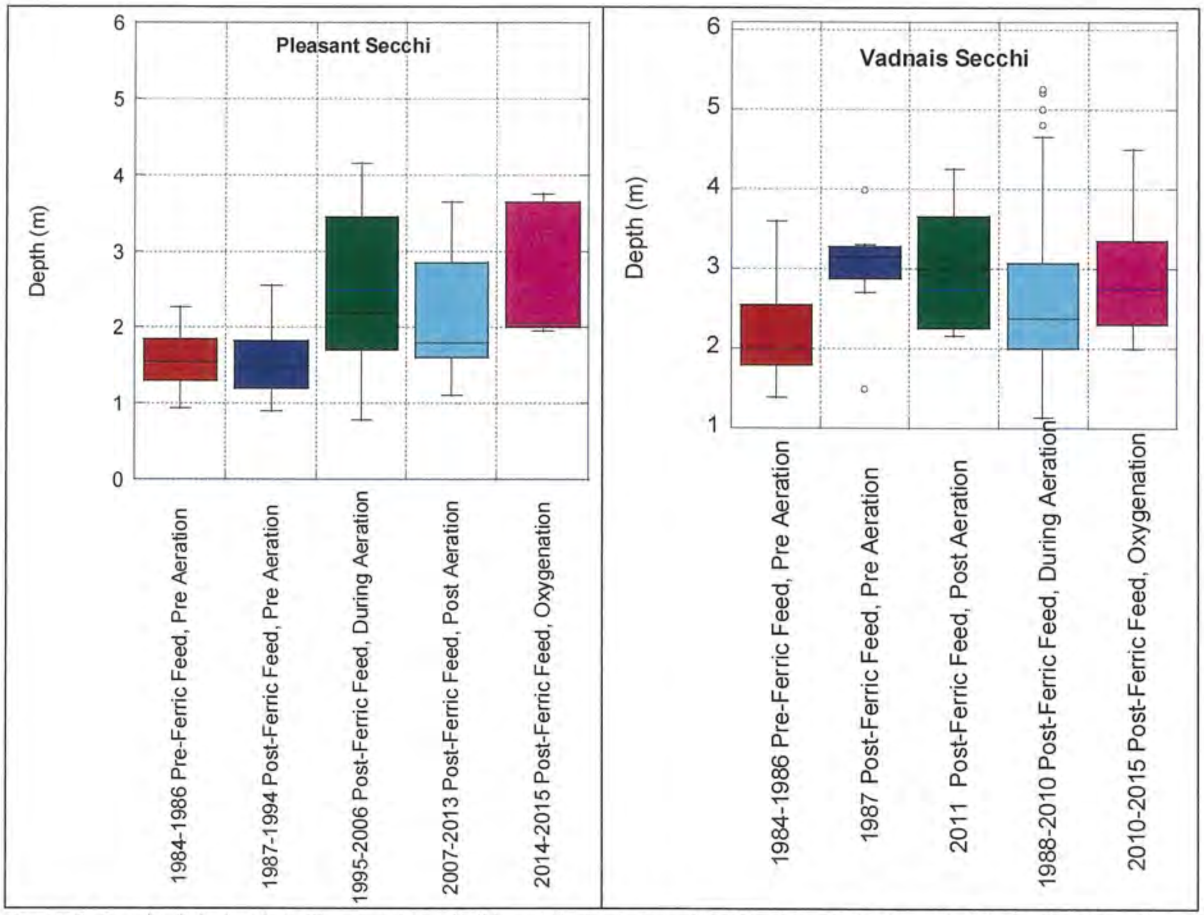


Figure 3. Secchi disk depth in Pleasant Lake (left) and Vadnais Lake (right). Note that a Secchi disk depth of 2 m is threshold over which cyanobacteria blooms are rarely observed[1]

---

[1] Graham, J. L., et al. (2004). "Environmental factors influencing microcystin distribution and concentration in the Midwestern United States." Water Research **38**(20): 4395-4404.

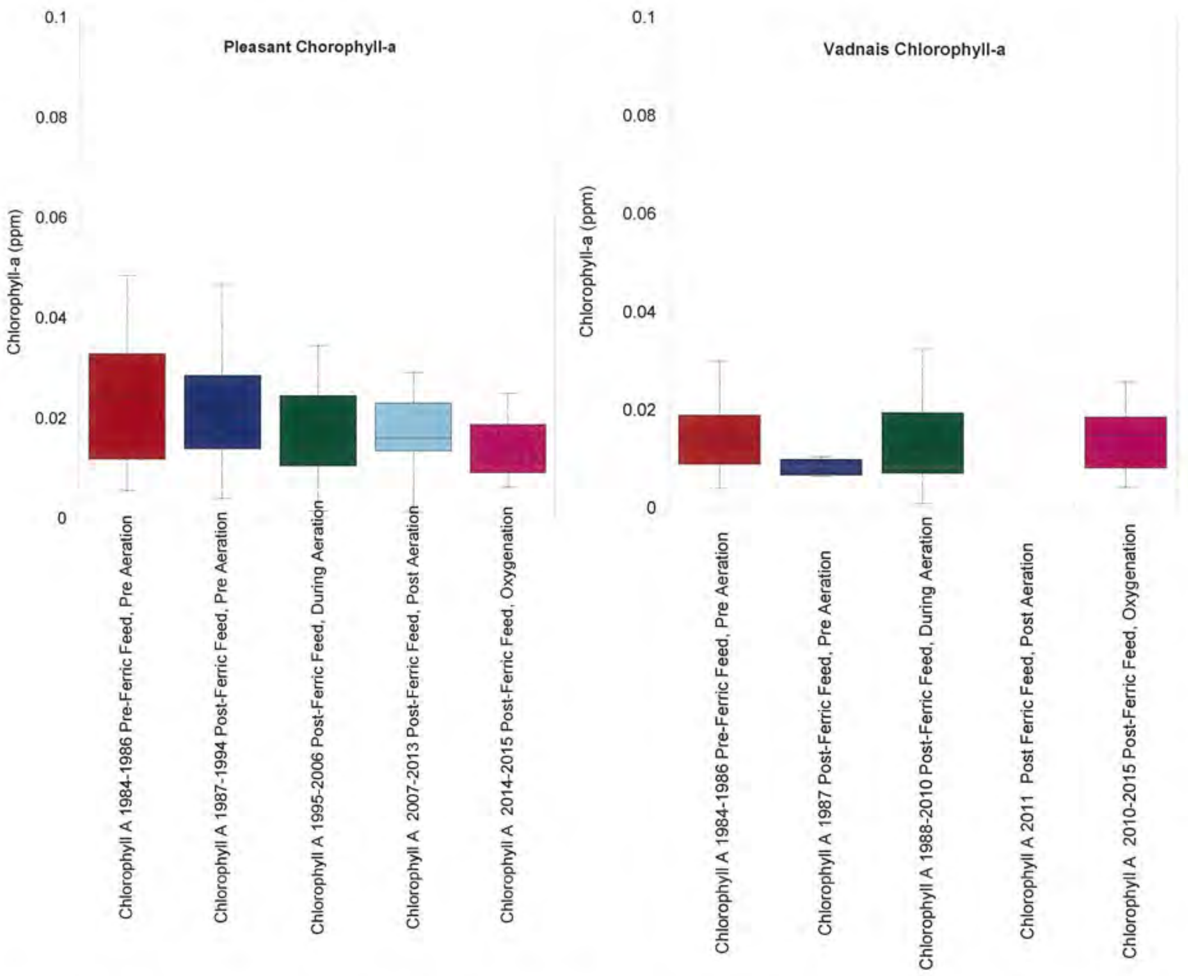


Figure 4. Chlorophyll-a in Pleasant Lake (left) and Vadnais Lake (right). Note that Vadnais Lake is downstream of Pleasant Lake.

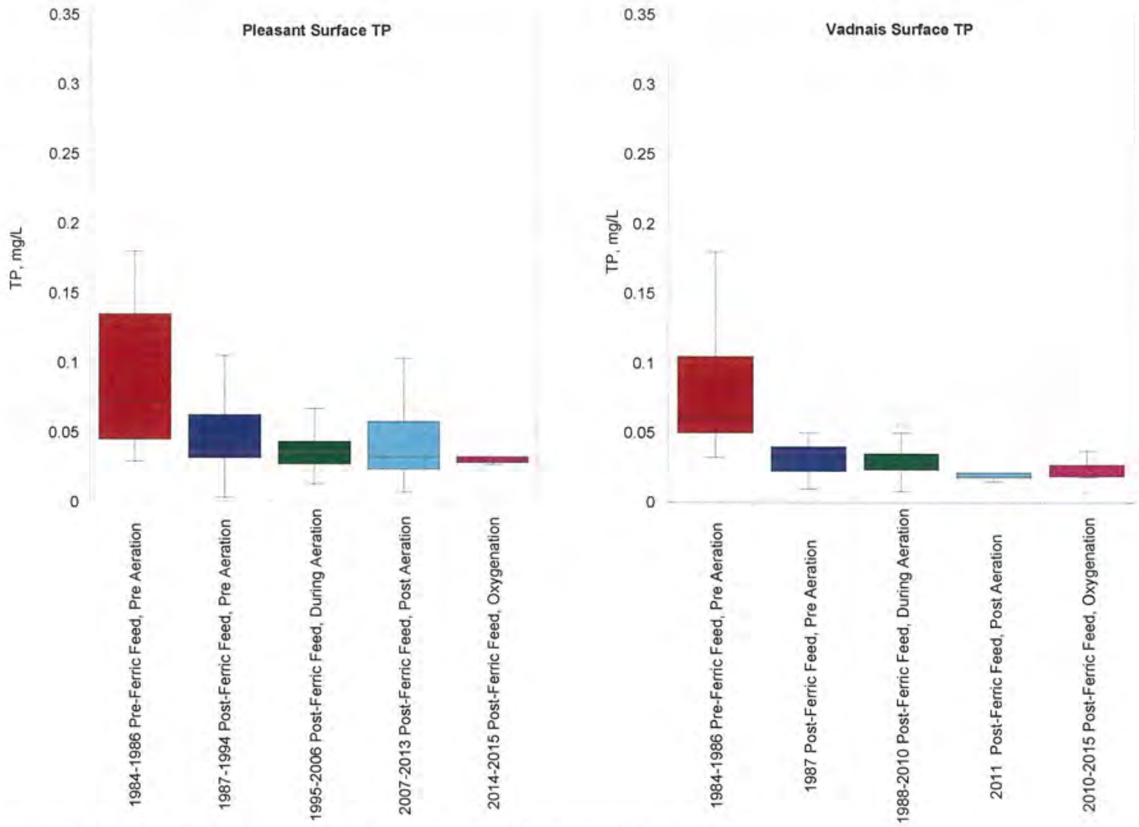


Figure 5. Surface TP in Pleasant lake (left) and Vadnais lake (right)

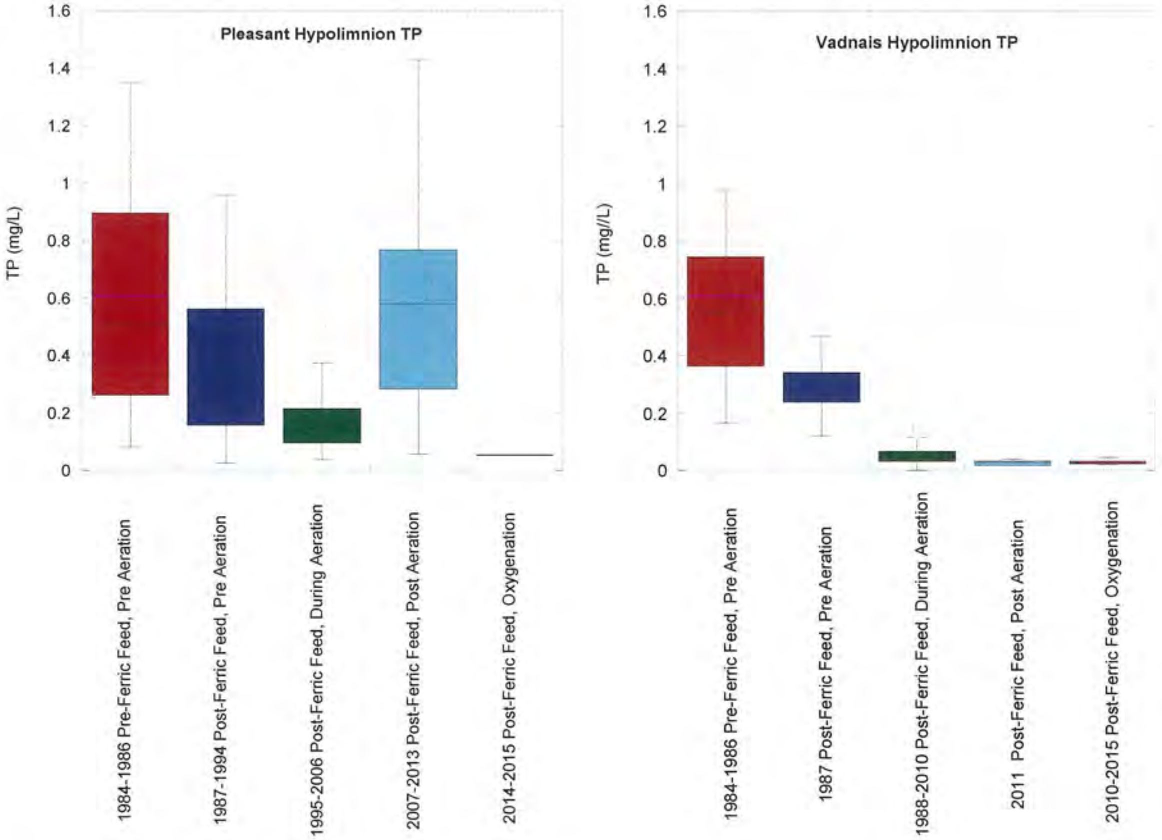


Figure 6. Hypolimion TP in Pleasant Lake (left) and Vadnais Lake (right)

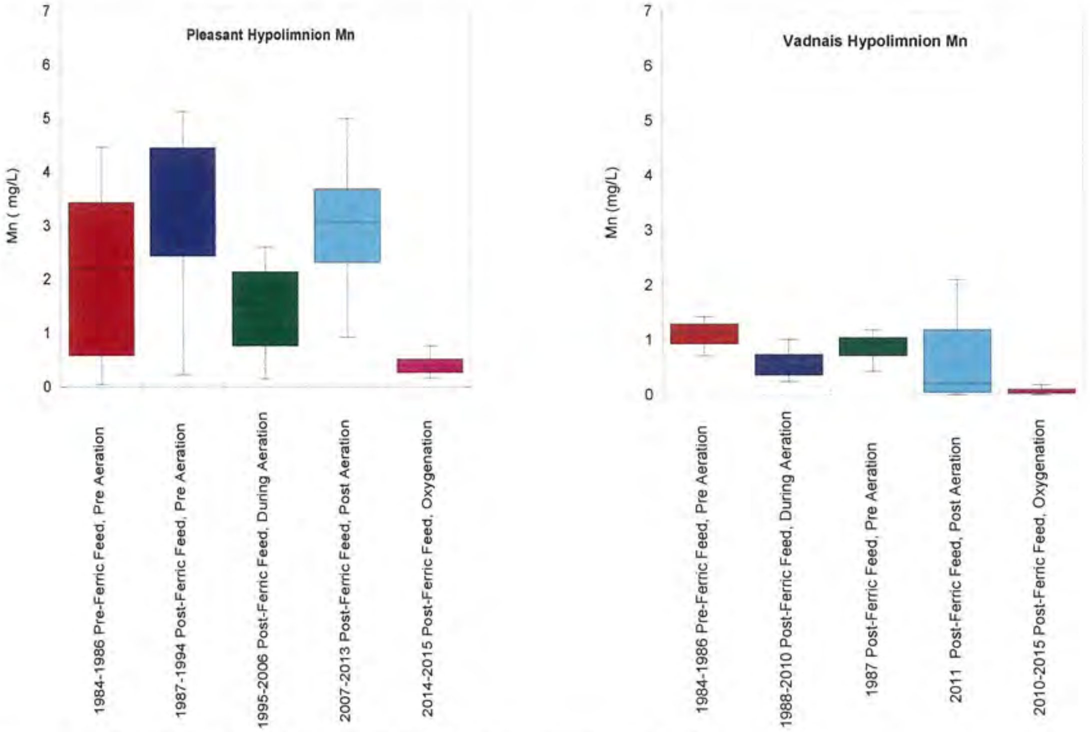


Figure 7. Hypolimion Mn in Pleasant Lake (left) and Vadnais Lake (right)

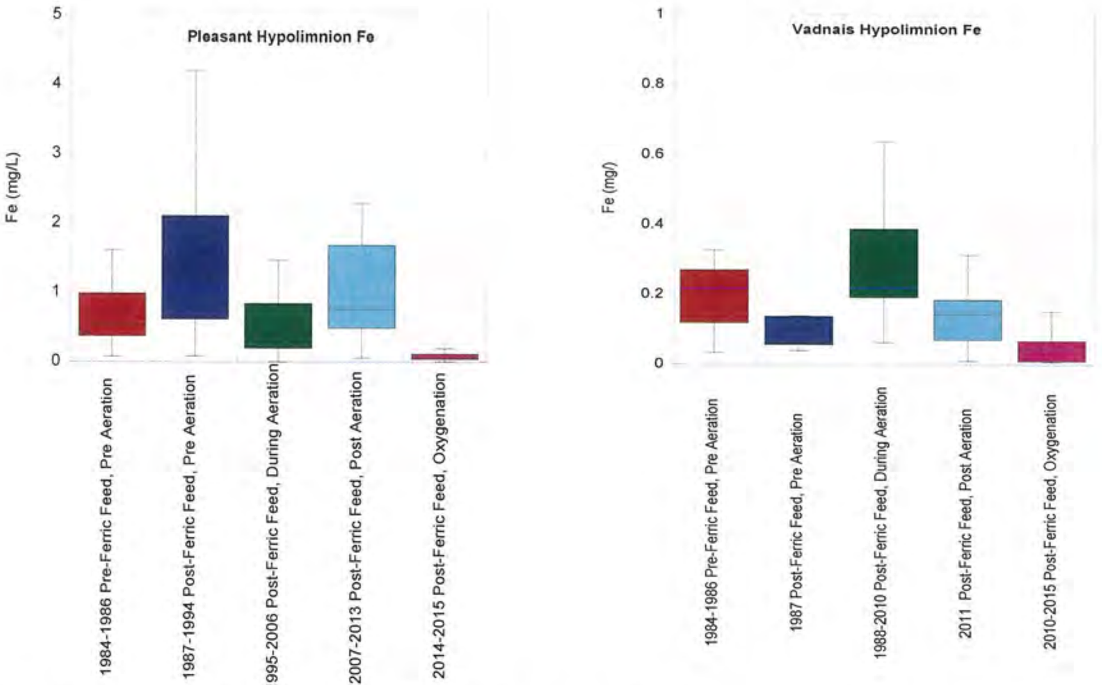


Figure 8. Hypolimion Fe in Pleasant Lake (left) and Vadnais Lake (right)

TECHNICAL MEMORANDUM

Conceptual Cost Projection

PREPARED FOR: North Texas Municipal Water District

PREPARED BY: CH2M HILL
Released for the purposes of review by Edward M. Motley,
PE Number 48243

DATE: December 2015

Introduction

This technical memorandum presents a budget-level (AACE International Class 4) estimate of construction costs for the Leonard Water Treatment Plant, Phase 1. These projections are based on construction cost data accumulated through January 2015.

These estimates reflect the projected construction costs of a 70-million-gallon-per-day (mgd) conventional surface water treatment plant with the following unit processes:

- Rapid mix
- Flocculation
- Sedimentation (with plate settlers)
- Ozonation
- Biologically active filtration
- Chemical feed
  - Polymer
  - Chlorine dioxide
  - Ferric sulfate
  - Chlorine
  - Sodium hydroxide
  - Ammonia
  - Fluoride
  - Hydrogen peroxide
  - Sulfuric acid
- Backwash water recovery
- Sludge thickening
- Sludge lagoons

All unit processes are designed for 70 mgd except for the following:

- Raw water influent control is designed for 280 mgd.
- Oxone contact basins are designed for 140 mgd. This configuration provides for more efficient plant operation at buildout with only four ozone basins.
- The ozone generation building will be sized for 140 mgd but equipped for 70 mgd.
- Filter units are designed for 70 mgd at an initial loading rate of 4 gallons per minute per square foot and 140 mgd at a target loading rate of 8 gallons per minute per square foot. This configuration will allow for expansion of the plant to 140 mgd without constructing additional filters, after

demonstrating to Texas Commission on Environmental Quality the higher rate treatment capability of the filters.

- The chlorine and ammonia buildings are sized to store enough chemical for the 280-mgd plant because of the common size of rail cars and ammonia storage tanks. Feed equipment will only be provided for the 70-mgd plant.

These estimates also include the following ancillary facilities:

- An administration building with the following:
  - Offices for plant management and administration
  - Water quality laboratory
  - Control room
  - Locker facilities
  - Break room
  - Training room
- 19,000-square-foot maintenance facility
- 10,000-square-foot maintenance warehouse
- 1-mile rail spur and turnout
- 1-mile water and wastewater utility extensions
- Site access roads and internal paving
- Site electrical distribution

These costs do not include the following:

- High service pump station
- Electrical substation
- Offsite electrical transmission lines
- Improvements to the mainline railroad

These cost projections are also based on the following assumptions:

- Excavations are common with no hard rock.
- There is no significant groundwater.
- The electrical substation is located near the treatment facilities.
- There are no stormwater treatment systems.

Projected Costs

Table 1 lists projected costs.

Table 1. Projected Costs

Processes	Projected Cost ($)
Raw Water Influent Control	2,350,000
Rapid Mix/Flocculation	3,190,000
Sedimentation	8,000,000
Ozonation	15,250,000
Filtration	20,480,000
Clearwells	9,700,000
Backwash Recovery	4,450,000
Sludge Thickeners	2,390,000
Sludge Lagoons	15,600,000

Table 1. Projected Costs

Processes	**Projected Cost ($)**
Backwash Pump Station	1,740,000
Chemicals	4,400,000
Chlorine	5,000,000
Ammonia	3,500,000
Administration/Operations	2,500,000
Maintenance	2,800,000
Utility Extensions (water and sewer)	1,290,000
Rail Spur and Turnout	830,000
Yard Piping	11,000,000
Site Work	4,700,000
Plant Computer System	3,810,000
Site Electrical	6,575,000
Total Hard Cost	**129,555,000**
Overhead, Bonds, Insurance, and Profit (23.5%)	30,445,000
Subtotal	160,000,000
Contingency (25%)	40,000,000
Total Projected Construction Cost	**200,000,000**

TECHNICAL MEMORANDUM

Leonard WTP Off-site Utilities

PREPARED FOR:	North Texas Municipal Water District
PREPARED BY:	Erika Cooper, PE
DATE:	November 5, 2015
PROJECT:	384 Leonard Water Treatment Plant; CH2M PN 666460
APPROVED BY:	Ed Motley, CH2M HILL

North Texas Municipal Water District (NTMWD) has contracted with CH2M HILL Engineers, Inc. (CH2M HILL) to design the Leonard Water Treatment Plant (WTP). The plant site will be located on a 333-acre parcel in the southwestern portion of a 1,120 acre tract purchased by NTWMD for the Lower Bois d'Arc Creek Water Supply Project. Water and wastewater service will be needed at the Leonard WTP, which will be approximately 1.5 miles west of Leonard, Texas. A site location map is provided in Figure 1. The purpose of this Technical Memorandum is to identify and evaluate options for providing water and wastewater service to the plant.

Water Service

The primary source for water service for the Leonard WTP will be treated water from the plant. However, a backup supply is recommended to meet plant domestic and fire protection needs during periods when the plant is shut down. An external water supply will also be necessary during construction of the Leonard WTP.

Water Demand

The estimated water demand for the Leonard WTP was calculated in order to identify and evaluate water service options.

Domestic Water Demand. Anticipated domestic water flow for the plant was estimated using Texas Commission on Environmental Quality (TCEQ) guidance on maximum daily water demands for various facilities as listed Table A in 30 TAC 290.45(d)(1). For a factory, which is the use most similar to a WTP, this demand is 24 gallons per capita per day (gpcd). Assuming 30 people work at the Leonard WTP, this equates to approximately 720 gallons per day (gpd), or 0.5 gallons per minute (gpm). This does not include any water required for processes at the WTP.

Fire Protection Water Demand. For estimating necessary fire flows for the Leonard WTP, the National Fire Protection Association (NFPA) 1 Fire Code, Chapter 18 was consulted. It was assumed plant buildings would be Type II construction (non-combustible) with two-hour fire resistive construction. Given these assumptions and a fire flow area of 70,900 square feet (SF) or less, the required fire flow is 2,750 gpm for a two-hour duration.

Construction Water Demand. Water service will be required during construction of the Leonard WTP. Assuming approximately 50 gpd per worker and approximately 30 workers, the construction water demand is 1,500 gpd, or 1.0 gpm. Water will also be needed to fill and test various WTP processes during construction. The maximum volume of water needed for this purpose is not quantified at this time.

Water Service Options

Three options for providing water service to the Leonard WTP have been identified:

- Connect to the West Leonard Water Supply Corporation (WLWSC) water system.
- Connect to the City of Leonard water system.
- Construct an on-site water well.

For each option, the water distribution infrastructure necessary was identified and conceptual level construction costs were estimated. The water service must be sufficient to meet the estimated plant domestic and fire protection needs during periods when the WTP is shut down. Given the minimal domestic water demand, the required fire flow is the controlling factor in sizing piping and determining pumping and storage needs.

WLWSC. The WLWSC holds the Certificate of Convenience and Necessity for water supply to the Leonard WTP site. A 6-inch water line would need to be constructed from the WLWSC system to the WTP (see Figure 2). The WLWSC system does not have sufficient storage capacity for fire protection; therefore, supplemental onsite storage and pumping facilities would have to be constructed, along with a water distribution system for the plant. A firm pumping capacity of 2,750 gpm would be required to meet projected fire flows. Three horizontal pumps sized for 1,375 gpm are recommended to provide this capacity. Based on the two hour fire duration at this flow, the volume of storage required would be 330,000 gallons. To prevent water quality issues resulting from stagnation, stored water would need to be periodically discharged to allow refilling. As such, multiple ground storage tanks (GSTs) would be needed to ensure sufficient volume for fire flows during periods of emptying and refilling. With four tanks, each sized for 110,000 gallons, the necessary water volume for fire protection could be met with one tank out of service. NTMWD would have to pay water usage fees to WLWSC for the water service. Additionally, there would be operations and maintenance (O&M) costs associated with the pump station, storage tanks, and water piping and appurtenances. The infrastructure needs, associated costs, and advantages and disadvantages for obtaining water service from WLWSC are summarized in Table 1.

City of Leonard. If the Leonard WTP site were to be annexed into the City of Leonard, water service could be provided by the City under an inter-local agreement with the WLWSC. The City of Leonard water system is fed by three wells located on the north side of the City. There is a 50,000 gallon GST and a 200,000 elevated storage tank in the distribution system. Connection to the City of Leonard system would require construction of a 6-inch water line from an existing 6-inch water line along Westlake Road just north of FM 4965 to the plant site (see Figure 2). In meeting with the City of Leonard, the flow and pressure available at the proposed point of connection are not known. It should be noted that this connection point is on a dead-end line at the far west end of the City of Leonard distribution system. This raises some concerns regarding available flow and pressure at the connection point. There are fire hydrants along Westlake Road that could be tested to obtain this information. At this point it is assumed supplemental onsite storage and pumping facilities similar to those described above would have to be constructed to meet required fire flows. Reliability is also a concern when connecting at a dead end line as any line breaks or maintenance would interrupt service. NTMWD would have to pay water usage fees to the City of Leonard for the water service and would have O&M costs associated with the pump station, storage tanks, and water piping and appurtenances. The infrastructure needs, associated costs, and advantages and disadvantages for obtaining water service from the City of Leonard are summarized in Table 1.

On-site Water Well. In lieu of obtaining water from the WLWCS or the City of Leonard, a water well could be drilled at the Leonard WTP to provide water for domestic and fire protection needs. A major issue with installing a well for water service is restrictions on water withdrawal rates. The Leonard WTP will be located in Fannin County, which is part of the Red River Groundwater Conservation District (GCD). This GCD manages groundwater resources through the implementation of conservation, augmentation, and management strategies. Given the likely limitations on groundwater usage, this option would also require supplemental onsite storage and pumping facilities sized for fire flows. NTMWD would have O&M costs associated with the well, pump station, storage tanks, and water piping and appurtenances. In addition, there would be water usage fees required by the GCD. Table 1 summarizes the infrastructure needs, associated costs, and advantages and disadvantages for an on-site water well.

Table 1. Comparison of Water Service Options
Leonard WTP Off-site Utilities

Water Service Option	Infrastructure	Estimated Construction Cost	Advantages	Disadvantages
WLWSC	LF 6-inch PVC (connection point & length not determined)	Not quantified	Closer in proximity for connection than City of Leonard	Limited storage capacity in system Long-term reliability of water source is questionable
	Pump station (3-1,375 gpm pumps)	$1,600,000		
	Water storage (4-110,000 gal GSTs)	$1,040,000		
	Water distribution yard piping	$20,000		
	Total Cost for WLWSC Service	> $ 2,640,000		
City of Leonard	8,000 LF 6-inc PVC	$750,000	Greater storage capacity in system than WLWSC	Requires over 1.5 miles of water piping for interconnection
	Pump station (3-1,375 gpm pumps)	$1,600,000		
	Water storage (4-110,000 gal GSTs)	$1,040,000		
	Water distribution yard piping	$20,000		
	Total Cost for City of Leonard	$3,410,000		
On-site Water Well	Water Well	$1,000,000	Does not require water piping for interconnection	Questionable reliability of water source due to increasing limitations on groundwater water withdrawal rates
	Pump station (3-1,375 gpm pumps)	$1,600,000		
	Water storage (4-110,000 gal GSTs)	$1,040,000		
	Water distribution yard piping	$20,000		
	Total Cost of On-site Water Well	$3,660,000		

Water Service Recommendations

The three options for providing water service to the Leonard WTP were evaluated, taking in to consideration estimated capital construction costs, water use fees, O&M costs and requirements, and reliability of service. Water use fees and O&M costs should be very similar for the three options. An on-site water well provides the least reliable long-term water source and has the highest estimated construction cost. While the estimated construction cost for connecting to the WLWSC water system is lower, the City of Leonard offers a more reliable water source given the well capacity, storage capacity, and distribution system. Flow and pressure testing at the fire hydrants along Westlake Road is recommended to gain a better understanding of the water supply available. With this information and more detailed information on the design of the Leonard WTP as it pertains to required fire flows, the pumping and storage capacity required can be refined and hopefully reduced.

Wastewater Service

The Leonard WTP site does not currently have wastewater service. Domestic wastewater flows for on-site plant personnel need to be addressed, along with process waste streams such as sample drains, chemical area drains, and basin blowdown drains.

Wastewater Flows

Anticipated domestic wastewater flow for the plant was estimated using TCEQ guidance on design organic loadings and flows for various facilities as listed Table B-1 in 30 TAC 217.32(a)(3). For an office building/factory, which is the use most similar to a WTP, this flow is 20 gpcd. Assuming 30 people work at the Leonard WTP, this equates to an average flow approximately 600 gpd. Applying a peaking factor of 4.0, the required capacity for wastewater piping, pumping, and treatment is 2,400 gpd, which is approximately 2 gpm. This does not include any process waste flows, which are not quantified at this time.

Wastewater Service Options

Two options for providing wastewater service to the Leonard WTP have been identified:

- Connect to the City of Leonard wastewater system.
- Construct an on-site wastewater treatment system.

For each option, the wastewater infrastructure necessary was identified and conceptual level construction costs were estimated.

City of Leonard. If the Leonard WTP site were to be annexed into the City of Leonard, wastewater service could be provided by the City. The City of Leonard wastewater system includes three lift stations and a network of wastewater collection piping. Wastewater flows would have to be conveyed to an existing 80 gpm City of Leonard lift station located on the east side of Westlake Road just north of FM 4965. This lift station pumps to a 6-inch gravity main that flows to a 100 gpm lift station. Given the area topography, construction of a lift station at the plant site would be required to convey flows via force main approximately 1.3 miles. From that point, wastewater would flow by gravity to the City lift station. TCEQ requires a minimum 4-inch diameter force main and 6-inch diameter gravity main. Manholes spaced at 500 feet maximum are required on the gravity main per TCEQ requirements. In order to maintain a minimum velocity of 2 feet per second (fps) in the force main, the lift station capacity would need to be 80 gpm. A simple duplex lift station with submersible pumps is recommended. At 80 gpm, the velocity in the gravity main would be approximately 3 fps. Figure 3 shows the wastewater infrastructure necessary for this option.

The City of Leonard indicated their system has sufficient capacity to accommodate the projected wastewater flows from the Leonard WTP. However, some improvements to City lift stations and collection system piping may be necessary to accommodate the flows from the Leonard WTP. NTMWD would have to pay wastewater fees to the City of Leonard for the service and would have O&M costs associated with the lift station and wastewater piping and appurtenances. The infrastructure needs, associated costs, and advantages and disadvantages for obtaining wastewater service from the City of Leonard are summarized in Table 2.

On-site Wastewater Treatment System. In lieu of conveying Leonard WTP wastewater flows to the City of Leonard, an on-site wastewater treatment system consisting of a septic tank and a leach field for effluent disposal could be constructed at the plant site. Per TCEQ requirements in 30 TAC 285.91(3), Table III, the wastewater usage rate for the purposes of sizing the septic tank for a factory is 15 gpcd, which equates to 450 gpd for 30 employees. Using 30 TAC 285.91(2), the required septic tank volume for this rate is 1,250 gallons. It should be noted that process waste streams from sample drains, chemical areas, and basin blowdown drains would have to be managed separately from domestic wastewater to avoid overloading the septic system. NTMWD would have O&M costs associated with the onsite treatment systems. Table 2 summarizes the infrastructure needs, associated costs, and advantages and disadvantages for an on-site wastewater treatment system.

Table 2. Comparison of Wastewater Service Options
Leonard WTP Off-site Utilities

Wastewater Service Option	**Infrastructure**	**Estimated Construction Cost**	**Advantages**	**Disadvantages**
City of Leonard	Lift station (2-80 gpm pumps)	$50,000	Minimal O&M	Requires over 1.5 mi of force main/gravity main for connection Requires lift station
	4-inch PVC force main (6,800 LF)	$480,000		
	6-invh PVC gravity main (1,200 LF)	$200,000		
	Total Cost for City of Leonard	$730,000		
On-site Wastewater Treatment System	Septic tank (1,250 gal) and leach field for domestic wastewater	$50,000	Low capital cost	More significant O&M requirements
	On-site wastewater treatment system for process wastes	$50,000		
	Total Cost of On-site Wastewater Treatment System	$100,000		

Wastewater Service Recommendations

The two options for providing wastewater service to the Leonard WTP were evaluated, taking in to consideration estimated capital construction costs, wastewater fees, O&M costs and requirements, and reliability of service. More detailed information regarding City of Leonard collection system flows and actual lift station pumping capacities should be evaluated to determine if any upgrades will be required to accommodate Leonard WTP wastewater flows. While providing on-site treatment for domestic and process wastewater has a significantly lower construction cost, NTMWD staff would have to maintain these systems.

Leonard Water Treatment Plant
Draft Basis of Design Report

Submitted to

North Texas Municipal Water District

North Texas
Municipal Water District

Prepared by

CH2M HILL Engineers Inc.
TBPE Firm No. 3699
12750 Merit Drive, Suite 1100
Dallas, TX 75251

July 2015

Released for review under the authority of:

Registered Professional Engineer No. 48243
Edward M Motley

Contents

Introduction

Technical Memorandums

* The Electrical, Instrumentation and Controls, Architectural, and Landscape Architecture Technical Memorandums are not included in this Draft Basis of Design Report; they will be submitted separately for review and incorporated into the Final Basis of Design Report. These technical memorandums have been delayed to get more input from North Texas Municipal Water District on facility preferences for those disciplines.

Introduction

PREPARED FOR: North Texas Municipal Water District
PREPARED BY: CH2M HILL
DATE: July 2015

General Information

This Basis of Design Report is the first in a series three reports; the Existing Conditions Report and Treatment Process Report will follow. This Basis of Design Report summarizes the design standards, codes, and preferences to be used by the discipline designers for the Leonard Water Treatment Plant Project. This draft report includes five of the nine individual technical memorandums (TMs) summarizing major disciplines:

1. Process Definition
2. Mechanical
3. Structural
4. Site Civil
5. Heating, Ventilation, and Air Conditioning; Plumbing; and Fire Protection

The concepts presented in these TMs will be further developed in construction drawings, details, and specifications for the subsequent project submittals.

TECHNICAL MEMORANDUM 1

Process Definition

PREPARED FOR: North Texas Municipal Water District

PREPARED BY: CH2M HILL
Released for the purposes of review by Brian Fuerst,
PE Number 68005 on July 13, 2015

DATE: July 2015

North Texas Municipal Water District

The North Texas Municipal Water District (NTMWD) supplies treated water to a large area of North Central Texas. NTMWD's water service area has seen rapid growth over the last 2 decades and is projected to continue the previous growth trends. Demands in the NTMWD system are expected to more than double from 2010 to 2060, requiring more than 368,000 acre-feet per year in additional supplies by 2060. The recommended water management strategy for NTMWD includes development of the Leonard Water Treatment Plant (WTP) to treat water from the new Lower Bois d' Arc Creek Reservoir and ultimately additional water from a secondary source.

Background

The proposed WTP is one component of NTMWD's Lower Bois d' Arc water supply program. The WTP will be located on a tract of land purchased by NTMWD just west of the small town of Leonard in Fannin County, Texas. The WTP will have an ultimate capacity of 280 million gallons per day (MGD) and an initial capacity of 70 MGD (peak day production). The water sources for the initial 70-MGD-phase WTP is the proposed Lower Bois d' Arc Creek Reservoir.

Source Water Quality

The Bois d' Arc Creek Reservoir is currently being designed by Freese & Nichols. Construction on the reservoir is anticipated to begin as soon as practicable after the necessary permits (Section 404 Permit from U.S. Army Corps of Engineers and a Water Rights Permit from the State of Texas) are secured. The current projection for commencing construction on the dam is spring 2016. The current schedule anticipates water will be available from the reservoir for testing and commissioning of the Leonard WTP late in 2019.

Given the schedule of the Lower Bois d' Arc Creek Reservoir, there will not be an opportunity to accumulate a significant amount of water quality data from the reservoir on which to base a treatment process design. Therefore, the strategy for quantifying water quality includes (1) sampling and testing water from Lower Bois d' Arc Creek and (2) developing a raw water quality model to simulate the water quality dynamics of the new reservoir.

Finished Water Quality Goals

The selected treatment train will be capable of meeting current drinking water quality regulations and producing water compatible with water produced at the existing Wylie WTP so that waters from the two plants can be mixed in customer cities' distribution systems without adverse effects. The selected process train should also provide the NTMWD with the flexibility to upgrade processes if required in response to anticipated future drinking water regulations or raw water quality that varies from projections.

Associated Project Facilities Designed by Others

The Leonard WTP project includes the design of all the facilities at the WTP site from the outlet of the balancing reservoir to the pipes feeding the high service pump station. Upstream facilities including the Lower Bois d' Arc Creek Reservoir, lake raw water pump station, raw water transmission piping, and balancing reservoir at the plant site are being designed by another consultant. Downstream facilities including the high service pump station and the finished water pipeline will also be designed by others. Offsite electrical transmission towers and conductors and the main facility substation are being designed and constructed by the power provider.

Leonard Water Treatment Plant Process

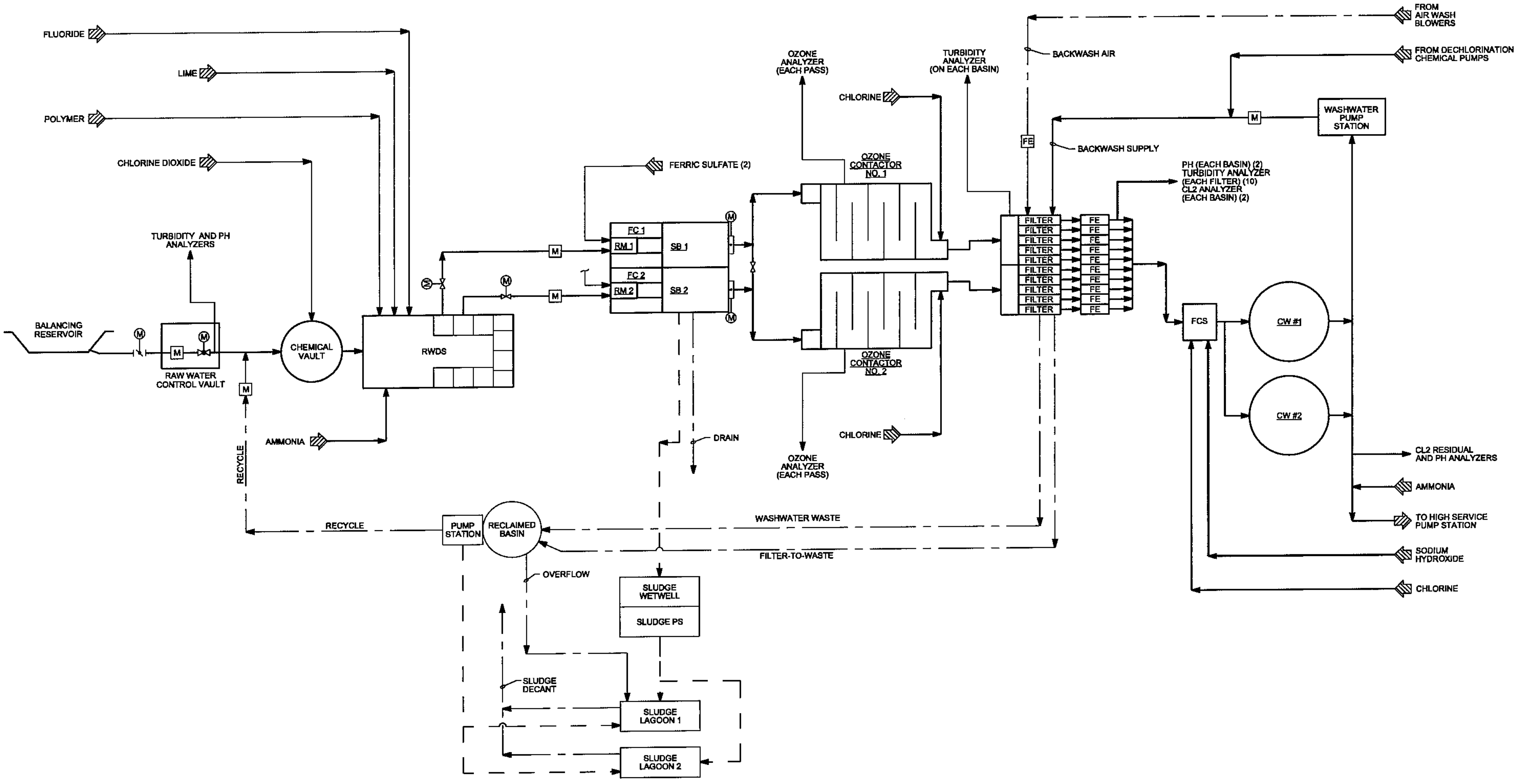
For the purposes of this Basis of Design Report, the assumed water treatment process at the Leonard facility will consist of the following:

- A raw water control vault
- Chemical feed vault
- Raw water distribution structure
- Rapid mix facilities
- Flocculation and sedimentation basins using either conventional sedimentation or plate settlers (to be determined during initial design)
- Ozone generation and contactors
- Biologically activated granular media filters (with either anthracite/sand or granular activated carbon (GAC)/sand media
- Primary disinfection with free chlorine
- Secondary disinfection with chloramines
- Finished water storage facilities

Residuals treatment philosophy will be developed during the initial phase of design but is expected to consist of the following:

- A reclaim basin for backwash waste and filter to waste
- Possibly a sludge thickener
- A combination of mechanical dewatering and/or sludge lagoons

Decant from the reclaim basin and the sludge lagoons or mechanical dewatering will be returned to the head of the plant. Support facilities such as an operations building, chemical storage and feed facilities, lab facility, maintenance facility, and emergency generators are also included to deliver a complete and operational WTP. Details of the treatment process will be included in the Treatment Process Report currently being developed. See Figure 1 for a preliminary process flow diagram of Leonard WTP.



PROCESS FLOW DIAGRAM
LEONARD WATER TREATMENT PLANT
NORTH TEXAS MUNICIPAL WATER DISTRICT

CH2MHILL

LWTP_FIG1_PFD.dgn

Mechanical

PREPARED FOR: North Texas Municipal Water District

PREPARED BY: CH2M HILL
Released for the purposes of review by Brian Fuerst,
PE Number 68005 on July 16, 2015

DATE: July 2015

General Description

This technical memorandum presents the mechanical design approach for the Leonard Water Treatment Plant (WTP) project. Design considerations associated with mechanical system design and configuration are included herein. The contract documents will include a piping schedule and schedules for manual, power-operated, and self-contained valves and gates. The schedules will be located within the drawings.

Codes, Standards, and Regulations

The following codes and applicable standards will be followed in the design process:

- Anti-Friction Bearing Manufacturers Association
- American Gear Manufacturers Association
- American Iron and Steel Institute
- American National Standards Institute (ANSI)
- American Petroleum Institute
- American Society of Heating, Refrigerating and Air Conditioning Engineers
- American Society of Mechanical Engineers (ASME)
- American Society for Testing and Materials (ASTM)
- American Welding Society
- American Water Works Association (AWWA)
- International Building Code
- International Fire Code
- Hydraulic Institute (HI)
- Manufacturers Standardization Society of the Valve and Fittings Industry, Inc.
- National Fire Protection Association
- National Sanitation Foundation (NSF)
- Occupational Safety and Health Administration
- Texas State Mechanical Code
- Underwriters' Laboratories

Design Criteria

General Mechanical Access and Layout

The design and construction of all facilities will incorporate equipment and piping system layout guidelines as follows:

- Typically, one type of equipment will be chosen as the basis of design. This make or model is referred to as the "design standard." Layout should be based on this selection. Where other manufacturer's products are also suitable, the layout will be checked to ensure that the arrangement does not preclude the use of these alternatives.
- In general, exposed piping will be located within 6 feet of the walls so that it can be supported easily, particularly in spaces with high ceilings. If piping must be run close to a wall, but is not supported by the wall, clearance will be provided between the outermost pipe flange and the wall to facilitate disassembly.
- The minimum clear space around equipment and pipe will allow the equipment and/or pipe to be completely removed and replaced without dismantling portions of the building or adjacent equipment or piping.
- The minimum clear space around equipment will be in accordance with the largest of the following requirements:
  - Horizontal clearance between adjacent items of equipment: 4 feet
  - The minimum clearance on sides around rotating equipment will be 4 feet.
  - Vertical clearance between finished floor and any overhead obstruction affecting personnel access: 7.5 feet.
  - Vertical clearance between finished floor and any overhead obstruction affecting equipment access: 10 feet.
  - Manufacturer's recommended minimum maintenance clearances plus 1 foot.
  - Horizontal clearance around large equipment (for example, engines, pump connections larger than 20 inches, and motors larger than 400 horsepower [hp]): 8 feet.
- Equipment will be located to maintain the minimum clearances on all four sides.
- Space provided for future equipment will be sufficient to provide the aforementioned minimum equipment clearances after future equipment is installed.
- All equipment and associated panels and cabinets will be located on reinforced concrete equipment bases, which will be a minimum of 6 inches high and extend a minimum of 3 inches beyond the footprint of the equipment, panels, or cabinets.
- Utility stations will be provided for wash-down so that the maximum hose length is 50 feet.
- Stairs, catwalks, platforms, and hatches will be provided to facilitate maintenance and operational access, and the removal of equipment. Ladders will not be used where frequent access is required.
- Lifting eyes, hoists, monorails, and/or cranes will be provided where necessary for disassembling or removing major pieces of equipment, where access by appropriate sized and configured mobile lifting equipment is not possible or practicable. Adequate head room will be provided for removal of equipment as a single unit, or equipment will be provided that may be removed in easily disassembled sections.

- Space for maintenance and operational access to valve and gate operators will be provided. Adequate clearance to accommodate all positions for rising stem valves and gates will be provided.
- Motorized operators, chain wheels with chains, or access platforms will be provided for easy operation of all valves placed on elevated piping.
- Facilities will be designed with adequate overhead clearance to allow for disassembly or removal of vertical turbine pumps.
- Flexible connections will be provided for ease of piping assembly and disassembly, and for connections to equipment. Adequate thrust restraint will be provided at each flexible coupling.
- Piping will be located so that it is not a tripping hazard, head-banger, or barrier to equipment access.
- Swing check valves will not be located in vertical piping runs in solids-bearing fluid services.

Equipment Uniformity

Similar pieces of equipment will be furnished by the same manufacturer to maintain uniformity. Uniformity with equipment at the Wylie campus will be considered to allow for the exchange of spare parts where possible. Equipment systems will be assembled as a unit by a single manufacturer responsible for the entire unit. Responsibility extends to selecting components of the system to assure compatibility, proper operation, and compliance with specified performance requirements.

Equipment Redundancy

The Leonard WTP is a critical link in the northern part of the North Texas Municipal Water District (NTMWD) transmission system and is the only treatment facility with access to the Bois d' Arc Creek Reservoir supply. Therefore, a high degree of reliability and redundancy is required for all systems, which is essential to delivering treated water to the transmission system.

In general, all mechanical equipment will be sized to meet design flow rate with one unit out of service for maintenance. There will be a minimum of two independent units for all processes. Filters will be designed to meet full design flow rates with one unit in backwash mode and one out of service for maintenance. Equipment will be designed to operate with a plant turndown of 3:1.

Piping

A preliminary piping schedule is provided as an attachment to this technical memorandum. It consists of a tabulated listing of piping requirements by service flowstream. The function of the schedule is to present the requirements for pipe materials, joints, lining and coating requirements, test pressure and type, and any special requirements for piping systems. The final selection of piping materials will be based on corrosion criteria, cost factors, and durability considerations. Not all services required for the project are included in the piping schedule at this time. Additional piping design criteria are provided in Table 1 and will guide the piping system(s) design for the project.

Table 1: Piping Standards
Leonard Water Treatment Plant Basis of Design Report

Pipe Material	Standard	Pipe Selection Comments
PVC Pressure Pipe	ANSI/AWWA C900-97/905-97	Use on pressurized water piping greater than 4-inch diameter. Minimum pressure rating will be 150 psi, DR18 for C900 and 165 psi (DR25) for C905. PVC pipe will be restrained with Megalug, EBBA Iron Sales, Inc. Fire service pipe will be DR14 pipe and 8-inch minimum diameter.
PVC	Schedule 80, Type I, Grade I or Class 12454-B conforming to ASTM D1784 with ASTM D1785	Use on chemical services where PVC is suitable and less than 4-inch diameter, such as liquid polymer, chlorine dioxide, chlorine solution, fluoride, sodium chlorite, and process drains. Use on buried pressurized water piping, such as non-potable water less than or equal to < 4-inch diameter.
FRP Pipe	ASTM	If required for buried piping in corrosive soils.
Ductile Iron Flanged Pipe	ANSI/AWWA C115/A21.15 and ANSI/AWWA C110/A21.10, 125-lb flat face	Minimum pressure rating 250 psi and thickness class 53. Ductile iron flanged pipe will be used for above-grade process pipe. Transition between PVC and ductile iron can be made with flanged connections or transition couplings, such as JCM Industries, 210 ductile iron couplings coated with fusion-bonded epoxy coating, 304 SST bolts and nuts, and ethylene propylene dimonomer (EPDM) gaskets. All ductile iron flanged pipe will be exterior coated with a shop primer. Flanged ductile iron pipe and fittings will be cement-lined.
Ductile Iron Concrete-Encased Pipe	AWWA C111/A21.11 and AWWA C151/A21.51	Minimum pressure class 250 psi. Use on concrete-encased pipes below the foundations of structures or buildings. Proprietary restrained joints in accordance with NTMWD standards. All encased ductile iron pipes will be exterior coated with a bituminous coating. Encased ductile iron pipe will be cement-lined.
Ductile Iron Pipe Buried	AWWA C111/A21.11 and AWWA C151/A21.51	Minimum pressure class 250 psi. Use on buried ductile iron pipe not below foundations. Proprietary restrained joints per NTMWD standards. Buried ductile iron pipe will be cement-lined and cement coated on exterior.
Fabricated Steel Pipe	AWWA C200	Joints will be welded except where flanges are required to connect to equipment. All large-diameter (>24-inch) piping will be cement mortar lined, and buried piping will be cement-mortar coated. Where required for corrosion protection, smaller-diameter fabricated welded steel pipe and fittings will be interior coated with Induron Protecto 401 Ceramic Epoxy, 40 mils.
SST Pipe and Fittings	2–inch diameter and smaller: Schedule 40S, ASTM A312/ A312M, Type 304 seamless, pickled and passivated; joints	Use on exposed and submerged low pressure air.

Table 1: Piping Standards
Leonard Water Treatment Plant Basis of Design Report

Pipe Material	Standard	Pipe Selection Comments
	to be Victaulic Pressfit System – 304 SST 2-1/2–inch diameter to 6-inch diameter: Schedule 10S, ASTM A778, as-welded grade Type 304L, pickled and passivated 8–inch diameter and larger: Schedule 5S, ASTM A778, as-welded grade, Type 304L, pickled and passivated	
Carbon Steel Pipe (BSP)	Black carbon steel, ASTM A106, Grade B seamless or ASTM A53, Grade B seamless or Electric Resistance Welded ERW	Use on fire sprinkler systems. Use on compatible chemical systems including anhydrous ammonia, ferric sulfate, sodium hydroxide and chlorine gas. Use on pressurized water piping and drains exposed to sunlight less than or equal to 4-inch diameter. Use on hot water system piping.

Notes:
FRP = fiberglass-reinforced plastic
lb = pound
psi = pounds per square inch
PVC = polyvinyl chloride
SST = stainless steel

The pipe design criteria beyond those described in the piping schedule are as follows:

- Flanges and/or couplings will be provided, as necessary, to facilitate removal of valves and equipment.
- The minimum depth of cover over buried piping will be 3 feet. Exceptions will be allowed on a case-by-case basis.
- The minimum design velocities for sludges will be 2 feet per second (fps) at average flow rates where practicable. Design velocities will be in the range of 2 to 5 fps for gravity pipelines. Maximum velocities for control valves will be less than 15 fps.
- Piping connected to equipment will be supported by the associated ~~pip~~ support system and not by the equipment. The loads for equipment piping will be carried by pipe supports framed to the facility floor or structure. Pipe supports will be designed to withstand the dead loads imposed by the weight of the pipes filled with water and will have a minimum safety factor of 5.
- In general, test pressures for pressure piping will be 1.5 times the maximum possible operating pressure for the pipe, such as pump shutoff head or peak surge pressure.
- Exposed water piping, or other piping considered to have freeze potential, located outdoors will be heat traced and insulated if determined necessary. Freeze susceptible piping located in pipe trenches will be insulated only. Piping in vaults or conditioned spaces will not be insulated or heat traced except for hot water piping. Efforts will be made to minimize the quantity of heat traced and insulated piping. Alternatively, in some cases, a piping drain or non-freeze post hydrant will be provided in lieu of heat tracing and pipe insulation.

- Piping in trenches will be insulated. Chemical service piping will only be heat traced as appropriate for the specific freezing potential of the chemical carried in the piping.
- Pipe will be labeled using Brady Snap-On labels or equal. Process pipes will be color-coded in accordance with Texas Commission on Environmental Quality color coding standards.
- Pipe sizes and friction losses for Newtonian liquids will be calculated with Darcy-Weisbach equations.
- When routed through the yard, chemical piping will be installed in utility trenches configured with low point sumps and alarms for leak detection. Each feed point will be provided with a dedicated supply pipe.
- Chemical piping materials will be provided to match NTMWD standards.

Pipe Supports

Pipe supports will be designed and detailed on the contract documents for piping greater than 24 inches in diameter. The design details will be referred to from one or more mechanical drawings, where locations for each pipe support will be indicated.

Pipe supports for piping less than or equal to 24 inches will be designed and detailed by the contractor in accordance with the contract documents and submitted for the engineer's review prior to installation.

Valves and Actuators

Valve materials and linings will be selected based on service conditions to be compatible with the pipeline materials.

Valve schedules and specifications will be developed during the preliminary design phase.

For valves located in classified hazardous locations, electrical power actuators will be explosion proof type (National Electrical Manufacturers Association [NEMA] 7). Classified locations will be as identified in National Electric Code (NEC).

The following valve standards will be followed:

- All valves will comply with AWWA standards and be constructed of the appropriate materials for the particular application.
- Valve operators will be accessible from the ground or from adequate platforms.
- For quarter-turn valves greater than 8 inches in diameter, a handwheel with gear will be provided.
- One valve will be provided for isolation of equipment or tanks. Multiple valves or provisions to remove spool pipe sections will not be provided to access equipment or tanks.
- Check valves will be provided on all pumped discharge lines. Check valves and butterfly valves will be installed with upstream and downstream separating spool pieces to achieve manufacturer-recommended separation distances and to avoid mechanical interference.
- Check valves will be provided with rugged, repeatable visual position indicators.

Swing check valves will be provided with an outside lever and a weight or spring.

- Valve boxes for buried valves will be cast iron, screw-type adjustable.
- All major buried valves will be installed with an access manhole to the valve gear box on the valve. The stem will be extended to ground level. Those valves operated infrequently will have a valve box and operating nut on top of the access manhole. Those operated more frequently will have an operator stand and electric operator on top of the manhole.

- Butterfly valves will be provided on process air lines and major process lines.
- Backflow prevention assemblies will be reduced pressure principal backflow preventers.
- Self-contained valves will be provided with adjustable set points that are in the mid-range of the valve's operating capability.
- All valves in lines 1 inch in diameter or greater requiring automatic actuators will be electrically or pneumatically operated unless the service demands otherwise. Solenoid valves will be used for service in lines smaller than 1-inch diameter.
- Actuators for modulating valves and filter valves will be pneumatically operated, vane style.
- Actuators for isolation valves that are operated routinely will be electrically operated and will be manual for those operated infrequently.

Pumps

Pump speeds will generally operate at a maximum of 1,750 revolutions per minute (RPM), unless high-head, multi-stage pumps are required. Centrifugal pump speeds will not exceed 1,750 RPM in most cases. Rotary lobe and progressing cavity pumps will not exceed 300 RPM. Pump seal types will be determined based on pump application.

Gates

Gates will be made of Type 304 or Type 316 SST, as required for the application. Metallic items that are partially embedded in concrete (including frames for grating, covers, slide gates, and similar items) will be made of Type 316 stainless steel where submerged or near water surface. Typically, isolation will be performed by butterfly valves and not gates.

Chemical Storage and Feed

Storage tanks will be constructed of FRP, if appropriate for the chemical. If FRP is not compatible, an appropriate tank material will be selected and reviewed with NTMWD. Tanks will be single-wall construction, and containment will be provided external to the tanks. Access to the top of the tank will be provided. Tanks will be sized for the greater of 30 days of storage at average plant flow conditions or 15 days of storage at maximum plant flow conditions. Day tanks will be used in the chemical storage and feed design for the plant. SST isolation valves will be used for tank isolation.

Chemical dosing (low flow applications) will use peristaltic pumps with adjustable-speed control. Diaphragm pumps may be used on ferric sulfate applications. A separate pump will be provided for each feed point, and a standby pump will be provided for each chemical system. For polymer and lime feed applications, progressing cavity pumps will be used. Flushing connections will be provided on each chemical line and provisions for dilution water made, if appropriate.

Gaseous chlorine will be used. The plant will receive rail delivery of tank cars and will also provide a stationary 30-ton bulk tank to receive truck delivery of chlorine as a backup to the railroad tank cars. Chlorine will be stored in a containment building equipped with a scrubber system designed to neutralize the contents of the railroad tank car in the event of a spill.

Liquid chemicals and ammonia gas will be provided by bulk truck deliveries to the plant. Ammonia storage will be in a containment building equipped with a scrubber designed to neutralize the contents of the stationary storage tank provided.

Rapid Mixer

An impeller-type mixing system will be provided, with turbine-style blades for better efficiency. The impeller mixer will be oriented as top entry with the drive located above the mixing chamber and a vertically oriented shaft connection to the impeller. A heavy-duty drive will be provided, rated for continuous duty. Two mixers will be provided (duty and standby) at each mixing point.

Ozone Generation and Injection

The ozone generation system will consist of liquid oxygen storage, ambient vaporization, nitrogen boost, and ozone gas generation. The ozone generators will be liquid cooled with a closed-loop cooling system.

Ozone injection will be done in a sidestream configuration.

Air Scour Blowers

Two blowers will be provided for filter air scour. High-speed turbocompressors will be considered for their higher efficiency, but may not be appropriate for this application, depending on the details of the backwash sequence. Turbocompressors are best suited for longer run periods and do not hold up well to a large number of starts and stops. If turbocompressors are determined to be a poor choice, rotary lobe blowers will be provided.

Other Process Equipment

Discussion of other process equipment (for example, flocculators, clarifiers, and filters) is provided in the *Process Definition Technical Memorandum.*

Motors

Electric motors will be Underwriters Laboratories (UL) listed, in accordance with UL674 and UL1004, and NEMA Class B temperature rated for 40 degrees Celsius ambient.

Rotating Equipment Protection

In general, rotating equipment will be monitored, as applicable, for motor moisture, motor winding temperature, overload, loss of power (at the motor control center), and vibration (large equipment).

Noise

Mechanical equipment noise levels generally will not exceed 85 decibels at 3 feet outside the structure.

North Texas Municipal Water District Preferences

At the Basis of Design Workshop on May 14, 2015, mechanical equipment, valve, and piping preferences for the Leonard WTP were provided by NTMWD staff. These preferences are listed in Table 2 and will form the basis of design for mechanical equipment unless exceptions are approved by NTMWD. In specific applications where the designer believes there are technical, operational, or life-cycle cost issues that make an alternative more attractive, an analysis of the options will be prepared and presented to NTMWD for consideration.

Table 2: NTMWD Equipment Preferences
Leonard Water Treatment Plant Basis of Design Report

Process Unit	Equipment/Component	NTMWD Preference
Rapid Mix	Mixers	Vertical turbine – Falk or Chemineer
Flocculation/ Sedimentation	Flocculators	Vertical turbine or horizontal paddlewheel – TO BE EVALUATED DURING PREDESIGN
	Launders	SST or FRP – must be rigid
	Clarification	Conventional or plate settlers – TO BE EVALUATED DURING PREDESIGN
	Baffles	Concrete
	Sludge collectors	TO BE EVALUATED DURING PREDESIGN
Filtration	Underdrains	Leopold Type S
	Media	Sand plus anthracite or granular activated carbon – TO BE EVALUATED DURING PREDESIGN
Chemical Systems	Storage tanks	FRP, if compatible
	Containment	Single-wall tanks, external containment
	Pipe containment	Pumped sumps with alarms
	Chlorine dioxide generation	Sodium chlorite and chlorine gas
	Day tanks	Yes
	Lime and polymer pumps	Progressive cavity
	Other chemical pumps	Peristaltic – Watson Marlow
	Chlorinators	Wallace and Tiernan
	Ammoniators	Wallace and Tiernan
	Ozone generators	Fuji
General	Piping materials	Steel or ductile, cement lined, cement coated if buried
	Piping for chemical services	Follow NTMWD-provided standards
	Rotating equipment protection	Thermal, moisture, overload, loss of power, and vibration for large equipment
	Electric actuators	Rotork, Limitorque, EIM, Auma (nonintrusive electronics)

Attachment

PIPING SCHEDULE

Flow Stream ID	Service	Nominal Diameter (inches)	Material[a]	Pressure Class Special Thickness Class Schedule Wall Thickness	Pipe Spec. Section	Joints/ Fittings[b]	Test Pressure/ Method[c]	Lining	Coating	Comments
AA	**Anhydrous Ammonia**									
	All		BSP	SCH 40		WLD		None		
CAL	**Calcium Thiosulfate**									
	All		PVC	SCH 80		SW		None	None	
CD	**Chemical Drain**									
	Buried		PVC	SCH 80		SW		None	None	
	Exposed		PVC	SCH 80		SW		None		
CLO2	**Chlorine Dioxide**									
	All		PVC	SCH 80		SW		None	None	
CLS	**Chlorine Solution**									
	All		PVC	SCH 80		SW		None	None	
CW	**Cold Water**									
	Exposed		Copper	Type L		SKW		None	None	
	Buried		Copper	Type K		SKW		None	None	
D	**Drain**									
	Exposed		GSP	SCH 40		SCRD		None		
	Buried		CISP			B&SP				
FS	**Ferric Sulfate**									
	Exposed		SST	SCH 10S		WLD/FL		None	None	

PIPING SCHEDULE

Flow Stream ID	Service	Nominal Diameter (inches)	Material[a]	Pressure Class Special Thickness Class Schedule Wall Thickness	Pipe Spec. Section	Joints/ Fittings[b]	Test Pressure/ Method[c]	Lining	Coating	Comments
HFA	**Hydrofluosilicic Acid 25%**									
	Exposed		PVC	SCH 80		SW		None		
HPX	**Hydrogen Peroxide**									
	All		SST	304L/316L		WLD		None	None	
HW	**Hot Water**									
	All		Copper	Type L		SKW		None	None	
HWR	**Hot Water Return**									
	Buried		BSP	SCH 40		SCRD/FL/GE		None	None	
	Exposed		BSP	SCH 40		SCRD/FL/GE		None	None	
HWS	**Hot Water Supply**									
	Buried		BSP	SCH 40		SCRD/FL/GE		None	None	
	Exposed		BSP	SCH 40		SCRD/FL/GE		None	None	
LIME	**Calcium Hydroxide Slurry**									
	All		PVC	SCH 80		SW		None		
NaOH	**Sodium Hydroxide 25%**									
	All		BSP	SCH 40		WLD		None		
NACLO2	**Sodium Chlorite**									
	All		PVC	SCH 80		SW		None	None	
NH3	**Ammonia Gas**									
	All		BSP	SCH 40		WLD		None		

PIPING SCHEDULE

Flow Stream ID	Service	Nominal Diameter (inches)	Material[a]	Pressure Class Special Thickness Class Schedule Wall Thickness	Pipe Spec. Section	Joints/ Fittings[b]	Test Pressure/ Method[c]	Lining	Coating	Comments
NPW	**Non-Potable Water**									
	Buried		PVC	SCH 80		SW		None	None	
	Exposed		PVC	SCH 80		SW		None		
PHA	**Phosphoric Acid**									
	All		PVC	SCH 80		SW		None	None	
POL	**Polymer (undiluted)**									
	Exposed		PVC	SCH 80		SW		None		
POLY	**Polymer 30%**									
	Exposed		PVC	SCH 80		SW		None	None	
PW	**Potable Water**									
	Exposed		Copper	Type L		SKW		None		
	Buried		PVC	SCH 80		SW		None	None	
SPD	**Sump Pump Discharge**									
	Exposed		PVC	SCH 80		SW/FL		None		
	Buried		PVC	SCH 80		SW		None	None	

PIPING SCHEDULE

Flow Stream ID	Service	Nominal Diameter (inches)	Material[a]	Pressure Class Special Thickness Class Schedule Wall Thickness	Pipe Spec. Section	Joints/ Fittings[b]	Test Pressure/ Method[c]	Lining	Coating	Comments

[a] Piping Material Abbreviations:

BSP	black carbon steel pipe
CI	cast iron
CISP	cast iron soil pipe
CLDI	cement lined ductile iron
GSP	galvanized steel pipe
PVC	polyvinyl chloride
SST	stainless steel
VCP	vitrified clay piping

[b] Joint Types Abbreviations:

B&SP	bell and spigot
FL	flange
GE	grooved end joint
MJ	mechanical joint
SCRD	screwed on
SKW	soldered socket
SW	solvent welded
WLD	weld

[c] Test Pressure Method Abbreviations:

H	hydrostatic
G	gravity method
P	pneumatic

Notes:

SCH = schedule

Internal linings are specified in the piping data sheets and detailed piping specifications.

External coatings will be as specified in Section 09 99 00 Painting and Coatings.

TECHNICAL MEMORANDUM 3

Structural

PREPARED FOR:	North Texas Municipal Water District
PREPARED BY:	CH2M HILL Released for the purposes of review by Mark Nanninga, PE Number 50823 on July 13, 2015
DATE:	July 2015

Introduction

This technical memorandum (TM) presents the general design criteria to be used for the structural design for the Leonard Water Treatment Plant.

This TM includes the following information:

- Applicable codes, standards, and regulations
- Design loads
- Load combinations
- Geotechnical design parameters
- Stability criteria
- Deflection criteria
- Structural system requirements

Codes, Standards, and Regulations

- International Building Code (IBC) (2012)
- American Society of Civil Engineers (ASCE) 7, Minimum Design Loads for Buildings and Other Structures
- American National Standards Institute (ANSI)/American Water Works Association (AWWA) D110, Wire- and Strand-Wound, Circular, Concrete Water Tanks
- Reinforced Concrete:
  - American Concrete Institute (ACI) 318 for Buildings and Non-Water-Holding Structures
  - ACI 350-01 for Water-Holding Structures
- Masonry: ACI 530
- Steel:
  - American Institute of Steel Construction (AISC) Specifications for Structural Joints Using American Society for Testing Materials (ASTM) A 325 or A 490 Bolts
  - American Welding Society (AWS) Structural Welding Code AWS D1.1
  - AISC Manual of Steel Construction, Thirteenth Edition
  - AISC 341-10 Seismic Provisions for Structural Steel Buildings, Including Supplements
- Aluminum: Aluminum Association Specifications for Aluminum Structures

- Open-Web Steel Joists: Steel Joist Institute Standard Specifications
- Metal Deck: American Iron and Steel Institute (AISI) Specifications for the Design of Light-Gauge, Cold-Formed Steel Structural Members
- Light-Gauge Metal Framing: AISI Specifications for the Design of Light-Gauge, Cold-Formed Steel Structural Members
- Metal Grating: National Association of Architectural Metal Manufacturers Metal Grating Manual and Heavy Duty Metal Grating Manual
- Fiberglass: Extren Glass Reinforced Structural Engineering Manual, Morrison Molded Fiber Glass Company

Design Loads

Loads will be based on the most stringent criteria of the building codes and standards listed above, and loads discussed in the following sections. In all cases, the minimum criteria will conform to the minimum requirements of the IBC with Texas Amendments.

Dead Loads

The loads resulting from the weight of all fixed construction, such as walls, floors, roof, equipment bases, and all permanent nonremovable stationary construction are considered to be dead loads. Numerical values used for these loads may be determined by either actual known weights of the respective items or by documentation presented in the IBC and other publications such as ASCE 7.

Collateral Loads

The collateral dead load accounts for ceilings; equipment; fixtures; and mechanical, electrical, and plumbing appurtenances. A collateral dead load of 10 pounds per square foot (psf) will be applied to floors and roofs, unless noted otherwise. In process buildings, collateral dead load will be increased to 25 psf, unless there is a moving crane directly beneath the structure that would prohibit large amounts of process piping from being attached to floor or roof members.

Live Loads

• Assembly, exit corridors, stairs:	100 psf
• Electrical rooms:	300 psf except when calculating foundation load, 200 psf, or actual loads, whichever is greater
• General office areas:	50 psf
• Grating:	150 psf
• Heating, ventilating, and air conditioning (HVAC) mechanical rooms:	150 psf or actual equipment weight plus 50 psf Allow for rolling equipment out
• Process areas:	250 psf, except design individual slabs and beams for 300 psf
• Roof, unless noted otherwise:	20 psf minimum
• Walkways and platforms unless noted:	60 psf
• Storage areas:	250 psf
• Vehicle access areas:	American Association of State Highway and Transportation Officials (AASHTO) HS 20-44

Seismic Loads

Unless Otherwise Noted (Reference ASCE 7):

- Spectral response acceleration at short period (Ss): 0.150 (U.S. Geological Survey [USGS] online tool)
- Spectral response acceleration at 1-second period (S_1): 0.059 (USGS online tool)
- Site classification: D (assumed, pending geotechnical report)
- Design spectral response acceleration at short period (S_{DS}): 0.160
- Spectral response acceleration at 1-second period (S_{D1}): 0.094
- Occupancy risk category: III ASCE 7 (Table 1.5-1)
- Seismic design category: B ASCE 7 (Tables 11.6-1 and 11.6-2)
- Importance factor (I): 1.25 ASCE 7 (Table 1.5-2)
- Response modification coefficient (R): Varies per structure, in accordance with ASCE 7
- Overstrength factor (Ωo): Varies per structure, in accordance with ASCE 7
- Deflection amplifier (Cd): Varies per structure, in accordance with ASCE 7

Seismic Design of Liquid-Containing Concrete Structures (Reference ACI 350.3-06):

- Seismic zone: 0 (Refer to Figure 4-1)

Wind Loads

Wind loads will be based on a design wind speed of 120 miles per hour (mph), Exposure B,.

Snow Loads

Ground snow load will be 5 psf.

Rain Loads

Loads will be increased as required assuming primary drains are plugged and water is at the overflow elevation.

Impact Loads

No significant impact loads are anticipated for the process or building structures. If cranes are included in the design, impact loads will be developed for their design based on the provisions of IBC 1607.13.

Thermal Loads

No significant thermal loads are anticipated for these structures.

Liquid Loads

Refer to drawings for design water levels and top of base slab elevations. The design of the containment structures will include a check of cracking under normal loads. Sloshing loads during a seismic event will also be taken into account during the design. Only the available capacity of the member has to be checked for seismic loads. A unit weight of 65 pounds per cubic foot (pcf) will be used for the liquid in these environmental structures.

Load cases that will be considered in design of liquid holding basins are as follows:

- All basins full of liquid to top of wall, no backfill
- Backfill and groundwater with empty tank
- Any tank cell empty or full in any combination

Earth Loads

Refer to the geotechnical report. Two feet of surcharge will be used where traffic loads can be within one-half the height of the wall. It will be assumed that traffic can be within this limit unless there is strong proof that this will never be possible.

Load Combinations

Load combinations and load factors will be as required by ACI 350, ACI 318, ASCE 7, and IBC.

Geotechnical Design Parameters

Geotechnical design parameters will be provided upon completion of the geotechnical investigation.

Stability Criteria

The stability of all buildings and structures will be analyzed using the appropriate loading combinations in ASCE 7-10, Chapter 2 and ACI 350.4R-04, Design Considerations for Environmental Engineering Concrete Structures. A minimum safety factor of 1.2 will be used when floodwater level is assumed to be at the top of the structure and resistance to uplift is provided by the dead weight of the structural concrete plus the weight of soil directly above the toe of the base mat of the foundation.

All safety factors are against unfactored soil loadings. The uplift pressure will be taken at the bottom of the foundation. The use of flap (hydrostatic relief) valves in the walls or pressure relief valves in the floor slab will not be an acceptable approach. The weight of items such as mechanical and electrical equipment, concrete fillets, and grout fill will not be considered in resistance against buoyant forces. The weight of water in the structure will not be considered in resistance against buoyant forces.

Deflection Criteria

Deflections will be limited to the following maximum values (deflections are due to live load only unless specifically indicated otherwise):

• Bridge crane girders:	Unsupported length of structural element (L)/1000
• Floor plates and grating:	L/360
• Beams, lintels, or slabs supporting masonry:	L/720 (3/8-inch maximum for lintels over windows)
• Roofs (check ponding):	
– Without ceilings	L/240
– With ceilings	L/360
• Floors:	
– Steel	L/360
– Concrete	See ACI 318 for limitations for dead and live load deflections

Structural System Requirements

Concrete Design

Materials, design procedures, and reinforcing for concrete follow.

Materials

- Cast-in-place structural concrete will have a minimum compressive strength:
  - For environmental engineered hydraulic structures: 4,500 pounds per square inch (psi) in accordance with the requirements of Tables 4.2.2 and 4.3.1 of ACI 350
  - Typical concrete unless noted: 4,000 psi
  - Concrete fill: 2,500 psi unless noted otherwise
4,500 psi in contact with process water
  - Curbs and sidewalks: 3,000 psi
  - Conduit encasements: 3,000 psi
  - Concrete pipe encasement not integral with foundation: 3,000 psi
  - Flowable fill: 1,500 psi
- Reinforcing steel will be grade 60 for all reinforcing.
- Prestressed, precast concrete will have a minimum compressive strength of 5,000 psi at 28, unless noted. The prestressing wires, strands, and tendons will be according to the manufacturer's standard.

Design Procedures

- Ultimate Strength Design Method will be used for all concrete design. The design of water-holding structures and below-grade structures will include a crack width check.
- Construction joint locations will be suggested on the drawings where the length of pour is critical for crack control. The contractor may revise construction joint locations subject to specified requirements and will submit all joint locations for review.
- Control and expansion joints will be located on the drawings. All construction, control, and expansion joints in hydraulic and below-grade structures will have a continuous waterstop as specified.
- Expansion joints will generally be spaced between 60 and 90 feet on center.
- Minimum temperature and shrinkage reinforcing will be designed in accordance with requirements and recommendations of referenced standards.

Details of Reinforcing

- Minimum concrete cover:

– Unformed concrete against earth	3 inches
– Formed concrete exposed to ozone	3 inches
– Formed concrete against earth	2 inches
– Liquid or exterior face, walls	2 inches
– Liquid or exterior face of slabs	2 inches
– Beams and columns, exposed to liquid:	
▪ Ties and stirrups	2 inches
▪ Primary reinforcement	2.5 inches

- Slabs, interior, dry face:
  - #3 - #5 — 1 inches
  - #6 - #11 — 1.5 inches
- Beams and columns, interior, dry face:
  - Ties and stirrups — 1½ inches
  - Primary reinforcement — 2 inches
- Laps and hooks will conform to requirements of referenced standards.

Masonry Design

Materials, design procedures, and reinforcing for masonry follow.

Materials

Hollow concrete masonry units will be ASTM C 90, normal weight. Masonry lintels will be used.

- Mortar will conform to ASTM C 270, Type S.
- Grout will conform to ASTM C 476.
- Minimum compressive strength will be 2,000 psi.
- Reinforcing will be grade 60.

Design Procedures

Design will be as partially reinforced masonry in accordance with ACI 530.

- Allowable Stress Design or Ultimate Strength Design Methods can be used.
- Assumed compressive strength (F'm) will be a minimum of 1,500 psi.
- Design will verify that the neutral axis of wall sections in bending fall in the face shell of the masonry.

Details of Reinforcing

- Maximum spacing of vertical reinforcing in bearing walls and partition walls will be limited to 4 feet and 8 feet, respectively.
- Bond beams will be provided at the top and bottom of walls and above and below intermediate floors. Intermediate bond beams will not be used without discussing reasons with the lead structural engineer.
- Joint reinforcing will be at 16-inch maximum vertical spacing.

Structural Steel Design

Materials and design procedures for structural steel follow.

Materials

	ASTM	Minimum yield strength (Fy) thousand pounds per square inch (ksi)
• Rolled members, plates, and rods:	A 36	36
• Wide flanges:	A992	50
• Steel pipe:	A 501 or A 53, Type E or S, Grade B	35
• Steel tubes:	A 500, Grade B	46
• Bolts for connections:	A 325-N unless noted otherwise	

• Anchor bolts:	
– Dry areas only	F1554, Grade 55 with weld-ability supplement S1, galvanized
– Anchor bolts, unless noted	F593 AISI Type 316, Condition CW
• Welding electrodes:	E70XX

Design Procedures

Design will be in accordance with AISC and AWS. Unless shown otherwise, all framing connections will be bolted connections with high-strength bolts. Stainless steel will be used for bolts and fasteners where corrosion concerns dictate.

Aluminum Design

Materials and design procedures for aluminum follow.

Materials

	ASTM Specification
• Aluminum shapes and plates	Alloy 6061-T6 conforming to the ASTM sections in the Aluminum Association Construction Manuals
• Grating	B221, Standard Specification for Aluminum and Aluminum–Alloy Extruded Bars, Rods, Wire, Shapes, and Tubes
• Handrails	Conform to the requirements of project specifications
• Bolts	F593 AISI Type 316, Condition CW; do not use aluminum bolts

Design Procedures

- Designs will conform to the requirements of the Aluminum Association Specifications for Aluminum Structures.
- Wide-flange beams, channels, and I-beams will be American Standard aluminum sections.

Some aluminum equipment platforms may be performance specified to fit the actual equipment purchased for the project. The contractor will employ a civil or structural engineer registered in the State of Texas for the final design and detailing of the platforms. The design will be in accordance with the project standard details and specifications, and compatible with the equipment.

Fiberglass Design

Design procedures for fiberglass follow.

Design Procedures

- Fiberglass will only be used in highly corrosive locations where other materials are not suitable.
- Corrosion resistance requirements of resin will be reviewed with the lead process engineer(s) and the project corrosion engineer. The lead structural engineer will be informed of type(s) of fiberglass selected for use.
- Fiberglass will be ultraviolet resistant.

Structural members and the design and detailing thereof will conform to the Extren Fiberglass Structural Shapes Design Manual published by Strongwell Corp., Bristol, Virginia (http://www.strongwell.com).

TECHNICAL MEMORANDUM 4

Site Civil

PREPARED FOR:	North Texas Municipal Water District
PREPARED BY:	CH2M HILL Released for the purposes of review by Doug Harris, PE Number 120585 on July 8, 2015
DATE:	July 2015

Introduction

Leonard Water Treatment Plant

This technical memorandum was prepared to document the site civil requirements and basis of design for the proposed new Leonard Water Treatment Plant (WTP). The facility site is located approximately 1.5 miles west of Leonard, between State Highway 69 and State Road 78 in Fannin County, Texas.

The North Texas Municipal Water District (NTMWD) has acquired several parcels of land that total approximately 1,020 acres for the Bois d'Arc Creek Reservoir and Leonard WTP that will include the WTP, a balancing reservoir, and areas for WTP sludge processing (see Figure 1). The WTP is planned to be located on the southwest block of the property in an area of approximately 320 acres. A seasonal stream runs through the far west side of the parcel that will be buffered from the developed areas.

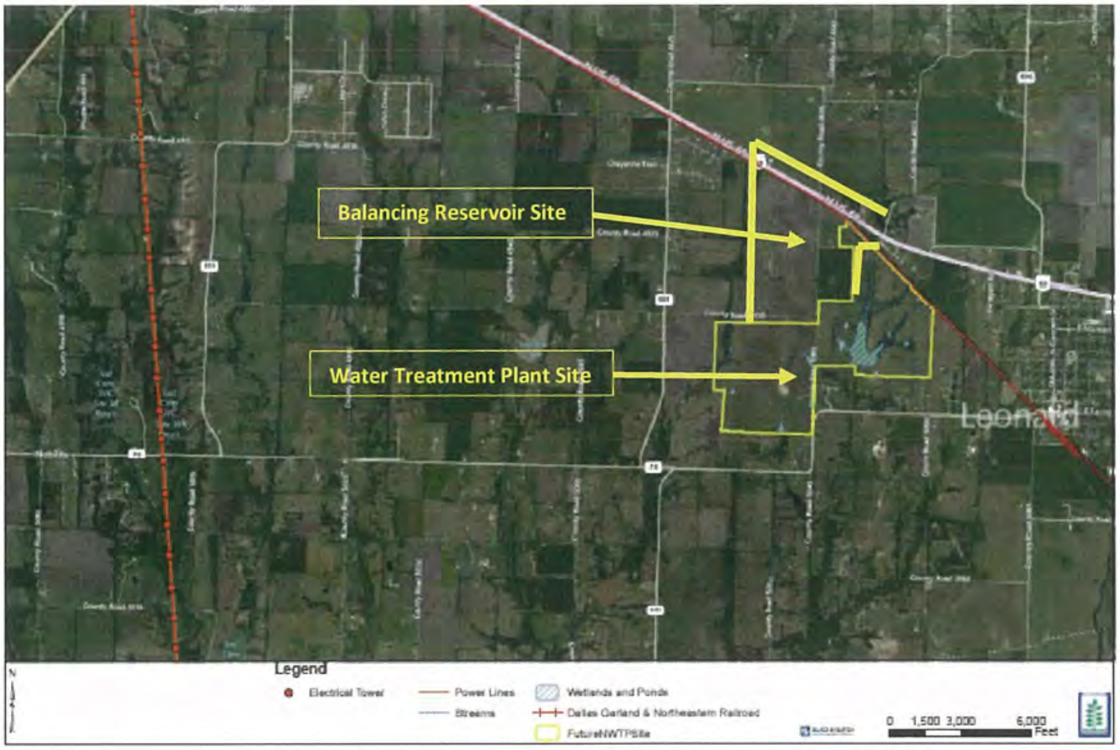


Figure 1: Site Location Map

This technical memorandum summarizes site civil information relevant to development of the schematic design; identifies applicable codes, design standards, and issues that require special consideration; and summarizes the criteria for pavement design, site layout, stormwater, grading, and utilities.

Applicable Codes, Standards, and Regulations

- American Association of State Highway and Transportation Officials (AASHTO)
- Policy on the Geometric Design of Highways and Streets, 2011
- American Concrete Institute (ACI)
- Americans with Disabilities Act (ADA), Standards for Accessible Design, 2010
- American National Standards Institute (ANSI)
- American Society for Testing and Materials (ASTM)
- Texas Department of Transportation (TxDOT) Standards, including:
  - TxDOT Roadway Design Manual, 2014
  - TxDOT Hydraulic Design Manual, 2014
  - Texas Manual on Uniform Traffic Control Devices (MUTCD), 2014
  - TxDOT Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges, 2014
- International Building Code (2012) and Local Amendments
- AASHTO Roadside Design Guide, 2011
- Requirements of Local Building Codes and Zoning Ordinances

Design Criteria

Site Topography and Survey

A topographic survey of the proposed Leonard WTP site will be developed by Gorrondona and Associates, Inc. (Surveyor). The survey will be performed in May and June 2015 using aerial mapping methods. Unless requested otherwise, all data and imagery will be referenced to the Texas State Plane Coordinate System, North Central Zone, North American Datum of 1983(1993) and to mean sea level based on the North American Vertical Datum of 1988. Units will be United States survey feet. All data and imagery will meet or exceed American Society for Photogrammetry and Remote Sensing (ASPRS) Class 1 accuracies for a 1 inch = 50 feet scale standard with a 1-foot contour interval.

Three semipermanent control points will be established for future site work.

The necessary field surveys and office calculations will be performed to produce the final property map of the proposed 1,020-acre Leonard WTP site. The field surveying will locate existing property corners and right-of-way marker on the affected parcels. The final property map will be delivered in an AutoCAD 2013 or MicroStation V8i file format.

Existing property fences, utilities, and additional features will be provided by the Surveyor, in color digital orthophotos produced to a 1 inch = 50 feet scale standard with a 3-inch pixel resolution. It is anticipated that additional ground survey will be required for more precise location of the proposed railroad spur, access road connections, and other critical facilities.

Proposed Development

The project includes developing a master plan for a WTP with an ultimate capacity of 280 million gallons per day (MGD) and design of an initial phase with a 70-MGD capacity. The initial phase will be a conventional surface water treatment process with peroxidation, coagulation/flocculation/sedimentation, ozonation, granular media/biologically active filtration, and chlorine/chloramine disinfection processes. The ultimate plant process scheme will mirror the initial phase, except accommodations will be made for the potential of future ultraviolet (UV) disinfection and side stream membrane treatment for a portion of the flow. The solids process is anticipated to include backwash water recovery, sludge thickening, and either dewatering in lagoons or mechanical dewatering. A high service pump station and an electrical substation (both designed by others) will be located on the WTP site. The location of these facilities will be established in the WTP master plan.

The WTP consists of the following facilities, buildings, and structures:

- Administration building[1]
- Operations building[1]
- Maintenance building[1]
- Lab building[1]
- Raw water control vault
- Chemical vault
- Pre-oxidation basin
- Flocculation/sedimentation basins
- Ozone facility (ozone generation building and ozone contact basins)
- Filtration facility
- Wash-water pump station
- Clear wells
- Chemical storage and feed facility
- Backwash equalization basin
- Sludge thickeners
- Solids dewatering (either lagoons or mechanical)

Roadway

Adequate roadways, parking, and maneuvering areas on the facility will be provided to allow for efficiency and safety for staff, visitors, and standard trucks and tractor-trailers for chemical deliveries, residuals disposal, sanitation services, and emergency services. Facilities will be located to allow for crane access during construction and long-term maintenance after completion of construction. Turning radii for truck movements will be based off a WB-62 as defined by AASHTO. A WB-62 is a tractor-trailer combination with trailer length of 48 feet and an overall bumper to bumper length of 69 feet. Placement of walls, fences, structures, signs, and landscaping will allow for adequate sight distance at intersections. The minimum cross slope of roadways will be 2 percent. Minimum vertical curve length at the intersection of two grades will be 50 feet. Vertical curves on all streets will be omitted where the algebraic difference in grades does not exceed 3 percent. Maximum slope in a parking lot is 4.5 percent, and the minimum slope is 1 percent. The minimum slope of concrete gutters is 0.5 percent. All paved streets include curb and gutter where needed for drainage.

---

[1] Building function listed. Multiple building functions may be combined into a particular structure (for example, administration, laboratory, and operations may be combined into a single structure). The WTP master plan will identify the number and functions of buildings.

Sidewalks

Sidewalks will be provided around all public access facilities and in process areas as needed to maintain access for operations and maintenance. Sidewalks will be constructed of concrete, and will be a minimum of 4 inches thick and 48 inches wide. The operations building, maintenance building, and lab building will provide ADA-compliant access. Treatment areas do not need to be ADA compliant.

Signage

Signs will be provided to clearly direct visitors to facilities. Facility roadways will be 24 feet minimum, and all two-way roads accessible by tractor-trailers will have a minimum width of 30 feet. Roadway intersections will be striped and signed. All striping and markings will be thermoplastic conforming to TxDOT Specifications. Bollards will be provided as needed to protect critical facilities from traffic.

Parking

A parking lot will be provided for the administration, operations building, maintenance building, lab, ozone generation building, high service pump station (designed by others), and at access points to major process units. Visitor parking spaces will be provided, including ADA stalls and aisles as required for ADA compliance, at the administration building and any other structure with potential public access.

Standard parking spaces of 10 feet wide by 20 feet long will be provided, except for ADA-compliant spaces. All parking spaces will be striped.

Pavement Design

Pavement structural section and subgrade improvements will be designed based on the TxDOT method for rigid pavement. Concrete is proposed for all roadway and parking area pavement, and design will be based on findings from the geotechnical exploration performed prior to preliminary design, in combination with an anticipated average daily traffic of 50 passenger vehicle trips and 10 tractor-trailer trips per day on the paved facilities. Pavement will have a design life of 20 years.

Facility Access Road

Fannin County Road 4965 bisects the property owned by NTMWD and connects State Highway 78 on the south of NTMWD's property to State Highway 69 on the north of the property. NTMWD desires to ask Fannin County to abandon County Road 4965 and convert it to an internal roadway maintained by NTMWD. If County Road 4965 is converted to an internal roadway, the access to the property and the WTP site can be from either State Highway 78, State Highway 69, or both. The location and configuration of the access will be addressed by the WTP master plan. After the access configuration is established, the alignment of the access roads and construction access will be determined during preliminary design. The following are included in the design:

- The facility entrance will include an entry gate with card reader and communications with the WTP control room. Gates and card readers will be located far enough from the state highway so that trucks can pull all the way off the road with the gate closed.
- The proposed intersection at the state highway will be coordinated with TxDOT and evaluated to ensure safe sight distance for vehicles making left and right turns out of the WTP, and for vehicles making left turns into the WTP.
- The need for improvements to state highways such as the addition of left and right turn lanes will be evaluated.

Railroad Access

An existing railroad line runs along the north and east sides of the site near State Highway 69. A rail spur will be constructed as part of the project to provide rail access from the main track to the WTP. The site will be designed to accommodate this rail spur and the associated chemical deliveries from the rail cars. Additional information describing the work associated with the rail spur will be outlined in the *Existing Conditions Technical Memorandum*.

Fencing, Gates, and Security

The entire project site will be enclosed by 8-foot-tall chain link with three-strand barbed wire fencing. The mesh spacing is a maximum 1 inch, and wire will be minimum 11 gauge. The main entrance gate will be a cantilever slide gate with operators, control system, and card readers. Standard manual swing gates consisting of chain-link fence will be located at alternate entry points, and between the WTP and other facilities onsite.

The WTP master plan will address the areas to be fenced, and the location and configuration of the gates. The master plan will also address any aesthetic amenities associated with the site fencing and gates.

Grading, Stormwater, and Drainage

All process, controls, electrical, and operations facilities are proposed to be located at elevations above 690 feet in accordance with North American Vertical Datum of 1988. This elevations is a minimum of 10 feet above the 100-year flood elevation of 680 feet. Parking areas, primary roadways, and other structures are proposed to be located a minimum of 3 feet above the 100-year floodplain.

Surface drainage will be directed away from buildings, top of cut and fill slopes, and pedestrian walkways. All facility site drainage flow will be captured in abovegrade ditches and swales where feasible, and carried away from the facilities. Where abovegrade facilities are not feasible, an inlet/pipe network will be used. All onsite flow will be directed to the west side of the site where it will ultimately make its way into the existing creek channel and leave the site.

Future expansion will be considered during drainage design. Stormwater facilities will be sized based on buildout runoff where feasible to minimize disruption of future operations.

Onsite stormwater facilities will be designed to the following standards:

- Onsite systems, including inlets and closed conduits, will be designed to convey the 10-year storm event with the hydraulic grade line 1 foot below the manhole top, drain inlet grate, or gutter flow line.
- Drainage designs will protect all structures from flooding during a 100-year storm (all structure entrances will be above the 100-year floodplain).
- Drainage from areas subject to contamination from chemicals will be captured separately and routed to containment basins.
- Minimum pipe size for storm drain pipes will be 18 inches.
- Storm drain pipe will be reinforced concrete pipe (RCP).
- TxDOT standards will be used for design of all storm inlets and outlets.
- Minimum velocity for storm drain pipes is 2 feet per second (fps).
- Manholes will be provided at horizontal points of intersection (PI) with a maximum spacing between manholes of 500 feet.

- Open channels are designed to convey the 100-year storm event while maintaining at least 1 foot of freeboard in cut sections and 3 feet of freeboard in levied sections.
- Culverts are designed to pass the channel design capacity while meeting freeboard requirements.
- Earth channels are designed to flow at a minimum velocity of 2 fps and a maximum velocity of 6 fps.
- Open channel calculations will be based on the Manning's equation.
- Onsite hydrology will be based on the rational method.
- A minimum concentration time of 10 minutes will be used for hydrologic calculations.
- The TxDOT Hydraulic Manual will be followed as applicable for hydrologic and hydraulic calculations.

Erosion and Sedimentation Control

Erosion control standards will be developed during the design of the project with input from the Construction Manager at Risk (CMAR) and will be incorporated into the site work while construction activities are taking place. These measures will include the use of silt fences at the toe of new slopes, along intermediate slope benches when available, around the limits of stockpiles, and generally downhill of disturbed areas. Temporary erosion control grasses consisting of a local erosion control seed mix (using native grasses when available) and straw mulch will be applied to disturbed bare ground surfaces exposed during the wet season. Plastic sheeting may also be used on erodible stockpiles and other disturbed areas where vegetation cannot be established in a timely manner, or where timing is critical to cover exposed surfaces prior to a storm event.

Yard Piping, Utilities, and Fire Protection

Yard piping will be laid out in corridors with a minimum spacing between pipes of one-half the larger diameter to allow adequate room for pipe repairs. Space will be allocated, as necessary, for future pipe installation and site electrical. A minimum horizontal spacing of 10 feet and vertical spacing of 18 inches will be provided between potable water and sanitary sewer lines.

Site piping will be installed on imported pipe bedding with native backfill. A minimum cover depth of 4 feet will be provided over potable water lines, a minimum vertical spacing of 1 foot will be provided between crossing pipes, and depth of cover will be minimized where possible while also minimizing changes in pipe grade and high or low points.

Piping under structures will be concrete-encased with the encasement extending to a distance outside the structure determined by a 45-degree angle from the outside of the footing to the pipe.

Onsite sanitary facilities will either discharge to the Publicly Owned Treatment Work of Leonard or use an onsite septic tank and leach field. Onsite sanitary sewer piping will be specified as polyvinyl chloride (PVC). The diameter will be based on the requirement that gravity pipelines will be designed to provide a minimum velocity of 2 fps when flowing half full with a minimum diameter of 8 inches. Additional information will be provided on sanitary sewer design criteria in the *Existing Conditions Technical Memorandum*. Manholes will be located at changes in direction of gravity sanitary sewer at no less than 300-foot intervals in a straight section of pipe.

Water supply will be provided for fire protection and domestic uses. A permanent water supply that is not dependent on WTP flows will be provided so that the plant has its minimum water supply needs met independent of plant operations. The water supply will either come from Leonard public water supply or from an onsite well. Leonard has capacity available to provide fire protection. The costs associated with extension of service and fees will be evaluated in the *Existing Conditions Technical Memorandum* to determine if this option would be cost effective.

The WTP master plan will address the source of potable water supply and sanitary sewer disposal.

Temporary Facilities for Construction

The existing site has no water, power, sanitary sewer, or roadway (except for County Road 4965) infrastructure. A temporary facilities plan will be developed with input from the CMAR during preliminary design and refined in final design. The temporary facilities plan will address the following:

- Water supply to support construction activities, fire protection, and domestic consumption
- Sanitary waste disposal for construction
- Drainage and sediment control during construction
- Roadway and parking facilities to facilitate efficient construction

The temporary facilities plan will integrate with the initial phase improvements to the extent that it is cost effective and feasible to do so.

TECHNICAL MEMORANDUM 5

Heating, Ventilation, and Air Conditioning; Plumbing; and Fire Protection

PREPARED FOR:	North Texas Municipal Water District
PREPARED BY:	CH2M HILL Released for the purposes of review by Matt Fulls, PE Number 96563 on July 8, 2015
DATE:	July 2015

Introduction

This technical memorandum was prepared to document the heating, ventilation, and air conditioning (HVAC); plumbing; and fire protection codes and design criteria for the design of the proposed new Leonard Water Treatment Plant (WTP).

It is anticipated HVAC and plumbing will be included in the proposed operations, lab, and maintenance facilities. HVAC will also be required for electrical and controls rooms in process facilities, and for some chemical storage areas. Plumbing will be needed for safety showers and eye washes in chemical storage areas. Fire protection will be provided where required by code in operations, lab, maintenance, and chemical storage areas.

Applicable Codes, Standards, and Regulations

HVAC, plumbing, and fire protection design will incorporate, at a minimum, the requirements of the following codes, standards, and regulations:

- Building Codes:
  - HVAC: International Mechanical Code (IMC)
  - Energy: 2009 International Energy Conservation Code (IECC)
  - Building: International Building Code (IBC)
  - Plumbing: International Plumbing Code (IPC)
  - Fire: International Fire Code (IFC)
  - Fuel Gas: International Fuel Gas Code (IFGC)
  - Plumbing: International Plumbing Code (IPC)
- Standards and Regulations:
  - Air Moving and Conditioning Association (AMCA)
  - American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE)
  - American Society of Mechanical Engineers (ASME)
  - American National Standards Institute (ANSI)
  - Associated Air Balance Council (AABC)
  - Occupational Safety and Health Administration (OSHA) Standards for General Industry
  - Sheet Metal and Air Conditioning Contractors National Association (SMACNA)
  - National Fire Protection Association (NFPA)
  - American Conference of Governmental Industrial Hygienists (ACGIH) Industrial Ventilation Manual

HVAC Design Criteria

Outdoor Design Conditions

The climatic data in Table 1 will be used for the design of HVAC systems.

Table 1: ASHRAE[a] Design Conditions
Leonard Water Treatment Plant Basis of Design Report

System	Design
Cooling	ASHRAE[a] 0.4% design
	100.1°F (dry bulb)
	75.1°F (wet bulb)
Heating	ASHRAE[a] 99.6% design
	30°F (dry bulb)
Elevation	700 feet +/-100

[a] Source: *Fundamentals Manual* (ASHRAE, 2013).

Notes:

Weather data from Collin County Regional Airport (McKinney National Airport).
°F = degrees Fahrenheit

Indoor Design Conditions

In general, the indoor design conditions listed in Table 2 will be used for this project.

Table 2: Indoor Design Conditions
Leonard Water Treatment Plant Basis of Design Report

Occupancy	Heating Design Temperature (°F)	Cooling Design Temperature (°F)
Process areas and some chemical storage (ventilated and heated)	50	104[a]
Process areas and some chemical storage (air conditioned and heated)	50	85
Electrical rooms (air conditioned and heated)	50	85
SCADA, server, and control rooms (air conditioned and heated)	50	85
Administration, operations, and lab space (air conditioned and heated; lab space humidity to be controlled to 40%)	68	78

[a] Electrical equipment is generally rated for a maximum ambient temperature of 104°F; ventilation-cooling fans will be sized on the basis of the temperature difference between inside and outside. Occasional excursions of higher temperatures can be expected.

Note:

SCADA = supervisory control and data acquisition

Energy Code Compliance

Design will be in compliance with the 2009 IECC as required by the State of Texas.

Ventilation Design Criteria

Ventilation rates for HVAC systems will comply with applicable building, fire, and mechanical codes as listed above.

General Equipment Selection Criteria

Quality

Systems and vendors that exhibit high reliability and long service life will be specified for the basis of design for HVAC systems. Process areas will be served by heavy-duty commercial- or industrial-grade equipment.

Humidity Control

Relative humidity will not be specifically controlled in most of the buildings. The lab space will have the humidity controlled to 40 percent +/-5 percent relative humidity.

Backup Systems

In this project, most building spaces do not contain equipment or processes that would be measurably harmed upon temporary loss of heating, ventilation, or air conditioning. Therefore, except as detailed below, no deliberate HVAC system backup is planned.

The following spaces will be served with at least two cooling or heating units as applicable, each sized at a minimum of 60 percent of the total required capacity, so that failure of one item of air handling, heating, or cooling system equipment will not result in the total loss of room cooling or heat:

- Electrical rooms
- SCADA, server, and control rooms
- Administration, operations, and lab facilities

Corrosion Protection

HVAC equipment, ductwork, and air distribution devices serving corrosive areas will be provided with protective coatings and/or constructed from corrosion-resistant materials.

Specific Equipment Selection Criteria

The following criteria are general in nature. Building- and zone-specific information regarding HVAC system concepts will be presented in later design phases.

Equipment Location

HVAC equipment will typically be located on the roof of the facility, and access will be provided by permanent ladders or stairs.

Heating Systems

Electrical resistance heating coils and heat pumps will be evaluated for space heating of facilities.

Cooling Systems

Packaged and split system direct expansion (DX) cooling systems will be used to provide cooling for manned facilities, electrical rooms, and control rooms. Evaporative cooling systems will be evaluated as an alternative for process or chemical areas that need cooling.

Ductwork

Metal ductwork will conform to the latest SMACNA standards. In general, all ductwork will be aluminum. Where aluminum is not suitable for the environment in which it is installed, stainless-steel ductwork will be used.

All ductwork conveying mechanically cooled and heated supply air will be externally insulated. Internal duct liner will not be used unless approved by the North Texas Municipal Water District for specific applications.

Starters and Disconnects

Motor starters/contactors for HVAC equipment will be factory installed by the equipment manufacturer, when available. If the option is not available, starters/contactors will be installed in a motor control center or wall mounted as required by an electrical engineer.

Equipment disconnects will be provided as required by electrical code.

Control Systems

All HVAC control systems will generally be stand-alone electronic or microprocessor-based electronic-type as required. Control systems will include local control panels for equipment, either provided with packaged equipment or free standing to serve one or more equipment items.

A central building automation system (BAS) will be provided for the entire WTP to monitor and control HVAC equipment throughout the plant. This BAS system will also have the ability to be monitored remotely. Critical pieces of HVAC equipment will have visible alarms at the BAS main computer and will be linked back to the SCADA system. Additional alarms required by the IMC and IFC for chemical storage spaces will also report back to the BAS and SCADA systems.

Specific Zone Design Criteria

Administration/Operations Building

Heating:	Electrical resistance heat or heat pump in air-handling unit
Ventilation:	Minimum ventilation required by code supplied through the air-handling unit
Exhaust:	For restrooms, locker rooms, breakrooms, and janitor's closets as required by code
Air Conditioning:	Indoor constant air volume system, electric split system DX cooling
Environment:	Nonhazardous, occupancy-driven loads, limited equipment loads
Comments:	Provide backup air-conditioning and heating systems so that failure of any one piece of HVAC equipment will not reduce cooling or heating capacity to less than 60 percent of peak demand

Lab Building

Heating:	Electrical resistance heat or heat pump in air-handling unit
Ventilation:	Minimum ventilation required by code, and makeup air to maintain slightly negative pressure in lab space, supplied through air-handling unit
Exhaust:	Exhaust stack height, velocity, and dissipation per code requirements for lab uses as determined in preliminary design
Air Conditioning:	Indoor variable air volume system, electric split system DX cooling proposed, lab functions to be determined may require different system
Environment:	Potentially hazardous fumes from hoods, limited lab equipment loads

Comments:	Provide backup air-conditioning and heating systems so that failure of any one piece of HVAC equipment will not reduce cooling or heating capacity to less than 60 percent of peak demand

Maintenance Building – Shop Areas

Heating:	Electrical resistance heat with wall-mounted unit heaters
Ventilation:	Makeup air through wall louvers
Exhaust:	Minimum exhaust air by code though wall- or roof-mounted exhaust fans; local exhaust for hazardous processes as required by code
Air Conditioning:	Not required, evaluate evaporative cooling
Environment:	Nonhazardous, limited equipment loads
Comments:	Space well ventilated, heated, no air conditioning

Maintenance Building – Office, Locker Area, and Electrical Room

Heating:	Electrical resistance heat or heat pump in air-handling unit
Ventilation:	Minimum ventilation required by code supplied through the air-handling unit
Exhaust:	Exhaust for restrooms, locker rooms, and breakrooms as required by code through roof-mounted exhaust fans
Air Conditioning:	Electric split system DX cooling; constant volume or variable volume system to be evaluated
Environment:	Nonhazardous, limited equipment loads
Comments:	Provide backup air-conditioning and heating systems so that failure of any one piece of HVAC equipment will not reduce cooling or heating capacity to less than 60 percent of peak demand

Chemical Building/Ozone Building – All Heated; Partial Air Conditioning for Select Chemicals

Heating:	Electric unit heaters, electrical resistance heat in air-handling unit as required by code
Ventilation:	Makeup air through wall louvers or through air-handling unit Ventilation rate to maintain negative pressure inside building
Exhaust:	Exhaust rate as required by code through wall- or roof-mounted exhaust fans, scrubbers for chlorine storage building
Air Conditioning:	Electric DX cooling in unitary air conditioner or evaporative coolers for designated chemicals
Environment:	Hazardous chemicals stored
Comments:	Cooling provided for chemicals that degrade significantly with local temperatures; minimum ventilation rates to meet code requirements

Process and Chemical Area Electrical and Control Equipment Rooms

Heating:	Electric heating through air handlers or heat pump
Ventilation:	Not required

Exhaust:	Not required
Air Conditioning:	Electric DX cooling in unitary air conditioners
Environment:	Nonhazardous, significant equipment heat loads
Comments:	Provide backup air-conditioning systems so that failure of any one unitary air conditioner will not reduce cooling capacity to less than 60 percent of peak demand

Plumbing and Fire Protection

General

This section summarizes the design criteria and requirements for building plumbing systems for the project.

Codes, Standards, and Regulations

Plumbing systems design will conform to the requirements of the listed codes and standards and any supplementary requirements of the authorities having jurisdiction.

Overall Design Criteria/Requirements

General

Options for potable water will be evaluated in the Existing Conditions Report based on availability from Leonard WTP and consideration of well options.

Complete plumbing systems will be designed for the new buildings.

Water hammer arresters will be provided at safety showers and quick-closing valves.

Safety Shower/Eye Wash

Safety shower/eye wash stations will be provided in areas with hazardous chemicals. Each safety shower/eye wash will have a nearby floor drain. Tepid water will be provided to each safety shower/eye wash station through a mixing valve when possible. If hot water is not available, an electric instant water heater will be located at the eye wash station.

Freeze Protection

Electric heat trace and insulation will be used for freeze protection where there is piping that contains water that is exposed to the outside, or is located in an unheated space, and has a risk of freezing.

Roof Drains

Roof drains will be a combination of roof drains and downspouts, or a gutter system, depending on the facility.

Cross Connection Control

Cross connection control will be provided in accordance with the IPC.

Fire Protection Systems

Local fire services for this facility will be provided by the volunteer force at Leonard WTP who have limited resources and may not be able to provide typical urban area response times. As a result, building fire sprinkler systems will be provided where required by code and, in addition, will be evaluated for other facilities to limit potential fire damage to critical facilities in the event of slow emergency response.

A performance-based specification and occupancy hazard drawing will be provided so a licensed Fire Protection Engineer or National Institute for Certification in Engineering Technologies-certified designer can complete the detailed design of the fire protection systems.

Thermal Insulation

Thermal insulation will be provided for the following piping systems:

- Potable cold water
- Potable hot water
- Exterior condensate drains from air-conditioning cooling coils
- Refrigerant suction and liquid lines in interior spaces
- Refrigerant liquid lines on the exterior of the building

Pipe Hanger Material

Plumbing:

- Process Buildings: Factory-applied plastic-coated steel
- Chemical Rooms: 304 stainless steel or other material that will not corrode when exposed to chemicals

Building Piping and Accessories

Piping materials of construction will be as follows:

- Potable cold water (PCW): PEXa or Type L copper
- Nonpotable cold water (NPW): PEXa or Type L copper
- Potable hot water (PHW): PEXa or Type L copper
- Sanitary drain and vent (SS, V): Schedule 40 polyvinyl chloride (PVC)-drain waste and vent (DWV) soil pipe
- Roof drain and emergency overflow drain (RD, ERD): Schedule 40 PVC-DWV soil pipe
- Refrigerant piping (RS, RL): air conditioning and refrigeration-type copper pipe
- Fire protection piping (FP): Above and below floor, based on Schedule 40 carbon steel; other schedule piping may be used based on available pressure and water flow requirements

Specific Zone Design Criteria/Requirements

Specific plumbing requirements for facilities will be developed in preliminary design after the architectural facility program has determined the needs for each facility.

Electrical

PREPARED FOR: North Texas Municipal Water District

PREPARED BY: CH2M HILL
Released for the purposes of review by Jason Clifford,
PE Number 117689 on January 25th, 2016

DATE: January 2016

Introduction

This technical memorandum has been prepared to document the basis of design and codes and standards to be used for the electrical design for the Leonard Water Treatment Plant (WTP). The facility site is located approximately 1.5 miles west of Leonard, between State Highway 69 and State Road 78. The source of power for the facility is a transmission main owned by Oncor, located approximately 4 miles west of the Leonard WTP site. Figure 1 shows the electrical location plan.

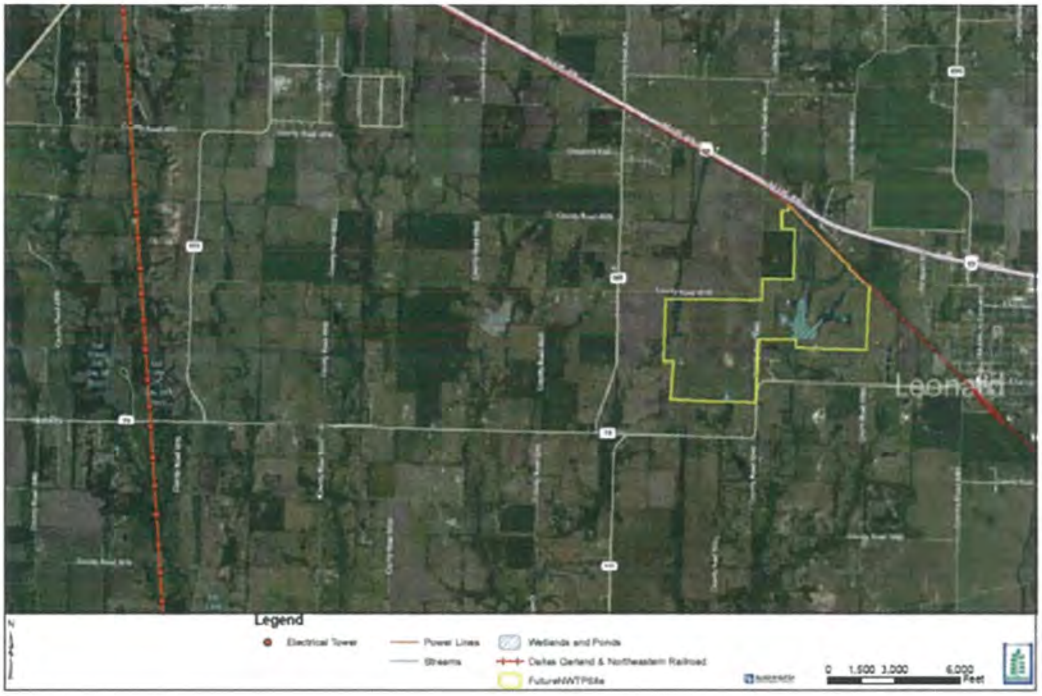


Figure 1: Electrical Location Plan

Objectives of Electrical System

Electrical systems will be designed to provide the following:

- Safe, reliable power to all facilities
- Onsite generation for standby power to critical processes and the operations and maintenance buildings

- Dual power feeds to each facility for redundancy
- Reserve power capacity for future upgrades

Electrical distribution equipment will be specified to name North Texas Municipal Water District's preferred manufacturers.

System Description

Electrical Power Distribution System

The estimated total connected facility power was developed on the basis of the preliminary process model. The connected power summary includes the liquid and residuals treatment processes at the Leonard WTP site; an estimate of high service pumping requirements; and an allowance for miscellaneous power loads for building lighting, HVAC (heating, ventilation, and air conditioning), electrical service, and site lighting. The power summary does not include the power associated with the raw water pump station that is located offsite. Power estimates for high service pumping were provided by Freese & Nichols.

Construction will be split into four phases. Phase 1 will include 70 million gallons per day (MGD) of treatment capacity, and Phase 2 will build on the Phase 1 equipment and structures to expand to 140 MGD of capacity. Phases 3 and 4 will bring the plant to its ultimate capacity of 280 MGD. Phase 4 provides for a 50-MGD membrane treatment system for water from a secondary brackish source, which results in significantly higher power demands for that phase. It is recommended that the offsite power transmission conductors be designed for the ultimate plant load with a 15 percent safety margin (45,000 kilovolt-ampere [kVA]), and the onsite substation be designed for the first 140-MGD power requirements with a 15 percent safety margin (15,000 kVA). The internal power distribution system should be designed for the appropriate loads (Phase 1 alone or Phases 1 and 2) depending on the future expansion strategies. Table 1 lists power supply design criteria.

Table 1: Power Supply Design Criteria for Leonard Water Treatment Plant, Including the High Service Pump Station
Leonard Water Treatment Plant Basis of Design Report

Parameter	Design Criteria	Comments
Electric Utility	Fannin County Electric Cooperative	
Service Voltage	25 kV	138 kV stepped down to 25 kV at substation onsite
70-MGD Connected Load, Total	8 MVA	70 MGD represents Phase 1.
70-MGD Demand Load, Total	6 MVA	
70-MGD Generator Load, Total	5 MW	Generation capability to power one process train (35 MGD), plus the operations and maintenance buildings
280-MGD Connected Load, Total	39 MVA	Estimate based on initial design and future load projections, including possible UV upgrades and membrane systems
280-MGD Demand Load, Total	35 MVA	Estimate based on initial design and future load projections, including UV and membrane systems

Notes:
kV = kilovolt
MVA = mega volt amp
MW = megawatt
UV = ultraviolet

The electric utility supplier to the Leonard WTP will be Fannin County Electric Cooperative (FCEC). The 138-kV Oncor-owned overhead transmission line will be tapped for plant service. The transmission to the site and onsite substation will be provided by FCEC. A utility substation will be provided to step down the 138-kV system to 25 kV for distribution around the WTP.

Two 25-kV feeders will be supplied by the utility substation, located onsite. These feeders will then be connected to the main customer-owned 25-kV substation switchgear, located adjacent to the utility substation, and will represent the service point of the plant. This switchgear will be configured for Main-Tie-Tie-Main functionality, where the middle bus will provide isolation when maintenance or replacement of components is necessary.

A single overhead loop at 25 kV will be distributed throughout the plant to provide power to each main loadcenter throughout the plant. Dual drops will be provided at each loadcenter, connected to two 100% load transformers. Each loadcenter will be configured for Main-Tie-Tie-Main functionality, where the middle bus will be connected to the local standby generator. Automatic transfer controls will be provided interior to each main loadcenter for control of the breakers and generator, upon loss or restoration of utility power.

Main loadcenters will be located at the east chemical facility, maintenance facility, ozone facility, high service pump station, and the north chemical facility. Other loads and facilities will be sub-fed from these main loadcenters.

Low- and medium-voltage switchgear, motor control centers (MCC), and low-voltage switchboards not connected directly to a generator will all be configured Main-Tie-Main for redundant power supplies to all facilities.

Legally Required Emergency System (NEC Article 700)

None.

Legally Required Standby Power System (NEC Article 701)

None.

Standby Power System (NEC Article 702)

Diesel generators will connect to the system at the 4,160V or 480V level, based on the associated loadcenter voltage. The generators will be located in weatherproof, sound-attenuated outdoor enclosures with sub-base fuel tanks, sized to provide 48 hours of fuel at 100% load.

Uninterruptible power supplies (UPS) will be provided at each electrical room and building to provide battery backup systems for programmable logic controller (PLC) and supervisory control and data acquisition (SCADA) equipment, fire alarm systems, security systems, and telecom systems. UPSs will be sized for handling their full load for 15 minutes, enough time for the electrical distribution system to transfer to standby (generator) power.

Critical Operations Power System (NEC Article 70x)

None.

Telecommunications Network

Conduit for telephone service will be provided from the property line to the main communications room located in the operations building.

Telephone service will be provided at the operations building offices and common rooms as well as the maintenance building office.

Horizontal telecommunications cabling will be unshielded, twisted pair cabling that meets or exceeds Category 6 requirements. Horizontal runs exceeding 300 feet will be served with fiber optic cable. Cabling will be listed for the environment installed (for example, riser and plenum).

Backbone telecommunications cabling will be fiber optic cabling.

No paging or mass-notification system will be provided.

Fiber Optic Cabling System

A fiber optic cabling system will be installed to provide communications connectivity between process buildings and the operations building. A common fiber optic system will be used for plant controls, security, and telecommunications.

Fire Alarm System

A fire alarm system will be installed in the operations and maintenance buildings, ozone facility, chemical facilities, and any other buildings required by code. A sprinkler control system and a manually initiated emergency alarm system will be installed in the chemical buildings. The various building fire alarm control panels will be networked together with the main system panel located within the operations building via fiber optic cables. The fire alarm system will require a dedicated telephone line from the Fire Alarm Master Control Panel to the local fire station.

Access Control, Security, and Surveillance Systems

See the Existing Conditions Report (September 2015).

Lightning Protection

A lightning protection system will be provided for those buildings and structures that are shown to be high risk, according to the analysis provided in National Fire Protection Association (NFPA) 780. The lightning protection system will be designed to comply with all applicable provisions of the most current edition of Lightning Protection Institute (LPI) 175, Underwriters' Laboratories, LLC (UL) 96, UL 96A, and NFPA 780.

Design Criteria – Applicable Codes, Standards, and Regulations

The authority having jurisdiction for the electrical system is Fannin County. The authority having jurisdiction for the fire alarm system is the City of Leonard Fire Marshall.

The electrical system design will be based on the following codes and standards.

Codes

- 2014 National Electrical Code (NEC)
- 2012 National Electrical Safety Code (ANSI C2-1987)

Standards

- American National Standards Association (ANSI)
- National Electrical Manufacturers Association (NEMA)
- Institute of Electrical and Electronic Engineers (IEEE)
- Instrument Society of America (ISA)
- Insulated Cable Engineers Association (ICEA)
- Occupational Safety and Health Administration (OSHA)
- American Society for Testing Materials (ASTM)

- Underwriters' Laboratories, LLC (UL)
- Illuminating Engineering Society (IES)
- National Fire Protection Association (NFPA), including NFPA 70E
- International Electrical Testing Association (NETA)

System Voltage

System voltage will be provided as follows:

- 25 kV, ungrounded delta, three-phase, three-wire
- 4.16 kV, ungrounded delta, three-phase, three-wire
- 480 volts solidly grounded wye, three-phase, three-wire
- 208Y/120 volts solidly grounded wye, three-phase, four-wire

Table 2 provides detailed use voltage.

Table 2: Use Voltage
Leonard Water Treatment Plant Basis of Design Report

Use	Voltage
Interior Lighting	120 or 208 volts, single-phase
Site Lighting	480 volts, single-phase
Convenience Outlets	120 volts, single-phase
Motor Control	120 volts, single-phase
Motors (less than 3/4 hp)	120 volts, single-phase
Motors (1 hp and larger)	480 volts, three-phase
Motors (400 hp and larger)	4,160 volts, three-phase

Note:
hp = horsepower

Sizing Criteria

Electrical systems will be designed using the following sizing criteria:

- Motor Control – Reduced voltage soft starters (RVSS) for constant-speed loads above 50 hp. Separately mounted adjustable-frequency drives (AFD), with active front end, passive filtration, or 18-pulse, for adjustable-speed motors above 100 hp.
- Generators – Provide power for operation of one complete train (35 MGD) of process equipment and associated support buildings, including the operations and maintenance buildings.
- Uninterruptable Power Supply – Operate at 100 percent capacity for a minimum of 15 minutes.

Power factor correction capacitors will be applied to produce an average facility power factor between 0.97 and 0.99 to reduce losses, release system capacity, avoid power company penalty, and improve voltage conditions. Capacitors may be applied as needed to process loads that are not on AFDs to get the plant power factor into the target range.

Motors

Generally, motors 50 hp and larger on drives and 100 hp and larger on constant speed will be provided with a temperature protection system.

Motors installed outdoors will include space heaters.

Motors will also be provided with enclosures that are suitable for operating in the environment in which they are installed. The following lists the enclosures proposed and the area in which they will be installed:

- Explosion-Proof (EXP) – Suitable for installation in a hazardous Class 1, Division 1, Group D Area or Class 1, Division 2, Group D Area
- Chemical Industry, Severe-Duty (CISD-TEFC) – Suitable for indoor and outdoor severe-duty applications including high humidity, corrosive, dirty, or salty atmospheres
- Totally Enclosed, Fan Cooled (TEFC) – Suitable for most indoor and outdoor applications in which the environment is not corrosive or hazardous
- Submersible – Suitable for applications in which the entire motor will be submerged in the nonhazardous liquid that it is pumping

Motors driven by AFDs will be inverter duty.

Voltage Drop

Limit starting voltage drop to less than 10 percent and running voltage drop to less than 3 percent.

Equipment Preferences

The following list of equipment manufacturers will be considered for this project. Note that other manufacturers may be installed if they meet the specifications developed during design.

- Oil-filled transformers: ABB, Cooper, or Eaton/Cutler-Hammer.
- Diesel power generators: Caterpillar or Cummins.
- Medium-voltage switchgear: GE or Eaton/Cutler-Hammer.
- MCCs: Square D, Allen Bradley, or Eaton/Cutler Hammer.
- AFDs: Allen Bradley, Eaton-Cutler Hammer, Toshiba, or Square D.
- Lighting and power panels: GE, Eaton-Cutler Hammer, or Square D. Power panels will be built to include a surge protective device (SPD).
- Lighting dry-type transformers: GE, Eaton-Cutler Hammer, or Square D. Transformers supplying nonlinear loads will have the appropriate K-factor rating.

Electrical Materials

The electrical materials used in the electrical system design will be based on the following NEC guidelines.

Section 26 05 02 Basic Electrical Requirements

Site Environmental Conditions

- Elevation: 700 feet
- Seismic: See Basis of Design Report, Technical Memorandum 3: Structural
- Wind Loading: See Basis of Design Report, Technical Memorandum 3: Structural
- Outdoor Temperature Range: See Basis of Design Report, Technical Memorandum 5: Heating, Ventilation, and Air Conditioning; Plumbing; and Fire Protection

Area Classification

The following areas are classified chemically corrosive to metals:

1. Chemical rooms
2. Exterior ozone contact basins
3. Exterior chemical storage buildings

The following areas are classified wet:

1. Below-grade vaults and galleries

The following areas are classified dry:

1. Mechanical and process rooms

The following areas are classified outdoor:

1. Outdoor above-grade areas

The following areas are classified indoor:

1. Maintenance building
2. Electrical rooms
3. Operations building
4. Building mechanical/HVAC rooms

Section 26 05 04 Basic Materials and Methods

Metering

- Electric utility metering will be in accordance with FCEC requirements (meet Electric Utility Service Equipment Requirements Committee [EUSERC] requirements).
- Power monitors will be installed on all switchgear, switchboards, MCCs, and the generator feeders. Power monitors will be connected to the plant control system for viewing via the SCADA system human-machine interface (HMI).

Safety Switches

- Safety switches will be heavy-duty type.
- Local disconnect switches will be located at motors where not in the same facility as the motor controller with lockable disconnect. An auxiliary switch will be provided in VFD disconnects, where applicable.
- A motor-rated toggle disconnect switch will be an alternative for nonfused local disconnect switches for poly-phase motors in the 0.5- to 5-hp range.

Control Stations

- ON-OFF-REMOTE will be maintained or LOCAL/REMOTE, START/STOP momentary controls in local control stations adjacent to each pump. REMOTE control, including pump shutdown, will be maintained by the plant control system.
- Local speed control will be provided at the control stations, and remotely by the plant control system.

Section 26 05 05 Conductors

- Copper with XHHW-2 insulation for 600-volt conductors
- Aluminum with 133 percent ethylene propylene rubber (EPR) insulation for 35-kV cables

- #12 American wire gauge (AWG) minimum for power, #14 AWG minimum for control, or as defined on drawings
- #16 AWG, 100 percent foil shield coverage, with drain wire, 600-volt for field instrument cables
- Four pair unshielded twisted pair #24 AWG solid conductors for indoor data network cables
- Four pair shielded twisted pair #24 AWG solid conductors for outdoor data network cables

Section 26 05 26 Grounding

- Ground rings will be placed around pad-mounted switches, transformers, and generator bonded to duct bank ground; ground rods will be placed at each building and in handholes, on building steel, and other electrodes as required by NEC.
- Ground rings will be provided around buildings that include a lightning protection system.
- All grounding electrodes will be connected to a master ground bar in the electrical room.

Section 26 05 33 Raceway and Boxes

Separate duct banks and manhole/handhole networks will be used for the following systems:

- Medium-voltage power distribution
- 480-volt power wiring, 120-volt control wiring, and fiber optic communications
- Route-opposing feeders on opposite sides of manholes

Duct banks will be provided as follows:

- Concrete-encased steel reinforced for all duct banks under roads and for all 25-kV feeders
- Direct-buried for all other duct banks
- Manholes/handholes located where duct banks are connected, or where required by pulling stress of cabling

Raceway types will be as follows:

- Concrete encased: Schedule 40 polyvinyl chloride (PVC) for power, 120-volt control, and fiber; rigid galvanized steel (RGS) for analog.
- Direct buried: Schedule 40 PVC for power, 120-volt control, and fiber; PVC-coated RGS for analog.
- Dry, exposed: Rigid aluminum.
- Outdoor and wet, exposed: Rigid aluminum.
- Stud-framed walls and above-ceiling tiles: Electrical metallic tubing (EMT).
- Concrete block walls and embedded in concrete/under concrete floors: PVC, Schedule 40.
- Transition from buried/embedded to exposed: PVC-coated RGS.
- Raceways for lighting, HVAC, and receptacle circuits will be surface mounted.
- Equipment cabinets or enclosures will be NEMA 4X, Type 316 stainless steel with Type 316 stainless steel quick release luggage-type latches or three-point handle-operated latching system, with integral conduit hubs for termination of aluminum conduits.

Section 26 08 00 Testing

- Independent visual and electrical testing of all major equipment

Section 26 22 00 Low-Voltage Transformers

- Copper windings

Section 26 43 00 Surge Protective Devices

- SPDs at the incoming medium-voltage switchgear, low-voltage switchboards, MCCs, and at panelboards
- SPDs on data and communication cables that exit a building

Section 26 50 00 Lighting

Table 3 lists the lighting levels.

Table 3: Lighting Levels
Leonard Water Treatment Plant Basis of Design Report

Area	Lighting Level
Indoor process areas	30 FC
Outdoor process areas	1 FC
Electrical equipment rooms	30 FC
Mechanical equipment rooms	30 FC
Street lighting	0.1 to 1 FC
Substation area	2 FC
Maintenance areas	General 30 FC (50 FC at task areas)
Offices	30 FC
Restrooms	10 to 15 FC
Control rooms	30 FC

Note:
FC = foot-candle

Interior

- Occupancy sensor-activated lighting.
- LED or fluorescent fixtures with high-efficiency lamps and electronic ballasts.
- Fluorescent lamps will be cool white, energy efficient, rapid start, extended life with 3100 initial lumens.
- Process area lights will be enclosed and gasketed suitable for wet locations.

Exterior

- LED 4000k
- PLC controlled
- Street lighting will be light-emitting diode (LED), mounted on 25-foot aluminum poles and controlled via photocell and automatic controls
- Process lighting shall be LED, mounted on 10-foot aluminum poles and controlled via photocell, automatic controls, and manual control

Major Electrical Equipment

Table 4 lists the equipment that will be provided as shown in one-line diagrams and schedules.

Table 4: Major Electrical Equipment
Leonard Water Treatment Plant Basis of Design Report

Section	Equipment	Comments
26 12 02	Pad-mount Transformers	Loop feed type
26 13 16	Medium-voltage switchgear	Metalclad type
26 14 13	Switchboards	65k amps interrupting capacity (AIC)
26 24 19	Low-voltage MCCs	RVSS will include bypass contactor
26 29 23	Low-voltage AFDs	Ethernet/IP communication module; over 40-hp 18-pulse or active front end, separately mounted
26 32 13	Engine generators	4,160V or 480V generation

Operations and Maintenance

Measured System Values

At a minimum, the following values will be monitored and recorded by the plant control system:

- Engine generator run status
- Transfer controller status (normal and standby power)
- Normal power plant demand in kW, volts, amps, etc.
- Critical power plant demand in kW, volts, amps, etc.
- Loadcenters demand in kW, volts, amps, etc.

Alarming and Shutdown Controls

At a minimum, the following alarms and shutdown controls will be needed:

- Fire alarms
- Security alarms
- Engine generator failure alarm
- Low generator fuel alarm
- Main circuit breaker trip

Division of Responsibility

Electric Service

Incoming underground electrical service provided by the serving utility as part of its normal obligation to customers is work provided by the serving utility. The electrical installer will provide customer-required service provisions and electrical work including, but not limited to, primary trench and backfill, primary duct system, metering components, and associated conduit.

Telecommunications Service

Incoming telephone and internet service facilities provided by the serving utilities as part of their normal obligation to customers is work provided by the telephone utility. The electrical installer will provide customer-required service provisions and interior telecommunications central and station equipment (telephone instruments, telephone switches, data switches, and hubs, servers, software, etc.) including all associated raceways, outlet and junction boxes, cover plates, and pull wires.

Standard Materials and Major Equipment

Materials and equipment specified in the Standards Manual will be provided and installed by the electrical installer. All equipment will be installed by the electrical installer.

Design Responsibility

The contractor's electrical installer or system supplier will provide detail design of the following:

- Site electrical duct bank routing, sizing, and configuration; manhole and handhole location and sizing
- Lighting and receptacle branch circuit wiring
- Short circuit and protective device coordination study
- Harmonic analysis
- Arc flash study and labeling
- Lightning protection system
- Telecommunication system
- Fire alarm system
- Security system

TECHNICAL MEMORANDUM

Leonard Water Treatment Plant – Schedule

PREPARED FOR:	North Texas Municipal Water District (NTMWD)
PREPARED BY:	CH2M HILL Released for the purposes of review by Doug Harris, PE Number 120585
DATE:	January 4, 2016

Background

The Leonard Water Treatment Plant (WTP) is a phased 280-million-gallon-per-day surface water treatment facility that North Texas Municipal Water District (NTMWD) plans to construct west of Leonard, Texas. The treatment facilities are one component of the overall project that also includes permitting, design, and construction of the Bois D'Arc Reservoir, raw water transmission and terminal storage, and high service pumping and transmission to the NTMWD distribution facilities.

This technical memorandum (TM) summarizes the proposed schedule for the design and construction of the Leonard water treatment facilities. Included in the TM are a key dates summary table (see Table 1), a Microsoft Project Gantt chart of the planned overall schedule for the design and construction of the treatment facilities (see attachment), and a more detailed deliverable schedule for the current design phase (see Table 2).

The design phase of the treatment facilities project was started in March of 2015 with the NTMWD award of a preliminary design contract to CH2M HILL. The project is currently in the conceptual (30 percent) design phase, which is scheduled to be complete in March 2016. The final design phases are scheduled to be completed by March 2017, with initial site construction packages available for the Construction Manager at Risk (CMAR) late in 2016. Construction duration will be developed with the CMAR once they come onboard in spring 2016, but the preliminary estimate of construction duration is 2.5 years running through 2019.

The overall project schedule is being maintained by Freeze and Nichols in their capacity as program managers. The critical path for bringing the Leonard WTP online currently runs through the Bois D'Arc Reservoir permitting, construction, and anticipated seasonal rains to store enough water to start up treatment at the Leonard WTP.

Key Dates for the Leonard Water Treatment Plant Facilities

Table 1 presents the key dates for the design, construction, and startup of the Leonard WTP facilities. The design activities are well under way, and the process has started to bring the CMAR on board; thus, design and construction activities appear to be tracking on schedule. At this point, two schedule variables have the potential to significantly affect the facility startup. First are permit issues related to the Bois D'Arc Reservoir that are pushing back the completion date for that facility. Second is the WTP startup's dependence on seasonal rains to generate sufficient raw water once the Bois D'Arc Reservoir is complete.

Table 1. Leonard Water Treatment Plant Key Dates

Design	
Start of design	March 2015
Deliver 30% design	March 2016
Deliver 60% design	July 2016
Deliver 95% design	November 2016
Deliver construction plans	March 2017
Construction	
Construction – mobilize and start site work	January 2017
Construction – projected completion	November 2019
Startup	
Commence phased startup	September 2019
Sufficient raw water stored for full startup	November 2019
Startup and commissioning completion	February 2020

Deliverables for 30 Percent Design

During the 30 percent design phase, the plan is to have regular workshops to review key interim deliverables to help the designers match facilities to NTMWD preferences. Many of these interim deliverables will be in the form of manufacturer cut sheets, 3-dimensional .pdfs, or model views to facilitate reviews. Table 2 tabulates the proposed workshop dates, key topics to be covered, and comment deadlines to keep the design process on schedule.

Table 2. NTMWD Review and Comment on Conceptual Design

	Review	Review Period	Meeting Dates	Comment Deadline
December 16 Review Meeting	Done			
Review FLOC/SED basin and CLEAR WELL layout	Present, review	1 week	16-Dec-15	23-Dec-15
Process flow diagram	Present, review	1 week	16-Dec-15	23-Dec-15
Non-process space planning table	Highlight questions	1 week	16-Dec-15	23-Dec-15
Review preliminary site layout and yard piping	Present, review	1 week	16-Dec-15	23-Dec-15
Approximate January 6/7 Review Meeting				
Electric distribution plan	NTMWD preferences	Live	16-Jan-16	N/A
Approximate January 6/7 Review Meeting				
Review FILTER facility layout	Present, review	1 week	7-Jan-16	14-Jan-16
Review select equipment recommendations	Present, review	1 week	7-Jan-16	14-Jan-16
Site layout updates	Present, review	1 week	7-Jan-16	14-Jan-16
Schedule technical memorandum	Summary review	2 weeks	7-Jan-16	21-Jan-16

Table 2. NTMWD Review and Comment on Conceptual Design

	Review	Review Period	Meeting Dates	Comment Deadline
Approximate January 20 Review Meeting				
Review OZONE facility layout and equipment	Present, review	1 week	20-Jan-16	27-Jan-16
Review hydraulic profile and pump station concepts	Present, review	1 week	20-Jan-16	27-Jan-16
Deliver Piping and Instrumentation Diagrams	Summary review	2 weeks	20-Jan-16	3-Feb-16
Site plan updates	Present, review	Live	20-Jan-16	N/A
Approximate February 3 Review Meeting				
Review CHEMICAL facility layout and equipment	Present, review	1 week	17-Feb-16	24-Feb-16
Review plant one line	Present, review	1 week	17-Feb-16	24-Feb-16
Additional design details as needed	Review questions	Live	17-Feb-16	N/A
Approximate February 17 Review Meeting				
Review EQUIPMENT LIST	Present, review	1 week	17-Feb-16	24-Feb-16
Review non-process facility layouts	Present, review	1 week	17-Feb-16	24-Feb-16
Additional design details as needed	Review questions	Live	17-Feb-16	N/A
March 30 Percent Delivery				
Facility master plan	Deliver	2 weeks	9-Mar-16	23-Mar-16
30 percent plans, renderings and specs/data	Deliver	3 weeks	23-Mar-16	13-Apr-16
Updated cost estimate	Deliver, review	2 weeks	30-Mar-16	13-Apr-16
Updated schedule	Deliver	2 weeks	30-Mar-16	13-Apr-16

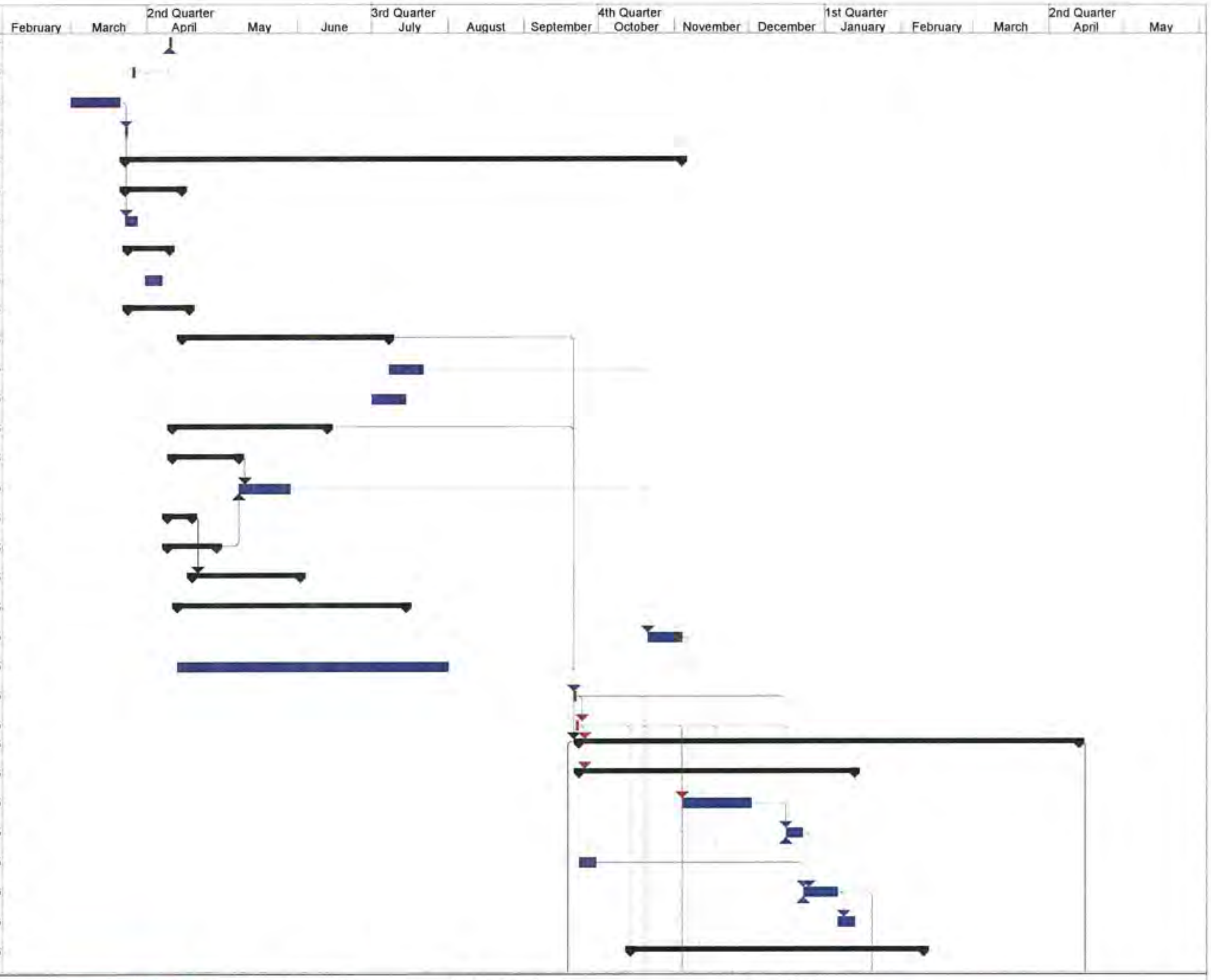
Note:
N/A = not applicable

Schedule Gantt Chart

The schedule in "Gantt" format with start and finish dates listed, and dependencies charted is attached. The schedule includes detailed design and review activities for the 30 percent design phase and overall activities for the upcoming phases. The complete schedule is available in Microsoft Project format upon request.

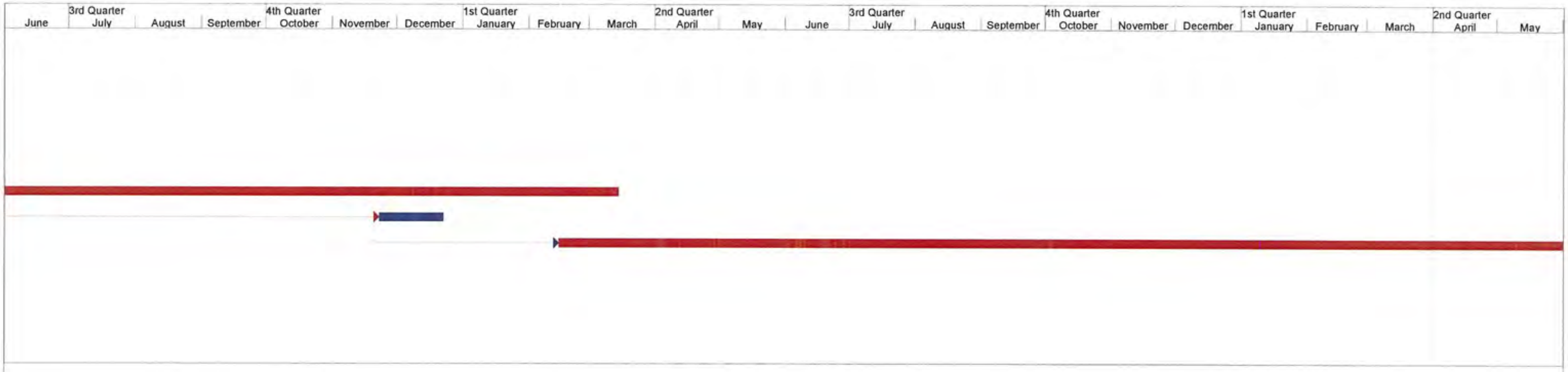
Attachment
Schedule Gantt Chart

ID	Task Name	Duration	Start	Finish
1	NTP Task 1, 3 & 4	1 day	Fri 4/10/15	Fri 4/10/15
2	Contract Award Task 1, 3 & 4	1 day	Thu 3/26/15	Thu 3/26/15
3	Complete Negotiations	20 edays	Sun 3/1/15	Sat 3/21/15
4	Pre NTP task 1, 3 & 4	1 day	Mon 3/23/15	Mon 3/23/15
5	**Task 1 Design Criteria Development**	**162 days?**	**Mon 3/23/15**	**Tue 11/3/15**
6	**Project Management**	**17 days**	**Mon 3/23/15**	**Tue 4/14/15**
28	Information Requests	5 days	Mon 3/23/15	Fri 3/27/15
29	**Client Charter Development**	**13 days**	**Tue 3/24/15**	**Thu 4/9/15**
34	CH2MHILL Team Charter	1 wk	Tue 3/31/15	Mon 4/6/15
35	**Project Set up**	**19 days**	**Tue 3/24/15**	**Fri 4/17/15**
40	**Process Refinement**	**60 days**	**Wed 4/15/15**	**Tue 7/7/15**
50	Conceptual process TM	2 wks	Wed 7/8/15	Tue 7/21/15
51	Residuals TM	2 wks	Wed 7/1/15	Tue 7/14/15
52	**Site Characterization**	**45 days?**	**Fri 4/10/15**	**Fri 6/12/15**
69	**Identify preferences**	**19 days**	**Fri 4/10/15**	**Thu 5/7/15**
73	Design Criteria TM	3 wks	Fri 5/8/15	Thu 5/28/15
74	**Identify schedule constraints**	**7 days**	**Wed 4/8/15**	**Sat 4/18/15**
78	**Project interface constraints**	**14 days**	**Wed 4/8/15**	**Tue 4/28/15**
81	**Develop initial schedule for project completion**	**31 days**	**Sat 4/18/15**	**Mon 6/1/15**
84	**Develop initial opinion of probable costs**	**67 days**	**Mon 4/13/15**	**Tue 7/14/15**
89	NTMWD Review & Comment on Phase 1 Repoı	10 days	Wed 10/21/15	Tue 11/3/15
90	Finalize Scope & Fee for Task 2	16 wks	Mon 4/13/15	Fri 7/31/15
91	Contract Award Task 2	1 day	Mon 9/21/15	Mon 9/21/15
92	NTP Task 2	1 day	Tue 9/22/15	Tue 9/22/15
93	**Task 2 Preliminary (30%) Design**	**145 days**	**Wed 9/23/15**	**Tue 4/12/16**
94	**Plant Hydraulics Development**	**80 days**	**Wed 9/23/15**	**Tue 1/12/16**
95	Refine process flow diagram	4 wks	Wed 11/4/15	Tue 12/1/15
96	Estimate Unit Process losses	1 wk	Wed 12/16/15	Tue 12/22/15
97	Estimate connecting pipeline losses	1 wk	Wed 9/23/15	Tue 9/29/15
98	Develop hydraulic profile	2 wks	Wed 12/23/15	Tue 1/5/16
99	Hydraulic profile TM	1 wk	Wed 1/6/16	Tue 1/12/16
100	**Plant Master Plan**	**85 days**	**Wed 10/14/15**	**Tue 2/9/16**

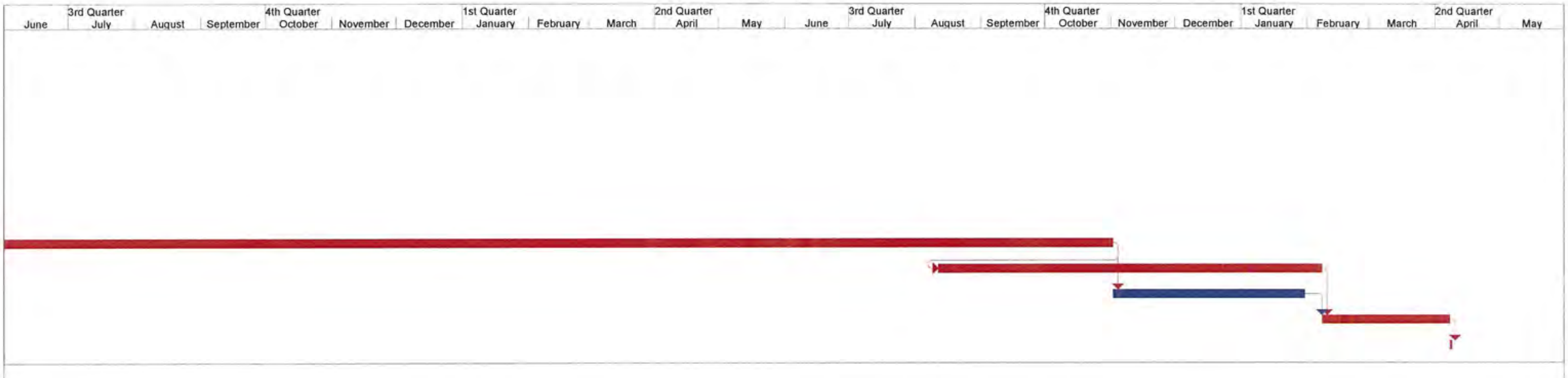


Project: North WTP
Date: Wed 12/23/15

Task		Rolled Up Critical Task		Project Summary		Duration-only		External Tasks	
Critical Task		Rolled Up Milestone	◇	Group By Summary		Manual Summary Rollup	◆	External Milestone	
Milestone	◆	Rolled Up Progress		Inactive Milestone		Manual Summary	◆	Progress	
Summary		Split		Inactive Summary		Start-only		Deadline	⇩
Rolled Up Task		External Tasks		Manual Task		Finish-only			



Task	▬	Rolled Up Critical Task	▬	Project Summary	▬	Duration-only	┈	External Tasks	◇
Critical Task	▬	Rolled Up Milestone	◇	Group By Summary	▬	Manual Summary Rollup	◆	External Milestone	▬
Milestone	◆	Rolled Up Progress	—	Inactive Milestone	◇	Manual Summary	◆	Progress	—
Summary	▬	Split	┈	Inactive Summary	┈	Start-only	▬	Deadline	⇩
Rolled Up Task	▬	External Tasks	▬	Manual Task	◇	Finish-only	▬		



Project: North WTP
Date: Wed 12/23/15

Task	🟦	Rolled Up Critical Task	🟥	Project Summary	▬	Duration-only	┈	External Tasks	◇
Critical Task	🟥	Rolled Up Milestone	◇	Group By Summary	▬	Manual Summary Rollup	◆	External Milestone	▬
Milestone	◆	Rolled Up Progress	—	Inactive Milestone	◇	Manual Summary	◆	Progress	—
Summary	▬	Split	┈	Inactive Summary	┈	Start-only	▬	Deadline	⇩
Rolled Up Task	🟦	External Tasks	▬	Manual Task	◇	Finish-only	▬		

Leonard Water Treatment Plant
Existing Conditions Report

Prepared for

North Texas Municipal Water District

Prepared by

CH2M HILL Engineers Inc.
TBPE Firm No. 3699
12750 Merit Drive, Suite 1100
Dallas, TX 75251

September 2015

Released for review under the authority of:

Registered Professional Engineer No. 48243
Edward M Motley

Contents

Introduction

PREPARED FOR: North Texas Municipal Water District

PREPARED BY: CH2M HILL

General Information

This Existing Conditions Report is the second in a series of three reports to be developed as a part of the Design Criteria and Conceptual Design Phase of the Leonard Water Treatment Plant Project. The other two reports are the Basis of Design Report and Treatment Process Report. This Existing Conditions Report summarizes the existing conditions and constraints that must be addressed in the planning and design of the water treatment plant. This draft report includes seven individual technical memorandums (TM) summarizing the following topics related to the water treatment plant site:

- TM 1 Site Boundary and Topography
- TM 2 Site Geotechnical Data
- TM 3 Jurisdictional Areas and Other Site Constraints
- TM 4 Local Jurisdictional Issues
- TM 5 Emergency Services
- TM 6 Offsite Utilities
- TM 7 Railroad Coordination and Requirements

The information presented in these TMs will define constraints that must be addressed in the planning and design of the Leonard Water Treatment Plant facilities.

TECHNICAL MEMORANDUM 1

Site Boundary and Topography

PREPARED FOR:	North Texas Municipal Water District
PREPARED BY:	CH2M HILL Released for the purposes of review by Edward Motley, PE Number 48243 on September 14, 2015

Introduction

The proposed Leonard Water Treatment Plant (WTP) will be located approximately 1.5 miles west of Leonard, Texas. The proposed plant site is part of a 1,120-acre tract purchased by North Texas Municipal Water District (NTMWD) for the Lower Bois d' Arc Creek Water Supply Project (see Figure 1). The WTP site will be located in the southwestern portion of the tract on a 323-acre parcel. A balancing reservoir is planned for the parcel north of the WTP site.

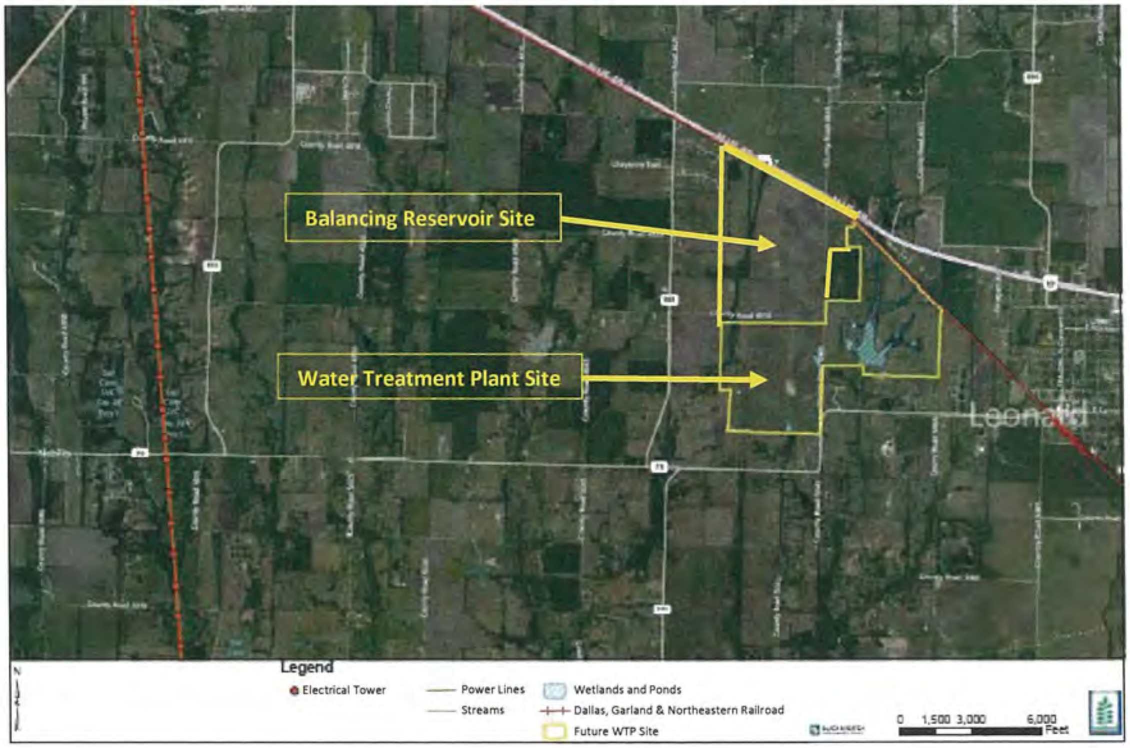


Figure 1. Site Location Map

Water Treatment Plant Boundary

The WTP site will be located on Tract 2 of the parcels owned by NTMWD as recorded in Volume 1424, Page 89 of the official public records of Fannin County. Figure 2 illustrates the boundary of the proposed WTP site.

Site Topography

Figure 3 presents a topographic map of the Leonard WTP site based on aerial photography obtained in June 2015. In general, the site is clear pastureland, with the exception of a small wooded area surrounding a small intermittent creek on the far west side of the plant site, and measures approximately 3,600 feet east-west and approximately 4,000 feet north-south. The site contains five small impoundments, two on the east side, one on the south side, and two on the west side. An unnamed tributary of Bear Creek (TBC) flows across the western extremity of the plant site, and a small drainage swale extends eastward from the tributary about one-third across the site.

The site has little relief with a maximum elevation of 712 feet mean sea level (msl) at a small rise in the southwest corner of the site and a low point of approximately 660 feet MLS in the TBC creekbed. A ridge runs from the southwest corner to the northeast corner of the site with elevations varying from 712 to 700 feet msl. From the ridge line, the property falls off to TBC on the west side and to an on-stream impoundment near the southeast corner. The elevations along the east side of the site vary from a low of 680 feet msl in the southeast corner to a high of 706 feet msl in the northeast corner. The elevations along the west side of the site vary from a low of 659 feet msl in the bottom of TBC to a high of 700 feet msl at the southwest corner.

The site also contains two structures, a former home and outbuilding, associated with a farm site near the southeast corner of the site. The site is fenced around its perimeter with barbed wire.

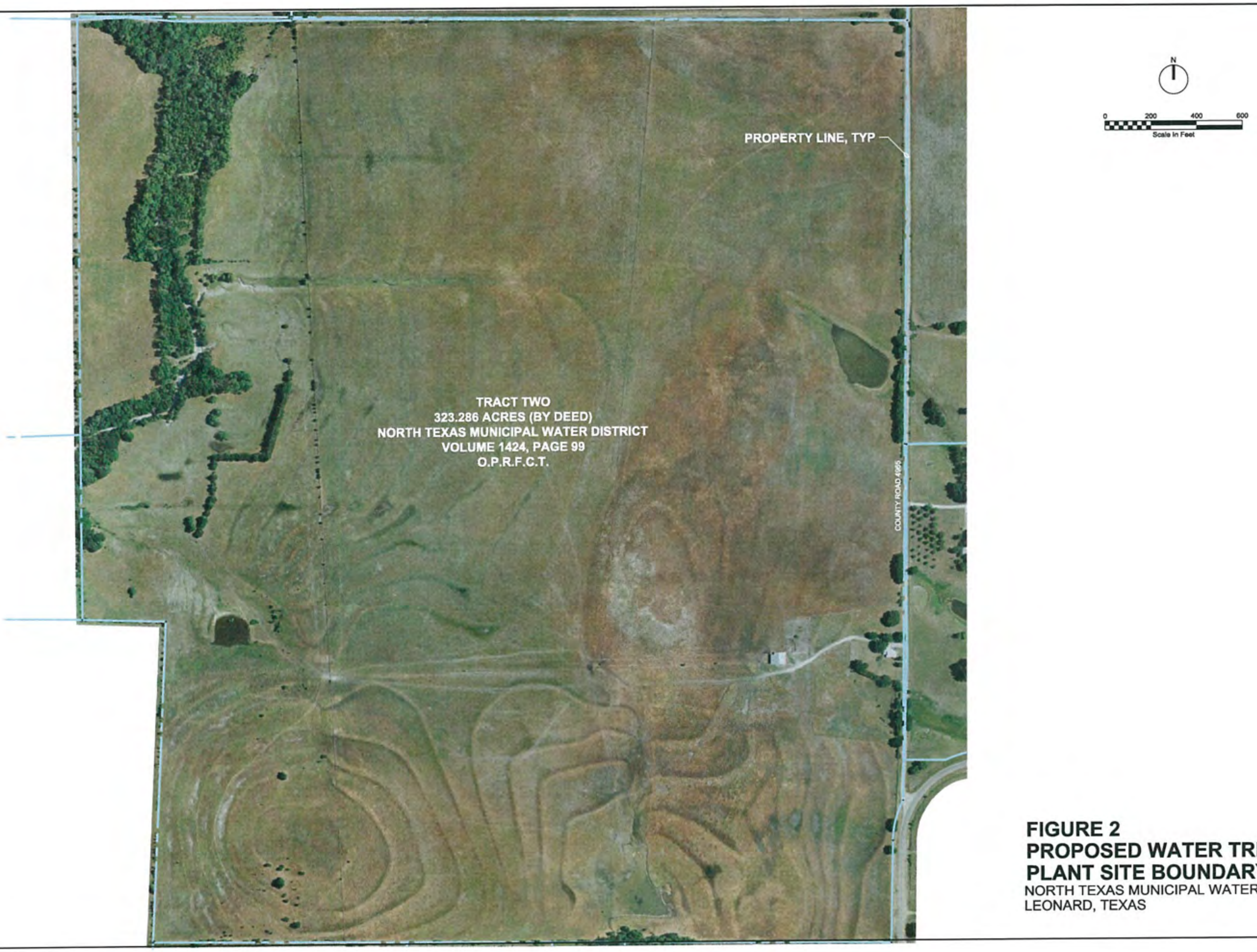


FIGURE 2
PROPOSED WATER TREATMENT PLANT SITE BOUNDARY
NORTH TEXAS MUNICIPAL WATER DISTRICT
LEONARD, TEXAS

ch2m:

FIGURE 3
PROPOSED WATER TREATMENT PLANT SITE TOPOGRAPHY

NORTH TEXAS MUNICIPAL WATER DISTRICT
LEONARD, TEXAS

ch2m:

TECHNICAL MEMORANDUM 2

Site Geotechnical Data

PREPARED FOR: North Texas Municipal Water District

PREPARED BY: CH2M HILL
Released for the purposes of review by Doug Harris,
PE Number 120585 on September 14, 2015

Introduction

This technical memorandum and the attached draft Geotechnical Data Report provide the findings of the initial soil investigations at the site of the proposed Leonard Water Treatment Plant (WTP).

The WTP is proposed to be located approximately 1.5 miles west of Leonard, Texas. The WTP site is a 323-acre tract in the southwestern portion of a 1,120-acre property purchased by North Texas Municipal Water District (NTMWD) for the Lower Bois d' Arc Creek Water Supply Project (see Figure 1).

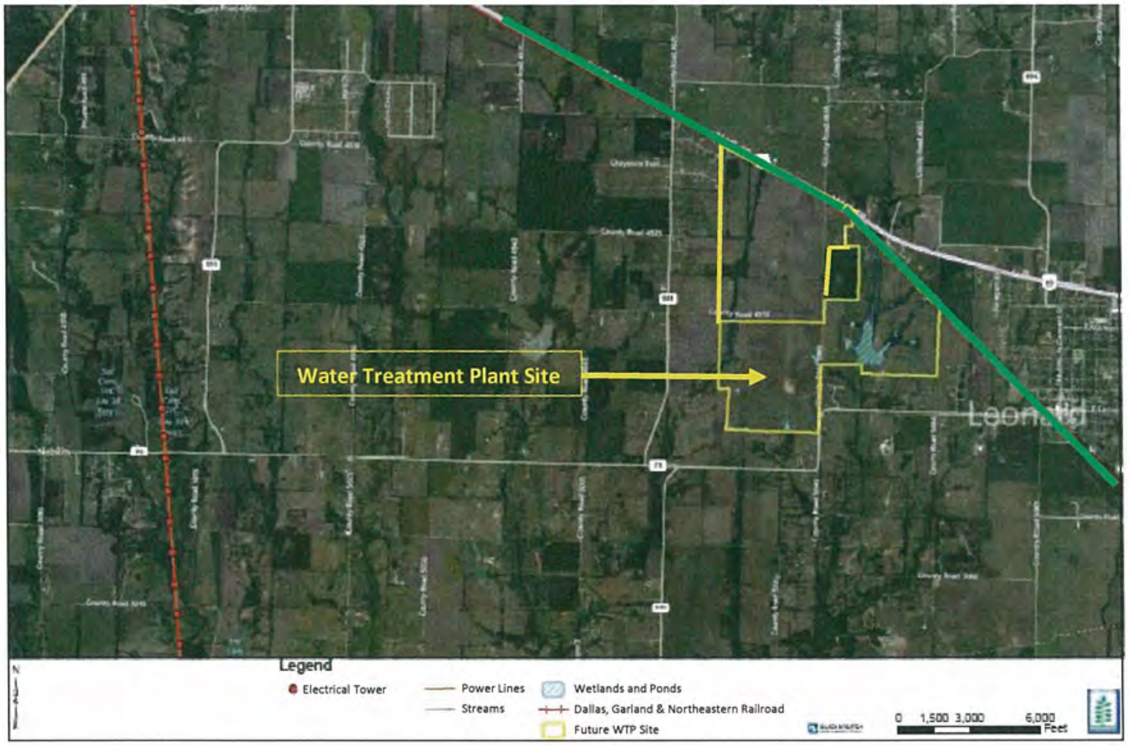


Figure 1. Site Location Map

Site Geotechnical Investigation

HVJ Associates, Inc. (HVJ) was retained by CH2M HILL (CH2M) to perform a geotechnical study for the proposed NTMWD Leonard Water Treatment Plant (WTP) in Leonard, Texas. Between June 8 and 18, 2015, HVJ was onsite and completed the drilling and sampling of 18 soil borings with depths ranging between 15 and 45 feet below the existing ground surface. Layout of the borings on the site is illustrated on Figure 2. On August 14, 2015, HVJ produced the draft Geotechnical Data Report (see Attachment 1).

A geotechnical interpretive report is currently being completed by CH2M on the basis of the data provided in the draft Geotechnical Data Report to develop design loadings for the various soil and rock layers encountered and to provide recommendations on foundations for the water treatment facilities. This interpretive report is scheduled to be issued in September 2015.

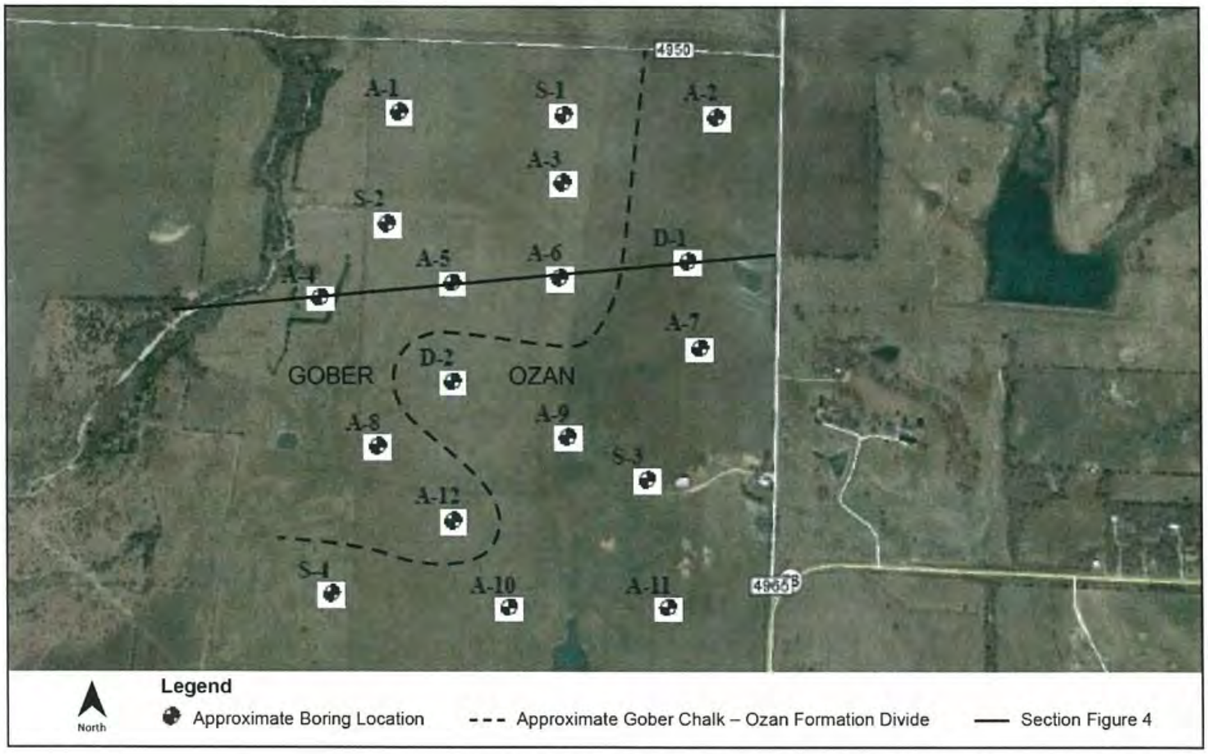


Figure 2. Boring Location Layout Plate from HVJ Geotechnical Data Report

Groundwater Levels

Groundwater was observed in borings D-2 and S-3 at depths ranging between about 4 and 9 feet during drilling operations and at depths ranging between about 9 and 16 feet after completion of drilling in borings D-1, D-2, and S-1 through S-4. Groundwater was not encountered in the remaining borings. It is anticipated that groundwater levels will fluctuate due to seasonal variations in climatic conditions. Groundwater may also be encountered through fissures and fractures of limestone with seasonal variations. It should be noted that these borings were completed during a period of extremely high seasonal rainfall.

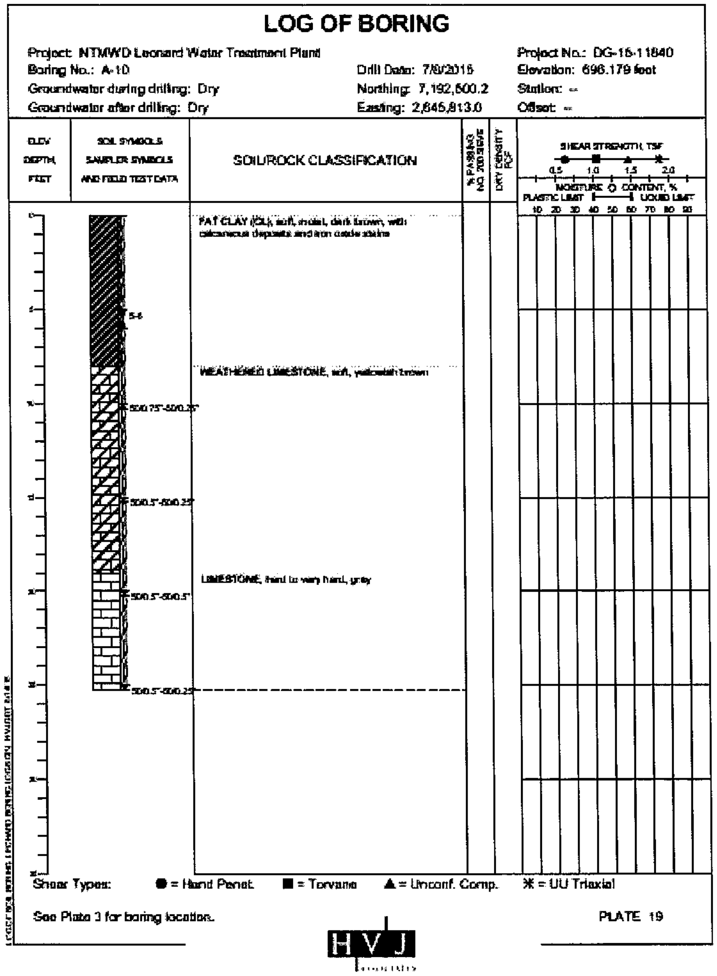
Site Geotechnical Findings Summary

The site sits on an area described by the "Geologic Atlas of Texas, Sherman Sheet," as a combination of Gober Chalk and the Ozan Formation.

The Ozan Formation mainly consists of dark gray clay; weathers to light brownish with weak fissility; is calcareous and poorly bedded; and has a variable amount of glauconite, some siltstone beds, and marine megafossils. The Ozan Formation is approximately 425 feet thick.

Gober Chalk mainly consists of bluish-gray limestone, weathers white, and is brittle and argillaceous. Gober Chalk is approximately 450 feet thick and thins eastward.

The typical profile of the soils in both areas is 3 to 10 feet of fat clay underlain by a 5- to 10-foot-thick layer of weathered shale or limestone with sound rock below at depth from surface ranging from 8 to 24 feet. Lean clay was identified in 3 of the 18 borings in a 4- to 9-foot layer between the fat clays and weathered shale. See sample boring log of A-10 illustrated on Figure 3 and site soils cross section on Figure 4.



LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant
Boring No.: A-10
Groundwater during drilling: Dry
Groundwater after drilling: Dry
Drill Date: 7/8/2015
Northing: 7,192,600.2
Easting: 2,646,813.0
Project No.: DG-15-11840
Elevation: 696.179 feet
Station: --
Offset: --

FAT CLAY (CH), soft, moist, dark brown, with calcareous deposits and iron oxide stains

WEATHERED LIMESTONE, soft, yellowish brown

LIMESTONE, hard to very hard, grey

Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

See Plate 3 for boring location.

PLATE 19

Figure 3. Sample Boring Log

Figure 4 is a cross section illustrating the site soils profile cut through borings A-4, A-5, A-6, and D-1.

This page intentionally left blank.

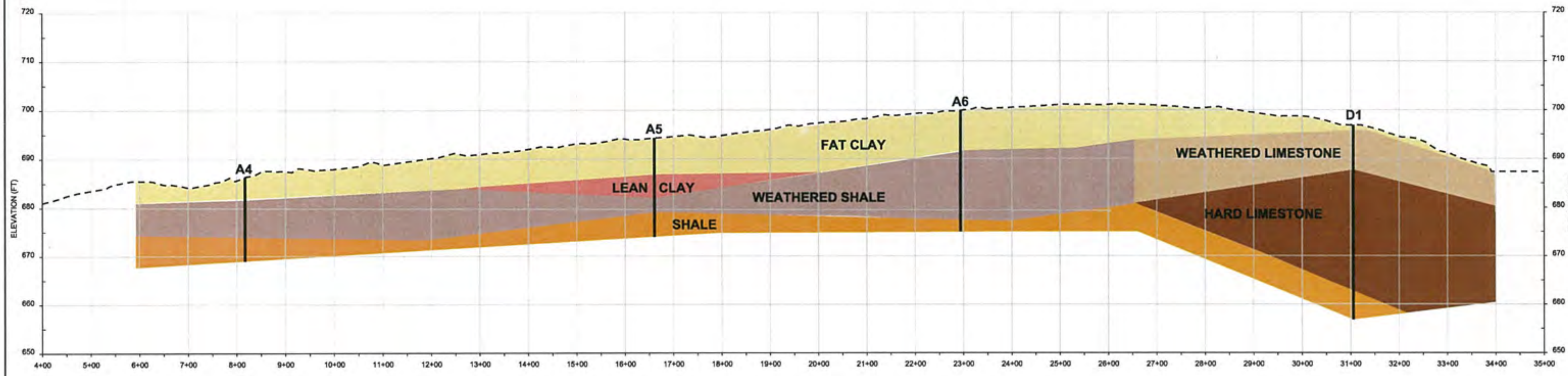


FIGURE 4
GEOLOGICAL CROSS SECTION AT BORINGS A4, A5, A6 & D1

NORTH TEXAS MUNICIPAL WATER DISTRICT
LEONARD, TEXAS

Figure 5 presents HVJ's table summarizing the subsurface conditions encountered.

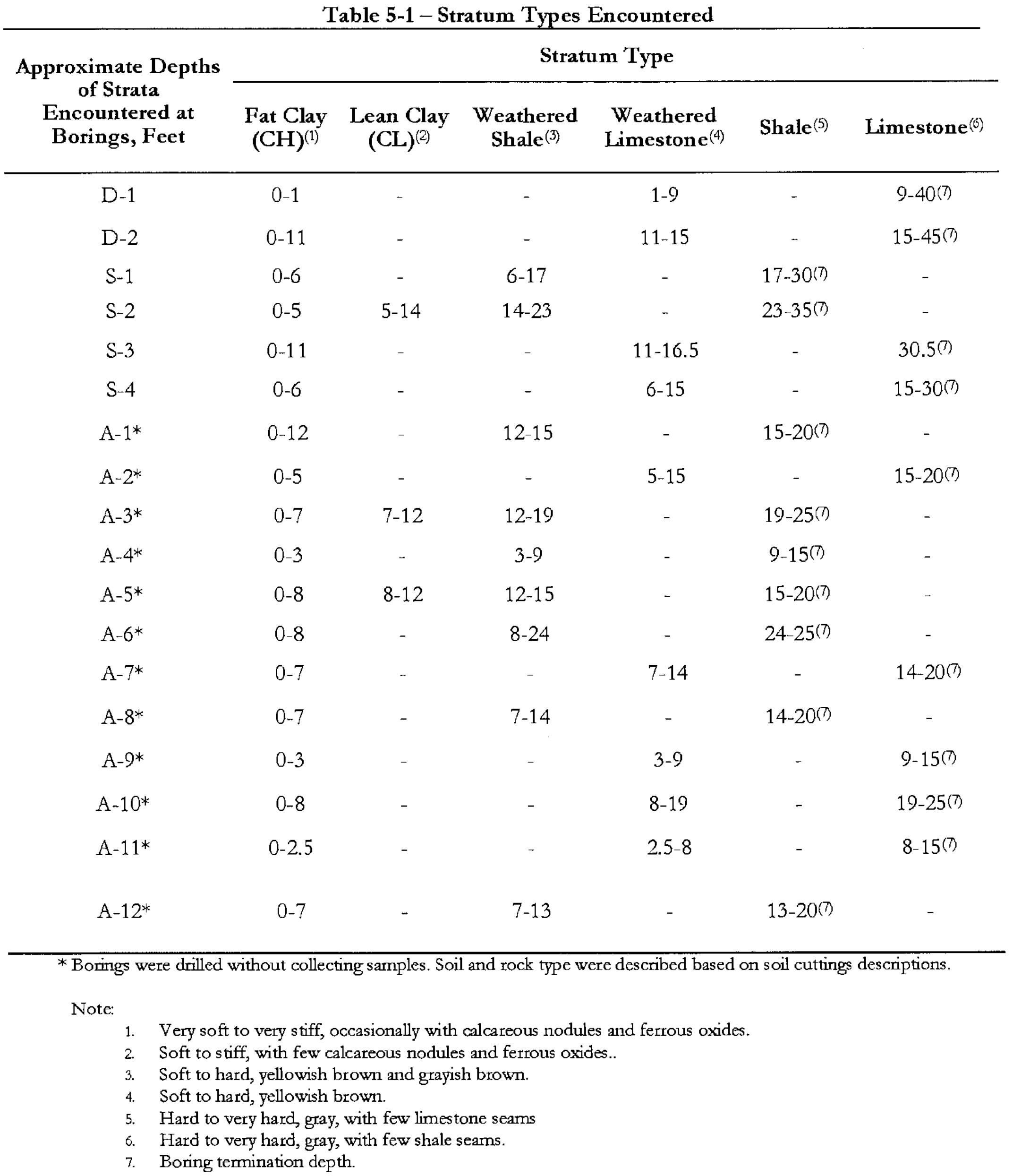


Table 5-1 – Stratum Types Encountered

Approximate Depths of Strata Encountered at Borings, Feet	Stratum Type					
	Fat Clay (CH)(1)	**Lean Clay (CL)(2)**	**Weathered Shale(3)**	**Weathered Limestone(4)**	**Shale(5)**	**Limestone(6)**
D-1	0-1	-	-	1-9	-	9-40(7)
D-2	0-11	-	-	11-15	-	15-45(7)
S-1	0-6	-	6-17	-	17-30(7)	-
S-2	0-5	5-14	14-23	-	23-35(7)	-
S-3	0-11	-	-	11-16.5	-	30.5(7)
S-4	0-6	-	-	6-15	-	15-30(7)
A-1*	0-12	-	12-15	-	15-20(7)	-
A-2*	0-5	-	-	5-15	-	15-20(7)
A-3*	0-7	7-12	12-19	-	19-25(7)	-
A-4*	0-3	-	3-9	-	9-15(7)	-
A-5*	0-8	8-12	12-15	-	15-20(7)	-
A-6*	0-8	-	8-24	-	24-25(7)	-
A-7*	0-7	-	-	7-14	-	14-20(7)
A-8*	0-7	-	7-14	-	14-20(7)	-
A-9*	0-3	-	-	3-9	-	9-15(7)
A-10*	0-8	-	-	8-19	-	19-25(7)
A-11*	0-2.5	-	-	2.5-8	-	8-15(7)
A-12*	0-7	-	7-13	-	13-20(7)	-

* Borings were drilled without collecting samples. Soil and rock type were described based on soil cuttings descriptions.

Note:

1. Very soft to very stiff, occasionally with calcareous nodules and ferrous oxides.
2. Soft to stiff, with few calcareous nodules and ferrous oxides..
3. Soft to hard, yellowish brown and grayish brown.
4. Soft to hard, yellowish brown.
5. Hard to very hard, gray, with few limestone seams
6. Hard to very hard, gray, with few shale seams.
7. Boring termination depth.

Figure 5. Subsurface Conditions Encountered

Attachment 1
Geotechnical Data Report NTMWD Leonard Water Treatment Plant, Leonard Texas

GEOTECHNICAL DATA REPORT
NTMWD LEONARD
WATER TREATMENT PLANT
LEONARD, TEXAS

BY
HVJ ASSOCIATES, INC.
DALLAS, TEXAS

AUGUST 14, 2015

REPORT NO. DG1511840

HVJ ASSOCIATES

Houston
Austin
Dallas
San Antonio

8701 John Carpenter Freeway, Suite 250
Dallas, Texas 75247-4640
214.678.0227 Ph
214.678.0228 Fax
www.hvj.com

August 14, 2015

Mr. Edward M. Motley, BCEE, PE
CH2M HILL
12750 Merit Drive, Suite 1100
Dallas, TX 75251

Re: Geotechnical Data Report
NTMWD Leonard Water Treatment Plant
Leonard, Texas
Owner: NTMWD
HVJ Proposal No. DG1511840

Dear Mr. Motley:

Submitted herein is the Geotechnical Data Report for the above referenced project. The study was conducted in general accordance with proposal number DG1511840 dated February 25, 2015 (Revised April 7, 2015) and is subject to the limitations presented in this report.

We appreciate the opportunity of working with you on this project. Please read the entire report and notify us if there are questions concerning this report or if we may be of further assistance.

Sincerely,

HVJ ASSOCIATES, INC.
Texas Firm Registration No. F-000646

DRAFT

Jae Hyun Park, PE
Project Manager

Damian Bozek, EIT
Staff Engineer

JP/DB/SP

This document was released for the purpose of interim review under the authority of Jae Hyun Park, PE 103692 on August 14, 2015. It is not to be used for construction, bidding, or permit purposes.

- Main Text – 11 pages
- Plates – 26 pages
- Appendix A – 4 pages
- Appendix B – 20 pages

TABLE OF CONTENTS

LIST OF TABLES

PLATES

APPENDICES

1 EXECUTIVE SUMMARY

HVJ Associates, Inc. was retained by CH2M HILL to perform geotechnical study for the proposed NTMWD Leonard Water Treatment Plant in Leonard, Texas. We understand that the project includes design of new structures for the proposed water treatment plant.

Subsurface conditions were evaluated by drilling and sampling a total of eighteen (18) soil borings with depths ranging between 15 and 45 feet below the existing ground surface. As proposed, two (2) borings were drilled and sampled to a depth of approximately 30 feet into bedrock (borings D-1 and D-2), four (4) borings were drilled and sampled to a depth of approximately 10 feet into bedrock (borings S-1 through S-4) and twelve (12) borings were augered continuously without sampling to a depth of approximately 5 feet into bedrock (borings A-1 through A-12). A brief summary of our investigational findings are presented below:

1. Subsurface conditions encountered during our field activity in the borings are summarized in the following table.

Stratum Types Encountered

Approximate Depths of Strata Encountered at Borings, Feet	**Stratum Type**					
	Fat Clay (CH)(1)	**Lean Clay (CL)(2)**	**Weathered Shale(3)**	**Weathered Limestone(4)**	**Shale(5)**	**Limestone(6)**
D-1	0-1	-	-	1-9	-	9-40(7)
D-2	0-11	-	-	11-15	-	15-45(7)
S-1	0-6	-	6-17	-	17-30(7)	-
S-2	0-5	5-14	14-23	-	23-35(7)	-
S-3	0-11	-	-	11-16.5	-	16.5-30.5(7)
S-4	0-6	-	-	6-15	-	15-30(7)
A-1*	0-12	-	12-15	-	15-20(7)	-
A-2*	0-5	-	-	5-15	-	15-20(7)
A-3*	0-7	7-12	12-19	-	19-25(7)	-
A-4*	0-3	-	3-9	-	9-15(7)	-
A-5*	0-8	8-12	12-15	-	15-20(7)	-
A-6*	0-8	-	8-24	-	24-25(7)	-
A-7*	0-7	-	-	7-14	-	14-20(7)
A-8*	0-7	-	7-14	-	14-20(7)	-
A-9*	0-3	-	-	3-9	-	9-15(7)
A-10*	0-8	-	-	8-19	-	19-25(7)

Approximate Depths of Strata Encountered at Borings, Feet	Stratum Type					
	Fat Clay (CH)(1)	Lean Clay (CL)(2)	Weathered Shale(3)	Weathered Limestone(4)	Shale(5)	Limestone(6)
A-11*	0-2.5	-	-	2.5-8	-	8-15(7)
A-12*	0-7	-	7-13	-	13-20(7)	-

* Borings were augered without collecting samples. Soil and rock types were described based on soil cuttings descriptions.

Note:

1. Very soft to very stiff, occasionally with calcareous nodules and ferrous oxides.
2. Soft to stiff, with few calcareous nodules and ferrous oxides.
3. Soft to hard, yellowish brown and grayish brown.
4. Soft to hard, yellowish brown.
5. Hard to very hard, gray, with few limestone seams
6. Hard to very hard, gray, with few shale seams.
7. Boring termination depth.

2. Groundwater was observed in borings D-2 and S-3 at depths ranging between about 4 and 9 feet during drilling operations and at depths ranging between about 9 and 16 feet after completion of drilling in borings D-1, D-2 and S-1 through S-4. Groundwater was not encountered in the remaining borings. It is anticipated that groundwater levels will fluctuate due to seasonal variations in climatic conditions. Groundwater may also be encountered through fissures and fractures of limestone with seasonal variations. Groundwater depths information is included on the boring logs, Plates 4 through 21.

3. A laboratory testing program, consisting of moisture contents, Atterberg limits, percent passing #200 sieve, unconfined compression, and dry unit weight, were performed on select soil and rock samples. The testing results are included on the boring logs and on the laboratory summary table in Appendix A. Swell index, soil box resistivity, sulfate, chloride and pH test results are included in Appendix B.

Please note that this executive summary does not fully relate our findings and opinions. Those findings and opinions are only presented through our full report.

2 INTRODUCTION

2.1 Project Description

HVJ Associates, Inc. was retained by CH2M HILL to perform geotechnical study for the proposed NTMWD Leonard Water Treatment Plant in Leonard, Texas. We understand that the project includes design of new structures for the proposed water treatment plant. A site vicinity map showing the approximate project location is presented on Plate 1 of the report.

2.2 Geotechnical Investigation Program

The objectives of this study were to gather information on subsurface conditions at the site and to provide geotechnical data report for the proposed structure. The objectives were accomplished by:

- Drilling six (18) borings at depths ranging between 15 and 45 feet below the existing ground surface to determine soil stratigraphy and to obtain samples for laboratory testing;
- Performing laboratory tests to determine physical and engineering characteristics of the soils; and

Subsequent sections of this report contain descriptions of the field exploration, laboratory-testing program and general subsurface conditions.

3 FIELD INVESTIGATION

3.1 General

The field exploration program for the eighteen borings were performed between June 8, 2015 and June 18, 2015. Subsurface conditions were investigated by drilling and sampling a total of six (18) bridge borings with depths ranging between 15 and 45 feet below the existing ground surface. As proposed, two (2) borings were drilled and sampled to a depth of approximately 30 feet into bedrock (boring D-1 and D-2), four (4) borings were drilled and sampled to a depth of approximately 10 feet into bedrock (borings S-1 through S-4) and twelve (12) borings were augered continuously without sampling to a depth of approximately 5 feet into bedrock (borings A-1 through A-12). A site plan showing approximate boring locations is presented on Plate 3, Plan of Borings.

3.2 Sampling Methods

Soil samples in borings D-1, D-2 and S-1 through S-4 were obtained continuously to a depth of 10 feet and then at 5-foot intervals thereafter to the termination depth of the borings. Borings A-1 through A-12 were augered without sampling to the termination depth of the borings. Cohesive soil samples were obtained with a three-inch thin-walled (Shelby) tube sampler in general accordance with ASTM D 1587 standard. Each sample was removed from the sampler in the field, carefully examined and then classified. The shear strengths of the cohesive soils were estimated by dividing the field values of Pocket Penetrometer (PP) with 3 and are shown on boring logs. Suitable portions of each sample were sealed and packaged for transportation to our laboratory.

Coring was performed when rock was encountered to their termination depths. The coring method employed consisted of a wire-lined NX core barrel with an inside diameter of 2 inches and length of 5 feet. The core samples were retrieved from the borehole and the percent recovery (REC) and the Rock Quality Designation (RQD) were recorded for each 5-foot run. The REC value was obtained by dividing the total length of core recovered by the total length of the core run. The RQD value was obtained by dividing the total length of sound core pieces with a minimum length of 4 inches by the total length of the core run. The core samples were visually examined for rock type and features, which were properly documented on boring logs along with the REC and RQD values. The samples were then wrapped and secured in core boxes for transported to our laboratory.

TxDOT cone penetrometer test was performed starting at 5 feet for bridge borings and at approximately 5-foot intervals thereafter to the maximum termination depth of the borings. The test consists of driving a 3-inch diameter cone with a 170-pound hammer, which is dropped for a distance of 2 feet. The cone is driven for two consecutive 6-inch increments, and the blow counts for each increment are noted. In hard materials, the cone is driven with the resulting penetration in inches recorded for the 50 blows. The numbers of blows for each 6-inch increment and/or the amount of penetration for each 50 blows are presented on the boring logs.

Detailed descriptions of the soils and rock strata encountered in the borings are given on the boring logs presented on Plates 4 through 21. A key to the soils and rock classification and symbols used in the boring logs are also presented on Plates 22A & 22B.

3.3 Groundwater Observations

Groundwater was observed in borings D-2 and S-3 at depths ranging between about 4 and 9 feet during drilling operations and at depths ranging between about 9 and 16 feet after completion of drilling in borings D-1, D-2 and S-1 through S-4. Groundwater was not encountered in the remaining borings. It is anticipated that groundwater levels will fluctuate due to seasonal variations in climatic conditions. Groundwater may also be encountered through fissures and fractures of limestone with seasonal variations. Groundwater depths information is included on the boring logs, Plates 4 through 21.

3.4 Borehole Completion

All borings were backfilled with soil cuttings and bentonite chips upon completion of drilling.

4 LABORATORY TESTING

4.1 Sample Examination and Classification

Soil samples transported to our laboratory were further examined and identified in accordance with ASTM D 2488 – *Description and Identification of Soils.* A preliminary soil classification was assigned to each soil sample based on ASTM D 2487 – *Classification of Soil for Engineering Purposes.* Classification testing was subsequently conducted on select samples and the result of each test was used to confirm or modify the given preliminary soil classification.

4.2 Geotechnical Testing

Selected soil samples were tested in the laboratory to determine applicable physical and engineering properties. All tests were performed according to the relevant ASTM Standards. These tests consisted of moisture contents, percent passing No. 200 sieve, Atterberg Limits, unconfined compression on soil and rock, unit weight tests, swell index, soil box resistivity, sulfate, chloride and pH tests.

The Atterberg limits and percent passing No. 200 sieve tests were utilized to verify field classification by the Unified Soils Classification System, and the unconfined compression tests and/or hand penetrometer were utilized to obtain the undrained shear strength of the soil and rock. The type and number of tests performed for this investigation are summarized below:

Table 4-1 – Type and Number of Laboratory Tests

Type of Test	Number of Tests
Moisture Content (ASTM D2216)	36
Atterberg Limits (ASTM D4318)	18
Percent Passing No. 200 Sieve (ASTM D1140)	17
Unconfined Compression (Soil) (ASTM D2166)	17
Compressive Strength of Intact Rock (ASTM D7012)	18
Unit Dry Weight (ASTM D2166/2850)	35
Swell Index (ASTM 4829)	6
Soil Box Resistivity (ASTM G187)	3
Sulfate (SW-846 9038)	3
Chloride (SM4500-CI- B)	3
PH (EPA 9045C)	3

Summary of laboratory test results is presented in Appendix A. Swell index, soil box resistivity, sulfate, chloride and pH test results are included in Appendix B.

5 SITE CHARACTERIZATION

5.1 Site Location

The project site is located on the west side of the intersection FM 78 and CR 4975, approximately 1.5 mile west from Leonard, Texas.

5.2 General Geology

According to the University of Texas at Austin, Bureau of Economic Geology "Geologic Atlas of Texas Sherman Sheet," the project area lies within the surface expression of Gober Chalk (map symbol Kgc) and Ozan Formation (map symbol Ko).

Ozan Formation mainly consists dark gray clay, weatheres to light brownish with weak fissility, calcareous, poorly bedded, variable amount of glauconite, some siltstone beds, and marine megafossils. Thickness of Ozan approximately 425 feet.

Gober Chalk bluish-gray, weathers white, brittle, argillaceous, thickness approximately 450 feet, thins eastward.

A geology map showing the project location is provided on Plate 2.

5.3 Soil Stratigraphy

Our interpretation of soil and groundwater conditions at the project site is based on information obtained at the boring locations only. This information has been used as the basis for our conclusions and recommendations. Significant variations at areas not explored by the project boring may require reevaluation of our findings and conclusions. Soil stratigraphy encountered at different borings and at different depths is detailed below.

Table 5-1 – Stratum Types Encountered

Approximate Depths of Strata Encountered at Borings, Feet	Stratum Type					
	Fat Clay (CH)(1)	Lean Clay (CL)(2)	Weathered Shale(3)	Weathered Limestone(4)	Shale(5)	Limestone(6)
D-1	0-1	-	-	1-9	-	9-40(7)
D-2	0-11	-	-	11-15	-	15-45(7)
S-1	0-6	-	6-17	-	17-30(7)	-
S-2	0-5	5-14	14-23	-	23-35(7)	-
S-3	0-11	-	-	11-16.5	-	30.5(7)
S-4	0-6	-	-	6-15	-	15-30(7)
A-1*	0-12	-	12-15	-	15-20(7)	-
A-2*	0-5	-	-	5-15	-	15-20(7)
A-3*	0-7	7-12	12-19	-	19-25(7)	-
A-4*	0-3	-	3-9	-	9-15(7)	-
A-5*	0-8	8-12	12-15	-	15-20(7)	-
A-6*	0-8	-	8-24	-	24-25(7)	-
A-7*	0-7	-	-	7-14	-	14-20(7)
A-8*	0-7	-	7-14	-	14-20(7)	-
A-9*	0-3	-	-	3-9	-	9-15(7)
A-10*	0-8	-	-	8-19	-	19-25(7)
A-11*	0-2.5	-	-	2.5-8	-	8-15(7)
A-12*	0-7	-	7-13	-	13-20(7)	-

* Borings were drilled without collecting samples. Soil and rock type were described based on soil cuttings descriptions.

Note:

1. Very soft to very stiff, occasionally with calcareous nodules and ferrous oxides.
2. Soft to stiff, with few calcareous nodules and ferrous oxides..
3. Soft to hard, yellowish brown and grayish brown.
4. Soft to hard, yellowish brown.
5. Hard to very hard, gray, with few limestone seams
6. Hard to very hard, gray, with few shale seams.
7. Boring termination depth.

Detailed descriptions of the soils encountered in the borings are given on the boring logs presented on Plates 4 through 21. A key to the soils and rock classification and symbols used in the boring logs is also presented on Plates 22A and 22B, respectively.

5.4 Groundwater Level

Groundwater was observed in borings D-2 and S-3 at depths ranging between about 4 and 9 feet during drilling operations and at depths ranging between about 9 and 16 feet after completion of drilling in borings D-1, D-2 and S-1 through S-4. Groundwater was not encountered in the remaining borings. It is anticipated that groundwater levels will fluctuate due to seasonal variations in climatic conditions. Groundwater may also be encountered through fissures and fractures of limestone with seasonal variations. Groundwater depths information is included on the boring logs, Plates 4 through 21.

6 LIMITATIONS

This investigation was performed for the exclusive use of CH2M HILL for the proposed NTMWD Leonard Water Treatment Plant in Leonard, Texas. HVJ Associates, Inc. has endeavored to comply with generally accepted geotechnical engineering practice common in the local area. HVJ Associates, Inc. makes no warranty, express or implied. The analyses and recommendations contained in this report are based on data obtained from subsurface exploration, laboratory testing, the project information provided to us and our experience with similar soils and site conditions. The methods used indicate subsurface conditions only at the specific locations where samples were obtained, only at the time they were obtained, and only to the depths penetrated. Samples cannot be relied on to accurately reflect the strata variations that usually exist between sampling locations. Should any subsurface conditions other than those described in our boring logs be encountered, HVJ Associates, Inc. should be immediately notified so that further investigation and supplemental recommendations can be provided.

PLATES

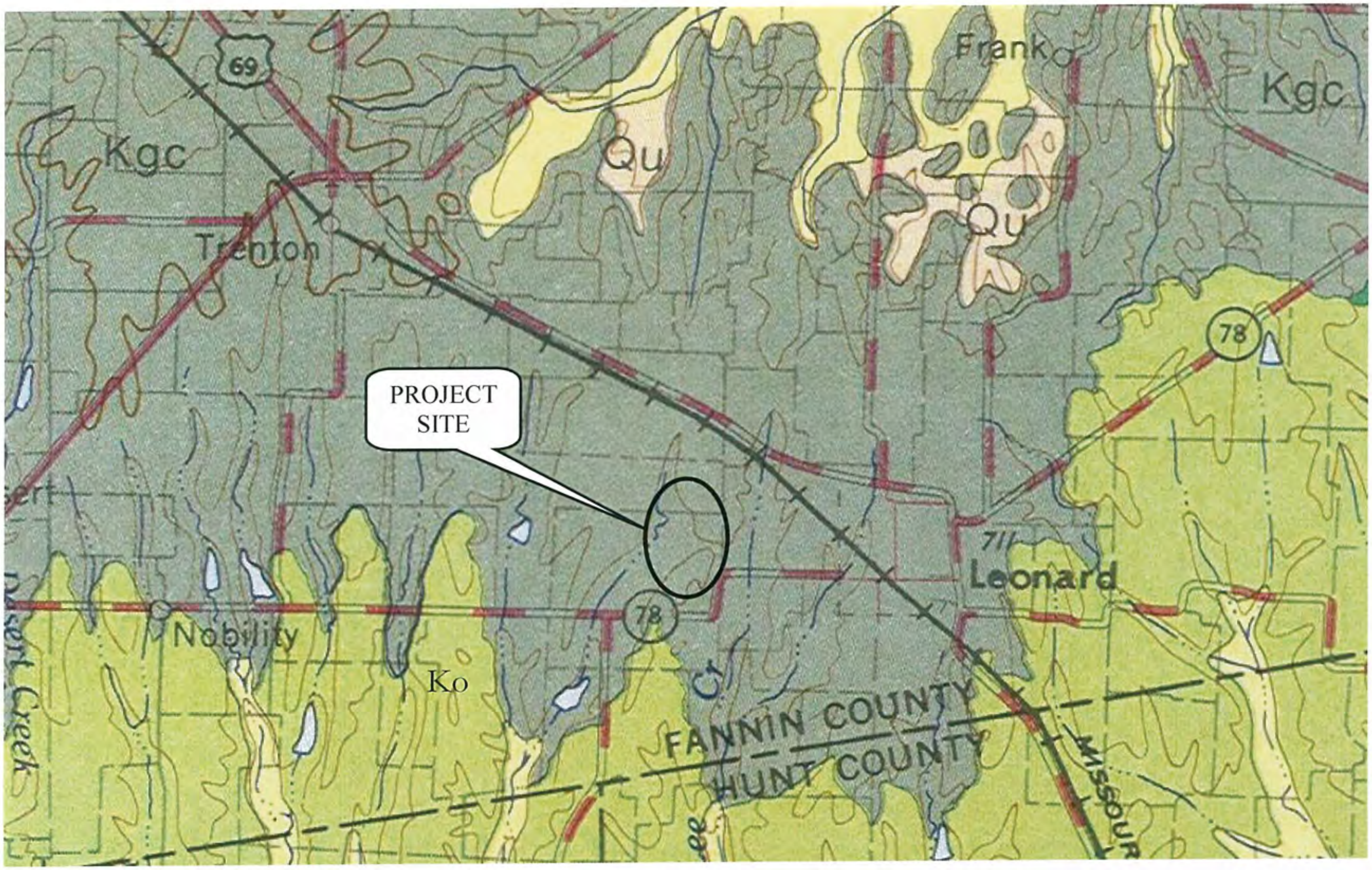
HVJ ASSOCIATES

8701 John Carpenter Fwy
Suite 250
Dallas, TX 75247

DATE: 08/05/15	APPROVED BY: JP	PREPARED BY: D

SITE VICINITY MAP
NTMWD LEONARD WATER TREATMENT PLANT

PROJECT NO.: DG-15-11840	DRAWING NO.: PLATE 1



N

Kgc: Gober Chalk
Ko: Ozan Formation

Source: **Geologic Atlas of Texas Sherman Sheet**
UT Austin Bureau of Economic Geology

HVJ
ASSOCIATES

8701 John Carpenter Fwy Suite 250
Dallas, TX 75247
214-678-0227 Ph
214-678-0228 Fax

DATE: 08/05/2015	APPROVED BY: JP	PREPARED BY: DB

GEOLOGY MAP
NTMWD LEONARD WATER TREATMENT PLANT

PROJECT NO.: DG-15-11840	DRAWING NO.: PLATE 2

◐ Approximate Boring location

HVJ ASSOCIATES

8701 John Carpenter Fwy Suite 250
Dallas, TX 75247
214-678-0227 Ph
214-678-0228 Fax

DATE: 08/05/2015	APPROVED BY: JP	PREPARED BY: DB

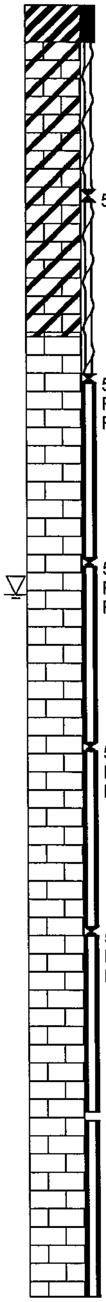
PLAN OF BORINGS
NTMWD LEONARD WATER TREATMENT PLANT

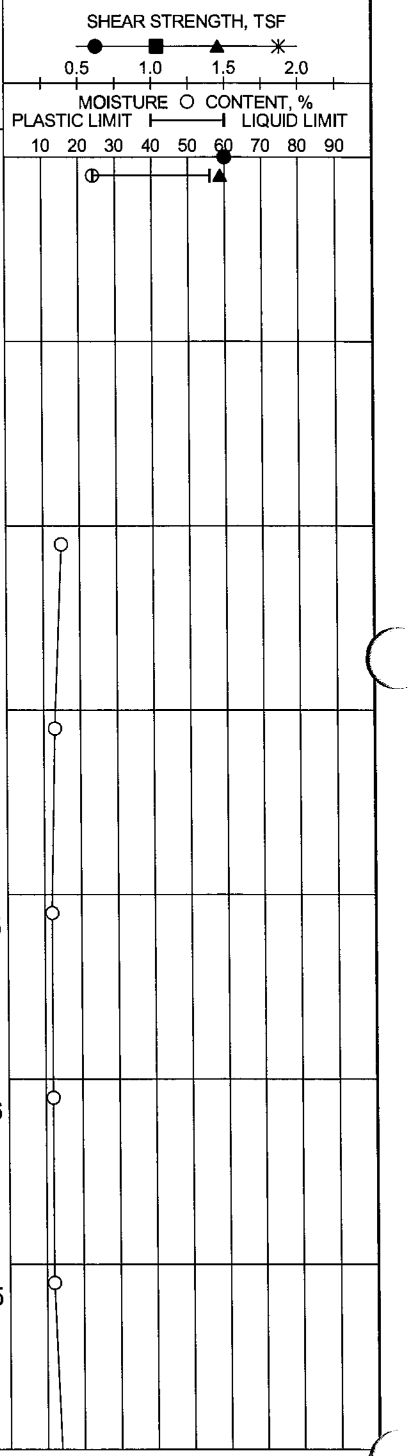
PROJECT NO.: DG-15-11840	DRAWING NO.: PLATE 3

LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant
Project No.: DG-15-11840
Boring No.: D-1
Drill Date: 7/13/2015
Elevation: 696.754 feet
Groundwater during drilling: Dry
Northing: 7,194,659.4
Station: --
Groundwater after drilling: 16 feet
Easting: 2,646,800.8
Offset: --

ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF
0		**FAT CLAY (CL)**, very stiff, dry, dark brown	92	99
		WEATHERED LIMESTONE, soft to hard, yellowish brown		
5	50/3"-50/1"			
		LIMESTONE, very hard, gray		
10	50/0.75"-50/0.5" REC=100%, RQD=100%	- Unconfined Compressive Strength Test at 10-11ft = 107.18tsf		118
15	50/0.25"-50/0.25" ∇ REC=95%, RQD=95%	- Unconfined Compressive Strength Test at 15-16ft = 108.86tsf		123
20	50/0.25"-50/0.25" REC=90%, RQD=87%	- Unconfined Compressive Strength Test at 20-21ft = 82.82tsf		125
25	50/0.25"-50/0.25" REC=100%, RQD=97%	- Unconfined Compressive Strength Test at 25-26ft = 102.92tsf		126
30	50/0.25"-50/0.25" REC=100%, RQD=90%	- Unconfined Compressive Strength Test at 30-31ft = 96.97tsf		125
		- with Shale layers below 33 feet		
35				





Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

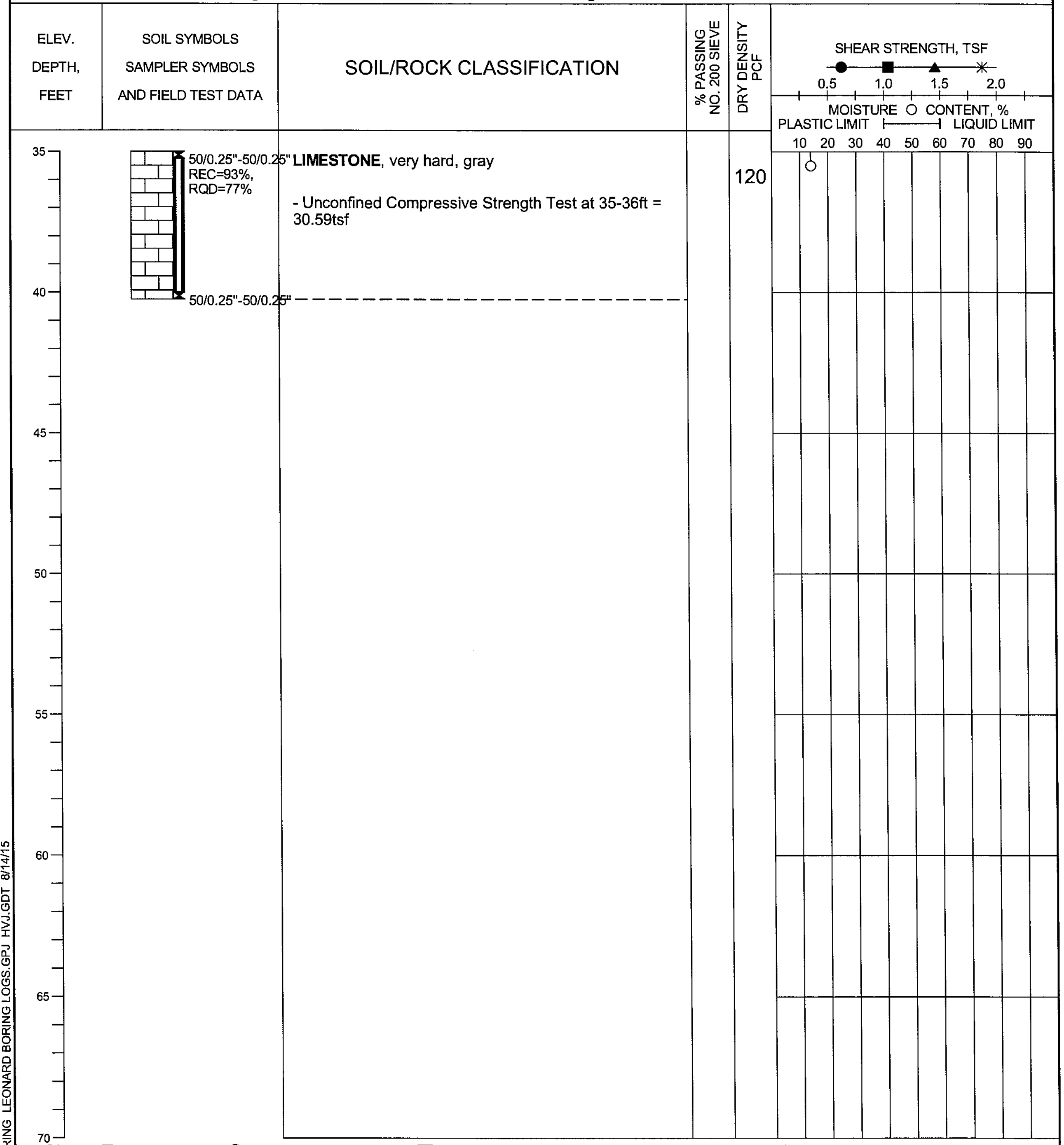
See Plate 3 for boring location.

PLATE 4a

HVJ ASSOCIATES

LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant
Project No.: DG-15-11840
Boring No.: D-1
Drill Date: 7/13/2015
Elevation: 696.754 feet
Groundwater during drilling: Dry
Northing: 7,194,659.4
Station: --
Groundwater after drilling: 16 feet
Easting: 2,646,800.8
Offset: --



ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF
35	50/0.25"-50/0.25" REC=93%, RQD=77%	**LIMESTONE**, very hard, gray - Unconfined Compressive Strength Test at 35-36ft = 30.59tsf		120
40	50/0.25"-50/0.25"			

Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

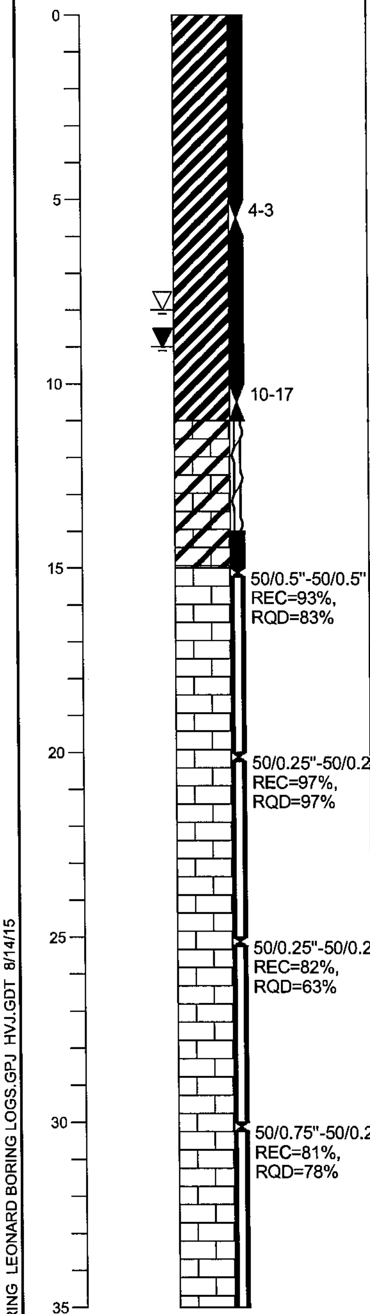
See Plate 3 for boring location.

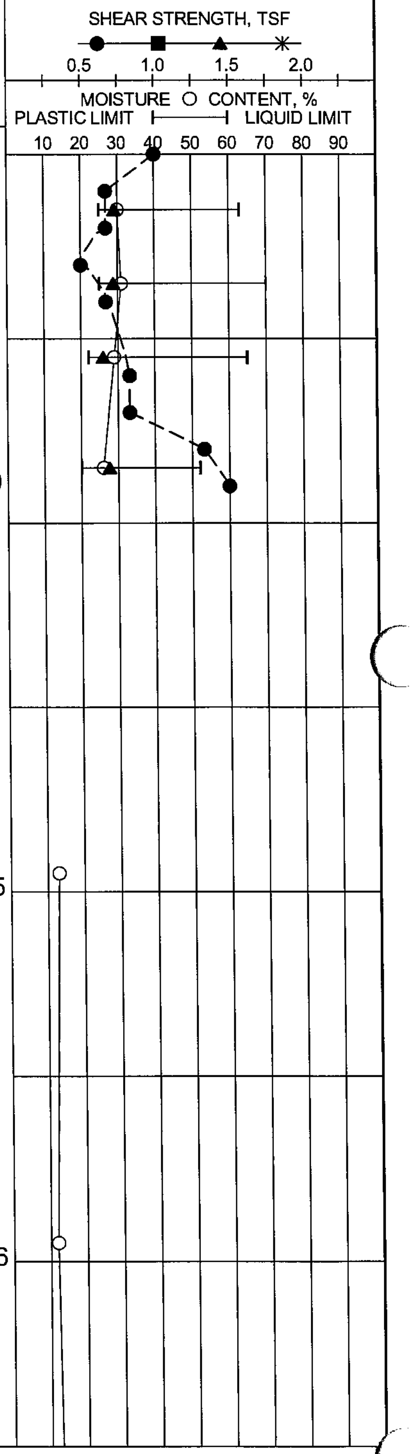
PLATE 4b

LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant	Project No.: DG-15-11840
Boring No.: D-2	Drill Date: 7/13/2015
Elevation: 697.425 feet	Groundwater during drilling: 9 feet
Northing: 7,193,878.3	Station: --
Groundwater after drilling: 8 feet	Easting: 2,645,441.4
Offset: --	

ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF
0		**FAT CLAY (CL)**, very stiff, dry, dark brown		
			96	91
			96	90
5	4-3			
		- brown and gray below 6 feet, with few small gravel	93	94
			93	100
10	10-17			
		WEATHERED LIMESTONE, soft to hard, yellowish brown		
15	50/0.5"-50/0.5" REC=93%, RQD=83%	**LIMESTONE**, very hard, gray		
20	50/0.25"-50/0.25" REC=97%, RQD=97%	- Unconfined Compressive Strength Test at 19-20ft = 69.59tsf		125
25	50/0.25"-50/0.25" REC=82%, RQD=63%			
30	50/0.75"-50/0.25" REC=81%, RQD=78%	- Unconfined Compressive Strength Test at 29-30ft = 77.66tsf		126
35				





Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

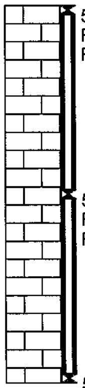
See Plate 3 for boring location.

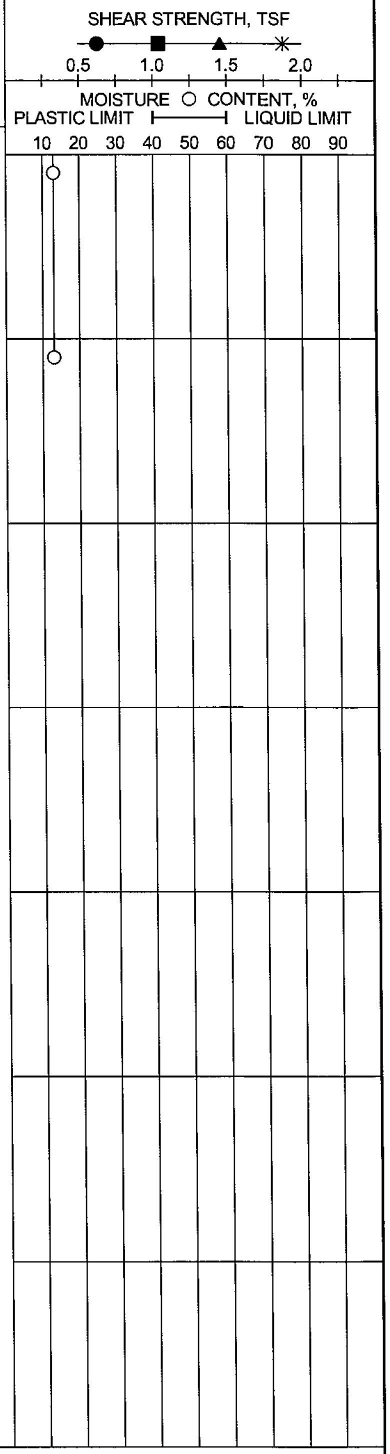
HVJ ASSOCIATES

LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant
Project No.: DG-15-11840
Boring No.: D-2
Drill Date: 7/13/2015
Elevation: 697.425 feet
Groundwater during drilling: 9 feet
Northing: 7,193,878.3
Station: --
Groundwater after drilling: 8 feet
Easting: 2,645,441.4
Offset: --

ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF
35	50/0.5"-50/0.25" REC=93%, RQD=93%	**LIMESTONE**, very hard, gray - Unconfined Compressive Strength Test at 35-36ft = 70.43tsf		129
40	50/0.25"-50/0.25" REC=97%, RQD=97%	- Unconfined Compressive Strength Test at 40-41ft = 103.45tsf		125
45	50/0.25"-50/0.25"			
50				
55				
60				
65				
70				





Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

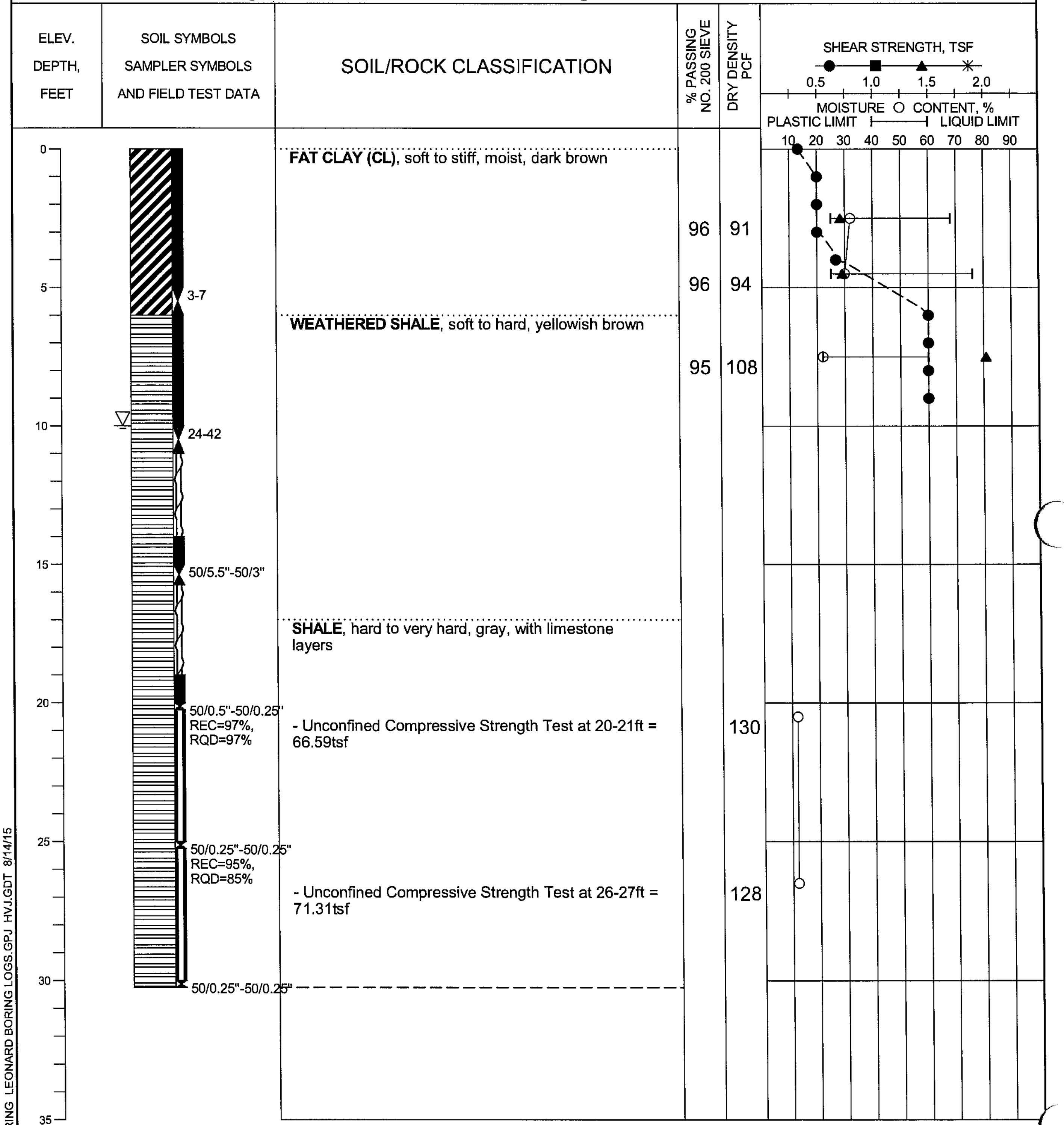
See Plate 3 for boring location.

PLATE 5b

HVJ ASSOCIATES

LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant
Project No.: DG-15-11840
Boring No.: S-1
Drill Date: 7/14/2015
Elevation: 702.186 feet
Groundwater during drilling: Dry
Northing: 7,195,553.4
Station: --
Groundwater after drilling: 10 feet
Easting: 2,646,050.1
Offset: --



DEPTH, FEET	FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF
0		**FAT CLAY (CL)**, soft to stiff, moist, dark brown		
3			96	91
5	3-7		96	94
6		**WEATHERED SHALE**, soft to hard, yellowish brown		
8			95	108
10	24-42			
15	50/5.5"-50/3"			
17		**SHALE**, hard to very hard, gray, with limestone layers		
20	50/0.5"-50/0.25" REC=97%, RQD=97%	- Unconfined Compressive Strength Test at 20-21ft = 66.59tsf		130
25	50/0.25"-50/0.25" REC=95%, RQD=85%			
26		- Unconfined Compressive Strength Test at 26-27ft = 71.31tsf		128
30	50/0.25"-50/0.25"			

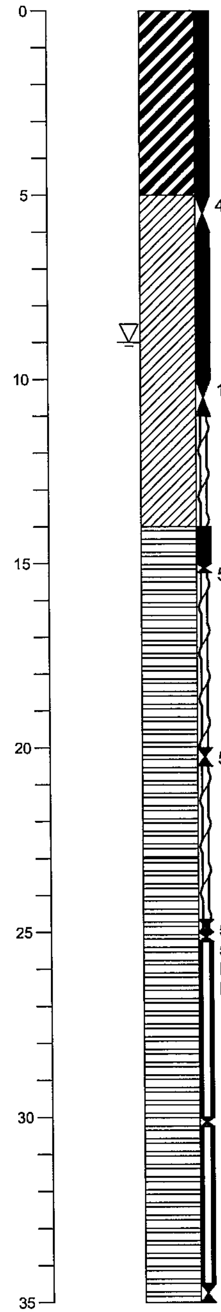
Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

See Plate 3 for boring location.

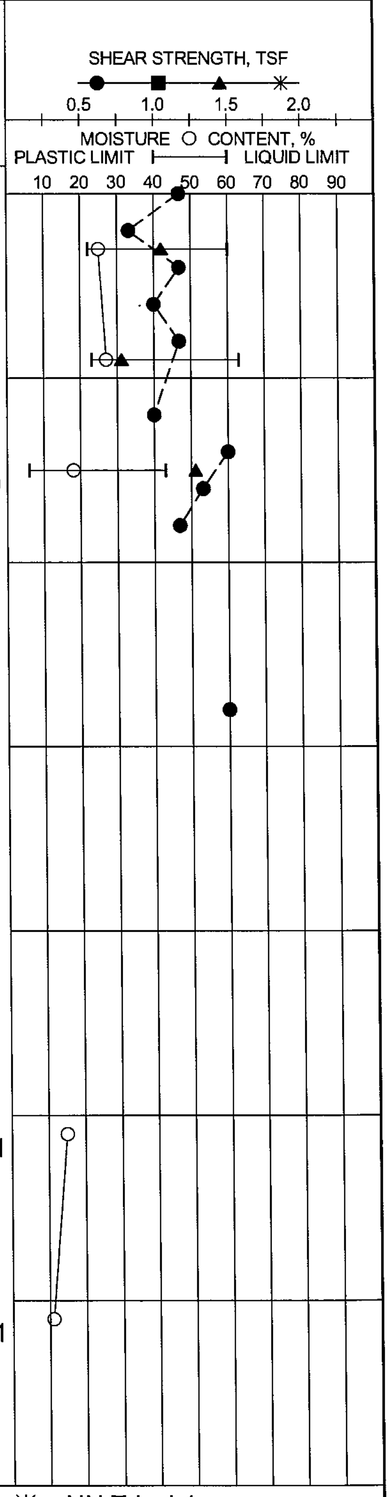
HVJ ASSOCIATES

LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant
Project No.: DG-15-11840
Boring No.: S-2
Drill Date: 7/14/2015
Elevation: 688.787 feet
Groundwater during drilling: Dry
Northing: 7,194,881.0
Station: --
Groundwater after drilling: 9 feet
Easting: 2,644,892.4
Offset: --



ELEV. DEPTH, FEET	FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF
0		**FAT CLAY (CL)**, soft to stiff, moist, dark brown		
			86	99
5	4-4	**LEAN CLAY (CL)**, soft to very stiff, gray, with few calcareous deposits and shale seams	93	97
			89	110
10	16-12			
		WEATHERED SHALE, hard, yellowish brown, grayish brown		
15	50/0.75"-50/0.5"			
20	50/3"-50/2"			
		SHALE, very hard, gray, with few limestone layers		
25	50/0.25"-50/0.25" 50/0.5"-50/0.25" REC=93%, RQD=93%	- Unconfined Compressive Strength Test at 25-26ft = 28.15tsf		121
30	50/0.25"-50/0.25" REC=100%, RQD=100%	- Unconfined Compressive Strength Test at 30-31ft = 98.25tsf		131
35	50/0.25"-50/0.25"			



Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

See Plate 3 for boring location.

PLATE 7

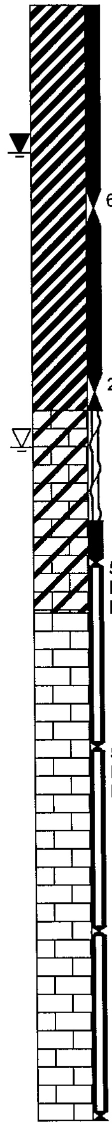
HVJ ASSOCIATES

LOG OF BORING

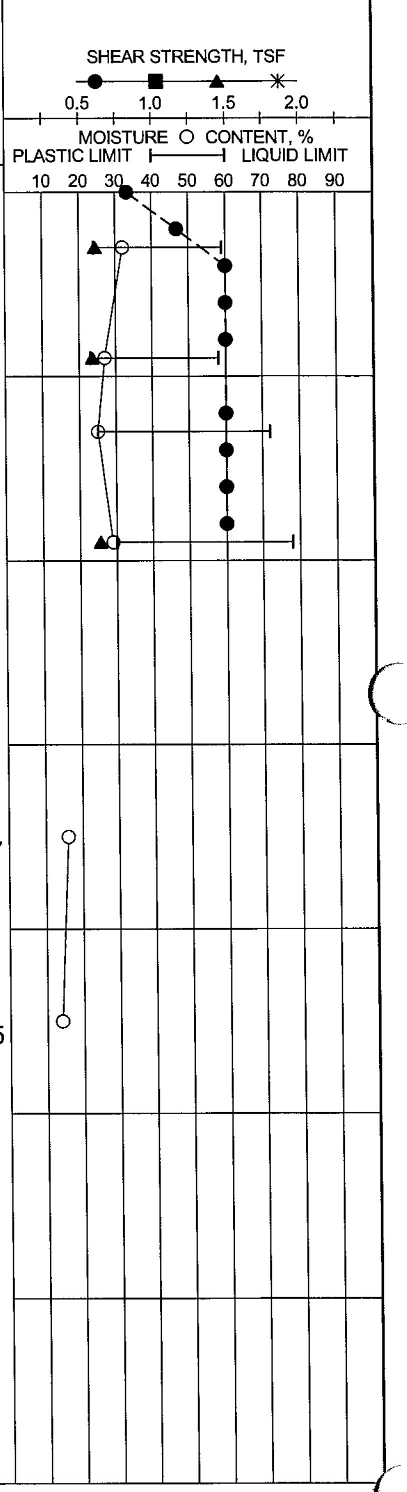
Project: NTMWD Leonard Water Treatment Plant
Boring No.: S-3
Groundwater during drilling: 4 feet
Groundwater after drilling: 12 feet

Drill Date: 7/15/2015
Northing: 7,193,271.5
Easting: 2,646,695.3

Project No.: DG-15-11840
Elevation: 695.226 feet
Station: --
Offset: --



ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF
0		**FAT CLAY (CL)**, soft to very stiff, dry, dark brown		
		- yellowish brown and light gray below 2 feet, with calcareous deposits	86	94
5	6-5		98	97
			98	
10	21-30		98	95
		WEATHERED LIMESTONE, soft to hard, yellowish brown		
15	50/0.5"-50/0.5" REC=90%, RQD=83%			
		LIMESTONE, very hard, gray		
		- Unconfined Compressive Strength Test at 17-18ft = 25.41tsf		117
20	50/0.5"-50/0.25" REC=97%, RQD=97%			
		- Unconfined Compressive Strength Test at 22-23ft = 61.93tsf		125
25	50/0.5"-50/0.25" REC=88%, RQD=87%			
30	50/0.5"-50/0.25"			
35				



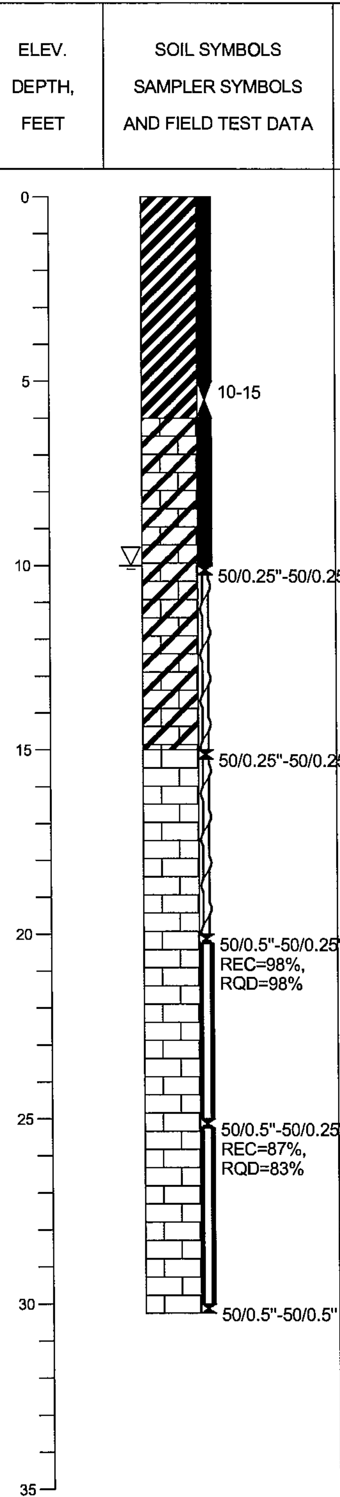
Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

See Plate 3 for boring location.

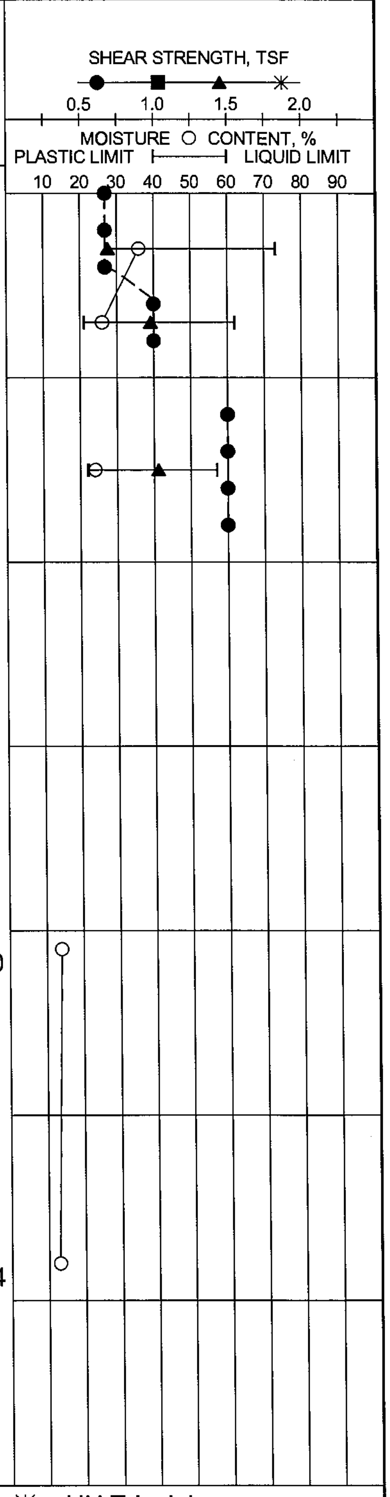
HVJ
ASSOCIATES

LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant
Project No.: DG-15-11840
Boring No.: S-4
Drill Date: 7/15/2015
Elevation: 710.715 feet
Groundwater during drilling: Dry
Northing: 7,192,512.0
Station: --
Groundwater after drilling: 10 feet
Easting: 2,644,780.7
Offset: --



SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF
FAT CLAY (CL), stiff, dry, dark brown		
		85
- yellowish brown below 4 feet	93	98
WEATHERED LIMESTONE, soft to hard, yellowish brown		
	88	97
LIMESTONE, very hard, gray, with some Shale seams		
- Unconfined Compressive Strength Test at 20-21ft = 95.42tsf		120
		124
- Unconfined Compressive Strength Test at 29-30ft = 90.46tsf		

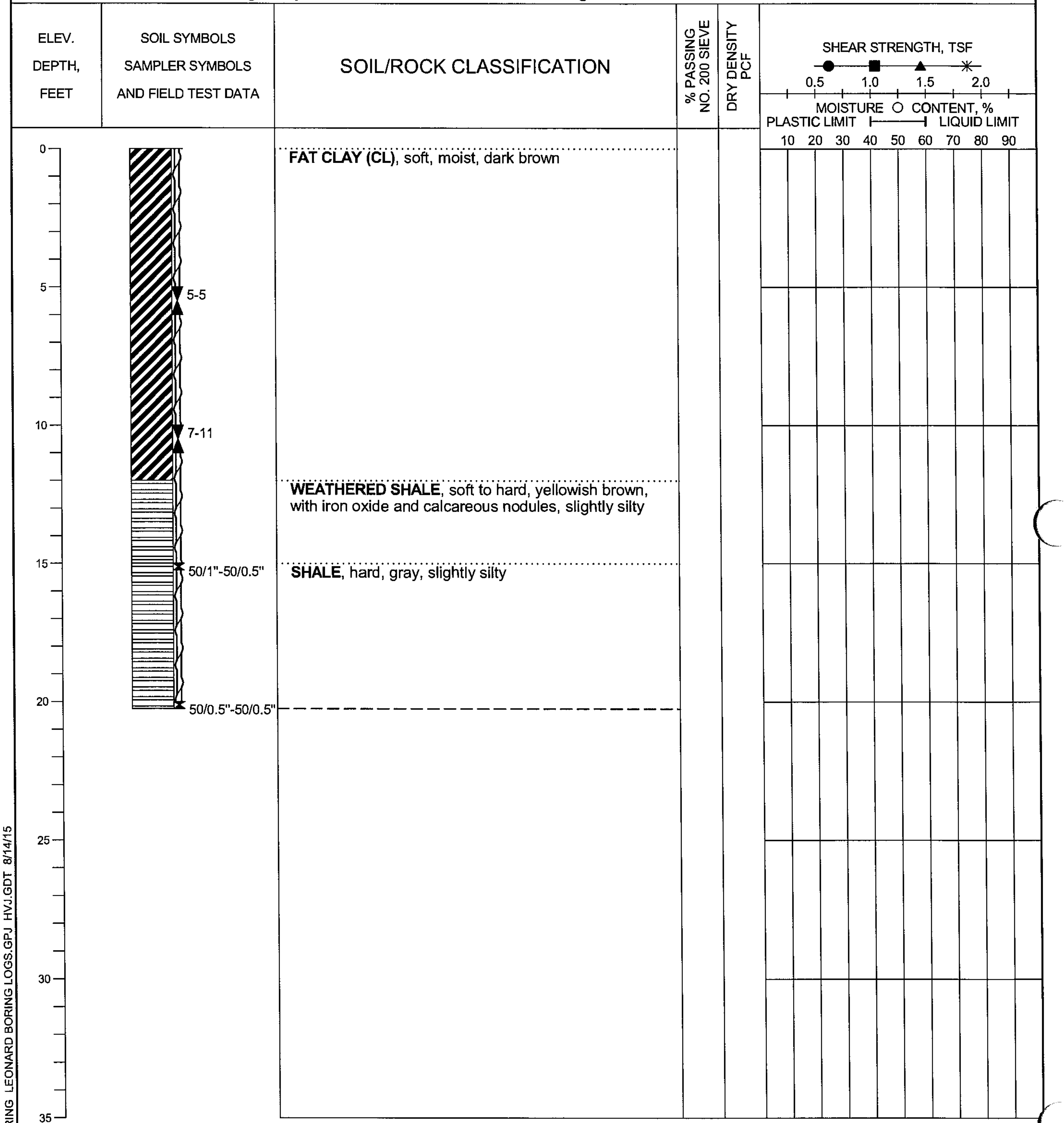


Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

See Plate 3 for boring location.

LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant
Project No.: DG-15-11840
Boring No.: A-1
Drill Date: 7/14/2015
Elevation: 689.106 feet
Groundwater during drilling: Dry
Northing: 7,195,555.0
Station: --
Groundwater after drilling: Dry
Easting: 2,644,902.5
Offset: --



FAT CLAY (CL), soft, moist, dark brown

WEATHERED SHALE, soft to hard, yellowish brown, with iron oxide and calcareous nodules, slightly silty

SHALE, hard, gray, slightly silty

Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

See Plate 3 for boring location.

HVJ ASSOCIATES

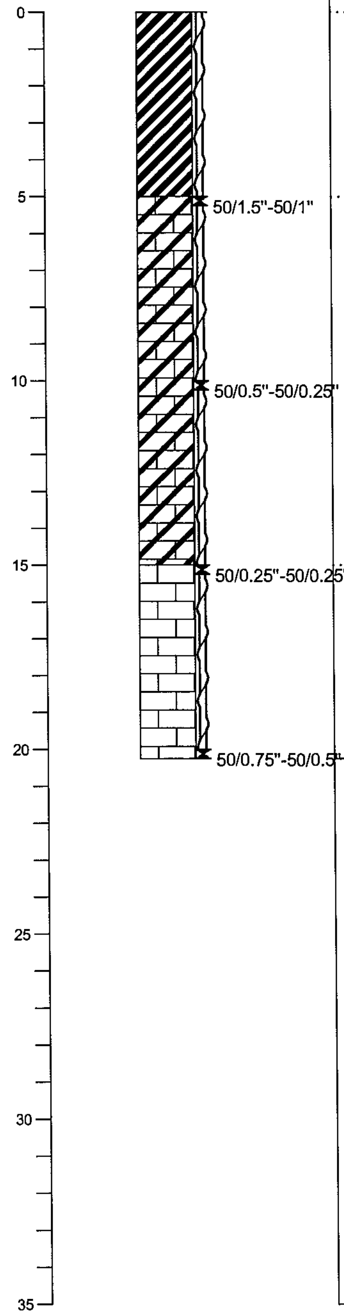
LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant
Boring No.: A-2
Groundwater during drilling: Dry
Groundwater after drilling: Dry

Drill Date: 7/14/2015
Northing: 7,195,534.4
Easting: 2,646,996.7

Project No.: DG-15-11840
Elevation: 701.299 feet
Station: --
Offset: --

ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF	SHEAR STRENGTH, TSF ● ■ ▲ ✳ 0.5 1.0 1.5 2.0 / MOISTURE ○ CONTENT, % PLASTIC LIMIT ├──┤ LIQUID LIMIT 10 20 30 40 50 60 70 80 90
0		**FAT CLAY (CL)**, soft, moist, dark brown			
5	50/1.5"-50/1"	**WEATHERED LIMESTONE**, soft to hard, yellowish brown			
10	50/0.5"-50/0.25"				
15	50/0.25"-50/0.25"	**LIMESTONE**, hard, gray			
20	50/0.75"-50/0.5"				
25					
30					
35					



Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

See Plate 3 for boring location.

HVJ ASSOCIATES

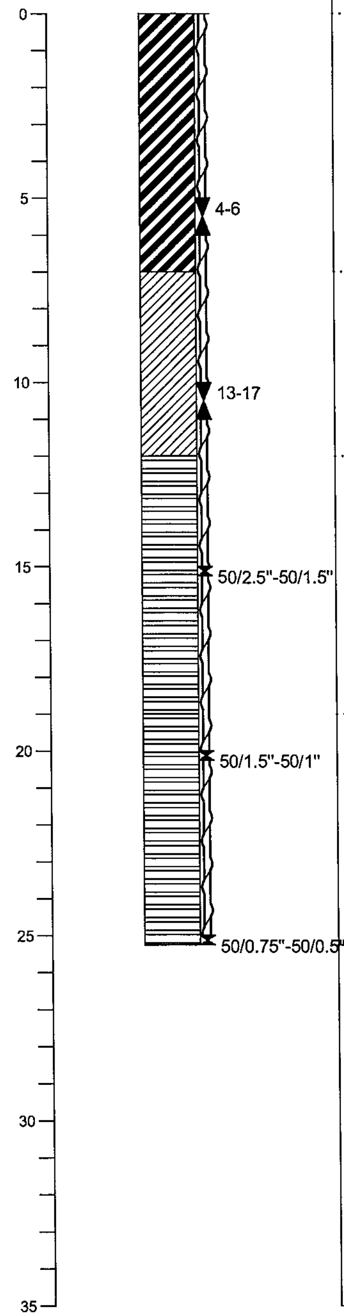
LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant
Boring No.: A-3
Groundwater during drilling: Dry
Groundwater after drilling: Dry

Drill Date: 7/14/2015
Northing: 7,195,117.2
Easting: 2,646,003.6

Project No.: DG-15-11840
Elevation: 701.012 feet
Station: --
Offset: --

ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF	SHEAR STRENGTH, TSF ● ■ ▲ ✳ 0.5 1.0 1.5 2.0 MOISTURE ○ CONTENT, % PLASTIC LIMIT ├──┤ LIQUID LIMIT 10 20 30 40 50 60 70 80 90



FAT CLAY (CL), soft, moist, dark brown

LEAN CLAY (CL), stiff, moist, yellowish brown

WEATHERED SHALE, soft, yellowish brown

SHALE, hard, gray, slightly silty

Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

See Plate 3 for boring location.

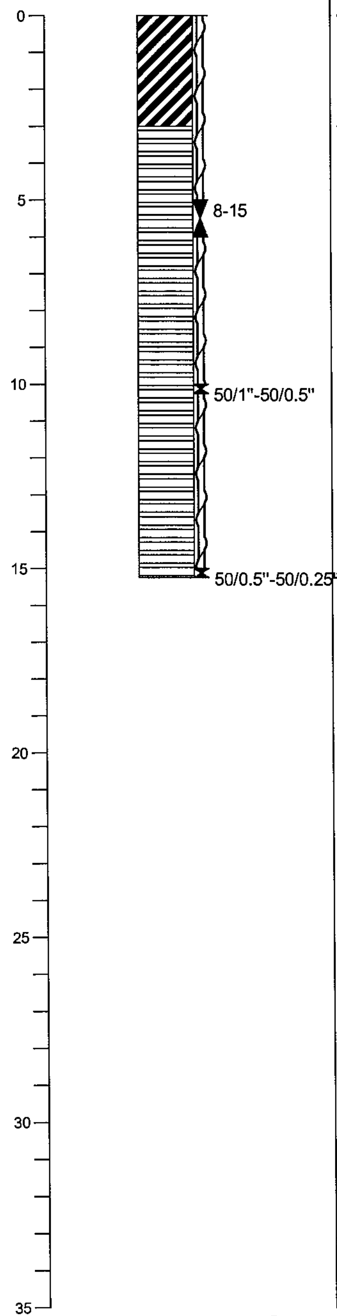
LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant
Boring No.: A-4
Groundwater during drilling: Dry
Groundwater after drilling: Dry

Drill Date: 7/15/2015
Northing: 7,194,286.8
Easting: 2,644,545.1

Project No.: DG-15-11840
Elevation: 686.040 feet
Station: --
Offset: --

ELEV. DEPTH, FEET | SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA | SOIL/ROCK CLASSIFICATION | % PASSING NO. 200 SIEVE | DRY DENSITY PCF | SHEAR STRENGTH, TSF (0.5, 1.0, 1.5, 2.0) MOISTURE ○ CONTENT, % PLASTIC LIMIT ├──┤ LIQUID LIMIT (10 20 30 40 50 60 70 80 90)



FAT CLAY (CL), soft, moist, brown

WEATHERED SHALE, soft to hard, yellowish brown, with iron oxide and calcareous nodules, slightly silty

SHALE, hard to very hard, gray, slightly silty

Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

See Plate 3 for boring location.

PLATE 13

HVJ ASSOCIATES

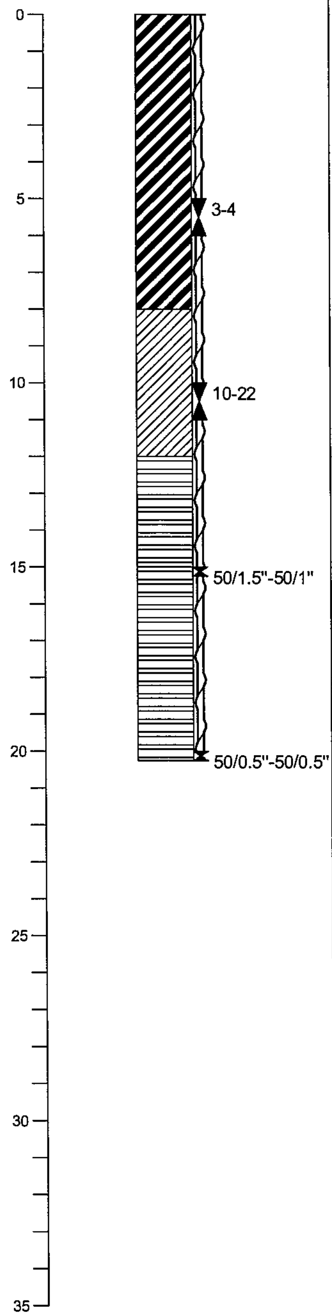
LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant
Boring No.: A-5
Groundwater during drilling: Dry
Groundwater after drilling: Dry

Drill Date: 7/15/2015
Northing: 7,194,415.5
Easting: 2,645,373.8

Project No.: DG-15-11840
Elevation: 693.949 feet
Station: --
Offset: --

ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF	SHEAR STRENGTH, TSF ● ■ ▲ ✳ 0.5 1.0 1.5 2.0 MOISTURE ○ CONTENT, % PLASTIC LIMIT ├──┤ LIQUID LIMIT 10 20 30 40 50 60 70 80 90



FAT CLAY (CL), very soft, moist, dark brown

LEAN CLAY (CL), stiff, moist, yellowish brown

WEATHERED SHALE, soft to hard, yellowish brown

SHALE, hard, gray

Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

See Plate 3 for boring location.

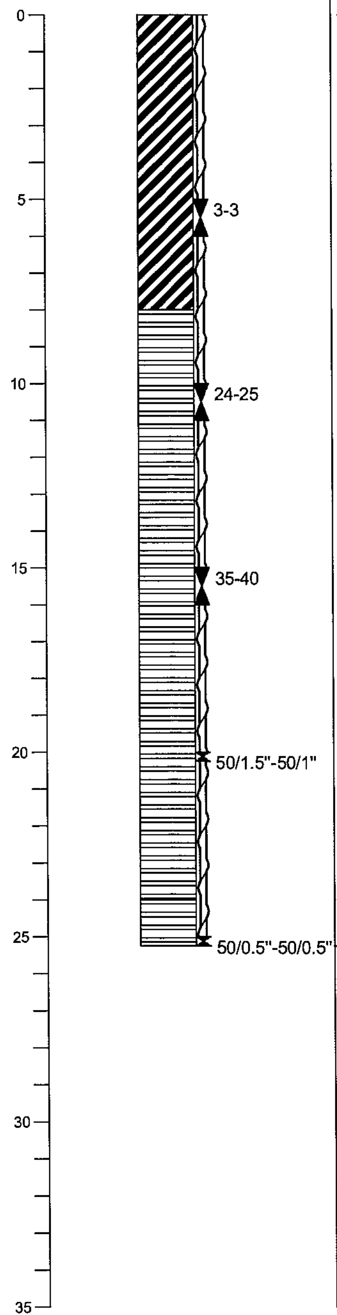
LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant
Boring No.: A-6
Groundwater during drilling: Dry
Groundwater after drilling: Dry

Drill Date: 7/14/2015
Northing: 7,194,476.1
Easting: 2,646,009.4

Project No.: DG-15-11840
Elevation: 699.414 feet
Station: --
Offset: --

ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF	SHEAR STRENGTH, TSF ● ■ ▲ ✳ 0.5 1.0 1.5 2.0 MOISTURE ○ CONTENT, % PLASTIC LIMIT ├──┤ LIQUID LIMIT 10 20 30 40 50 60 70 80 90



FAT CLAY (CL), very soft, moist, brown

WEATHERED SHALE, soft to hard, yellowish brown

SHALE, hard, gray

Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

See Plate 3 for boring location.

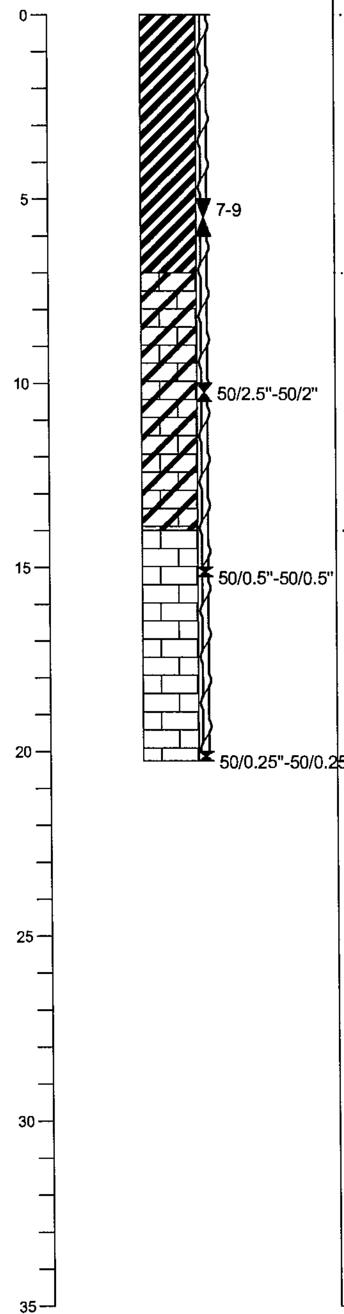
PLATE 15

HVJ ASSOCIATES

LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant
Project No.: DG-15-11840
Boring No.: A-7
Drill Date: 7/13/2015
Elevation: 698.385 feet
Groundwater during drilling: Dry
Northing: 7,194,042.1
Station: --
Groundwater after drilling: Dry
Easting: 2,646,822.0
Offset: --

ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF	SHEAR STRENGTH, TSF ● ■ ▲ ✳ 0.5 1.0 1.5 2.0 MOISTURE ○ CONTENT, % PLASTIC LIMIT ├──┤ LIQUID LIMIT 10 20 30 40 50 60 70 80 90



FAT CLAY (CL), soft, moist, dark brown

WEATHERED LIMESTONE, soft, yellowish brown

LIMESTONE, hard to very hard, gray

Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

See Plate 3 for boring location.

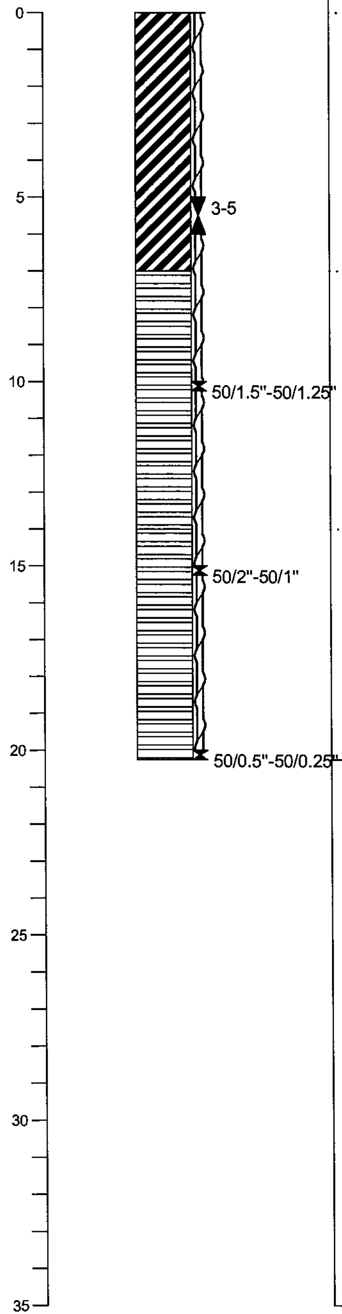
LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant
Boring No.: A-8
Groundwater during drilling: Dry
Groundwater after drilling: Dry

Drill Date: 7/15/2015
Northing: 7,193,392.4
Easting: 2,644,934.9

Project No.: DG-15-11840
Elevation: 698.829 feet
Station: --
Offset: --

ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF	SHEAR STRENGTH, TSF ● ■ ▲ ✳ 0.5 1.0 1.5 2.0 / MOISTURE ○ CONTENT, % PLASTIC LIMIT ├──┤ LIQUID LIMIT 10 20 30 40 50 60 70 80 90



FAT CLAY (CL), soft, moist, dark brown

WEATHERED SHALE, soft to hard, yellowish brown

SHALE, hard, gray

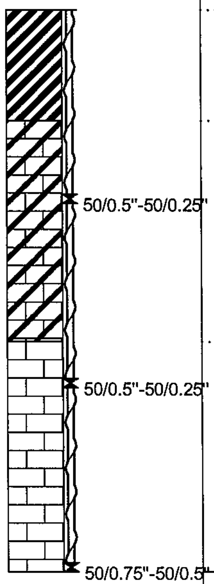
Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

See Plate 3 for boring location.

HVJ ASSOCIATES

LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant		Project No.: DG-15-11840
Boring No.: A-9	Drill Date: 7/15/2015	Elevation: 702.206 feet
Groundwater during drilling: Dry	Northing: 7,193,504.4	Station: --
Groundwater after drilling: Dry	Easting: 2,646,086.0	Offset: --



ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF	SHEAR STRENGTH, TSF ● ■ ▲ ✳ 0.5 1.0 1.5 2.0 / MOISTURE ○ CONTENT, % PLASTIC LIMIT ⊢—⊣ LIQUID LIMIT 10 20 30 40 50 60 70 80 90
0		**FAT CLAY (CL)**, soft, moist, dark brown, with calcareous deposits and iron oxide stains			
3		**WEATHERED LIMESTONE**, hard, yellowish brown			
5	50/0.5"-50/0.25"				
9		**LIMESTONE**, hard to very hard, gray			
10	50/0.5"-50/0.25"				
15	50/0.75"-50/0.5"				
20					
25					
30					
35					

Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

See Plate 3 for boring location.

HVJ ASSOCIATES

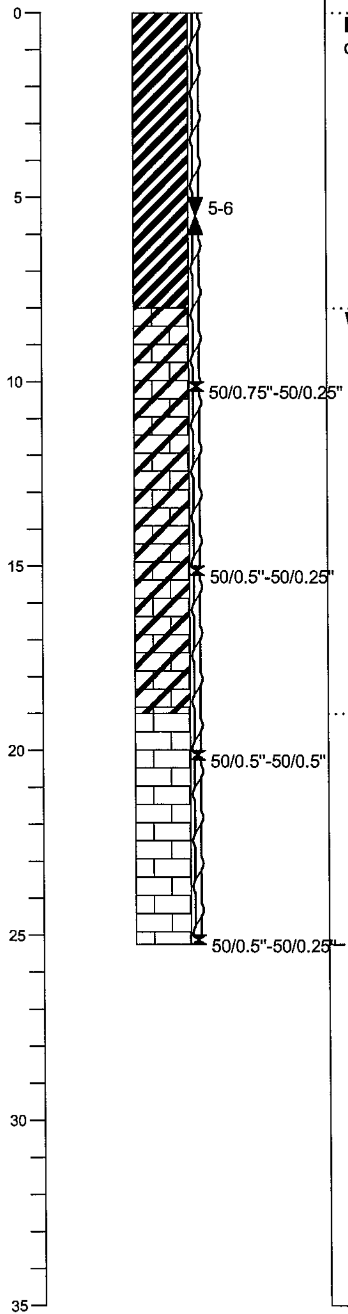
LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant
Boring No.: A-10
Groundwater during drilling: Dry
Groundwater after drilling: Dry

Drill Date: 7/8/2015
Northing: 7,192,500.2
Easting: 2,645,813.0

Project No.: DG-15-11840
Elevation: 696.179 feet
Station: --
Offset: --

ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF	SHEAR STRENGTH, TSF ● ■ ▲ ✳ 0.5 1.0 1.5 2.0 / MOISTURE ○ CONTENT, % PLASTIC LIMIT ├──┤ LIQUID LIMIT 10 20 30 40 50 60 70 80 90
0		**FAT CLAY (CL)**, soft, moist, dark brown, with calcareous deposits and iron oxide stains			
5	5-6				
		WEATHERED LIMESTONE, soft, yellowish brown			
10	50/0.75"-50/0.25"				
15	50/0.5"-50/0.25"				
		LIMESTONE, hard to very hard, gray			
20	50/0.5"-50/0.5"				
25	50/0.5"-50/0.25"				
30					
35					



Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

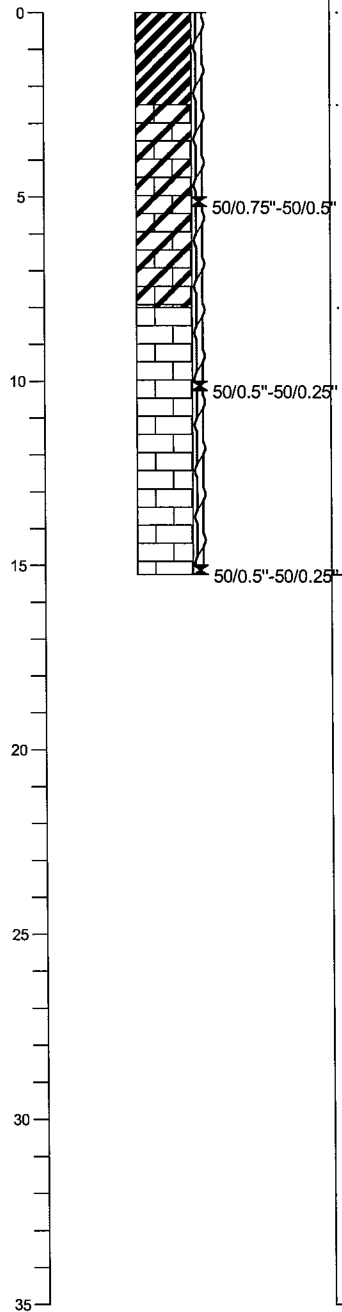
See Plate 3 for boring location.

PLATE 19

LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant
Project No.: DG-15-11840
Boring No.: A-11
Drill Date: 7/8/2015
Elevation: 693.441 feet
Groundwater during drilling: Dry
Northing: 7,192,544.1
Station: --
Groundwater after drilling: Dry
Easting: 2,646,766.8
Offset: --

ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF	SHEAR STRENGTH, TSF ● ■ ▲ ✳ 0.5 1.0 1.5 2.0 MOISTURE ○ CONTENT, % PLASTIC LIMIT ├──┤ LIQUID LIMIT 10 20 30 40 50 60 70 80 90
0		**FAT CLAY (CL)**, soft, moist, dark brown, with calcareous deposits and iron oxide stains			
		WEATHERED LIMESTONE, soft to hard, yellowish brown			
5	50/0.75"-50/0.5"				
		LIMESTONE, very hard, gray			
10	50/0.5"-50/0.25"				
15	50/0.5"-50/0.25"				



Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

See Plate 3 for boring location.

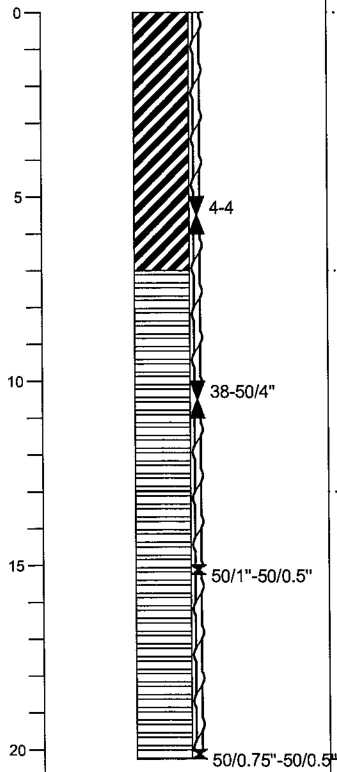
PLATE 20

HVJ ASSOCIATES

LOG OF BORING

Project: NTMWD Leonard Water Treatment Plant
Project No.: DG-15-11840
Boring No.: A-12
Drill Date: 7/15/2015
Elevation:
Groundwater during drilling: Dry
Northing: --
Station: --
Groundwater after drilling: Dry
Easting: --
Offset: --

ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF	SHEAR STRENGTH, TSF ● ■ ▲ ✳ 0.5 1.0 1.5 2.0 MOISTURE ○ CONTENT, % PLASTIC LIMIT ⊢—⊣ LIQUID LIMIT 10 20 30 40 50 60 70 80 90
		FAT CLAY (CL), soft, moist, dark brown			
		WEATHERED SHALE, soft to hard, yellowish brown			
		SHALE, hard, gray			



25
30
35

Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

See Plate 3 for boring location.

HVJ ASSOCIATES

SOIL SYMBOLS

Soil Types

▨	▥	░	▒
Clay	Silt	Sand	Gravel

Modifiers

▨	▥	░	▒
Clayey	Silty	Sandy	Cemented

Construction Materials

▤	▒	▒	▒
Asphaltic Concrete	Stabilized Base	Fill or Debris	Portland Cement Concrete

SAMPLER TYPES

■	Thin Walled Shelby Tube	◸	No Recovery
☒	Split Barrel	≀	Auger
◧	Liner Tube	✋	Jar Sample

WATER LEVEL SYMBOLS

▽	Groundwater level determined during drilling operations
▼	Groundwater level after drilling in open borehole or piezometer

SOIL GRAIN SIZE

Classification	Particle Size	Particle Size or Sieve No. (U.S. Standard)
Clay	< 0.002 mm	< 0.002 mm
Silt	0.002 - 0.075 mm	0.002 mm - #200 sieve
Sand	0.075 - 4.75 mm	#200 sieve - #4 sieve
Gravel	4.75 - 75 mm	#4 sieve - 3 in.
Cobble	75 - 200 mm	3 in. - 8 in.
Boulder	> 200 mm	> 8 in.

DENSITY OF COHESIONLESS SOILS

Descriptive Term	Penetration Resistance "N" * Blows/Foot
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	> 50

CONSISTENCY OF COHESIVE SOILS

Consistency	Undrained Shear Strength (tsf)	Penetration Resistance "N" * (Blows/ft)
Very Soft	0 - 0.125	< 2
Soft	0.125 - 0.25	2-4
Firm	0.25 - 0.5	4-8
Stiff	0.5 – 1.0	8-15
Very Stiff	1.0 – 2.0	15-30
Hard	> 2.0	>30

PENETRATION RESISTANCE

#-#-#	Blows required penetrating each of three consecutive 6-inches per ASTM D-1586*
50/4"	If more than 50 blows are required, driving is discontinued and penetration at 50 blows is noted
(4/6")	Texas Cone Penetration blows required penetrating each of two consecutive 6-inches per TEX- 132-E

* The N value is taken as the blows required to penetrate the final 12 inches

TERMS DESCRIBING SOIL STRUCTURE

Slickensided	Fracture planes appear polished or glossy, sometimes striated
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Inclusion	Small pockets of different soils, such as small lenses of sand scattered through a mass of clay
Parting	Inclusion less than 1/4 inch thick extending through the sample
Seam	Inclusion 1/4 inch to 3 inches thick extending through the sample
Layer	Inclusion greater than 3 inches thick extending through the sample
Laminated	Soil sample composed of alternating partings of different soil type
Stratified	Soil sample composed of alternating seams or layers of different soil type
Intermixed	Soil sample composed of pockets of different soil type and laminated or stratified structure is not evident
Calcareous	Having appreciable quantities of calcium carbonate
Ferrous	Having appreciable quantities of iron
Nodule	A small mass of irregular shape

HVJ
ASSOCIATES

8701 John Carpenter Fwy Suite 250
Dallas, TX 75247
214-678-0227 Ph
214-678-0228 Fax

KEY TO TERMS AND SYMBOLS
USED ON BORING LOGS

PROJECT NO.:	DRAWING NO.:
DG-15-11840	Plate 22A

ROCK TYPES

▦ Limestone	☰ Shale	⁘ Sandstone
▨ Weathered Limestone	▨ Weathered Shale	▨ Weathered Sandstone
▨ Highly Weathered Limestone	▤ Dolomite	⊠ Granite

SAMPLER TYPES

■ Thin-Walled Tube	‖ Rock Core
☒ Standard Penetration Test	⟩⟩ Auger Sample
⧗ THD Cone Penetration Test	☝ Bag Sample

SOLUTION AND VOID CONDITIONS

Void	Interstice; a general term for pore space or other openings in rock.
Cavities	Small solutional concavities.
Vuggy	Containing small cavities, usually lined with a mineral of different composition from that of the surrounding rock.
Vesicular	Containing numerous small, unlined cavities, formed by expansion of gas bubbles or steam during solidification of the rock.
Porous	Containing pores, interstices, or other openings which may or may not interconnect.
Cavernous	Containing cavities or caverns, sometimes quite large. Most frequent in limestones and dolomites.

HARDNESS

Very Soft	Can be carved with a knife, broken with finger pressure, or UCS less than 30 tsf
Soft	Can be gouged or grooved readily with a knife, or UCS between 30 and 100 tsf
Moderately Hard	Can be scratched easily with a knife, or UCS between 100 and 250 tsf
Hard	Can be scratched rarely with a knife, or UCS greater than 250 tsf
Very Hard	Cannot be scratched with a knife

WEATHERING GRADES OF ROCKMASS (1)

Slightly	Discoloration indicates weathering of rock material and discontinuity surfaces.
Moderately	Less than half of the rock material is decomposed or disintegrated to a soil.
Highly	More than half of the rock material is decomposed or disintegrated to a soil.
Completely	All rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.
Residual Soil	All rock material is converted to soil. The mass structure and material fabric are destroyed.

JOINT DESCRIPTION

SPACING		INCLINATION		SURFACES	
Very Close	<2"	Horizontal	0-5	Slickensided	Polished, grooved
Close	2"-12"	Shallow	5-35	Smooth	Planar
Medium Close	12"-3'	Moderate	35-65	Irregular	Undulating or granular
Wide	>3'	Steep	65-85	Rough	Jagged or pitted
		Vertical	85-90		

REFERENCES:

(1) British Standard (1981) Code of Practice for Site Investigation, BS 5930.

(2) The Bridge Div., Tx. Highway Dept. Foundation Exploration & Design Manual, 2nd Division, revised June, 1974.

BEDDING THICKNESS (2)

Very Thick	>4'
Thick	2'-4'
Thin	2"-2'
Very Thin	1/2"-2"
Laminated	0.08"-1/2"
Thinly Laminated	<0.08"

Information on each boring log is a compilation of subsurface conditions and soil and rock classifications obtained from the field as well as from laboratory testing of samples. Strata have been interpreted by commonly accepted procedures. The stratum lines on the logs may be transitional and approximate in nature. Water level measurements refer only to those observed at the times and places indicated, and may vary with time, geologic condition or construction activity.

HVJ ASSOCIATES

8701 John Carpenter Fwy Suite 250
Dallas, TX 75247
214-678-0227 Ph
214-678-0228 Fax

KEY TO TERMS AND SYMBOLS
USED ON BORING LOGS

PROJECT NO.:	DRAWING NO.:
DG-15-11840	Plate 22B

APPENDIX A

SUMMARY OF LABORATORY RESULTS

Boring#	Depth	Liquid Limit	Plastic Limit	PI	Percent Finer Than #200 Sieve	Moisture Content (%)	Dry Unit Weight (pcf)	Shear Strength (UC) (tsf)	Rock UC (tsf)	Shear Strength (Pocket Pen) (tsf)
D-1	0									1.5
D-1	0.5	56	24	32	92	23.8	98.9	1.47		
D-1	10.5					15.1	118.4		107.2	
D-1	15.5					13	123.3		108.9	
D-1	20.5					12.2	125.1		82.8	
D-1	25.5					11.8	125.8		102.9	
D-1	30.5					12.2	124.8		97.0	
D-1	35.5					14.3	120.4		30.6	
D-2	0									1
D-2	1									0.67
D-2	1.5	63	25	38	96	30.2	91	0.73		
D-2	2									0.67
D-2	3									0.5
D-2	3.5	70	25	45	96	30.7	90.3	0.72		
D-2	4									0.67
D-2	5.5	65	22	43	93	29.2	93.5	0.65		
D-2	6									0.83
D-2	7									0.83
D-2	8									1.33
D-2	8.5	52	20	32	93	25.5	99.7	0.69		
D-2	9									1.5
D-2	19.5					12.9	124.5		69.6	
D-2	29.5					12.4	126.1		77.7	
D-2	35.5					12.8	129.2		70.4	
D-2	40.5					12.7	124.5		103.5	
S-1	0									0.33
S-1	1									0.5
S-1	2									0.5
S-1	2.5	68	25	43	96	31.5	91.3	0.71		
S-1	3									0.5
S-1	4									0.67
S-1	4.5	76	25	51	96	29.7	93.6	0.73		
S-1	6									1.5

HVJ ASSOCIATES

8701 John Carpenter Fwy Suite 250
Dallas, TX 75247
214-678-0227 Ph
214-678-0228 Fax

DATE: 08/05/2015	APPROVED BY: JP	PREPARED BY: DB

SUMMARY OF LAB TEST RESULTS
NTMWD LEONARD WATER TREATMENT PLANT

PROJECT NO.: DG-15-11840	DRAWING NO.: Plate A-I

Boring#	Depth	Liquid Limit	Plastic Limit	PI	Percent Finer Than #200 Sieve	Moisture Content (%)	Dry Unit Weight (pcf)	Shear Strength (UC) (tsf)	Rock UC (tsf)	Shear Strength (Pocket Pen) (tsf)
S-1	7									1.5
S-1	7.5	60	22	38	95	21.5	107.7	2.02		
S-1	8									1.5
S-1	9									1.5
S-1	20.5					12	129.9		66.6	
S-1	26.5					11.7	127.6		71.3	
S-2	0									1.17
S-2	1									0.83
S-2	1.5	60	22	38	86	25	98.8	1.05		
S-2	2									1.17
S-2	3									1
S-2	4									1.17
S-2	4.5	63	23	40	93	26.6	97.1	0.78		
S-2	6									1
S-2	7									1.5
S-2	7.5	43	6	37	89	18.4	110.1	1.28		
S-2	8									1.33
S-2	9									1.17
S-2	14									1.5
S-2	25.5					15.3	121.2		28.5	
S-2	30.5					10.8	131		98.3	
S-3	0									0.83
S-3	1									1.17
S-3	1.5	59	24	35	86	32.3	94	0.61		
S-3	2									1.5
S-3	3									1.5
S-3	4									1.5
S-3	4.5	58	23	35	98	26.7	96.8	0.59		
S-3	6									1.5
S-3	6.5	72	25	47	98	24.6				
S-3	7									1.5
S-3	8									1.5
S-3	9									1.5

HVJ ASSOCIATES

8701 John Carpenter Fwy Suite 250
Dallas, TX 75247
214-678-0227 Ph
214-678-0228 Fax

DATE: 08/05/2015	APPROVED BY: JP	PREPARED BY: DB

SUMMARY OF LAB TEST RESULTS
NTMWD LEONARD WATER TREATMENT PLANT

PROJECT NO.: DG-15-11840	DRAWING NO.: Plate A-II

Boring#	**Depth**	**Liquid Limit**	**Plastic Limit**	**PI**	**Percent Finer Than #200 Sieve**	**Moisture Content (%)**	**Dry Unit Weight (pcf)**	**Shear Strength (UC) (tsf)**	**Rock UC (tsf)**	**Shear Strength (Pocket Pen) (tsf)**
S-3	9.5	78	30	48	98	29.1	95.1	0.64		
S-3	17.5					16.4	117.4		25.4	
S-3	22.5					14	124.7		61.9	
S-4	0									0.67
S-4	1									0.67
S-4	1.5	73	27	46		36.4	84.7	0.69		
S-4	2									0.67
S-4	3									1
S-4	3.5	62	21	41	93	26	97.6	0.98		
S-4	4									1
S-4	6									1.5
S-4	7									1.5
S-4	7.5	57	22	35	88	23.8	97	1.03		
S-4	8									1.5
S-4	9									1.5
S-4	20.5					14	119.7		95.4	
S-4	29					12.8	124.1		90.5	
Total		**18**	**18**	**18**	**17**	**36**	**35**	**17**	**18**	**47**

HVJ ASSOCIATES

8701 John Carpenter Fwy Suite 250
Dallas, TX 75247
214-678-0227 Ph
214-678-0228 Fax

DATE: 08/05/2015	APPROVED BY: JP	PREPARED BY: DB

SUMMARY OF LAB TEST RESULTS
NTMWD LEONARD WATER TREATMENT PLANT

PROJECT NO.: DG-15-11840

DRAWING NO.: Plate A-III

APPENDIX B

ADVANCED LABORATORY TEST RESULTS

(SWELL INDEX TEST, SULFATE, CHLORODE. PH AND SOIL BOX RESISTIVITY TEST RESULTS)

HVJ ASSOCIATES, INC.
EXPANSION INDEX OF SOILS ASTM D-4829-11

Project Name:	NTMWD Leonard WTP	Boring No.	D-1
Project No.	DG-15-11840	Sample Depth.	0-1'
Date Tested:	07/28/15	Ring No.	1
Technician:	KM	Date Calculated:	08/07/15

well Sample Data	Initial	Final	Test Data	Initial	Final
Sample Height (in)	1.002	1.076	Wet + Ring (g)	699.26	759.51
Diameter (in)	4.002	4.002	Dry + Ring (g)	656.41	656.41
Volume (cc)	206.544	221.695	Ring Wt. (g)	360.28	360.53
Height of Solids (in)	0.532	0.532	Moisture Data (Trimmings)		LL
Specific Gravity	2.700	2.700	Wet + Tare (g)	64.85	56
Moisture Content (%)	16.1	34.8	Dry + Tare (g)	60.22	PI
Wet Density (pcf)	102.4	112.3	Tare (g)	31.47	32
Dry Density (pcf)	88.2	83.3	Moisture Content (%)	16.1	
Saturation (%)	47.8%	92.0%	Hand Penetrometer (tsf)	4.5	
Sample Description	Fat Clay (CL)				

Date	Time	Elapsed Time (min)	Load (lbf/in²)	Swell Readings (in)	
7/28/2015	9:50	0.0	1	0.2296	
7/28/2015	10:00	10.0	1	0.2286	
7/28/2015	10:00	0.0	1	0.2286	D1
7/28/2015	10:00	0.1	1	0.2291	
7/28/2015	10:00	0.2	1	0.2299	
7/28/2015	10:00	0.5	1	0.2314	
7/28/2015	10:01	1.0	1	0.2334	
7/28/2015	10:02	2.0	1	0.2367	
7/28/2015	10:05	5.0	1	0.2479	
7/28/2015	10:08	8.0	1	0.2562	
7/28/2015	10:15	15.0	1	0.2649	
7/28/2015	10:30	30.0	1	0.2732	
7/28/2015	11:00	60.0	1	0.2809	
7/28/2015	12:00	120.0	1	0.2894	
7/28/2015	14:00	240.0	1	0.2945	
7/28/2015	17:00	420.0	1	0.2978	
7/31/2015	6:00	4080.0	1	0.3015	
7/31/2015	8:00	4200.0	1	0.3021	D2

Swell Index Calculation	
Initial Swell Readings D1 (in)	0.2286
Final Swell Readings D2 (in)	0.3021
ΔH=D2-D1 (in)	0.07350
EI= ΔH*1000/H1	73.4

Comments

Expansion Index, EI	Potential Expansion	Result
0-20	Very Low	
21-50	Low	
51-90	**Medium**	**73.4**
91-130	High	
>130	Very High	

Calculated by: DB
Computed by: DB
Checked by: RE

HVJ ASSOCIATES, INC.
EXPANSION INDEX OF SOILS ASTM D-4829-11

Project Name:	NTMWD Leonard WTP	Boring No.	D-2
Project No.	DG-15-11840	Sample Depth.	2-3'
Date Tested:	08/04/2015	Ring No.	1
Technician:	KM	Date Calculated:	08/07/15

well Sample Data	Initial	Final
Sample Height (in)	1.002	1.077
Diameter (in)	4.002	4.002
Volume (cc)	206.544	222.004
Height of Solids (in)	0.530	0.529
Specific Gravity	2.700	2.700
Moisture Content (%)	16.9	36.2
Wet Density (pcf)	103.7	112.6
Dry Density (pcf)	88.6	82.7
Saturation (%)	50.8%	94.2%
Sample Description	Fat Clay (CL)	

Test Data	Initial	Final
Wet + Ring (g)	703.40	761.85
Dry + Ring (g)	655.39	655.39
Ring Wt. (g)	360.31	361.09
Moisture Data (Trimmings)		LL
Wet + Tare (g)	56.27	70
Dry + Tare (g)	52.63	PI
Tare (g)	31.15	45
Moisture Content (%)	16.9	
Hand Penetrometer (tsf)	2.0	

Date	Time	Elapsed Time (min)	Load (lbf/in²)	Swell Readings (in)	
8/4/2015	9:50	0.0	1	0.4232	
8/4/2015	10:00	10.0	1	0.4230	
8/4/2015	10:00	0.0	1	0.4230	D1
8/4/2015	10:00	0.1	1	0.4191	
8/4/2015	10:00	0.2	1	0.4195	
8/4/2015	10:00	0.5	1	0.4202	
8/4/2015	10:01	1.0	1	0.4219	
8/4/2015	10:02	2.0	1	0.2530	
8/4/2015	10:05	5.0	1	0.4351	
8/4/2015	10:08	8.0	1	0.4410	
8/4/2015	10:15	15.0	1	0.4524	
8/4/2015	10:30	30.0	1	0.4710	
8/4/2015	11:00	60.0	1	0.4810	
8/4/2015	12:00	120.0	1	0.4857	
8/4/2015	14:00	240.0	1	0.4888	
8/4/2015	17:00	420.0	1	0.4905	
8/5/2015	6:00	1200.0	1	0.4971	
8/5/2015	8:00	1320.0	1	0.4980	D2

Swell Index Calculation	
Initial Swell Readings D1 (in)	0.4230
Final Swell Readings D2 (in)	0.4980
ΔH=D2-D1 (in)	0.07500
EI= ΔH*1000/H1	74.9

Comments

Expansion Index, EI	Potential Expansion	Result
0-20	Very Low	
21-50	Low	
51-90	**Medium**	**74.9**
91-130	High	
>130	Very High	

Calculated by: DB
Computed by: DB
Checked by: RE

HVJ ASSOCIATES, INC.
EXPANSION INDEX OF SOILS ASTM D-4829-11

Project Name:	NTMWD Leonard WTP	Boring No.	S-1
Project No.	DG-15-11840	Sample Depth.	2-3'
Date Tested:	07/30/15	Ring No.	1
Technician:	KM	Date Calculated:	08/04/15

well Sample Data	Initial	Final	Test Data	Initial	Final
Sample Height (in)	1.002	1.055	Wet + Ring (g)	692.86	748.71
Diameter (in)	4.002	4.002	Dry + Ring (g)	643.14	643.14
Volume (cc)	206.544	217.387	Ring Wt. (g)	360.28	360.57
Height of Solids (in)	0.508	0.508	Moisture Data (Trimmings)		LL
Specific Gravity	2.700	2.700	Wet + Tare (g)	62.61	60
Moisture Content (%)	18.1	37.4	Dry + Tare (g)	57.73	PI
Wet Density (pcf)	100.5	111.4	Tare (g)	30.77	38
Dry Density (pcf)	85.1	81.1	Moisture Content (%)	18.1	
Saturation (%)	49.9%	93.6%	Hand Penetrometer (tsf)	1.5	
Sample Description	Fat Clay (CL)				

Date	Time	Elapsed Time (min)	Load (lbf/in²)	Swell Readings (in)	
7/30/2015	9:50	0.0	1	0.4516	
7/30/2015	10:00	10.0	1	0.4510	
7/30/2015	10:00	0.0	1	0.4510	D1
7/30/2015	10:00	0.1	1	0.4488	
7/30/2015	10:00	0.2	1	0.4484	
7/30/2015	10:00	0.5	1	0.4482	
7/30/2015	10:01	1.0	1	0.4491	
7/30/2015	10:02	2.0	1	0.4508	
7/30/2015	10:05	5.0	1	0.4581	
7/30/2015	10:08	8.0	1	0.4635	
7/30/2015	10:15	15.0	1	0.4740	
7/30/2015	10:30	30.0	1	0.4836	
7/30/2015	11:00	60.0	1	0.4879	
7/30/2015	12:00	120.0	1	0.4907	
7/30/2015	14:00	240.0	1	0.4937	
7/30/2015	17:00	420.0	1	0.4968	
7/31/2015	6:00	1200.0	1	0.5014	
7/31/2015	8:00	1320.0	1	0.5026	
7/31/2015	11:00	1500.0	1	0.5032	
7/31/2015	12:00	1560.0	1	0.5036	D2

Swell Index Calculation	
Initial Swell Readings D1 (in)	0.4510
Final Swell Readings D2 (in)	0.5036
ΔH=D2-D1 (in)	0.05260
EI= ΔH*1000/H1	52.5

Comments

Expansion Index, EI	Potential Expansion	Result
0-20	Very Low	
21-50	Low	
51-90	**Medium**	**52.5**
91-130	High	
>130	Very High	

Calculated by: DB
Computed by: DB
Checked by: RE

HVJ ASSOCIATES, INC.
EXPANSION INDEX OF SOILS ASTM D-4829-11

Project Name:	NTMWD Leonard WTP	Boring No.	S-2
Project No.	DG-15-11840	Sample Depth.	4-5'
Date Tested:	7/24/15	Ring No.	1
Technician:	KM	Date Calculated:	07/27/15

well Sample Data	Initial	Final	Test Data	Initial	Final
Sample Height (in)	1.002	1.090	Wet + Ring (g)	709.47	772.56
Diameter (in)	4.002	4.002	Dry + Ring (g)	669.22	669.22
Volume (cc)	206.544	224.745	Ring Wt. (g)	360.29	361.19
Height of Solids (in)	0.555	0.553	**Moisture Data (Trimmings)**		**LL**
Specific Gravity	2.700	2.700	Wet + Tare (g)	56.62	63
Moisture Content (%)	15.0	33.5	Dry + Tare (g)	53.33	**PI**
Wet Density (pcf)	105.5	114.2	Tare (g)	31.34	40
Dry Density (pcf)	91.8	85.5	Moisture Content (%)	15.0	
Saturation (%)	48.3%	93.4%	Hand Penetrometer (tsf)	3.0	
Sample Description	Fat Clay (CL)				

Date	Time	Elapsed Time (min)	Load (lbf/in^2)	Swell Readings (in)	
7/24/2015	9:55	0.0	1	0.2408	
7/24/2015	10:05	10.0	1	0.2402	
7/24/2015	10:05	0.0	1	0.2402	D1
7/24/2015	10:05	0.1	1	0.2410	
7/24/2015	10:05	0.3	1	0.2415	
7/24/2015	10:05	0.5	1	0.2428	
7/24/2015	10:06	1.0	1	0.2450	
7/24/2015	10:07	2.0	1	0.2478	
7/24/2015	10:10	5.0	1	0.2553	
7/24/2015	10:13	8.0	1	0.2601	
7/24/2015	10:20	15.0	1	0.2685	
7/24/2015	10:35	30.0	1	0.2810	
7/24/2015	11:05	60.0	1	0.2939	
7/24/2015	12:46	161.0	1	0.3011	
7/25/2015	8:30	1345.0	1	0.3225	
7/26/2015	7:30	2725.0	1	0.3263	
7/27/2015	7:30	4165.0	1	0.3283	
7/27/2015	8:30	4225.0	1	0.3285	D2

Swell Index Calculation	
Initial Swell Readings D1 (in)	0.2402
Final Swell Readings D2 (in)	0.3285
ΔH=D2-D1 (in)	0.08830
EI= ΔH*1000/H1	88.1

Comments

Expansion Index, EI	Potential Expansion	Result
0-20	Very Low	
21-50	Low	
51-90	**Medium**	**88.1**
91-130	High	
>130	Very High	

Calculated by: DB
Computed by: DB
Checked by: RE

HVJ ASSOCIATES, INC.
EXPANSION INDEX OF SOILS ASTM D-4829-11

Project Name:	NTMWD Leonard WTP	Boring No.	S-3
Project No.	DG-15-11840	Sample Depth.	1-2'
Date Tested:	08/06/15	Ring No.	1
Technician:	KM	Date Calculated:	08/08/15

well Sample Data	Initial	Final	Test Data	Initial	Final
Sample Height (in)	1.002	1.054	Wet + Ring (g)	688.95	740.70
Diameter (in)	4.002	4.002	Dry + Ring (g)	637.37	637.37
Volume (cc)	206.544	217.325	Ring Wt. (g)	360.31	360.99
Height of Solids (in)	0.498	0.497	Moisture Data (Trimmings)		LL
Specific Gravity	2.700	2.700	Wet + Tare (g)	48.31	59
Moisture Content (%)	17.9	37.4	Dry + Tare (g)	45.74	PI
Wet Density (pcf)	99.3	109.0	Tare (g)	31.38	35
Dry Density (pcf)	84.2	79.4	Moisture Content (%)	17.9	
Saturation (%)	48.3%	89.9%	Hand Penetrometer (tsf)	3.5	
Sample Description	Fat Clay (CL)				

Date	Time	Elapsed Time (min)	Load (lbf/in^2)	Swell Readings (in)	
8/6/2015	9:55	0.0	1	0.4947	
8/6/2015	10:05	10.0	1	0.4946	
8/6/2015	10:05	0.0	1	0.4946	D1
8/6/2015	10:05	0.1	1	0.4941	
8/6/2015	10:05	0.3	1	0.4943	
8/6/2015	10:05	0.5	1	0.4945	
8/6/2015	10:06	1.0	1	0.4950	
8/6/2015	10:07	2.0	1	0.4962	
8/6/2015	10:10	5.0	1	0.5009	
8/6/2015	10:13	8.0	1	0.5030	
8/6/2015	10:20	15.0	1	0.5082	
8/6/2015	10:35	30.0	1	0.5149	
8/6/2015	11:05	60.0	1	0.5268	
8/6/2015	12:05	120.0	1	0.5344	
8/6/2015	14:05	240.0	1	0.5381	
8/6/2015	16:05	360.0	1	0.5398	
8/7/2015	6:00	1195.0	1	0.5461	
8/7/2015	8:00	1315.0	1	0.5469	D2

Swell Index Calculation	
Initial Swell Readings D1 (in)	0.4946
Final Swell Readings D2 (in)	0.5469
ΔH=D2-D1 (in)	0.05230
EI= ΔH*1000/H1	52.2

Comments

Expansion Index, EI	Potential Expansion	Result
0-20	Very Low	
21-50	Low	
51-90	**Medium**	**52.2**
91-130	High	
>130	Very High	

Calculated by: DB

Computed by: DB

Checked by: RE

HVJ ASSOCIATES, INC.
EXPANSION INDEX OF SOILS ASTM D-4829-11

Project Name:	NTMWD Leonard WTP	Boring No.	S-4
Project No.	DG-15-11840	Sample Depth.	3-4
Date Tested:	08/06/15	Ring No.	1
Technician:	KM	Date Calculated:	08/08/15

well Sample Data	Initial	Final	Test Data	Initial	Final
Sample Height (in)	1.002	1.080	Wet + Ring (g)	694.43	763.81
Diameter (in)	4.002	4.002	Dry + Ring (g)	653.06	653.06
Volume (cc)	206.544	222.602	Ring Wt. (g)	360.28	361.66
Height of Solids (in)	0.526	0.524	Moisture Data (Trimmings)		LL
Specific Gravity	2.700	2.700	Wet + Tare (g)	49.76	62
Moisture Content (%)	17.1	38.0	Dry + Tare (g)	47.07	PI
Wet Density (pcf)	101.0	112.7	Tare (g)	31.36	41
Dry Density (pcf)	86.2	81.7	Moisture Content (%)	17.1	
Saturation (%)	48.4%	96.6%	Hand Penetrometer (tsf)	3.0	
Sample Description	Fat Clay (CL)				

Date	Time	Elapsed Time (min)	Load (lbf/in^2)	Swell Readings (in)	
8/10/2015	9:55	0.0	1	0.4877	
8/10/2015	10:05	10.0	1	0.4873	
8/10/2015	10:05	0.0	1	0.4873	D1
8/10/2015	10:05	0.1	1	0.4847	
8/10/2015	10:05	0.3	1	0.4847	
8/10/2015	10:05	0.5	1	0.4848	
8/10/2015	10:06	1.0	1	0.4859	
8/10/2015	10:07	2.0	1	0.4888	
8/10/2015	10:10	5.0	1	0.4960	
8/10/2015	10:13	8.0	1	0.5042	
8/10/2015	10:20	15.0	1	0.5198	
8/10/2015	10:35	30.0	1	0.5316	
8/10/2015	11:05	60.0	1	0.5460	
8/10/2015	12:05	120.0	1	0.5527	
8/10/2015	14:05	240.0	1	0.5565	
8/10/2015	16:05	360.0	1	0.5593	
8/11/2015	6:00	1195.0	1	0.5641	
8/11/2015	8:00	1315.0	1	0.5652	D2

Swell Index Calculation	
Initial Swell Readings D1 (in)	0.4873
Final Swell Readings D2 (in)	0.5652
ΔH=D2-D1 (in)	0.07790
EI= ΔH*1000/H1	77.7

Comments

Expansion Index, EI	**Potential Expansion**	**Result**
0-20	Very Low	
21-50	Low	
51-90	**Medium**	**77.7**
91-130	High	
>130	Very High	

Calculated by: DB
Computed by: DB
Checked by: RE

Analytical Report 512106

for

HVJ Associates-Dallas

Project Manager: Damian Bozek

DG-15-11840

DG-15-11840

04-AUG-15

Collected By: Client

XENCO
Laboratories

9701 Harry Hines Blvd, Dallas, TX 75220

Xenco-Houston (EPA Lab code: TX00122):
Texas (T104704215-15-19), Arizona (AZ0765), Florida (E871002), Louisiana (03054)
Oklahoma (9218)

Xenco-Atlanta (EPA Lab Code: GA00046):
Florida (E87429), North Carolina (483), South Carolina (98015), Kentucky (85), DoD (L10-135)
Texas (T104704477), Louisiana (04176), USDA (P330-07-00105)

Xenco-Lakeland: Florida (E84098)
Xenco-Odessa (EPA Lab code: TX00158): Texas (T104704400-TX)
Xenco-Dallas (EPA Lab code: TX01468): Texas (T104704295-TX)
Xenco Phoenix (EPA Lab Code: AZ00901): Arizona(AZ0757)
Xenco-Phoenix Mobile (EPA Lab code: AZ00901): Arizona (AZM757)
Xenco Tucson (EPA Lab code:AZ000989): Arizona (AZ0758)

XENCO Laboratories

Table of Contents

XENCO
Laboratories

04-AUG-15

Project Manager: **Damian Bozek**
HVJ Associates-Dallas
8701 John Carpenter Fwy. Suite 250
Dallas, TX 75247

Reference: XENCO Report No(s): **512106**
DG-15-11840
Project Address: Leonard TX

Damian Bozek:

We are reporting to you the results of the analyses performed on the samples received under the project name referenced above and identified with the XENCO Report Number(s) 512106. All results being reported under this Report Number apply to the samples analyzed and properly identified with a Laboratory ID number. Subcontracted analyses are identified in this report with either the NELAC certification number of the subcontract lab in the analyst ID field, or the complete subcontracted report attached to this report.

Unless otherwise noted in a Case Narrative, all data reported in this Analytical Report are in compliance with NELAC standards. The uncertainty of measurement associated with the results of analysis reported is available upon request. Should insufficient sample be provided to the laboratory to meet the method and NELAC Matrix Duplicate and Matrix Spike requirements, then the data will be analyzed, evaluated and reported using all other available quality control measures.

The validity and integrity of this report will remain intact as long as it is accompanied by this letter and reproduced in full, unless written approval is granted by XENCO Laboratories. This report will be filed for at least 5 years in our archives after which time it will be destroyed without further notice, unless otherwise arranged with you. The samples received, and described as recorded in Report No. 512106 will be filed for 60 days, and after that time they will be properly disposed without further notice, unless otherwise arranged with you. We reserve the right to return to you any unused samples, extracts or solutions related to them if we consider so necessary (e.g., samples identified as hazardous waste, sample sizes exceeding analytical standard practices, controlled substances under regulated protocols, etc).

We thank you for selecting XENCO Laboratories to serve your analytical needs. If you have any questions concerning this report, please feel free to contact us at any time.

Respectfully,

Monica Tobar

Monica Tobar
Project Manager

Recipient of the Prestigious Small Business Administration Award of Excellence in 1994.
Certified and approved by numerous States and Agencies.
A Small Business and Minority Status Company that delivers SERVICE and QUALITY

Houston - Dallas - Odessa - San Antonio - Tampa - Lakeland - Atlanta - Phoenix - Oklahoma - Latin America

Sample Cross Reference 512106

HVJ Associates-Dallas, Dallas, TX

DG-15-11840

Sample Id	Matrix	Date Collected	Sample Depth	Lab Sample Id
BHS1	S	07-13-15 11:00	1 - 2	512106-001
BHS2	S	07-13-15 11:00	3 - 4	512106-002
BHS3	S	07-13-15 11:00	0 - 1	512106-003

CASE NARRATIVE

Client Name: HVJ Associates-Dallas
Project Name: DG-15-11840

Project ID:	*DG-15-11840*	Report Date:	*04-AUG-15*
Work Order Number(s):	*512106*	Date Received:	*07/23/2015*

Sample receipt non conformances and comments:

Sample receipt non conformances and comments per sample:

None

XENCO Laboratories

Certificate of Analytical Results 512106

HVJ Associates-Dallas, Dallas, TX

DG-15-11840

Sample Id:	**BHS1**	Matrix:	Solid	Date Received:	07.23.15 13.09
Lab Sample Id:	512106-001	Date Collected:	07.13.15 11.00	Sample Depth:	1 - 2

Analytical Method: Chloride, Mercuric Nitrate Method by SM4500-CI- B

Tech: JHE
Analyst: JHE
Seq Number: 973503

% Moisture:
Basis: Wet Weight

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Chloride	16887-00-6	<5.00	5.00	mg/kg	07.31.15 09.02	U	1

Analytical Method: Soil pH by SW-846 9045C

Tech: JHE
Analyst: JHE
Seq Number: 973731

% Moisture:
Basis: Wet Weight

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
pH	12408-02-5	**8.67**		SU	08.04.15 10.13		1

Analytical Method: Sulfate by SW-846 9038

Tech: JHE
Analyst: JHE
Seq Number: 973256

% Moisture:
Basis: Wet Weight

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Sulfate	14808-79-8	<50.0	50.0	mg/kg	07.28.15 14.57	U	1

Sample Id: **BHS2**	Matrix: Solid	Date Received:07.23.15 13.09
Lab Sample Id: 512106-002	Date Collected: 07.13.15 11.00	Sample Depth: 3 - 4

Analytical Method: Chloride, Mercuric Nitrate Method by SM4500-CI- B
Tech: JHE
Analyst: JHE
Seq Number: 973503
% Moisture:
Basis: Wet Weight

Parameter	**Cas Number**	**Result**	**RL**	**Units**	**Analysis Date**	**Flag**	**Dil**
Chloride	16887-00-6	<5.00	5.00	mg/kg	07.31.15 09.02	U	1

Analytical Method: Soil pH by SW-846 9045C
Tech: JHE
Analyst: JHE
Seq Number: 973731
% Moisture:
Basis: Wet Weight

Parameter	**Cas Number**	**Result**	**RL**	**Units**	**Analysis Date**	**Flag**	**Dil**
pH	12408-02-5	**8.37**		SU	08.04.15 10.13		1

Analytical Method: Sulfate by SW-846 9038
Tech: JHE
Analyst: JHE
Seq Number: 973256
% Moisture:
Basis: Wet Weight

Parameter	**Cas Number**	**Result**	**RL**	**Units**	**Analysis Date**	**Flag**	**Dil**
Sulfate	14808-79-8	<50.0	50.0	mg/kg	07.28.15 14.57	U	1

Sample Id: **BHS3**
Lab Sample Id: 512106-003
Matrix: Solid
Date Collected: 07.13.15 11.00
Date Received:07.23.15 13.09
Sample Depth: 0 - 1

Analytical Method: Chloride, Mercuric Nitrate Method by SM4500-CI- B
Tech: JHE
Analyst: JHE
Seq Number: 973503
% Moisture:
Basis: Wet Weight

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Chloride	16887-00-6	<5.00	5.00	mg/kg	07.31.15 09.02	U	1

Analytical Method: Soil pH by SW-846 9045C
Tech: JHE
Analyst: JHE
Seq Number: 973731
% Moisture:
Basis: Wet Weight

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
pH	12408-02-5	**8.33**		SU	08.04.15 10.13		1

Analytical Method: Sulfate by SW-846 9038
Tech: JHE
Analyst: JHE
Seq Number: 973256
% Moisture:
Basis: Wet Weight

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Sulfate	14808-79-8	**59.1**	50.0	mg/kg	07.28.15 14.57		1

Analytical Method: **Chloride, Mercuric Nitrate Method by SM4500-CI- B**
Seq Number: 973503 Matrix: Solid
MB Sample Id: 973503-1-BLK LCS Sample Id: 973503-1-BKS LCSD Sample Id: 973503-1-BSD

Parameter	MB Result	Spike Amount	LCS Result	LCS %Rec	LCSD Result	LCSD %Rec	Limits	%RPD	RPD Limit	Units	Analysis Date	Flag
Chloride	<5.00	50.0	50.0	100	50.0	100	70-125	0	25	mg/kg	07.31.15 09:02	

Analytical Method: **Chloride, Mercuric Nitrate Method by SM4500-CI- B**
Seq Number: 973503 Matrix: Solid
Parent Sample Id: 512106-001 MS Sample Id: 512106-001 S MSD Sample Id: 512106-001 SD

Parameter	Parent Result	Spike Amount	MS Result	MS %Rec	MSD Result	MSD %Rec	Limits	%RPD	RPD Limit	Units	Analysis Date	Flag
Chloride	<5.00	50.0	58.5	117	56.5	113	70-125	3	25	mg/kg	07.31.15 09:02	

Analytical Method: **Soil pH by SW-846 9045C**
Seq Number: 973731 Matrix: Solid
Parent Sample Id: 512106-001 MD Sample Id: 512106-001 D

Parameter	Parent Result	MD Result	%RPD	RPD Limit	Units	Analysis Date	Flag
pH	8.67	8.66	0	20	SU	08.04.15 10:13	

Analytical Method: **Sulfate by SW-846 9038**
Seq Number: 973256 Matrix: Solid
MB Sample Id: 973256-1-BLK LCS Sample Id: 973256-1-BKS LCSD Sample Id: 973256-1-BSD

Parameter	MB Result	Spike Amount	LCS Result	LCS %Rec	LCSD Result	LCSD %Rec	Limits	%RPD	RPD Limit	Units	Analysis Date	Flag
Sulfate	<50.0	200	212	106	215	108	80-120	1	20	mg/kg	07.28.15 14:57	

Analytical Method: **Sulfate by SW-846 9038**
Seq Number: 973256 Matrix: Solid
Parent Sample Id: 512214-001 MS Sample Id: 512214-001 S MSD Sample Id: 512214-001 SD

Parameter	Parent Result	Spike Amount	MS Result	MS %Rec	MSD Result	MSD %Rec	Limits	%RPD	RPD Limit	Units	Analysis Date	Flag
Sulfate	385	1000	1320	94	1340	96	75-125	2	20	mg/kg	07.28.15 14:57	

XENCO Laboratories

Flagging Criteria

X In our quality control review of the data a QC deficiency was observed and flagged as noted. MS/MSD recoveries were found to be outside of the laboratory control limits due to possible matrix /chemical interference, or a concentration of target analyte high enough to affect the recovery of the spike concentration. This condition could also affect the relative percent difference in the MS/MSD.

B A target analyte or common laboratory contaminant was identified in the method blank. Its presence indicates possible field or laboratory contamination.

D The sample(s) were diluted due to targets detected over the highest point of the calibration curve, or due to matrix interference. Dilution factors are included in the final results. The result is from a diluted sample.

E The data exceeds the upper calibration limit; therefore, the concentration is reported as estimated.

F RPD exceeded lab control limits.

J The target analyte was positively identified below the quantitation limit and above the detection limit.

U Analyte was not detected.

L The LCS data for this analytical batch was reported below the laboratory control limits for this analyte. The department supervisor and QA Director reviewed data. The samples were either reanalyzed or flagged as estimated concentrations.

H The LCS data for this analytical batch was reported above the laboratory control limits. Supporting QC Data were reviewed by the Department Supervisor and QA Director. Data were determined to be valid for reporting.

K Sample analyzed outside of recommended hold time.

JN A combination of the "N" and the "J" qualifier. The analysis indicates that the analyte is "tentatively identified" and the associated numerical value may not be consistent with the amount actually present in the environmental sample.

** Surrogate recovered outside laboratory control limit.

BRL Below Reporting Limit.

RL Reporting Limit

MDL Method Detection Limit **SDL** Sample Detection Limit **LOD** Limit of Detection

PQL Practical Quantitation Limit **MQL** Method Quantitation Limit **LOQ** Limit of Quantitation

DL Method Detection Limit

NC Non-Calculable

\+ NELAC certification not offered for this compound.

* (Next to analyte name or method description) = Outside XENCO's scope of NELAC accreditation

Recipient of the Prestigious Small Business Administration Award of Excellence in 1994.

Certified and approved by numerous States and Agencies.

A Small Business and Minority Status Company that delivers SERVICE and QUALITY

Houston - Dallas - San Antonio - Atlanta - Midland/Odessa - Tampa/Lakeland - Phoenix - Latin America

	Phone	Fax
4143 Greenbriar Dr, Stafford, TX 77477	(281) 240-4200	(281) 240-4280
9701 Harry Hines Blvd , Dallas, TX 75220	(214) 902 0300	(214) 351-9139
5332 Blackberry Drive, San Antonio TX 78238	(210) 509-3334	(210) 509-3335
2505 North Falkenburg Rd, Tampa, FL 33619	(813) 620-2000	(813) 620-2033
12600 West I-20 East, Odessa, TX 79765	(432) 563-1800	(432) 563-1713
6017 Financial Drive, Norcross, GA 30071	(770) 449-8800	(770) 449-5477
3725 E. Atlanta Ave, Phoenix, AZ 85040	(602) 437-0330	

XENCO LABORATORIES

Setting the Standard since 1990

Stafford,Texas (281-240-4200)

Dallas, Texas (214-902-0300)

Service Center - San Antonio, Texas (210-509-3334)

CHAIN OF CUSTODY

Page ___ Of ___

www.xenco.com

Odessa, Texas (432-563-1800)

Norcross, Georgia (770-449-8800)

Lakeland, Florida (863-646-8526)

Tampa, Florida (813-620-2000)

Xenco Quote #

Xenco Job # 512106.0

Client / Reporting Information	Project Information
Company Name / Branch: HVJ - Dallas, TX	Project Name/Number: DG-15-11840
Company Address: 8701 John Carpenter Fwy, Dallas, TX 75247	Project Location: Leonard, TX
Email: ~~Damian~~ DBozek@hvj.com Phone No:	Invoice To: HVJ Associates
Project Contact: Damian Bozek	PO Number: DG-15-11840
Samplers's Name: Damian Bozek	

Analytical Information

No.	Field ID / Point of Collection	Sample Depth	Date	Time	Matrix	# of bottles	HCl	NaOH/Zn Acetate	HNO3	H2SO4	NaOH	NaHSO4	MEOH	NONE	chloride	sulfate	pH	Field Comments
1	BHS1	1-2	7-13	11:00											X	X	X	
2	BHS2	3-4	7-13	11:00											X	X	X	
3	BHS3	0-1	7-13	11:00											X	X	X	
4																		
5																		
6																		
7																		
8																		
9																		
10																		

Matrix Codes

A= Air
S = Soil/Sed/Solid
GW =Ground Water
DW = Drinking Water
P = Product
SW = Surface water
SL = Sludge
WW= Waste Water
W = Wipe
O = Oil

WW= Waste Water

Turnaround Time (Business days)

☐ Same Day TAT
☐ Next Day EMERGENCY
☐ 2 Day EMERGENCY
☐ 3 Day EMERGENCY
☐ 5 Day TAT
☒ 7 Day TAT
☐ Contract TAT

Data Deliverable Information

☐ Level II Std QC
☐ Level III Std QC+ Forms
☐ Level 3 (CLP Forms)
☐ TRRP Checklist
☐ Level IV (Full Data Pkg /raw data)
☐ TRRP Level IV
☐ UST / RG -411

Notes:

TAT Starts Day received by Lab, if received by 3:00 pm

FED-EX / UPS: Tracking #

SAMPLE CUSTODY MUST BE DOCUMENTED BELOW EACH TIME SAMPLES CHANGE POSSESSION, INCLUDING COURIER DELIVERY

Relinquished by Sampler: 1	Date Time: 7-23-15 1:0	Received By: 7.23.15 109	Relinquished By: 2	Date Time:	Received By: 2
Relinquished by: 3	Date Time:	Received By: 3	Relinquished By: 4	Date Time:	Received By: 4
Relinquished by: 5	Date Time:	Received By: 5	Custody Seal #	Preserved where applicable ☐	On Ice ☐ Cooler Temp. Thermo. Corr. Factor

Notice: Signature of this document and relinquishment of samples constitutes a valid purchase order from client company to XENCO Laboratories and its affiliates. subcontractors and assigns XENCO's standard terms and conditions of service unless previously negiotiated under a fully executed client contract.

XENCO Laboratories
Prelogin/Nonconformance Report- Sample Log-In

Client: HVJ Associates-Dallas

Date/ Time Received: 07/23/2015 01:09:00 PM

Work Order #: 512106

Acceptable Temperature Range: 0 - 6 degC
Air and Metal samples Acceptable Range: Ambient

Temperature Measuring device used :

Sample Receipt Checklist		Comments
#1 *Temperature of cooler(s)?		
#2 *Shipping container in good condition?	**Yes**	
#3 *Samples received on ice?	**N/A**	
#4 *Custody Seals intact on shipping container/ cooler?	**N/A**	
#5 Custody Seals intact on sample bottles?	**N/A**	
#6 *Custody Seals Signed and dated?	**N/A**	
#7 *Chain of Custody present?	**Yes**	
#8 Sample instructions complete on Chain of Custody?	**Yes**	
#9 Any missing/extra samples?	**No**	
#10 Chain of Custody signed when relinquished/ received?	**Yes**	
#11 Chain of Custody agrees with sample label(s)?	**Yes**	
#12 Container label(s) legible and intact?	**Yes**	
#13 Sample matrix/ properties agree with Chain of Custody?	**Yes**	
#14 Samples in proper container/ bottle?	**Yes**	
#15 Samples properly preserved?	**Yes**	
#16 Sample container(s) intact?	**Yes**	
#17 Sufficient sample amount for indicated test(s)?	**Yes**	
#18 All samples received within hold time?	**Yes**	
#19 Subcontract of sample(s)?	**No**	
#20 VOC samples have zero headspace (less than 1/4 inch bubble)?	**N/A**	
#21 <2 for all samples preserved with HNO3,HCL, H2SO4? Except for samples for the analysis of HEM or HEM-SGT which are verified by the analysts.	**N/A**	
#22 >10 for all samples preserved with NaAsO2+NaOH, ZnAc+NaOH?	**N/A**	

*** Must be completed for after-hours delivery of samples prior to placing in the refrigerator**

Analyst:

PH Device/Lot#:

Checklist completed by: Angelica Martinez Date: 07/23/2015

Checklist reviewed by: Monica Tobar Date: 07/23/2015

Soil Resistivity Test Using the Two-Electrode Soil Box Method
ASTM G187

Company:	HVJ Associates	**Meter Used:**	Miller 400A
Test Date:	8/12/2015	**Technician:**	MA
Project Name:	NTMWD Leonard WTP	**Soil Box Sizes, cm (LxWxH):**	10.8 x 3 x 2.4
Project Number:	DG-15-11840	**Soil Box Factor:**	0.67

Boring No.	Sample Depth	Description	Collection Date	Sample Condition (Moisture)	MC (%)	Meassured Resistance (ohms)	Calculated Resistivity (ohm-cm)
S-1	2-3'	Dark gray Fat Clay (CH)	7/14/2015	As Received	29.6	610	409
S-1	2-3'	Dark gray Fat Clay (CH)	7/14/2015	Saturated	53.9	800	536
S-2	4-5'	Dark brown Fat Clay (CH)	7/14/2015	As Received	23.9	720	482
S-2	4-5'	Dark brown Fat Clay (CH)	7/14/2015	Saturated	48.3	980	657
S-3	2-3'	Light brown Fat Clay (CH)	7/14/2015	As Received	21.0	4900	3283
S-4	2-3'	Light brown Fat Clay (CH)	7/14/2015	Saturated	44.2	3300	2211

TECHNICAL MEMORANDUM 3

Jurisdictional Areas and Other Site Constraints

PREPARED FOR: North Texas Municipal Water District

PREPARED BY: CH2M HILL
Released for the purposes of review by Edward Motley,
PE Number 48243 on September 14, 2015

Introduction

The proposed Leonard Water Treatment Plant (WTP) will be located approximately 1.5 miles west of Leonard, Texas. The proposed plant site is part of a 1,120-acre tract purchased by North Texas Municipal Water District (NTMWD) for the Lower Bois d' Arc Creek Water Supply Project (see Figure 1). The WTP site will be located in the southwestern portion of the tract on a 323-acre parcel. A balancing reservoir is planned for the parcel north of the WTP site.

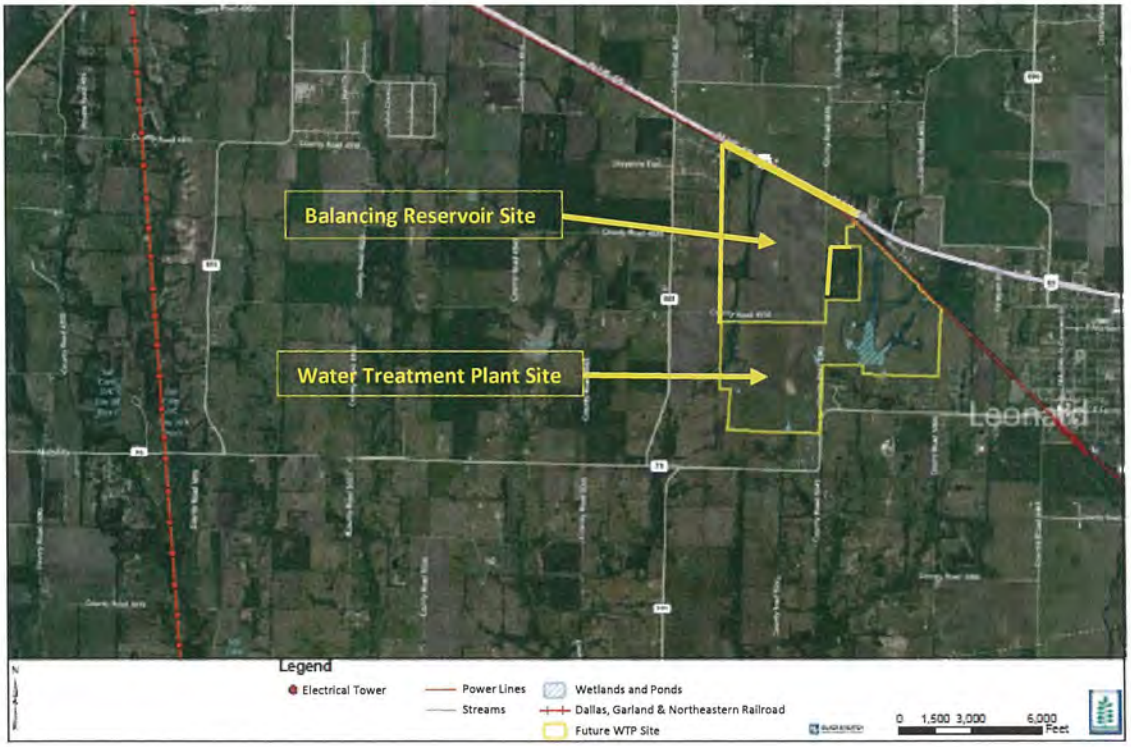


Figure 1. Site Location Map

Jurisdictional Area Determination

Alan Plummer and Associates, Inc. (APAI) completed a *Preliminary Jurisdictional Determination of Waters of the United States* (PJD) for the Leonard WTP site dated June 11, 2010 (see Attachment 1). The findings of the APAI study are the basis for identifying constraints relating to potential impacts on waters of the United States.

The purpose of the APAI preliminary jurisdictional determination (PJD) report was to document the extent of jurisdictional waters of the United States (U.S.) and adjacent wetlands within the proposed WTP site. The information contained within the PJD report will be used for permitting and to evaluate designs that will avoid and minimize impacts (to the maximum extent practicable) on any identified waters of the U.S. within the limits of the PJD.

Figure 2 (copied from the APAI report) illustrates the potential jurisdictional waters of the U.S. located on the WTP site, including the following:

- A small on-channel impoundment on the south side of the site designated as Lee Creek Tributary Impoundment 1 (LCTI1) with an estimated area of 1 acre
- An emergent swale upstream of LCTI1 that contains vegetation adapted to saturated soil conditions designated as Wetland Swale 1 (WS1) with an estimated length of 370 feet and area of 0.12 acre
- The largest water feature is an unnamed tributary of Bear Creek classified as an intermittent stream with perineal pools on the west side of the site, designated as Tributary Bear Creek (TBC) with an estimated length onsite of 2,663 feet and area of 1.53 acres
- Feeding into TBC are two ephemeral tributaries designated as TBC Tributary 1 (TBCT1) at 114 linear feet and 0.01 acre and TBC Tributary 2 (TBCT2) at 126 linear feet and 0.01 acre onsite
- A small on-channel impoundment on TBCT1 upstream of the convergence with TCB that appears to have been breached between 2004 and 2007, designated as Wetland Impoundment 1 (WI1) with an estimated area of 0.10 acre
- A small emergent swale extending eastward from WI1 designated as Wetland Swale 2 (WS2) with a length of approximately 960 feet and an area of 0.18 acre

The scope of APAI's PJD only included the WTP site and NTMWD's property east of County Road (CR) 4965. The APAI study did not address the determination of jurisdictional areas that may be affected by a railroad spur extending across the future terminal storage reservoir site to the north.

NTMWD submitted the APAI PJD to the Tulsa District United States Army Corps of Engineers (USACE) for review. As a result of their review, the USACE determined that only the unnamed tributary of Bear Creek (TBC) was jurisdictional. The remaining features were determined to be non-jurisdictional. A copy of the USACE jurisdictional determination is included in Attachment 2

The principal impact of these determinations on design and construction will be to prohibit grading and construction of new facilities within the footprint of the unnamed tributary of Bear Creek (TBC) and a buffer zone around the creek. A one-hundred foot wide buffer on the east and south side of the tributary is proposed (see Figure 3). Since the creek isolates the extreme north-west portion of the site (approximately 20 acres), no construction will be planned for the north and west side of the creek.

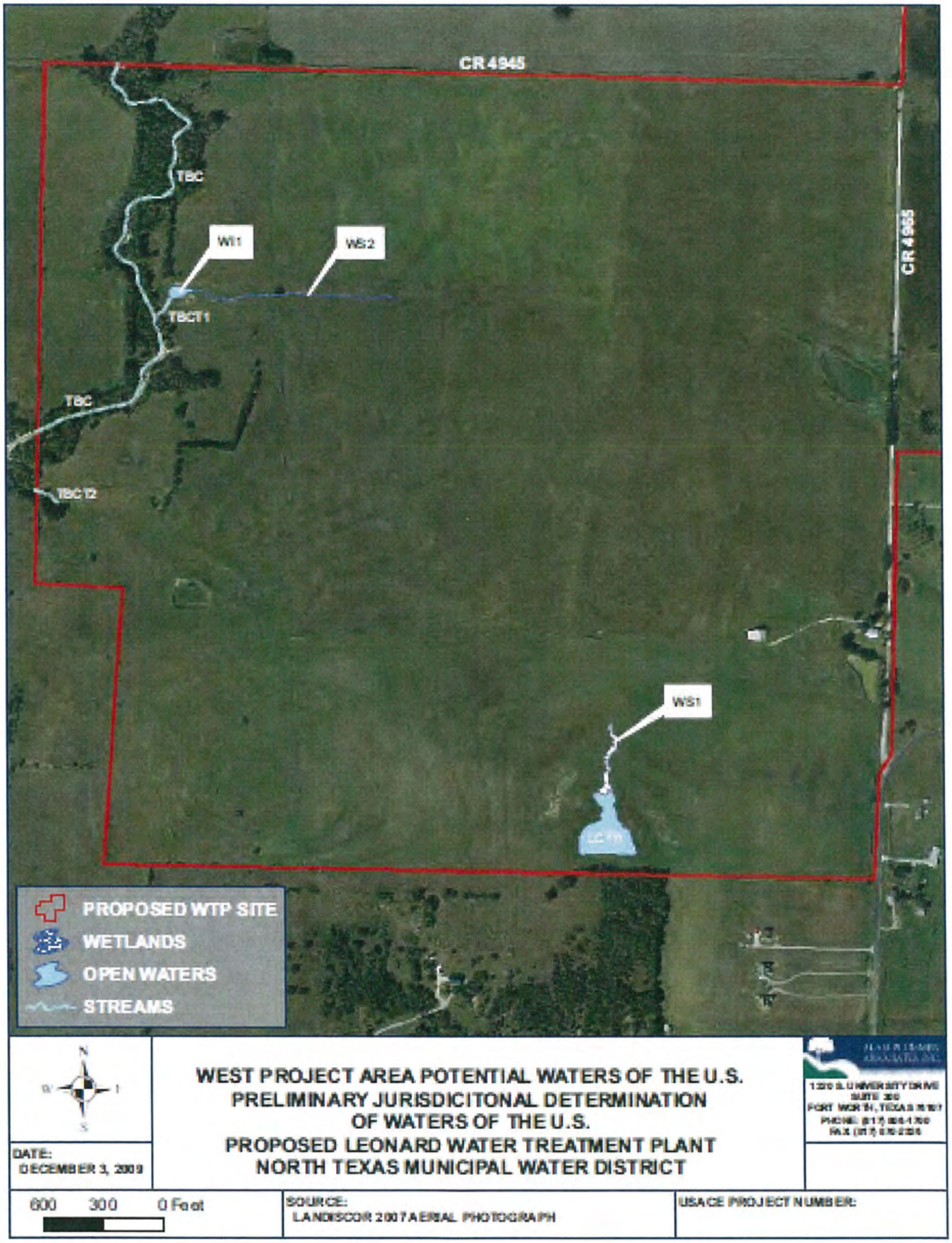


Figure 2. WTP Site Waters of the U.S.

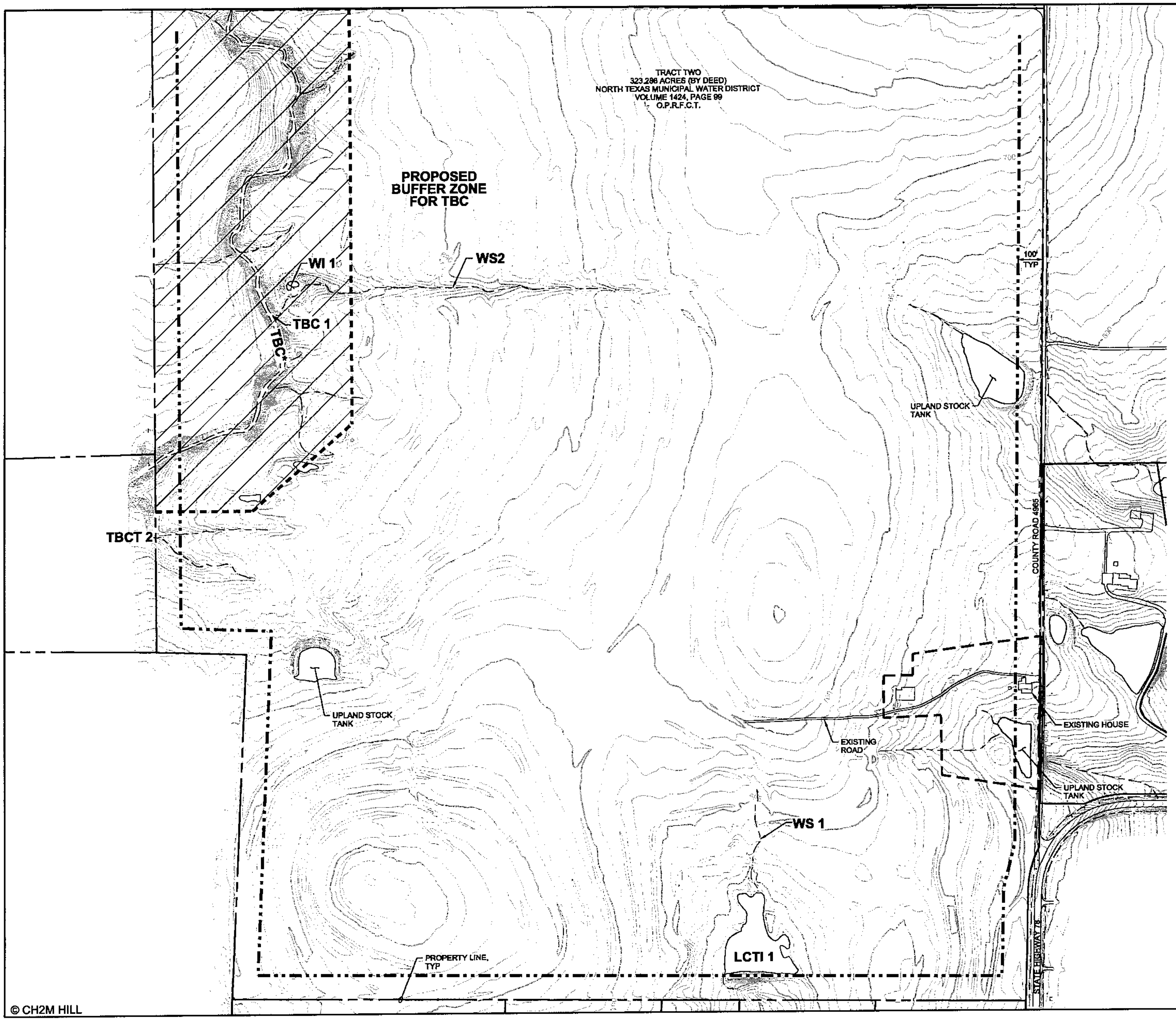
Cultural Resources

AR Consultants, Inc. completed a cultural resource survey and report on the raw water pipeline route, WTP site, and terminal storage site in December 2013. The AR Consultant report titled *Archaeological Survey of the Proposed Lower Bois D'Arc Creek Reservoir Pipeline Project* (AR Report) identified and investigated the following four potential resources:

- 41FN172 – A historic well-cistern and homestead located at the southwest corner of the intersection of CR 4965 and Highway 69; potentially affected by the proposed railroad spur
- 41FN173 – A well-cistern located in a plowed field approximately 900 feet west of CR 4965 and 350 feet north of CR 4950; potentially affected by the proposed terminal storage reservoir
- 41FN174 – A well-cistern located in a plowed field approximately 800 feet west of CR 4965 and 1,500 feet north of CR 4950; potentially affected by the proposed terminal storage reservoir
- 41FN175 – A farmstead on the west side of CR 4966 approximately 2,700 feet south of the intersection of CR 4965 and CR 4950; potentially affected by the WTP

Of the four sites, only 41FN175 is located on the WTP site. Site 41FN172 is located along the proposed railroad spur alignment. The other two sites are on the proposed terminal storage reservoir site. The structures associated with 41FN175 and 41FN172 will most likely be demolished as a part of construction for the WTP and associated railroad spur. The AR Report states that both of these sites are *"recommended as not eligible for listing in the National Register of Historic Places (NRHP) or for designation as a State Antiquities Listing (SAL)."* This recommendation allows demolition of the site if it interferes with an efficient plant layout.

A copy of the AR Report is included in Attachment 3.



LEGEND

TBC*	UNNAMED TRIBUTARY TO BEAR CREEK (INTERMITTENT)
TBCT 1	TRIBUTARY 1 TO TBC (EPHEMERAL)
TBCT 2	TRIBUTARY 2 TO TBC (EPHEMERAL)
WI 1	WETLAND IMPOUNDMENT 1 (ON CHANNEL)
WS 1	EMERGENT WETLAND SWALE 1
WS 2	EMERGENT WETLAND SWALE 2
LCTI 1	LEE CREEK TRIBUTARY IMPOUNDMENT 1 (ON CHANNEL)
▨	JURISDICTIONAL AREA BUFFER
— · · —	100 FT BUILDING SET BACK (CITY OF LEONARD)
— — —	EXISTING WATER FLOW LINE
▬ ▬	POTENTIAL CULTURAL OR HISTORICAL RESOURCE

*JURISDICTIONAL WATER OF THE U.S., ALL OTHER WATER FEATURES DETERMINED TO BE NON-JURISDICTIONAL

PROPOSED BUFFER:

- 100 FOOT MINIMUM BUFFER FROM EDGE OF BANK ON TBC.

FIGURE 3
SITE JURISDICTIONAL CONSTRAINTS

NORTH TEXAS MUNICIPAL WATER DISTRICT
LEONARD, TEXAS

ch2m:

FILENAME: FIG004_659925.DGN

Attachment 1
Preliminary Jurisdictional Determination of Waters of the United States

PRELIMINARY JURISDICTIONAL DETERMINATION OF WATERS OF THE UNITED STATES

NORTH TEXAS MUNICIPAL WATER DISTRICT'S

PROPOSED WATER TREATMENT PLANT SITE
CITY OF LEONARD, FANNIN COUNTY, TEXAS

June 11, 2010

PREPARED BY:	PREPARED FOR:
ALAN PLUMMER ASSOCIATES, INC. ENVIRONMENTAL ENGINEERS - DESIGNERS - SCIENTISTS	FREESE• NICHOLS
ALAN PLUMMER ASSOCIATES, INC.	FREESE AND NICHOLS, INC.

TABLE OF CONTENTS

APPENDIX A-	FIGURES
APPENDIX B -	PHOTOGRAPHS FROM THE ON-SITE INVESTIGATION
APPENDIX C-	NATIONAL WETLAND INVENTORY MAP AND COWARDIN (NWI) CLASSIFICATION EXPLANATIONS
APPENDIX D-	MAPPED SOIL TYPES AND SOIL SERIES DESCRIPTIONS
APPENDIX E-	WETLAND DETERMINATION DATA FORMS AND SAMPLING LOCATIONS

Preliminary Jurisdictional Determination of Waters of the United States and Adjacent Wetlands
North Texas Municipal Water District's Proposed Water Treatment Plant Site
City of Leonard, Fannin County, Texas

1. Purpose

The purpose of this Preliminary Jurisdictional Determination (PJD) report is to document the extent of jurisdictional waters of the United States (U.S.) and adjacent wetlands within an approximately 662-acre tract near the City of Leonard, Fannin County, Texas. The water treatment plant, including an approximately 44-mile long raw water transmission pipeline, are components of the overarching Lower Bois d'Arc Reservoir project. The information contained within this PJD report will be utilized during Section 404 permitting and National Environmental Policy Act (NEPA) compliance phases of the reservoir project, and in the design of the water treatment plant in order to evaluate designs that will avoid and minimize impacts (to the maximum extent practicable) to any identified waters of the U.S. within the limits of the PJD.

2. Methods

a. Contact Information

Freese and Nichols, Incorporated (FNI), as agent for the North Texas Municipal Water District (NTMWD), has contracted with Alan Plummer Associates, Incorporated (APAI) to provide environmental documentation services including this PJD report for the proposed water treatment plant site. Questions concerning the content of this PJD report should be directed toward either FNI or APAI. Information regarding contacts for FNI and APAI are as follows:

Entity	Contact	Address	Telephone	Fax
Freese and Nichols, Inc.	Mr. Steven Watters	4055 International Plaza, Suite 200 Fort Worth, Texas 76109	(817) 735-7300	(817) 735-7492
Alan Plummer Associates, Inc.	Mr. Jason Voight	1320 S. University Drive, Suite 300 Fort Worth, Texas 76107-5764	(817) 806-1700	(817) 870-2536

b. Delineation Methods

An on-site investigation for potential waters of the U.S. and adjacent wetlands was conducted on September 14 and 15, 2009 by APAI. The delineation of waters of the U.S. was conducted based on the current regulatory procedures as outlined in the U.S. Army

Corps of Engineers (USACE) *Wetland Delineation Manual, Technical Report Y-87-1* (on-line edition) and the *Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Great Plains Region.* Preliminary data (including but not limited to USGS topographic maps, National Wetland Inventory Maps, aerial photographs, and soil survey maps) suggested the potential for waters of the U.S.; therefore, the procedures for a routine, on-site determination for sites greater than five acres (as outlined in the previously referenced manuals) were followed to determine the extent of waters of the U.S. within the limits of the PJD.

c. Mapping Techniques

Prior to the on-site investigation, a review of the available resources was conducted to identify potential waters of the U.S. within the limits of the PJD. The resources reviewed included current and historical aerial photographs, the USGS topographic map (Trenton, Texas Quadrangle), and the Soil Survey of Fannin County.

Once located during the on-site investigation, the limits of the waters of the U.S. were determined using the guidelines outlined in the above referenced manuals, then mapped using a hand-held global positioning system (GPS) receiver (Garmin Oregon 400T with 3-meter accuracy; field tested to 5-foot accuracy). Waypoints recorded during the investigation were cross-referenced with the topographic map and aerial photographs to determine the extent of waters of the U.S. within the limits of the PJD.

3. Results

a. Project Location

The proposed project site is located in southwestern Fannin County near the City of Leonard, Texas. The approximate boundaries of the limits of the PJD are shown on the general location map included as Figure A-1 in Appendix A. Figure A-2 shows the limits of the PJD on a USGS topographic map (Trenton, Texas Quadrangle).

b. Description of Project Area

The area investigated for this PJD is an approximately 662-acre, rural site. The project site and surrounding properties are primarily used for livestock grazing and hay production. Within the area investigated, the tracts mostly consist of areas containing upland herbaceous vegetation; however, wooded areas do exist along riparian corridors and along fence lines. For descriptive purposes, the project site is divided into eastern (339 acres) and western (323 acres) sections by County Road 4965. The topography of the project site consists of gentle slopes to Lee Creek and its tributaries in the eastern and portions of the western section, and gentle slopes to tributaries of Bear Creek in the far western section of the area investigated. Figure A-2 in Appendix A shows the topography of the PJD area on a USGS topographic map. Figure A-3 in Appendix A shows the limits of the PJD on a 2007 aerial photograph. Representative photographs of the property taken during the on-site investigation are included in Appendix B with a map (Figure B-1) showing the approximate locations of the photographs.

c. Hydrology

The proposed project area is located in the East Fork Trinity River watershed, near the Trinity River, Red River, and Sulphur River divides. The eastern project area and a small eastern portion of the western project area drain to Lee Creek and its tributaries. Lee Creek converges with Arnold Creek approximately eight (8) miles downstream of the southern limits of the project area. Arnold Creek converges with Indian Creek approximately four (4) miles downstream of the confluence of Lee and Arnold Creeks. The majority of the western portion of the project area drains to an unnamed tributary to Bear Creek. The unnamed tributary to Bear Creek ties into Bear Creek approximately 2.5 miles downstream of the project area limits. Bear Creek ties into Indian Creek approximately 10 miles downstream of the confluence of Bear Creek and its unnamed tributary.

As presented, water flowing through the limits of the PJD eventually reaches Indian Creek. Indian Creek converges with Pilot Grove Creek, which empties into Lavon Lake approximately 9.5 miles downstream of the confluence of Indian and Pilot Grove Creeks.

Lavon Lake is located on the East Fork Trinity River, which is a major tributary to the Trinity River. Upstream portions of the Trinity River are listed navigable waters of the U.S., and the length of the Trinity River is considered to be a traditionally navigable water of the U.S.

According to the Federal Emergency Management Agency's (FEMA) flood insurance rate map, number 480807 0010 b, the only 100-year floodplain in the project area is located immediately around Lee Creek, an impoundment of Lee Creek, and two unnamed tributaries to Lee Creek. No 100-year floodplain areas were identified in the project area west of County Road 4965. Figure A-4 in Appendix A shows the limits of the FEMA identified 100-year floodplains. Figure C-1 in Appendix C shows the limits of the PJD superimposed onto the National Wetland Inventory (NWI) map for the Trenton, Texas Quadrangle map. An explanation of the Cowardin (NWI) Classification for the identified wetlands on the NWI map is also included in Appendix C.

Hydrologic Features – Eastern Project Area

The dominant hydrologic features within the eastern project site consist of Lee Creek, five unnamed tributaries to Lee Creek, and seven impoundments (both on- and off-channel). Beyond these primary hydrologic features, both seasonal and likely perennial wetlands were identified within the eastern limits of the PJD. The majority of the seasonal wetlands were located behind areas that were either contoured for erosion prevention or terraced for farming practices. The perennial wetlands were identified adjacent to stream channels or impoundments, and consisted of backwater and fringe emergent wetlands associated with impoundments, a potential meander scar, and streamside adjacent emergent wetlands. It should be noted that numerous areas in slight depressions were identified. Although these areas contain vegetation adapted to more sodden conditions, these areas do not stay inundated or saturated for sufficient duration to develop hydric soil conditions. Figure 1 shows the hydrologic features identified within the eastern project area.

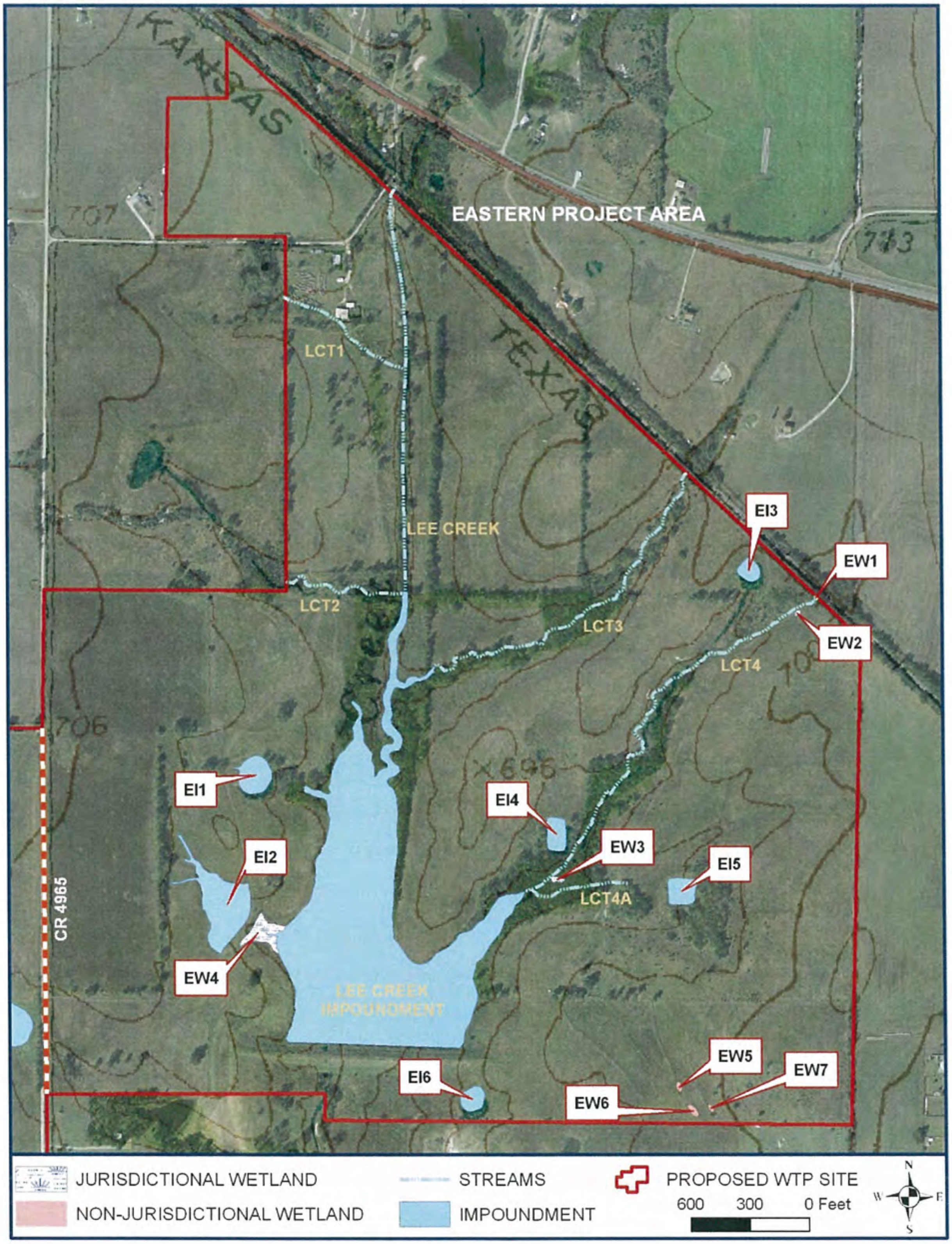


Figure 1: Hydrologic Elements Observed within the Eastern Limits of the PJD

Lee Creek enters the eastern limits of the project area at the northern site boundary under the Missouri Kansas Texas railroad trestle. Lee Creek maintains an average ordinary high water mark (OHWM) width of 25 feet in the upper portion of the limits of the project area. The OHWM progressively increases downstream to an average width of 43 feet. Within the upper portion of the project area, Lee Creek has steep banks and a bedrock channel bottom. Flow was observed during the on-site investigation due to recent heavy rains. Towards the southern property boundary, Lee Creek is impounded by an earthen dam. The surface area of the impoundment covers approximately 22 acres. The upper reaches of the impoundment were identified approximately 2,075 feet downstream of where Lee Creek enters the project area, where no identifiable flow was observed and the water appeared slack.

Five tributaries were identified within the eastern project area, four of which are tributaries to Lee Creek, and one is a secondary tributary. Tributary LCT1 enters the project site from the western boundary approximately 940 feet downstream of where Lee Creek enters the project area. Tributary LCT1 joins Lee Creek approximately 745 feet east of where it enters the project area, and has an average OHWM width of three (3) feet. Tributary LCT1 is not identified on the USGS topographic map, and should be considered ephemeral due to its limited watershed and lack of ground water influenced hydrology. During the site investigation, water was observed in the LCT1 channel due to recent heavy rainfall.

Tributary LCT2 enters the project site from the western project boundary, and follows a slightly meandering course for approximately 680 linear feet before converging with Lee Creek approximately 1,140 feet downstream of the LCT1 and Lee Creek confluence. Tributary LCT2 has an average OHWM width of five (5) feet. LCT2 empties into the upper reaches of the Lee Creek impoundment. LCT2 is shown as an intermittent stream on the USGS topographic map; however, it should be considered ephemeral due to its limited drainage area and lack of groundwater influenced hydrology.

Two left bank tributaries to Lee Creek were identified: LCT3 and LCT4. The northernmost tributary (LCT3) enters the project site from the northeast through a culvert under the Missouri Kansas Texas railroad. LCT3 follows a southwesterly course for approximately 1,935 linear feet before emptying into the upper reaches of the Lee Creek impoundment. The OHWM width of LCT3 varies from six (6) feet in its upper reaches to 11 feet near its confluence with Lee Creek. LCT3 is not shown on the USGS topographic map and should be considered ephemeral. As LCT3 approaches the impoundment on Lee Creek, the channel should be considered intermittent with perennial pools due its depth of incision and its proximity to back water associated with the Lee Creek impoundment.

Tributary LCT4 also enters the project site along the northeast boundary. LCT4 follows a southwesterly course for approximately 2,380 feet before converging with the Lee Creek impoundment. LCT4 maintains an average OHWM width of four (4) feet. LCT4 is shown as an intermittent stream on the USGS topographic map; however, it should be classified as ephemeral for the majority of its course. As LCT4 approaches the Lee Creek impoundment, it should be considered intermittent with perennial pools due to its depth of incision and its proximity to the impoundment's associated back water. One tributary to LCT4 was identified (LCT4a). Tributary LCT4a converges with LCT4 approximately 215 feet upstream of the confluence of LCT4 and the Lee Creek impoundment. From the confluence of the tributary and LCT4, the tributary extends to the east for approximately 525 feet before losing channel definition and continuing northwesterly as a swale. Tributary LCT4a has an average OHWM width of approximately three (3) feet and should be considered ephemeral due to its limited drainage area and lack of sufficient channel incision.

Six (6) impoundments other than the Lee Creek impoundment were identified within the eastern project area. Two impoundments west of Lee Creek (EI1 and EI2) are the only other on-channel impoundments identified within the eastern project area. EI1 is the northernmost impoundment and is approximately 0.6-acre in size, which includes the impoundment's fringe wetland. Downstream of the EI1 dam, a defined channel with an emergent wetland dominated by *Sagittaria spp.* was observed and appeared to be routinely back-flooded by the Lee Creek impoundment. The EI2 impoundment is south of EI1. While there is no defined channel leading into the impoundment, there is a vegetated wetland swale following the drainage path to the impoundment. Downstream of the EI2 dam, a fringe wetland and back water area associated with the Lee Creek impoundment provides a hydrologic connection with EI2 and the Lee Creek impoundment. The EI2 impoundment with its fringe wetlands occupies an area of approximately 1.75-acres.

The four impoundments observed east of Lee Creek (EI3-6) should be considered upland stock tanks with the exception of EI4. EI3 is approximately 0.2-acre in size and is located between tributaries LCT3 and LCT4 near the northeastern project boundary. There was no sign of a defined channel or drainage pattern feature up or down slope of this impoundment. There was also no sign of a hydrologic connection to either tributary LCT3 or LCT4. Impoundment EI4 is an approximately 0.35-acre pond located north and east of tributary LCT4 near its confluence with the Lee Creek impoundment. It displayed no sign of a defined channel or drainage pattern feature up or down slope of the impoundment. Although there was no sign of a hydrologic connection to tributary LCT4, impoundment EI4 appears to be situated within the 100-year floodplain associated with the Lee Creek impoundment. Impoundment EI5 is approximately 0.45-acre in size. Like EI3 and EI4, there was no sign of a defined channel or drainage pattern feature up or down slope of the impoundment. There was also no sign of a hydrologic connection to tributary LCT4a. Impoundment EI6 is located immediately southeast of the dam associated with the Lee Creek impoundment. There was no sign of a defined channel or drainage pattern feature up or down slope of the impoundment and no sign of a hydrologic connection to Lee Creek or the Lee Creek impoundment.

In addition to fringe wetlands around the impoundments within the eastern project area, several other sites supporting vegetation adapted to saturated soil conditions were identified. Of these areas, wetland EW1 is located where tributary LCT4 enters the project area. This wetland appears to be formed by poor drainage where tributary LCT4 passes under the railroad and enters the eastern project area. The wetland was observed to be approximately 0.01-acre in size and appears to be heavily dependent on storm events for hydrology. Downstream of EW1 and immediately adjacent to LCT4, an emergent wetland (EW2) was observed in a low lying area. This area appears to receive hydrology through overbank flows associated with LCT4. Lastly, another wetland area (EW3) was identified near the confluence of tributary LCT4 and the Lee Creek impoundment. Hydrology for this wetland area is likely from storm flows associated with tributary LCT4 as well as flooding associated with the Lee Creek impoundment. Wetlands EW1, EW2, and EW3 should be considered hydrologically connected to the Lee Creek system. Wetland EW4, located between EI2 and the Lee Creek Impoundment, should also be considered hydrologically connected to the Lee Creek impoundment.

Finally, three seasonal wetland areas (EW5, EW6, and EW7) were identified in the project area behind terraces associated with contour farming. The wetland areas are small, and most likely only retain vegetation adapted to living in saturated soil conditions during periods of above normal rainfall. Furthermore, none of these wetland areas are located in the 100-year floodplain associated with Lee Creek and none are connected hydrologically to the Lee Creek system. As such, these areas seems to be isolated and do not appear to be jurisdictional.

Hydrologic Features – Western Project Area

The dominant hydrologic features within the western project area consist of an unnamed tributary to Bear Creek (TBC) and five (5) impoundments. Three of the impoundments appear to be upland stock tanks; however, two impoundments should be considered on-channel impoundments. Like the eastern project area, contour farming practices have been utilized in several areas, which have led to the formation of small seasonal wetlands behind the contours. Figure 2 shows the hydrologic features indentified in the western project area.

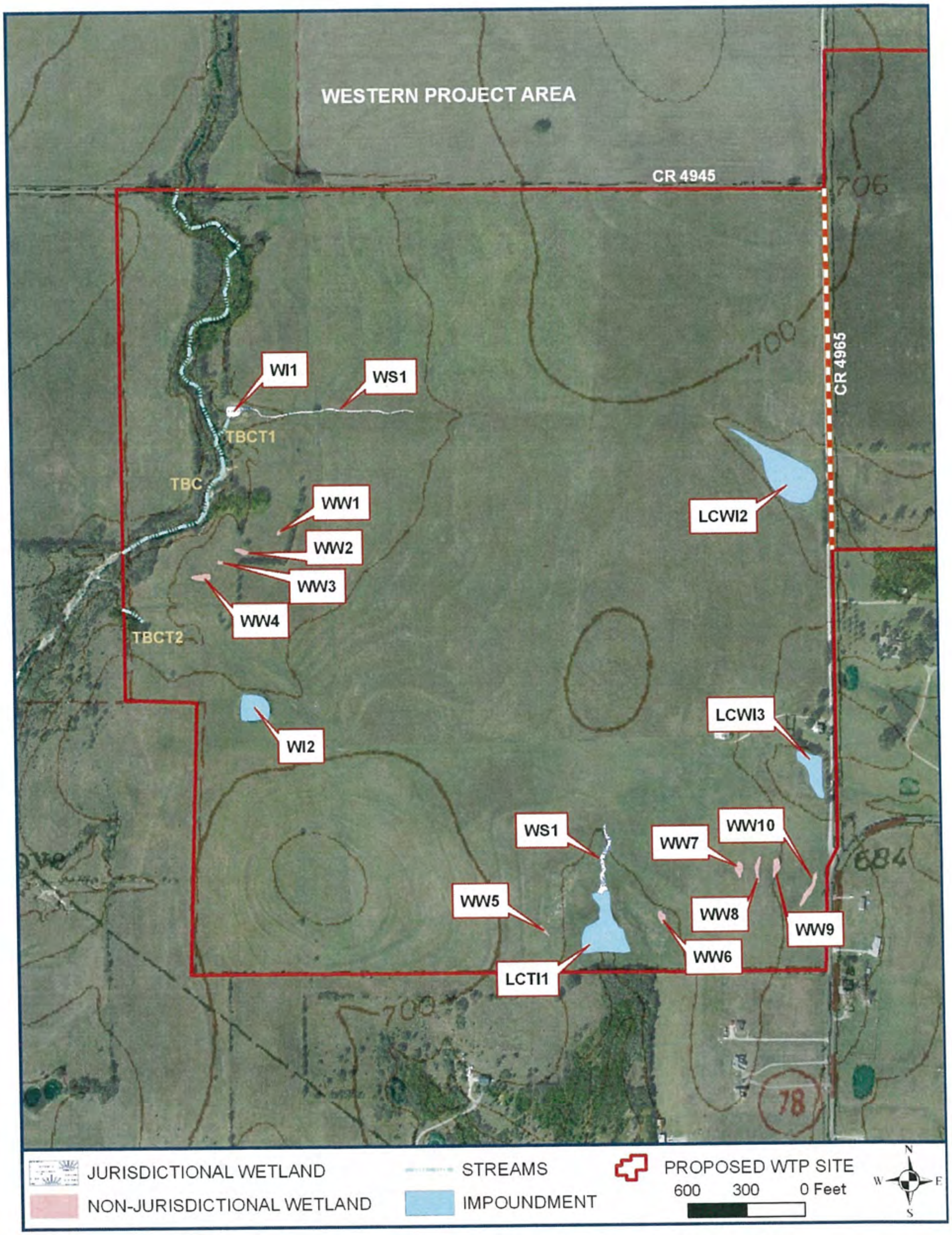


Figure 2: Hydrologic Features Observed within the Western Limits of the PJD

The unnamed tributary to Bear Creek enters the northern project boundary under County Road 4945 through a large culvert and maintains an average OHWM width of 25 feet for its entire course within the limits of the PJD. Its channel banks are steep and deeply incised, and the channel bottom substrate is bedrock. According to the USGS topographic map, the tributary is intermittent. Due to the size of the tributary's drainage area as well as it being highly incised, ground water influence could be assumed. The more appropriate classification of the channel is intermittent with perennial pools due to the fractured and pitted nature of the bedrock channel bottom.

There are two unnamed ephemeral tributaries to the unnamed tributary to Bear Creek within the western project area. Both of the tributaries are left bank tributaries of the tributary to Bear Creek. The northernmost tributary (TBCT1) has an OHWM width of four (4) feet and has a defined channel for 114 linear feet in the project area. Upstream of the convergence of TBCT1 with TBC, an impoundment (WI1) was identified. Based on review of aerial photographs, this impoundment appears to have been breached between 2004 and 2007. The OHWM of Tributary TBCT1 develops downstream of the breached impoundment. Upstream of the breached impoundment there is no defined channel; however, a swale (WS1) was identified following the drainage path that contains vegetation adapted to saturated soil conditions. The southernmost tributary (TBCT2) to the Bear Creek tributary has an OHWM width of approximately five (5) feet, and has a defined channel for approximately 125 linear feet prior to exiting the western project area.

Impoundments in the western project area are a mixture of on-channel ponds and upland stock tanks. The largest on-channel impoundment (LCTI1) in the western project area is located along the southern property boundary, and is an impoundment of an unnamed tributary to Lee Creek. This impoundment has a surface water area of approximately 1.0-acre. A swale (WS2) approximately 0.18-acre in area fed into the upper reaches of the impoundment, which contained vegetation adapted to saturated soil conditions. Immediately off site the impounded channel developed an OHWM.

In the eastern portion of the western project area, two additional impoundments in the Lee Creek watershed were identified. These impoundments (LCWI2 and LCWI3) are located along the fence line bordering County Road 4965. These impoundments appear to collect primarily overland storm flow since no defined channels were observed up or down slope of the impoundments. Additionally, according to FEMA floodplain maps, these impoundments are not within the 100-year floodplain associated with Lee Creek. Therefore, these impoundments should be considered upland stock tanks.

In the western portion of the western project area, the remaining two impoundments were identified east of the tributary to Bear Creek. These impoundments (WI1 and WI2) appear to collect overland storm flows from the surrounding watershed. According to FEMA floodplain maps, these impoundments are not within any 100-year floodplains. As mentioned, impoundment WI1 is a breached, on-channel impoundment of tributary TBCT1, which still retains water following heavy storm events. Since this impoundment was breached and tends to retain shallow water, it currently contains mostly emergent wetland vegetation both within the former impoundment and upstream of the impoundment along the swale that drains to the impoundment. Impoundment WI1 and its upstream swale occupy an area of approximately 0.2 acres. Impoundment WI2 is an approximately 0.4-acre upland stock tank that appears to collect primarily overland storm flow from its immediate watershed.

As with the eastern portion of the project area, portions of the western project area have been terraced (contoured) in order to retain and/or spread overland storm flows. These terraces have led to the formation of several small seasonal wetlands. Four such wetlands (WW1-4) were identified east of the unnamed tributary to Bear Creek, and the remaining wetlands (WW5-10) were identified near impoundment LCTI1 in the southeastern portion of the western project area. According to the FEMA floodplain map, wetlands (WW1-10) are not within any 100-year floodplains associated with either Lee Creek or the unnamed tributary to Bear Creek.

d. Vegetation

As previously mentioned, the site consists mostly of upland areas dominated by upland pasture grasses and sparse woodland areas. Areas adjacent to streams and some impoundments are dominated by riparian woody, herbaceous, and vine species. A listing of vegetation species observed during the on-site investigation is provided in Table 1. The Region 6 indicator status is noted for each species, and explanations of the indicator status categories are included in Table 2.

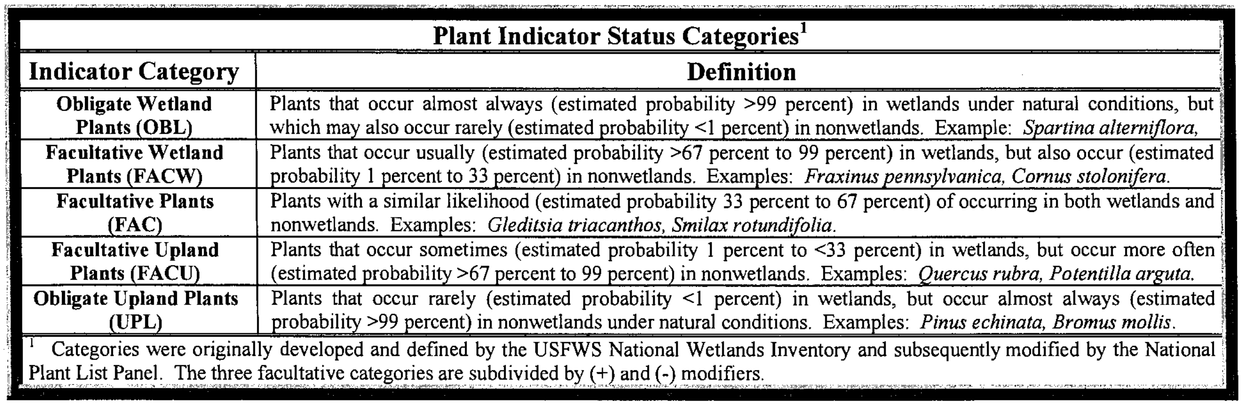
TABLE 1: VEGETATION LIST

Common Name	Scientific Name	Region 6 Indicator Status
	Canopy Species	
Bois d' Arc	*Maclura pomifera*	UPL
Cedar Elm	*Ulmus crassifolia*	FAC
Green Ash	*Fraxinus pennsylvanica*	FACW-
Black Willow	*Salix nigra*	FACW+
Honey-Locust	*Gleditsia triacanthos*	FAC
Sugar Hackberry	*Celtis laevigata*	FAC
Eastern Red Cedar	*Juniperus virginiana*	FACU-
Pecan	*Carya illinoensis*	FAC+
Gum Bumelia	*Bumelia langinosa*	FACU
Boxelder	*Acer negundo*	FACW-
American Elm	*Ulmus americana*	FAC
	Sapling/Shrub Species	
Mexican Plum	*Prunus mexicana*	NA
Rough-leaf Dogwood	*Cornus drummondii*	FAC
Chinese Tallow	*Sapium sebiferum*	FACU-
Honey-Locust	*Gleditsia triacanthos*	FAC
Eastern Red Cedar	*Juniperus virginiana*	FACU-
Rusty Blackhaw	*Viburnum rufidulum*	FACU-
Toothache Tree	*Zanthoxylum clava-herculis*	FAC
Hawthorn	*Crataegus texana*	FAC
Persimmon	*Diospyros virginiana*	FAC
	Herbaceous Species	
Bermudagrass	*Cynodon dactylon*	FACU+
Annual Ragweed	*Ambrosia artemisiifolia*	FACU-
Dallisgrass	*Paspalum dilatatum*	FAC
American Germander	*Teucrinum candense*	FACW-
Common Sunflower	*Helianthus annuus*	FAC
Coralberry	*Symphoricarpos orbiculatus*	FACU
Giant Ragweed	*Ambrosia trifida*	FAC

TABLE 1 CONTINUED

Common Name	Scientific Name	Region 6 Indicator Status
Greenbriar	*Smilax spp.*	FAC
Snow on the Prairie	*Euphorbia bicolor*	NA
Milkweed	*Asclepias sp.*	NA
Frog Fruit	*Phyla nodiflora*	FACW
Buffalograss	*Buchloe dactyloides*	FACU-
Paspalum	*Paspalum spp.*	NA
Ironweed	*Vernonia altissima*	NA
Johnsongrass	*Sorghum halepense*	FACU
Erygno	*Erygnium leavenworthii*	NA
One-seed Croton	*Croton capitatus*	NA
Nightshade	*Solanum spp.*	NA
Verbena	*Verbena spp.*	NA
Poison Ivy	*Toxicodendron radicans*	FAC
Mustang Grape	*Vitis mustangensis*	NI
Missouri Violet	*Viola missourienses*	FACW
Honeysuckle	*Lonicera japonica*	FAC
HERBACEOUS VEGETATION OBSERVED IN MORE SATURATED AREAS		
Compressed Spikerush	*Eleochoris compressa*	FACW
Cocklebur	*Xanthium strumarium*	FAC-
Marsh Spikerush	*Eleochoris smallii*	OBL
Lotus	*Nelumbo lutea*	OBL
Pondweed	*Potamogeton spp.*	NA
Switchgrass	*Panicum virgatum*	FACW
Smartweed	*Polygonum spp.*	NA
Sedge	*Carex spp.*	NA
Arrowhead	*Sagittaria spp.*	OBL
Balloonvine	*Cardiospermum halicacabum*	FAC
Common Sunflower	*Helianthus annuus*	FAC
Virginia Wildrye	*Elymus virginicus*	FAC
Vine Mesquite	*Panicum obtusum*	FAC+
Sumpweed	*Iva annua*	FAC

TABLE 2: EXPLANATION OF REGION 6 INDICATOR CATEGORIES



Plant Indicator Status Categories[1]

Indicator Category	Definition
Obligate Wetland Plants (OBL)	Plants that occur almost always (estimated probability >99 percent) in wetlands under natural conditions, but which may also occur rarely (estimated probability <1 percent) in nonwetlands. Example: *Spartina alterniflora,*
Facultative Wetland Plants (FACW)	Plants that occur usually (estimated probability >67 percent to 99 percent) in wetlands, but also occur (estimated probability 1 percent to 33 percent) in nonwetlands. Examples: *Fraxinus pennsylvanica, Cornus stolonifera.*
Facultative Plants (FAC)	Plants with a similar likelihood (estimated probability 33 percent to 67 percent) of occurring in both wetlands and nonwetlands. Examples: *Gleditsia triacanthos, Smilax rotundifolia.*
Facultative Upland Plants (FACU)	Plants that occur sometimes (estimated probability 1 percent to <33 percent) in wetlands, but occur more often (estimated probability >67 percent to 99 percent) in nonwetlands. Examples: *Quercus rubra, Potentilla arguta.*
Obligate Upland Plants (UPL)	Plants that occur rarely (estimated probability <1 percent) in wetlands, but occur almost always (estimated probability >99 percent) in nonwetlands under natural conditions. Examples: *Pinus echinata, Bromus mollis.*

[1] Categories were originally developed and defined by the USFWS National Wetlands Inventory and subsequently modified by the National Plant List Panel. The three facultative categories are subdivided by (+) and (-) modifiers.

e. Soils

According to information obtained from the Fannin County Soil Survey and United States Department of Agriculture Soil Data Mart, a total of six (6) different soil types are found within the project area. None of the soils contained within the proposed project area are nationally listed hydric soils. These soil types are identified in Table 3.

TABLE 3: DESCRIPTION OF SOILS WITHIN THE LIMITS OF THE PJD

Map Unit Symbol	Soil Description	Depth to High Water Table
FdB	Fairlie-Dalco complex, 1 to 3 percent slopes	>6 Feet
HwC	Howe-Whitewright complex, 3 to 5 percent slopes	>6 Feet
LeB	Leson clay, 1 to 3 percent slopes	>6 Feet
ShB	Stephen silty clay, 1 to 3 percent slopes	>6 Feet
Tc	Tinn clay, occasionally flooded	>6 Feet
WwD2	Whitewright-Howe complex, 5 to 12 percent slopes, eroded	>6 Feet

Figure D-1 located in Appendix D shows the locations of the soil types relative to the site. Descriptions of the mapped soil types are included in Appendix D. Wetland determination data sheets from areas sampled within the limits of the PJD are included in Appendix E with Figure E-1 showing the locations of the sampling points.

4. Conclusions

a. Aquatic Resources Observed within the Limits of the PJD

Numerous types of aquatic resources ranging from small seasonal wetlands to large impoundments to ephemeral and intermittent streams were observed within the limits of the PJD. Table 4 below lists by category the aquatic resources observed within the eastern and western portions of the project area.

TABLE 4: SUMMARY OF AQUATIC RESOURCES IDENTIFIED WITHIN THE LIMITS OF THE PJD

Resource	Type	Linear Feet	Area (Acres)
Lakes, Ponds, Tanks	On-channel	NA	25.02
	Off-channel	NA	3.42
Streams	Ephemeral	6,506.3	3.15
	Intermittent	4,738.5	0.89
Emergent Wetlands	Seasonal	NA	0.49
	Perennial	NA	0.78
TOTAL		**11,244.8**	**33.75**

b. **Description of Waters of the U.S.**

Potential waters of the U.S. within the proposed project site should be limited to the identified creeks and tributaries, on-channel impoundments, and wetlands provided they have a significant nexus to either Lee Creek or the unnamed tributary to Bear Creek. Tables 5 and 6 list the potential jurisdictional waters on the eastern and western portions of the project area respectively. Figure A-5 in Appendix A shows the potentially jurisdictional waters identified in the project area.

TABLE 5: POTENTIAL WATERS OF THE U.S. IN THE EASTERN PROJECT AREA

JURISDICTIONAL AREA	CLASSIFICATION	LENGTH (LINEAR FEET)	WIDTH AT OHWM (FEET)	AREA (ACRES)
		STREAMS		
Lee Creek	Intermittent/Perennial	2,075	25-43 ~ 34 average	1.62
LCT1	Ephemeral	745	9	0.15
LCT2	Ephemeral	683	5	0.08
LCT3	Ephemeral	1,935	6-11 ~ 8.5 average	0.38
LCT4	Ephemeral	2,380	4	0.22
LCT4a	Ephemeral	523	3	0.04
TOTAL STREAMS		**8,342**	**VARIES**	**2.49**
		IMPOUNDMENTS		
Lee Creek	On-channel Impoundment	NA	NA	21.58
EI1	On-channel Impoundment	NA	NA	0.59
EI2	On-channel Impoundment	NA	NA	1.75
EI4	Off-channel Impoundment	NA	NA	0.35
TOTAL IMPOUNDMENTS		**NA**	**NA**	**24.27**
		WETLANDS		
EW1	Emergent	NA	NA	0.01
EW2	Emergent	NA	NA	0.02
EW3	Emergent	NA	NA	0.03
EW4	Emergent	NA	NA	0.42
TOTAL WETLANDS		**NA**	**NA**	**0.48**
TOTAL WATERS OF THE U.S.		**8,342**	**VARIES**	**27.24**

TABLE 6: POTENTIAL WATERS OF THE U.S. IN THE WESTERN PROJECT AREA

JURISDICTIONAL AREA	CLASSIFICATION	LENGTH (LINEAR FEET)	WIDTH AT OHWM (FEET)	AREA (ACRES)
STREAMS				
TBC	Intermittent	2,663	25	1.53
TBCT1	Ephemeral	114	4	0.01
TBCT2	Ephemeral	126	5	0.01
TOTAL STREAMS		**2,903**	**VARIES**	**1.55**
IMPOUNDMENTS				
LCTI1	On-channel Impoundment	NA	NA	1.00
WI1	On-channel Impoundment	NA	NA	0.10
TOTAL IMPOUNDMENTS		**NA**	**NA**	**1.10**
WETLANDS				
WS1	Emergent	NA	NA	0.12
WS2	Emergent	NA	NA	0.18
TOTAL WETLANDS		**NA**	**NA**	**0.3**
TOTAL WATERS OF THE U.S.		**2,903**	**VARIES**	**2.95**

5. Supporting Information

a. References

Ajilvsgi, G. (1988) Wildflowers of Texas, Third Edition. Fredericksburg, Texas : Shearer Publishing.

Correll, Donovan S. and Marshall C. Johnston. (1996). Manual of the Vascular Plants of Texas. University of Texas at Dallas Press. Richardson, Texas.

Diggs, G.M., B.L. Lipscomb, and R.J. O'Kennon. (1999) Shinners and Mahler's Illustrated Flora of North Central Texas. Fort Worth, Texas: Botanical Research Institute of Texas.

Environmental Laboratory. (1987). "Corps of Engineers Wetlands Delineation Manual," Technical Report Y-87-1. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Environmental Laboratory. (2008). *Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Great Plains Region – ERDC/EL TR-08-12.* U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

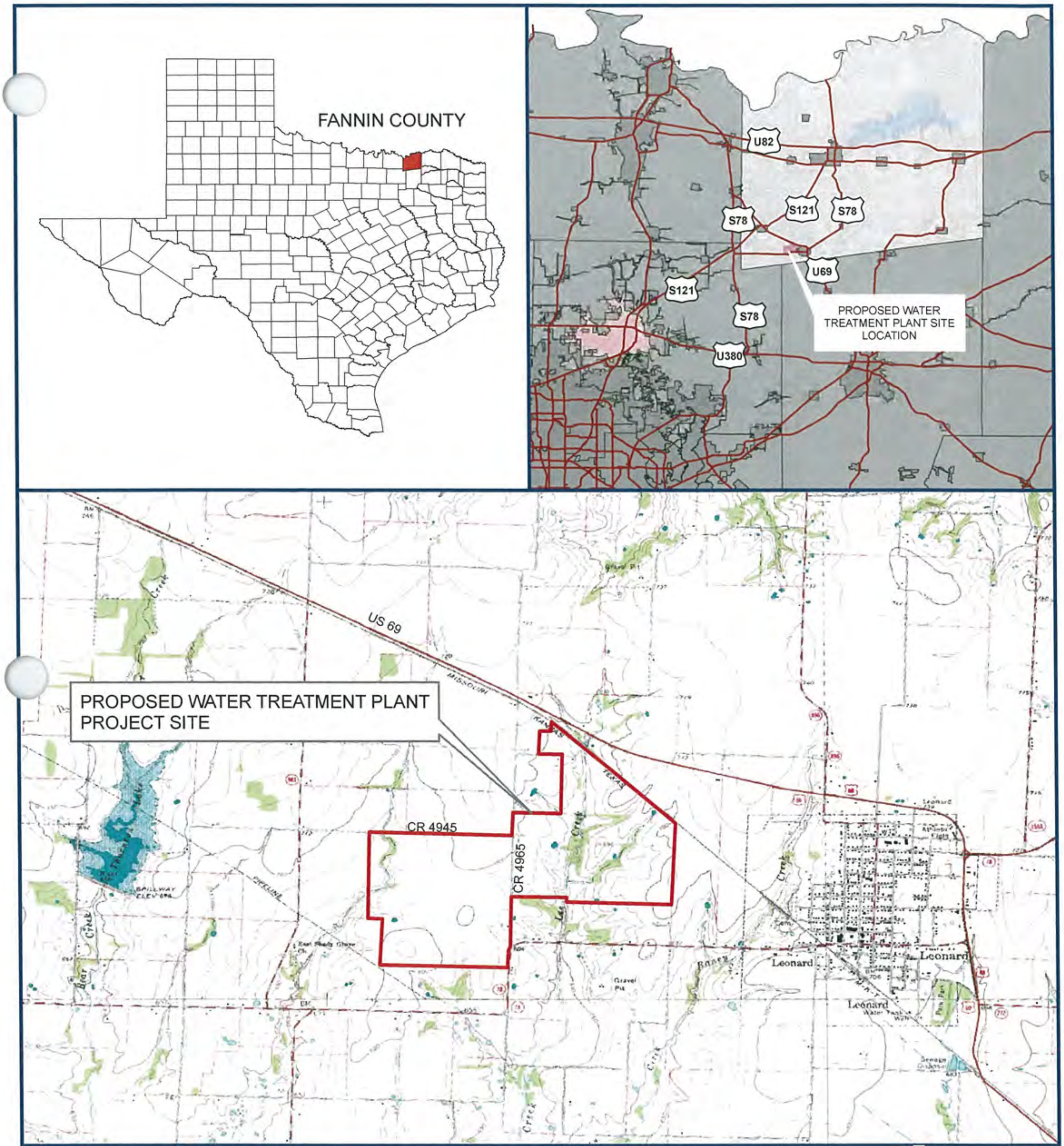
Goerdel, A.R. (2002). *Soil Survey of Fannin County, Texas.* United States Department of Agriculture – Natural Resources Conservation Service, in cooperation with the Texas Agriculture Experiment Station, the Texas State Soil and Water Conservation Board, and the United States Forest Service.

Reed, P.B., Jr. 1988. National list of plant species that occur in wetlands: South Plains (Region 6). U.S. Fish and Wildlife Service Biol. Rep. 88(26.6). 94 pp.

Willis, M.M., and H.S. Irwin (1983) Roadside Flowers of Texas. Austin, Texas : University of Texas Press.

APPENDIX A

FIGURES



N
W E
S

DATE:
DECEMBER 3, 2009

FIGURE A-1
GENERAL LOCATION MAP
PRELIMINARY JURISDICTIONAL DETERMINATION OF WATERS OF THE U.S.
PROPOSED LEONARD WATER TREATMENT PLANT
NORTH TEXAS MUNICIPAL WATER DISTRICT

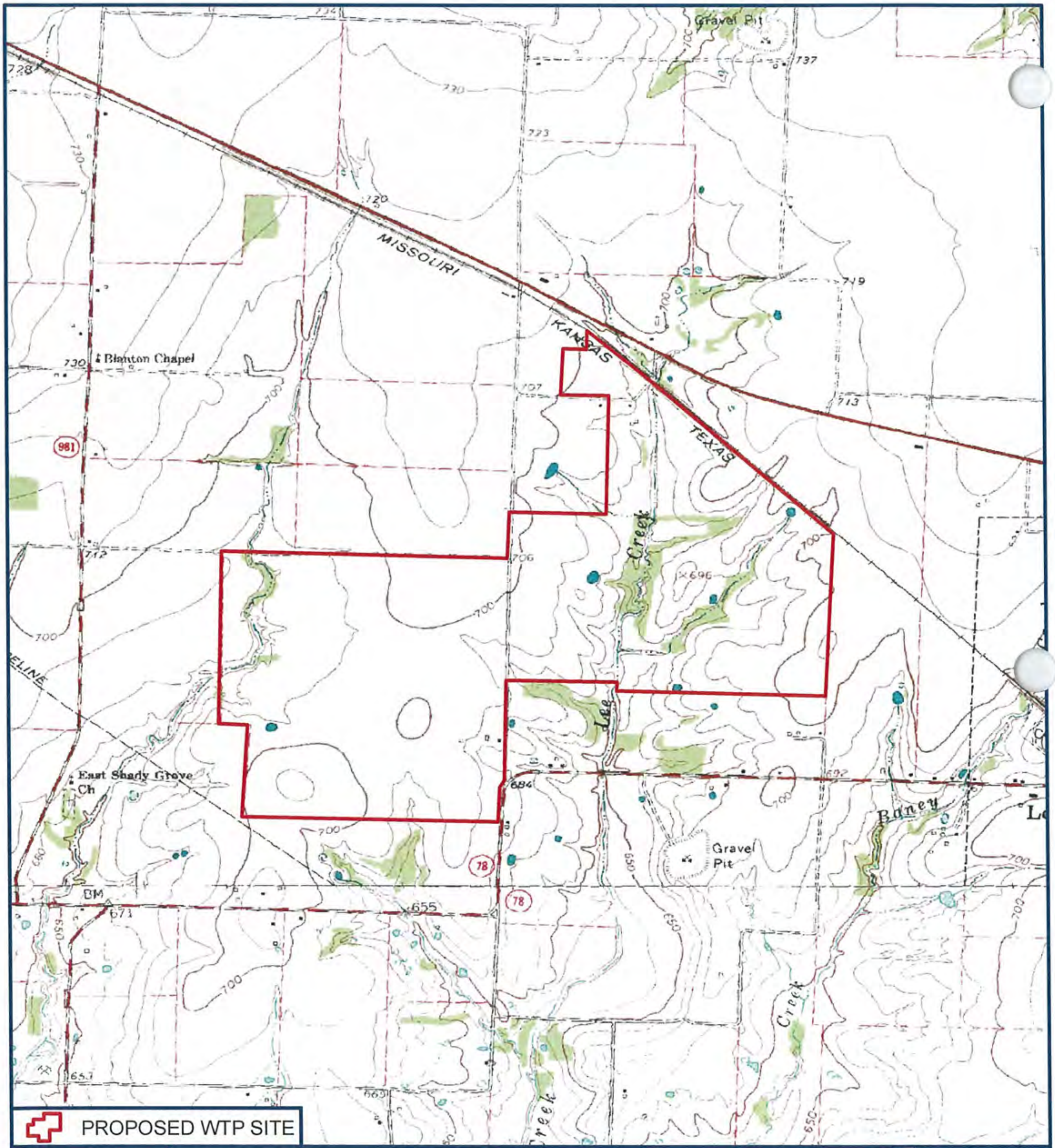
ALAN PLUMMER ASSOCIATES, INC.
1320 S. UNIVERSITY DRIVE
SUITE 300
FORT WORTH, TEXAS 76107
PHONE: (817) 806-1700
FAX: (817) 870-2536

FIGURE 1 OF 6

4,000 2,000 0 Feet

SOURCE:
TNRIS TRENTON, TEXAS QUADRANGLE

USACE PROJECT NUMBER:



N
W
E
S

DATE:
DECEMBER 3, 2009

FIGURE A-2
USGS TOPOGRAPHIC MAP
PRELIMINARY JURISDICITONAL DETERMINATION OF WATERS OF THE U.S.
PROPOSED LEONARD WATER TREATMENT PLANT
NORTH TEXAS MUNICIPAL WATER DISTRICT

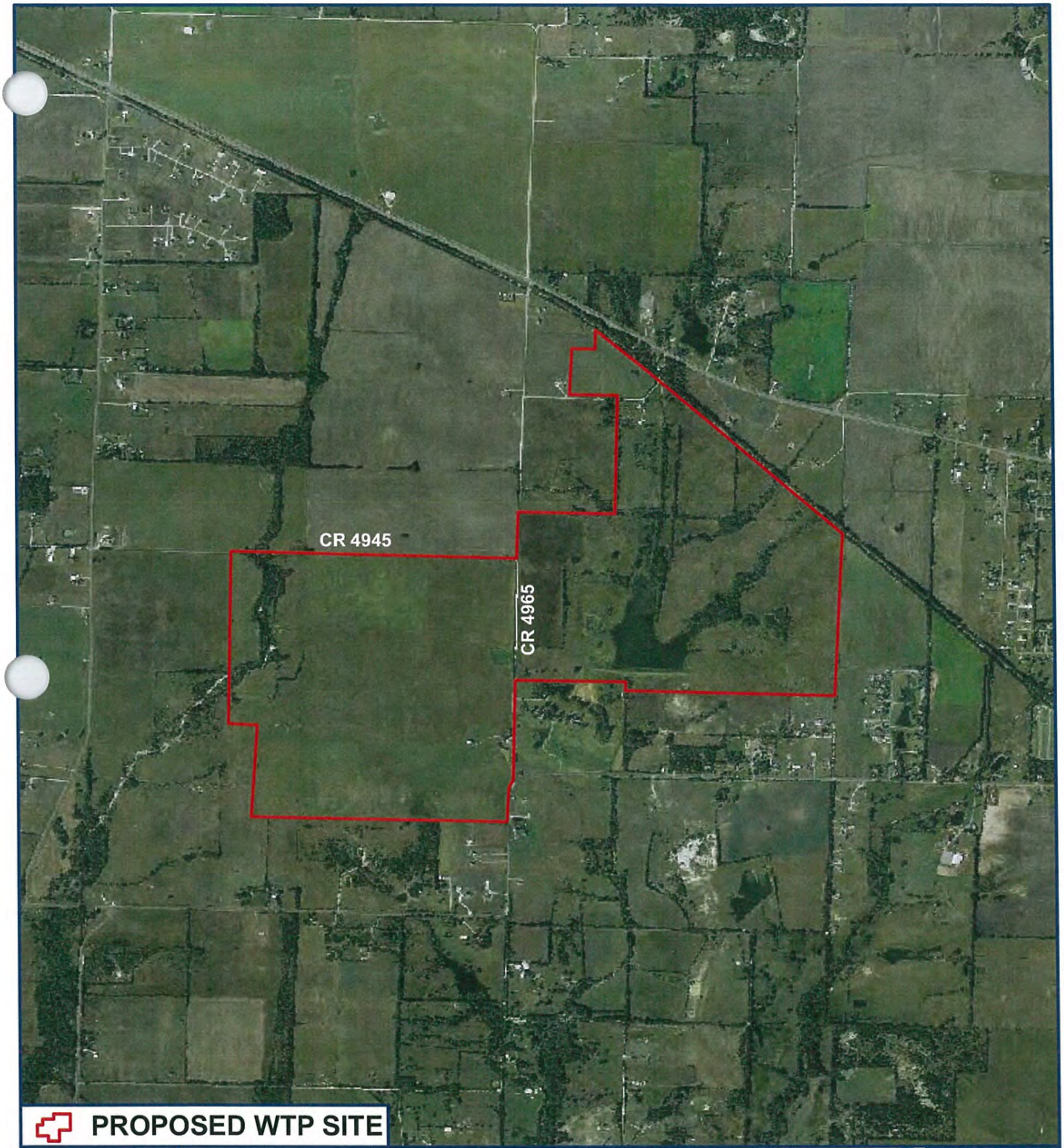
ALAN PLUMMER ASSOCIATES, INC.
1320 S. UNIVERSITY DRIVE
SUITE 300
FORT WORTH, TEXAS 7
PHONE: (817) 806-1
FAX: (817) 870-2536

FIGURE 2 OF 6

2,000 1,000 0 Feet

SOURCE:
TNRIS - TRENTON, TEXAS QUADRANGLE

USACE PROJECT NUMBER:



N
W E
S

DATE:
DECEMBER 3, 2009

FIGURE A-3
2007 AERIAL PHOTOGRAPH
PRELIMINARY JURISDICITONAL DETERMINATION OF WATERS OF THE U.S.
PROPOSED LEONARD WATER TREATMENT PLANT
NORTH TEXAS MUNICIPAL WATER DISTRICT

ALAN PLUMMER ASSOCIATES, INC.

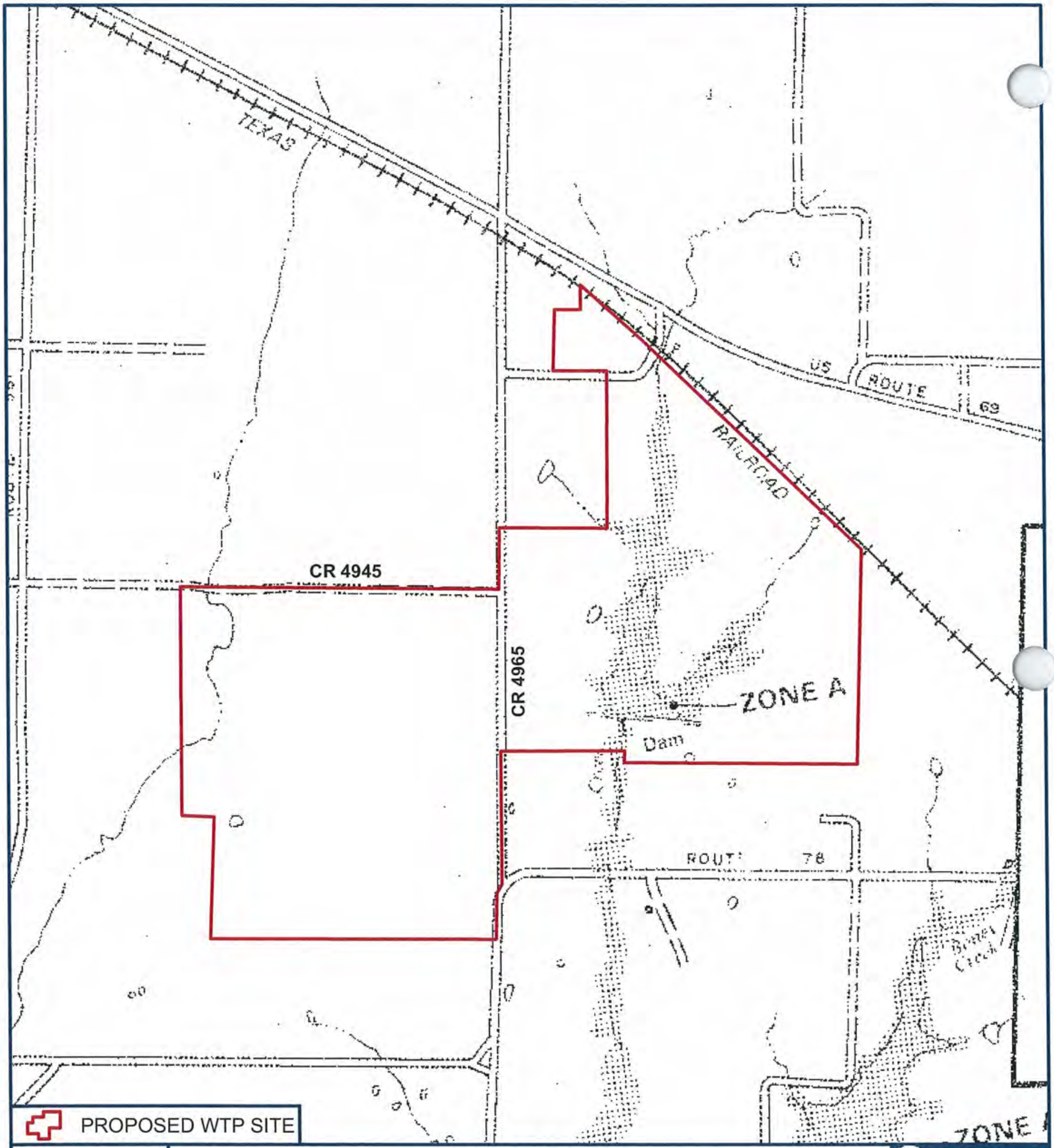
1320 S. UNIVERSITY DRIVE
SUITE 300
FORT WORTH, TEXAS 76107
PHONE: (817) 806-1700
FAX: (817) 870-2536

FIGURE 3 OF 6

2,000 1,000 0 Feet

SOURCE:
LANDISCOR 2007 AERIAL PHOTOGRAPH

USACE PROJECT NUMBER:



N
W E
S

DATE:
DECEMBER 3, 2009

FIGURE A-4
FEMA FLOOD INSURANCE RATE MAP
PRELIMINARY JURISDICTIONAL DETERMINATION OF WATERS OF THE U.S.
PROPOSED LEONARD WATER TREATMENT PLANT
NORTH TEXAS MUNICIPAL WATER DISTRICT

ALAN PLUMMER ASSOCIATES, INC.
1320 S. UNIVERSITY DRIVE
SUITE 300
FORT WORTH, TEXAS 7
PHONE: (817) 806-17
FAX: (817) 870-253

FIGURE 4 OF 6

1,500 750 0 Feet

SOURCE: FEMA Flood Hazard Boundary Map
Community Panel No. 480807 0010 A
Effective Date: November 8, 1977

USACE PROJECT NUMBER:

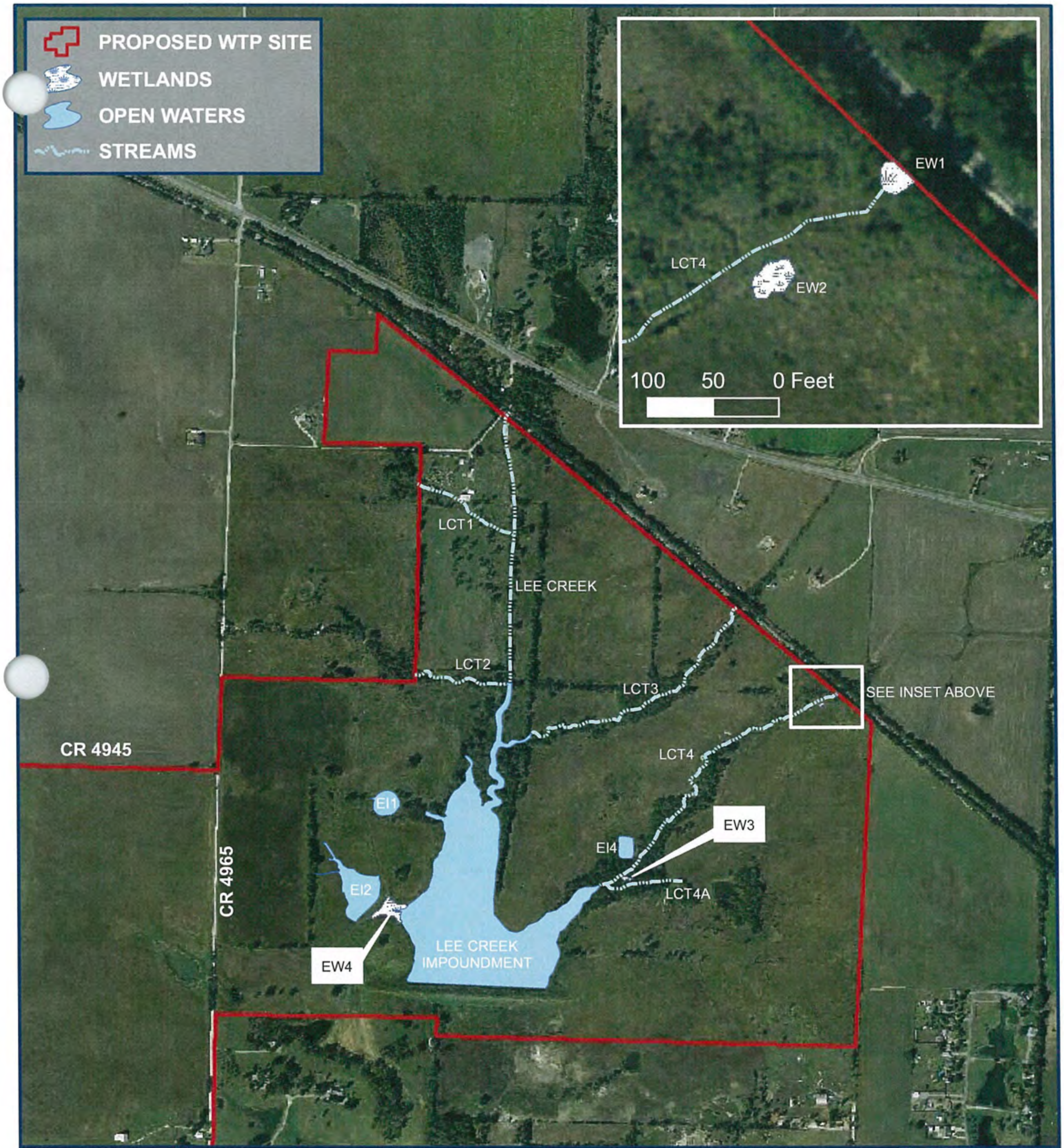


FIGURE A-5
EAST PROJECT AREA POTENTIAL WATERS OF THE U.S. PRELIMINARY JURISDICITONAL DETERMINATION OF WATERS OF THE U.S. PROPOSED LEONARD WATER TREATMENT PLANT NORTH TEXAS MUNICIPAL WATER DISTRICT

DATE:
DECEMBER 3, 2009

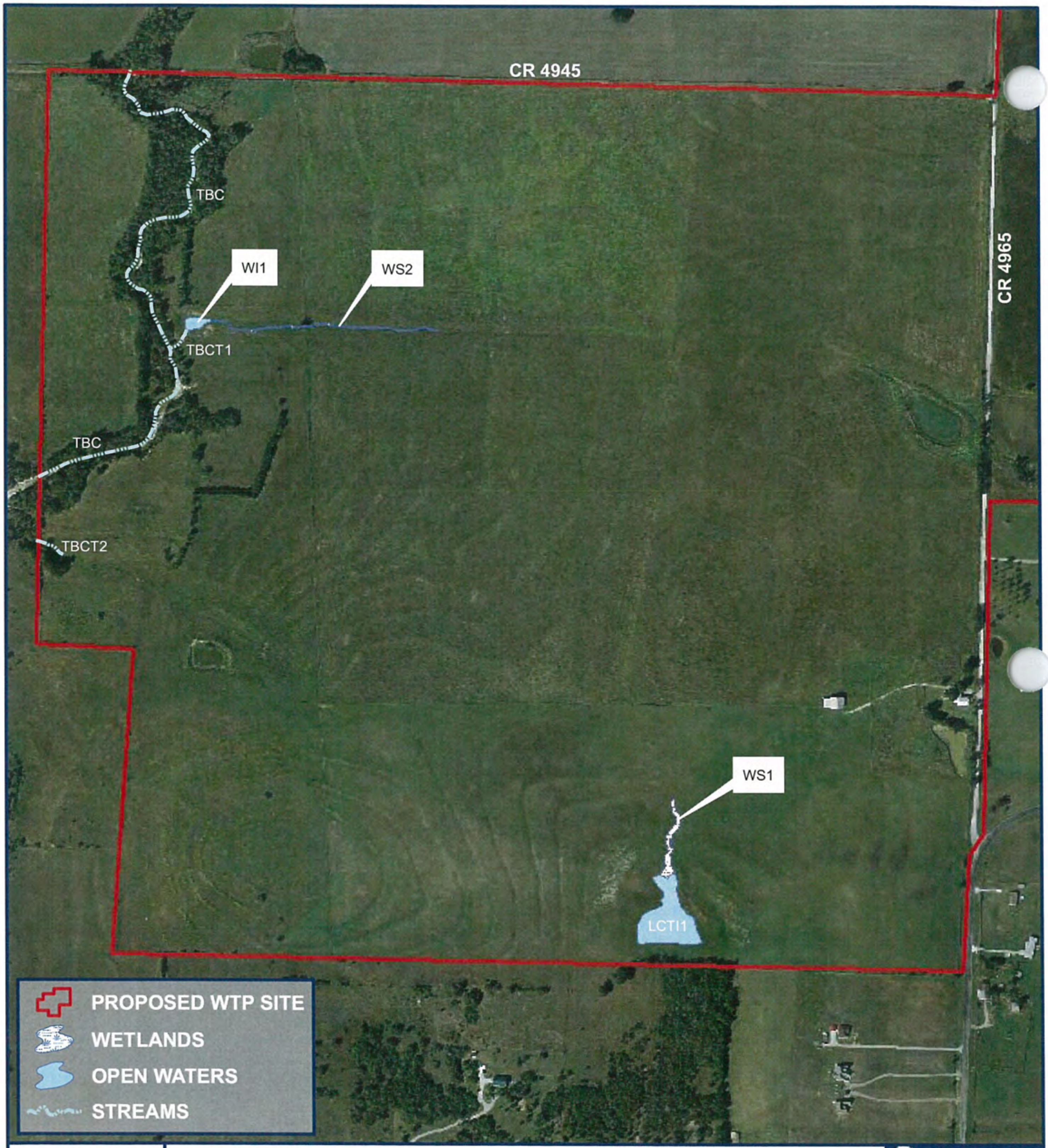
ALAN PLUMMER ASSOCIATES, INC.
1320 S. UNIVERSITY DRIVE
SUITE 300
FORT WORTH, TEXAS 76107
PHONE: (817) 806-1700
FAX: (817) 870-2536

FIGURE 5 OF 6

1,000 500 0 Feet

SOURCE:
LANDISCOR 2007 AERIAL PHOTOGRAPH

USACE PROJECT NUMBER:



N
W E
S

DATE:
DECEMBER 3, 2009

FIGURE A-6
WEST PROJECT AREA POTENTIAL WATERS OF THE U.S. PRELIMINARY JURISDICITONAL DETERMINATION OF WATERS OF THE U.S.
PROPOSED LEONARD WATER TREATMENT PLANT
NORTH TEXAS MUNICIPAL WATER DISTRICT

ALAN PLUMMER ASSOCIATES, INC.
1320 S. UNIVERSITY DRIVE
SUITE 300
FORT WORTH, TEXAS 7
PHONE: (817) 806-17
FAX: (817) 870-253

FIGURE 6 OF 6

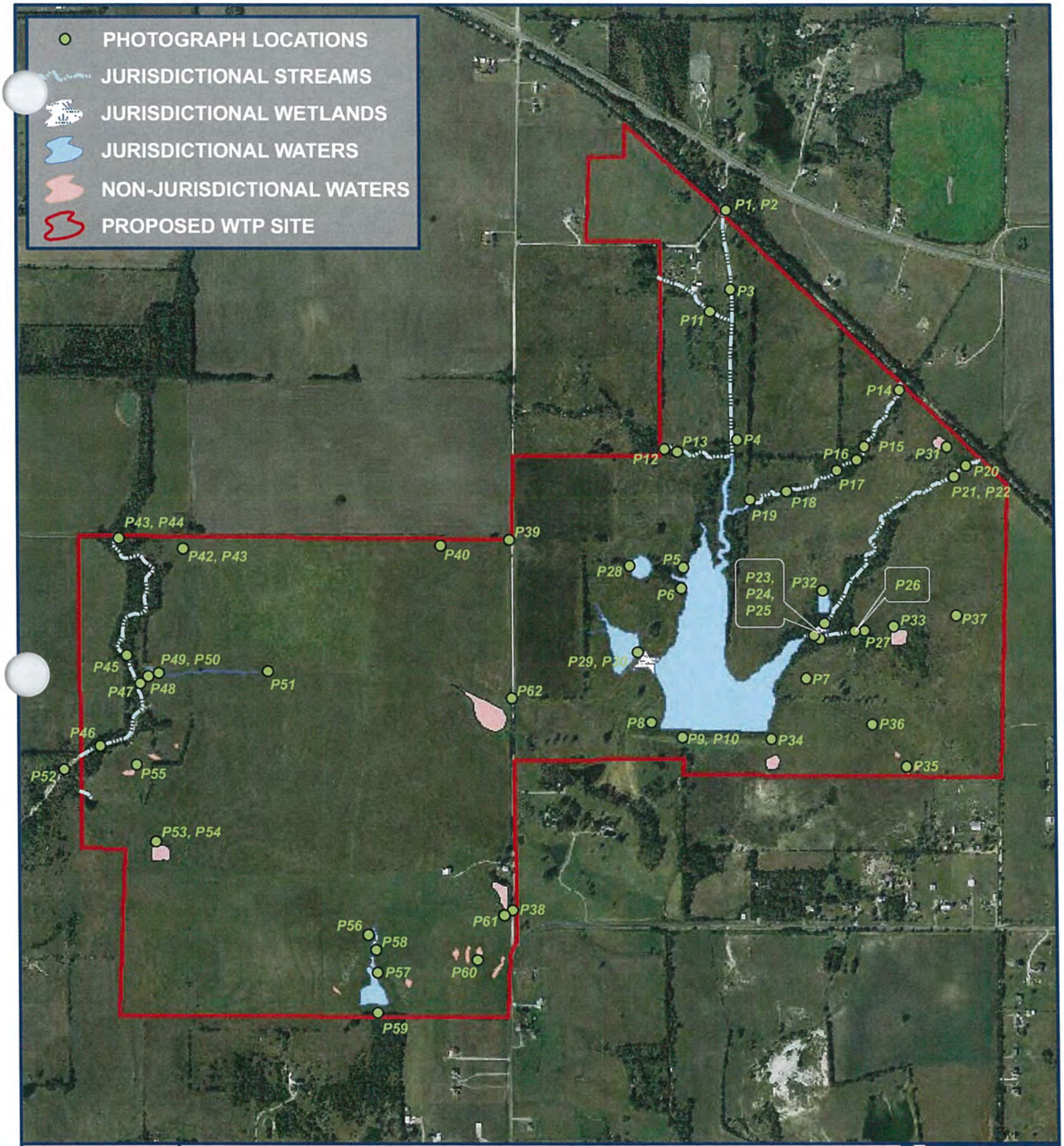
600 300 0 Feet

SOURCE:
LANDISCOR 2007 AERIAL PHOTOGRAPH

USACE PROJECT NUMBER:

APPENDIX B

PHOTOGRAPHS FROM THE ONSITE INVESTIGATION



N
W E
S

DATE:
DECEMBER 3, 2009

FIGURE B-1
PHOTOGRAPH LOCATIONS
PRELIMINARY JURISDICITONAL DETERMINATION OF WATERS OF THE U.S.
PROPOSED LEONARD WATER TREATMENT PLANT
NORTH TEXAS MUNICIPAL WATER DISTRICT

ALAN PLUMMER ASSOCIATES, INC.
1320 S. UNIVERSITY DRIVE
SUITE 300
FORT WORTH, TEXAS 76107
PHONE: (817) 806-1700
FAX: (817) 870-2536

FIGURE 1 OF 1

1,100 550 0 Feet

SOURCE:
LANDISCOR 2007 AERIAL PHOTOGRAPH

USACE PROJECT NUMBER:

EASTERN PROJECT AREA

P1. Lee Creek at the MKT Railroad trestle along the northern boundary for the eastern project area.

P2. Looking south (downstream) along Lee Creek from the MKT Railroad trestle.

P3. Looking south (downstream) along Lee Creek.

P4. Looking south (downstream) as Lee Creek becomes a backwater of the Lee Creek impoundment.

P5. Upper portion of the Lee Creek impoundment.

P6. Looking south toward the dam on Lee Creek forming the Lee Creek impoundment.

P7. Looking west across the Lee Creek impoundment.

P8. From the emergency spillway for Lee Creek impoundment looking east at the dam on Lee Creek.

P9. Discharge structure located within the Lee Creek impoundment.

P10. Outfall for the overflow of the Lee Creek impoundment.

P11. Typical channel bottom of LCT1.

P12. Upper reach of LCT2 in the northern portion of the eastern project area.

P13. Looking east (downstream) along LCT2. Stream has circumvented a culverted ranch road crossing in this location.

P14. Looking south (downstream) along LCT3 just south of where LCT3 enters the subject property.

P15. Looking southwest (downstream) along LCT3. Channel bottom is bedrock.

P16. Looking southwest (downstream) along LCT3.

P17. Looking along steep, incised channel banks along LCT3.

P18. Looking southwest (downstream) along LCT3 as the channel approaches its confluence with the Lee Creek impoundment.

P19. Looking northeast along LCT3 at emergent wetland vegetation associated with the backwater formed as a result the Lee Creek impoundment at its confluence with Lee Creek.

P20. Looking northeast (upstream) at LCT4 and EW1 where LCT4 enters the subject property beneath the MKT railro (background of photograph).

P21. Looking northeast (upstream) along LCT4 near the northern property boundary. EW2 is located immediately east of this channel (portion located on right hand side of photograph).

P22. Looking southwest (downstream) along LCT4. A defined channel was identified within the cocklebur area in the photograph.

P23. Looking northeast (upstream) along LCT4 within the forested floodplain associated with the Lee Creek impoundment.

P24. Wooded floodplain area near the confluence of LCT4 with the Lee Creek Impoundment.

P25. LCT4A near its confluence with LCT4.

P26. Looking east (upstream) along LCT4A near a ranch road crossing.

P27. Looking east (upstream) along LCT4A where headcutting ends and the channel looses definition.

P28. Looking east across EI1 located in the central portion of the eastern project area.

P29. Looking northwest across EI2. Lotus dominates this on-channel impoundment.

P30. Spikerush dominated wetland (EW 4) below the dam for EI2 and west of the Lee Creek Impoundment.

P31. Looking west across EI3 located between streams LCT3 and LCT4 along the northern property boundary of the eastern project area.

P32. Looking south across EI4

P33. Looking south across EI5.

P34. Looking south from the Lee Creek Impoundment dam toward EI6.

P35. Looking south across a typical seasonal wetland which is located behind terracing on the eastern project area.

P36. Typical cocklebur dominated areas behind terracing within the eastern project area.

P37. Typical pasture located on the eastern project area.

P38. Looking north along County Road 4965, which separates the eastern and western project areas.

WESTERN PROJECT AREA

P39. Looking west along County Road 4945, which forms the northern property boundary of the western project are

P40. Looking south at typical pasture located along the western property boundary. This area was recently tilled.

P41. Vegetation transition approaching the unnamed tributary to Bear Creek (TBC).

P42. Typical pasture located in the western project area that was not tilled.

P43. Large diameter pipe culvert beneath County Road 4945 conveying flows for TBC.

P44. Looking south (downstream) along TBC from the culvert at County Road 4945.

P45. Looking southwest (downstream) along TBC.

P46. Looking southwest (downstream) along TBC at where TBC exits the subject property.

P47. Looking southwest (downstream) at the confluence of TBCT1 with TBC.

P48. Looking southwest (downstream) along TBCT1 near the breach in WI1.

P49. Looking north at WI1. The breach of WI1 is located on the left hand side of the photograph.

P50. Looking east along a swale (WS2) dominated by spikerush and sumpweed. Swale is located upstream of WI1 and TBCT1.

P51. Looking west along the aforementioned swale (WS2) where the vegetation transitions to cocklebur and commo sunflower.

P52. Looking east (upstream) where TBCT2 joins TBC.

P53. Upland stock tank (WI2) located along the western property boundary of the western project area.

P54. Swale area located between WI2 (pictured above) and TBCT2. This swale eventually becomes defined as TBCT2.

P55. Typical seasonal spikerush dominated wetland identified behind terracing on the western project area.

P56. Looking south toward LCTI1 located along the southern property boundary of the western project area.

P57. Looking north along the upper portion of LCTI1 at the swale that provides hydrology to the impoundment.

58. Looking south along the wetland swale (WS2) which leads to LCTI1. Portions of the swale were defined with other sections dominated with spikerush.

P59. Looking south at the defined channel (south of subject property). LCTI1 impounds the upper portion of this stream.

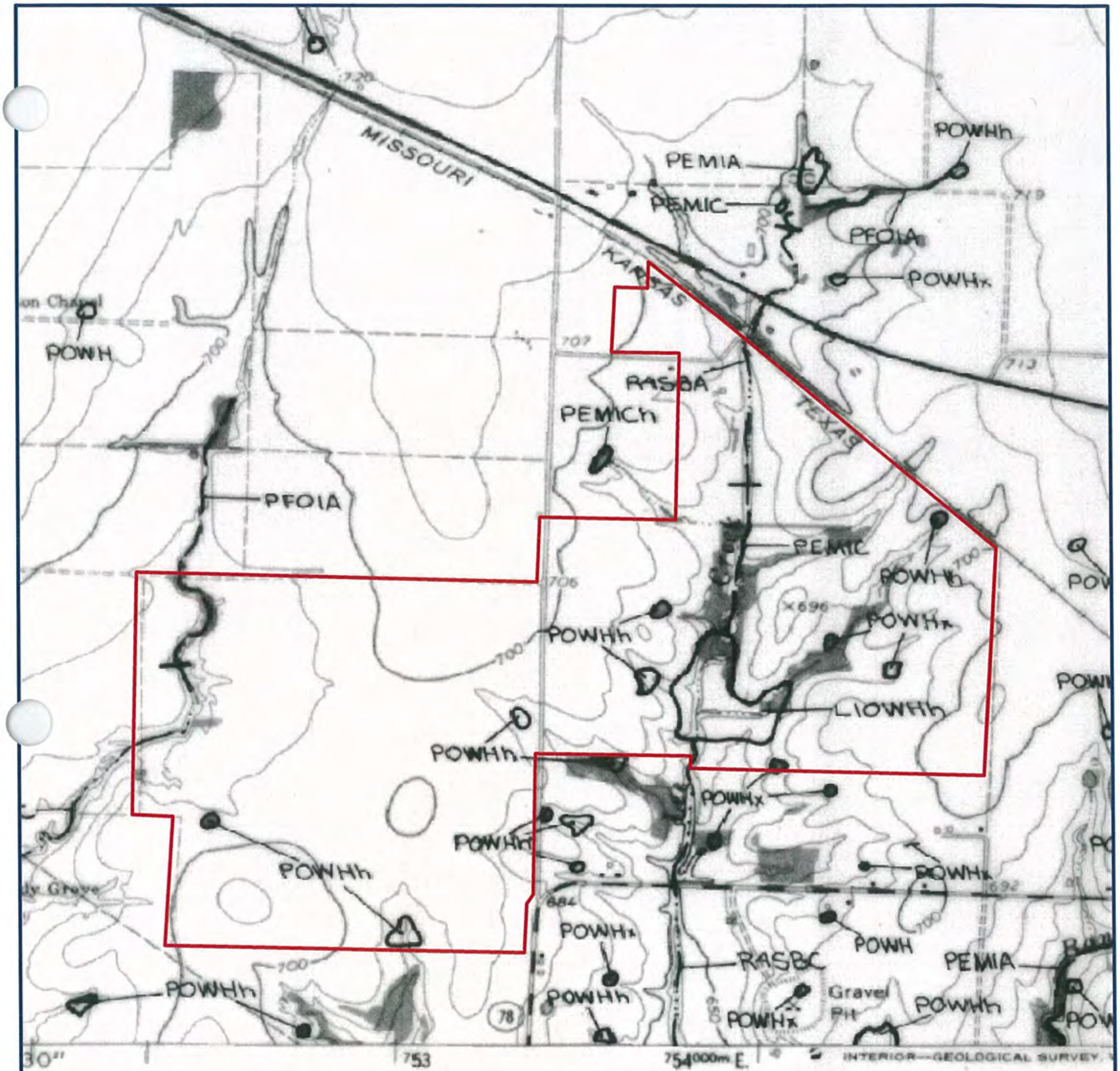
P60. Typical seasonal spikerush dominated wetlands located along the southeastern portion of the western project area.

P61. Looking north across LCWI3.

P62. Looking west toward LCWI2.

APPENDIX C

NATIONAL WETLANDS INVENTORY MAP AND COWARDIN CLASSIFICATION CODES



PROPOSED WTP SITE

N
W E
S

DATE:
DECEMBER 3, 2009

FIGURE C-1
NATIONAL WETLANDS INVENTORY MAP
PRELIMINARY JURISDICITONAL DETERMINATION OF WATERS OF THE U.S.
PROPOSED LEONARD WATER TREATMENT PLANT
NORTH TEXAS MUNICIPAL WATER DISTRICT

ALAN PLUMMER ASSOCIATES, INC.
1320 S. UNIVERSITY DRIVE
SUITE 300
FORT WORTH, TEXAS 76107
PHONE: (817) 806-1700
FAX: (817) 870-2536

FIGURE 1 OF 1

1,500 750 0 Feet

SOURCE:
TNRIS WETLAND INVENTORY MAP (TRENTON, TEXAS QUADRANGLE)
GEOREFERENCED BY APAI

USACE PROJECT NUMBER:

National Wetlands Inventory Map Codes

R-RIVERINE

1-TIDAL

RB-ROCK	UB-UNCONSOLIDATED BOTTOM	SB-STREAMBED	AB-AQUATIC BED	RS-ROCKY SHORE	US-UNCONSOLIDATED SHORE	EM-EMERGENT	OW-OPEN WATER
1 Bedrock	1 Cobble-Gravel	1 Bedrock	1 Algal	1 Bedrock	1 Cobble-Gravel	2 Nonpersistent	*Unknown Bottom*
2 Rubble	2 Sand	2 Rubble	2 Aquatic Moss	2 Rubble	2 Sand		
	3 Mud	3 Cobble-Gravel	3 Rooted Vascular		3 Mud		
	4 Organic	4 Sand	4 Floating Vascular		4 Organic		
		5 Mud	5 *Unknown Submergent*		5 Vegetated		
		6 Organic	6 *Unknown Surface*				
		7 Vegetated					

2-LOWER PERENNIAL

RB-ROCK	UB-UNCONSOLIDATED BOTTOM	AB-AQUATIC BED	RS-ROCKY SHORE	US-UNCONSOLIDATED SHORE	EM-EMERGENT	OW-OPEN WATER
1 Bedrock	1 Cobble-Gravel	1 Algal	1 Bedrock	1 Cobble-Gravel	2 Nonpersistent	*Unknown Bottom*
2 Rubble	2 Sand	2 Aquatic Moss	2 Rubble	2 Sand		
	3 Mud	3 Rooted Vascular		3 Mud		
	4 Organic	4 Floating Vascular		4 Organic		
		5 *Unknown Submergent*		5 Vegetated		
		6 *Unknown Surface*				

3-UPPER PERENNIAL

RB-ROCK	UB-UNCONSOLIDATED BOTTOM	AB-AQUATIC BED	RS-ROCKY SHORE	US-UNCONSOLIDATED SHORE	OW-OPEN WATER
1 Bedrock	1 Cobble-Gravel	1 Algal	1 Bedrock	1 Cobble-Gravel	*Unknown Bottom*
2 Rubble	2 Sand	2 Aquatic Moss	2 Rubble	2 Sand	
	3 Mud	3 Rooted Vascular		3 Mud	
	4 Organic	4 Floating Vascular		4 Organic	
		5 *Unknown Submergent*		5 Vegetated	
		6 *Unknown Surface*			

4-INTERMITTENT

SB-STREAMBED
1 Bedrock
2 Rubble
3 Cobble-Gravel
4 Sand
5 Mud
6 Organic
7 Vegetated

National Wetlands Inventory Map Codes (Cont.)

R-RIVERINE (Cont.)

5-UNKNOWN PERENNIAL

RB-ROCK	UB-UNCONSOLIDATED BOTTOM	AB-AQUATIC BED	RS-ROCKY SHORE	US-UNCONSOLIDATED SHORE	OW-OPEN WATER
1 Bedrock	1 Cobble-Gravel	1 Algal	1 Bedrock	1 Cobble-Gravel	*Unknown Bottom*
2 Rubble	2 Sand	2 Aquatic Moss	2 Rubble	2 Sand	
	3 Mud	3 Rooted Vascular		3 Mud	
	4 Organic	4 Floating Vascular		4 Organic	
		5 *Unknown Submergent*		5 Vegetated	
		6 *Unknown Surface*			

L-LACUSTRINE

1-LIMNETIC

RB-ROCK BOTTOM	UB-UNCONSOLIDATED BOTTOM	AB-AQUATIC BED	OW-OPEN WATER/
1 Bedrock	1 Cobble-Gravel	1 Algal	*Unknown Bottom*
2 Rubble	2 Sand	2 Aquatic Moss	
	3 Mud	3 Rooted Vascular	
	4 Organic	4 Floating Vascular	
		5 *Unknown Submergent*	
		6 *Unknown Surface*	

2-LITTORAL

RB-ROCK BOTTOM	UB-UNCONSOLIDATED BOTTOM	AB-AQUATIC BED	RS-ROCKY SHORE	US-UNCONSOLIDATED SHORE	EM-EMERGENT	OW-OPEN WATER/
1 Bedrock	1 Cobble-Gravel	1 Algal	1 Bedrock	1 Cobble-Gravel	2 Nonpersistent	*Unknown Bottom*
2 Rubble	2 Sand	2 Aquatic Moss	2 Rubble	2 Sand		
	3 Mud	3 Rooted Vascular		3 Mud		
	4 Organic	4 Floating Vascular		4 Organic		
		5 *Unknown Submergent*		5 Vegetated		
		6 *Unknown Surface*				

National Wetlands Inventory Map Codes (Cont.)

P-PALUSTRINE

RB-ROCK BOTTOM	UB-UNCONSOLIDATED BOTTOM	AB-AQUATIC BED	US-UNCONSOLIDATED SHORE	ML-MOSS LICHEN	EM-EMERGENT	SS-SCRUB-SHRUB	FO-FORESTED	OW-OPEN WATER/ *Unknown Bottom*
1 Bedrock	1 Cobble-Gravel	1 Algal	1 Cobble-Gravel	1 Moss	1 Persistent	1 Broad-Leaved Deciduous	1 Broad-Leaved Deciduous	
2 Rubble	2 Sand	2 Aquatic Moss	2 Sand	2 Lichen	2 Nonpersistent	2 Needle-Leaved Deciduous	2 Needle-Leaved Deciduous	
	3 Mud	3 Rooted Vascular	3 Mud			3 Broad-Leaved Evergreen	3 Broad-Leaved Evergreen	
	4 Organic	4 Floating Vascular	4 Organic			4 Needle-Leaved Evergreen	4 Needle-Leaved Evergreen	
		5 *Unknown Bottom*	5 Vegetated			5 Dead	5 Dead	
		6 *Unknown Surface*				6 *Deciduous*	6 *Deciduous*	
						7 *Evergreen*	7 *Evergreen*	

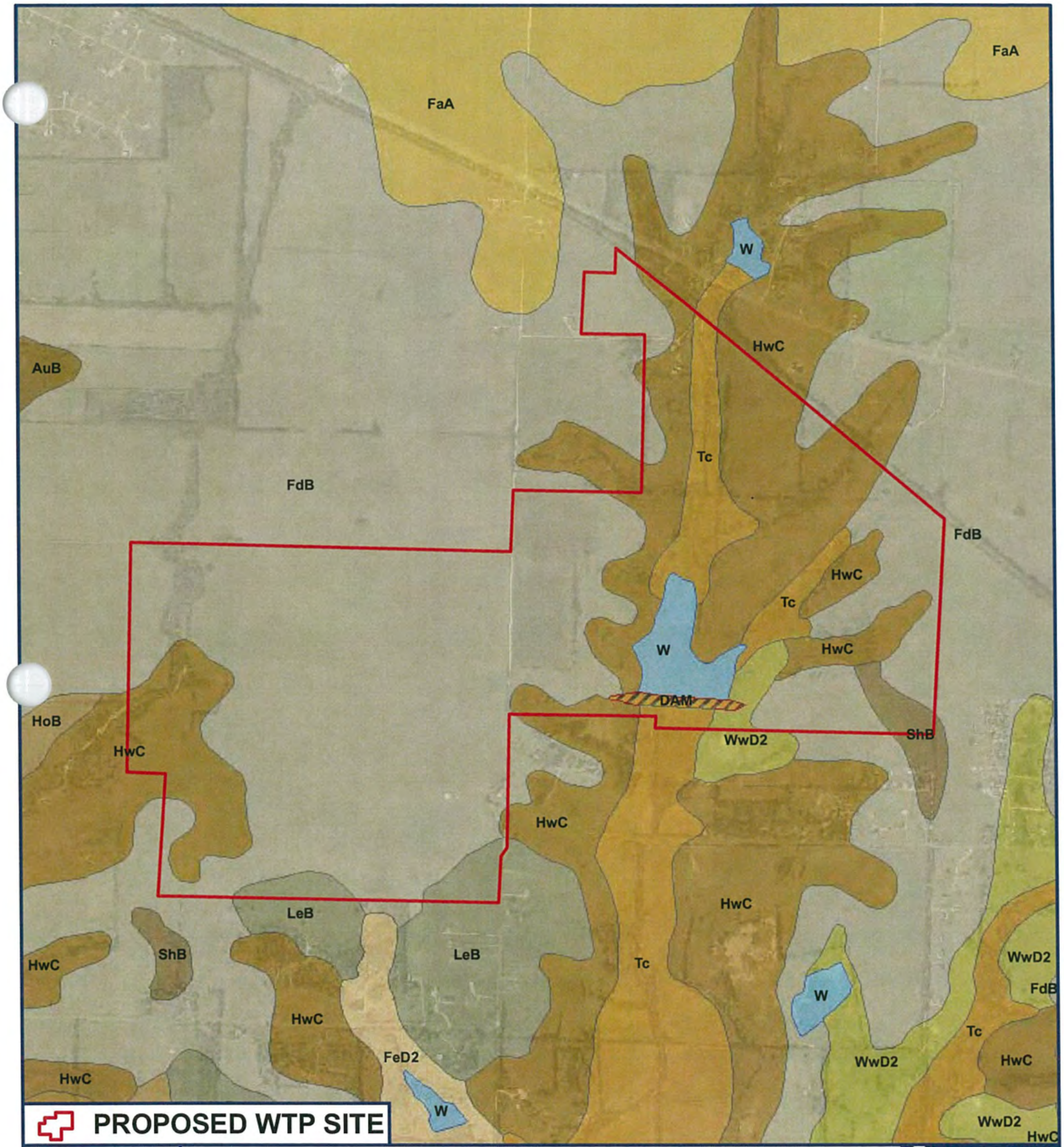
MODIFIERS

In order to more adequately describe wetland and deepwater habitats, one or more of the water regime, water chemistry, soil, or special modifiers may be applied at the class or lower level in the hierarchy. The farmed modifier may also be applied to the ecological system.

WATER REGIME				WATER CHEMISTRY			SOIL	SPECIAL MODIFIERS	
NON-TIDAL		TIDAL		COASTAL HALINITY	INLAND SALINITY	pH MODIFIERS FOR ALL FRESH WATER			
A Temporarily Flooded	H Permanently Flooded	K *Artificially Flooded*	*S Temporary-Tidal	1 Hyperhaline	7 Hypersaline	a Acid	g Organic	b Beaver	h *Diked Impounded*
B Saturated	J Intermittently Flooded	L Subtidal	*R Seasonal-Tidal	2 Euhaline	8 Eusaline	t Circumneutral	n Mineral	d *Partially Drained/Ditched*	r Artificial Substrate
C Seasonally Flooded	K Artificially Flooded	M Irregularly Exposed	*T Semipermanent-Tidal	3 Mixohaline *(Brackish)*	9 Mixosaline	l Alkaline		f Farmed	s *Spoil*
D *Seasonally Flooded/ Well Drained*	W Intermittently Flooded/ Temporarily	N Regularly Flooded	*V Permanent-Tidal	4 Polyhaline	0 Fresh				x Excavated
E *Seasonally Flooded/ Saturated*	Y Saturated/ Semipermanent/ Seasonal	P Irregularly Flooded	U *Unknown*	5 Mesohaline					
F Semipermanently Flooded	Z Intermittently Exposed/ Permanent	*These water regimes are only used in tidally influenced freshwater systems		6 Oligohaline					
G Intermittently Exposed	U *Unknown*			0 Fresh					

APPENDIX D

MAPPED SOIL TYPE AND SOIL SERIES DESCRIPTIONS



N
W E
S

DATE:
DECEMBER 3, 2009

FIGURE D-1
MAPPED SOIL UNITS
PRELIMINARY JURISDICITONAL DETERMINATION OF WATERS OF THE U.S.
PROPOSED LEONARD WATER TREATMENT PLANT
NORTH TEXAS MUNICIPAL WATER DISTRICT

ALAN PLUMMER ASSOCIATES, INC.

1320 S. UNIVERSITY DRIVE
SUITE 300
FORT WORTH, TEXAS 76107
PHONE: (817) 806-1700
FAX: (817) 870-2536

FIGURE 1 OF 1

1,500 750 0 Feet

SOURCE:
USDA WEB SOIL SURVEY
LANDISCOR 2007 AERIAL PHOTOGRAPH

USACE PROJECT NUMBER:

DALCO SERIES

The Dalco series consists of moderately deep, moderately well drained, very slowly permeable soils. These soils are on nearly level to gently sloping uplands. Slopes range from 0 to 5 percent.

TAXONOMIC CLASS: Fine, smectitic, thermic Leptic Udic Haplusterts

TYPICAL PEDON: Dalco clay--cropland - described at center of microdepression. (Colors are for dry soil unless otherwise stated.)

Ap--0 to 9 inches; very dark gray (10YR 3/1) clay, black (10YR 2/1) moist; weak very fine angular and subangular blocky structure; very hard, very firm, very sticky and plastic; few fine roots; few fine chalk fragments and siliceous pebbles; slight effervescence; slightly alkaline; gradual smooth boundary. (4 to 10 inches thick)

Bss1--9 to 26 inches; black (10YR 2/1) clay, black (10YR 2/1) moist; moderate; very fine angular blocky structure; extremely hard, very firm, very sticky and plastic; few fine roots; common pressure faces; few grooved slickensides; slight effervescence; slightly alkaline; gradual wavy boundary.

Bss2--26 to 35 inches; dark gray (10YR 4/1) clay, very dark gray (10YR 3/1) moist; fine and very fine angular blocky structure; extremely hard, very firm, very sticky and plastic; few fine roots; common pressure faces; common grooved slickensides; few fine fragments of chalk in lower part; strong effervescence; moderately alkaline, abrupt wavy boundary. (combined Bss subhorizons are 18 to 34 inches thick)

Cr--35 to 60 inches; white (10YR 8/2) chalk that is platy in the upper 6 inches and massive below; few crevices between plates of chalk filled with marly soil material; hardness of chalk is less than 3 on Mohs scale.

TYPE LOCATION: Dallas County, Texas; 3.2 miles north of Garland. About 100 feet west of Galaxy Road and 1000 feet south of the intersection of Galaxy and Arapaho Roads.

RANGE IN CHARACTERISTICS: The solum and depth to a paralithic contact with chalk is 24 to 40 inches. It is silty clay or clay throughout. The weighted average clay content of the particle-size control section ranges from 40 to 50 percent. In undisturbed areas, gilgai microrelief consists of knolls 4 to 8 inches higher than depressions; distance between center of knoll and center of depression is 5 to 12 feet. When dry, cracks 1/2 to 2 inches wide extend from the surface to depths of 12 inches or more. Cracks remain open for 90 to 150 cumulative days during most years. Slickensides and/or wedge shaped peds begin at a depth of 8 to 18 inches. The effervescence ranges from very slight to strong. The reaction is slightly alkaline or moderately alkaline throughout.

The A horizon is black or very dark gray in hue of 10YR to 5Y, value of 2 or 3, and chroma of 1.

The Bss horizon has colors in hue of 10YR to 5Y, value of 2 to 5, and chroma of 1 or 2. Most pedons contain a few iron-manganese concretions. Calcium carbonate films, masses, and concretions and/or fragments of chalk range fron few to common in most pedons.

The Cr layer is massive chalk bedrock or stratified chalk and marl. The bedrock is platy in the upper part of some pedons and commonly becomes massive within a depth of 6 to 18 inches. It is white, light gray, or very pale brown with or without streaks or coatings in shades of yellow or brown. The hardness is less than 3 on Mohs scale.

COMPETING SERIES: These include the Crawford, Greenvine, San Saba, and the similar Anhalt, Austin, Fairlie, and Vertel series. Crawford and Anhalt soils have subsoils with hue redder than 10YR. Greenvine soils have a paralithic contact with tuffaceous siltstone or shale. San Saba soils have a lithic contact of limestone. Anhalt and Vertel soils have a very-fine particle-size control section and are noneffervescent in the upper part. Austin soils have carbonatic mineralogy and do not have large slickensides. Fairlie soils are 40 to 60 inches deep to a paralithic contact of chalk.

GEOGRAPHIC SETTING: Dalco soils are on nearly level to gently sloping uplands underlain by chalk. These soils formed mainly in the Austin Chalk of Upper Cretaceous Age. Slope gradients are generally less than 3 percent but range from 0 to 5 percent. The climate is warm subhumid. Average annual precipitation ranges from 30 to 42 inches, mean annual temperature from 64 to 68 degrees F. Frost free days range from 230 to 260. Elevation ranges from 550 to 850 above sea level. Thornthwaite P-E indices from from 54 to 70.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the competing Austin and Fairlie series and the Eddy, Heiden, Houston Black, and Stephen series. The Austin soils are on slightly higher positions. Fairlie soils are on similar positions. Eddy and Stephen soils are shallow to chalk and are on similar to slightly lower positions. Heiden and Houston Black soils are very deep and are on similar positions of adjacent areas with different parent material.

DRAINAGE AND PERMEABILITY: Moderately well drained with very slow permeability. Water enters the soil rapidly when it is dry and very slow when it is moist. Runoff is low on 0 to 1 percent slopes; medium on 1 to 3 percent slopes; and high on 3 to 5 percent slopes.

USE AND VEGETATION: Mostly cultivated, some areas are used for pastures with bermudagrass or kleingrass. The main crops are cotton, grain sorghum, corn, and small grain. Native vegetation consists of tall and mid grass prairies of little bluestem, big bluestem, indiangrass, switchgrass, sideoats grama and annual grasses.

DISTRIBUTION AND EXTENT: The Blackland Prairies of Texas (MLRA 86A). The series is moderately extensive.

MLRA OFFICE RESPONSIBLE: Temple, Texas

SERIES ESTABLISHED: Dallas County, Texas; 1974.

REMARKS: The Dalco series were previously included with the Austin, Houston Black, or San Saba series. Classification changed from Udic Pellusterts to Leptic Udic Haplusterts (2/94) based on issue 16, a revision to Soil Taxonomy.

Diagnostic horizons and features recognized in this pedon are:

Mollic epipedon--0 to 35 inches, the A, and Bss horizons.

Vertisol features--Cracks when dry, slickensides in Bss subhorizons.

Paralithic contact of chalk at a depth of 35 inches.

SOIL INTERPRETAAION RECORD NUMBER: TX0158

FAIRLIE SERIES

The Fairlie series consists of deep, moderately well drained, very slowly permeable soils. These soils are on nearly level to gently sloping uplands. The slope is typically 1 to 3 percent but ranges from 0 to 5 percent.

TAXONOMIC CLASS: Fine, smectitic, thermic Udic Haplusterts

TYPICAL PEDON: Fairlie silty clay loam, on a smooth plain 2 percent slope, in a cultivated field. (Colors are for moist soil unless otherwise stated.)

Ap--0 to 5 inches; very dark gray (10YR 3/1) silty clay loam, dark gray (10YR 4/1) dry; weak medium platy structure parting to weak fine and medium blocky structure; extremely hard, firm, sticky and plastic; few fine roots; few fine black concretions; slight effervescence in spots; mildly alkaline; abrupt smooth boundary.

A--5 to 12 inches; black (5Y 2/1) silty clay, very dark gray (5Y 3/1) dry; moderate fine and medium angular blocky structure; very hard, firm, sticky and plastic; few fine roots; few pressure faces; strong effervescence; moderately alkaline; gradual wavy boundary. (combined A subhorizons are 6 to 18 inches thick)

Bss1--12 to 24 inches; black (5Y 2/1) silty clay, very dark gray (5Y 3/1) dry; moderate medium angular blocky structure; very hard, firm, sticky and plastic; few fine roots; common pressure faces; few grooved slickensides; few fine and medium concretions of calcium carbonate; few fine iron-manganese concretions; strong effervescence; moderately alkaline; gradual wavy boundary.

Bss2--24 to 35 inches; very dark gray (5Y 3/1) silty clay, dark gray (5Y 4/1) dry; moderate fine and medium angular blocky structure; very hard, firm, sticky and plastic; few fine roots; few medium distinct olive (5Y 5/3) redox concentrations or masses with sharp boundaries; common grooved slickensides; few fine iron-manganese concretions; few medium and coarse concretions and soft masses of calcium carbonate; few fine and medium pebbles of chert; strong effervescence; moderately alkaline; gradual wavy boundary. (combined Bss subhorizons are 12 to 40 inches thick)

Bkss--35 to 54 inches; dark gray (10YR 4/1) clay, gray (10YR 5/1) dry; moderate fine and medium angular blocky structure; very hard, firm, sticky and plastic; few fine roots; common grooved slickensides; few fine and medium distinct yellowish brown (10YR 5/8) and olive (5Y 5/6) redox concentrations or masses with sharp boundaries; few vertical streaks of black (5Y 2/1) associated with cracks; few fine iron-manganese concretions; common medium and coarse concretions and soft masses of calcium carbonate; few medium pebbles of chert; strong effervescence; moderately alkaline; abrupt wavy boundary. (0 to 30 inches thick)

Cr--54 to 60 inches; white (N 8/0; 2.5Y 8/2) chalk bedrock; with streaks of olive yellow; medium platy in upper 2 inches; massive below; hardness is less than 3 on Mohs' scale.

TYPE LOCATION: Hunt County, Texas; from the intersection of Texas Highways 11 and 34 in Wolfe City, Texas; 3 miles southeast on Texas Highway 11; 1.8 miles south on county road; 0.8 mile west on county road; 0.1 mile south along turn row and 40 feet east in a cultivated field.

RANGE IN CHARACTERISTICS: The range in characteristics includes 50 percent or more of the pedon. Solum thickness and depth to a paralithic contact of chalk ranges from 40 to 60 inches. The weighted average clay content of the control section is 40 to 50 percent. When dry, cracks ranging from 0.4 to 3 inches wide extend from the surface to a depth of more than 12 inches. Cracks are open for 90 to 150 cumulative days in most years. Slickensides and/or wedge shaped peds begin at a depth of 8 to 20 inches. These are cyclic soils, and in undisturbed areas, gilgai microrelief consists of microknolls 4 to 16 inches higher than microdepressions; distance between center of knoll and center of the depression is 5 to 12 feet. Reaction is slightly or moderately alkaline, and ranges from very slight to strong effervescence. There are few to common concretions and soft masses of calcium carbonate and/or chalk fragments in most subhorizons. Iron-manganese concretions and siliceous pebbles range from none to few throughout the solum.

The A horizon has colors in hue of 10YR to 5Y, value of 2 or 3, and chroma of 1. The texture is silty clay loam, silty clay, or clay.

The Bss horizon has colors in hue of 10YR to 5Y, value of 2 to 5, and chroma of 2 or less. Texture is silty clay or clay. Redox concentrations or masses with sharp boundaries in shades of brown, yellow, or olive range from none to common.

The Bkss horizons has colors in hue of 10YR to 5Y, value of 3 to 5, and chroma of 1 or 2. Texture is silty clay or clay. Redox concentrations or masses with sharp boundaries in shades of brown, yellow, or olive range from none to common.

In some pedons, there is a discontinuous C horizon of clay, silty clay, or marly clay with thin strata of weathered chalk. Colors are mainly in shades of gray, olive, or brown. The C horizon is not diagnostic to the series and is absent in most pedons.

The Cr horizon is limestone bedrock. It is mainly chalk, or interbedded chalk and marl. It is light gray or white, and typically platy in the upper few inches, and massive below with a hardness of less than 3 on Mohs' scale.

COMPETING SERIES: These are the Bleiblerville, Branyon, Burleson, Dimebox, Heiden, Houston Black, Ovan, Leson, Luling, Sanger, Slidell, and Watonga series. These soils do not have a paralithic contact with chalk within a depth of 40 to 60 inches.

GEOGRAPHIC SETTING: Fairlie soils are on nearly level to gently sloping uplands. They formed mainly in the Pecan Gap, Gober, and Austin Chalk Formations of Upper Cretaceous Age. Slopes are mainly 1 to 3 percent but range from 0 to 5 percent. Mean annual precipitation ranges from 30 to 42 inches, mean annual temperature from 64 degrees to 68 degrees F. Frost free days range from 230 to 260. Elevation ranges from 550 to 850 feet above sea level. Thornthwaite P-E indices range from 54 to 70.

GEOGRAPHICALLY ASSOCIATED SOILS: These include the competing Branyon, Burleson, Heiden, Houston Black, and Leson series. Also the Austin, Dalco, and Lott soils are associated. Austin and Lott soils are mollisols on slightly higher convex areas. Branyon and Burleson soils are on lower lying terrace positions. Dalco soils are 24 to 40 inches thick over a paralithic contact of chalk and are on similar positions. Heiden, Houston Black, and Leson soils are on similar positions of adjacent areas with different parent material.

DRAINAGE AND PERMEABILITY: Fairlie soils are moderately well drained and very slow permeablility. Water enters the soil rapidly when it is dry and cracked, and very slow when the soil is saturated. Runoff is low on 0 to 1 percent slopes; moderate on 1 to 3 percent slopes; and high on 3 to 5 percent slopes.

USE AND VEGETATION: Used mainly for cultivated crops of cotton, grain sorghum, corn, and small grain, however, some areas are used for pasture and a few small areas are in rangeland. Pastures are mainly bermudagrasses; rangeland plants include eastern grama, little bluestem, indiangrass, Florida paspalum, sideoats grama, switchgrass, meadow dropseed, forbs and annual grasses.

DISTRIBUTION AND EXTENT: Blackland Prairie of Texas, MLRA 86A. The series is moderately extensive.

MLRA OFFICE RESPONSIBLE: Temple, Texas

SERIES ESTABLISHED: Grayson County, Texas; 1977.

REMARKS: Fairlie soils were previously included with the Houston Black or Austin series. Classification changed from Pellusterts to Haplusterts (2/94) based on Issue 16, a revison of Soil Taxonomy.

Diagnostic horizons and features recognized in this pedon are:

Mollic colors--0 to 35 inches, the Ap, A, Bss horizon.

Cambic horizon - 35 to 54 inches.

Vertisols features--Cracks when dry, slickensides in Bss subhorizons.

Paralithic contact of chalk at a depth of 54 inches.

SOIL INTERPRETATION RECORD NUMBER: TX0726

HOWE SERIES

The Howe series consists of moderately deep, well drained, moderately permeable soils that formed in weakly cemented chalk interbedded with marl of Upper Cretaceous Age. These soils are on gently sloping to strongly sloping uplands. Slopes are dominantly 5 to 12 percent but range from 3 to 12 percent.

TAXONOMIC CLASS: Fine-silty, carbonatic, thermic Udic Haplustepts

TYPICAL PEDON: Howe silty clay loam--pasture. (Colors are for dry soil unless otherwise stated.)

A--0 to 7 inches; grayish brown (10YR 5/2) silty clay loam, dark grayish brown (10YR 4/2) moist; moderate medium subangular blocky and fine granular structure; hard, firm; common fine and medium roots; common wormcasts; few weakly cemented fragments of chalk that are less than 10 mm in diameter; calcium carbonate equivalent is about 60 percent; calcareous, moderately alkaline; gradual smooth boundary. (5 to 13 inches thick)

Bk1--7 to 15 inches; light gray (10YR 7/2) silty clay loam, light brownish gray (10YR 6/2) moist; moderate fine subangular blocky structure; hard, firm; common fine roots; common wormcasts; few weakly cemented fragments of chalk that are less than 5 mm in diameter; calcium carbonate equivalent about 60 percent; calcareous, moderately alkaline; gradual wavy boundary. (7 to 20 inches thick)

Bk2--15 to 26 inches; very pale brown (10YR 7/3) silty clay loam, pale brown (10YR 6/3) moist; moderate fine subangular blocky structure; hard, firm; few fine roots; about 27 percent weakly cemented platy fragments of chalk that are slightly hard dry, but break down on wetting and gentle rubbing; calcium carbonate equivalent about 60 percent; few threads and films of calcium carbonate; calcareous, moderately alkaline; gradual wavy boundary. (4 to 17 inches thick.)

Cr--26 to 32 inches; white (10YR 8/1) weakly cemented platy chalk with few thin seams of very pale brown silty clay loam in the upper part in vertical fractures and between plates of chalk; rock structure, distinct horizontal bedding; slightly hard to hard when dry, but can be easily cut with spade when moist; hardness less than about 2 on Mohs scale; calcareous, moderately alkaline.

TYPE LOCATION: Grayson County, Texas; from the intersection of U. S. Highway 82 and Texas Highway 11 in Sherman, Texas; 3.9 miles southeast on Texas Highway 11 to Luella; 0.1 mile west on paved county road; south 1.7 miles on paved county road to gate at the Holloway Cemetery; 25 feet west of road right-of-way in pasture.

RANGE IN CHARACTE RISTICS: Solum thickness ranges from 20 to 40 inches. Calcium carbonate equivalent of the control section ranges from 40 to about 80 percent. The texture of the soil is silty clay loam, silty clay or clay loam, with total clay content ranging from 30 to 45 percent and silicate clay content ranging from 25 to 35 percent.

The A horizon has colors with hue of 10YR, value of 4 to 6, and chroma of 2 or 3. Where moist values and chromas are less than 3.5, the A horizon is less than 7 inches thick. Fragments of weakly cemented chalk range from none to common.

The B horizons have colors with hue of 10YR or 2.5Y, value of 5 or 6, and chroma of 2 to 4. Some pedons have few to common yellow or brown mottles in the lower B horizon. The B horizons are silty clay loam, clay loam or silty clay. Pseudo rock fragments of chalk range from none to about 20 percent by volume in the upper B horizon and from about 5 percent 35 percent by volume in the lower B horizon. The fragments are hard to slightly hard when dry, but disintegrate upon overnight soaking in calgon and water. Platy fragments of calcite range from none to few.

The Cr horizon is white, light gray, very pale brown, or light brownish gray weakly cemented platy chalk or brittle marl. The upper few inches has thin seams of yellowish brown, brownish yellow, very pale brown, or pale yellow silty clay loam in fractures and between plates of chalk. The chalk becomes more massive and less fractured with depth. The chalk is easily cut with a spade when moist.

COMPETING SERIES: These include the Altoga and McLennan in the same family and the similar Austin, Brackett, Cuthand, Ellis, Lamar, Seawillow, and Whitewright series. Altoga, Lamar, McLennan and Seawillow soils lack a paralithic contact with chalk. In addition, Lamar soils have mixed mineralogy and Seawillow soils have fine-loamy control sections. Austin soils have mollic epipedons. Brackett and Whitewright soils have sola less than 20 inches thick. Cuthand soils have coarse-silty control sections. Ellis soils have COLE values of .09 or more and are noncalcareous.

GEOGRAPHIC SETTING: Howe soils are on upland ridges and upper sideslopes. Slope gradients are mostly 5 to 12 percent but range from 3 to 12 percent. The soil formed in weakly cemented marine chalk interbedded with marl, mainly of the Austin Group of Upper Cretaceous Age. Mean annual precipitation ranges from about 35 to 41 inches. The mean annual temperature ranges from 63 degrees to 66 degrees F. and the Thornthwaite P-E index ranges from 56 to 66.

GEOGRAPHICALLY ASSOCIATED SOILS: These include the competing Altoga, Austin, and Whitewright series and the Eddy, Fairlie and Lewisville series. Altoga and Lewisville soils are on lower lying stream terraces. Lewisville soils have mollic epipedons and lack a paralithic contact with chalk. Austin and Fairlie soils are on higher lying uplands. Fairlie soils have intersecting slickensides and wide cracks when dry. Eddy and Whitewright soils are in similar positions.

DRAINAGE AND PERMEABILITY: Well drained; medium runoff; moderate permeability.

USE AND VEGETATION: Used mostly for pasture. The main grasses are common and improved bermudagrass and K. R. bluestem. Native vegetation includes little bluestem, silver bluestem, sideoats grams, Texas wintergrass, threeawn with scattered elm and oak trees. A few areas are cultivated with cotton, small grain, and grain sorghum being the main crops grown.

DISTRIBUTION AND E XTENT: The Blackland Prairie of north-central Texas. The soil is moderately extensive.

MLRA OFFICE RESPONSIBLE: Temple, Texas

SERIES ESTABLISHED: Grayson County, Texas; 1977.

REMARKS: Howe soils have formerly been included in the Austin series.

Classification was changed 11/89 from Typic Ustochrepts to Udic Ustochrepts.

Diagnostic horizons and features recognized in this pedon are:

Ochric epipedon - 0 to 7 inches, the A horizon.

Cambic horizon - 7 to 26 inches the Bk horizon.

Paralithic contact of chalk at a depth of 26 inches.

LOWE SERIES

The Lowe series consists of very deep, poorly drained and very poory drained soils formed in loamy alluvium on flood plains. Permeability is moderate. Slopes range from 0 to 2 percent. Mean annual precipitation is about 23 inches and mean annual temperature is about 46 degrees F.

TAXONOMIC CLASS: Fine-loamy, mixed, superactive, frigid Typic Calciaquolls

TYPICAL PEDON: Lowe loam - on a slope of less than 1 percent in a cultivated field. When described the soil was moist throughout. (Colors are for moist soils unless otherwise stated.)

Ap--0 to 8 inches; black (10YR 2/1) loam, very dark gray (10YR 3/1) dry; weak fine granular structure; slightly hard, friable, slightly sticky and slightly plastic; strong effervescence; 5 percent calcium carbonate equivalent; moderately alkaline; abrupt smooth boundary. (7 to 16 inches thick)

Bk--8 to 15 inches; gray (10YR 5/1) and very dark gray (10YR 3/1) clay loam, gray (10YR 6/1) and dark gray (10YR 4/1) dry; weak medium subangular blocky structure; hard, friable, slightly sticky and slightly plastic; about 20 percent worm casts; many fine accumulations of carbonate; violent effervescence; 15 percent calcium carbonate equivalent; moderately alkaline; gradual smooth boundary.

Bkg1--15 to 28 inches; gray (5Y 5/1) loam, light gray (5Y 7/2) dry; few fine distinct black (5Y 2/1) and olive brown (2.5Y 4/3) mottles; weak medium and coarse subangular blocky structure; hard, friable, slightly sticky and slightly plastic; about 5 percent very dark gray (5Y 3/1) worm casts; violent effervescence; 26 percent calcium carbonate equivalent; moderately alkaline; gradual smooth boundary.

Bkg2--28 to 32 inches; dark gray (5Y 4/1) loam, gray (5Y 5/1) dry; few fine distinct black (5Y 2/1) mottles; weak medium subangular blocky structure; hard, friable, slightly sticky and slightly plastic; strong effervescence; 23 percent calcium carbonate equivalent; moderately alkaline; gradual smooth boundary. (Combined Bk horizon is 10 to 30 inches thick.)

Akb--32 to 42 inches; very dark gray (5Y 3/1) sandy loam, dark gray (5Y 4/1) dry; weak coarse subangular blocky structure; soft, very friable; common fine accumulations of carbonate; strong effervescence; 8 percent calcium carbonate equivalent; slightly alkaline; gradual smooth boundary. (0 to 14 inches thick)

Cg1--42 to 56 inches; olive gray (5Y 5/2) stratified sandy loam with a few strata of loamy sand, light olive gray (5Y 6/2) dry; massive; soft, very friable; common fine coats of carbonate; strong effervescence; 13 percent calcium carbonate equivalent; slightly alkaline; clear smooth boundary.

Cg2--56 to 60 inches; olive gray (5Y 4/2) stratified loam and sandy loam, gray (5Y 5/1) dry; few fine prominent light olive brown (2.5Y 5/6) and distinct black (5Y 2/1) mottles; massive, hard, friable, slightly sticky and slightly plastic; many fine and medium coats of carbonate; strong effervescence; 15 percent calcium carbonate equivalent; slightly alkaline.

TYPE LOCATION: Deuel County, South Dakota; about 1 mile south and 2 miles east of Estelline; 135 feet south and 1,725 feet west of the northeast corner, sec. 31, T. 113 N., R. 50 W.

RANGE IN CHARACTERISTICS: The mollic epipedon ranges from 7 to 36 inches in thickness and extends into the Bk horizon of most pedons. The 10 to 40 inch control section averages 18 to 35 percent clay and 15 to 35 percent fine sand and coarser sand. The soil typically is calcareous throughout, but some pedons do not have carbonate to a depth of 10 inches. The calcic horizon has a calcium carbonate equivalent of 15 to 45 percent. Electrical conductivity of the saturation extract is typically less than 4 mmhos/cm but a saline phases are recognized where the conductivity is up to 16 mmhos/cm.

The Ap horizon is neutral or has hue of 10YR, 2.5Y, or 5Y; value of 2 or 3 and 3 or 4 dry; and chroma of 1 or less. It typically is loam, but in some pedons is clay loam, silt loam or silty clay loam. It is neutral to moderately alkaline.

The Bk and Bkg horizons have hue of 10YR, 2.5Y, or 5Y or are neutral; value of 2 to 5 and 3 to 7 dry; and chroma of 0 to 2. If mottles are not present, chroma is 1 or less moist, below the mollic epipedon. It typically is loam or clay loam, but in some pedons it is silt loam. Carbonates are disseminated in most pedons, but some have few to many accumulations of carbonate. Few to common gypsum crystals are in some pedons. It is slightly alkaline or moderately alkaline. Some pedons have a Bkb horizon.

The Akb horizon has hue of 10YR, 2.5Y, or 5Y; value of 2 or 3 and 3 to 5 dry. It is sandy loam, loam, clay loam or sandy clay loam. It is slightly alkaline or moderately alkaline. Some pedons do not have an Ab horizon.

The Cg horizon has hue of 2.5Y or 5Y, value of 3 to 6 and 4 to 7 dry, and chroma of 1 to 3. It typically is stratified loam, clay loam, or sandy loam, but strata of silty clay loam, sandy clay loam or loamy sand are in some pedons. It is slightly alkaline or moderately alkaline. Some pedons have gravelly material below a depth of 40 inches. Some pedons have few or common gypsum crystals in the Cg horizon. Some pedons are not stratified in the Cg horizon.

COMPETING SERIES: These are the Easby, Hapur, Nortonville, and Vallers series. Easby soils have an EC greater than 16 mmhos/cm. The Hapur soils have a drier soil moisture control section and have a shorter growing season. Nortonville soils have a gypsic horizon. Vallers soils do not have a uniform sand size distribution in the series control section and have more coarse fragments.

GEOGRAPHIC SETTING: Lowe soils are on nearly level flood plains. Surfaces are plane or slightly concave and slopes are less than 2 percent. They formed in loamy alluvium. Mean annual temperature ranges from 43 to 48 degrees F, and mean annual precipitation ranges from 20 to 24 inches. Growing season is about 125 to 130 days; average growing season precipitation from 15 to 18 inches; and growing degree days are about 2500 to 2900.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Divide, Fulda, La Prairie, Lamoure, and Marysland soils. Divide and Marysland soils have sand and gravel at a depth of 20 to 40 inches. They are in positions on the landscape similar to the Lowe series. Fulda, Lamoure, and La Prairie soils do not have a calcic horizon within a depth of 16 inches. In addition, Fulda soils have a fine textured series control section and are in slight depressions and drainageways. Lamoure soils typically are adjacent to the stream channel. The moderately well drained La Prairie soils are in slightly higher landscape positions.

DRAINAGE AND PERMEABILITY: Poorly drained and very poorly drained. Runoff is low or very low. Permeability is moderate. These soils are commonly flooded. A seasonal high water table is at +1 to 1.5 feet.

USE AND VEGETATION: Most areas are in cropland. The main crops are corn, soybeans, small grain, and hay. Native grasses include big bluestem, indiangrass, switchgrass, prairie cordgrass, little bluestem, forbs and sedges.

DISTRIBUTION AND EXTENT: Northeastern South Dakota and possibly west central Minnesota. The series is of small extent.

MLRA OFFICE RESPONSIBLE: Bismarck, North Dakota

SERIES ESTABLISHED: Deuel County, South Dakota, 1990.

REMARKS: Diagnostic horizons and features recognized in this pedon are: Mollic epipedon - the zone from the surface of the soil to a depth of about 15 inches (Ap and Bk1 horizons); Calcic horizon - the zone of carbonate accumulation from about 8 to 32 inches (Bk1, Bk2, and Bk3).

STEPHEN SERIES

The Stephen series consists of shallow, well drained, moderately slowly permeable soils formed in interbedded marl and chalky limestone. These soils are on gently sloping to sloping uplands. Slopes are mainly 1 to 5 percent but range from 1 to 8 percent.

TAXONOMIC CLASS: Clayey, mixed, active, thermic, shallow Udorthentic Haplustolls

TYPICAL PEDON: Stephen silty clay--cropland. (Colors are for dry soil unless otherwise stated.)

Ap--0 to 8 inches; dark brown (7.5YR 4/2) silty clay, dark brown (7.5YR 3/2) moist; moderate fine subangular blocky and granular structure parting to very fine subangular blocky structure; hard, firm, sticky, plastic; many fine roots; few fine chalk fragments; calcareous, moderately alkaline; abrupt wavy boundary. (7 to 20 inches thick)

C/A--8 to 12 inches; about 65 percent platy chalk fragments and platy chalk in place and about 35 percent dark brown (7.5YR 3/3) moist silty clay in the horizontal and vertical crevices and between the loose chalk fragments; few to strongly cemented cobblestones and limestone; few fine roots; few fine pores; calcareous, moderately alkaline; abrupt irregular boundary. (0 to 6 inches thick)

Cr--12 to 28 inches; pink (5YR 8/3) and white (10YR 8/2) platy chalk this is less hard than 3, Mohs scale; few thin tongues of dark brown calcareous silty clay in crevices between some chalk plates.

TYPE LOCATION: McLennan County, Texas; from the intersection of Farm Road 1695 and Farm Road 2837 in Lorena, 0.6 mile northwest on Farm Road 2837 to intersection with county road, 300 feet west and 100 feet north of intersection in cropland.

RANGE IN CHARACTERISTICS: Solum thickness to chalky limestone ranges from 7 to 20 inches. The chalky limestone, when moist, can be cut with a spade. The layer below the A horizon ranges from 40 to 80 percent or more calcium carbonate equivalent.

The A horizon has hue of 7.5YR or 10YR; value of 3 to 5, and chroma of 1 to 3. It is clay, silty clay, silty clay loam, or clay loam with 35 to 55 percent clay. Chalk fragments in the A horizon range from 2 to 15 percent by volume. Olive mottles or streaks range from none to common in the lower part to the A horizon. The lower boundary of the A horizon ranges from wavy to irregular.

The C/A or A/C horizons, where present, have color and texture similar to those of the A and Cr horizons.

The Cr horizon is interbedded chalk and limy earths or soft limestone and limy earths. It has hue of 5YR to 10YR in shades of pink, white, and gray.

COMPETING SERIES: There are no series in the same family. Similar soils are Brackett, Castephen, Doss, Eckrant, Purves, Real, and Whitewright series. Brackett and Whitewright soils lack a mollic epipedon. Brackett, Castephen, Doss, Real, and Whitewright soils have carbonatic mineralogy and contain less than 35 percent silicate clay. Eckrant and Purves soils have a Lithic contact with indurated limestone. In addition, Eckrant and Real soils contain more than 35 percent coarse fragments.

GEOGRAPHIC SETTING: Stephen soils are on uplands. Surfaces are plane to convex, with gradients mainly less than 5 percent, but range from 1 to 8 percent. The soils formed in interbedded chalk, marl, or soft limestone rubble, mainly of the Austin Formation. The climate is warm and subhumid; mean annual precipitation ranges from 30 to 42 inches, mean annual temperature from 63 to 69 degrees F., and the Thornthwaite annual P-E indices from 44 to 66.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Altoga, Austin, Brackett, Eddy, and Lott series. All of these soils have carbonatic

mineralogy and less than 35 percent clay in the control section. In addition; Altoga, Brackett, and Eddy do not have mollic epipedons.

DRAINAGE AND PERMEABILITY: Well drained; medium to rapid runoff; medium internal drainage; moderately slow permeability.

USE AND VEGETATION: Mainly in cultivation and used for growing small grains. A few areas are in native range. Native grasses are little bluestem, sideoats grama, hairy grama, and buffalograss.

DISTRIBUTION AND EXTENT: The Blackland Prairie of Texas. The series is extensive.

MLRA OFFICE RESPONSIBLE: Temple, Texas

SERIES ESTABLISHED: Ellis County, Texas; 1962.

REMARKS: Classification was changed 11/89 from clayey, mixed, thermic, shallow Entic Haplustolls to clayey, mixed, thermic, shallow Udorthentic Haplustolls.

Diagnostic horizons and features recognized in this pedon are:

Mollic epipedon - 0 to 8 inches, the Ap horizon.

Paralithic contact of chalk at a depth of 12 inches.

TINN SERIES

The Tinn series consists of very deep, moderately well drained, very slowly permeable soils that formed in calcareous clayey alluvium. These soils are on flood plains of streams that drain the Blackland Prairies. Slopes are dominantly less than 1 percent but range from 0 to 2 percent.

TAXONOMIC CLASS: Fine, smectitic, thermic Typic Hapluderts

TYPICAL PEDON: Tinn clay--cultivated. (Colors are for moist soil unless otherwise noted.)

Ap--0 to 6 inches; black (10YR 2/1) clay, very dark gray (10YR 3/1) dry; moderate coarse angular blocky structure parting to moderate very fine and fine angular blocky structure; very hard, very firm; plastic; few fine roots; few fine and medium pores; slightly effervescent; moderately alkaline; abrupt smooth boundary. (4 to 8 inches thick)

A--6 to 18 inches; black (10YR 2/1) clay, very dark gray (10YR 3/1) dry; moderate coarse angular blocky structure parting to moderate very fine and fine angular blocky; very hard, very firm; few fine roots; few fine and medium pores; common pressure faces; few fine slickensides; about 2 percent fine siliceous pebbles, and about 2 percent fine ironstone pebbles; few worm casts; few medium grayish brown (2.5Y 5/2) streaks along root channels; slightly effervescent; moderately alkaline; gradual wavy boundary. (6 to 15 inches thick)

Bss1--18 to 28 inches; black (10YR 2/1) clay, very dark gray (10YR 3/1) dry; moderate coarse angular blocky structure parting to moderate fine and medium angular blocky; very hard, very firm; few fine roots; few fine and medium pores; common fine pressure faces; common fine slickensides; about 2 percent fine siliceous pebbles, and about 2 percent fine ironstone pebbles; few worm casts; few medium grayish brown (2.5Y 5/2) streaks along root channels; slightly effervescent; moderately alkaline; gradual wavy boundary. (8 to 20 inches thick)

Bss2--28 to 54 inches; black (10YR 2/1) clay, very dark gray (10YR 3/1) dry; moderate coarse angular blocky structure parting to moderate fine and medium angular blocky structure; very hard, very firm; few fine roots; few fine and medium pores; many prominent grooved slickensides that range from 5 to 10 cm across; most slickensides are oriented at 45 degrees; few fine black concretions; few medium calcium carbonate concretions that are pitted; about 2 percent siliceous pebbles; about 2 percent shell fragments; few worm casts; few coarse very dark gray (10YR 3/1) masses; slightly effervescent; moderately alkaline; gradual wavy boundary. (0 to 30 inches thick)

Bss3--54 to 72 inches; very dark gray (10YR 3/1) clay, dark gray (10YR 4/1) dry; moderate coarse angular blocky structure parting to moderate fine and medium angular blocky; very hard, very firm; few fine roots; few fine and medium pores; common prominent grooved slickensides up to 1 meter across, slickensides are oriented at 45 to 60 degrees; few fine and medium calcium carbonate concretions that are pitted; few worm casts; slightly effervescent; moderately alkaline; gradual wavy boundary. (10 to 24 inches thick)

Bkss--72 to 80 inches; very dark grayish brown (2.5Y 3/2) clay, dark grayish brown (2.5Y 4/2) dry, moderate coarse angular blocky structure parting to moderate fine and medium angular blocky; very hard, very firm; few fine roots; few fine and medium pores; few fine grooved slickensides up to 50 cm across, slickensides are oriented at 45 to 60 degrees; common fine and medium calcium carbonate concretions; few fine and medium masses of gypsum; few black (10YR 2/1) streaks; slightly effervescent; moderately alkaline.

TYPE LOCATION: Limestone County, Texas; from the intersection of Farm Road 171 and Farm Road 73 in Coolidge, 2.8 miles northeast on Farm Road 73, 0.6 miles north on county road, and 400 feet east on Pin Oak Creek floodplain in cropland.

RANGE IN CHARACTERISTICS: Solum thickness is greater than 80 inches. Reaction is slightly alkaline or moderately alkaline. Effervescence ranges from very slight to strong. Weighted average clay content of the particle size control section ranges from 40 to 60 inches. Texture is silty clay or clay throughout. Undisturbed areas have subdued gilgai, with microhighs 2 to 6 inches higher than microlows. Slickensides and/or wedge-shaped aggregates begin at depths from 6 to 20 inches, becoming more distantly expressed between 20 and 60 inches. The soil cracks when dry and the cracks are 0.5 inch to about 2 inches wide and extend to a depth of more than 12 inches. The cracks remain open from 60 to 90 cumulative days in most years.

The A horizon has dark colors in hue of 10YR to 5Y, value of 2 or 3, and chroma of 1. Texture is silty clay or clay.

A Bw horizon is present in some pedons. Where present, the colors and textures are similar to those of the A horizon.

The Bss and Bkss horizons have hue of 10YR to 5Y, value of 3 to 6, and chroma of 1 to 4. Redox concentrations in shades of brown, olive or yellow range from none to common. Calcium carbonate masses and concretions range from none to common.

COMPETING SERIES: These are the Eastham and Hallsbluff series. Similar soils are the Branyon, Burleson, Kaufman, and Trinity soils. Eastham soils are not calcareous in the upper 20 inches. Hallsbluff soils have a mollic epipedon with chroma of 2. Branyon and Burleson soils are Usterts. In addition, Burleson soils are noncalcareous in the upper 20 inches. Kaufman and Trinity soils have very-fine control sections.

GEOGRAPHIC SETTING: Tinn soils are on nearly level flood plains. Slopes are mainly less than 1 percent, but some are as much as 2 percent. The soil formed in calcareous clayey alluvium. Mean annual precipitation ranges from 32 to 42 inches, and mean annual temperature ranges from 64 to 68 degrees F. Frost free days range 230 to 270 days and elevation ranges from 250 to 550 feet. Thornthwaite P-E indices exceed 44.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Branyon, Burleson, Ferris, Heiden, Houston Black, and Trinity series. Branyon and Burleson soils are on higher terrace positions. Ferris and Heiden soils have chroma of 2 or more in the upper 12 inches. Houston

Black soils have greater amplitude of waviness and are on uplands in a higher position. Trinity soils have very-fine particle-size control sections and are in similar positions.

DRAINAGE AND PERMEABILITY: Moderately well drained. Permeability is very slow. Runoff is low. Flooding is common except where the soil is protected. Duration of flooding is very brief or brief.

USE AND VEGETATION: Most areas are in pasture or cultivated to crops such as cotton, corn, sorghums, or small grains. Native vegetation is elm, hackberry, oak, and ash, with an understory of grasses such as species of paspalums and panicums.

DISTRIBUTION AND EXTENT: Mainly in central Texas on streams draining the Blackland Prairies (MLRA 86A). The series is extensive.

MLRA OFFICE RESPONSIBLE: Temple, Texas

SERIES ESTABLISHED: Hill County, Texas; 1975.

REMARKS: Classification of the Tinn series was changed from Vertic Haplaquolls to Typic Pelluderts (3/88). This change was based on several years study and analysis of the soils mapped in the Tinn series. The series type location was moved from Hill County to Limestone County to a pedon that is near the center of the series range in characteristics and near the center of the geographic distribution. Classification change from Typic Pelluderts to Typic Hapluderts based on Amendment 16, SOIL TAXONOMY (2/94).

Diagnostic horizons and features recognized in this pedon are:

Mollic colors - throughout this pedon.

Vertic Properties - slickensides from 6 to 80 inches.

SOIL INTERPRETATION RECORD NO: TX0456

WHITEWRIGHT SERIES

The Whitewright series consists of shallow, well drained, moderately permeable soils that formed in weakly cemented chalk and marl of Upper Cretaceous Age. These gently sloping to moderately steep soils are on convex upland ridges. Slopes are dominantly 4 to 10 percent but range from 1 to 15 percent.

TAXONOMIC CLASS: Loamy, carbonatic, thermic, shallow Typic Haplustepts

TYPICAL PEDON: Whitewright silty clay loam--pasture. (Colors are for dry soil unless otherwise stated.)

A--0 to 5 inches; light brownish gray (10YR 6/2) silty clay loam, grayish brown (10YR 5/2) moist; moderate medium subangular blocky and granular structure; hard, friable; common medium and fine roots; few fine and medium pores; common wormcasts; few fragments of weakly cemented chalk that are 2 mm to 10 mm in size; few strongly cemented fragments of calcite that are 5 to 15 mm across the long axis; calcium carbonate equivalent is about 60 percent; calcareous, moderately alkaline; clear smooth boundary. (6 to 14 inches thick)

Bk--5 to 16 inches; very pale brown (10YR 7/3) silty clay loam, pale brown (10YR 6/3) moist; few medium distinct brownish yellow (10YR 6/6) mottles; moderate fine and medium subangular blocky structure; hard, friable; common fine and medium roots; few fine pores; common wormcasts; about 20 percent by volume of weakly cemented platy fragments of chalk 5 to 20 mm across the long axis; most of the chalk fragments disintegrate upon moistening and gentle rubbing; few fine shell fragments; calcium carbonate equivalent is about 65 percent; few films and threads of calcium carbonate; calcareous, moderately alkaline; abrupt wavy boundary. (6 to 14 inches thick)

Cr--16 to 34 inches; white (10YR 8/1) weakly cemented fractured chalk, interbedded with thin horizontal strata of olive yellow (2.5Y 6/6) silty clay loam; cleavage planes of rock structure are evident in the chalk; the chalk becomes less fractured and more massive below 30 inches depth; few fine roots in the upper part in vertical crevices and between horizontal plates; calcareous, moderately alkaline.

TYPE LOCATION: Grayson County, Texas; from the intersection of Texas Highway 5 and Farm Road 121 in Van Alstyne, Texas, 0.75 mile east on Farm Road 121; 1.25 miles north on an unpaved county road; 100 feet west of road in pasture.

RANGE IN CHARACTERISTICS: Solum thickness ranges from 10 to 20 inches. Siliate clay ranges from 20 to 35 percent in the control section. The soil is calcareous and ranges from 40 to more than 80 percent calcium carbonate equivalent.

The A horizon has colors in hues of 10YR, value 4 to 6, and chroma of 2 to 4. Where the horizon has moist values and chromas of 3 or less, it is less than 7 inches thick. It is silty clay loam or clay loam. Fragments of weakly cemented chalk range from none to about 15 percent by volume.

They are platy and range from 2 mm to 3 cm across the long axis. The fragments are weakly to strongly cemented when dry but most of the fragments slake or soften on soaking in water.

The Bw horizon has colors with hue of 10YR, value of 5 to 7, and chroma of 2 to 4. Some pedons have mottles of brown or yellow that are believed to be inherited from the parent material. It is silty clay loam, or clay loam, or their gravelly counterparts. Fragments of weakly to strongly cemented chalk range from a few to 35 percent by volume. However, upon soaking in water, the chalk fragments slake to where the percentage of strongly cemented fragments range from a few to about 20 percent by volume.

The Cr horizon has colors in shades of gray, brown or white. It is weakly cemented platy chalk interbedded with thin strata of light yellowish brown, pale yellow, brownish yellow, or olive yellow clay loam or silty clay loam. The platy fragments of chalk are weakly to strongly cemented but can be readily cut with a spade when moist. In most pedons the chalk becomes less fractured and more massive at 25 to 40 inches depth.

COMPETING SERIES: There are no other series in this family, similar families include the Altoga, Brackett, Cuthand, Dugout, Eddy, Howe, Seawillow, Shiner, Stephen, and Quinlan series. Altoga, Cuthand, Howe, and Seawillow soils have sola more than 20 inches thick. Brackett, Dugout, and Quinlan soils are dry in the moisture control section for longer periods of time. In addition, Brackett soils contain fragments of hard limestone, Dugout soils have a lithic contact to limestone and Quinlan soils have mixed mineralogy and B horizons with redder hues. Eddy soils lack B horizons and have more than 35 percent chalk fragments in the control section. Shiner soils have a mean annual soil temperature of more than 72 degrees F. Stephen soils have mollic epipedons and mixed mineralogy.

GEOGRAPHIC SETTING: Whitewright soils occupy gently sloping to moderately steep uplands. Slopes are mainly 4 to 10 percent but range from 1 to 15 percent. The soil formed in chalk and interbedded marl of the Austin Group of Upper Cretaceous Age. The mean annual temperature is 63 degrees to 66 degrees F. Average annual precipitation ranges from about 35 to 41 inches, and the Thornthwaite P-E index ranges from 56 to 66.

GEOGRAPHICALLY ASSOCIATED SOILS: These include the competing Eddy, Howe, and Stephen series as well as the Austin series. Eddy and Howe soils occupy similar positions. Stephen and Austin soils occupy slightly higher less sloping positions. Stephen and Austin soils have mollic epipedons, and in addition, Austin soils have sola thicker than 20 inches.

DRAINAGE AND PERMEABILITY: Well drained; rapid runoff; moderate permeability.

USE AND VEGETATION: Used mainly for pasture. A few areas are planted to small grain and sorghum. Dominant pasture grasses are King Ranch bluestem, common and improved bermudagrass. Areas that were formerly in cropland are growing silver bluestem, sideoats grama, hairy grama, little bluestem, threeawn, and annual weeds. Woody vegetation is mainly scattered elm, hackberry, and small oak trees.

DISTRIBUTION AND EXTENT: North-central Texas; in the Blackland Prairie Land Resource area. The series is of moderate extent.

MLRA OFFICE RESPONSIBLE: Temple, Texas

SERIES ESTABLISHED: Grayson County, Texas; 1977.

REMARKS: These soils were formerly as a shallow phase of the Austin series and in more recent years they were included in the Brackett series.

Diagnostic horizons and features recognized in this pedon are:

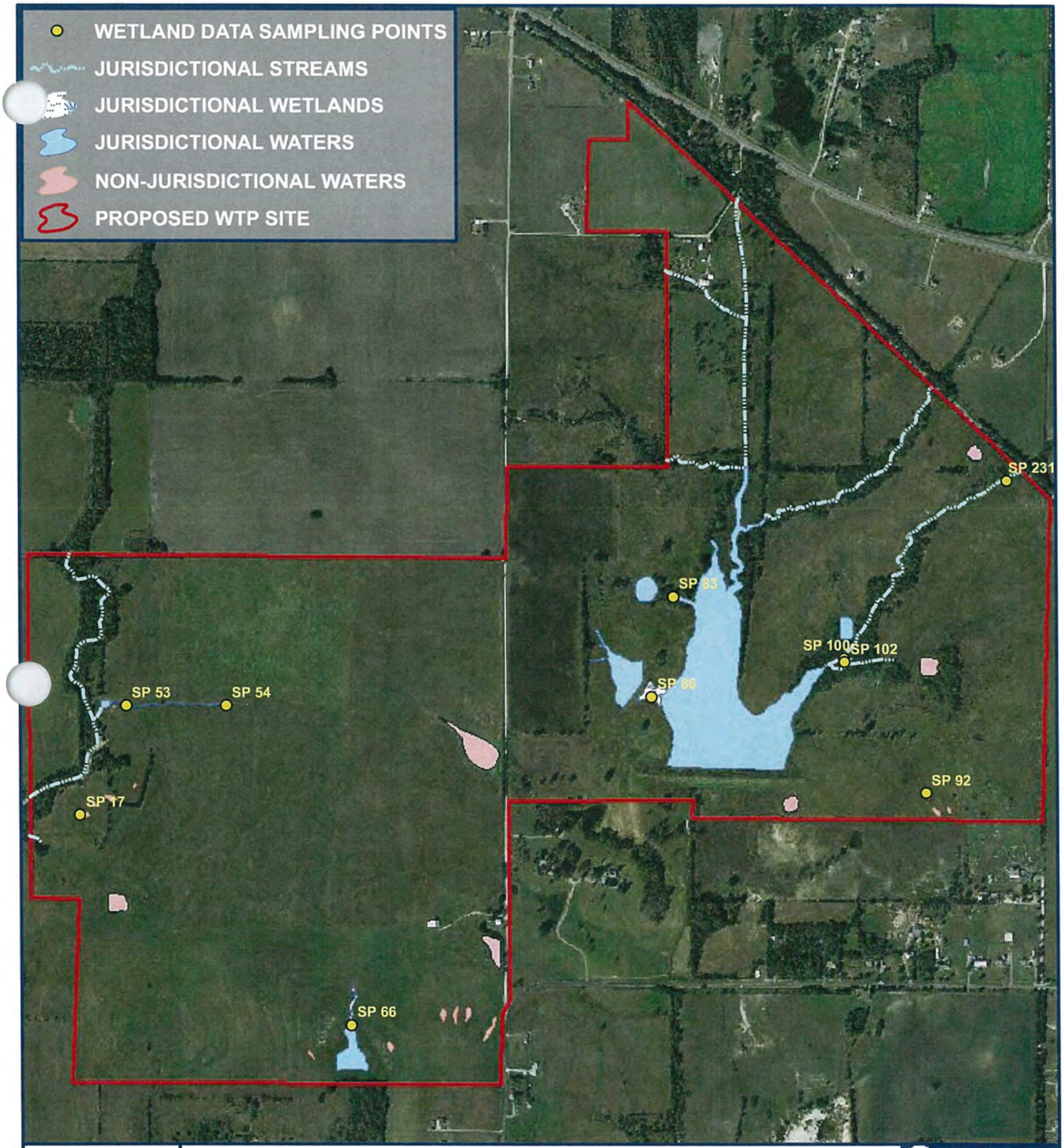
Ochric epipedon - 0 to 5 inches, the A horizon.

Calcic horizon - 5 to 16 inches, the Bk horizon.

Paralithic contact of chalk at a depth of 16 inches.

APPENDIX E

WETLAND DETERMINATION DATA FORMS AND SAMPLING LOCATIONS



N
W E
S

DATE:
DECEMBER 3, 2009

FIGURE E-1
WETLAND DETERMINATION DATA SAMPLING LOCATIONS PRELIMINARY JURISDICITONAL DETERMINATION OF WATERS OF THE U.S.
PROPOSED LEONARD WATER TREATMENT PLANT
NORTH TEXAS MUNICIPAL WATER DISTRICT

ALAN PLUMMER ASSOCIATES, INC.
1320 S. UNIVERSITY DRIVE
SUITE 300
FORT WORTH, TEXAS 76107
PHONE: (817) 806-1700
FAX: (817) 870-2536

FIGURE 1 OF 1

1,000 500 0 Feet

SOURCE:
LANDISCOR 2007 AERIAL PHOTOGRAPH

USACE PROJECT NUMBER:

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: PROPOSED WATER TREATMENT PLANT SITE City/County: LEONARD/FANNIN Sampling Date: 9/14/2009
Applicant/Owner: NORTH TEXAS MUNICIPAL WATER DISTRICT State: TEXAS Sampling Point: 17
Investigator(s): VOIGHT AND CAPPS Section, Township, Range: ---
Landform (hillslope, terrace, etc.): DEPRESSION Local relief (concave, convex, none): CONCAVE Slope (%): XX
Subregion (LRR): LRR J Lat: 33*23'0.758"N Long: 96*17'13.374"N Datum: NAD 83
Soil Map Unit Name: HOWE-WHITEWRIGHT COMPLEX, 3 TO 5 PERCENT SLOPES NWI classification: NONE
Are climatic / hydrologic conditions on the site typical for this time of year? Yes XX No ____ (If no, explain in Remarks.)
Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? NO Are "Normal Circumstances" present? Yes XX No ____
Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? NO (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present? Yes XX No ____
Hydric Soil Present? Yes XX No ____
Wetland Hydrology Present? Yes XX No ____

Is the Sampled Area within a Wetland? Yes XX No ____

Remarks:

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: ____)			
1. NONE			
2.			
3.			
4.			
= Total Cover			
Sapling/Shrub Stratum (Plot size: 15')			
1. GLEDITSIA TRIACANTHOS	2	XX	FAC
2.			
3.			
4.			
5.			
= Total Cover	2		
Herb Stratum (Plot size: 5')			
1. ELEOCHARIS COMPRESSA	30	XX	FACW
2. ELEOCHARIS PARVULA	30	XX	OBL
3. IVA ANNUA	25	XX	FAC
4. XANTHIUM STRUMARIUM	15		FAC-
5.			
6.			
7.			
8.			
9.			
10.			
= Total Cover	100		
Woody Vine Stratum (Plot size: ____)			
1. NONE			
2.			
= Total Cover			

% Bare Ground in Herb Stratum --

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC–): 4 (A)
Total Number of Dominant Species Across All Strata: 4 (B)
Percent of Dominant Species That Are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species		x 1 =
FACW species		x 2 =
FAC species		x 3 =
FACU species		x 4 =
UPL species		x 5 =
Column Totals:	(A)	(B)

Prevalence Index = B/A = ____

Hydrophytic Vegetation Indicators:

XX Dominance Test is >50%
__ Prevalence Index is ≤3.0[1]
__ Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
__ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes XX No ____

Remarks:

SOIL

Sampling Point: 17

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Type[1]	Loc[2]	Texture	Remarks
0-8	10YR 4/2	95	10YR 5/6	5	C	PL	CLAY	
8-16	10YR 6/2	95	10YR 5/6	5	C	PL	CLAY	

[1] Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2] Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

___ Histosol (A1)
___ Histic Epipedon (A2)
___ Black Histic (A3)
___ Hydrogen Sulfide (A4)
___ Stratified Layers (A5) (**LRR F**)
___ 1 cm Muck (A9) (**LRR F, G, H**)
___ Depleted Below Dark Surface (A11)
___ Thick Dark Surface (A12)
___ Sandy Mucky Mineral (S1)
___ 2.5 cm Mucky Peat or Peat (S2) (**LRR G, H**)
___ 5 cm Mucky Peat or Peat (S3) (**LRR F**)
___ Sandy Gleyed Matrix (S4)
___ Sandy Redox (S5)
___ Stripped Matrix (S6)
___ Loamy Mucky Mineral (F1)
___ Loamy Gleyed Matrix (F2)
___ Depleted Matrix (F3)
___ Redox Dark Surface (F6)
___ Depleted Dark Surface (F7)
XX Redox Depressions (F8)
___ High Plains Depressions (F16) (**MLRA 72 & 73 of LRR H**)

Indicators for Problematic Hydric Soils[3]:

___ 1 cm Muck (A9) (**LRR I, J**)
___ Coast Prairie Redox (A16) (**LRR F, G, H**)
___ Dark Surface (S7) (**LRR G**)
___ High Plains Depressions (F16) (**LRR H outside of MLRA 72 & 73**)
___ Reduced Vertic (F18)
___ Red Parent Material (TF2)
XX Other (Explain in Remarks)

[3] Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ______

Depth (inches): ______

Hydric Soil Present? Yes XX No ______

Remarks:
REDOX DEPRESSIONS PRESENT (F8). HYDROPHYTIC VEGETATION AND DISTINCT HYDROLOGY WERE OBSERVED

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

XX Surface Water (A1)
___ High Water Table (A2)
XX Saturation (A3)
___ Water Marks (B1)
___ Sediment Deposits (B2)
___ Drift Deposits (B3)
___ Algal Mat or Crust (B4)
___ Iron Deposits (B5)
___ Inundation Visible on Aerial Imagery (B7)
___ Water-Stained Leaves (B9)
___ Salt Crust (B11)
___ Aquatic Invertebrates (B13)
___ Hydrogen Sulfide Odor (C1)
___ Dry-Season Water Table (C2)
XX Oxidized Rhizospheres on Living Roots (C3) (**where not tilled**)
___ Presence of Reduced Iron (C4)
___ Thin Muck Surface (C7)
___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

___ Surface Soil Cracks (B6)
___ Sparsely Vegetated Concave Surface (B8)
___ Drainage Patterns (B10)
___ Oxidized Rhizospheres on Living Roots (C3) (**where tilled**)
___ Crayfish Burrows (C8)
___ Saturation Visible on Aerial Imagery (C9)
___ Geomorphic Position (D2)
XX FAC-Neutral Test (D5)
___ Frost-Heave Hummocks (D7) (**LRR F**)

Field Observations:

Surface Water Present? Yes XX No ______ Depth (inches): 2
Water Table Present? Yes ______ No ______ Depth (inches): UNKNOWN
Saturation Present? (includes capillary fringe) Yes XX No ______ Depth (inches): 0

Wetland Hydrology Present? Yes XX No ______

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: PROPOSED WATER TREATMENT PLANT SITE City/County: LEONARD/FANNIN Sampling Date: 9/14/2009
Applicant/Owner: NORTH TEXAS MUNICIPAL WATER DISTRICT State: TEXAS Sampling Point: 53
Investigator(s): VOIGHT AND CAPPS Section, Township, Range: ---
Landform (hillslope, terrace, etc.): SWALE Local relief (concave, convex, none): CONCAVE Slope (%): --
Subregion (LRR): LRR J Lat: 32*23'8.98"N Long: 96*17'9.309"W Datum: NAD 83
Soil Map Unit Name: FAIRLIE-DALCO COMPLEX, 1 TO 3 PERCENT SLOPES NWI classification: NONE
Are climatic / hydrologic conditions on the site typical for this time of year? Yes XX No ______ (If no, explain in Remarks.)
Are Vegetation ______, Soil ______, or Hydrology ______ significantly disturbed? NO Are "Normal Circumstances" present? Yes XX No ______
Are Vegetation ______, Soil ______, or Hydrology ______ naturally problematic? NO (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes XX No ______	Is the Sampled Area within a Wetland?	Yes XX No ______
Hydric Soil Present?	Yes XX No ______		
Wetland Hydrology Present?	Yes XX No ______		

Remarks:
SITE IS LOCATED EAST OF A POND ALONG A SWALE DOMINATED BY SPIKERUSH AND SUMPWEED.

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: 30')			
1. NONE			
2.			
3.			
4.			
= Total Cover			
Sapling/Shrub Stratum (Plot size: 15')			
1. NONE			
2.			
3.			
4.			
5.			
= Total Cover			
Herb Stratum (Plot size: 5')			
1. ELEOCHARIS COMPRESSA	35	XX	FACW
2. IVA ANNUA	35	XX	FAC
3. ELEOCHARIS PARVULA	2		OBL
4. XANTHIUM STRUMARIUM	2		FAC-
5.			
6.			
7.			
8.			
9.			
10.			
= Total Cover	74		
Woody Vine Stratum (Plot size: 30')			
1. NONE			
2.			
= Total Cover			

% Bare Ground in Herb Stratum 5

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC–):	2	(A)
Total Number of Dominant Species Across All Strata:	2	(B)
Percent of Dominant Species That Are OBL, FACW, or FAC:	100	(A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species		x 1 =
FACW species		x 2 =
FAC species		x 3 =
FACU species		x 4 =
UPL species		x 5 =
Column Totals:	(A)	(B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:

XX Dominance Test is >50%
__ Prevalence Index is ≤3.0[1]
__ Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
__ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes XX No ______

Remarks:

SOIL

Sampling Point: 53

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix		Redox Features				Texture	Remarks
	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]		
0-4	10YR 4/1	100					CLAY	
4-16	10YR 5/2	96	10YR 5/6	4	C	PL	CLAY	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5) (**LRR F**)
- ___ 1 cm Muck (A9) (**LRR F, G, H**)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 2.5 cm Mucky Peat or Peat (S2) (**LRR G, H**)
- ___ 5 cm Mucky Peat or Peat (S3) (**LRR F**)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ High Plains Depressions (F16)
  (MLRA 72 & 73 of LRR H)

Indicators for Problematic Hydric Soils[3]:

- ___ 1 cm Muck (A9) (**LRR I, J**)
- ___ Coast Prairie Redox (A16) (**LRR F, G, H**)
- ___ Dark Surface (S7) (**LRR G**)
- ___ High Plains Depressions (F16)
  (LRR H outside of MLRA 72 & 73)
- ___ Reduced Vertic (F18)
- ___ Red Parent Material (TF2)
- XX Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ____________

Depth (inches): ____________

Hydric Soil Present? Yes XX No ____

Remarks:
HYDROPHYTIC VEGETATION AND DISTINCT HYDROLOGY WERE OBSERVED.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- XX Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Water-Stained Leaves (B9)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Dry-Season Water Table (C2)
- XX Oxidized Rhizospheres on Living Roots (C3)
  (where not tilled)
- ___ Presence of Reduced Iron (C4)
- ___ Thin Muck Surface (C7)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Sparsely Vegetated Concave Surface (B8)
- XX Drainage Patterns (B10)
- ___ Oxidized Rhizospheres on Living Roots (C3)
  (where tilled)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- XX FAC-Neutral Test (D5)
- ___ Frost-Heave Hummocks (D7) (**LRR F**)

Field Observations:

Surface Water Present? Yes ____ No XX Depth (inches): ____

Water Table Present? Yes ____ No XX Depth (inches): ____

Saturation Present? Yes ____ No XX Depth (inches): ____
(includes capillary fringe)

Wetland Hydrology Present? Yes XX No ____

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: PROPOSED WATER TREATMENT PLANT SITE City/County: LEONARD/FANNIN Sampling Date: 9/14/2009
Applicant/Owner: NORTH TEXAS MUNICIPAL WATER DISTRICT State: TEXAS Sampling Point: 54
Investigator(s): VOIGHT AND CAPPS Section, Township, Range: ---
Landform (hillslope, terrace, etc.): SWALE Local relief (concave, convex, none): CONCAVE Slope (%): --
Subregion (LRR): LRR J Lat: 32*23'8.82"N Long: 96*17'0.289"W Datum: NAD 83
Soil Map Unit Name: FAIRLIE-DALCO COMPLEX, 1 TO 3 PERCENT SLOPES NWI classification: NONE
Are climatic / hydrologic conditions on the site typical for this time of year? Yes XX No ____ (If no, explain in Remarks.)
Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? NO Are "Normal Circumstances" present? Yes XX No ____
Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? NO (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes XX	No ____
Hydric Soil Present?	Yes ____	No XX
Wetland Hydrology Present?	Yes ____	No XX

Is the Sampled Area within a Wetland? Yes ____ No XX

Remarks:
SITE IS LOCATED EAST OF SP 53 TOWARDS THE TERMINUS OF A SWALE.

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: 30')			
1. NONE			
2.			
3.			
4.			
= Total Cover			
Sapling/Shrub Stratum (Plot size: 15')			
1. NONE			
2.			
3.			
4.			
5.			
= Total Cover			
Herb Stratum (Plot size: 5')			
1. XANTHIUM STRUMARIUM	40	XX	FAC-
2. IVA ANNUA	30	XX	FAC
3. HELIANTHUS ANNUUS	15	XX	FAC
4. CAREX SPP.	8		FAC-OBL
5. CYNODON DACTYLON	7		FACU+
6.			
7.			
8.			
9.			
10.			
= Total Cover	74		
Woody Vine Stratum (Plot size: 30')			
1. NONE			
2.			
= Total Cover			

% Bare Ground in Herb Stratum 0

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC−):	2	(A)
Total Number of Dominant Species Across All Strata:	3	(B)
Percent of Dominant Species That Are OBL, FACW, or FAC:	67	(A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species		x 1 =
FACW species		x 2 =
FAC species		x 3 =
FACU species		x 4 =
UPL species		x 5 =
Column Totals:	(A)	(B)

Prevalence Index = B/A = ____

Hydrophytic Vegetation Indicators:

XX Dominance Test is >50%
__ Prevalence Index is ≤3.0[1]
__ Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
__ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes XX No ____

Remarks:

SOIL

Sampling Point: 54

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-6	10YR 4/1	100					CLAY	
6-16	10YR 3/1	100					CLAY	

[1] Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2] Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

___ Histosol (A1)
___ Histic Epipedon (A2)
___ Black Histic (A3)
___ Hydrogen Sulfide (A4)
___ Stratified Layers (A5) (**LRR F**)
___ 1 cm Muck (A9) (**LRR F, G, H**)
___ Depleted Below Dark Surface (A11)
___ Thick Dark Surface (A12)
___ Sandy Mucky Mineral (S1)
___ 2.5 cm Mucky Peat or Peat (S2) (**LRR G, H**)
___ 5 cm Mucky Peat or Peat (S3) (**LRR F**)
___ Sandy Gleyed Matrix (S4)
___ Sandy Redox (S5)
___ Stripped Matrix (S6)
___ Loamy Mucky Mineral (F1)
___ Loamy Gleyed Matrix (F2)
___ Depleted Matrix (F3)
___ Redox Dark Surface (F6)
___ Depleted Dark Surface (F7)
___ Redox Depressions (F8)
___ High Plains Depressions (F16)
(MLRA 72 & 73 of LRR H)

Indicators for Problematic Hydric Soils[3]:

___ 1 cm Muck (A9) (**LRR I, J**)
___ Coast Prairie Redox (A16) (**LRR F, G, H**)
___ Dark Surface (S7) (**LRR G**)
___ High Plains Depressions (F16)
(**LRR H outside of MLRA 72 & 73**)
___ Reduced Vertic (F18)
___ Red Parent Material (TF2)
___ Other (Explain in Remarks)

[3] Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ______

Depth (inches): ______

Hydric Soil Present? Yes ______ No XX

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

___ Surface Water (A1)
___ High Water Table (A2)
___ Saturation (A3)
___ Water Marks (B1)
___ Sediment Deposits (B2)
___ Drift Deposits (B3)
___ Algal Mat or Crust (B4)
___ Iron Deposits (B5)
___ Inundation Visible on Aerial Imagery (B7)
___ Water-Stained Leaves (B9)
___ Salt Crust (B11)
___ Aquatic Invertebrates (B13)
___ Hydrogen Sulfide Odor (C1)
___ Dry-Season Water Table (C2)
___ Oxidized Rhizospheres on Living Roots (C3)
(where not tilled)
___ Presence of Reduced Iron (C4)
___ Thin Muck Surface (C7)
___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

___ Surface Soil Cracks (B6)
___ Sparsely Vegetated Concave Surface (B8)
XX Drainage Patterns (B10)
___ Oxidized Rhizospheres on Living Roots (C3)
(where tilled)
___ Crayfish Burrows (C8)
___ Saturation Visible on Aerial Imagery (C9)
___ Geomorphic Position (D2)
___ FAC-Neutral Test (D5)
___ Frost-Heave Hummocks (D7) (**LRR F**)

Field Observations:

Surface Water Present? Yes ______ No XX Depth (inches): ______

Water Table Present? Yes ______ No XX Depth (inches): ______

Saturation Present? (includes capillary fringe) Yes ______ No XX Depth (inches): ______

Wetland Hydrology Present? Yes ______ No XX

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: PROPOSED WATER TREATMENT PLANT SITE City/County: LEONARD/FANNIN Sampling Date: 9/14/2009

Applicant/Owner: NORTH TEXAS MUNICIPAL WATER DISTRICT State: TEXAS Sampling Point: 66

Investigator(s): VOIGHT AND CAPPS Section, Township, Range: ---

Landform (hillslope, terrace, etc.): SWALE Local relief (concave, convex, none): CONCAVE Slope (%): --

Subregion (LRR): LRR J Lat: 32*22'45.1"N Long: 96*16'49.973"W Datum: NAD 83

Soil Map Unit Name: FAIRLIE-DALCO COMPLEX, 1 TO 3 PERCENT SLOPES NWI classification: POWHh

Are climatic / hydrologic conditions on the site typical for this time of year? Yes XX No ____ (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? NO Are "Normal Circumstances" present? Yes XX No ____

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? NO (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes XX No ____	**Is the Sampled Area within a Wetland?** Yes XX No ____
Hydric Soil Present?	Yes XX No ____	
Wetland Hydrology Present?	Yes XX No ____	

Remarks:
SITE IS LOCATED NORTH OF AN ON-CHANNEL POND ALONG A SWALE DOMINATED BY SPIKERUSH AND SEDGE.

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: 30')			
1. NONE			
2.			
3.			
4.			
= Total Cover			
Sapling/Shrub Stratum (Plot size: 15')			
1. NONE			
2.			
3.			
4.			
5.			
= Total Cover			
Herb Stratum (Plot size: 5')			
1. ELEOCHARIS COMPRESSA	60	XX	FACW
2. CAREX SPP.	20	XX	FAC
3. JUNCUS EFFUSUS	5		OBL
4. XANTHIUM STRUMARIUM	5		FAC-
5.			
6.			
7.			
8.			
9.			
10.			
= Total Cover	90		
Woody Vine Stratum (Plot size: 30')			
1. NONE			
2.			
= Total Cover			
% Bare Ground in Herb Stratum 10			

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC−):	2	(A)
Total Number of Dominant Species Across All Strata:	2	(B)
Percent of Dominant Species That Are OBL, FACW, or FAC:	100	(A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species		x 1 =
FACW species		x 2 =
FAC species		x 3 =
FACU species		x 4 =
UPL species		x 5 =
Column Totals:	(A)	(B)

Prevalence Index = B/A = ____

Hydrophytic Vegetation Indicators:

XX Dominance Test is >50%
__ Prevalence Index is ≤3.0[1]
__ Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
__ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes XX No ____

Remarks:

SOIL

Sampling Point: 66

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Redox Features Type[1]	Redox Features Loc[2]	Texture	Remarks
0-9	10YR 4/1	95	10YR 5/6	5	C	PL	CLAY	
9-16	10YR 3/1	100					CLAY	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

___ Histosol (A1)
___ Histic Epipedon (A2)
___ Black Histic (A3)
___ Hydrogen Sulfide (A4)
___ Stratified Layers (A5) (**LRR F**)
___ 1 cm Muck (A9) (**LRR F, G, H**)
___ Depleted Below Dark Surface (A11)
___ Thick Dark Surface (A12)
___ Sandy Mucky Mineral (S1)
___ 2.5 cm Mucky Peat or Peat (S2) (**LRR G, H**)
___ 5 cm Mucky Peat or Peat (S3) (**LRR F**)
___ Sandy Gleyed Matrix (S4)
___ Sandy Redox (S5)
___ Stripped Matrix (S6)
___ Loamy Mucky Mineral (F1)
___ Loamy Gleyed Matrix (F2)
___ Depleted Matrix (F3)
XX Redox Dark Surface (F6)
___ Depleted Dark Surface (F7)
___ Redox Depressions (F8)
___ High Plains Depressions (F16)
(MLRA 72 & 73 of LRR H)

Indicators for Problematic Hydric Soils[3]:

___ 1 cm Muck (A9) (**LRR I, J**)
___ Coast Prairie Redox (A16) (**LRR F, G, H**)
___ Dark Surface (S7) (**LRR G**)
___ High Plains Depressions (F16)
(**LRR H outside of MLRA 72 & 73**)
___ Reduced Vertic (F18)
___ Red Parent Material (TF2)
XX Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):
Type: ___
Depth (inches): ___

Hydric Soil Present? Yes XX No ___

Remarks:
HYDROPHYTIC VEGETATION AND DISTINCT HYDROLOGY WERE OBSERVED.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

___ Surface Water (A1)
___ High Water Table (A2)
XX Saturation (A3)
___ Water Marks (B1)
___ Sediment Deposits (B2)
XX Drift Deposits (B3)
___ Algal Mat or Crust (B4)
___ Iron Deposits (B5)
___ Inundation Visible on Aerial Imagery (B7)
___ Water-Stained Leaves (B9)
___ Salt Crust (B11)
___ Aquatic Invertebrates (B13)
___ Hydrogen Sulfide Odor (C1)
___ Dry-Season Water Table (C2)
XX Oxidized Rhizospheres on Living Roots (C3)
(where not tilled)
___ Presence of Reduced Iron (C4)
___ Thin Muck Surface (C7)
___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

___ Surface Soil Cracks (B6)
___ Sparsely Vegetated Concave Surface (B8)
XX Drainage Patterns (B10)
___ Oxidized Rhizospheres on Living Roots (C3)
(where tilled)
___ Crayfish Burrows (C8)
___ Saturation Visible on Aerial Imagery (C9)
___ Geomorphic Position (D2)
XX FAC-Neutral Test (D5)
___ Frost-Heave Hummocks (D7) (**LRR F**)

Field Observations:
Surface Water Present? Yes ___ No XX Depth (inches): ___
Water Table Present? Yes ___ No XX Depth (inches): ___
Saturation Present? (includes capillary fringe) Yes XX No ___ Depth (inches): 2

Wetland Hydrology Present? Yes XX No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: PROPOSED WATER TREATMENT PLANT SITE City/County: LEONARD/FANNIN Sampling Date: 9/15/2009
Applicant/Owner: NORTH TEXAS MUNICIPAL WATER DISTRICT State: TEXAS Sampling Point: 83
Investigator(s): VOIGHT AND CAPPS Section, Township, Range: ---
Landform (hillslope, terrace, etc.): SWALE Local relief (concave, convex, none): CONCAVE Slope (%): XX
Subregion (LRR): LRR J Lat: 33*23'16.549"N Long: 96*16'19.388"N Datum: NAD 83
Soil Map Unit Name: HOWE-WHITEWRIGHT COMPLEX, 3 TO 5 PERCENT SLOPES NWI classification: NONE
Are climatic / hydrologic conditions on the site typical for this time of year? Yes XX No ___ (If no, explain in Remarks.)
Are Vegetation ___, Soil ___, or Hydrology ___ significantly disturbed? NO Are "Normal Circumstances" present? Yes XX No ___
Are Vegetation ___, Soil ___, or Hydrology ___ naturally problematic? NO (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ___	No XX
Hydric Soil Present?	Yes ___	No XX
Wetland Hydrology Present?	Yes XX	No ___

Is the Sampled Area within a Wetland? **Yes** ___ **No** XX

Remarks:
THIS SITE IS LOCATED BETWEEN A POND AND THE IMPOUNDMENT OF LEE CREEK UPSTREAM OF AN AREA DOMINATED BY ARROWHEAD.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size: 30')	Absolute % Cover	Dominant Species?	Indicator Status
1. MACLURA POMIFERA	45	XX	UPL
2. ULMUS CRASSIFOLIA	35	XX	FAC
3. FRAXINUS PENNSYLVANICA	1		FACW-
4.			
	81	= Total Cover	
Sapling/Shrub Stratum (Plot size: 15')			
1. JUNIPERUS VIRGINIANA	1		FACU-
2.			
3.			
4.			
5.			
	1	= Total Cover	
Herb Stratum (Plot size: 5')			
1. XANTHIUM STRUMARIUM	1		FAC-
2. CAREX SPP.	1		FAC-OBL
3. ELYMUS VIRGINICUS	1		FAC
4. SYMPHORICARPOS ORBICULATUS	1		FACU
5.			
6.			
7.			
8.			
9.			
10.			
	4	= Total Cover	
Woody Vine Stratum (Plot size: 30')			
1. NONE			
2.			
		= Total Cover	

% Bare Ground in Herb Stratum 20

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC–):	1	(A)
Total Number of Dominant Species Across All Strata:	2	(B)
Percent of Dominant Species That Are OBL, FACW, or FAC:	50	(A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species		x 1 =
FACW species		x 2 =
FAC species		x 3 =
FACU species		x 4 =
UPL species		x 5 =
Column Totals:	(A)	(B)

Prevalence Index = B/A = ___

Hydrophytic Vegetation Indicators:

- __ Dominance Test is >50%
- __ Prevalence Index is ≤3.0[1]
- __ Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- __ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes** XX **No** ___

Remarks:
THIS SITE IS LOCATED UPSLOPE OF WHAT APPEARS TO BE A FORMER TRIBUTARY CHANNEL TO LEE CREEK.

SOIL

Sampling Point: 17

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-8	10YR 4/1	100					CLAY	
8-16	10YR 4/1	98	10YR 6/3	2	C	M	CLAY	

[1] Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2] Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5) (**LRR F**)
- ___ 1 cm Muck (A9) (**LRR F, G, H**)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 2.5 cm Mucky Peat or Peat (S2) (**LRR G, H**)
- ___ 5 cm Mucky Peat or Peat (S3) (**LRR F**)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ High Plains Depressions (F16)
  (**MLRA 72 & 73 of LRR H**)

Indicators for Problematic Hydric Soils[3]:

- ___ 1 cm Muck (A9) (**LRR I, J**)
- ___ Coast Prairie Redox (A16) (**LRR F, G, H**)
- ___ Dark Surface (S7) (**LRR G**)
- ___ High Plains Depressions (F16)
  (**LRR H outside of MLRA 72 & 73**)
- ___ Reduced Vertic (F18)
- ___ Red Parent Material (TF2)
- ___ Other (Explain in Remarks)

[3] Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ______

Depth (inches): ______

Hydric Soil Present? **Yes** ______ **No** XX

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- XX High Water Table (A2)
- XX Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Water-Stained Leaves (B9)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Dry-Season Water Table (C2)
- ___ Oxidized Rhizospheres on Living Roots (C3)
  (**where not tilled**)
- ___ Presence of Reduced Iron (C4)
- ___ Thin Muck Surface (C7)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Drainage Patterns (B10)
- ___ Oxidized Rhizospheres on Living Roots (C3)
  (**where tilled**)
- XX Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)
- ___ Frost-Heave Hummocks (D7) (**LRR F**)

Field Observations:

Surface Water Present? Yes ______ No XX Depth (inches): ______

Water Table Present? Yes XX No ______ Depth (inches): 6

Saturation Present? (includes capillary fringe) Yes XX No ______ Depth (inches): 6

Wetland Hydrology Present? **Yes** XX **No** ______

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:
AREA HAD RECENTLY EXPERIENCED A 5 TO 6 INCH RAIN, INCLUDING RAIN PRIOR TO ON-SITE INVESTIGATION.

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: PROPOSED WATER TREATMENT PLANT SITE City/County: LEONARD/FANNIN Sampling Date: 9/15/2009

Applicant/Owner: NORTH TEXAS MUNICIPAL WATER DISTRICT State: TEXAS Sampling Point: 86

Investigator(s): VOIGHT AND CAPPS Section, Township, Range: ---

Landform (hillslope, terrace, etc.): SWALE Local relief (concave, convex, none): CONCAVE Slope (%): XX

Subregion (LRR): LRR J Lat: 33*23'8.847"N Long: 96*16'22.431"N Datum: NAD 83

Soil Map Unit Name: HOWE-WHITEWRIGHT COMPLEX, 3 TO 5 PERCENT SLOPES NWI classification: NONE

Are climatic / hydrologic conditions on the site typical for this time of year? Yes XX No ______ (If no, explain in Remarks.)

Are Vegetation ______, Soil ______, or Hydrology ______ significantly disturbed? NO Are "Normal Circumstances" present? Yes XX No ______

Are Vegetation ______, Soil ______, or Hydrology ______ naturally problematic? NO (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes XX No ______	Is the Sampled Area within a Wetland?	Yes XX No ______
Hydric Soil Present?	Yes XX No ______		
Wetland Hydrology Present?	Yes XX No ______		

Remarks:
THIS SITE IS LOCATED BETWEEN AN ON-CHANNEL POND AND THE LEE CREEK IMPOUNDMENT IN AN AREA DOMINATED BY SPIKERUSH. IMMEDIATELY OUTSIDE OF SPIKERUSH, BERMUDA DOMINATES.

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: 30')			
1. NONE			
2.			
3.			
4.			
= Total Cover			
Sapling/Shrub Stratum (Plot size: 15')			
1. NONE			
2.			
3.			
4.			
5.			
= Total Cover			
Herb Stratum (Plot size: 5')			
1. ELEOCHARIS COMPRESSA	80	XX	FACW
2. CARDIOSPERMUM HALICACABUM	2		FAC
3. IVA ANNUA	2		FAC
4. XANTHIUM STRUMARIUM	2		FAC-
5.			
6.			
7.			
8.			
9.			
10.			
= Total Cover	86		
Woody Vine Stratum (Plot size: 30')			
1. NONE			
2.			
= Total Cover			
% Bare Ground in Herb Stratum 14			

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC–):	1	(A)
Total Number of Dominant Species Across All Strata:	1	(B)
Percent of Dominant Species That Are OBL, FACW, or FAC:	100	(A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species		x 1 =
FACW species		x 2 =
FAC species		x 3 =
FACU species		x 4 =
UPL species		x 5 =
Column Totals:	(A)	(B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:

XX Dominance Test is >50%

__ Prevalence Index is ≤3.0[1]

__ Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

__ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes XX No ______

Remarks:

SOIL

Sampling Point: 86

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix		Redox Features				Texture	Remarks
	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]		
0-7	10YR 4/2	98	10YR 5/6	2	C	PL	CLAY	
7-16	10YR 6/2	95	10YR 5/6	5	C	PL	CLAY	

[1] Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2] Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

___ Histosol (A1)
___ Histic Epipedon (A2)
___ Black Histic (A3)
___ Hydrogen Sulfide (A4)
___ Stratified Layers (A5) (**LRR F**)
___ 1 cm Muck (A9) (**LRR F, G, H**)
___ Depleted Below Dark Surface (A11)
___ Thick Dark Surface (A12)
___ Sandy Mucky Mineral (S1)
___ 2.5 cm Mucky Peat or Peat (S2) (**LRR G, H**)
___ 5 cm Mucky Peat or Peat (S3) (**LRR F**)
___ Sandy Gleyed Matrix (S4)
___ Sandy Redox (S5)
___ Stripped Matrix (S6)
___ Loamy Mucky Mineral (F1)
___ Loamy Gleyed Matrix (F2)
___ Depleted Matrix (F3)
___ Redox Dark Surface (F6)
___ Depleted Dark Surface (F7)
___ Redox Depressions (F8)
___ High Plains Depressions (F16) (**MLRA 72 & 73 of LRR H**)

Indicators for Problematic Hydric Soils[3]:

___ 1 cm Muck (A9) (**LRR I, J**)
___ Coast Prairie Redox (A16) (**LRR F, G, H**)
___ Dark Surface (S7) (**LRR G**)
___ High Plains Depressions (F16) (**LRR H outside of MLRA 72 & 73**)
___ Reduced Vertic (F18)
___ Red Parent Material (TF2)
XX Other (Explain in Remarks)

[3] Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):
Type: ___
Depth (inches): ___

Hydric Soil Present? Yes XX No ___

Remarks:
HYDROPHYTIC VEGETATION AND DISTINCT HYDROLOGY WERE OBSERVED.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

___ Surface Water (A1)
XX High Water Table (A2)
XX Saturation (A3)
___ Water Marks (B1)
___ Sediment Deposits (B2)
___ Drift Deposits (B3)
___ Algal Mat or Crust (B4)
___ Iron Deposits (B5)
___ Inundation Visible on Aerial Imagery (B7)
___ Water-Stained Leaves (B9)
___ Salt Crust (B11)
___ Aquatic Invertebrates (B13)
___ Hydrogen Sulfide Odor (C1)
___ Dry-Season Water Table (C2)
XX Oxidized Rhizospheres on Living Roots (C3) (**where not tilled**)
___ Presence of Reduced Iron (C4)
___ Thin Muck Surface (C7)
___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

___ Surface Soil Cracks (B6)
___ Sparsely Vegetated Concave Surface (B8)
___ Drainage Patterns (B10)
___ Oxidized Rhizospheres on Living Roots (C3) (**where tilled**)
XX Crayfish Burrows (C8)
___ Saturation Visible on Aerial Imagery (C9)
___ Geomorphic Position (D2)
XX FAC-Neutral Test (D5)
___ Frost-Heave Hummocks (D7) (**LRR F**)

Field Observations:

Surface Water Present? Yes ___ No XX Depth (inches): ___
Water Table Present? Yes XX No ___ Depth (inches): 14
Saturation Present? (includes capillary fringe) Yes XX No ___ Depth (inches): 0

Wetland Hydrology Present? Yes XX No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:
AREA HAD RECENTLY EXPERIENCED A 5 TO 6 INCH RAIN, INCLUDING RAIN PRIOR TO ON-SITE INVESTIGATION.

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: PROPOSED WATER TREATMENT PLANT SITE City/County: LEONARD/FANNIN Sampling Date: 9/15/2009
Applicant/Owner: NORTH TEXAS MUNICIPAL WATER DISTRICT State: TEXAS Sampling Point: 92
Investigator(s): VOIGHT AND CAPPS Section, Township, Range: ---
Landform (hillslope, terrace, etc.): DEPRESSION Local relief (concave, convex, none): CONCAVE Slope (%): --
Subregion (LRR): LRR J Lat: 32*23'0.932"N Long: 96*15'57.57"W Datum: NAD 83
Soil Map Unit Name: FAIRLIE-DALCO COMPLEX, 1 TO 3 PERCENT SLOPES NWI classification: NONE
Are climatic / hydrologic conditions on the site typical for this time of year? Yes XX No ____ (If no, explain in Remarks.)
Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? NO Are "Normal Circumstances" present? Yes XX No ____
Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? NO (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes XX	No ____	**Is the Sampled Area within a Wetland?** Yes XX No ____
Hydric Soil Present?	Yes XX	No ____	
Wetland Hydrology Present?	Yes XX	No ____	

Remarks:
SITE IS LOCATED BEHIND AN AREA THAT HAS BEEN TERRACED ALONG A HILLSIDE.

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: 30')			
1. NONE			
2.			
3.			
4.			
	= Total Cover		
Sapling/Shrub Stratum (Plot size: 15')			
1. NONE			
2.			
3.			
4.			
5.			
	= Total Cover		
Herb Stratum (Plot size: 5')			
1. CARDIOSPERMUM HALICACABUM	25	XX	FAC
2. XANTHIUM STRUMARIUM	25	XX	FAC-
3. ELEOCHARIS COMPRESSA	25	XX	FACW
4. PANICUM OBTUSUM	22	XX	FAC+
5.			
6.			
7.			
8.			
9.			
10.			
	97 = Total Cover		
Woody Vine Stratum (Plot size: 30')			
1. NONE			
2.			
	= Total Cover		
% Bare Ground in Herb Stratum 3			

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC−):	3	(A)
Total Number of Dominant Species Across All Strata:	4	(B)
Percent of Dominant Species That Are OBL, FACW, or FAC:	75	(A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species		x 1 =
FACW species		x 2 =
FAC species		x 3 =
FACU species		x 4 =
UPL species		x 5 =
Column Totals:	(A)	(B)

Prevalence Index = B/A = ____

Hydrophytic Vegetation Indicators:

- XX Dominance Test is >50%
- ___ Prevalence Index is ≤3.0[1]
- ___ Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ___ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes XX No ____

Remarks:
SMALL POCKET OF FAC TO FACW VEGETATION SURROUNDED BY COASTAL BERMUDAGRASS PASTURE.

SOIL

Sampling Point: 92

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Type[1]	Loc[2]	Texture	Remarks
0-4	10YR 4/1	100					CLAY	CONTAIN LIMESTONE GRAVEL
4-16	10YR 5/2	96	10YR 5/6	4	C	PL	CLAY	CONTAIN LIMESTONE GRAVEL

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

___ Histosol (A1)
___ Histic Epipedon (A2)
___ Black Histic (A3)
___ Hydrogen Sulfide (A4)
___ Stratified Layers (A5) (**LRR F**)
___ 1 cm Muck (A9) (**LRR F, G, H**)
___ Depleted Below Dark Surface (A11)
___ Thick Dark Surface (A12)
___ Sandy Mucky Mineral (S1)
___ 2.5 cm Mucky Peat or Peat (S2) (**LRR G, H**)
___ 5 cm Mucky Peat or Peat (S3) (**LRR F**)
___ Sandy Gleyed Matrix (S4)
___ Sandy Redox (S5)
___ Stripped Matrix (S6)
___ Loamy Mucky Mineral (F1)
___ Loamy Gleyed Matrix (F2)
___ Depleted Matrix (F3)
___ Redox Dark Surface (F6)
___ Depleted Dark Surface (F7)
___ Redox Depressions (F8)
___ High Plains Depressions (F16) **(MLRA 72 & 73 of LRR H)**

Indicators for Problematic Hydric Soils[3]:

___ 1 cm Muck (A9) (**LRR I, J**)
___ Coast Prairie Redox (A16) (**LRR F, G, H**)
___ Dark Surface (S7) (**LRR G**)
___ High Plains Depressions (F16) **(LRR H outside of MLRA 72 & 73)**
___ Reduced Vertic (F18)
___ Red Parent Material (TF2)
XX Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ___

Depth (inches): ___

Hydric Soil Present? Yes XX No ___

Remarks:
HYDROPHYTIC VEGETATION AND DISTINCT HYDROLOGY WERE OBSERVED.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

___ Surface Water (A1)
___ High Water Table (A2)
XX Saturation (A3)
___ Water Marks (B1)
___ Sediment Deposits (B2)
___ Drift Deposits (B3)
___ Algal Mat or Crust (B4)
___ Iron Deposits (B5)
___ Inundation Visible on Aerial Imagery (B7)
___ Water-Stained Leaves (B9)
___ Salt Crust (B11)
___ Aquatic Invertebrates (B13)
___ Hydrogen Sulfide Odor (C1)
___ Dry-Season Water Table (C2)
XX Oxidized Rhizospheres on Living Roots (C3) **(where not tilled)**
___ Presence of Reduced Iron (C4)
___ Thin Muck Surface (C7)
___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

___ Surface Soil Cracks (B6)
___ Sparsely Vegetated Concave Surface (B8)
XX Drainage Patterns (B10)
___ Oxidized Rhizospheres on Living Roots (C3) **(where tilled)**
___ Crayfish Burrows (C8)
___ Saturation Visible on Aerial Imagery (C9)
___ Geomorphic Position (D2)
XX FAC-Neutral Test (D5)
___ Frost-Heave Hummocks (D7) (**LRR F**)

Field Observations:

Surface Water Present? Yes ___ No XX Depth (inches): ___
Water Table Present? Yes ___ No XX Depth (inches): ___
Saturation Present? (includes capillary fringe) Yes XX No ___ Depth (inches): 4

Wetland Hydrology Present? Yes XX No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:
HYDROLOGY COLLECTS OVERLAND STORMFLOW FROM IMMEDIATE WATERSHED.

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: PROPOSED WATER TREATMENT PLANT SITE City/County: LEONARD/FANNIN Sampling Date: 9/15/2009
Applicant/Owner: NORTH TEXAS MUNICIPAL WATER DISTRICT State: TEXAS Sampling Point: 100
Investigator(s): VOIGHT AND CAPPS Section, Township, Range: ---
Landform (hillslope, terrace, etc.): DEPRESSION Local relief (concave, convex, none): CONCAVE Slope (%): --
Subregion (LRR): LRR J Lat: 33*23'10.875"N Long: 96*16'6.37"W Datum: NAD 83
Soil Map Unit Name: TINN CLAY, OCCASSIONALLY FLOODED NWI classification: NONE
Are climatic / hydrologic conditions on the site typical for this time of year? Yes XX No ____ (If no, explain in Remarks.)
Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? NO Are "Normal Circumstances" present? Yes XX No ____
Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? NO (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes XX No ____	Is the Sampled Area within a Wetland?	Yes XX No ____
Hydric Soil Present?	Yes XX No ____		
Wetland Hydrology Present?	Yes XX No ____		

Remarks:
THIS SITE IS LOCATED NEAR THE CONFLUENCE OF TRIBUTARIES TO LEE CREEK AND THE LEE CREEK IMPOUNDMENT. FORESTED AREA ADJACENT TO AN APPARENT MEANDER SCAR.

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: 30')			
1. ULMUS CRASSIFOLIA	50	XX	FAC
2. FRAXINUS PENNSYLVANICA	50	XX	FACW-
3.			
4.			
	100 = Total Cover		
Sapling/Shrub Stratum (Plot size: 15')			
1. FRAXINUS PENNSYLVANICA	20	XX	FACW-
2.			
3.			
4.			
5.			
	20 = Total Cover		
Herb Stratum (Plot size: 5')			
1. POLYGONUM PENSYLVANICUM	40	XX	FACW-
2. SYMPHORICARPOS ORBICULATUS	10	XX	FACU
3. VIOLA MISSOURIENSIS	10		FACW
4.			
5.			
6.			
7.			
8.			
9.			
10.			
	60 = Total Cover		
Woody Vine Stratum (Plot size: 30')			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum 20

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC–):	5	(A)
Total Number of Dominant Species Across All Strata:	5	(B)
Percent of Dominant Species That Are OBL, FACW, or FAC:	100	(A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species		x 1 =
FACW species		x 2 =
FAC species		x 3 =
FACU species		x 4 =
UPL species		x 5 =
Column Totals:	(A)	(B)

Prevalence Index = B/A = ____

Hydrophytic Vegetation Indicators:

XX Dominance Test is >50%
__ Prevalence Index is ≤3.0[1]
__ Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
__ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes XX No ____

Remarks:

SOIL

Sampling Point: 100

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Type[1]	Loc[2]	Texture	Remarks
0-16	10YR 3/1	99	10YR 5/6	1	C	PL	CLAY	

[1] Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2] Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

___ Histosol (A1)
___ Histic Epipedon (A2)
___ Black Histic (A3)
___ Hydrogen Sulfide (A4)
___ Stratified Layers (A5) (**LRR F**)
___ 1 cm Muck (A9) (**LRR F, G, H**)
___ Depleted Below Dark Surface (A11)
___ Thick Dark Surface (A12)
___ Sandy Mucky Mineral (S1)
___ 2.5 cm Mucky Peat or Peat (S2) (**LRR G, H**)
___ 5 cm Mucky Peat or Peat (S3) (**LRR F**)
___ Sandy Gleyed Matrix (S4)
___ Sandy Redox (S5)
___ Stripped Matrix (S6)
___ Loamy Mucky Mineral (F1)
___ Loamy Gleyed Matrix (F2)
___ Depleted Matrix (F3)
XX Redox Dark Surface (F6)
___ Depleted Dark Surface (F7)
___ Redox Depressions (F8)
___ High Plains Depressions (F16)
(**MLRA 72 & 73 of LRR H**)

Indicators for Problematic Hydric Soils[3]:

___ 1 cm Muck (A9) (**LRR I, J**)
___ Coast Prairie Redox (A16) (**LRR F, G, H**)
___ Dark Surface (S7) (**LRR G**)
___ High Plains Depressions (F16)
(**LRR H outside of MLRA 72 & 73**)
___ Reduced Vertic (F18)
___ Red Parent Material (TF2)
XX Other (Explain in Remarks)

[3] Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):
Type: ___
Depth (inches): ___

Hydric Soil Present? Yes XX No ___

Remarks:
HYDROPHYTIC VEGETATION AND DISTINCT HYDROLOGY WERE OBSERVED.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

___ Surface Water (A1)
XX High Water Table (A2)
XX Saturation (A3)
___ Water Marks (B1)
___ Sediment Deposits (B2)
___ Drift Deposits (B3)
___ Algal Mat or Crust (B4)
___ Iron Deposits (B5)
___ Inundation Visible on Aerial Imagery (B7)
___ Water-Stained Leaves (B9)
___ Salt Crust (B11)
___ Aquatic Invertebrates (B13) .
___ Hydrogen Sulfide Odor (C1)
___ Dry-Season Water Table (C2)
XX Oxidized Rhizospheres on Living Roots (C3)
(**where not tilled**)
___ Presence of Reduced Iron (C4)
___ Thin Muck Surface (C7)
___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

___ Surface Soil Cracks (B6)
___ Sparsely Vegetated Concave Surface (B8)
XX Drainage Patterns (B10)
___ Oxidized Rhizospheres on Living Roots (C3)
(**where tilled**)
___ Crayfish Burrows (C8)
___ Saturation Visible on Aerial Imagery (C9)
___ Geomorphic Position (D2)
XX FAC-Neutral Test (D5)
___ Frost-Heave Hummocks (D7) (**LRR F**)

Field Observations:

Surface Water Present? Yes ___ No XX Depth (inches): ___
Water Table Present? Yes XX No ___ Depth (inches): 16
Saturation Present? (includes capillary fringe) Yes XX No ___ Depth (inches): 3

Wetland Hydrology Present? Yes XX No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:
AREA EXPERIENCED RECENT HEAVY RAINS.

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: PROPOSED WATER TREATMENT PLANT SITE City/County: LEONARD/FANNIN Sampling Date: 9/15/2009

Applicant/Owner: NORTH TEXAS MUNICIPAL WATER DISTRICT State: TEXAS Sampling Point: 102

Investigator(s): VOIGHT AND CAPPS Section, Township, Range: ---

Landform (hillslope, terrace, etc.): DEPRESSION Local relief (concave, convex, none): CONCAVE Slope (%): --

Subregion (LRR): LRR J Lat: 33*23'10.321"N Long: 96*16'6.359"W Datum: NAD 83

Soil Map Unit Name: TINN CLAY, OCCASSIONALLY FLOODED NWI classification: NONE

Are climatic / hydrologic conditions on the site typical for this time of year? Yes XX No ____ (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? NO Are "Normal Circumstances" present? Yes XX No ____

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? NO (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes XX	No ____
Hydric Soil Present?	Yes ____	No XX
Wetland Hydrology Present?	Yes ____	No XX

Is the Sampled Area within a Wetland? Yes ____ No XX

Remarks:
THIS SITE IS LOCATED SOUTH AND UPSLOPE OF SP 100.

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: 30')			
1. ULMUS CRASSIFOLIA	70	XX	FAC
2. FRAXINUS PENNSYLVANICA	30	XX	FACW-
3.			
4.			
	100	= Total Cover	
Sapling/Shrub Stratum (Plot size: 15')			
1. ULMUS CRASSIFOLIA	30	XX	FAC
2. JUNIPERUS VIRGINIANA	15	XX	FACU
3.			
4.			
5.			
	45	= Total Cover	
Herb Stratum (Plot size: 5')			
1. SYMPHORICARPOS ORBICULATUS	55	XX	FACU
2. ELYMUS VIRGINICUS	20	XX	FAC
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
	75	= Total Cover	
Woody Vine Stratum (Plot size: 30')			
1. SMILAX SPP.	10		FAC
2.			
	10	= Total Cover	

% Bare Ground in Herb Stratum 25

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC–):	4	(A)
Total Number of Dominant Species Across All Strata:	6	(B)
Percent of Dominant Species That Are OBL, FACW, or FAC:	67	(A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species		x 1 =
FACW species		x 2 =
FAC species		x 3 =
FACU species		x 4 =
UPL species		x 5 =
Column Totals:	(A)	(B)

Prevalence Index = B/A = ____

Hydrophytic Vegetation Indicators:

XX Dominance Test is >50%

__ Prevalence Index is ≤3.0[1]

__ Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

__ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes XX No ____

Remarks:

SOIL

Sampling Point: 102

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Type[1]	Loc[2]	Texture	Remarks
0-16	10YR 3/1	100					CLAY	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

___ Histosol (A1)
___ Histic Epipedon (A2)
___ Black Histic (A3)
___ Hydrogen Sulfide (A4)
___ Stratified Layers (A5) (**LRR F**)
___ 1 cm Muck (A9) (**LRR F, G, H**)
___ Depleted Below Dark Surface (A11)
___ Thick Dark Surface (A12)
___ Sandy Mucky Mineral (S1)
___ 2.5 cm Mucky Peat or Peat (S2) (**LRR G, H**)
___ 5 cm Mucky Peat or Peat (S3) (**LRR F**)
___ Sandy Gleyed Matrix (S4)
___ Sandy Redox (S5)
___ Stripped Matrix (S6)
___ Loamy Mucky Mineral (F1)
___ Loamy Gleyed Matrix (F2)
___ Depleted Matrix (F3)
___ Redox Dark Surface (F6)
___ Depleted Dark Surface (F7)
___ Redox Depressions (F8)
___ High Plains Depressions (F16)
(**MLRA 72 & 73 of LRR H**)

Indicators for Problematic Hydric Soils[3]:

___ 1 cm Muck (A9) (**LRR I, J**)
___ Coast Prairie Redox (A16) (**LRR F, G, H**)
___ Dark Surface (S7) (**LRR G**)
___ High Plains Depressions (F16)
(**LRR H outside of MLRA 72 & 73**)
___ Reduced Vertic (F18)
___ Red Parent Material (TF2)
___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ____________

Depth (inches): ____________

Hydric Soil Present? Yes ______ No XX

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

___ Surface Water (A1)
___ High Water Table (A2)
___ Saturation (A3)
___ Water Marks (B1)
___ Sediment Deposits (B2)
___ Drift Deposits (B3)
___ Algal Mat or Crust (B4)
___ Iron Deposits (B5)
___ Inundation Visible on Aerial Imagery (B7)
___ Water-Stained Leaves (B9)
___ Salt Crust (B11)
___ Aquatic Invertebrates (B13)
___ Hydrogen Sulfide Odor (C1)
___ Dry-Season Water Table (C2)
___ Oxidized Rhizospheres on Living Roots (C3)
(**where not tilled**)
___ Presence of Reduced Iron (C4)
___ Thin Muck Surface (C7)
___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

___ Surface Soil Cracks (B6)
___ Sparsely Vegetated Concave Surface (B8)
___ Drainage Patterns (B10)
___ Oxidized Rhizospheres on Living Roots (C3)
(**where tilled**)
___ Crayfish Burrows (C8)
___ Saturation Visible on Aerial Imagery (C9)
___ Geomorphic Position (D2)
XX FAC-Neutral Test (D5)
___ Frost-Heave Hummocks (D7) (**LRR F**)

Field Observations:

Surface Water Present? Yes ______ No XX Depth (inches): ____________

Water Table Present? Yes ______ No XX Depth (inches): ____________

Saturation Present? (includes capillary fringe) Yes ______ No XX Depth (inches): ____________

Wetland Hydrology Present? Yes ______ No XX

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:
AREA EXPERIENCED RECENT HEAVY RAINS.

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: PROPOSED WATER TREATMENT PLANT SITE City/County: LEONARD/FANNIN Sampling Date: 9/15/2009

Applicant/Owner: NORTH TEXAS MUNICIPAL WATER DISTRICT State: TEXAS Sampling Point: 231

Investigator(s): VOIGHT AND CAPPS Section, Township, Range: ---

Landform (hillslope, terrace, etc.): DEPRESSION Local relief (concave, convex, none): CONCAVE Slope (%): --

Subregion (LRR): LRR J Lat: 32*23'24.615"N Long: 96*15'49.625"W Datum: NAD 83

Soil Map Unit Name: FAIRLIE-DALCO COMPLEX, 1 TO 3 PERCENT SLOPES NWI classification: NONE

Are climatic / hydrologic conditions on the site typical for this time of year? Yes XX No ____ (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? NO Are "Normal Circumstances" present? Yes XX No ____

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? NO (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes XX	No ____	**Is the Sampled Area within a Wetland?** Yes XX No ____
Hydric Soil Present?	Yes XX	No ____	
Wetland Hydrology Present?	Yes XX	No ____	

Remarks:
SITE IS LOCATED EAST OF A TRIBUTARY TO LEE CREEK WITHIN A DEPRESSIONAL AREA.

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: 30')			
1. NONE			
2.			
3.			
4.			
= Total Cover			
Sapling/Shrub Stratum (Plot size: 15')			
1. NONE			
2.			
3.			
4.			
5.			
= Total Cover			
Herb Stratum (Plot size: 5')			
1. ELEOCHARIS PARVULA	60	XX	OBL
2. XANTHIUM STRUMARIUM	20	XX	FAC-
3. CARDIOSPERMUM HALICACABUM	10		FAC
4. CAREX SPP.	10		FAC-OBL
5.			
6.			
7.			
8.			
9.			
10.			
= Total Cover	100		
Woody Vine Stratum (Plot size: 30')			
1. NONE			
2.			
= Total Cover			
% Bare Ground in Herb Stratum --			

Remarks:

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC–):	1	(A)
Total Number of Dominant Species Across All Strata:	2	(B)
Percent of Dominant Species That Are OBL, FACW, or FAC:	50	(A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:	
OBL species	60	x 1 =	60
FACW species		x 2 =	
FAC species	20	x 3 =	60
FACU species		x 4 =	
UPL species		x 5 =	
Column Totals:	80 (A)		120 (B)

Prevalence Index = B/A = 1.5

Hydrophytic Vegetation Indicators:

- ___ Dominance Test is >50%
- XX Prevalence Index is ≤3.0[1]
- ___ Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ___ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes XX No ____

SOIL

Sampling Point: 66

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Type[1]	Loc[2]	Texture	Remarks
0-16	10YR 4/1	100					CLAY	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- __ Histosol (A1)
- __ Histic Epipedon (A2)
- __ Black Histic (A3)
- __ Hydrogen Sulfide (A4)
- __ Stratified Layers (A5) (**LRR F**)
- __ 1 cm Muck (A9) (**LRR F, G, H**)
- __ Depleted Below Dark Surface (A11)
- __ Thick Dark Surface (A12)
- __ Sandy Mucky Mineral (S1)
- __ 2.5 cm Mucky Peat or Peat (S2) (**LRR G, H**)
- __ 5 cm Mucky Peat or Peat (S3) (**LRR F**)
- __ Sandy Gleyed Matrix (S4)
- __ Sandy Redox (S5)
- __ Stripped Matrix (S6)
- __ Loamy Mucky Mineral (F1)
- __ Loamy Gleyed Matrix (F2)
- __ Depleted Matrix (F3)
- __ Redox Dark Surface (F6)
- __ Depleted Dark Surface (F7)
- __ Redox Depressions (F8)
- __ High Plains Depressions (F16) (**MLRA 72 & 73 of LRR H**)

Indicators for Problematic Hydric Soils[3]:

- __ 1 cm Muck (A9) (**LRR I, J**)
- __ Coast Prairie Redox (A16) (**LRR F, G, H**)
- __ Dark Surface (S7) (**LRR G**)
- __ High Plains Depressions (F16) (**LRR H outside of MLRA 72 & 73**)
- __ Reduced Vertic (F18)
- __ Red Parent Material (TF2)
- XX Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ______

Depth (inches): ______

Hydric Soil Present? Yes XX No ___

Remarks:
HYDROPHYTIC VEGETATION AND DISTINCT HYDROLOGY WERE OBSERVED.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- XX Surface Water (A1)
- XX High Water Table (A2)
- XX Saturation (A3)
- __ Water Marks (B1)
- __ Sediment Deposits (B2)
- __ Drift Deposits (B3)
- __ Algal Mat or Crust (B4)
- __ Iron Deposits (B5)
- __ Inundation Visible on Aerial Imagery (B7)
- __ Water-Stained Leaves (B9)
- __ Salt Crust (B11)
- __ Aquatic Invertebrates (B13)
- __ Hydrogen Sulfide Odor (C1)
- __ Dry-Season Water Table (C2)
- __ Oxidized Rhizospheres on Living Roots (C3) (**where not tilled**)
- __ Presence of Reduced Iron (C4)
- __ Thin Muck Surface (C7)
- __ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- __ Surface Soil Cracks (B6)
- __ Sparsely Vegetated Concave Surface (B8)
- __ Drainage Patterns (B10)
- __ Oxidized Rhizospheres on Living Roots (C3) (**where tilled**)
- __ Crayfish Burrows (C8)
- __ Saturation Visible on Aerial Imagery (C9)
- __ Geomorphic Position (D2)
- XX FAC-Neutral Test (D5)
- __ Frost-Heave Hummocks (D7) (**LRR F**)

Field Observations:

Surface Water Present? Yes XX No ___ Depth (inches): 2

Water Table Present? Yes XX No ___ Depth (inches): 0

Saturation Present? (includes capillary fringe) Yes XX No ___ Depth (inches): 0

Wetland Hydrology Present? Yes XX No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:
AREA EXPERIENCED RECENT HEAVY RAINS.

PRELIMINARY JURISDICTIONAL DETERMINATION FORM

BACKGROUND INFORMATION

A. REPORT COMPLETION DATE FOR PRELIMINARY JURISDICTIONAL DETERMINATION (JD): ***December 4, 2009***

B. NAME AND ADDRESS OF PERSON REQUESTING PRELIMINARY JD:

C. DISTRICT OFFICE, FILE NAME, AND NUMBER: ***Fort Worth and Tulsa District Offices***

D. PROJECT LOCATION(S) AND BACKGROUND INFORMATION: (USE THE ATTACHED TABLE TO DOCUMENT MULTIPLE WATERBODIES AT DIFFERENT SITES)

State: *Texas* County/parish/borough: *Fannin* City: *Leonard*
Center coordinates of site (lat/long in degree decimal format): Lat. *33.38635°* North, Long. *-96.27651*

Coordinate System:
NAD_1983_StatePlane_Texas_North_Central_FIPS_4202_Feet

Name of nearest waterbody: *Lee Creek, Bear Creek*

Identify (estimate) amount of waters in the review area:
Non-wetland waters (Streams): *11,245 linear feet: 3.04 acres*
Cowardin Class: *Palustrine and Riverine*
Stream Flow: *Ephemeral, Intermittent, and Perennial- See Attached Table*

Non-wetland waters (Impoundments) *25.02 acres*
Cowardin Class: *Palustrine and Lacustrine*
Stream Flow: *NA*

Wetlands: *0.78 acres*
Cowardin Class: *Palustrine*

Name of any water bodies on the site that have been identified as Section 10 waters:
Tidal: *NA*
Non-Tidal: *NA*

E. REVIEW PERFORMED FOR SITE EVALUATION (CHECK ALL THAT APPLY):

☐ Office (Desk) Determination. Date:
☒ Field Determination. Date(s): *September 14, 15, 2009*

1. The Corps of Engineers believes that there may be jurisdictional waters of the United States on the subject site, and the permit applicant or other affected party who requested this preliminary JD is hereby advised of his or her option to request and obtain an approved jurisdictional determination (JD) for that site. Nevertheless, the permit applicant or other person who requested this preliminary JD has declined to exercise the option to obtain an approved JD in this instance and at this time.

2. In any circumstance where a permit applicant obtains an individual permit, or a Nationwide General Permit (NWP) or other general permit verification requiring "pre-construction notification" (PCN), or requests verification for a non-reporting NWP or other general permit, and the permit applicant has not requested an approved JD for the activity, the permit applicant is hereby made aware of the following: (1) the permit applicant has elected to seek a permit authorization based on a preliminary JD, which does not make an official determination of jurisdictional waters; (2) that the applicant has the option to request an approved JD before accepting the terms and conditions of the permit authorization, and that basing a permit authorization on an approved JD could possibly result in less compensatory mitigation being required or different special conditions; (3) that the applicant has the right to request an individual permit rather than accepting the terms and conditions of the NWP or other general permit authorization; (4) that the applicant can accept a permit authorization and thereby agree to comply with all the terms and conditions of that permit, including whatever mitigation requirements the Corps has determined to be necessary; (5) that undertaking any activity in reliance upon the subject permit authorization without requesting an approved JD constitutes the applicant's acceptance of the use of the preliminary JD, but that either form of JD will be processed as soon as is practicable; (6) accepting a permit authorization (e.g., signing a proffered individual permit) or undertaking any activity in reliance on any form of Corps permit authorization based on a preliminary JD constitutes agreement that all wetlands and other water bodies on the site affected in any way by that activity are jurisdictional waters of the United States, and precludes any challenge to such jurisdiction in any administrative or judicial compliance or enforcement action, or in any administrative appeal or in any Federal court; and (7) whether the applicant elects to use either an approved JD or a preliminary JD, that JD will be processed as soon as is practicable. Further, an approved JD, a proffered individual permit (and all terms and conditions contained therein), or individual permit denial can be administratively appealed pursuant to 33 C.F.R. Part 331, and that in any administrative appeal, jurisdictional issues can be raised (see 33 C.F.R. 331.5(a)(2)). If, during that administrative appeal, it becomes necessary to make an official determination whether CWA jurisdiction exists over a site, or to provide an official delineation of jurisdictional waters on the site, the Corps will provide an approved JD to accomplish that result, as soon as is practicable.

This preliminary JD finds that there *"may be"* waters of the United States on the subject project site, and identifies all aquatic features on the site that could be affected by the proposed activity, based on the following information:

SUPPORTING DATA. Data reviewed for preliminary JD (check all that apply - checked items should be included in case file and, where checked and requested, appropriately reference sources below):

☒ Maps, plans, plots or plat submitted by or on behalf of the applicant/consultant: Figures and Maps included in PJD Report.

☒ Data sheets prepared/submitted by or on behalf of the applicant/consultant.
  ☐ Office concurs with data sheets/delineation report.
  ☐ Office does not concur with data sheets/delineation report.

☐ Data sheets prepared by the Corps: .

☐ Corps navigable waters' study: .

☒ U.S. Geological Survey Hydrologic Atlas: .
  ☒ USGS NHD data.
  ☒ USGS 8 and 12 digit HUC maps.

☒ U.S. Geological Survey map(s). Cite scale & quad name:
24 K, Trenton, Texas Quadrangle.

☒ USDA Natural Resources Conservation Service Soil Survey. Citation: Goerdel, A.R. (2002). *Soil Survey of Fannin County, Texas.* United States Department of Agriculture – Natural Resources Conservation Service, in cooperation with the Texas Agriculture Experiment Station, the Texas State Soil and Water Conservation Board, and the United States Forest Service.

☒ National wetlands inventory map(s). Cite name:
U.S. Department of the Interior, Fish and Wildlife Service. 1992. National Wetland Inventory Map, Trenton, Texas Sheet.

☐ State/Local wetland inventory map(s): .

☒ FEMA/FIRM maps:
FEMA Flood Hazard Boundary Map. Community Panel No. 480807 0010 A. Historical map, effective date November 8, 1977.

☐ 100-year Floodplain Elevation is: (National Geodectic Vertical Datum of 1929)

☒ Photographs: ☒ Aerial (Name & Date):
USDA NAIP 2004, 2008, 2007 DFW area aerial photograph.

or ☒ Other (Name & Date):
Field photographs from September 14 and 15, 2009. From APAI Inc., included in PJD Report.

☐ Previous determination(s). File no. and date of response letter: .

☐ Other information (please specify): .

IMPORTANT NOTE: The information recorded on this form has not necessarily been verified by the Corps and should not be relied upon for later jurisdictional determinations.

Signature and date of Regulatory Project Manager (REQUIRED)	Signature and date of person requesting preliminary JD (REQUIRED, unless obtaining the signature is impracticable)

Site number	Latitude	Longitude Co	w ardin Class	Estimated amount of aquatic resource in review area	Class of aquatic resource
Lee Creek	33.39286	-96.2703	Riverine	2,075 Linear Feet 1.62 Acres	Non-section 10, Stream
LCT1	33.39425	-96.27127	Palustrine	745 Linear Feet 0.15 Acre	Non-section 10, Stream
LCT2	33.39061	-96.27142	Riverine	683 Linear Feet 0.08 Acre	Non-section 10, Stream
LCT3	33.3902	-96.26746	Palustrine	1,935 Linear Feet 0.38 Acre	Non-section 10, Stream
LCT4	33.38814	-96.26671	Palustrine	2,380 Linear Feet 0.22 Acre	Non-section 10, Stream
LCT4a	33.38643	-96.26761	Palustrine	523 Linear Feet 0.04 Acre	Non-section 10, Stream
TBC	33.38722	-96.28684	Palustrine/Riverine	2,663 Linear Feet 1.53 Acres	Non-section 10, Stream
TBCT1	33.38569	-96.28663	Palustrine	114 Linear Feet 0.01 Acre	Non-section 10, Stream
TBCT2	33.38311	-96.28827	Palustrine	126 Linear Feet 0.01 Acre	Non-section 10, Stream
Lee Creek Impoundment	33.38605	-96.27131	Lacustrine	21.58 Acres	Non-section 10, Impoundment
EI1	33.38807	-96.27291	Palustrine	0.59 Acre	Non-section 10, Impoundment
EI2	33.38626	-96.27343	Palustrine	1.75 Acres	Non-section 10, Impoundment
EI4	33.38717	-96.2679	Palustrine	0.35 Acre	Non-section 10, Upland Impoundment
LCTI	33.3784	-96.28054	Palustrine	1.00 Acre	Non-section 10, Impoundment
WI1	33.3859	-96.28646	Palustrine	0.10 Acre	Non-section 10, Impoundment
EW1	33.39039	-96.26349	Palustrine	0.01 Acre	Non-section 10 - wetland
EW2	33.39019	-96.2638	Palustrine	0.02 Acre	Non-section 10 - wetland
EW3	33.38654	-96.26792	Palustrine	0.03 Acre	Non-section 10 - wetland
EW4	33.38592	-96.27278	Palustrine	0.42 Acre	Non-section 10 - wetland
WS1	33.38587	-96.28499	Palustrine	0.12 Acre	Non-section 10 - wetland
WS2	33.37938	-96.28056	Palustrine	0.18 Acre	Non-section 10 - wetland

Attachment 2
USACE Jurisdictional Determination

From: "Parisotto, Edward SWT" <Edward.Parisotto@usace.army.mil>
Date:08/25/2015 2:40 PM (GMT-06:00)
To: Robert McCarthy <rmccarthy@NTMWD.COM>
Cc: "Commer, Andrew SWT" <Andrew.Commer@usace.army.mil>, "Hoffmann, Robert SWT" <Robert.B.Hoffmann@usace.army.mil>
Subject: Proposed WTP site near Leonard (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: NONE

Robert,

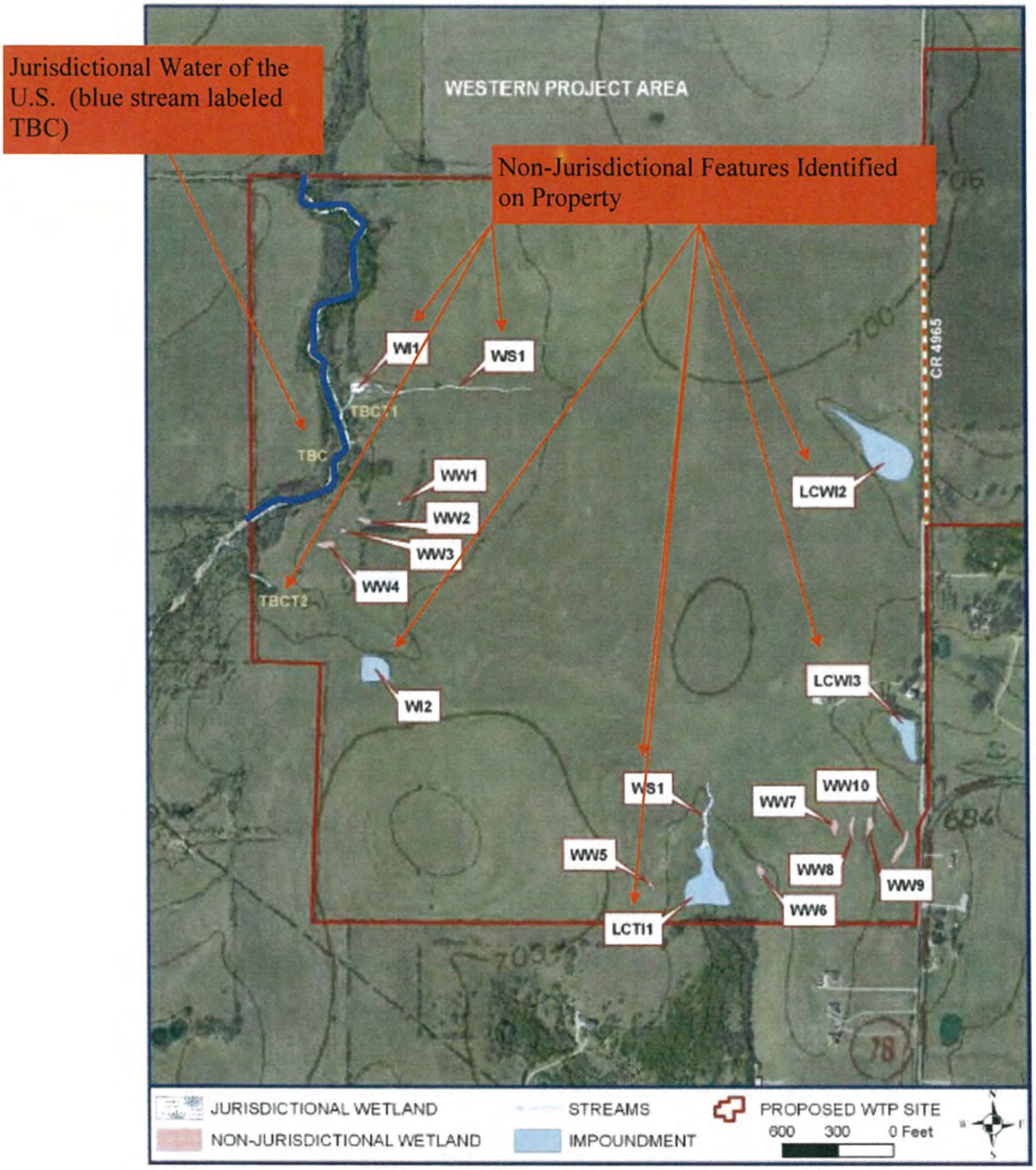
The Corps has completed an Approved Jurisdictional Determination regarding the PJD dated June 11, 2010 prepared by Alan Plummer Assoc. A complete formal letter will be sent to NTMWD regarding the results of our determination.

Last week during our meeting there was a question regarding features identified by the consultant. Please refer to the attached drawing. The "features" in question (WI1 and WS1) has been identified as an eroded agricultural ditch. The Corps will not assert jurisdiction over this ditch.

Let me know if you have any additional questions.

Ed

Ed Parisotto
Supervisory Regulatory Project Manager
Tulsa District U.S. Army Corps of Engineers
(918) 669-7549 / Fax: (918) 669-4306
http://www.swt.usace.army.mil/Missions/Regulatory.aspx
You are invited to complete our Regulatory Service Survey at:
http://corpsmapu.usace.army.mil/cm_apex/f?p=136:4:0



Jurisdictional Water of the U.S. (blue stream labeled TBC)

Non-Jurisdictional Features Identified on Property

Figure 2: Hydrologic Features Observed within the Western Limits of the PJD

Attachment 3

Archaeological Survey of the Proposed Lower Bois D'Arc Creek Reservoir Pipeline Project

AR Consultants, Inc.

Archaeological and Environmental Consulting
805 Business Parkway, Richardson, Texas 75081
Phone: (214) 368-0478
Fax: (214) 221-1519
E-mail: arcdigs@aol.com

ARCHAEOLOGICAL SURVEY OF THE PROPOSED

LOWER BOIS D'ARC CREEK RESERVOIR PIPELINE PROJECT

FANNIN COUNTY, TEXAS

Texas Antiquities Code Permit 6626

Cody S. Davis, MA
S. Alan Skinner, PhD
Deborah Anglin, MA
and
Kathryn M. Pocklington, BS

Submitted to:

FREESE AND NICHOLS, INC.
4055 International Plaza
Fort Worth, TX 76109

Submitted by:

AR CONSULTANTS, INC.
805 Business Parkway
Richardson, TX 75081

Cultural Resources Report 2013-DRAFT
December 20, 2013

ARCHAEOLOGICAL SURVEY OF THE PROPOSED

LOWER BOIS D'ARC CREEK RESERVOIR PIPELINE PROJECT

FANNIN COUNTY, TEXAS

Texas Antiquities Code Permit 6626

Cody S. Davis, MA
S. Alan Skinner, PhD
Deborah Anglin, MA
and
Kathryn M. Pocklington, BS

Submitted to:

FREESE AND NICHOLS, INC.
4055 International Plaza
Fort Worth, TX 76109

Submitted by:

AR CONSULTANTS, INC.
805 Business Parkway
Richardson, TX 75081

Cultural Resources Report 2013-DRAFT
December 20, 2013

ABSTRACT

North Texas Municipal Water District is proposing to construct additional components associated with the proposed Lower Bois d'Arc Creek Reservoir in Fannin County, Texas. These include 35 mi of 90- to 96-in diameter pipeline extending south-southwest from the pump station located near the dam to a terminal storage reservoir (TSR) north of the proposed water treatment plant (WTP). The pipeline is routed south-southeast around the periphery of Lower Bois d'Arc Creek Reservoir, crossing through the headwaters of several Bois d'Arc Creek drainages. On the south side of US 82, the route enters the upland divide between the Red and Sulphur river watersheds to the northwest side of Leonard, TX. The TSR and WTP are situated south of US 69 and CR 4965. The TSR also has an overflow discharge pipeline that runs north under US 69 and discharges into headwaters of Valley Creek. The final component of the project will be a railroad spur, which will extend from the MKT tracks south along CR 4965 to the WTP. The approximate final footprint acreage for these project components is 875 acres. Approximately 1033 acres were surveyed. A total of seven historic sites were recorded. Additionally, three standing structures were found to meet the historic-age guidelines; these were evaluated for eligibility for listing on the National Register of Historic Places. Some of these architectural resources were associated with recorded archaeological sites. These historic sites recorded appear to represent the sparse remains of late 19th to early 20th century homesteads and farmsteads. These were represented largely by the remains of well-cisterns. Based on the results of the archaeological and architectural investigations, AR Consultants, Inc. recommends that historic resources are not eligible for listing on the National Register of Historic Places or as State Archeological Landmarks. AR Consultants, Inc. requests that the Tulsa District of the U.S. Army Corps of Engineers and the Texas Historical Commission concur with the findings of this report. Furthermore, if buried cultural deposits are discovered during construction, work should cease in that area immediately, and U.S. Army Corps of Engineers and the Archeology Division of the Texas Historical Commission should be notified.

ACKNOWLEDGEMENTS

AR Consultants, Inc. would like to offer our thanks to the many people who contributed to the development of this report. You may recognize some of your thoughts and interpretations as well as a variety of facts that you shared with the writers. The writers accept full responsibility for the conclusions and formulations that are presented in this report.

We want to thank the numerous people with North Texas Municipal Water District, who assisted us in the field and during report writing. In particular, we thank Robert M. McCarthy, Permit Manager, for being there in the field. Ashley Burt assisted us with North Texas office matters and shared in the field experiences. Jennifer Flippo provided contacts with people throughout Fannin County and helped us access the project components.

A variety of people at Freese and Nichols, Inc. contributed to the development of this document. Michael Votaw was always available to share his familiarity with the project and helped us in the field. Additionally, we want to thank Jeff Payne for helping coordinate fieldwork and keeping everyone on track. We also want to thank the field crew members for their hard work and long days in the field.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1. INTRODUCTION

North Texas Municipal Water District (NTMWD) is proposing to construct additional components associated with the proposed Lower Bois d'Arc Creek Reservoir in Fannin County, Texas (Figure 1). These include 35 mi of 90- to 96-in diameter raw water pipeline extending south-southwest from the Intake Pump Station located near the dam to a terminal storage reservoir (TSR) north of the proposed water treatment plant (WTP). The proposed pipeline would have a permanent easement width of 50 ft and a temporary easement width of 70 ft. A 120 ft wide survey corridor (PL survey corridor) was utilized for the survey of the pipeline route. The pipeline starts at the pump station, which would be powered by a nearby electrical substation, near the proposed dam site and goes south-southeast around the periphery of Lower Bois d'Arc Creek Reservoir, crossing the headwaters of several Bois d'Arc Creek drainages. On the south side of U.S. Highway 82 (US 82), the route is on the upland divide between the Bois d'Arc Creek and the North Sulphur River watersheds. It continues along the divide to the northwest side of Leonard, TX, where it feeds into the 153.5-acre TSR. The TSR is southwest of the intersection of US 69, the Missouri-Kansas-Texas (MKT) Railroad tracks, and County Road (CR) 4965. The TSR connects with the WTP on the south side of CR 4950. The WTP property includes 323 acres of which186.2 will be used to construct the WTP. The TSR also has an overflow pipeline that will run north under US 69 and discharge into headwaters of Valley Creek, which flows approximately 4 mi north into Bois d'Arc Creek. The final component of the project will be a railroad spur, which will extend from the MKT tracks south along CR 4965 to the WTP. The rail spur is approximately 6,600 ft long. The approximate final footprint acreage for these project components is 875 acres.

AR Consultants, Inc. (ARC) prepared a comprehensive research design (Skinner et al. 2010) that provided a foundation for field research and laboratory analysis done in conjunction with archaeological investigations for the overall project. The archaeological survey, as described in the research design for the Lower Bois d'Arc Creek Reservoir, was conducted by ARC in 2011 and 2013 under Texas Antiquities Permit (TAP) 5950 (Davis et al. 2013). The pump station and associated electrical substation discussed above were surveyed as part of the Dam Survey Area in the reservoir report (Davis et al. 2013). The archaeological survey for the pipeline and associated components was conducted under TAP 6626. Because reservoir construction will affect Waters of the US, the project will require an individual 404 permit be issued by the Tulsa District of the U.S. Army Corps of Engineers (USACE). Relevant federal legislation includes the National Historic Preservation Act of 1966, as amended (PL-96-515), the National Environmental Policy Act of 1969 (PL-90-190), and the Archeological and Historical Preservation Act of 1974, as amended (PL-93-291). The Texas Antiquities Code (Texas Natural Resources Code, Title 9, Chapter 191) applies to the cultural resource investigations at Lower Bois d'Arc Creek Reservoir since NTMWD is an entity of the state of Texas. ARC has prepared this report for review by the Tulsa District of the USACE and the Archeology Division of the Texas Historical Commission (THC) as part of their Section 106 review process. This document is written in accordance with report guidelines adopted by the Archeology Division of the THC. The following report contains a brief description of the natural environment and then a summary of previous archaeological investigations in the area as known from published sources. This is followed by the research design and methodology. The results of the field investigation constitute the majority of the report. The last chapter presents recommendations that arise from the study. A list of references cited concludes the report, followed by appendices.

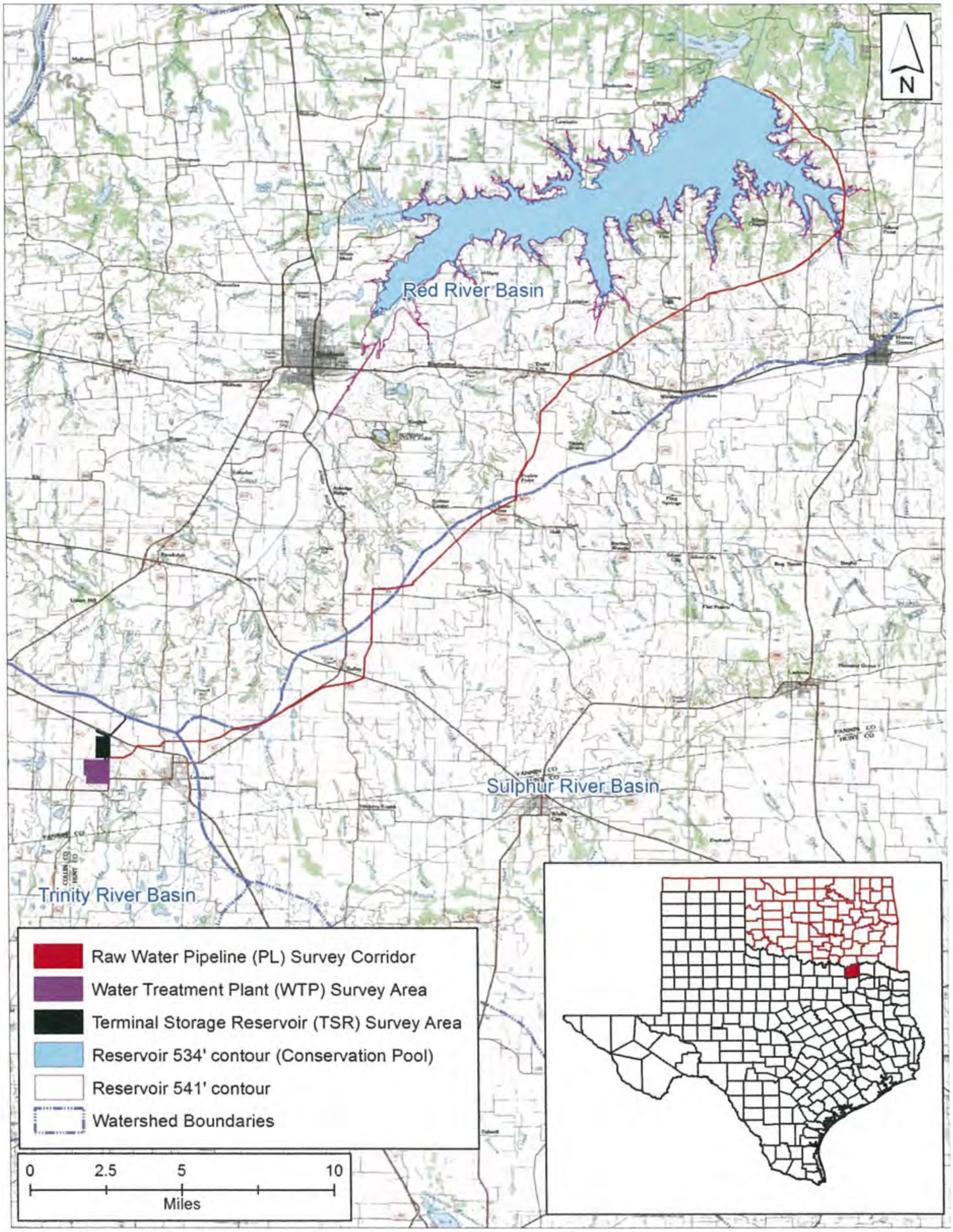


Figure 1. The locations of the Lower Bois d'Arc Creek Reservoir and associated project components shown on portions of the Sherman, McKinney, Paris, and Sulphur Springs, Texas 100 k USGS topographic maps.

Administrative Information:

Sponsor:	North Texas Municipal Water District
Review Agencies:	Tulsa District, US Army Corps of Engineers Texas Historical Commission, Archeology Division
Principal Investigator:	Cody S. Davis, MA
Architectural Historian:	Deborah Anglin, MA
Field Crew:	Nick Coleman, Brett Lang, Kathryn M. Pocklington, Neil Hargrove, and Cody S. Davis
Acres Surveyed:	approximately 1033
Sites Investigated:	
Historic:	41FN169-175
Prehistoric:	none
Curation Facility:	TARL, the University of Texas at Austin

CHAPTER 2. NATURAL ENVIRONMENT

The pipeline route is largely situated in the Red River Watershed. However, south of US 82 it follows the divide between the Red River and Sulphur River watersheds before terminating in the northeastern edge of the Trinity River Watershed. The WTP, TSR, TSR associated pipelines, and rail spur are all in the Trinity River Watershed. The topography of the majority of the pipeline route has been sculpted by the down-cutting of several tributaries of Bois d'Arc Creek. Bedrock is exposed outside the major drainage valleys, but is generally covered in the valleys by recent Quaternary alluvium. The northern end of the route is underlain by Bonham Marl, covered by a thin layer of sandy loam that is exposed in the uplands east of the proposed dam location. This has created the appearance of a geologic terrace on the southeast side of Bois d'Arc Creek. The Blossom Sand formation, along the southern edge of the reservoir, is backed by Brownstown Marl and Gober Chalk. Erosion of these formations, particularly the Blossom Sand, has created a steep slope, rising to 600' above mean seal level (amsl), contrasting with the more gradual slope on the north side of Bois d'Arc Creek. The valley is filled with small remnants of first and second Quaternary terraces, while elsewhere clay alluvium rests on the decomposing Bonham Marl and Eagle Ford formations. The majority of the project components are underlain by Gober Chalk and Roxton Limestone, which weather into the various clays that make up the Blackland Prairie. The second through fifth terraces contain un-quantified amounts of gravel (Jacobs 1981:Table 7), which originated in West Texas and southern Oklahoma. Lag gravel mantles, probably Pliocene in age, have been documented in Northeast Texas and may be related to deposits described in adjacent parts of North Central Texas (Byrd 1971; Menzer and Slaughter 1971; Banks 1990:56-57).

Bois d'Arc Creek's floodplain is primarily composed of Tinn clay, with a slope of up to one percent and is inundated, on average, more than once a year (Goerdel 2001:71). The typical soil profile has a 10-in thick black clay surface layer and a 40-inch thick very dark gray clay that overlies the subsoil. The subsoil is typically 30-inch thick and is dark gray clay with dark grayish brown mottles. In a climax condition, the floodplain would have been covered with a mixture of hardwood forest and grass understory. Today much of the floodplain is farmed or used as pasture. Varieties of silty clay loams (occasionally flooded Frio, frequently flooded Elbon, and occasionally flooded Hopco) parallel the Tinn clay on the south side of the Bois d'Arc Creek valley. These soils fill the valleys of the long and short tributaries, which drain the uplands. The floodplain is primarily an aggrading environment. Low, almost imperceptible, point-bar levees parallel the outside bends of Bois d'Arc Creek.

On the north side of Bois d'Arc Creek, the drainage valleys are shorter and are filled with Delta loam in their lower reaches and Porum loam near their headwaters. Ivanhoe silt loam makes up the fourth Quaternary terrace level of the Red River that covers the upland between Bois d'Arc Creek and the Red River. The Porum loam and Ivanhoe silt loam have a high available water capacity and a very slow permeability, thus allowing seeps and springs to occur. These can flow regularly from the soil, or the junction of the soil and the underlying Bonham Marl, near the northern end of the pipeline route and the proposed dam. Climax vegetation associated with these upland soils is a mid- to tall-grass prairie. Narrow bands of Whakana very fine sandy loam are on the slopes between the rolling upland divide and the creek floodplains. This sloping setting is a slowly degrading environment containing springs.

Ellis clay is on the valley side slopes south of Bois d'Arc Creek and the majority of the project components; it continues upslope to abut with Houston Black clay and Fairlie-Dalco complex, which overlie the Gober Chalk. In contrast to the soils on the north, these high-clay content soils have a lower water capacity and the clay promotes rapid runoff, because of its slow permeability. The climax vegetation on these slopes and rolling uplands is a mid- to tall-grass prairie with scattered elm, hackberry, and bois d'arc trees.

The tributaries on the south side of Bois d'Arc Creek are generally more than seven miles long and rapidly carry rainfall off the upland prairie. Numerous springs have been documented in Fannin County (Brune 1981:179-181); most originated from Upper Cretaceous sand and silt, and river terrace gravel and sand. On the ridge north of Bois d'Arc Creek, springs, such as Bryant Springs, occur at the junction of the overlying fourth terrace sands and the Eagle Ford formation. Additionally some springs originate in Quaternary terrace sands at the edge of the creek floodplain. On the south side of the creek, water comes out of the Ozan silt, which is above the Gober Chalk, Roxton Limestone, and the Brownstown Formation. Brune describes four springs in Fannin County that seep from these formations. Indian Springs is the source of Indian Creek, approximately 5 mi northwest of the TSR and WTP (Brune 1982:181). The other three are south of the pipeline route. Shawnee Springs seeps form the headwaters of Shawnee Creek, five kilometers southwest of Gober, TX. Five kilometers south of Windom, TX is Flat Springs and just north of Honey Grove, TX, is Honey Grove Springs forming the headwaters of Honey Grove Creek (Brune 1982:181).

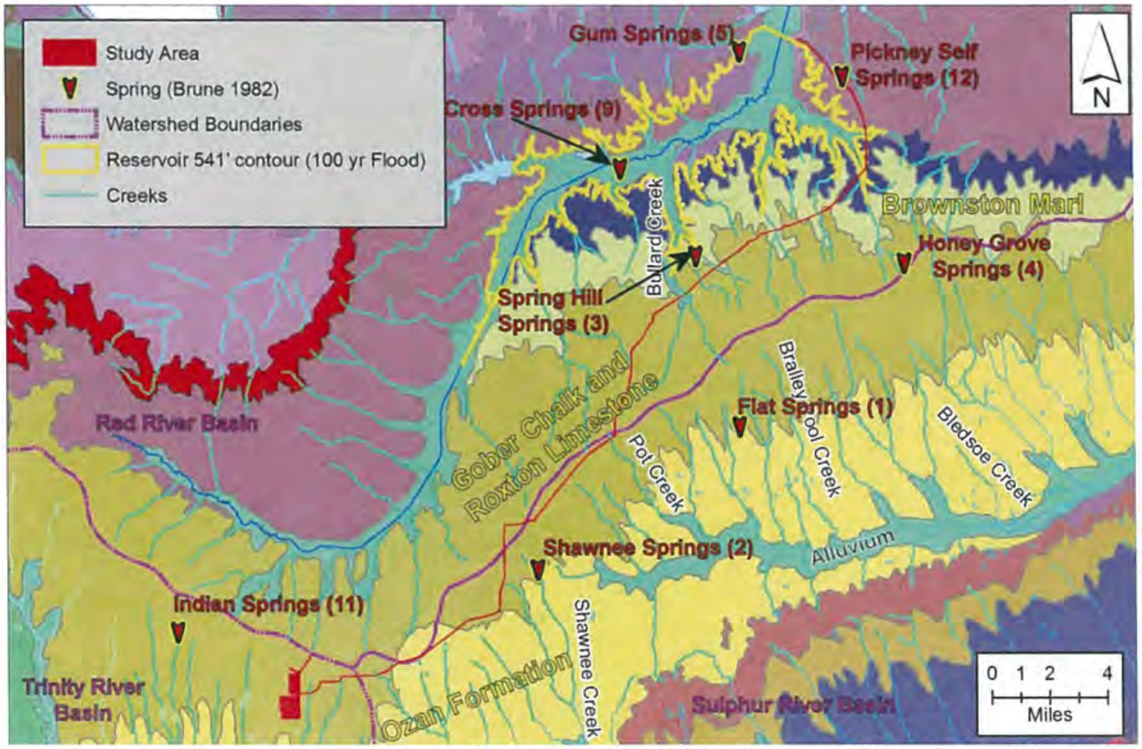


Figure 2. Approximate locations of springs reported by Brune (1982) shown in relation to the underlying geology, major river watersheds, and drainages.

In a broad sense, the project components are found in two major climax vegetation communities, as defined by Küchler (1964). The pipeline route starts on the north in the Oak-Hickory forest that covers the Red River terraces. The remainder of the pipeline route and the other project components are found in the Blackland Prairie.

An unmapped hardwood forest fills the Bois d'Arc Creek floodplain, as well as the tributaries. All the forested areas produced nuts that were available to humans, including acorns that were foraged by forest-dwelling mammals. It appears from the research of Jurney (1994), Flores (1984, 1985), and Schambach (1995) that bois d'arc trees (Burton 1973) were historically abundant in the creek valley; this may have been the case for hundreds or thousands of years (Smith and Perino 1981; Winberry 1979).

These forested areas were inhabited by deer, raccoons, opossums, rabbits, squirrels, skunks, beavers, minks, muskrats, and others; rabbits, antelope, and bison lived in the upland prairies (Blair 1950). The river and creeks were home to fish, turtles, frogs, snakes, mussels, and crayfish. Ducks made their homes in the sloughs and flowing channels, while an abundance of other bird species inhabited the forests permanently or during yearly migrations.

The Fannin County climate is warm and humid with hot summers and moderate winter temperatures. Rainfall averages 43.99 in annually with monthly precipitation ranging from 2.02 in (January) to 6.06 in (May). High rainfall occurs in the spring and fall.

Six microenvironments are used to predict and interpret prehistoric and historic land use. These were detailed in the Research Design (Skinner et al. 2010) and in the reservoir survey report (Davis et al. 2013). The majority of the project components fall within the rolling upland prairie (Zone 1). This zone is found south of Bois d'Arc Creek, where herbivores grazed on the prairie grasses and rainwater drained rapidly into short, steep, intermittent tributaries. This rolling upland zone includes the upland slopes and the steep tributary valleys.

CHAPTER 3. CULTURAL HISTORY

Introduction

The culture history is presented in two parts: the Native American occupation and the European settlement of Fannin County. Information from adjacent Lamar County is included, where appropriate, due to the limited information available about the archaeology in Fannin County. A review of previous archaeological investigations in Fannin County is followed by a description of recorded archaeological sites in the study area and vicinity.

Native American Occupation

The following timeline for the Native American occupation of the area relies on Mahoney (2001) and Perttula (1998, 2004):

Anglo-American settlement	A.D. 1815 to present
Historic European	A.D. 1700 to 1815
Late Caddo	A.D. 1400 to 1700
Middle Caddo	A.D. 1200 to 1400
Early Caddo	A.D. 1000 to 1200
Formative Caddo	A.D. 800 to 1000
Woodland/Fourche Maline	200 B.C. to A.D. 800
Late Archaic	2,000 to 200 B.C.
Middle Archaic	4,000 to 2,000 B.C.
Early Archaic	6,000 to 4,000 B.C.
Paleoindian	12,000 to 6,000 B.C.

The earliest Native American occupation seems to have occurred in Fannin County was during the early Paleoindian period when fluted Clovis dart points were being made. Dozens and maybe hundreds of Clovis points have been collected from the North Sulphur River channel in southern part of the county but only one has been documented (Bever and Meltzer 2007:Table 1; Carley 1986; Todd and Skinner 2007; Jennings 2008; Green Chapter 10 in this volume). Virtually all of these Clovis points were made from exotic cherts that occur elsewhere in Texas and Oklahoma. None of these finds came from well-dated geologic contexts. The only geological profile in the county that extends to pre-Clovis time is from the bank of the North Sulphur River at Ralph Hall Reservoir (Skinner et al. 2005; Bousman and Skinner 2007). A cobble core found on the face of the adjacent river bank could possibly date to the time of Clovis or earlier. In addition to early point types, such as Clovis and Folsom, later styles including San Patrice, Dalton, and Plainview have been found in the area (Story 1990:177-211; Johnson 1989; Jennings 2008). It is apparent that the surrounding area was visited or occupied during the Paleoindian period, but evidence of undisturbed campsites has not been found. The low density sites and the abundance of exotic chert artifacts found in the drainage channels suggest that Paleoindian people were highly nomadic hunters and gatherers (Mahoney 2001:8) who came to Fannin County on a periodic basis for the purpose of acquiring specific resources or spending the winter in an environment that was protected from the harsh winters on the high plains. They may have come as "ridge runners" (Hofman 1988; Thurmond and Wyckoff 1999:245-246) but evidence of such a mode of transportation has not been thoroughly documented in Northeastern Texas. The transition from the Paleoindian period to the Archaic has recently been discussed a series of economic, settlement, technological, and social changes that can be termed the "ProtoArchaic (Bousman and Oksanen 2012:224)."

During the Archaic, which is divided into Early, Middle, and Late periods, groups continued to live as mobile hunting and gathering bands. In the Early Archaic, group territories have not been defined, though they might be determined by analysis of lithic artifact source locations. Sites dating to this period were briefly and seasonally occupied; they are represented by lithic scatters, some of which were found at repeatedly revisited locations. Burned rock features occur at Middle Archaic sites where plant cooking was more common. In the southern part of the county, Middle Archaic people harvested mussels from the North Sulphur River channel (Skinner et al. 2005:47-48). Mussel shells were found at several prehistoric sites along Bois d'Arc Creek (Hsu 1968:10-17) upstream from the study area. In the Late Archaic, increased population density limited group mobility, causing groups to settle into restricted territories and to use locally available lithic sources for chipped stone tools (Perttula 1998:17–18).

During the Woodland period, which is also known as the Fourche Maline period, a sedentary lifestyle is indicated by the presence of circular and rectangular houses, undecorated thick-walled Williams Plain pottery, and increased amounts of native plant foods. Arrow points replaced Gary dart points during this period (Perttula et al. 2001:67). During excavations at the Gene and Ruth Ann Stallings site (41LR297), north of Paris in Lamar County, numerous postholes were uncovered, which possibly represent a rectangular house 80' long and more than 20' wide (Skinner 2007, 2012). A house with a similar pattern and size was uncovered at the Poole site in southwestern Arkansas (Wood 1981). If the postholes at LR297 represent a rectangular house, the Stallings site and the Poole site would be the only known examples of rectangular Fourche Maline houses. Coles Creek pottery and associated chipped stone artifacts appeared after A.D. 600. Prehistoric Native Americans at this time settled into small hamlets and camps, dispersed within recognizable territories (Perttula et al. 1993:99). These technological changes coincided with a gradual population increase. The Ray site in east central Lamar County contains a deposit that spans this period (Bruseth et al. 2001).

Formative Caddo people are first recognized about A.D. 800 and this time period lasted until approximately A.D. 1000. Horticulture was developing, but hunting and gathering continued to provide the main foods (Mahoney 2001:10). Settlements consisted of villages, hamlets, and single-family dwellings. Some of the villages contained burial mounds. In the Early Caddo period, intensive maize agriculture dominated subsistence (Perttula 2004:383), but was still supplemented by foraging (Mahoney 2001:10). The material culture was as diverse as during later Caddo times.

Middle Caddo period sites along the Red River have been related to the Sanders phase; they include dispersed farmsteads and hamlets, along with a few large villages. The period is characterized by multiple earthen mounds that contained burials with abundant and exotic grave goods, indicating the presence of high status individuals (Perttula 1998:11). The best known site from this period and in the Red River Watershed in Texas is the T. M. Sanders site (41LR2), which is located adjacent to the mouth of Bois d'Arc Creek. The site is located approximately one-half mile south of the Red River and is at an elevation of approximately 450' amsl. The site includes of two earthen mounds containing 21 graves, many containing multiple burials, with a wide variety and number of grave goods (Krieger 1946:171-218; Jackson, Goldstein, and Krieger 2000). Conch shell dippers, gorgets, and shell beads were found with burials at the site, as well as on the plowed site surface. These correspond to artifacts attributed to the Southeastern ceremonial complex or the Southern Death Cult (Krieger 1946:177; Waring and Holder 1945; Hamilton 1997; Skinner et al. 1969:106). Other exotic artifacts recovered from the site include bar gorgets (Harris 1953), ear spools, stone pipes, and celts. Some authors (Bruseth et al. 1995; Schambach 1999, 2000) have debated whether this site was an outpost for the Spiro site in Oklahoma. The Sanders phase was characterized by exchange between Northeastern Texas, the South Plains, and the Southeastern Ceremonial Complex. Pottery types associated with the Sanders phase include Sanders Plain, Sanders Engraved, Canton Incised, and Maxey Noded Redware. Polished Ouachita sandstone elbow pipes indicate trade with Oklahoma residents. Houses were four-sided with one side open. Agricultural hoes made of freshwater mussel shells and bison-scapula were found at the site (Jackson et al. 2000:34; Krieger 1946:183-184, 194). Krieger (1946:216) stated that the Sanders site (41LR2) was occupied by A.D. 1300. More recent investigations in the area indicate that the Sanders site was occupied by A.D. 1000 (Schambach 2000:8).

Large temple and mound structures are associated with Middle Caddo times, further indicating socially complex societies, as inferred from the Sanders site. These sites may include the Harling Mound in Fannin County (Davis 1962a and b), but also include the Mackin Mound in Lamar County (Mallouf 1976) and the Faskin and Wright Plantation Mound sites in Red River County (Perttula et al. 2001). A Middle Caddo shaft burial was reported from the Bentsen-Clark site in Red River County. Pottery at the site included Spiro Engraved, Hickory Engraved, Holly Fine Engraved, Kiam Incised, and Crockett Curvilinear Incised (Banks and Winters 1975).

In the Late Caddo period, there is a shift in site location from the major drainages to the headwaters of smaller tributaries. This shift resulted in numerous small hamlets scattered throughout most of Northeastern Texas. However, major sites such as Sam Kaufman (Roitsch) and the Belcher Mound (Harris 1953; Skinner et al. 1969; Webb 1959; Perttula et al. 2001) were continuously occupied on the banks of the Red River in Texas and Louisiana during this period. Farming was an important contributor to their diet (Perttula 2008). The historic descendants of these prehistoric people are recognized as the Hasinai Confederacy of the Caddo. The intensive use of maize resulted in health and diet problems, as noted in the Late Caddo skeletal record. Materials were traded from the Plains/Southwest to the Texas Gulf Coast (Perttula 1998:12; Vehik 2002) to the Southeastern United States (Skinner et al. 1969:101, 103).

There is a break in the archaeological record for a period of two hundred years, at the end of the Late Caddo period. There is no evidence of Spanish or French occupation in Fannin or Lamar counties. The Womack site represents the primary evidence for historic Native American occupation; it is located on a bluff, overlooking the Red River, in northern Lamar County (Harris et al. 1965; Schambach 1996). The site dates from approximately A.D. 1700 to 1729. Other evidence of historic Native American occupation has been found at several other sites in the area. Glass trade beads were recovered from individual burials at the Sanders site (Harris 1953:20). A mold-made, long-stemmed, effigy smoking pipe with the head of a lamb or sheep was found on the surface near one of the graves. The pipe may have been trade material from the early 1800s (Wilson 1971:20), but the glass beads were dated to the 1700s (Harris and Harris 1967:131;

Duffield and Jelks 1967:70-71). A hundred glass trade beads were also recovered from site 41FN12 (A1-2) (Harris 1953:20), which is plotted on the Texas Archeological Sites Atlas (TASA) in the vicinity of the proposed mitigation land for this project.

European Settlement of Fannin County

Fannin County was created from a portion of Red River County and was one of the first counties founded in Texas. On December 14, 1837, the Republic of Texas Congress named the county after James Walker Fannin, Jr., a Texas Revolution hero (Carter 1885; Hodge 1966; Scott 1982; Strickland 1930; Tate 2001; Pigott 2010). Texas became a state on December 29, 1845, and, shortly thereafter, the Texas Legislature approved the present boundaries of Fannin County. Most early settlers of Fannin County were from southern states, particularly North Carolina, Tennessee, and Kentucky (Strickland 1930, Templin 1946). The Fannin County communities of Bonham, Carson (Gum Springs), Dodd City, Honey Grove, Lamasco, Telephone, and Windom border the project area. Each is discussed below in order to provide a clear understanding of the history and growth patterns of the Lower Bois d'Arc valley. At one time the area was home to several additional farming communities: Danner, Hilger, Jones Mill, Spoonamore/Oliver-Hill, Greens Chapel, Shiloh, and Hudsonville, but nothing remains of these communities today, other than a few small cemeteries and a few sentences in local history books.

The original county seat was located at Old Warren, also known as Fort Kitchen, on the Grayson/Fannin county line. Old Warren was established in 1836 when Abel Warren, an Indian trader from Fort Smith, Arkansas, settled there. He built a fort to serve as protection against raiding Indians and a trading post for friendly tribes (Hodge 1966). Old Warren was home to the first courthouse, school, post office, and Masonic Lodge in the county. Due to an increased concern over Indian attacks and a political shift, which strengthened the community of Bois d'Arc the county seat was moved from Old Warren to the city of Bois d'Arc, on January 16, 1843. In 1844, Bois d'Arc was renamed Bonham.

Historically, several tribes inhabited the area: the Cherokee, Tehuacana, Keechi, Waco, Caddo, Shawnee, and others. Fannin County's early settlers describe numerous conflicts with the Native Americans in the area. Stories of Natives murdering and mutilating local residents, as well as tails of horse and livestock thievery were common along Bois d'Arc Creek (Strickland 1930). Early accounts state that a Shawnee Village was situated northeast of Bois d'Arc Creek's confluence with Honey Grove Creek (Strickland 1930:287; Brune 1981:181). The village was a mile northeast of the proposed reservoir and due north of the Shiloh Church and Cemetery. Between 1837 and 1839, tensions escalated between the settlers and Native American groups in the area. The Shawnee were described in most oral tradition stories, but some conflicts were described between the Caddo, Choctaw, and Kickapoo (Strickland 1930). According to early accounts in 1839, Holland Coffee, an early settler, used his prestige and influence to negotiate a peace treaty with the Natives until they were finally pushed out of the county a few years later (Strickland 1930:298).

In 1860, the county's population was 9,217; less than 1,800 of whom were African-American. During this time, Fannin County's major industry was agriculture. Prior to the Civil War, there were approximately 25,000 beef cattle in the county, making cattle the largest commodity. By the end of the Civil War, the number of cattle was less than half the pre-war population.

When the Civil War broke out in April 1861, Fannin County's citizens supported the Confederacy and secession from the Union. Several companies of men from Fannin County joined the Trans-Mississippi Confederate army. Bonham was the site of three important Confederate facilities during the war: a hospital for the soldiers, a commissary which supported seven brigades, and the military headquarters of the Northern Sub-District of Texas, Confederate States of American (C.S.A.) In addition, Camp Benjamin was established in the Bois d'Arc Creek floodplain, northeast of Bonham. Camp Benjamin was occupied by the 9th Regiment Volunteer Texas Infantry from December 13, 1861 until January 1, 1862. At that time, the 10 company regiment left for Memphis, Tennessee (Brothers 2010). Over 1,200 enlisted men and officers lived at the camp. A concrete cross was erected in 1980 at the reputed location of a cemetery, where at least seven 9th Regiment soldiers were buried after dying from measles or pneumonia (Honey Grove Signal-Citizen 1980).

After the Civil War, the county began to prosper; many new businesses opened between 1865 and 1900. Prior to the war, Fannin County was home to five manufacturing plants; by 1870 that number had increased to 54. In 1872, the Fannin County Bank opened and in 1873 the Texas & Pacific Railway built its tracks across the county. The county also experienced record growth thanks to its agricultural economy; the major crops were corn and cotton. Between 1860 and 1883, new schools opened to serve the growing population and in 1888, the Fannin County School Board was organized to educate the county's children.

The first three decades of the 20th century brought many changes to the county. In 1900, the population reached a record high of 51,793; farms produced record numbers of swine and bushels of corn, and over 58-percent of the county was working farmland (Templin 1946). The number of farms reached over 7,000; 35 percent were owner-occupied farms and the remainder were tenant farms. Cotton production peaked in 1920, after which production of all crops began to decline (Templin 1946). Although the 1920s saw a sharp reduction in the number of dairy cows and milk production, the number of beef cattle began to increase. In 1925, the Lone Star Gas Company ran natural gas lines through the county. In 1929, Jones Field airport was built on the north side of Bonham.

As in most areas of the United States, the Great Depression of the 1930s imposed economic hardship on the county's businesses and residents; a hardship that lasted until World War II. The number of manufacturing jobs decreased to a record low of 310 and farms were only 46-percent of their 1920 value. By 1940, the number of farms had dwindled to 4,638, although 83.5 percent of the county was still working farmland (Templin 1946). Cotton production steadily decreased from the 1930s through the 1950s and, by 1987, only 337 bales were produced in the county. Corn production decreased until the late 1980s; wheat, peanuts, and sorghum increased during the same period. The only livestock to show a continual increase throughout the remainder of the century was beef cattle. By the end of the century beef cattle outnumbered milk cows nearly five to one.

That period between the Great Depression and WWII also saw the population of the county decrease and then finally stabilize at about 40,000 residents. The population began to decrease again in the 1950s; by 1970 it had decreased to the population level of the 1880s. Throughout its history, the county's racial proportions have remained between 10- and 20-percent (Pigott 2011).

In 1955, the remainder of FM 1396 from north of Allen's Chapel, through Carson and Lamasco, to FM 273 was improved and paved. While the new road provided easy access from the rural areas to larger communities, such as Honey Grove and Bonham, it reduced the need for tiny, local communities, which had at one time been invaluable to farmers and ranchers.

Between 1947 and 1987, employment in manufacturing companies more than doubled from 15- to 37-percent, mostly in the lumber and wood products industry. Service industries also increased, as did the banking, retail, wholesale, construction, utilities, and transportation industries. These businesses are still prominent in the county's economy.

Area Communities

Bonham

The largest town in the project area is Bonham, both in terms of population and economic growth. It was established in 1837 when Bailey Inglish, along with 10 other families from Miller County, Arkansas, stopped along the banks of the Bois d'Arc Creek (City of Bonham:2011; Bonham Area Chamber of Commerce 2011). The group, which also included John P. Simpson and Mabel Gilbert, appreciated the quality of the area and decided to make it their home. However, Indian hostilities soon forced Bailey and his neighbors to construct a two-story log fort at a spot approximately one mile north of the present day square, thus laying the foundation of the future Bonham. Originally known as Bois d'Arc, the town was renamed in 1844, in honor of James Butler Bonham, the famed messenger of the Alamo who twice tried to bring assistance to the Alamo before dying in the final battle (Scott 1993). At the same time Bonham was designated as county seat for Fannin County. Between 1843 and 1845, Bonham acquired the county records from Fort Warren and the post office from Fort Inglish. In 1873 Bonham, including all land within one mile of the Courthouse, was chartered. The growth of Bonham was spurred by the building of the Texas and Pacific Railroad in 1873. By 1885 Bonham had electric light service, eight churches, three colleges, two public schools, three weekly newspapers, a furniture factory, a saw mill, two grist mills, and several gins. In 1889, a telephone exchange was added.

Between 1885 and 1890, the population of Bonham increased from 2,300 to 3,361 and, as early as 1888, had a total of 117 businesses. Throughout the early 20th century the population continued to grow, reaching 6,349 in 1940. During WWII Bonham had an Air Force training school, a POW camp which housed mainly German soldiers, and over 20 manufacturing plants. By 1988, the number of businesses had risen to 286. In 1990, the population was 6,686, almost the same as the 1940 level (Kleiner 2011).

Carson (Gum Springs)

Carson, first known as Gum Springs, is located approximately 10 miles northeast of Bonham, on FM 1396. Early settlers included Elijah Blair and Wash Leonard. The small community had a post office, cotton gin, blacksmith, saloon, school, and church. Cotton was an early product of the area (Jones 1997). The Gum Springs School was listed in the County Clerk's records and newspaper articles between 1885 and 1900, but is no longer standing (Hodge 1966).

Dodd City

Dodd City is located on SH 56, five miles east of Bonham. The town was settled in 1839 when Kentucky immigrants Major Edmund Hall Dodd and his wife set up their home one mile west of present site of Dodd City (Hodge 1966; Jones 1997). Their log cabin served as a home, stagecoach inn, and post office. The post office was originally named Lick, but in 1852 the name was changed to Quincy. The growth of the community during the 1850s-1860s was responsible for the establishment of a hotel, a saloon, and a grocery store. The railroad entered the community in 1872 and was named Dodd Station in honor of Major Dodd. In 1873, the community was renamed Dodd City and incorporation followed in 1879. Dodd City reached its peak between 1880 and 1910 thanks to the economy created by farming and the railroad. The Dodd City Water Company was established in 1911, electric service was introduced in 1914-1917, and Lone Star Gas installed gas lines in 1926. However, by the 1930's the decline was in full swing and by 1950 all train service had ended. In 1976 only five business, three churches and one public school remained. By 1979 the population had dwindled to 302, less than the mid-1880s population.

Honey Grove

Honey Grove is located on SH 56, fifteen miles east of Bonham. As early as 1816, hunters and trappers referred to this area as Honey Grove due to the abundance of honey found in the area. Davy Crockett visited the area in 1836 and is said to have carved his initials on one of the trees in the honey grove. The first permanent settler, Samuel Erwin of Tennessee, arrived in 1842. Other early settlers included Captain Yeary, Dr. Nicholson and his brother A.J., John McKinzie, J.T. Allen, James Gilmer, Wilson Allen, Dr. Gambill, J. Guqua, David Drennan, and Thomas Hobbs. In 1846, Benjamin S. Walcott, who had been a millwright in New England, arrived in Honey Grove. Mr. Walcott began surveying and purchasing additional land, providing access to "coarse goods" and, in the process, became known as the developer of Honey Grove. By 1856, the growth of Honey Grove was strong enough to warrant the building of a two-story hotel on the square, which also served as a co-educational school—an innovation at the time (Conrad 1988: Carter 1975[1885]).

During the Civil War, Honey Grove, very pro-Confederate, was the site of a training camp, an ordinance shop, and a blacksmith shop, which produced swords and "Bowie" knives for soldiers. The town was incorporated in 1873. By 1888 the population had grown to more than 400 and the town was home to over 90 businesses, including 12 dry-goods stores, two cotton gins, two railroads, two banks, seven churches, four large hotels, two lumber yards, as well as numerous restaurants and boarding houses (Jones 1997). Instrumental to the success of Honey Grove was the visionary leadership provided by the city leaders, who realized the symbiotic relationship between the city and the farmers and worked hard to develop it. In addition, for the farmers, the practice of sharecropping greatly improved their prosperity. Between 1890 and 1920, the number of sharecroppers doubled. Working on the "half system," landlords furnished the land, fuel, tools, stock, feed, seed, and other necessities, while sharecroppers furnished the labor. At the end of the season the crops were split 50/50. The local sharecrop houses were generally two to three rooms, had no indoor plumbing and few screens, were unpainted, relied on coal or wood stoves, and housed between four and 15 family members. The practice of sharecropping began to decrease in the 1930s and continued until its demise in the 1950s (Conrad 1988). Although Honey Grove remains the second largest town in Fannin County with a population of 1,861 (1988), the number of businesses has dwindled to 25, far below its 1888 level (Minor 2011).

Greens Chapel and Bois d'Arc Springs

Greens Chapel is located approximately 2 mi northeast of the proposed dam area. The small rural town was just east of Bois d'Arc springs. According to Brune, the springs seeped from the base of the Bonham sandstone cliffs resting on Eagle Ford shale at the confluence of Bois d'Arc and Coffee Mill creeks (Brune 1980:180; Dobbs 2012:9). The pure water found there was very attractive to early settlers and people would come from all over the county to enjoy the area. Early settlers describe that the area was inhabited by the Caddo Indians (Dobbs 2012:3), while Brune reports the area to be the location of a Shawnee Village. Greens Chapel, was the closest town to the springs, approximately one mile due east. The town was named after Parris Green, who moved to the area before the Civil War, to start a tannery which employed thirty to forty men (Dobbs 2012:ii). He reportedly moved to Arkansas in the late 1860s, but the community continued to grow due to its close proximity to numerous springs, many of which were not reported by Brune (Dobbs 2012:16). By the 1930s, there were dozens of families living the area like the Martins, Roses, Newhouses, Rowtons, and Higginbothams, to name a few. The area boasted a grist mill, saw mill, cotton gin, a tannery, and a syrup mill (Dobbs 2012). However, the area began to empty out the in 1930s after the Bankhead-Jones Farm Tenant Act was passed (Long 2011). Many of these families sold or were bought out by the Federal government, in order to build Lake Crockett and Lake Coffee Mill and along with recreational lands, now the Caddo National Grasslands.

Lamasco

Lamasco, located on the northern periphery of the project area on FM 1396 approximately 9 mi northeast of Bonham, was established in the late 1800s. The names of three men, Law, Mason, and Scott were combined to create the town's name. In 1890, the town included a general store, a drug store, a blacksmith shop, a steam gristmill, a sawmill, a school and a church. Between 1886 and 1920, the community also had a post office (Jones 1997). By the 1950s, the population of Lamasco had declined to 70, with only two businesses remaining in operation. The population continued to decline and by the 1980s had dwindled to 32 (Hart 2011a).

Leonard

In 1845, in southern Fannin County around the present-day city of Leonard, Martin Moore was granted five land grants for a total of 1,600 acres (Hymer 2013; Jones 1977; LPL 2005). This acreage traveled through several hands until it was purchased by Solomon Langdon (S. L.)

Leonard in 1859. This, plus additional land, constitutes what is known today as the Leonard Survey. Unfortunately, Leonard was never able to enjoy his new land as he drowned while returning from Missouri to Texas. His land, extending from north of Leonard southwest to Nobility, was on some of the richest Backland Prairie land available, making it some of the best agricultural land in the area. His death left his wife sole proprietor of the land and sole parent to eight children.

In 1880, the MKT Railroad extended its line from Denison to Greenville (Hymer 2013; Jones 1977; Leonard Preservation League (LPL) 2005). The General Manager, Robert S. Stevens, resigned his position with the railroad to become an entrepreneur and to organize the Denison and Southern Railroad. Acting as agent for the Leonard heirs, H.L. Parmlee negotiated with Stevens in order to locate a new town along his new line and thus the town of Leonard was born. Within a few weeks of the town being platted and lots being sold two businesses were established—Mark Daniels built a saloon and H.L. Parmlee opened a general store. Within a year the population had already grown to 50 and town boasted a hotel, post office, and school. Within five years the population had grown to 350. In 1889, the city incorporated and extended 1/2 mile north, south, east, and west of the present day town square. By 1890, the town had installed phone service, began the Leonard Graphic newspaper—which is still in business, and opened the Leonard City Bank.

Leonard continued to grow throughout the first half of the twentieth century (Hymer 2013; LPL 2005). The first brick school was built in 1901, waterworks services were established in 1913, and a modernized dairy was opened in 1923. The city saw a boom in industrial growth after the end of WWI. By the 1930s, Leonard had become the trading center of southwest Fannin County and the surrounding area. The principal crop was cotton, followed by corn and wheat.

In 1963, the MKT railroad closed its passenger services through Leonard, although it continued to operate freight trains (Hymer 2013, Jones 1977; LPL 2005). Nonetheless, the old town square remained prosperous and the city continued to grow, although the new growth headed toward the new U.S. 69 Bypass. Cotton, which had been the main cash crop for almost 100 years, saw its last bumper crop in 1970 (Figure 3). By 1971 there was only one cotton gin remaining in Leonard. By 1989, cotton had been replaced by wheat and grain sorghum as the principal crop(s) and ranching had replaced farming.

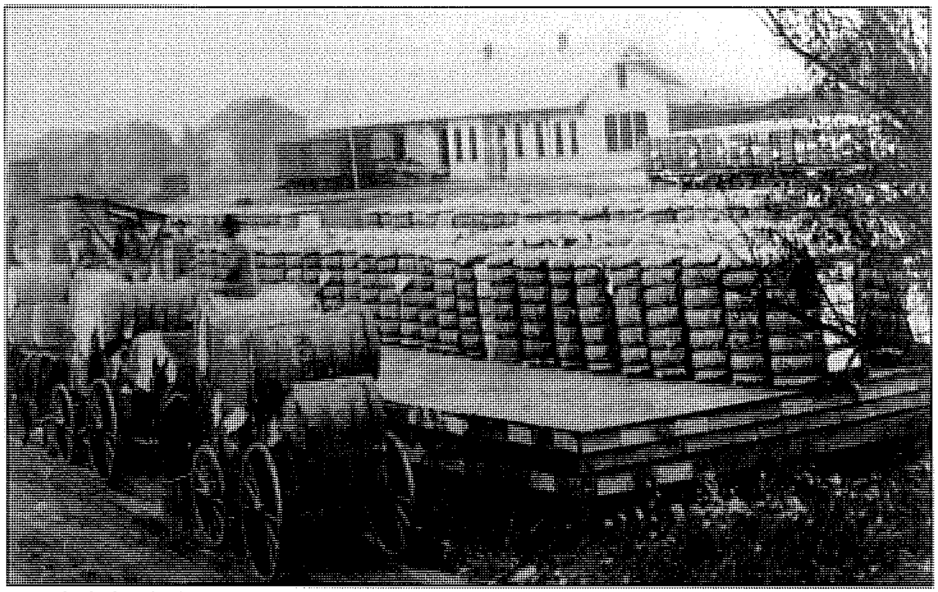


Figure 3. Original depot on Main Street, Leonard, TX 1912. Photo courtesy of Leonard Preservation League.

Selfs

Near the proposed reservoir dam, the area was once populated by a handful of small, rural communities: Selfs, Jones Mill, Spoonamore/Oliver-Hill, Greens Chapel, and Shiloh. Of these, the only one in existence today is the community of Selfs. In the 1880s, brothers, G. W. and G. T. Self built a cotton gin and gristmill at the location of the present-day Selfs (Hart 2013; Jones1977). Area settlers, drawn to the gin and mill, soon formed a small community. By 1900, the community had a population of 800 and boasted two mills, four stores, two blacksmith shops, two barbershops, three doctors, a school, broom factory, post officer, confectionery, furniture store, Woodman Hall, and the North Texas Business College. The college operated for 15 years and reached an enrollment of 200 students. The early 1900s were to be the zenith for Selfs. During the mid-1930s the population declined to 25 and continued to fluctuate between 25 and 50 for the next 30 years, again reaching 50 in the mid-1960s. Selfs was never to again experience its early success.

Windom

Windom, located 10 mi east of Bonham on SH 56, was settled by Nancy Fitzgerald, Abraham McClellan, Jacob Baldwin, Major James Donaldson, and Billy Longmire in 1870. The Texas & Pacific Railroad arrived in 1872. The origin of the name is unclear as two explanations are often found—the town was either named Windom in honor of the first railroad conductor, Thomas H. Windom, or due to its location on the highest, and most windblown, point between Texarkana and Fort Worth. The town was platted in 1876-77 and had its first school by 1884. By 1890, the community consisted of 100 people, a post office, a railroad station, B.J. Cagel Lumber Yard, Smith and Settle Grocery, Hooper Bros Gin and Grist Mill, and a blacksmith. In 1898, additional land was platted and added to the town. In the early 1900s several more grocery stores were added, along with a drug store, a garage, an Oldsmobile agency, a cafe, a silent movie theatre, and several wholesalers. The town was incorporated in 1918 and by 1929 the population had reached 317. As with many of the other rural town, the population dwindled and by 1940 was only 240. The decline continued and in the 1950s, the passenger trains were discontinued and the school consolidated. Unlike many of the rural communities, Windom still maintains a small presence (Becker n.d.; Jones 1997).

Caddo National Grasslands

The Caddo National Grasslands, located in the northeastern of the project area, was purchased and developed under the 1930s Bankhead-Jones Farm Tenant Act. Bordering Coffeemill Lake, the 17,785 acres were purchased in order to improve land-use management and to provide various recreational opportunities (Long 2011). However, as a result many farms and ranches were bought or seized by the government and their owners and tenants displaced.

By looking in more detail at the history and growth patterns of the small rural communities it becomes clear that in the early days, particularly when travel was limited and difficult at best, they served as an important gathering place for local farmers and provided critical access to necessities otherwise not available. As travel became easier and technology made startling advances more and more people were pulled away from the agricultural lifestyle. Whether this move was due to desire or necessity, it was to the detriment of the small rural communities.

Previous Archaeological Investigations in Fannin County

In 1930, a team from The University of Texas excavated several skeletons and recovered a few artifacts from a prehistoric Caddo site (41FN12) at the Goss Farm near the mouth of Bois d'Arc Creek. Subsequently, Rex Housewright of the Dallas Archeological Society (1946) uncovered a child burial at the site. The site was on a ridge, at the west end of the Goss Plantation, in the Red River floodplain. The burial, assumed to be prehistoric in age, included a necklace of more than 260 turquoise beads and two turquoise pendants. The turquoise was assumed to be from New Mexico, but more recent research indicates that workable turquoise occurs naturally in Arkansas, as well (Early 1978); the source of this turquoise has not been determined. In 1953, R.K. Harris (1953) collected a cache of four mussel shell hoes from the site.

In 1962, the Harling Mound, formerly the Morgan Mound, at Riverby, Texas was investigated by The University of Texas (Davis 1962a and 1962b). The mound was approximately 230 ft long, 170 ft wide and 7 ft high. No burials were found during mound excavation, but the ceramics recovered dated to the Sanders phase (ca. A.D. 1000-1200). Excavation was done because the landowner wanted to level the mound to use the land for agriculture; a final report on this investigation has not been written. A "heavy" boatstone made of red-black hematite was collected on an earlier visit to the site (Harris 1951).

According to TASA (2011), the first recorded survey in Fannin County was conducted in 1960 for the proposed Brushy Creek Reservoir, now called Valley Lake, located near Bells, TX in west central Fannin County. During the survey, several prehistoric lithic scatters were recorded (Davis et al. 1962); they range in age from the Archaic to Caddo. Ground stone fragments were also found at one site.

The Texas State Building Commission (now the Texas Historical Commission [THC]) and the Texas State Water Development Board performed an archaeological survey of the proposed Timber Creek and Bois d'Arc Reservoirs in 1968 (Hsu 1968). Timber Creek Lake became Lake Bonham. Two sites (41FN15 and 41FN16) were discovered during the survey of Timber Creek Reservoir. Site 41FN15 consisted of a lithic scatter, a Scallorn point, two Gary points, and a potsherd. A Gary point and lithic scatter made up site 41FN16. Both sites were found on the edge of the first terrace of Timber Creek.

Bois d'Arc Reservoir was not constructed; the proposed dam location was upstream from the present reservoir location. Thirteen sites (41FN17 through 41FN29) were found adjacent to Bois d'Arc Creek, approximately seven miles southwest of Bonham. Sites were found on knolls within the floodplain and on terraces adjacent to Bois d'Arc Creek. Sites contained mussel shells, animal bones, pottery, flakes, arrow and dart points, celts, axes, fire-cracked rock (FCR), and even evidence of human burials. It is important to note that these sites were found either eroding out of creek banks or on the surface of plowed fields. A comprehensive survey was not done. One site of particular interest (41FN19) is located on a knoll adjacent to the old Bois d'Arc Creek channel (Hsu 1968:11-12). The knoll, and presumably the site, is 300 m long by 50 m wide. Hsu's collection included two projectile points, two sherds, and lithic debris. The landowner had collected a small ground hematite axe, a polished full groove axe, the proximal half of a polished cylindrical celt, and two incised sherds from the site surface. These sites ranged in age from the Middle Archaic to the Caddo. Since subsurface testing was not part of this survey, there is no substantive information about the potential of finding buried cultural resources in the Bois d'Arc Creek floodplain. However, numerous avocational archaeologists have reported finding dart points in the eroding channel bed.

In 1989, Southern Methodist University (Jurney et al. 1989) conducted an archaeological evaluation of three units of the Caddo Grasslands in Fannin County. According to their report, the Bois d'Arc Creek floodplain has high potential for prehistoric archaeological sites, while the valley slope has a medium potential (Jurney et al. 1989:Figure 33). Figure 34, in the report, showed that the uplands have a high potential for historic sites. The authors stated that the areas of low potential for historic sites are too far removed from historic transportation routes such as roads and railroads. Additionally, the bottomlands appears to have a medium potential for historic sites, such as crossings or mills, since flooding prevented domestic occupation (Jurney et al. 1989:123).

Various small-scale surveys have been conducted throughout Fannin County. Most of these studies have found little or no evidence of prehistoric or historic occupation. ARC surveyed for the South Wastewater Interceptor in Bonham, which tested in the Bois d'Arc Creek floodplain, as well as on the upland toeslope and the overlooking upland ridge, but did not find sites in those settings (Skinner and Davis 2009).

In 2005, ARC (Skinner et al. 2005) investigated approximately 1,700 acres at the proposed location of Lake Ralph Hall, which will be constructed in Fannin County, north of Ladonia, in the North Sulphur River floodplain. Seventeen historic and prehistoric sites were recorded in the course of the survey (41FN60-76). ARC recommended further testing for a Middle to Late Archaic campsite (41FN68), a deeply buried Middle Archaic campsite (41FN66), and near site

41FN73. The date for this site may be older than 10,860±40 B.P. (Beta 206953). Further survey should lead to the discovery of more deeply buried archaeological sites (Bousman and Skinner 2007).

In 2011 and 2013, ARC surveyed approximately 5,000 acres for the proposed Lower Bois d'Arc Creek Reservoir (Davis et al. 2013). The research design developed a sampling strategy that focused on landforms likely to have been occupied prehistorically and historically (Skinner et al. 2010). A total of 61 sites (31 prehistoric, 26 historic, and four prehistoric/historic) were recorded. Based on the results of the investigations, the earliest occupations were during the Paleoindian and Early Archaic periods; however, the terrace sediments were flushed out of the valley before 2000 B.C. In situ occupation during the Late Archaic and Woodland periods was sporadic and Early Caddo occupation may have occurred about A.D. 1000 but no subsequent Caddo occupation was found to exist in the reservoir study area. The majority of the historic sites date to the 20th century, with the exception of Wilks Cemetery (41FN96) and sites 41FN129, 137, 138, 148, 154, 157, 158, and 159. These last eight appear to represent the sparse remains of late 19th- to early 20th-century homesteads and farmsteads. Oral histories confirm that most 19th-century residences were removed to increase farm and pasture land, or were replaced by modern structures. Based on the results of the archaeological and architectural investigations, the majority of the prehistoric sites were not eligible for listing on the National Register of Historic Places (NRHP) or as State Antiquities Landmarks (SAL). Nine sites were recommended for further testing and research, to determine their eligibility: 41FN110, 113, 114, 120, 137, 138, 148, 151, and 159.

Major investigations have been conducted in the South Sulphur River valley at Cooper Lake in Delta and Hopkins counties. Survey, testing, and site excavation were carried out along Sanders Creek, just east of Bois d'Arc Creek, at Pat Mayse Reservoir and at Camp Maxey. Pine Creek is just to the east and studies have been conducted there at Crook Lake, B&B Landfill, and at the Gene Stallings Ranch near Powderly. The Womack site, a historic Native American site, is located adjacent to the Red River channel in northwest Lamar County. Further east in Red River County, survey was conducted at Big Pine Reservoir and test excavations were conducted at the Mackin Mound site. The Texas Archeological Society (TAS) conducted summer field schools at the Sam Kaufman site in the early 1990s, after site discovery and major excavation at the site in 1968. TAS also excavated the Ray site in Lamar County. In adjacent parts of Oklahoma, relevant site information is available from excavations at Hugo Reservoir, McGee Creek Reservoir, and Pine Creek Reservoir. This information will be used later in the report to provide a regional perspective on the archaeology of the Lower Bois d'Arc Creek valley.

Recorded Sites in the Study Area

Discussions with several members of the Valley of the Caddo Archeological Society (VOCAS) in Paris confirmed the presence of several buried sites along Bois d'Arc Creek and its tributaries. One such site, which reportedly contains an Early Archaic component with a possible Paleoindian component, is located east of the Bonham Lake dam on Bois d'Arc Creek. A buried site was discovered in a creek bank near Lannius, its presence illustrates the potential of finding sites along Bois d'Arc Creek's tributaries.

No SAL or NRHP sites have been recorded within the study area. Several prehistoric and historic sites have been recorded within the mitigation lands and adjacent to Bois d'Arc Creek tributaries. The Goss Farm site (41FN12) and the Harling Mound (41FN1) are within the mitigation lands, as are several other unstudied historic and prehistoric sites.

Prehistoric archaeological sites recorded within the general area are mainly located on knolls within Bois d'Arc Creek's floodplain. However, sites have been found within the creek's floodplain and along terraces of tributaries to Bois d'Arc Creek. Artifact collectors who have walked up and down the channelized and unchannelized portions of the creek have found Paleoindian dart points. No sites have been recorded in these settings, but it seems most likely that these buried sites were situated adjacent to the creek channel, either on overbank flooding levees or on the floodplain back from the low levees. Channelization exposed parts of these sites, moving artifacts downstream, out of their original context.

In addition to the trade beads reported from the Goss Farm site, there is no other archaeological evidence of historic Native American occupation in Fannin County. Brune mentioned a Shawnee village that was occupied in 1836 at Pinkney Selfs Springs approximately two kilometers (km) west of Selfs (1981:181). Just north of that, at Bois d'Arc springs, Dobbs (2012:3) describes early settlers coming in contact with the Caddo.

Geo-referenced historical maps, provided an efficient way to analyze data, and to highlight areas of high and low probability for historic land use. According to the 1939 Soil Map for Fannin County (US Department of Agriculture 1939), numerous historic residential locations may be encountered by the various project components. Historic structures that might be affected were located on historic maps, including the 1936 Fannin County Highway Map; the 1939 Soil Map for Fannin County (USDA 1939); the 1949 Honey Grove; the 1958 Bonham 15' USGS topographic maps; the 1964 7.5' USGS quadrangles of Gober, Leonard, and Trenton, and the 1984 quadrangles of Selfs, Honey Grove, Dodd City, Texas. The USGS maps show numerous structures that roughly correspond to those on the soil map; however, many of them were not occupied in 1984. Using GIS and the geo-referenced historic maps, structure locations were compared with modern aerial photographs of the study area. Structures on the USGS maps correlated most closely with the structures on the aerials. These resources helped guide the survey and the assessment of the historic potential. In total, 14 structures were shown to be within the study area.

CHAPTER 4. RESEARCH DESIGN AND METHODOLOGY

ARC prepared a comprehensive research design (Skinner et al. 2010) that provided a foundation for field research and laboratory analysis done in conjunction with archaeological investigations in the reservoir area (Davis et al. 2013). That document presented research topics which provided a foundation to direct and interpret the findings of the comprehensive sample survey of the Lower Bois d'Arc Creek Reservoir and associated project components. Broad ranging statements about the archaeology of the Eastern Planning Region (Kenmotsu and Perttula 1993:Sections I and II) provided a foundation that was useful for relating to the environment and archaeology in Fannin County. The THC planning document was used to develop three historic contexts for the project: Late Pleistocene Geomorphology, The Shifting Ecotone, and Settling Into the Region (Skinner et al. 2010:20; Davis et al. 2013:26). Eleven research topics were then derived from the contexts, which guided the overall study.

Research Design

The majority of the pipeline route and other components are situated in the rolling uplands on the south of Bois d'Arc Creek, and along the northern edge of the Trinity and Sulphur river watersheds. These uplands are dissected by primarily low-order intermittent drainages; however, seep springs are described in the area coming from the underlying geologic formations (Brune 1982:181). Prehistoric utilization of the uplands was expected. Lithic procurement sites were expected to be found on the drainage divides where Ogallala Gravels were deposited in the Late Pliocene, before the present drainages dissected the landscape. Several examples of this site type were recorded during a transmission line survey west of the project area and artifacts were found only on the surface, not in shovel tests (Cliff and Shortes 2001). Similar results occurred at the NTMWD landfill site in the same area (Clow and Hoyt 2000). Additionally, there was potential for buried prehistoric site deposits being found in floodplain sediments at the valley edges along the pipeline route north of US 82. Sites are also likely to be found on elevations in the narrow floodplains. The three largest creeks crossed by the pipeline route are Bullard, Ward, and Honey Grove. However, the route crosses these drainages and some of their tributaries high in their headwaters. Based upon this location in the watershed and the results of the Lower Bois d'Arc Creek Reservoir study (Davis et al. 2013), the potential for finding these site types was considered to be fairly low. Additionally, these three drainages will be tunneled, further reducing the likelihood of encountering buried sites.

In contrast, it was predicted that historic residences would be found within a hundred feet of present and past roadways primarily in upland settings. Based upon the historic map and aerial review, 14 structures were mapped on the 1964 and 1984 USGS topographic maps within the study area. However, only the three structures in the WTP were found to be historic-in-age. The other 11 structures had been removed or replaced with new structures. These locations could contain foundations, subterranean features, pole barns, sheet trash middens, cisterns, wells, or other places where 19th and 20th century artifacts could be found. The three structures in the WTP were evaluated by an architectural historian and are discussed in detail in Chapter 7.

Using the environmental variables described in Chapter 2, as well as known archaeology in and near the proposed reservoir, areas of high and low archaeological potential were defined. Aside from the floodplain, evidence of prehistoric and historic occupations is often found in the same areas. The following areas have low potential for archaeology: the various floodplains crossed by the pipeline route, the south slope of Bois d'Arc Creek valley and slopes of the southern tributaries, and the fourth terrace of the Red River. The floodplain's propensity for flooding made it less desirable for occupation. Steep slopes in Bois d'Arc Creek valley and southern tributaries detracted settlers; those drainages only carry rainfall runoff, unlike the northern tributaries, which are spring-fed. The fourth terrace of the Red River has low potential because of its distance from water sources. Overall, the proposed project components have an approximate footprint of 875 acres. However, the intensive pedestrian survey for this project evaluated approximately 1033 acres, of which 948 acres (92%) were classified as upland, 24 acres (2%) were floodplain, and 61 acres (6%) were terrace.

Methodology

Field methods were designed to gather baseline information, as well as to locate and record cultural resources within the survey areas. These data were used as part of the preliminary assessment of NRHP eligibility. An inventory of sites present in the survey areas provides the USACE information regarding site distribution and density, site size and deposit depth, artifact assemblages, ecofact preservation, and dating potential. ARC used this information to develop recommendations for further cultural resource investigations, which include testing and mitigation of sites that are eligible for listing on the NRHP. Data collection methods included pedestrian survey and shovel testing, geomorphological assessment, and archival and oral history research. These methods were detailed in Chapter 5 of both the Research Design (Skinner et al. 2010) and reservoir survey report (Davis et al. 2013). Methodology for the Architectural Investigations is presented in the beginning of Chapter 7 of this report and is consistent with the one used in the survey report.

In general, the field teams walked parallel transects spaced 20-30 meters apart within the 120 foot wide PL survey corridor and throughout the entire properties for the WTP and TSR. Sites were described as they were encountered and shovel tested when necessary. Artifact locations were recorded with hand-held GPS units and were described in the field notes. At each road crossing, surveyors stopped and noted ground exposure, soil types, and disturbed areas from the section that had been walked. Shovel tests were excavated to the bottom of the plow zone in the upland where ground surface visibility was less than 30 percent (THC n.d.), and where hills or upland edges overlooked drainage crossings. Shovel tests were concentrated on the terraces and in the floodplain sediments and were augmented by the use of augers to reach the estimated depth of the subsoil. Shovel tests averaged 30 cm in diameter. The clay fill from the shovel tests was inspected visually and broken into small chunks in order to determine if cultural materials were present. Photographs were taken throughout the survey area using Casio digital cameras. Shovel test matrices were described on the basis of composition, texture, and color. The Munsell Soil Color Chart (2010) was used to identify soil colors. Shovel test locations were recorded using a Garmin GPS receiver.

CHAPTER 5. SURVEY AREA DESCRIPTIONS

This chapter describes the landscape conditions recorded during the pedestrian archaeological survey. The descriptions are presented from north to south. Maps throughout this chapter are presented on recent aerial photographs, and an additional set of these maps with 7.5' USGS topographic backgrounds are available in Appendix A, which include previously recorded site boundaries in relation to the project components. Archaeological sites are mentioned in relation to the various project components in which they were recorded. Isolated occurrences (IOs) of artifacts are discussed in this chapter. The next chapter presents archaeological site descriptions, while Chapter 7 details architectural investigations. Chapter 8 presents the conclusions developed from the results of the investigations.

Pedestrian Survey

The pipeline survey corridor and the other project components repeatedly crossed similar settings throughout the survey. The majority of the properties consisted of farmed cropland or grazed pastures. Dense vegetation was typically only encountered at creek crossings or along fence and property lines (Figure 4). Vegetation at these crossings typically contained oak, bois d'arc, cottonwood, and an occasional pecan tree. Several invasive tree and plant species were noted and these include juniper, mesquite, greenbriar, and Virginia creeper.

Figure 4. Typical dense vegetation seen throughout the study area.

Raw Water Pipeline Route

The route begins at the pump station and electrical substation on the north side of a two-track road near the proposed dam site (Figure 5). The footprints for the pump station, electrical substation, and beginning of the pipeline, all fall within the Dam Survey Area described in the reservoir report (Davis et al. 2013:80-81). After the initial alignment was surveyed, the route was adjusted near the dam and moved slightly to the north on the east side of CR 2725. The new alignment was then surveyed. This northern end of the route is situated in the few terrace deposits found on the south side of Bois d'Arc Creek and near the locations of five archaeological sites (41FN132, 137-138, 142, and 159) recorded during survey of the dam area. Site 41FN132 is the remains of a bridge crossing on Bois d'Arc Creek, where no further work was recommended (Davis et al. 2013:210-211). Sites 41FN137 and 138 both contain prehistoric and historic site components as well as architectural remains (Davis et al. 2013:219-233). Site 41FN159 is a historic site associated with 41FN137 and 138 (Davis et al. 2013:280-284). While none of the structures associated with the sites were recommended as eligible for listing on the NRHP or as SALs, additional work was recommended for all three. The survey corridor clips the edge of sites 41FN137 and 159, in areas that are not contributing components to the overall site eligibility. Site 41FN142 is the only one directly intersected by the pipeline and pump station. This site was initially reported to ARC by a collector as an upland gravel quarry; the site could not be located during the survey (Davis et al. 2013:235-236).

The survey corridor ascends the densely wooded terrace slope from the pump station and travels southeast towards CR 2725. This area contained the first of the 14 structures shown on the USGS topographic maps within the survey corridor. The 1984 Selfs, TX quadrangle showed one structure just north of the two-track road running through the property. No evidence of the structure was present and artifacts were not observed on the surface or in the shovel tests excavated in the area. According to Google Earth aerials, a structure was there in 1995, but was removed before 2005. The route through this area crossed pastures as it continues southwest toward CR 2730. Ground surface visibility through this area, was between 20 and 60 percent, but because of the terrace setting, it was shovel tested at 100 m intervals. Only one shovel test was positive and it contained a single interior flake in Level 3 (20-30 cm). This IO was found near where the survey corridor crosses the two-track road between sites 41FN137 and 159. Additional shovel tests were excavated at 10 m intervals, but all were negative. In total, 60 shovel tests were excavated along both the initial and final route alignments in this area. Shovel tests typically revealed profiles with brown or yellowish brown sand or sandy loam over red clay. The sterile clay zone was reached between 20 and 90 cm below the surface (cmbs).

After the route crosses CR 2730, it enters the uplands, through more cleared pastures and cropland (Figure 6). Ground surface visibility in this area ranged from 30 to 100 percent. The survey was conducted after fall harvest and many of the properties had recently been plowed. The route continues south toward Fox Creek, where it crosses a floodplain flanked by terrace deposits (Figure 7). This crossing was surveyed during the reservoir study, as part of Survey Area G (Davis et al. 2013:87-88). It was intensively investigated, as was the Fox Creek channel (Davis et al. 2013:52-63). Based upon previous investigations and its location high in the watershed, backhoe trenching was unnecessary. No archaeological sites or IOs were recorded in this area.

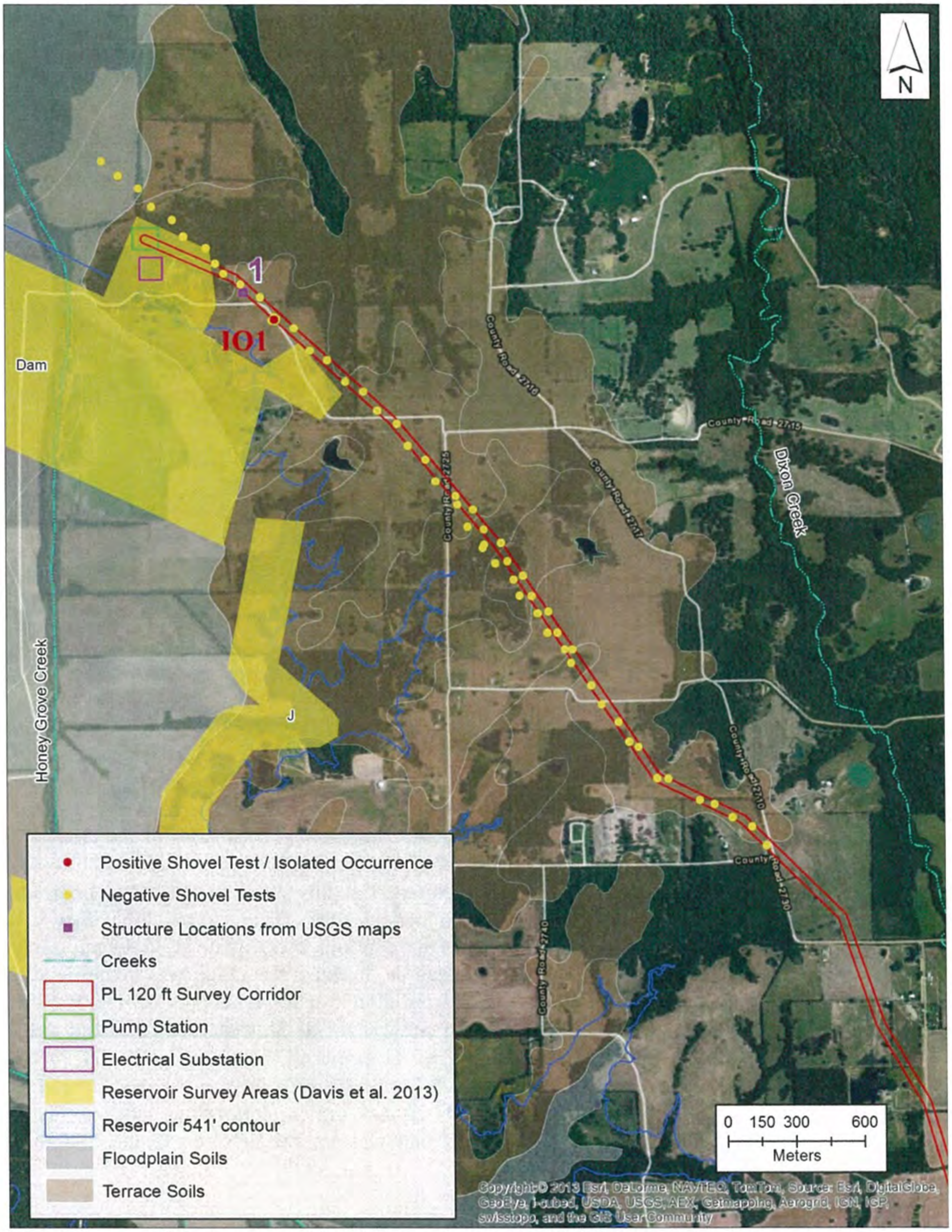


Figure 5. The survey corridor shown on a recent aerial photograph.

Figure 6. Field conditions typical of the upland pastures north of Fox Creek. View is to the north.

Once the survey corridor exited the previously surveyed area, shovel testing resumed in terrace deposits between Fox and Honey Grove creeks. An initial alignment was surveyed through this area; however the route was moved west and was resurveyed (Figure 7). In the realignment, just north of CR 2780, the first archaeological site (41FN171) was recorded. Two structures were shown on the 1984 Selfs, TX 7.5' USGS map within the survey corridor. Based on the 1950 aerials, this was a farmstead consisting of 5 to 6 structures. By 1976, only two structures remained and by 1995 all had been removed. Shovel testing continued south across Honey Grove Creek to the north side of CR 2770. Shovel tests were excavated on both sides of the creek and the channel banks were inspected. The channel was approximately 8 to 10 m wide and 6 to 8 m deep (Figure 8). No cultural resources were documented at this crossing and none had been found downstream during the Honey Grove Creek channel walks (Davis et al. 2013:52-63). In addition, this crossing will be tunneled. Based upon the previous investigations, its location high in the watershed, and the proposed construction methods, backhoe trenching was determined to be unnecessary. In total, 72 shovel tests were excavated along the alignments down to CR 2770. Thirty-four of the shovel tests were associated with site 41FN171. Shovel tests excavated in the terrace setting, typically presented profiles similar to the previous, brown or yellowish brown sand, sandy loams, or loams over red clays. Clay was typically encountered between 20 and 80 cmbs. In the floodplain, soil profiles typically contained dark gray to dark brown sandy or loamy clays over black or very dark brown clay. The sterile clay was reached between 30 and 70 cmbs.

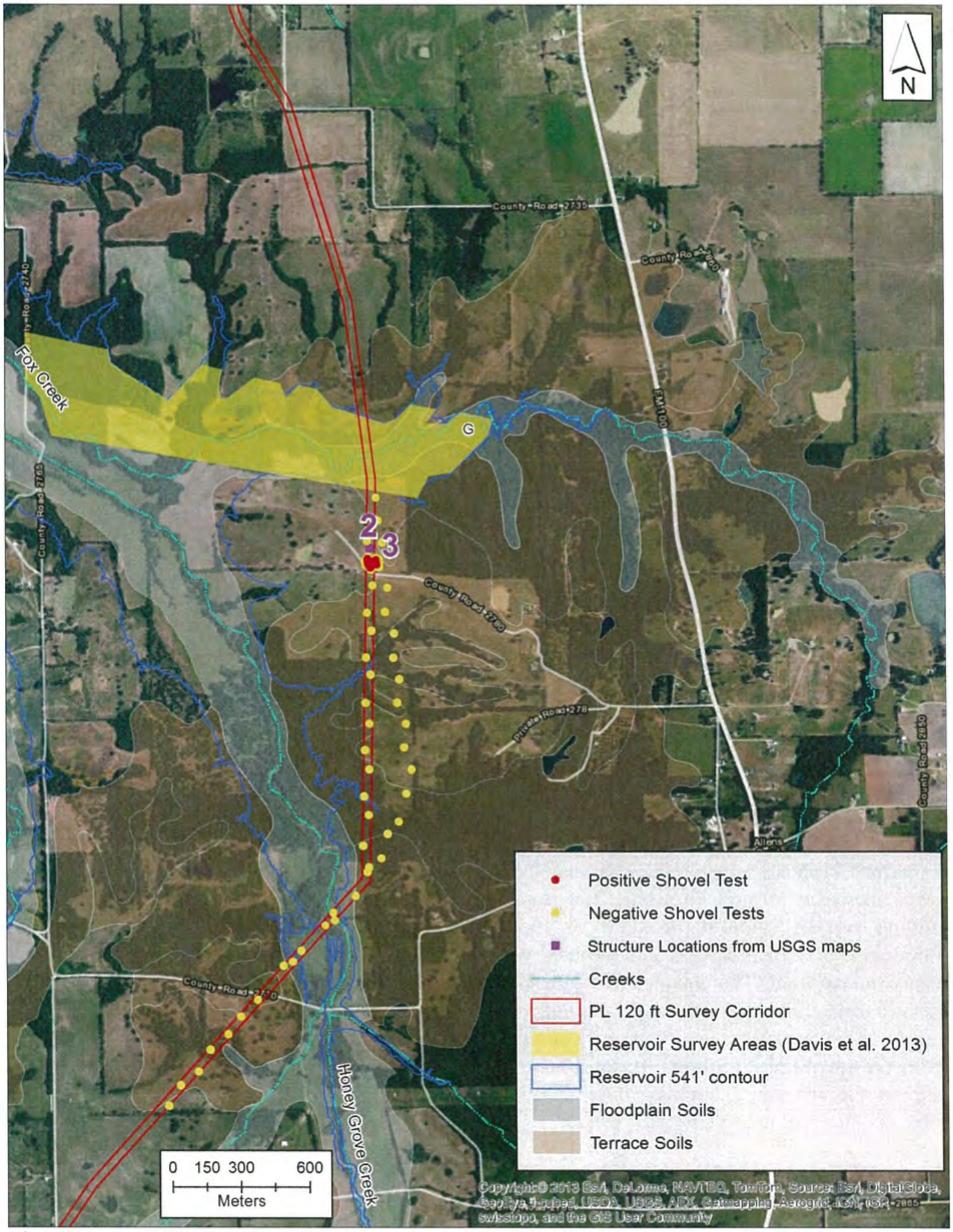


Figure 7. The survey corridor shown on a recent aerial photograph.

Figure 8. The survey corridor crossing of Honey Grove Creek. View is to the south.

South of CR 2770, the terrace deposit flanking Honey Grove Creek extended for approximately 700 m before reaching the uplands south of an existing transmission line (Figure 9). Seven shovel tests were excavated along this portion of the alignment. Typically these shovel tests contained black to brown loamy or sandy clays over dark yellowish brown to yellowish brown clays, between 50 and 70 cmbs. The route continues southwest across upland pastures, with ground surface visibility between 50 and 100 percent. Once the route reached the narrow floodplain of Allens Creek, shovel tests were excavated on both banks and the crossing was visually inspected. The channel was 5 to 8 m wide and 4 to 6 m deep. Typical profile for these shovel tests contained very dark gray to very dark grayish brown loamy clays over very dark brown to yellowish brown clays, between 60 and 100 cmbs. The bank profiles generally agreed with the shovel test findings. Based upon the previous investigations and the crossing location high in the watershed, backhoe trenching was determined to be unnecessary. No archaeological sites or IOs were recorded in this area.

Figure 9. The survey corridor shown on a recent aerial photograph.

The route then begins ascending the upland divide towards Ward Creek and FM 1396 through more pastures and cropland, with excellent ground surface visibility. The floodplain on both sides of Ward Creek was shovel tested and the channel was inspected. The channel was 3 to 5 m wide and 2 to 3 m deep. The shovel tests revealed a profile similar to the exposed banks. Typically, there was black loamy clay on top of very dark gray clay with $CaCO_3$ resting on black clay with more $CaCO_3$. The black clay at the bottom was between 80 and 90 cmbs. During the inspection of the creek crossing, it was noted that just upstream from the crossing there were three pipes crossing the creek (Figure 10). These pipes could represent the remains of a bridge; however no roads show on the USGS maps or aerials. The floodplain at the crossing was generally flat. No cultural resources were documented at this crossing and none were found downstream during the previous channel walk of Ward Creek. Additionally, this crossing will be tunneled. Based on these factors backhoe trenching was determined to be unnecessary. The route continues southwest toward US 82, through the upland setting (Figure 11). Ground surface visibility throughout this portion was excellent between 40 and 80 percent.

Figure 10. The survey corridor crossing of Ward Creek. The pipeline will cross near existing pipes.

Figure 11. The survey corridor shown on a recent aerial photograph.

After the corridor crosses under US 82, it continues through upland cropland that contained corn at the time of survey (Figure 12). Even though, the property still contained crops, ground surface visibility between the rows was 50 to 100 percent. After crossing FM 1743, the route began descending to the Cottonwood Creek floodplain. The Cottonwood Creek channel was very narrow (2-3 m wide) and shallow (1-2 m deep) (Figure 13). Shovel tests excavated on either bank revealed dark grayish brown to yellowish brown sandy clays over very dark gray clay, typically encountered between 90 and 105 cmbs. Visual inspection of the banks showed no buried cultural materials and none were recovered in the shovel tests. Based upon these factors, backhoe trenching was determined to be unnecessary. The route continues southwest towards CR 2998. In total, 11 shovel tests were excavated between US 82 and CR 2998 and all were negative.

On the southwest side of CR 2998, the route continues in a southwesterly direction towards Spring Branch, an intermittent tributary of Cottonwood Creek. The crossing is just south of the mapped floodplain sediments. Shovel tests were excavated on either bank and contained dark gray clay down to 60 cmbs, where shale was encountered. The creek channel was heavily eroded, approximately 4 m deep and 10 to 12 m wide (Figure 14). Visual inspection of the banks showed no buried cultural materials and none were recovered in the shovel tests. Backhoe trenching was not necessary at this crossing.

The route begins to ascend the upland divide between Spring Branch and Bullard Creek, as it approaches CR 2975. This portion of the alignment was mainly pastures with ground surface visibility between 30 and 50 percent. Field crews noted that shale was exposed in eroded areas of the pastures. On the south side of CR 2975, shovel testing resumed as ground surface visibility diminished to less than 30 percent. Here the route will cross near the confluence of Bullard Creek and its tributary Burnett Creek. The channel for Burnett Creek was 12 to 15 m wide and 5 to 6 m deep, with bedrock exposed in the bottom (Figure 15). Additionally, the field crew noted that the creek appeared to have been channelized and that there were man-made levees along the bank edges. Shovel tests in the area revealed a variety of dark gray and dark grayish brown clayey loams and sandy clays over similarly colored clay, between 43 and 105 cmbs. No cultural resources were documented at this crossing and none had been found downstream during the channel walks of Bullard Creek. Based upon the setting, backhoe trenching was determined to be unnecessary.

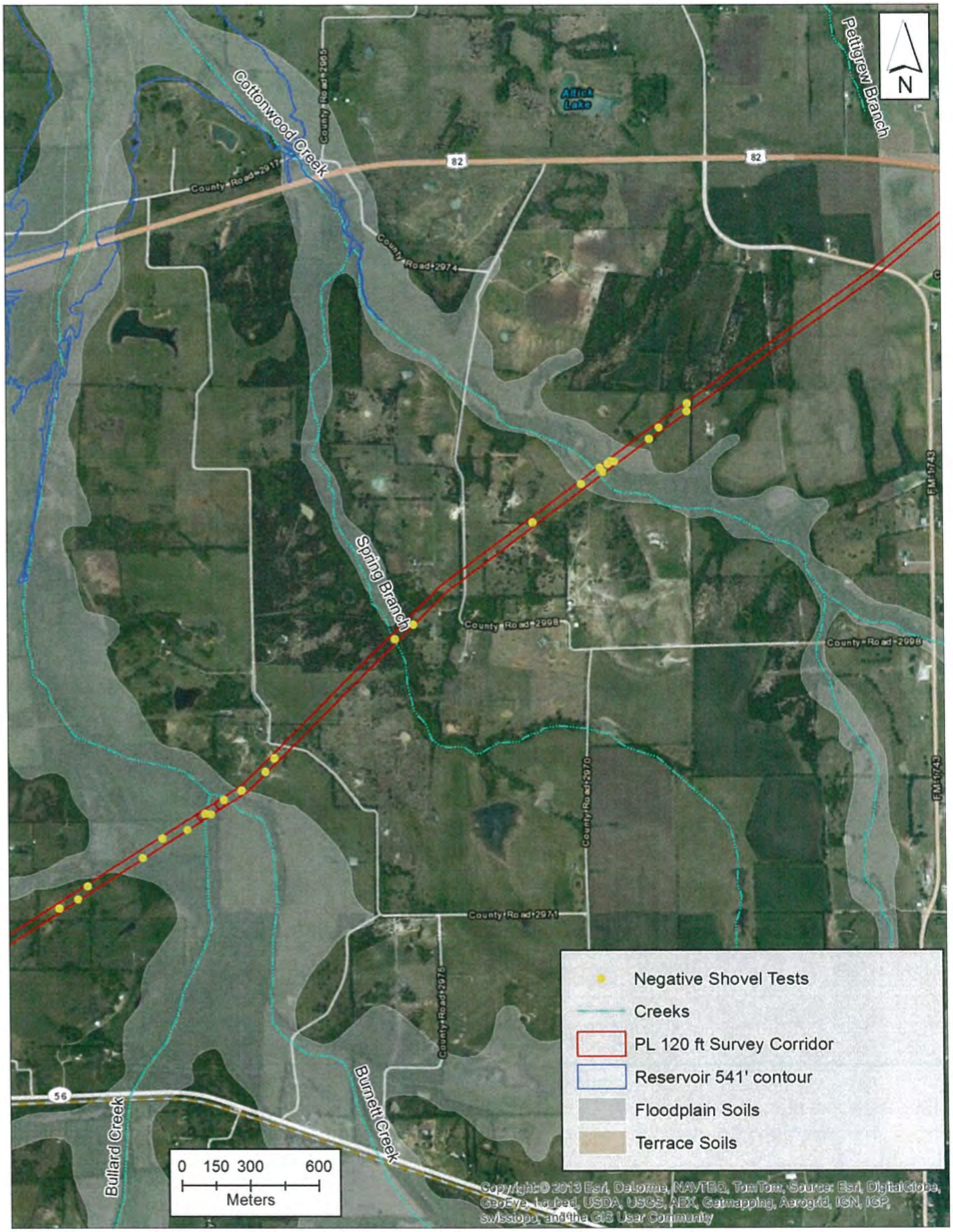


Figure 12. The survey corridor shown on a recent aerial photograph.

Figure 13. The Cottonwood Creek channel at the proposed crossing. View is to the north.

Figure 14. Spring Branch channel at proposed crossing. View is to the south.

Figure 15. The proposed crossing of Burnett Creek. View is to the southeast.

The route then immediately crosses Bullard Creek. Shovel tests in the area revealed a variety of dark gray and dark grayish brown clay loams and sandy clays over similarly colored clay, between 100 and 110 cmbs. Field crews noted that $CaCO_3$ increased with depth. The channel was approximately 15 m wide and 4 to 6 m deep (Figure 16). The profile exposed in the channel was similar to those described in the shovel tests. No cultural resources were documented at this crossing and none were found downstream during the reservoir study. Additionally, this crossing will be tunneled and, backhoe trenching was unnecessary. In total, 12 negative shovel tests were excavated between CR 2975 and CR 3211.

Figure 16. Bullard Creek channel at proposed crossing. View is to the north.

The route continued southwest through upland pastures and cropland. Once again ground surface visibility was better than 30 percent. The survey corridor crosses under SH 56 and continues through upland pastures before reaching the headwater floodplain of an unnamed tributary of Bullard Creek (Figure 17). The drainage channel was situated near CR 3210, and consisted of a low-lying area with flat terrain. Eight shovel tests were excavated along the route and all were negative. The channel was approximately 3 to 5 m wide and 3 to 5 m deep (Figure 18). The profile revealed in the shovel tests and bank profiles, consisted of very dark gray to very dark grayish brown sandy clays on top of similarly colored clay, between 40 and 120 cmbs. Due to the nature of the drainage, the previous investigations downstream on Bullard Creek, trenching was determined not to be necessary. Once the route leaves the floodplain, it ascends the upland divide near CR 3200. This area consisted of pasture and cropland with ground surface visibility between 30 and 100 percent, and dense vegetation along the fence lines. No cultural resources or archaeological sites were documented in this portion of the route.

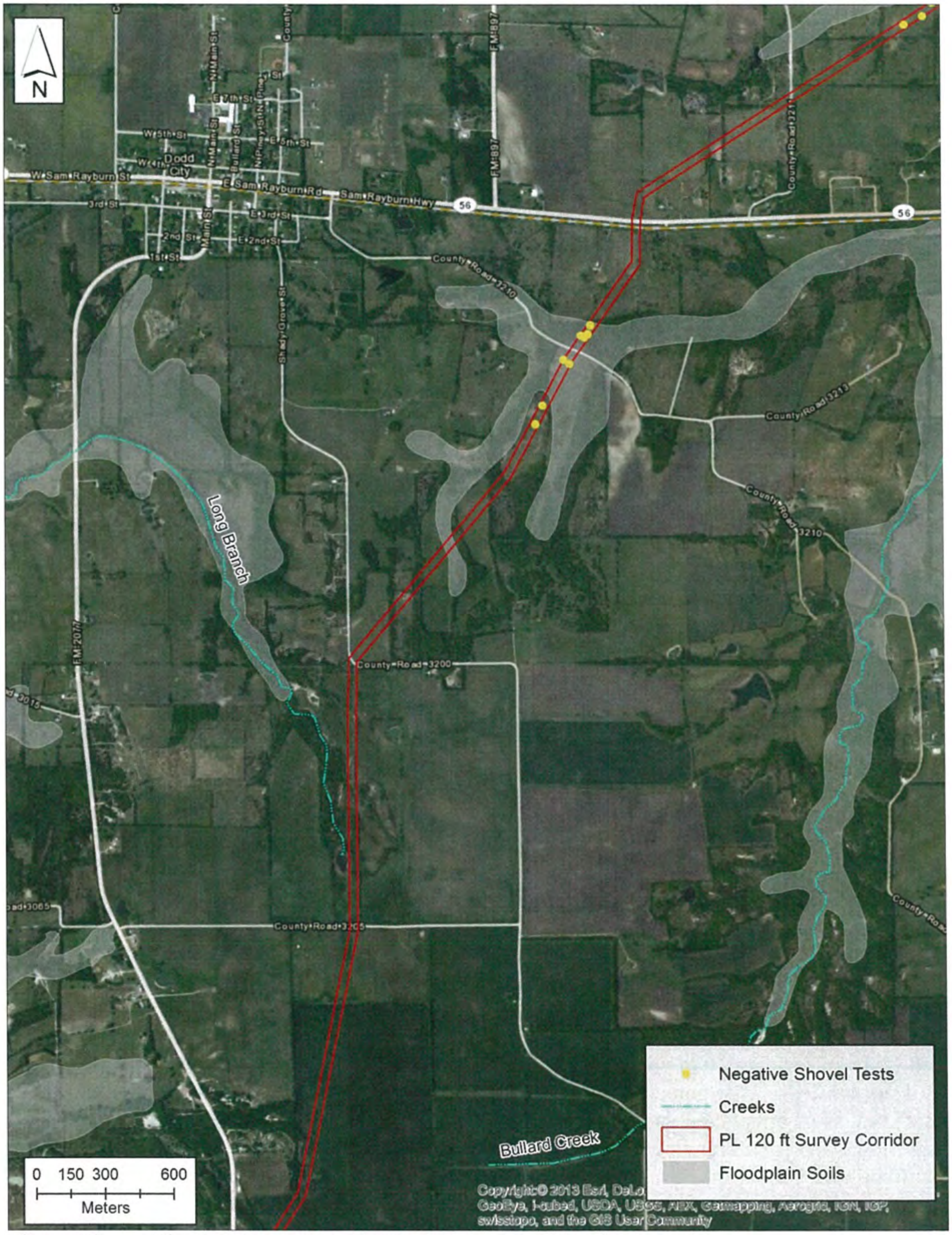


Figure 17. The survey corridor shown on a recent aerial photograph.

Figure 18. Unnamed tributary channel of Bullard Creek. View is to the north.

After the CR 3200 crossing, the corridor turns due south and begins ascending the upland divide between the Red and Sulphur river watersheds. North of CR 3205, the corridor parallels the headwaters of Long Branch, a tributary of Sloan Creek. The route does not intersect the drainage or any floodplain sediments. It continues south-southwest through plowed fields, until reaching FM 2077 (Figure 19). Here the route parallels the east side of the road for approximately 2 km before turning southwest. The majority of the properties down to FM 1550, were cropland or pastures, many of which had been recently plowed (Figure 20). At the intersection of FM 2077 and CR 3235, the fourth and fifth structures mapped on the 1984 Dodd City, TX 7.5' USGS maps appear within the survey corridor. The structure on the north side of the intersection remains standing. The temporary easement was narrowed on the west side of the occupied home and is now more than 10 m outside the permanent easement (Figure 21). Additionally, it appears as if the home has undergone significant renovations and possibly has been moved slightly to the southeast, as its orientation does not match that of the USGS structure. The home appears to have new siding and is resting on cinder block piers. An existing pipeline easement is routed through the front yard, which the new pipeline will parallel. No artifacts were present within the survey corridor. No evidence of the structure shown on the south side of CR 3235 was present. According to Google Earth aerials, the structure was still standing in 1995, but was gone by 2005.

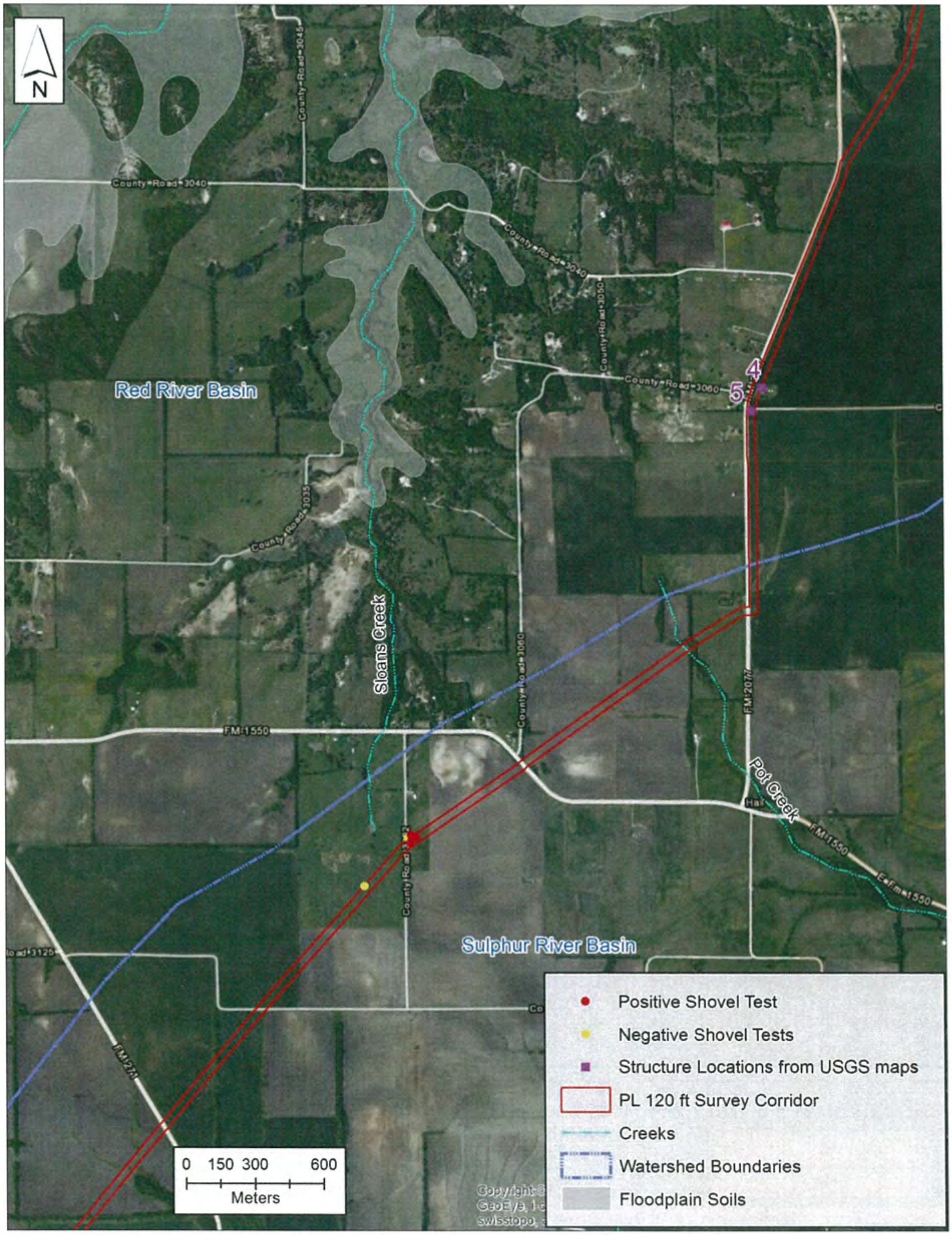


Figure 19. The survey corridor shown on a recent aerial photograph.

Figure 20. Typical ground conditions of the route between CR 3200 and FM 1550.

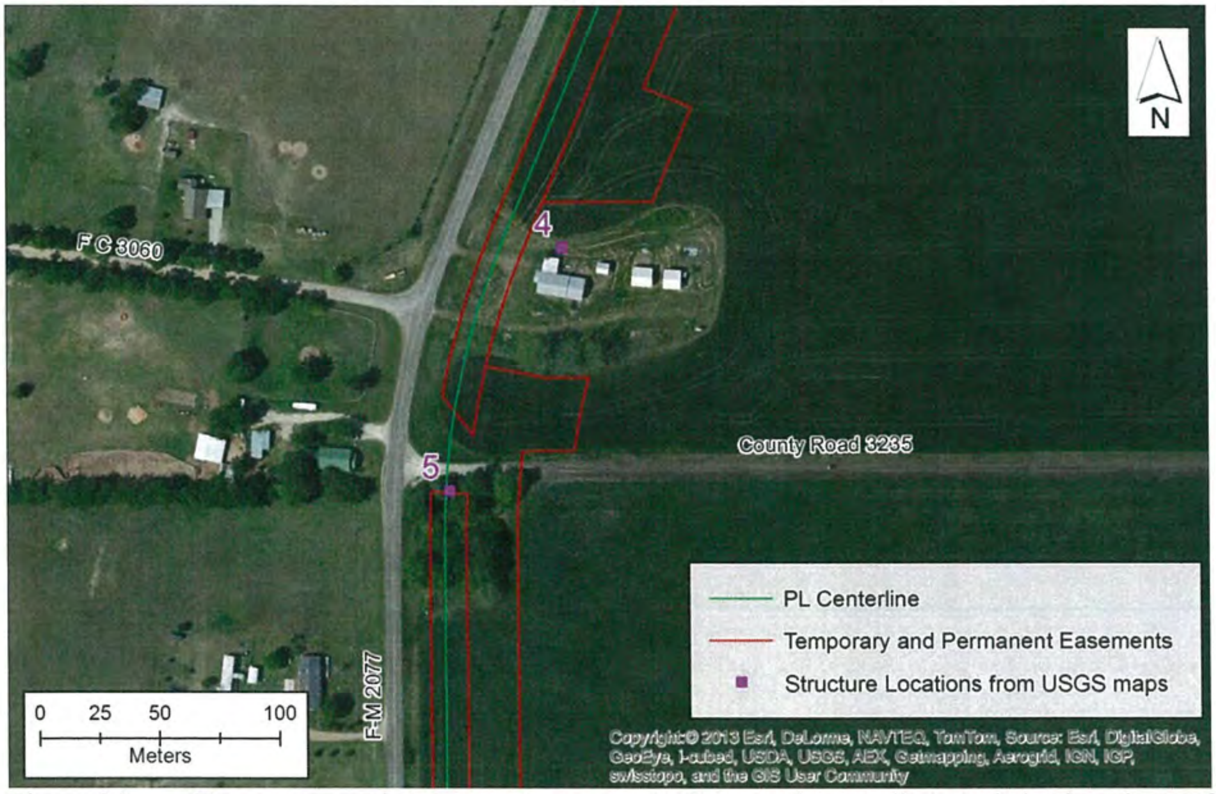


Figure 21. Temporary and permanent easements, proposed centerline, and the locations of structures mapped on the USGS maps shown on a recent aerial photograph.

Figure 22. Structure on the northeast side of the intersection of FM 2077 and CR 3235. Note the new exterior on the structure and its foundation piers consist of modern cinder blocks.

On the west side of FM 2077, the corridor continues through recently plowed fields with 100 percent ground surface visibility for approximately 300 m to the headwaters of Pot Creek. The drainage channel was nearly indiscernible from the surrounding terrain, and the channel was only 5 to 10 cm deep and approximately 1 m wide. Pot Creek is a first order drainage that flows southeast to Brushy Creek in the Sulphur River Watershed. The route remains situated in recently plowed fields on the upland divide. On the east side of CR 3302, a historic artifact scatter associated with a cistern or well was recorded as 41FN169. The route remains in a recently plowed field southwest to FM 271. It stays in this upland setting past CR 3120 to FM 68 (Figure 23). On the south side of FM 68, it parallels the west side of FM 3700 to FM 1552, through plowed fields. On the south side of FM 1552, it remains in plowed fields (Figure 24). Approximately, 860 m south of FM 1552, the sixth structure shown on the USGS maps appears in the survey corridor. The structure was originally mapped on the 1964 Leonard, TX 7.5' quadrangle. Google Earth aerials show no structure in the location in 1995. No evidence of the structure or artifacts was observed during survey. The route maintains a southernly direction toward SH 11 through plowed fields.

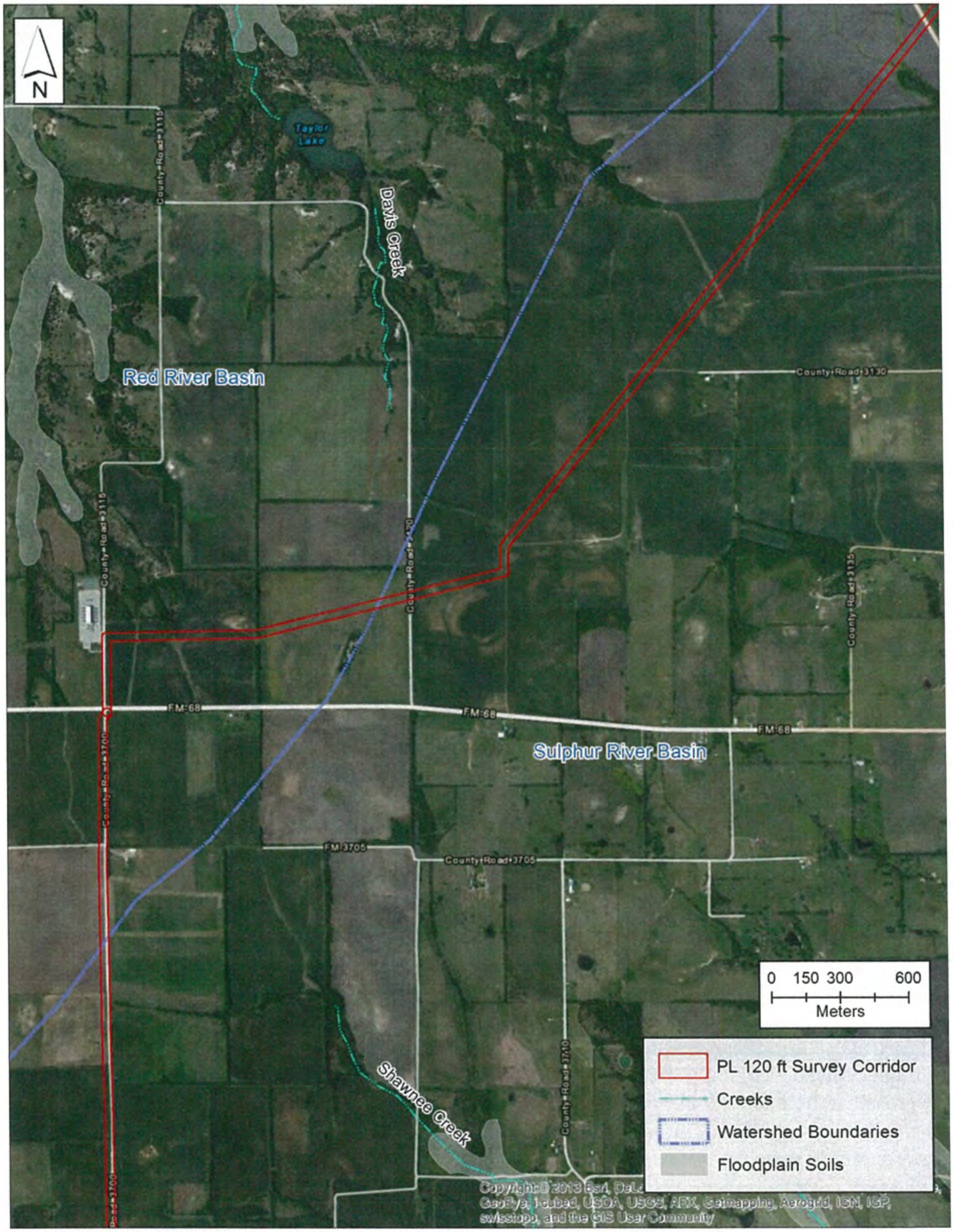


Figure 23. The survey corridor shown on a recent aerial photograph.

Figure 24. The survey corridor shown on a recent aerial photograph.

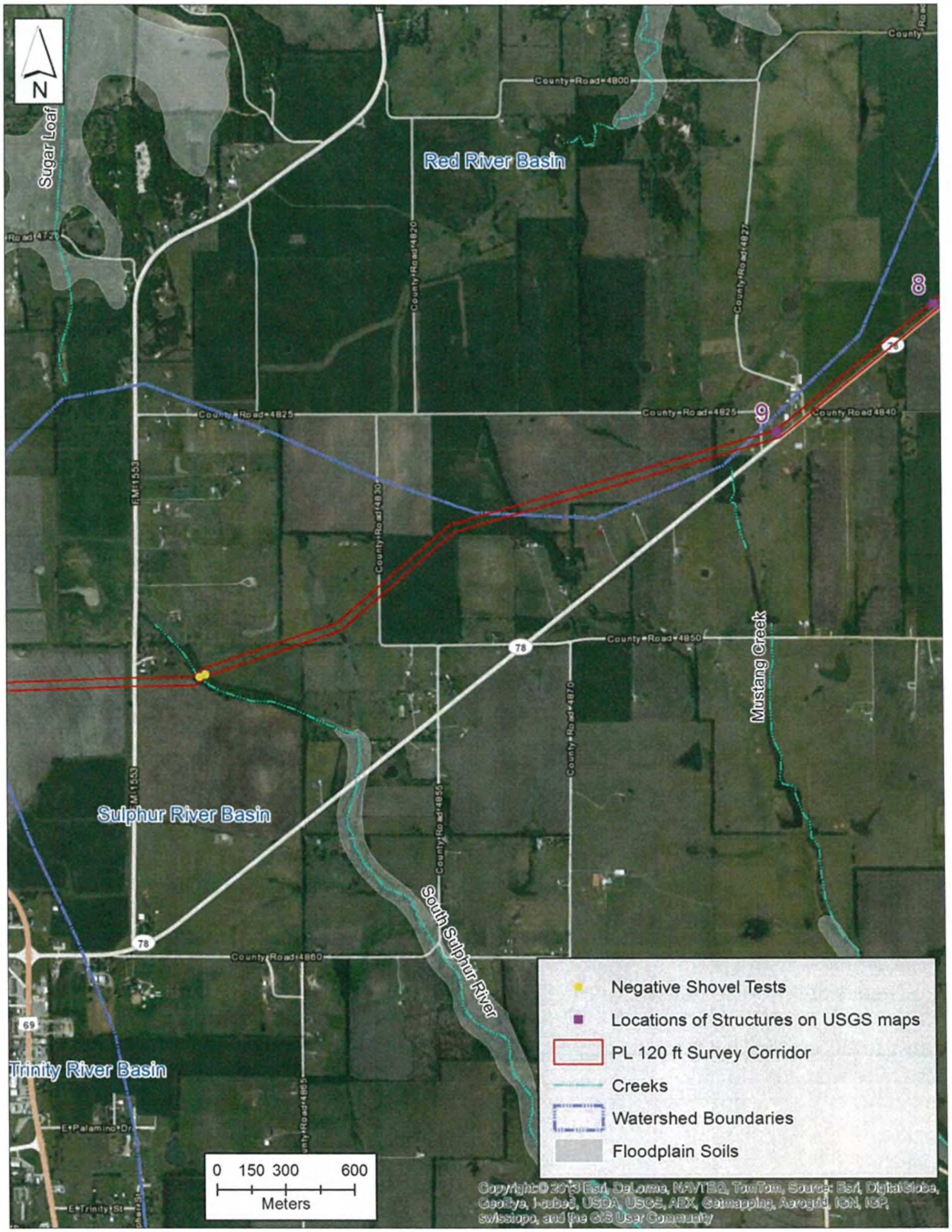
Between SH 11, FM 816, and SH 78, the pipeline is to be routed through more cropland that had been recently plowed. Additionally, it crosses through the headwaters of three unnamed tributaries that drain south into Loring Creek, in the Sulphur River Watershed. The most significant channel encountered in this portion of the route was shovel tested. The channel was approximately 4 to 6 m wide and 2 m deep. The shovel tests revealed 40 cm of black clay on top of degrading caliche. Additionally, Ogallala gravels were noted in this area, some up to 20 cm in diameter, however no artifacts were found and very few were suitable for knapping.

Once the route reaches SH 78, it parallels the south side for approximately 1.6 km. It is here, where the seventh structure was found on the 1964 Leonard, TX quadrangle. While no evidence of the structure was present, a small pump house and cistern were recorded as 41FN170. No evidence of the structure appears on the 1995 Google Earth aerials. Once the route crosses under SH 78, it parallels the north side for approximately 1.5 km. The eighth structure shown on the Leonard quadrangle was encountered by the route. No evidence of this structure or artifacts were observed. Google Earth aerials show that the structure may have just been demolished prior to 1995. Additionally, the map showed a secondary structure just outside the survey corridor (Figure 25). This secondary structure was still standing (Figure 26). Ground surface visibility through the area was 100 percent.

Figure 25. Survey corridor, centerline, standing structures, and the locations of structures mapped on the USGS maps shown on a recent aerial photograph.

Figure 26. Small outbuilding on the west side of SH 78, just outside the survey corridor.

Eventually the route diverges from SH 78 and turns west-southwest towards CR 4830 (Figure 27). At the turn from SH 78, the ninth structure was found on the Leonard quadrangle appears in the survey corridor. The Google Earth aerials show that the structure was gone before 1995. No evidence of the structure or artifacts was found in the pasture. Approximately 200 m southwest of the route turn, it crosses the headwaters of Mustang Creek, which drains south into the Sulphur River Watershed. The channel had no hardwood vegetation lining the banks and the channel was only 50 cm deep and 1 m wide. The corridor continued through recently plowed fields all the way to FM 1553. Approximately 290 m east of the FM 1553, the route crosses the headwaters of the South Sulphur River (Figure 28). The channel was only a meter wide and 10 to 20 cm deep. Shovel tests dug at the crossing contained dark brown or brown clay on the surface down to 50 cmbs. There are no mapped floodplain sediments at the crossing and no cultural resources were identified.



Copyright:© 2013 Esri, DeLorme, NAVTEQ, TomTom, Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 27. The survey corridor shown on a recent aerial photograph.

Figure 28. The headwaters of the South Sulphur River where the proposed route crosses. View is to the east.

The route stays in a westerly direction past CR 4720 and FM 896, then parallels the north side of CR 4670 through plowed fields all the way to US 69 on the northwest side of Leonard, TX (Figure 29). After crossing under US 69 and the MTK Railroad tracks, it remains in plowed fields until reaching the narrow headwater floodplain of the channelized Lee Creek (Figure 30). Five shovel tests were excavated between the railroad tracks and the southern terminus of the pipeline at the TSR site. Most of the area consisted of pastures with ground surface visibility around 30 percent. Shovel tests revealed that the area contained black or very dark brown clay and degraded shale, limestone, and caliche around 60 cmbs. Due to the shallow nature of the creek, channelization, and the crossing high in the watershed, trenching was not warranted.

In summary, 209 shovel tests were excavated along the 35 mi long pipeline route. Most of the shovel tests were concentrated in terrace and floodplain sediments. Of those, only 23 shovel tests were positive, and 22 of those are associated with the three historic archaeological sites (41FN169-171) recorded in the survey corridor. In addition, nine structures had been mapped within the survey corridor on the USGS quadrangles. However, eight had been demolished prior to the survey. The permanent and temporary easement was reduced in the area of the fourth structure, so the structure is outside the project boundary and will not be impacted. A secondary structure was found associated with the eighth mapped structure, but it fell outside the project boundaries.

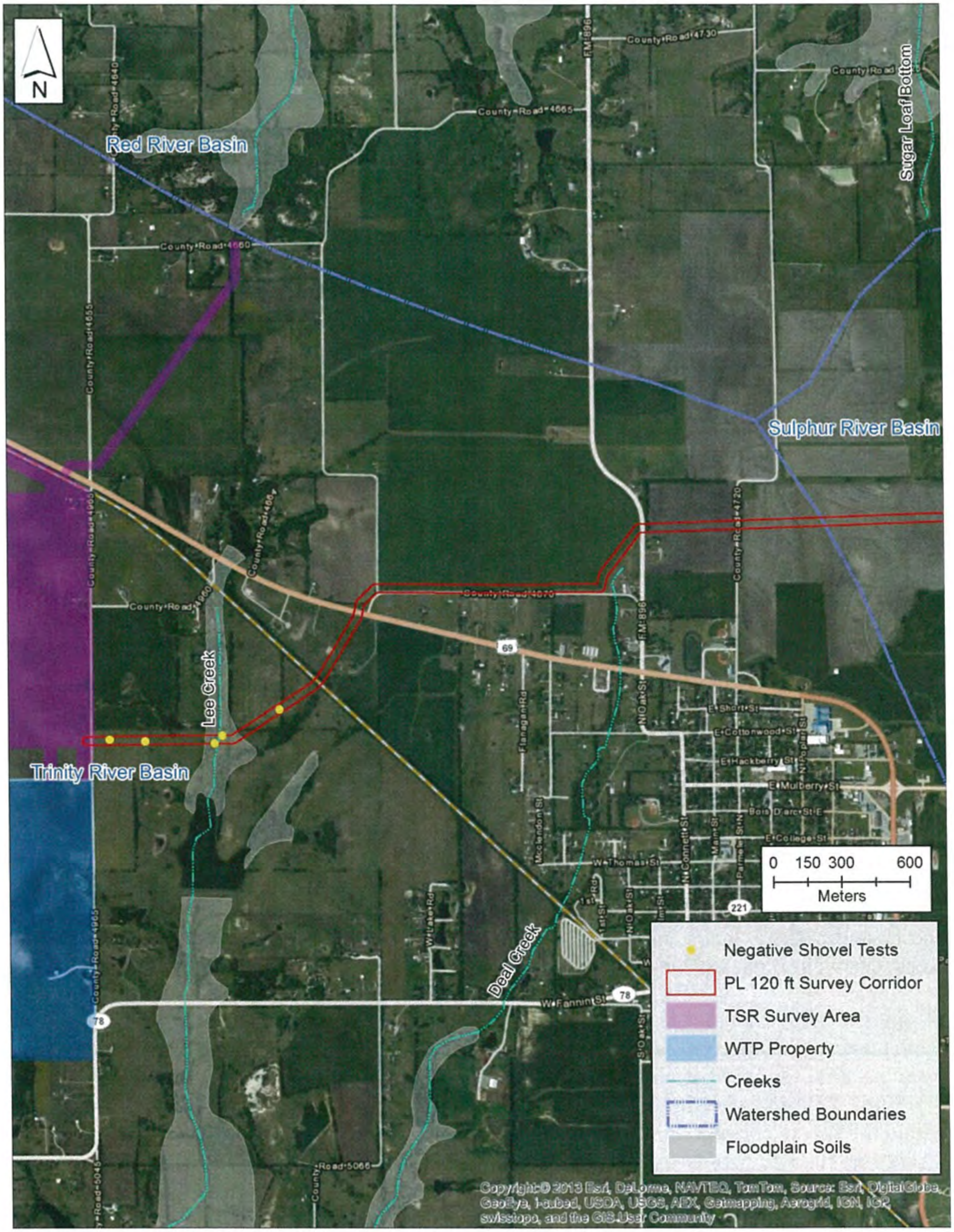


Figure 29. The survey corridor shown on a recent aerial photograph.

Figure 30. The proposed crossing of Lee Creek. Note the exposed bedrock in the background.

Terminal Storage Reservoir (TSR)

The TSR is situated southwest of the intersection of US 69, the MKT Railroad tracks, and CR 4965. The TSR will consist of a north and south cell and will be approximately 153.5 acres in size. Each cell would hold approximately 210 million gallons of water, which would provide for approximately two days of storage during peak water demands. The TSR site will be designed so it can be drained and the flow would be directed into the Red River Watershed via the proposed drainage pipeline into Valley Creek to the north. The proposed drainage pipeline will be approximately 72-in in diameter and approximately 4,918 ft in length. Additionally, a network of pipes will connect the TSR to the WTP just south of CR 4950 (Figure 31).

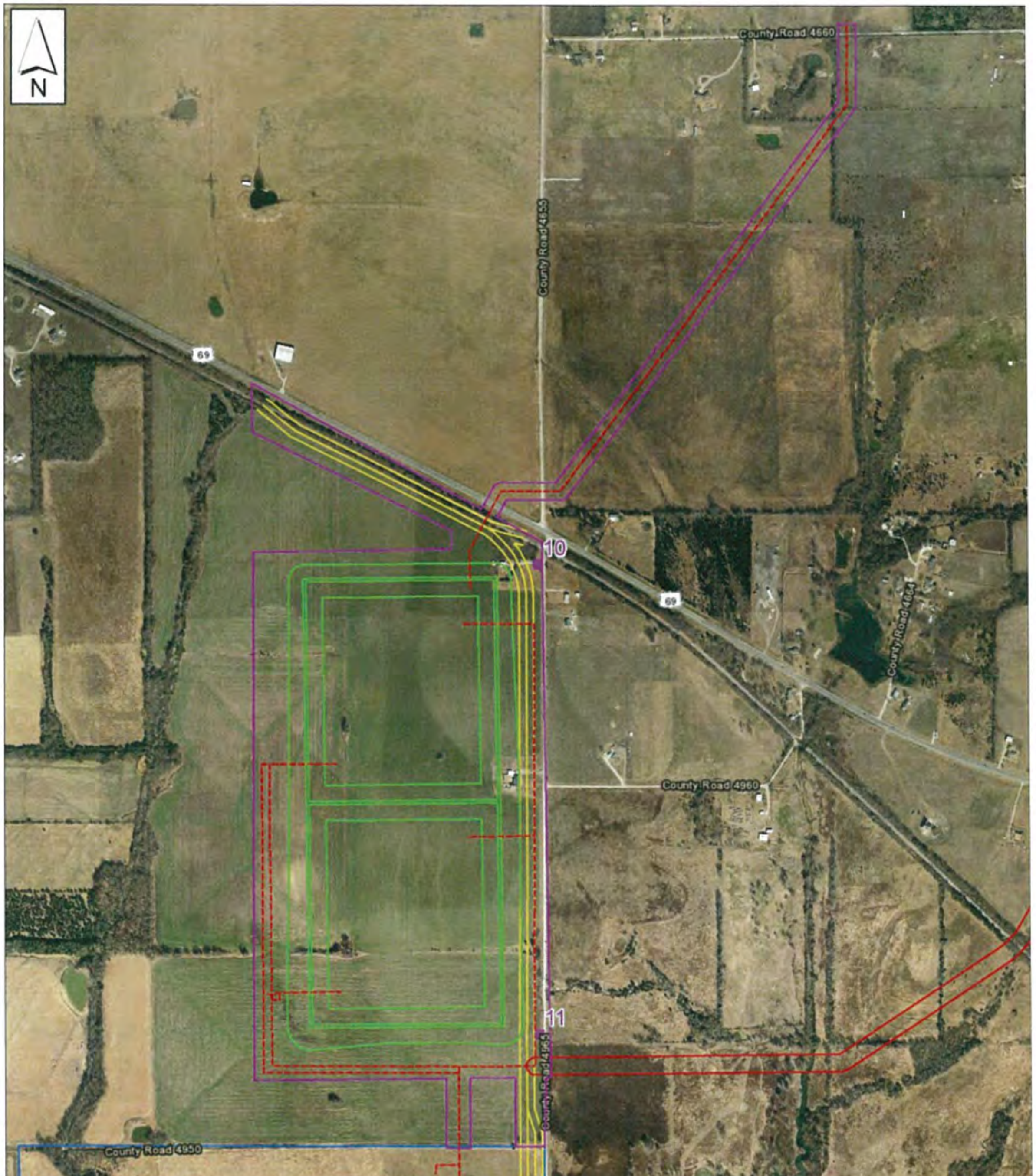


Figure 31. The survey area for the TSR with the north and south cells, TSR pipelines, Rail Spur shown in relation to the tenth and eleventh structures mapped on the USGS maps, the PL and the WTP on a recent aerial photograph.

Given that the proposed rail spur is also situated on the TSR property, its description is included here. The rail spur is proposed to be constructed off the MKT Railroad north of the TSR site that would terminate at the proposed WTP site. The rail spur would be approximately 6,600 ft long. A 120 ft wide survey corridor was utilized for the proposed drainage pipeline to Valley Creek.

The survey area consists of portions of eight different parcels, most of which are cropland. At the time of the survey, ground surface visibility was between 50 and 100 percent, largely due to recent plowing (Figure 32). Twenty-one north/south parallel transects were walked throughout the survey area. Overall, the terrain was generally level and appears to have been farmed for more than a century. Additionally there was some evidence that the fields had been terraced in the past.

Figure 32. The typical terrain and ground surface visibility of the TSR survey area.

Three archaeological sites (41FN172-174) were recorded in the TSR survey area. Additionally, the review of the 1964 Trenton, TX USGS quadrangle showed the tenth and eleventh structures noted during the map review. The tenth structure corresponds to the location of site 41FN172. However, the 1964 aerials show a different arrangement of the structures on the property, and this was confirmed by Jimmy Roy James, the current landowner. The home was moved to its current location in 1975 and was significantly remodeled. The historic aerials and the landowner confirmed that none of the original structures remain. A cistern is located near the original location of the home and is the only intact feature at the site. This site is discussed in further detail in the next chapter. The eleventh structure on the quadrangle had been removed prior to 1995. The other two archaeological sites recorded in the study area, were cisterns. Additionally, one other structure was present during the survey. This structure is situated near the intersection of CR 4965 and CR 4960. Google Earth aerials show no structure in the location in 1995, however, it was present by 2005.

Water Treatment Plant (WTP)

The proposed WTP site will be situated on the 323 acre property southwest of the intersection of CR 4965 and CR 4950 (Figure 33). The property was largely open pasture that was farmed and terraced. In the northwest corner is an unnamed intermittent tributary that drains southwest to Bear Creek. The majority of the property east of the creek had ground surface visibility between 30 and 100 percent (Figure 34). Typical vegetation was short prairie grasses and weeds. On the west side of the creek, ground surface visibility was 30 percent or less, necessitating shovel tests. It was covered in taller prairie grasses and weeds.

Overall, 49 shovel tests were excavated in the WTP property. Twenty-four were on the west side of the creek. While 16 shovel tests were excavated on the east bank. The final nine were dug on top of the terraced knolls shown on the USGS map. The second IO for the project was recorded in the top 10 cmbs of a shovel test on the knoll in the southwest corner of the property. The IO was a small sherd of undecorated whiteware. All other shovel tests were negative. Shovel test profiles typically showed very dark gray to very dark grayish brown clays on the surface. Bedrock was encountered in some shovel tests as shallow as 35 cmbs. On the west side of the creek near CR 4950, a large pile of scrap metal, wire fencing, t-posts, corrugated sheet metal, concrete debris, plastic and clear glass bottles, and tires was found. The trash dump was situated in an erosional gully that feed east into the creek. None of the trash in the area appeared to be more than 30 years old; therefore it was not documented as an archaeological site. Between the creek and CR 4965, the property was walked in parallel north/south transects spaced 30 m apart. Overall, 32 transects were walked by the field crew.

Additionally, the entire creek channel was inspected from CR 4950 to where it exits the property. The channel width varied between 5 and 8 m wide at the north end and 10 to 15 m wide near southern end. The channel was approximately 3 to 5 m deep, and had eroded 1 to 1.5 m into the underlying bedrock for most of the channel (Figure 35). Overall the creek bottom was dry; however, there were a couple deep spots that held water and aquatic life. The eastern creek bank tended to be 1 to 2 m higher than the west bank, yet bedrock was typically exposed in both. Only limestone gravels were noted in the area, and no knapped material was noted on the property. Visual inspection of both banks demonstrated that there was between 60 and 140 cm of very dark gray, pale brown, and very dark grayish brown clays resting on the bedrock. No cultural resources were observed or recorded in the creek channel.

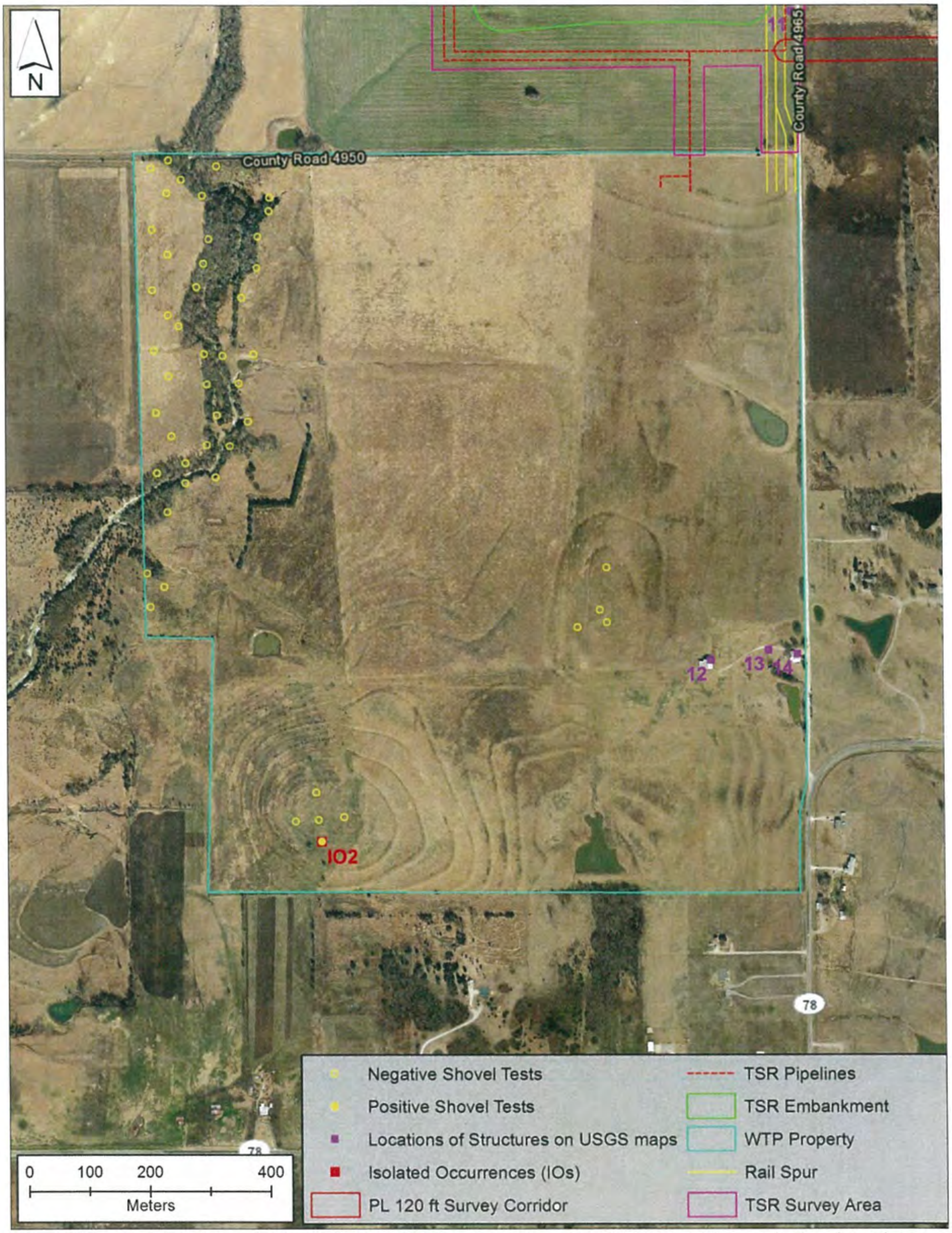


Figure 33. The boundaries of the WTP property, shovel tests, IO, and the locations of structures mapped on the USGS maps are shown on a recent aerial photograph in relation to the TSR Survey Area.

Figure 34. The typical terrain, vegetation, and ground surface visibility throughout the majority of the WTP. View is to the south.

Figure 35. Typical profile seen throughout the creek channel on the WTP property. View is to the southwest near the creek bend.

The twelfth through fourteenth structures mapped on the USGS quadrangles were within the WTP property. The 1964 Trenton, TX quadrangle showed three structures on the east side of CR 4965, just north of the 90 degree turn on SH 78. Structures were still present at the time of the survey, and the farmstead was recorded as site 41FN175 and is detailed in the following chapter. The structures (Resources 1a-c) were evaluated by Deborah Anglin, Architectural Historian, and are described in Chapter 7. Of the 49 shovel tests dug on the property, only one was positive. The artifact was classified as an IO. Only the one archaeological site was recorded within the WTP property.

CHAPTER 6. ARCHAEOLOGICAL SITES

This chapter describes the seven sites recorded during the pedestrian survey (Figure 36). Shovel tests are described generally within the text, and shovel test matrices are presented within associated tables.

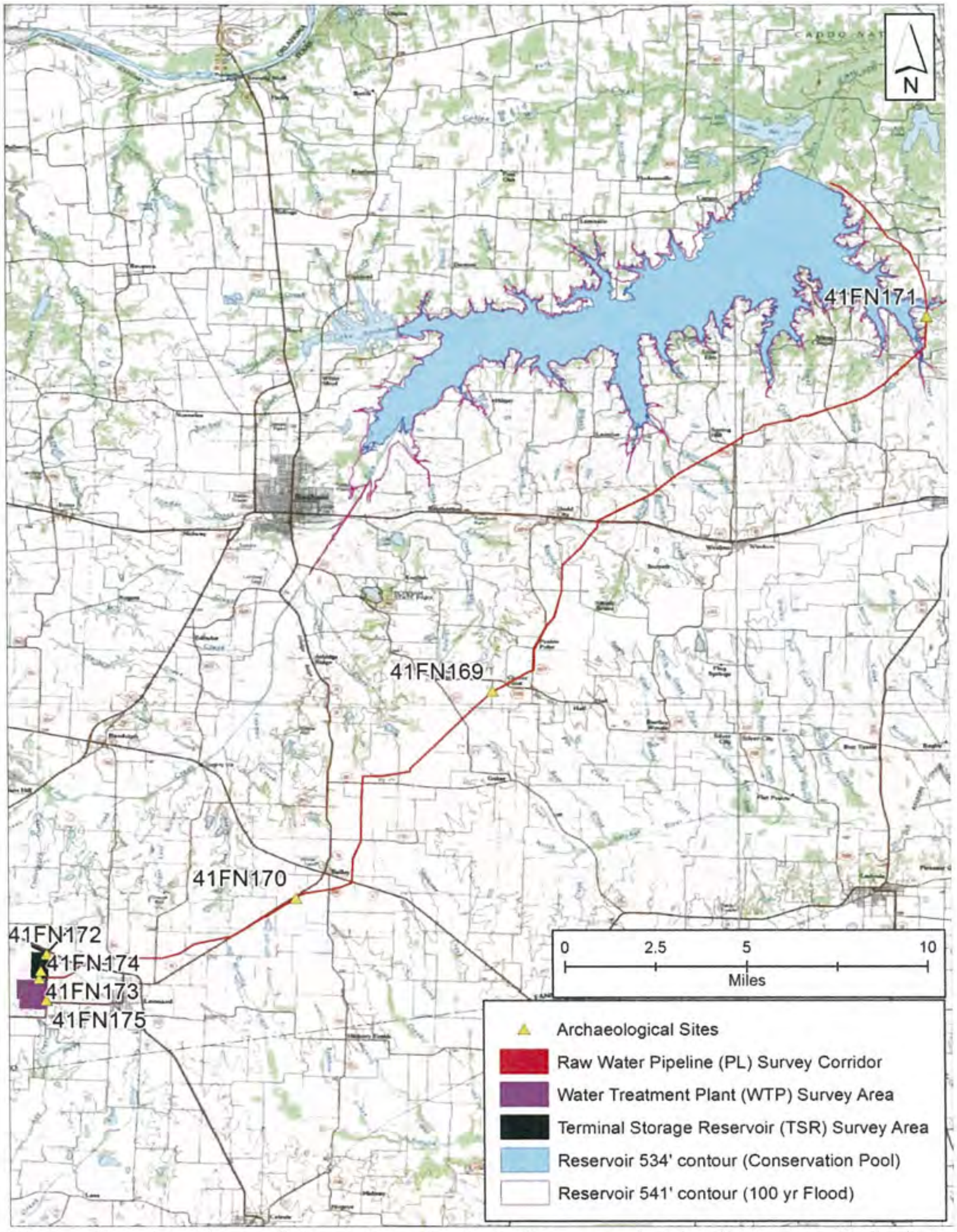


Figure 36. The locations of the archaeological sites recorded in the Lower Bois d'Arc Creek Reservoir Pipeline study area shown on portions of the Sherman, McKinney, Paris, and Sulphur Springs, Texas 100 k USGS topographic maps.

41FN169

East of CR 3302 is an historic cistern or well and associated artifact scatter recorded as site 41FN169 (Figure 37). The site is located on a relatively level, upland formation in a plowed field approximately 550 meters west of Sloans Creek. The field had been planted in hay and recently harvested providing ground surface visibility between 50 and 100 percent (Figure 38). The site is bounded on the west by a fence that parallels to the road. The remaining boundaries are defined by the surface scatter. The cistern or well is the only feature at the site (Figure 39); it is lined with rough cut limestone and measures 1.5 ft in diameter at the top. It has no collar and is 9 ft deep. Due to the small opening, it could not be determined whether the feature currently holds water or whether it has a defined shape and type. A limestone slab had been jammed in the mouth to prevent things from falling in (Figure 40). Based upon visible characteristics, the feature resembles descriptions of both cisterns (Denton 2007) and wells (Mace 1994).

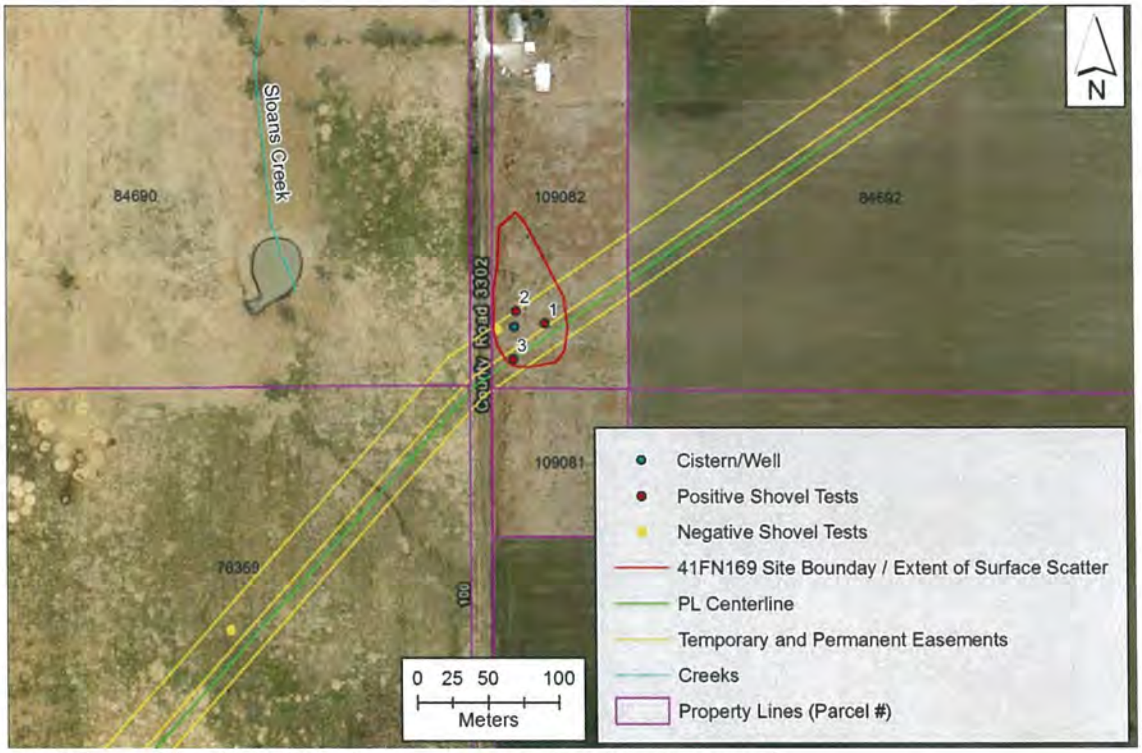


Figure 37. Site 41FN169 shown on a recent aerial photograph.

The historic artifact scatter is ephemeral but wide-spread and clearly visible in the plowed field. Artifacts include several hand turned bottle necks; clear, amber, cobalt, and sun-colored amethyst (SCA) glass shards (vessel and window glass); whiteware and stoneware sherds; a ceramic toy car wheel; fence staples, wire nails, and one square cut nail; indeterminate metal fragments; and concrete fragments. This surface scatter covers an area of 44,866.8 ft^2 (1.03 acres), and extends beyond the limits of the survey corridor. In order to test for a buried site deposit, four shovel tests were excavated in the survey corridor, three of which encountered artifacts within the top 30 cm of clay (Table 1).

Figure 38. Overview of site 41FN169; view is to the northwest.

Figure 39. The cistern or well feature at 41FN169; view is to the northeast.

Figure 40. The limestone slab jammed inside the feature at 41FN169.

Table 1. 41FN169 Shovel Test Descriptions.

ST#	Depth (cm)	Description*	Comments/Artifacts
1	0-40	Very dark gray (10YR3/1) sandy clay with 5-10% caliche	0-10 cm: glass (7), historic ceramic (1), square-cut nail (1), historic metal (1) 10-20 cm: glass (5), wire nail (2) 20-30 cm: historic ceramic (1), glass (6), historic metal (3)
2	0-40	Very dark gray (10YR3/1) clay with caliche	0-10 cm: historic ceramic (2), glass (1), concrete (1) 10-20 cm: concrete (2), historic ceramic (2), glass (2), wire nail (1) 20-30 cm: square-cut nail (1), brick (1), historic metal (1), glass (1) 30-40 cm: ceramic toy car wheel (1)
3	0-40	Very dark gray (10YR3/1) clay with 5% caliche	0-10 cm: glass (4), historic ceramic (2) 10-20 cm: glass (5), historic ceramic (1), burnt clay (1)

In addition to the pedestrian survey, historic maps and the deed records for the property were reviewed. Aerial photographs and historic topographic maps from the 1950s to present do not show structures at the site location but do show a structure less than 100 meters north of the site on the same property. The current landowner is Juan A. Huerta. He purchased the property in 2012 from Elberto and Porfirio Perez (Fannin County Deed Book [FCDB] 1598:492; Appendix B). The Perez family obtained the property from Dortha M. Williams in 2009 (FCDB 1418:355). Williams purchased the land from Mathew and Kim McCarty in 2008 (FCDB 1407:242), who in turn purchased it from Williams in 2005 (FCDB 1152:192). The property had in the Williams family since 1931, when J.E. and Nina Meade sold them the land (FCDB 214:267). It had been in the Meade family since 1910, when J.E. and G.B. Meade purchased it from T.W. Ragsdale (FCDB 118:347). No earlier records could be located.

Based on the construction style of the cistern or well feature and the associated artifacts, it is likely that the site constitutes a portion of a farmstead dating from the late 19th to the early 20th century. The only remnant of the site is the cistern or well. It appears that the site is not associated with noteworthy historic persons or events. Given the site's poor integrity and continued disturbance from plowing, it seems that it has quite limited potential to offer significant insights into the area's history. As such, it has been recommended to be ineligible for listing in the NRHP or for nomination as an SAL.

41FN170

On the east side of SH 78, approximately one mile south of Bailey, TX is site 41FN170. This historic site contains a well-cistern, a pump house, and an accompanying historic artifact scatter (Figure 41). The site is located approximately 10 meters from the highway in a relatively level upland pasture with a small erosional drainage marking the southwestern boundary of the site. Loring Creek is located approximately 240 meters to the southeast, and the gully represents the headwaters of the creek. The area is covered with thick short grasses, shrubs, and Snow on the Prairie flowers with a few scattered trees that include bois d'arc. The vegetation resulted in ground surface visibility ranging from 0 to 30 percent.

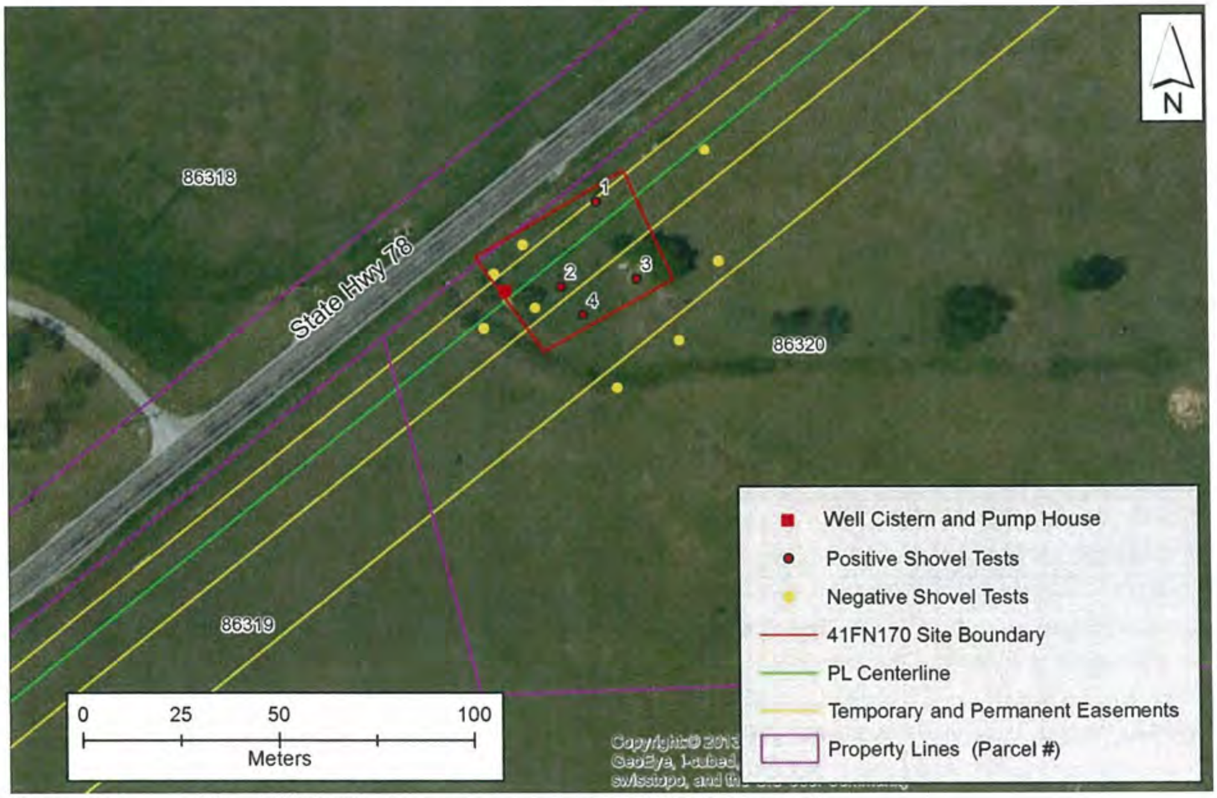


Figure 41. Site 41FN170 shown on a recent aerial photograph.

Figure 42. Overview of site 41FN170. View is to the northwest.

The well-cistern is brick-lined, as is its neck, and appears to be either concrete, rock-lined, or dug into bedrock in the lower portion, but this could not be confirmed in the field (Figure 43). The neck is 2 ft 7 in tall and approximately 4 in thick with an interior diameter of 2 ft 8 in. The entire structure is 20.5 ft deep and currently contains 10 ft of water (Figure 44). Approximately 5.5 ft below the neck and brick the feature expands in diameter. It also appears that some of the bricks have plaster lining. Four feet south of the cistern is a pump house with a concrete block foundation and commercial brick walls (Figure 45). This was likely connected to the out-take line that exits the wall. The pump house is 4 ft 3.5 in high, 6 ft 7 in long and 4 ft 8 in wide; it appears to have had a wood panel roof. The panel would have been held by the 8 anchor bolts mounted to the top of the brick wall. The commercial bricks that form the walls, rest on a poured concrete foundation. The interior space of the pump house measures 5 ft 6 in long by 3 ft 5 in wide and has metal piping protruding from it. No structural remnants or other features were visible near the cistern and pump house, but a scatter of historic artifacts is located to the northeast. The site covers an area of 0.31 acres (13,503.6 ft^2).

Given the poor ground surface visibility, shovel testing was conducted to test for a buried site deposit surrounding the features. A total of 11 shovel tests were excavated, four of which encountered artifacts (Table 2). Shovel testing recovered 53 artifacts, which were all found in the plow zone (0 to 30 cmbs). Artifacts recovered include cobalt, clear, and green glass (window and vessel); soda bottles; a light fuse; an insulator fragment; indeterminate metal fragments; and commercial brick fragments.

Figure 43. Overview of site 41FN170 features; view is to the southeast.

Figure 44. View looking down into the well-cistern at site 41FN170. Note the eroded plaster lining on some of the bricks.

Figure 45. View of pump house opening; looking northwest.

Table 2. 41FN170 Shovel Test Descriptions.

ST#	Depth (cm)	Description*	Comments/Artifacts
1	0-40	Very dark gray (10YR3/1) dry clay with abundant caliche	0-10 cm: historic ceramic (1), glass (1)
2	0-40	Very dark gray (10YR3/1) sandy clay with 5-10% caliche	10-20 cm: glass (2), metal (2)
3	0-40	Very dark gray (10YR3/1) sandy clay with 5-10% caliche	0-10 cm: glass (17) 10-20 cm: glass (17), historic metal (2) 20-30 cm: glass (9)
4	0-40	Very dark grayish brown (10YR3/2) clay with caliche beginning at 15 cmbs	0-10 cm: historic ceramic (1), historic metal knife (1)

Historic aerials and maps helped determine that the site is at least 50 years old. A structure is visible in the approximate location on the 1964 topographic map and aerials. However, the structure had been removed by 1995 according to the Google Earth aerials, leaving only the cistern and pump house. The property is presently owned by Jimmie Evans, who purchased it in 1993 from Bobby G. and Joan C. Thacker (FCDB 783:925; Appendix B). The Thackers owned the property since 1978, when the Veteran's Land Board of the State of Texas sold it to them (FCDB 577:321). Earlier that year, the Veteran's Land Board had acquired the land from Jerry Lee and Elaine Davis (FCDB 577:319). The Davis family bought the land from Raymond A. and Pauline Bevel in 1977 (FCDB 573:118). The Bevels bought the land in 1965 from M.K. McDonald (FCDB 484:454). G.E. Carpenter and his wife sold McDonald the property in 1947 (FCDB 277:372). The Carpenters obtained the land from the Clark family in 1943 (FCDB 256:98), who had owned it since 1920 when it was purchased from D.J. and R.J. Bowdry (FCDB 171:447). The Bowdry family purchased it from G.B. Tefteller in 1901 (FCDB 82:170). He bought it from the Texas Loan Agency in 1887 (FCDB 48:333).

The historic features and artifacts are part of an early- to mid-20th-century homestead. The remaining features do not appear to exemplify any noteworthy construction styles. Furthermore, it would appear that the site is not associated with notable historic persons or events. The site has little potential to contribute to our understanding of early history. As such, 41FN170 is recommended ineligible for listing in the NRHP or for nomination as an SAL.

41FN171

A scatter of historic artifacts is located in a pasture approximately 1.3 miles east of FM 100, just north of an abandoned portion of CR 2780 (Figure 46). This site is located atop the upland ridge between Fox and Honey Grove creeks. The pasture is well maintained and had recently been plowed and seeded with grass (Figure 47). These short grasses result in no ground surface visibility. The pasture has a few scattered trees but only one tree is located within the site boundaries and appears to be a pecan. There was little surface evidence of the site and only a few isolated artifacts were visible. The majority of the assemblage was recovered in shovel tests. A total of 32 shovel tests were excavated, 15 of which encountered historic artifacts (Table 3). These include clear, amber, cobalt, and milk vessel glass; stoneware, porcelain, and whiteware; mammal bone; wire nails, square-cut nails, unidentified metal fragments, and rebar; and commercial brick. A total of 68 artifacts were recovered in the plow zone (0 to 20 cmbs). Based on the extent of the shovel tests, the site covers an area of approximately 0.30 acres (13,202 ft^2).

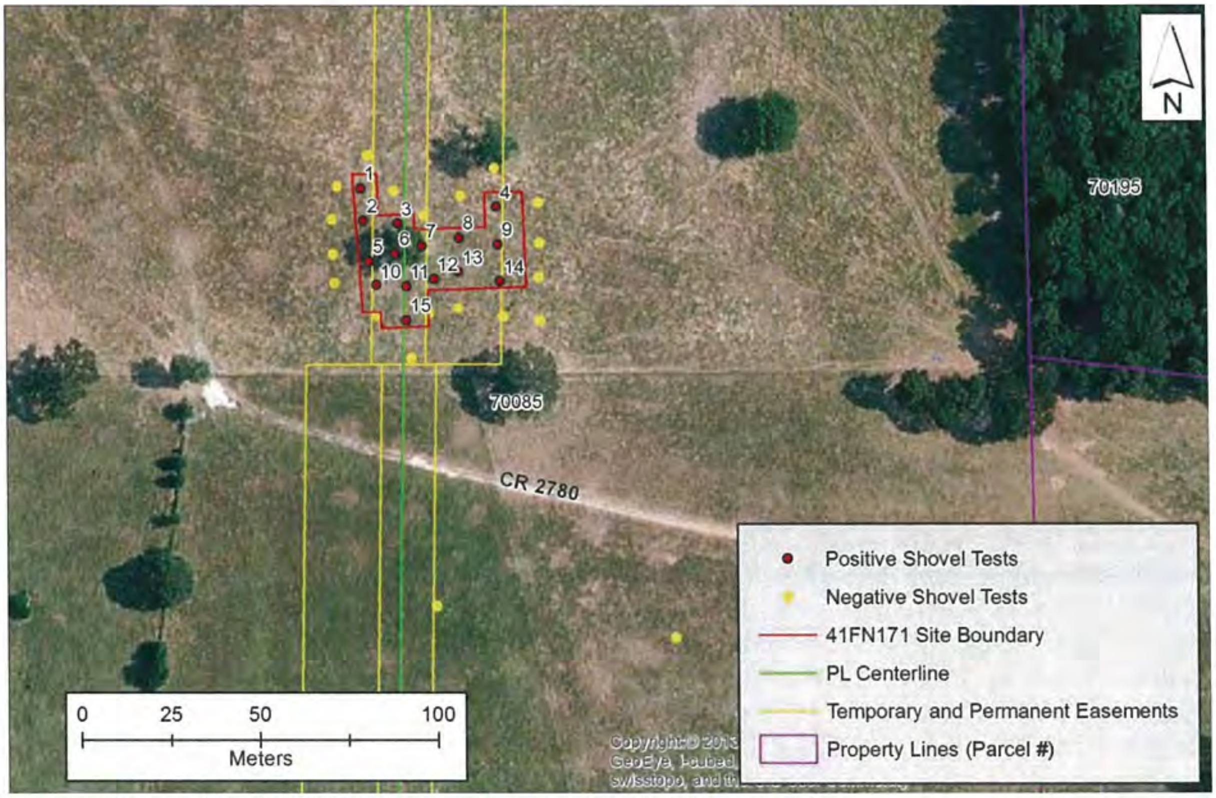


Figure 46. Site 41FN171 shown on a recent aerial photograph

Figure 47. Overview of site 41FN171; view is to the north.

Table 3. 41FN171 Shovel Test Descriptions.

ST#	Depth (cm)	Description*	Comments/Artifacts
1	0-13 13-18 18-25	Dark yellowish brown (10YR4/4) sandy loam Dark brown (10YR3/3) sandy clay Dark brown (7.5YR3/2) with 25% red (2.5YR4/6) clay	0-10 cm: historic ceramic (1)
2	0-20 20-30	Dark yellowish brown (10YR4/4) sandy loam Dark brown (10YR3/3) sandy clay	0-10 cm: glass (2), historic ceramic (1)
3	0-20 20-25	Dark yellowish brown (10YR4/4) sandy clay loam Dark brown (10YR3/3) sandy clay with 25% red (2.5YR4/6) clay	0-10 cm: historic ceramic (1), glass (1)
4	0-12 12-26	Very dark grayish brown (10YR3/2) clay loam Dark grayish brown (10YR4/2) with 20% red (2.5YR4/6) and 10% yellowish red (5YR4/6)	0-10 cm: historic metal (2), square cut nail (1), wire nail (1)
5	0-20 20-30	Dark yellowish brown (10YR4/4) sandy loam Dark brown (10YR3/3) sandy clay	0-10 cm: brick fragment (1), glass (2)
6	0-25 25-35	Dark brown (10YR3/3) sandy clay loam Dark brown (10YR3/3) sandy clay with 5% yellowish red (5YR4/6) clay	0-10 cm: historic metal (1), glass (2) 10-20 cm: glass (3)
7	0-25 25-40	Very dark grayish brown (10YR3/2) clay loam Red (2.5YR4/8) with 40% dark grayish brown (10YR4/2) sandy clay	0-10 cm: glass (4), bone (1), wire nails (3), brick fragment (1)
8	0-17 17-30	Very dark grayish brown (10YR3/2) clay loam Red (2.5YR4/8) with 40% dark grayish brown (10YR4/2) sandy clay	0-10 cm: glass (2), historic ceramic (1)
9	0-20 20-33	Very dark grayish brown (10YR3/2) clay loam Very pale brown (10YR7/4) with 50% yellowish red (5YR5/8) sandy clay	0-10 cm: glass (4), historic ceramic (2), historic metal (2), wire nail (1) 10-20 cm: historic metal (2), glass (1), wire nail (1)
10	0-15 15-22	Dark yellowish brown (10YR4/4) sandy loam Brown (7.5YR4/2) with 25% red (2.5YR4/6) clay	0-10 cm: historic metal (1), glass (2)
11	0-18 18-30	Very dark grayish brown (10YR3/2) clay loam Reddish brown (5YR4/4) with 40% (2.5YR4/6) sandy clay	0-10 cm: brick fragment (1), bone (1), glass (6), historic ceramic (2)
12	0-20 20-30	Very dark grayish brown (10YR3/2) clay loam Red (2.5YR4/8) with 40% dark grayish brown (10YR4/2) sandy clay	0-10 cm: bone (1), glass (1), historic ceramic (1)
13	0-16 16-26	Very dark grayish brown (10YR3/2) clay loam Yellowish red (5YR4/6) with 20% (2.5YR4/6) sandy clay	0-10 cm: glass (1), wire nail (1)
14	0-18 18-27	Very dark grayish brown (10YR3/2) clay loam Yellowish red (5YR4/6) with 10% red (2.5YR4/8) sandy clay	0-10 cm: wire nail (1), historic ceramic (1)
15	0-25 25-35	Very dark grayish brown (10YR3/2) clay loam Dark gray (10YR4/1) clay	0-10 cm: brick fragment (1), glass (1), historic metal (1), square cut nail (1)

Historic maps, aerials, and the deed records were also reviewed. Historic topographic maps show five structures at the site as early as 1949. The 1950 aerial reveals at least 6 to 7 structures (Figure 48). However, the 1984 topographic map only shows two structures remained. By 1995, no structures are visible on the Google Earth aerials. This area has been repeatedly cleared over the years. The majority of the artifacts were broken into small pieces probably due to repeated plowing and structure clearing. The property is currently owned by Thomas Bradley Lane. It has been owned by his family since 1928 when R.D. Lane purchased it from J.T. Newsome (FCDB 205:125). Newsome bought it from J.F. and P.H. Gibson in 1909 (FCDB 119:118). The records of the Gibsons purchase could not be found. However, some of the later records describe that C.D. Cosner bought the land from J.C. McDonald in 1873 (FCDB Y:343) and he had purchased it from Isom Wright in 1867 (FCDB Y:342). Wright purchased it from Anna Allen in 1858 (FCDB M:416). Given this early date, it is likely that Anna Allen is related to the original land grantee, H.S. Allen, but the supporting documents could not be located.

Figure 48. Site 41FN171 site boundary, PL easements, and property lines shown on the 1950 aerial photograph.

The site contains no standing structures or features, and consists of a surface to shallowly-buried scatter of historic artifacts. It is not associated with notable persons or events in history, and has little potential to offer significant insights into the history of the area. As such, it is recommended ineligible for listing in the NRHP or for nomination as an SAL.

41FN172

On the east side of CR 4965, northwest of Leonard, Texas is an historic well-cistern and homestead. The site is in the northeast corner of the TSR survey area. The site is located on a relatively level, upland divide between Lee and Bear creeks. Recently plowed fields surround the homestead. The site covers approximately 2.65 acres (115,434 ft^2). The home is currently occupied and well maintained. Vegetation consists of short, manicured grasses resulting in a ground surface visibility of 30 to 60 percent. Additionally, there are a few scattered trees throughout the yard that include post oak, red oak, and cottonwood. The site consists of a brick house, a mobile home, two sheds, a garage, a septic tank, and a well-cistern (Figure 50). Jimmy Roy James is the current owner of the property. James told the field crew that the house had been relocated to its current location in 1975 (personal communication 2013). He also said that after it was moved it was significantly remodeled and the brick exterior was added (Figure 51). Southwest of the house is a mobile home. Northwest of the home is a modern garage. West of the home there are two sheds. The shed to the southwest is modern (Figure 52) and the other is a composite structure (Figure 53). This composite shed is made from five different types of material. The front (southern façade) is made from wooden panels, while the western wall is made from sheet metal. The northern wall is made from modern aluminum siding (Figure 54) and the eastern wall is made of corrugated steel and older type of aluminum siding (Figure 55). The well-cistern, located on the eastern side of the site, is slightly expands in diameter below clay pipe protruding from wall (Figure 56). The neck is 6 ft in diameter, 2 ft 3 in high and the exterior is covered with concrete; the walls are lined with commercial brick. The well-cistern is 19 ft deep with 6 ft of water present in the bottom. It appears that well-cistern is dug into the underlying bedrock just below the bricks. It does not appear to have a plaster lining on the bricks or bedrock. The lid is hexagonal in shape, 4 in thick, and made of concrete (Figure 57).

Figure 49. Structures and site features associated with 41FN172 shown on a recent aerial photograph.

Figure 50. Overview of western half of site 41FN172; view is to the northeast.

Figure 51. Brick house at 41FN172; view is to the west.

Figure 52. The shed southwest of the home. View is to the southwest.

Figure 53. The south and west walls of the composite shed. View is to the northeast.

Figure 54. The north and west walls of the composite shed. View is to the southeast.

Figure 55. The south and the east walls of the composite shed. Note the three different materials used for construction. View is to the northwest.

Figure 56. View inside the well-cistern with exposed clay intake line. Note no plaster lining appears to be present.

Figure 57. Well-cistern at 41FN172; view is to the north.

Due to the good ground surface visibility, the degrading upland setting, and because the home was currently occupied, shovel tests were not excavated. A surface inspection was conducted and no artifacts were noted. Some historic farm and railroad equipment has been gathered and piled on top of the well-cistern and around the shed and mobile home. Historic maps, aerials, and the deed records for the property were reviewed. A homestead shows on the 1964 historic aerial photograph and on the 1967 topographic map. The historic aerial shows at least five structures, while the USGS map only shows one. However, when the locations of the modern structures are superimposed on the historic aerial it is clear that none of the original structures remain in situ. This was confirmed by James (personal communication 2013). The composite shed was likely constructed from recycled portions of some of the original structures and continuously updated over the years. James purchased the property from Mary and Lucy Neale in 1974 (FCBD 548:648; Appendix B). The land was inherited by Mary Neale in 1917 by Roy and Lucy Neale (FCBD 135:119). No earlier records were located.

Figure 58. The 1964 aerial superimposed on a modern aerial show none of the original structures of the site remain.

The structures that constitute site 41FN172 are mostly recent with only two of the structures containing historic components. The house was moved to its current location in 1975 and has been remodeled, severely compromising its historic integrity. The composite shed is made from portions of other structures and does not contain any historic integrity. The well-cistern is the only feature at the site that remains in situ and corresponds to the location of the home on the 1964 aerial. The well-cistern is made with commercial brick, indicating a 20th century construction date. The site is not associated with notable persons or events in history, and has little potential to offer significant insights into the history of the area. Additionally, due to the overall lack of site integrity, it is recommended as ineligible for listing on the NRHP for nomination as an SAL.

41FN173

Approximately one kilometer south of 41FN172, in a neighboring plowed field, is another well-cistern recorded as site 41FN173 (Figure 59). The site is located on the same upland formation between branches of Lee and Bear Creek. The area was recently plowed and had very little vegetation, resulting in 100 percent ground surface visibility. The site was identified during survey by a t-post sticking up around an area with taller grasses and had been intentionally avoided by the farmer (Figure 60). The well-cistern is lined with dry-laid, cut limestone with the inside diameter measuring 32 in (Figure 61). It has been filled and only 32 in show from the top of the well-cistern to the top of the fill. No structural remnants or other features were visible near the well-cistern and no artifacts were noted on the surface in the surrounding area.

Figure 59. Site 41FN173 shown on a recent aerial photograph.

Given the excellent surface visibility and lack of artifacts on the surface, shovel testing was not conducted. In addition to pedestrian survey at the site, historic maps and the deed records for the area were reviewed. No structures in the general area of the site were shown on historic aerials, topographic maps, or highway maps.

Figure 60. Overview of well-cistern and surrounding area at 41FN173; view to the southeast.

Figure 61. Close up of well-cistern at 41NF173 with view of dry laid limestone and fill.

The property is currently owned by Bobby Jack and Texanna Norman. They purchased it in 2005 from Alton and Jack Norman (FCDB 1196:389; Appendix B). The Normans purchased it from Bryan H. Burg in 1993 (FCDB 781:554). The property had been in the Burg family under the Paul Burg Trust since 1984 when it was purchased from Elgin R. and Cora E. Lewis (FCDB 643:223). The Lewis family obtained the property from Dale and Lois Shramm in 1981 (FCDB 613:650). The Shramms were in possession of the property since 1978, when Jerry Lee Davis, Murrell T. Lucas and Bill D. Murphy sold the land (FCDB 587:889). Davis, Lucas and Murphy had purchased it days before from Barbara Stevens and Verna Wharton (FCDB 584:654). Stevens joined Wharton in ownership of the property in 1953 (FCDB 554:105). Wharton turned two separate properties into the one observed today when she purchased land from Meddie Ruth Blackburn (FCDB 413:154) and Luther Deel (FCDB 358:81) in 1953. H.H. Blackburn, husband of Meddie Ruth, had purchased the part of the land he would share with his wife from Luther Deel in 1944 (FCDB 259:607). Earlier records could not be located.

The well-cistern located at 41FN173 is one typical of being associated with an historic farmstead or homestead; however no associated structures or artifacts were identified to indicate an age. Without context it would appear that the site is not associated with notable historic persons or events and the cistern alone contributes little to our understanding of the history of the area. As such, 41FN173 is recommended ineligible for listing in the NRHP or for nomination as an SAL.

41FN174

In the adjacent field, approximately 360 meters north of 41FN173, is another well-cistern, recorded as site 41FN174 (Figure 62). This field contained short cut grasses resulting in ground surface visibility of 30 to 50 percent. The site is similarly marked by t-post wrapped with white tape surrounded by taller grasses (Figure 63). The well-cistern walls are formed by dry laid rough limestone slabs. It is seven ft deep with approximately one and half feet of water in the bottom. The opening is 2 ft^2 and there are six logs (bois d'arc) notched together on top (Figure 64). These logs likely made up the neck at one time. These logs were approximately 6 in wide and 2 in thick. It is likely that soil has accumulated around the well-cistern from the repeated plowing. Like at 41FN173, there were no structural remnants or other features visible near the cistern and only one whiteware body sherd and one SCA glass shard were noted on the surface in the surrounding area.

Given the good surface visibility and few visible artifacts on the surface, shovel testing was not conducted. In addition to pedestrian survey at the site, historic maps, aerials, and deed records for the property were reviewed. Similar to 41FN173, no structures in the general area were noted on historic aerials, topographic maps, or highway maps. The structure that is on the property to the northeast was not present on the 1995 Google Earth aerials. The structure first appears on the 2005 aerials.

This property is presently owned by Charlie and Cynthia Hendrix, who bought it from Sid Andrew and Jimmy Page in 2011 (FCDB 1573:275; Appendix B). Andrew and Page obtained the land from the Lund and Livestock Trust in 2010 (FCDB 1496:50) which was created in 1993 (FCDB 788:228). Prior to the trust, Joe Donals Crain and Windell Crain owned the land; they purchased it from Lewis and Betty Gaskill in 1985 (FCDB 658:240). The Gaskills obtained the land earlier that year from the Veteran's Land Board (FCDB 659:232). The Veteran's Land Board owned the land since 1955 when W.F. and Erah Lee Sims sold it (FCDB 375:330). The Sims obtained it from T.F. Sims in 1932 (FCDB 216:98) who bought it from A.H. and Lillian Pigg in 1912 (FCDB 130:99). The earliest record available is a deed from 1903 when J.N. Pigg sold the land to Tom Pigg (FCDB 94:161). The property remained in the family from 1903 until it was sold in 1912.

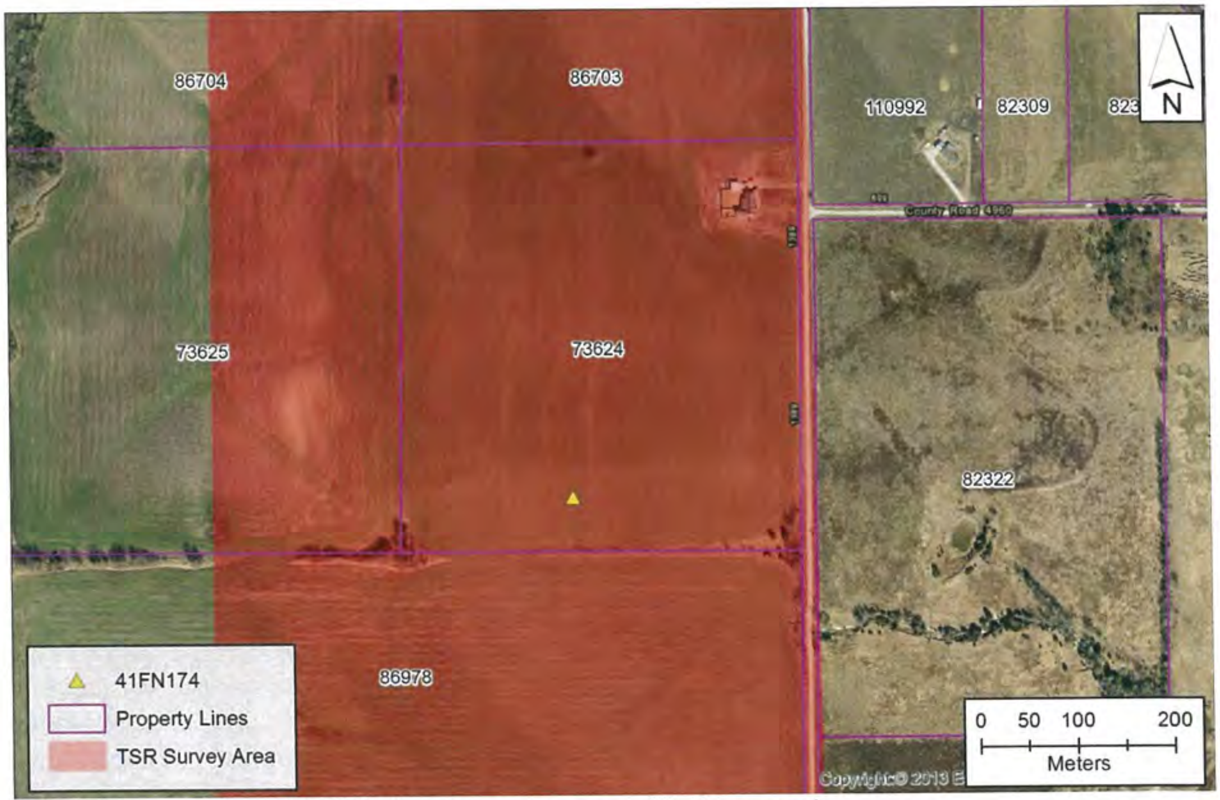


Figure 62. Site 41FN174 shown on a recent aerial photograph.

The well-cistern located at 41FN174, as with the one at 41FN173, would typically be associated with an historic farmstead or homestead; however historic maps and aerials could not confirm this. The two artifacts noted on the surface are potentially late 19th to early 20th century in age, but did not possess temporally diagnostic features. The two cisterns are relatively close to each other, but on separate properties. The site is not associated with notable historic persons or events. The cistern does contain a unique collar, and no similar ones have been reported. However, it alone contributes little to our understanding of the history of the area. As such, 41FN174 is recommended ineligible for listing in the NRHP or for nomination as an SAL.

Figure 63. Overview of well-cistern at 41FN174; view is to the northeast.

Figure 64. Close up of notched boards and dry laid limestone at 41FN174.

41FN175

A historic farmstead was recorded on the southeastern portion of the proposed WTP and the west side of County Road 4965 (Figure 65). It sits on the upland divide between Lee and Bear creeks. The homestead is currently occupied and the property is well maintained, and surrounded by pasture. Vegetation consists of short, manicured grasses resulting in ground surface visibility of 30 to 60 percent. Additionally, there were a few scattered trees throughout the yard that include post oak and red oak. The site covers approximately six acres (265,227 ft^2) and consists of a house, storm cellar, outbuilding, and barn. The structures were evaluated by the architectural historian and are referenced as Architectural Resources 1a, 1b, and 1c (Chapter 7). The house (1a) has a pier and beam foundation. The home has undergone significant renovations over the years. The storm cellar behind the house is made of concrete and measures 3 ft tall, 9 ft wide, and 12 ft long with a 6 ft by 3 ft entryway. The outbuilding (1b) is 12 ft by 20 ft in size and has corrugated metal covering the original paneling and roof. It is currently used as a chicken coop and has evidence of extensive modifications. The barn (1c) is located approximately 420 ft west of the house and has a construction date prior to 1964, according to county tax records. It is a pole barn with evidence of modifications including shed additions. The barn is approximately 50 ft^2 and the shed extension is 41 ft by 25 ft.

Figure 65. Site 41FN175 shown on a recent aerial photograph.

Shovel tests were not excavated at the site due to its degrading upland setting and excellent ground surface visibility. Surface inspection was conducted and no artifacts were noted on the ground. Historic maps, aerials, and deed records for the property were reviewed. The house has a 1920 construction date according to the Fannin County Appraisal District and was mapped on the 1936, 1939, and 1967 historic maps. The land is currently owned by NTMWD, who acquired the property from North Texas Aggregate Acquisitions in 2009 (FCBD 1424:99; Appendix B). Earlier that year, North Texas Aggregate Acquisitions purchased the land from Donald M. Spurgin (FCDB 1424:84). He had been in possession of the property since 1993 when he and his wife bought it from Richard Sikes (FCDB 783:1041). Sikes had been in possession of the property since 1973 when Jerry Lee and Elaine Davis sold the land (FCDB 541:151). The property was in the Davis family since 1939 when J.D. Davis purchased it from Bankers Life Company (FCDB: 242:666). The vice president of Bankers Life Company, G.W. Fowler, signed for the land in 1926 when Bess D. Hall released it. This information is referenced in the Davis deed; however the volume number was illegible on the copy of the records at the courthouse and could not be identified. In 1903, Willard P. Hall, husband of Bess D. Hall purchased the land from W.H. Leonard (FCDB 92:363). Given this early date, it is likely that W.H. Leonard is related S.L. Leonard, the original land grantee. However, the site is likely only associated with the Hall family based on the construction date.

Figure 66. The house (architectural resource 1a) at 41FN175; facing east.

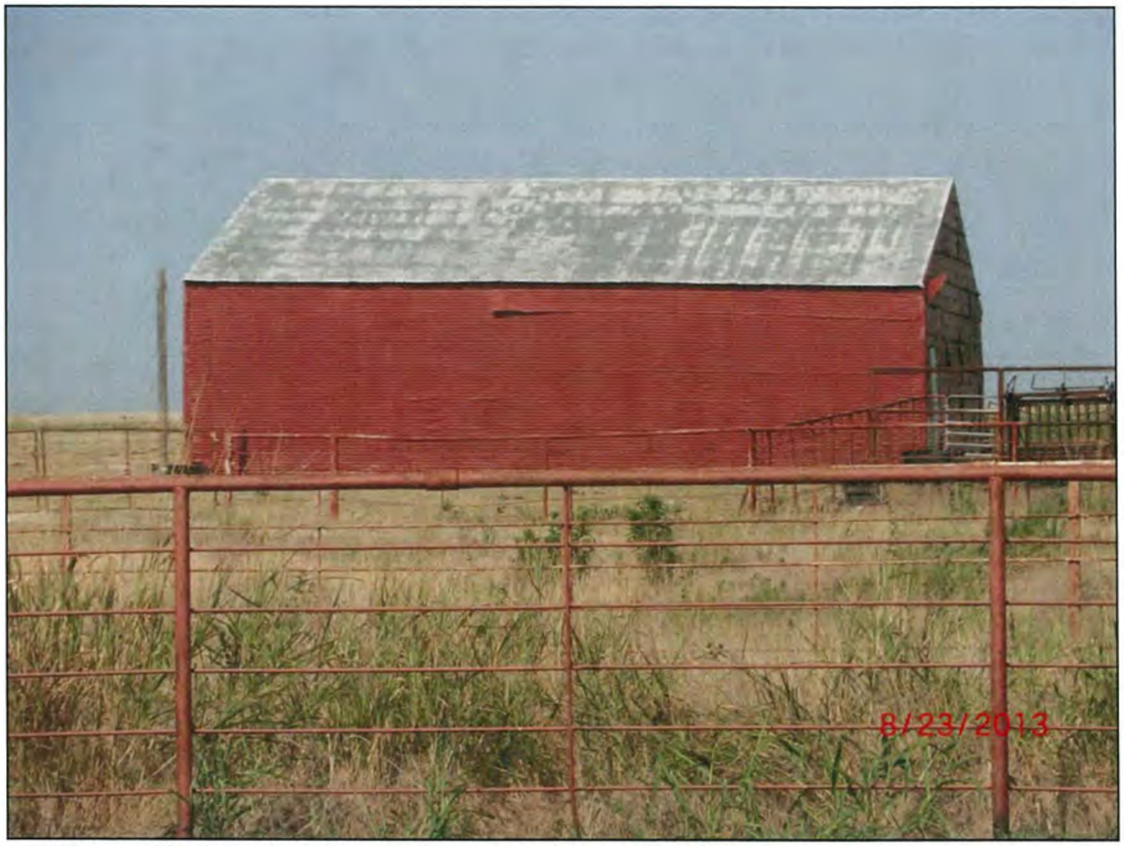


Figure 67. The barn (architectural resource 1c) at 41FN175; facing north.

The structures at 41FN174 were evaluated by the architectural historian as having no significant connections with either historically significant events or people. Additionally, it was concluded that the buildings do not qualify as outstanding examples of architecture and have lost integrity as a result of modifications. Additionally, the property has been well maintained and contained no surface artifacts. The site has very little potential contribute to the understanding of the history of the area. Therefore, this 20th century site is recommended as not eligible for listing in the NRHP or for designation as a SAL.

CHAPTER 7. ARCHITECTURAL INVESTIGATIONS

Deborah Anglin

This chapter of the report provides the results of a reconnaissance-level historic-age resource survey conducted by Secretary of Interior qualified architectural historian Deborah Anglin. The term "historic-age resource" typically refers to any architectural or engineering element that is 50 years old or older. In order to allow for project completion the standard guideline of 45 years or older was utilized for this project, thus the letting date is 1968. The purpose of the survey was to determine the presence of any historic-age resources within the project area and their eligibility for listing in the NRPH. The archaeological field crew, which walked parallel and individually numbered transects spaced 20-30 m apart, assisted in the location of potentially historic-age resources. An additional field survey was conducted on August 28, 2013 by the architectural historian in order to photograph and inspect the potentially historic-age resources located.

Research Design and Methodology

Buildings more than 50 years of age may be eligible for inclusion in the NRHP based on four criteria presented in 36 CFR §60.4[a–d]. These four criteria are applied following the identification of relevant historic themes or patterns. In brief, a resource may possess significance for:

(a) its association with events that have made a significant contribution to the broad patterns of history; or
(b) its association with the lives of persons significant in our past; or
(c) its illustration of a type, period, or method of construction, or for its aesthetic values, or its representation of the work of a master, or if it represents a significant and distinguishable entity whose components may lack individual distinction; or
(d) its ability or potential to yield information important in prehistory or history [36 CFR §60.4(a–d)].

This reconnaissance-level, historic-age resources survey will only consider Criteria A-C as a separate archaeological evaluation has been completed by ARC archaeologists and is discussed in a previous chapter as archaeological site 41FN175.

Not only must a resource possess significance in order to be eligible for inclusion in the NRHP, it must also maintain a certain level of integrity. The NRHP defines seven aspects of integrity: (1) location, (2) setting, (3) design, (4) materials, (5) workmanship, (6) feeling, and (7) association. Although not all seven aspects of integrity must be present for a resource to be eligible, the resource must retain, overall, the defining features and characteristics that were present during the property's period of significance.

In addition to the field work, a literature and records review was also conducted. The Texas Historic Sites Atlas was reviewed in order to determine the presence of existing NRHP properties, State Archeological Landmarks (SALs), and Official Texas Historical Markers.

In order to establish the historic context, archival research was conducted utilizing resources at the Bonham Public Library, the Handbook of Texas Online, Texas Historic Sites Atlas, the Texas State Library and Archives, the Portal to Texas History, the Leonard Preservation League, as well as numerous other resources.

To assist in identifying potential historic-age resources and to aid in determining their ages, numerous maps were reviewed including the 1926 Historical Fannin County Map (Kirk n.d.), 1836-1996 Fannin County Kin Map (Kirk n.d.), 1936 (photo revised 1940) Fannin County General Highway Map (Texas Highway Department), 1939 Fannin County Soil Survey Map (USDA), and topographic maps and aerials (1964, 1967, 2004) from the National Environment Title Research (NETR). Fannin County Central Appraisal District (CAD) records were consulted for dates of construction and other pertinent data. In addition, Fannin County warranty deeds were searched in order to determine chain of ownership (Appendix B).

Results

The review of the Texas Historic Sites Atlas confirmed that there are no NRHP properties, SALs, or OTHMs located within one mile of any of the historic-age resources located within or adjacent to the project area. The field survey revealed one area with potentially historic-age resources found in the southwestern section of the project area where the proposed WTP is to be located (Figure 68). This site contains three resources, all of which will be demolished in the completion of this project (Figure 69). The resources are associated with archaeological site 41FN175.

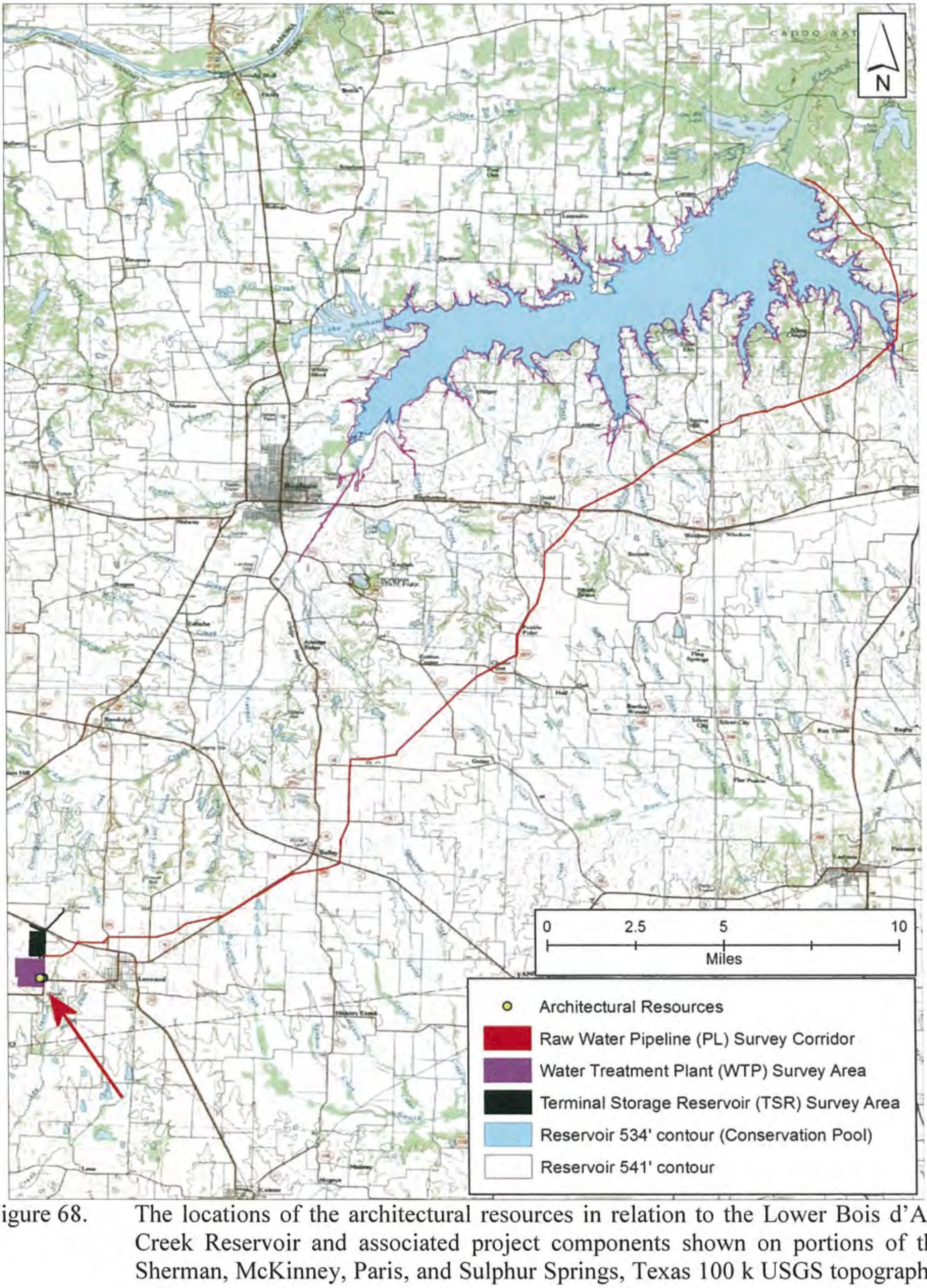


Figure 68. The locations of the architectural resources in relation to the Lower Bois d'Arc Creek Reservoir and associated project components shown on portions of the Sherman, McKinney, Paris, and Sulphur Springs, Texas 100 k USGS topographic maps.

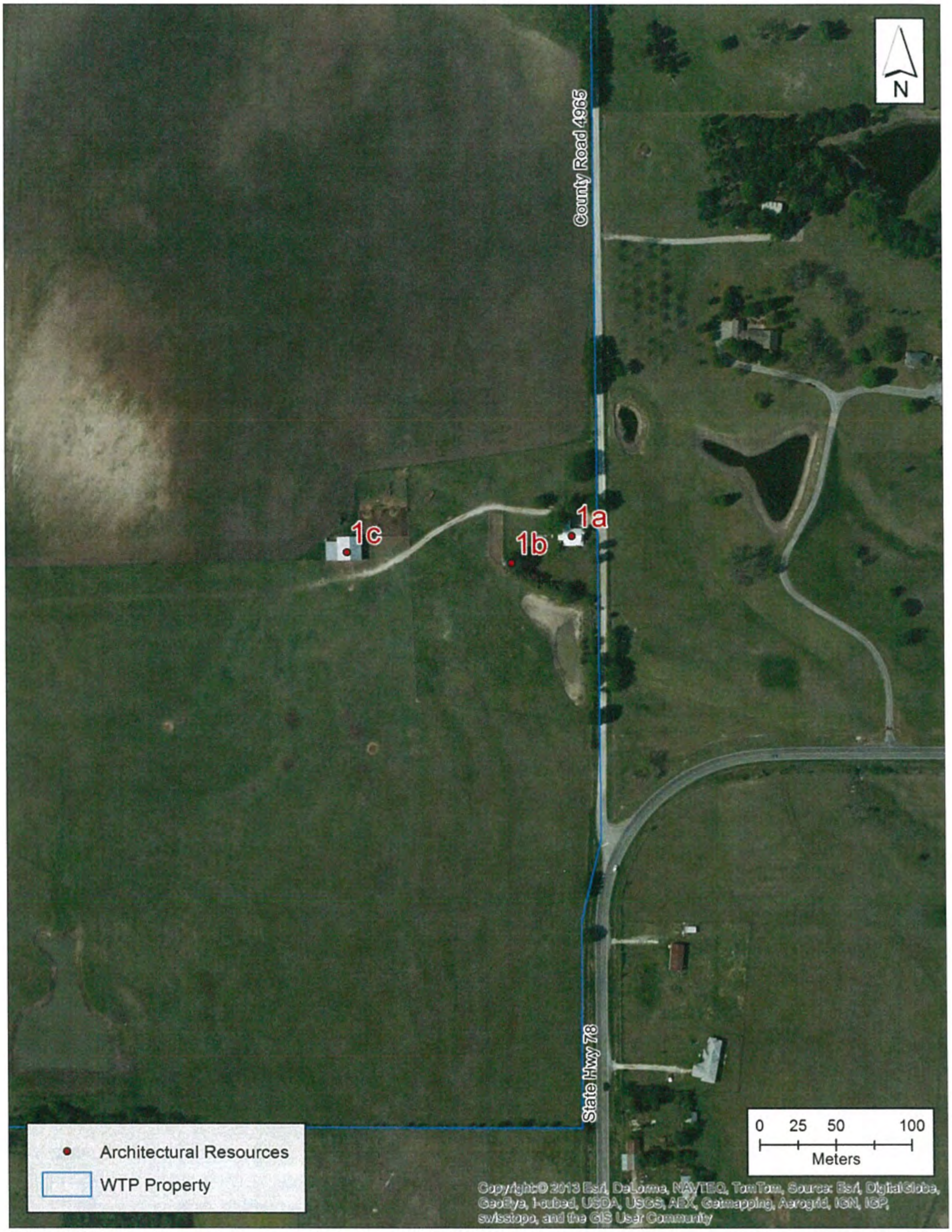


Figure 69. Resources 1a-c shown on a recent aerial photograph.

Figure 70. Resource 1a: Facade, looking west.

Resource ID Number:	1a
Location:	361 CR 4965, Leonard, TX
Property type, Subtype:	Domestic, single dwelling
Construction Date:	1920
Style/Description:	Craftsman; frame house; three bays; pier and beam and solid slab; double front-gables; enclosed extended eaves; triangle knee braces; wrap-around porch covered by extended roof; square supports.
Additional Notes:	Noted on the 1936, 1939, and 1967 maps. Original roof cladding has been replaced with V-notched metal; doors and windows have been replaced; garage is a later addition with both pole and cut-lumber framing and rests on a solid concrete slab; received major additions and/or alterations in 1979 per CAD records.
Documentation:	Fannin CAD, photographs, field survey, 1936 Fannin County Highway map, 1939 USDA Fannin County Soil Map, topographic maps and aerials (1964,1967, 2004) from NETR, Warranty Deeds (Appendix).
Recommendation:	No significant connections with either historically significant events or people (Criteria A and B); not an outstanding example of its type nor the work of a master (Criterion c). Does not maintain integrity in design due to change in the organization of space and proportions; loss of integrity in materials, workmanship and feeling due to the alterations; limited integrity in association as additional historic-age outbuildings are no longer extant; not an outstanding representative of its type; recommended ineligible for listing in the NRHP.

Figure 71. Resource 1a: West elevation, looking east.

Figure 72. Resource 1a: South elevation, looking north.

Figure 73. Resource 1a: Oblique of facade and south elevation, looking northwest.

Figure 74. Resource 1a: Garage, looking west.

Figure 75. Resource 1b: Facade, looking north.

Resource ID Number: 1b
Location: 361 CR 4965, Leonard, TX
Property type, Subtype: Agricultural, outbuilding
Construction Date: pre-1964
Style/Description: Approximately 12 ft by 20 ft; side gabled; framing of both poles and square-cut lumber, door and waist-high cladding on facade are new plywood; roof and remaining elevations clad with corrugated metal; currently serves as a chicken coop at one end and storage on the other.
Additional Notes: Extensively altered throughout the years as evidenced by the mixture of old and new materials; metal sheets in various stages of rust; received major additions and/or alterations in 1983 per CAD records; visible on 1964 aerial (NETR).
Documentation: Fannin CAD, photographs, field survey, 1936 Fannin County Highway map, 1939 USDA Fannin County Soil Map, topographic maps and aerials (1964,1967, 2004) from NETR, Warranty Deeds (Appendix).
Recommendation: No significant connections with either historically significant events or people (Criteria A and B); not an outstanding example of its type nor the work of a master (Criterion c). Does not maintain integrity in design, materials, workmanship, association and feeling due to the alterations and loss of original function; not an outstanding representative of its type; recommended ineligible for listing in the NRHP.

Figure 76. Resource 1b: Oblique of north and east elevations, looking southwest.

Figure 77. Resource 1c: Oblique of facade and east, looking northwest.

Resource ID Number: 1c

Location: 361 CR 4965, Leonard, TX

Property type, Subtype: Agricultural, outbuilding

Construction Date: pre-1964

Style/Description: Pole barn with shed addition; barn approximately 50 ft by 50 ft; shed addition approximately 41 ft by 25 ft; entire structure clad with sheets of metal painted red; roof cladding on barn is unpainted corrugated metal sheets; roof cladding on shed addition is unpainted V-notched metal sheets; exposed rafters on west elevation of the shed addition

Additional Notes: Visible on the 1964 aerial; received extensive improvements in 1991 according to CAD records; overall sheeting is in poor condition and poorly attached in many places.

Documentation: Fannin CAD, photographs, field survey, 1936 Fannin County Highway map, 1939 USDA Fannin County Soil Map, topographic maps and aerials 1964,1967, 2004) from NETR, Warranty Deeds (Appendix).

Recommendation: No significant connections with either historically significant events or people (Criteria A and B); not an outstanding example of its type nor the work of a master (Criterion c). Does not maintain integrity in design, workmanship, materials, and feeling; limited integrity in association as additional historic-age outbuildings are no longer extant; not an outstanding representative of its type; recommended ineligible for listing in the NRHP.

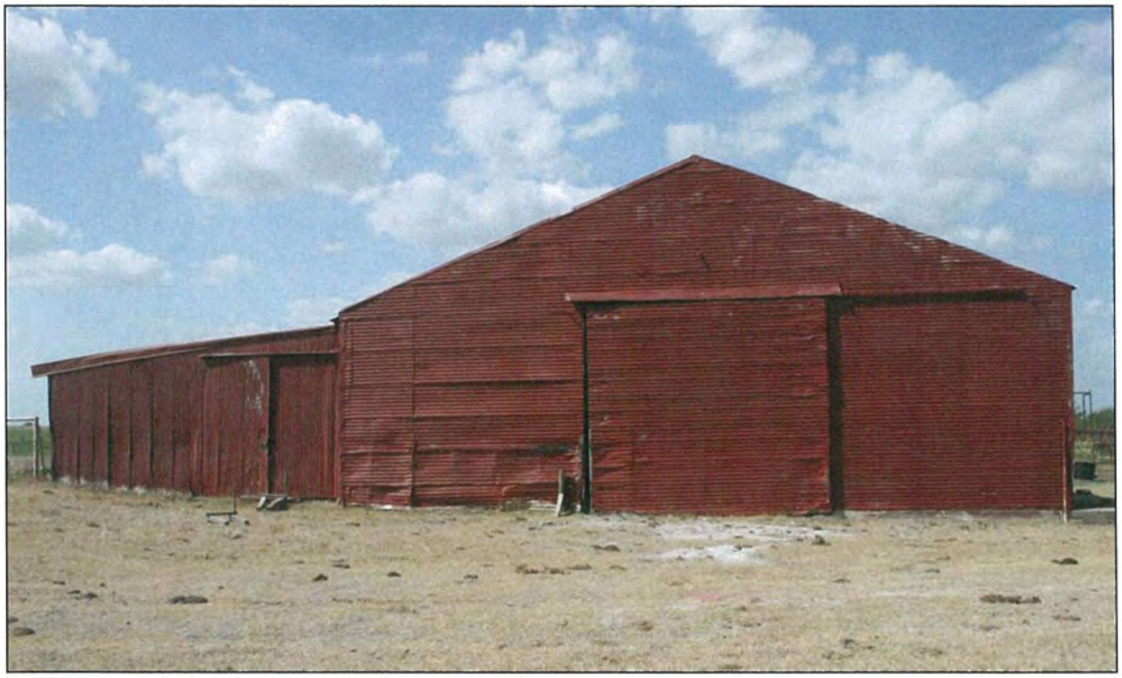


Figure 78. Resource 1c: Facade, looking north.

Figure 79. Resource 1c: Oblique of north and west elevations, looking southeast.

CHAPTER 8. CONCLUSIONS

The pedestrian survey of the proposed Lower Bois d'Arc Creek Reservoir Pipeline project intensively investigated approximately 1033 acres. Of which, 948 acres (92%) were classified as upland, 24 acres (2%) were floodplain, and 61 acres (6%) were terrace. The WTP and TSR are situated on the upland divide between the Red, Sulphur, and Trinity river watersheds. The pipeline route crossed several low order drainage valleys before ascending the upland divide. Overall seven historic archaeological sites were documented. Only one prehistoric artifact (IO1) was found during the survey and this was an interior chert flake. The flake was found in the terrace sediments near the proposed dam site.

It was initially thought that there was potential for buried prehistoric site deposits in the floodplain sediments in the portion of the pipeline route north of US 82. Additionally, sites might have been found on elevations in the narrow floodplains. However, the results of the survey demonstrated that they were not present as no prehistoric archaeological sites were recorded. While several named drainages are intersected by the route, it crosses all of them high in the headwaters. Even though seep springs were reported by Brune (1982:181) to originate from the geologic formations underlying the study area, they may not have produced enough water to attract prehistoric occupants. For the most part, all of the drainages crossed by the route contained relatively level floodplains. These negative findings are consistent with previous investigations of uplands in the surrounding region.

Lithic procurement sites were another type of prehistoric site expected to be found on the drainage divides where Ogallala Gravels were deposited in Late Pliocene times. However, the survey found no evidence of major gravel fields containing quartzite and chert cobbles. These fields would have been the primary potential source for knappable material or for resources that could have been used in the process of cooking plant or animal foods. Several examples of this site type have been recorded in the region. These artifacts were typically found only on site surfaces not in shovel tests (Cliff and Shortes 2001). Similar results were reported at the NTMWD landfill site in neighboring Collin County (Clow and Hoyt 2000). The lithic procurement sites along the Valley Junction-Anna Switch 345-kV Transmission Line (Cliff and Shortes 2001:27-31) coincided with recognizable accumulations of Ogallala cobbles that covered 12,078 m^2 [41COL142] and 2,100 m^2 [41COL144]. Both sites had an estimated density of one chipped stone artifact per ten square meters, but with no datable tools or evidence of food consumption or of fire-cracked rocks.

Likewise, the reservoir survey did not identify any significant gravel fields or quarry sites (Davis et al. 2013). Gravels were observed on the eroded uplands and terrace slopes on the south side of the reservoir, yet most of the gravels were not suitable for knapping (Davis et al. 2013:100). Site 41FN142, near the dam site, was reported to be a gravel quarry site by local collectors, but when the location was surveyed no artifacts were found. While a thin gravel deposit was present on the terrace slope, none of the gravels were suitable for knapping. Only one site (41FN113) recorded in the reservoir contained a significant gravel deposit (Davis et al. 2013:141-144). The site is situated on the north side of the watershed and is likely associated with the remnant T4 terrace of the Red River. Still the gravels at the site were not suitable for knapping. Similar results were reported on the Texoma to Wylie pipeline study, where nearly 40 mi of upland divides and lower order drainages were surveyed, yet no significant gravel fields were documented (Davis et al. 2012:114).

It has been proposed that Paleoindian groups likely used the upland divides as travel routes through the region (Skinner 2010; Skinner et al. 2010). Yet no evidence of temporary campsites was recorded in this setting and the same results were reported by the Texoma to Wylie project (Davis et al. 2012). Nonetheless there is evidence that prehistoric populations inhabited the Bois d'Arc Creek Watershed since the Paleoindian and Early Archaic periods. However all of these artifacts have been found by collectors and deflated in the creek channels (Davis et al. 2013:285-292). This is consistent with the geomorphic data reported at the reservoir, where the earliest sediments appear to have been flushed out of the watershed. The oldest in situ sediments documented were radiocarbon dated before 3,700-3,800 years ago (Davis et al. 2013:373). A site of similar age and composition was documented in the proposed Lake Ralph Hall study in southeastern Fannin County (Skinner et al. 2005:48). However, geomorphic results of that study demonstrate that the North Sulphur River has more than 17,000 years of stratified sediments resting unconformably on the Late Cretaceous shale bedrock (Bousman 2005).

Approximately, 2600 acres and 12 mi of tributary creek channel were surveyed on the south side of Bois d'Arc Creek during the reservoir study, but only 15 of the 61 reported sites were found on the south side of the creek. This is understandable as the north side of the creek is situated in the Oak-Hickory forest that covers the Red River terraces. This setting contained larger and more significant terrace deposits as well as prominent elevations in the floodplain of the shorter spring fed tributaries. There were no sites recorded in the 12 mi of creek channels that were walked. Many of these channels, like Ward, Bullard, and Honey Grove creeks were thoroughly inspected upstream from Bois d'Arc Creek and demonstrated little potential for containing buried site deposits. Of those 15, only six of them contained a prehistoric component, and five of these were located within 1.3 km of Bois d'Arc Creek. Overall, it was appears that the most intense prehistoric occupation reported in the study area is represented by the ephemeral remains of Woodland to Early Caddo occupations. These sites were largely situated on the north side of the creek in terraces, elevations in the floodplain or the Bois d'Arc Creek channel, all settings not found on the south side.

Historic European sites dating prior to the Civil War are rare in Northeast Texas and none were found during the survey. These sites tend to be situated out of the floodplain and contain rock-lined wells or cisterns, chimneys with scatters of hand-made brick or rock, and various glass and metal artifacts. This was confirmed by the larger reservoir investigations in the county (Skinner et al. 2005; Davis et al. 2013). While it is well known that the area was occupied during this time, most of these sites have been lost over the years. Oral history work conducted with the reservoir suggest that many of the early 20th century occupants cleared the area of older sites as they expanded their farming capabilities (Davis et al. 2013:377-378). Only eight of the 30 historic sites recorded during that study potentially date to the late 19th century. These were mainly farmstead and homestead features like cisterns, wells, foundation remains, and artifact scatters. The historic homesteads and farmsteads documented there dated to the first and second quarters of the 20th century. Only a few of the sites contained sparse artifact deposits, while the majority had none, similar to the sites recorded during this survey. It was reported that many of the structures associated with these sites were in secondary context, similar to what was seen at 41FN172 in the TSR survey area.

This was the same situation for the seven historic sites recorded during this study. All of the sites represent the remains of either late 19th or 20th century farmsteads or homesteads found on upland divides. Only one, 41FN175, contained historic-age structures. Yet, these structures had been modified and updated over the years, dimensioning their integrity. Additionally, the well maintained degrading upland surface surrounding the structures contained no artifacts. Of the remaining six sites, only one did not have any associated features. Site 41FN171 consists of historic artifacts found on the surface and worked into the plow zone. The location of the site corresponds to a farmstead, which was demolished prior to 1995 according to Google Earth aerials.

The remaining five sites likely represent the remains of homestead and farmstead, but are only represented by historic artifacts and water related features. Sites 41FN169-170 and 171-174) represent a diverse selection of late 19th or early 20th century cisterns, wells, or well-cisterns. According to Denton (2007), there are six types of cisterns: Bottle, Rectangular, Beveled Shoulder, Bell, Semi-Masonry, and Well-Cisterns found in Texas. None of the features recorded during this survey resemble the Rectangular Type, which are very rare, have a rectangular shape and are typically associated with German communities (Denton 2007). The Bottle, Beveled Shoulder, and Bell types are the best defined. These three types typically are completely encased in courses of mortared brick or the rough cut rock that comprises the entire shape and are plastered on the inside. They are also always associated with a structure, which was used to help capture water. These types are largely defined by the type of shoulder and shape. Bottle and Beveled Shoulder cisterns typically have an exposed neck, while Bell Cisterns are flush with the ground surface and usually under the home. Cisterns tend to ballon drastically below the shoulders and ranged from 8 to 18 ft deep, with bottom widths between 6 and 14 ft. Even though these types are well defined, there was great variation in the individual designs of each none of the recorded features match these types.

The last two types Denton describes are the Semi-Masonry and Well-Cistern types as having an upper portion similar to the first three, but that the bottom portion was dug into bedrock eliminating the need to use brick in the bottom. With the Semi-Masonry type the bedrock was plaster along with the brick to form the water tight seal. This is not the case with the Well-Cistern. Denton says that while in the process of digging, they encountered a reliable water source and then were used as a cistern and a well. Similar types of hand-dug wells were reported in Ellis County, and were thought to function as both cisterns and wells (Mace 1994:347). In order for a well-cistern to work, the underlying geology needs to be conducive to producing seep springs or spring aquifers (Mace 1994:347). Brune (1982:181) describes Indian, Shawnee, Flat, and Honey Grove springs coming from the underlying geologic formation of the study area.

The features associated with these sites, all contain elements of both cisterns and wells. The feature at 41FN169, has a very narrow shaft, and is only nine feet deep, however due to the limited view, it is unclear if it had been filled or was just that shallow. The feature is near the headwaters of Sloans Creek, and might have been spring feed based on the geology and locations of springs reported by Brune. If that's the case it would make it a well. Given the limited information on the feature no definitive type could be established and the feature was described as a cistern or well. The features at 41FN170, 172, 173, and 174 were tentatively designated as Well-Cisterns. 41FN170 and 172 are both brick lined with exposed necks and both held water and appeared to be dug into the underlying limestone. 41FN170 had an out-take line connected to a nearby pump house and held nearly 10 ft of water. 41FN171 had an exposed intake line and presently held nearly 6 ft of water. While 41FN170 had evidence of interior plastering, 172 did not. Both were originally associated with a structure and contain features and construction methods used in cistern construction. Given the amount of water remaining inside them and their location on the same upland formation that created Indian and Shawnee springs, it is possible that they are spring fed.

The final two (41FN173 and 174) are south of 41FN172. 41FN173 had been filled prior to survey and only the dry laid cut limestone interior was exposed for a couple feet. On the other hand, 41FN174 utilized dry laid rough cut limestone and a bois d'arc log neck. It too held almost a foot of water and was only seven feet deep. Given that these two are so close to 41FN172 and in the same setting they were classified as Well-Cisterns. Overall, all five of these features are distinct and have a combination of features found in both wells and cisterns. Denton describes Well-Cisterns as being very diverse in construction methods and this is certainly the case for these five. Each was distinctively different form the other, likely meaning they were each built by different people. There were seven sites (41FN109, 137-138, 148, 157-159) recorded during the reservoir study that contained similar types of features (Davis et al. 2013). All of them utilized brick for the lining, but three contained handmade bricks, while another three used commercial. The brick utilized at 41FN159 could not be identified during the survey due to the heavy cap placed over the opening. The openings of the cisterns reported there ranged from 32 to 42 inches in diameter. Only four of them had not been filled, and their depths ranged from 11 to 22 ft. Three of them had exposed necks and three were confirmed were similar to the brick ones documented during this study. Well-Cisterns date from the 1860s through the 20th century, which fits with the estimated dates of most of these sites. Based on the variation seen in the sites recorded they do not represent the work of single person or group. 41FN174 is the most unusual, with its bois d'arc log collar, but given that this wood was used for numerous construction components in North Central Texas, it could only be expected that someone would have used it for this purpose.

In general, the results of this study agree with those conducted in the county. Prehistoric sites appear to be very ephemeral on the south side of Bois d'Arc Creek, while historic sites are common on the upland divide. However, farming and urban growth has removed nearly all evidence of mid-19th century sites. Only sparse remains of late 19th and early 20th century sites remain, and more often than not, they contain no structures and are only represented by artifacts and features such as cisterns or wells. The historic sites documented during this study have all been heavily impacted by farming and can offer no little information about the early history of Fannin County.

CHAPTER 9. RECOMMENDATIONS

The proposed Lower Bois d'Arc Creek Reservoir pipeline, water treatment plant, and terminal storage reservoir study areas contain cultural resources dating from the late 19th to mid-20th century. Based on the results of the archaeological and architectural inventories the following recommendations are made regarding determinations of eligibility for listing on the NRHP and SAL and further work in the project area (Table 4).

Three structures at 41FN175 were found to be of historic age and were evaluated for eligibility in the NRHP. None were found to have significant associations with events that made a contribution to the broad patterns of history (NRHP Criterion A) or persons important to the past (NRHP Criterion B). None of the resources evaluated were found to be an outstanding example of a type, period, or method of construction, nor were any found to be the work of a master (NRHP Criterion C), nor were any of the resources found likely to yield information important to history or prehistory (NRHP Criterion D). Furthermore, no resource was found to meet any of the special requirements under Criteria Considerations A-G. These historic-age resources evaluated are recommended ineligible for listing in the NRHP.

Based on the results of the archaeological survey, further testing and research is not needed for the sites recorded during survey. These sites do not appear to be associated with noteworthy historic persons or events. Additionally, all sites recorded have poor integrity due to continued destruction from plowing or maintenance over the years. The sites recorded during survey have limited potential to offer significant insights into the area's history and it is recommended that these sites are ineligible for listing in the NRHP or for nomination as SALs.

Table 4. Archaeological Sites Recorded and Associated Recommendations.

Trinomial	Site Type	NRHP Eligibility	Recommendations
41FN169	Late 19th to early 20th century cistern or well with associated artifacts	Not Eligible	No Further Work
41FN170	20th century cistern and pump house with associated artifacts	Not Eligible	No Further Work
41FN171	Late 19th to early 20th century artifacts	Not Eligible	No Further Work
41FN172	Early 20th century farmstead	Not Eligible	No Further Work
41FN173	Late 19th or early 20th century cistern	Not Eligible	No Further Work
41FN174	Late 19th or early 20th century cistern	Not Eligible	No Further Work
41FN175	Early to mid-20th century farmstead	Not Eligible	No Further Work

REFERENCES CITED

Banks, Larry D.
1990 *From Mountain Peaks to Alligator Stomachs: A Review of Lithic Sources in the Trans-Mississippi South, the Southern Plains, and Adjacent Southwest.* Memoir #4, Oklahoma Anthropological Society, Norman.
Banks, L. D. and J. Winters
1975 *The Bentsen-Clark Site: A Preliminary Report.* Texas Archeological Society, Special Publication No. 2.
Becker, Lyle
n.d. *A Pictorial History of Fannin County: Project Of Bonham Daily Favorite.* Publishing Plus, Bonham, Texas.
Bever, Michael R. and David J. Meltzer
2007 Exploring Variation in Paleoindian Life Ways: The Third Revised Edition of the Texas Clovis Fluted Point Survey. *Bulletin of the Texas Archeological Society* 78:65-99.
Blair, W. F.
1950 The Biotic Provinces of Texas. *Texas Journal of Science* 2(1):93-117.
Bonham Area Chamber of Commerce
2011 *Bonham Texas: Rich in Opportunity*
Bousman, C. Britt
1991 Paleoenvironments. In *Excavations at the Bottoms, Rena Branch, and Moccasin Springs Sites, Jewett Mine Project, Freestone and Leon Counties, Texas* by R.C. Fields, L.W. Clement, C.B. Bousman, S.A. Tomka, E.F. Gatus, and M.A. Howard, pp. 21-35. Reports of Investigations, No. 82, Prewitt and Associates, Inc., Austin.
Bousman, C. Britt and Eric Oksanen
2012 The Protoarchaic in Central Texas and Surrounding Areas. In *From the Pleistocene to the Holocene, Human Organization and Cultural Transformations in Prehistoric North America*, pp. 197-227, edited by C. Britt Bousman and Bradley J. Vierra, Texas A&M University Press, College Station.
Bousman, C. Britt and S. Alan Skinner
2007 The Search for Late Pleistocene and pre-Clovis Archeology in Texas: Problems and Potentials. *Bulletin of the Texas Archeological Society* 78:37-46.
Brothers, Rod
2010 "Camp Benjamin, Fannin County, Texas." Electronic Document. http://gen1startnet.com/civilwarben.htm, accessed October 6, 2011.
Brune, Gunnar
1981 *Springs of Texas, Volume I.* Branch-Smith, Inc., Fort Worth.
Bruseth, James E., Larry Banks and Jimmy Smith
2001 The Ray Site (41LR135). *Bulletin of the Texas Archeological Society* 72:197–213.
Bruseth, James E., D.E. Wilson, and Timothy K. Perttula
1995 The Sanders Site: A Spiroan Entrepot in Texas? *Plains Anthropologist* 40(153):223-236.
Burton, James D.
1973 *Osage-Orange* (*Maclura pomifera* Raf. Schneid.). FS-248, USDA, Forest Service.
Byrd, Clifford Leon
1971 *Origin and History of the Uvalde Gravel of Central Texas.* Baylor Geological Studies Bulletin 20, Baylor University, Waco.
Carley, Denny
1986 Evidence of Early Man in Northeast Texas. A Preliminary Report Submitted to the Texas Historical Commission by the Author. Limited Special Publication No. 1.
Carter, W.A.
1885 *History of Fannin County, Texas.* Bonham, Texas.
1975 *History of Fannin County, Texas and Biographies, Business Cards, and A Complete*
(1885) *Director of the County.* Bonham, Texas.
City of Bonham
2011 "History of Bonham, Fannin County, Texas." Electronic Document, http://www.cobon.net/history.htm, accessed August 30, 2011.
City of Bonham

Cliff, Maynard and Russell Shortes
2001 *A Cultural Resources Survey for the Valley Junction-Anna Switch 345-kV Transmission Line Project, Collin County, Texas*. Document No. 010223, PBS&J, Dallas.
Clow, Charles M. and Steven M. Hunt
2000 *Intensive Pedestrian Survey of a Proposed 1,460-Acre Landfill Site Near Melissa, Collin County, Texas.* Miscellaneous Reports of Investigations Number 209. Geo-Marine, Inc. Plano
Conrad, James H.
1988 *John Black's Pictorial History: Honey Grove Texas, 1880-1925*. Henington, Wolfe City, Texas.
Crook, Wilson W., III
2007 The Frognot Site (41COL165): A Late Paleoindian to Middle Archaic Occupation in Collin County, Texas. *The Record* 55(2):1-10.
Davis, Mott E.
1962a Archaeological Salvage Investigation of the Harling Mound in Fannin County, Texas. *Yearbook of the American Philosophical Society* (1961). American Philosophical Society, Philadelphia.
1962b The Harling Site (41FN1), Fannin County, Texas. *Plains Anthropologist* 7(16):86.
Davis, W.A., E. Mott Davis, and Curtis D. Tunnell
1962 *Appraisal of the Archeological Resources of the Brushy Creek Reservoir, Fannin and Grayson Counties, Texas*. Report submitted to the National Park Service by the Texas Archeological Salvage Project, The University of Texas, Austin.
Davis, Cody S., S. Alan Skinner, and Molly A. Hall
2013 *Archaeological Survey of the Proposed Lower Bois d'Arc Creek Reservoir, Fannin County, Texas*. Cultural Resources Report 2013-DRAFT, AR Consultants, Inc., Dallas.
Denton, Mark
2007 *Cisterns in Texas*. Paper presented at the SAA Meeting . April 26. Austin.
Dobbs, Larry (editor)
2012 *A History of Bois d' Arc Springs and the Greens Chapel Community Fannin County, Texas*. Published by Rebecca Todd Shirley.
Duffield, Lathel F. and Edward B. Jelks
1961 *The Pearson site, A Historic Indian Site in Iron Bridge Reservoir, Rains County, Texas*. Archaeology Series No. 4, Department of Anthropology, The University of Texas at Austin.
Early, Ann
1978 Turquoise Beads from the Standridge Site. *The Arkansas Archeologist* 19:25-30.
Ferring, C. Reid
1994 *Archaeological Investigations at Four Sites Along Potapo Creek, McGee Creek Reservoir, Atoka County, Oklahoma.* Volume V, Part 3 of the McGee Creek Archaeological Project Reports. Institute of Applied Sciences, University of North Texas, Denton.
Fields, R.C. and S.A. Tomka
1993 Hunter-Gatherer Mobility in Northeast Texas, 10,000-200 B.C. In *Archeology in the Eastern Planning Region, Texas: A Planning Document*, edited by N.A. Kenmotsu and T.K. Perttula, pp. 69-95. Cultural Resource Management Report 3, Department of Antiquities Protection, Texas Historical Commission, Austin.
Flores, Dan L., editor
1984 *Jefferson and Southwestern Exploration: The Freeman and Custis Accounts of the Red River Expedition of 1806*. University of Oklahoma Press, Norman.
1985 *Journal of an Indian Trader: Anthony Glass and the Texas Trading Frontier, 1790-1810.* Texas A&M Press, College Station.
Bureau of Economic Geology, The University of Texas at Austin.
Goerdel, A. R.
2001 *Soil Survey of Fannin County, Texas.* USDA, Natural Resources Conservation Service in cooperation with the Texas Agricultural Experiment Station, the U. S. Forest Service, and the Texas State Soil and Water Conservation Board.
Hamilton, Donny L.
1997 Observations of Caddoan Burial Practices at the Sanders Site (41LR2). *Bulletin of the Texas Archeological Society* 68:116-134.

Harris, R. K.
1951 Two Mussel Shell Hoes from Site 19A1-2. *The Record* 9(4):20.
1953 Two Recent Trips to Sites in Fannin and Lamar Counties. *The Record* 11(5):19-20.
Harris R. K. and Inus Marie Harris
1967 Trade Beads, Projectile Point, and Knives. In *A Pilot Study of Wichita Indian Archeology and Ethnohistory*, assembled by Robert E. Bell, Edward B. Jelks, and W. W. Newcomb, pp. 129-183, Final Report for Grant GS-964, National Science Foundation.
Harris, R. King, Inus M. Harris, Jay C. Blaine and Jerrylee Blaine
1965 A Preliminary Archeological and Documentary Study of the Womack Site, Lamar County, Texas. *Bulletin of the Texas Archeological Society* 36:287-365.
Hart, Brian
2011a *Handbook of Texas Online*, "Lamasco, Texas," http://www.tshaonline.org/handbook/online/articles/hnl08, accessed August 31, 2011.
2011b *Handbook of Texas Online*, "Telephone, TX," http://www.tshaonline.org/handbook/online/articles/hlt05, accessed August 31, 2011.
2013 *Handbook of Texas Online*, "Selfs, TX," http://www.tshaonline.org/handbook/online/articles/hlw38, accessed October 02, 2013.
Hodge, Floyd Crandall
1966 *A History of Fannin County: Featuring Pioneer Families.* Pioneer Press, Hereford, TX.
Hofman, Jack L.
1988 Folsom Research in Western Oklahoma: Rethinking the Folsom Occupation of the Southern Plains. *Transactions of the 23rd Regional Archeological Symposium for Southeastern New Mexico and Western Texas* 23:6-30.
Honey Grove Signal-Citizen
1980 North of Dodd City, Texas Volunteers of CSA Buried in Fannin County. 2 May 1980.
Housewright, Rex
1946 A Turquoise Bead Necklace. *The Record* 5(2):9-10.
Hsu, Dick Ping
1968 *An Appraisal of the Archeological Resources of Timber Creek and Bois D'Arc Reservoirs, Fannin County, Texas.* Archeological Survey Report Number 2, Texas State Building Commission and Texas State Water Development Board, Austin.
Humphrey, J.D. and C.R. Ferring
1994 Stable Isotopic Evidence for Latest Pleistocene and Holocene Climatic Change in North-Central Texas. *Quaternary Research* 41:200-13.
Hymer, Tom
2013 "Leonard, Texas." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/hjl05. Last accessed August 27, 2013.
Jackson, A. T., Marcus S. Goldstein and Alex D. Krieger
2000 *The 1931 Excavations at the Sanders Site Lamar County, Texas: Notes on the Fieldwork, Human Osteology, and Ceramics.* Archival Series 2, Texas Archeological Research Laboratory, The University of Texas at Austin.
Jacobs, James Alan
1981 Depositional and Quaternary History of the Red River in Northeast Texas. Masters Thesis presented to the University of Texas at Austin.
Jelks, Edward B.
1967 The Gilbert Site, A Norteño Site in Northeastern Texas. *Bulletin of the Texas Archeological Society*, Volume 37.
Jennings, Thomas A
2008 *San Patrice Technology and Mobility across the Plains-Woodland Border.* Memoir 12, Oklahoma Anthropological Society, R.E. Bell Monographs in Anthropology No. 5, Sam Noble Oklahoma Museum of Natural History, Norman.
Jones, Sheryn R.
1997 *Fannin County Folks and Facts.* Bonham Public Library, Bonham, Texas.

Johnson, Leroy, Jr.
1989 *Great Plains Interlopers in the Eastern Woodlands during Late Paleo-Indian Times, Evidence from Oklahoma, Texas, and Areas Close By*. Office of the State Archeologist Report 36, Texas Historical Commission, Austin.
Jordan, Terry G.
1978 *Texas Log Buildings, A Folk Architecture*. University of Texas Press, Austin.
Jurney, David H.
1994 The Original Distribution of Bois d'Arc . Part 1: Texas. *Caddoan Archeology Newsletter* 5(2):7-13.
Jurney, David H., Frank Winchell and Randall W. Moir
1989 *Cultural Resources Overview of the National Grasslands in North Texas, Studies in Predictive Archaeological Modeling for the Caddo and LBJ Grasslands.* Archaeology Research Program, Institute for the Study of Earth and Man, Southern Methodist University, Dallas
Kenmotsu, Nancy A. and Timothy K. Perttula
1993 *Archeology in the Eastern Planning Region, Texas: A Planning Document*. Cultural Resource Management Report 3, Department of Antiquities Protection, Texas Historical Commission, Austin.
Kirk, Rickey L.
n.d. *1926 Historical Fannin County Map.* Fannin County Museum, Bonham, Texas
n.d. *1836-1996 Fannin County Kin Map.* Fannin County Museum, Bonham, Texas
Kleiner, Diana J.
2011 *Handbook of Texas Online*, "Bonham, TX." http://www.tshaonline.org/handbook/online /articles/hfb02, accessed August 26, 2011.
Krieger, Alex D.
1946 *Culture Complexes and Chronology in Northern Texas with Extension of Pueblo Datings to the Mississippi Valley*. The University of Texas Publication No. 4640, The University of Texas, Austin.
Küchler, A. W.
1964 *Potential Natural Vegetation of the Coterminous United States*. Special Publication No. 36, American Geographical Society.
Leonard Preservation League (LPL)
2005 *The History of Leonard, Texas, VOL II.* Leonard Centennial Commission, Leonard, Texas
Long, Christopher
2011 *Handbook of Texas Online,* "Caddo National Grasslands." http://www. tshaonline.org /handbook/online/articles/gkc08, accessed August 26, 2011.
Mahoney, Richard B.
2001 *Archaeological Testing of 23 Prehistoric Sites, Lamar County, Texas*. Archaeological Survey Report No. 314, Center for Archaeological Research, The University of Texas at San Antonio.
Mallouf, Robert J.
1976 *Archeological Investigations at Proposed Big Pine Lake, 1974-1975 Lamar and Red River Counties, Texas*. Archeological Survey Report 18, Office of the State Archeologist, Texas Historical Commission, Austin.
Mase, Robert E.
1994 Abandonment of Hand-Dug Wells: A Case Study in Ellis County, Texas. *The Texas Journal of Science 46 (4):345-359.*
Mckee, Arlo
2010 *Archaeological Testing and Data Recovery Excavations at Site 41COL172, Collin County, Texas*. Miscellaneous Reports of Investigations Number 513. Geo-Marine, Inc., Plano.
Menzer, Fred J., Jr. and B.H. Slaughter
1971 Upland Gravel in Dallas County, Texas and Their Bearing on the Former Extent of the High Plains Physiographic Province. *The Texas Journal of Science* XXII (2&3):217-222.
Minor, David
2011 *Handbook of Texas Online,* "Honey Grove, TX." http://www.tshaonline.org/handbook/online /articles/hjh11, accessed August 31, 2011.
Nationwide Environmental Title Research
1966 "Historical Aerials Online." http://www.netronline.com/. Last accessed September 27, 2013. In partnership with the USDA and the USGS.

1970 "Historical Aerials Online." http://www.netronline.com/. Last accessed September 27, 2013. In partnership with the USDA and the USGS.

1985 "Historical Aerials Online." http://www.netronline.com/. Last accessed September 27, 2013. In partnership with the USDA and the USGS.

Perttula, Timothy K.

1998 Previous Archaeological Research and Historic Context. In *Archaeological Survey of Southwest Block and Selected Roads and Firebreaks at Camp Maxey, Lamar County, Texas.* by David L. Nichols, Lee C. Nordt, Timothy K. Perttula, C. Britt Bousman and Kristi Miller. Archaeological Research Report No. 290, pp. 16–20, Center for Archaeological Research, The University of Texas at San Antonio.

2004 The Prehistoric and Caddoan Archeology of the Northeastern Texas Pineywoods. In *The Prehistory of Texas*, edited by Timothy K. Perttula, pp. 370-407, Texas A & M University Press, College Station.

2008 Archaeological Survey of the Roitsch Farm and Adjoining Lands, 1991 and 1992 Texas Archaeological Society Field School, Red River County, Texas. In *Collected Papers from Past Texas Archaeological Society Field Schools,* edited by Timothy K. Perttula, pp 173-312. Special Publication No. 5. Texas Archaeological Society.

Perttula, Timothy K., James E. Bruseth, Nancy A. Kenmotsu, William A. Martin, Larry Banks, Jimmy Smith, Nancy G. Reese, and Sergio A. Ireguas

2001 Archeological Investigations on the Red River and Tributaries: Summary of the Findings of the 1991 and 1992 Texas Archeological Society Field School in Red River and Lamar Counties, Texas. *Bulletin of the Texas Archeological Society* 72:165-250

Perttula, Timothy K., Ross C. Fields, James E. Corbin and Nancy A. Kenmotsu

1993 The Emergence of Sedentism in Northeast Texas, ca. 500 B.C. to A.D. 1100. In *Archeology in the Eastern Planning Region, Texas: A Planning Document.* Nancy A. Kenmotsu and Timothy K. Perttula, Editors. Cultural Resource Management Report 3, pp. 97–120, Department of Antiquities Protection, Texas Historical Commission, Austin.

Pigott, Kelley

2010 *Handbook of Texas Online*, s. v. "FANNIN COUNTY." http://www.tsha.utexas.edu/handbook /online/articles/FF/hcf2.html, accessed May 3, 2011 and September 27, 2011

Schambach, Frank F.

1995 A Probable Spiroan Entrepot in the Red River Valley in Northeast Texas. *Caddoan Archeology Newsletter* 6(1):10-25.

1996 The Womack, Gilbert and Pearson Sites: Early Eighteenth Century Tunica Entrepots in Northeast Texas. *Caddoan Archeology* 7(3):9-31.

1999 Deconstructing the "Sanders Focus" and the "Sanders Phase": A Reply to Perttula Regarding the Taxonomy and Significance of the So-called Sanders Focus, or Sanders Phase, Pottery of Northeast Texas and Southeast Oklahoma. *Caddoan Archeology* 9(3/4):3-55.

2000 Spiroan Traders, the Sanders Site, and the Plains Interaction Sphere: A Reply to Bruseth, Wilson, and Perttula. *Plains Anthropologist* 45(171):7-33.

Scott, Tom

1982 *Fannin County: The Early Years.* Bonham, Texas: *Fannin County Genealogical Quarterly.*

1993 *North Texas: The People, The Places, The Times.* Texoma Council of Governments, Denison, Texas.

Skinner, S. Alan

2007 An Update on the Gene and Ruth Ann Stallings Site & A Plea for Your Help. *Texas Archeology* 51(1):13.

Skinner, S. Alan, C. Britt Bousman, Neely Plumb, Anita P. Wilson, Jesse Todd and Thomas A. Jennings

2005 *Archaeology and Quaternary Geology at Lake Ralph Hall, Fannin County, Texas.* Cultural Resources Report 2005-31, AR Consultants, Inc., Dallas.

Skinner, S. Alan and Cody S. Davis

2009 *Archaeological Survey of the South Wastewater Interceptor, Bonham, Texas, "Archaeological Survey along the edge of the Bois d'Arc Creek Floodplain."* Cultural Resources Report 2009-31, AR Consultants, Inc., Dallas.

Skinner, S. Alan, Cody S. Davis, and Rebecca Shelton

2010 *Research Design for the Proposed Lower Bois d'Arc Creek Reservoir Project, Fannin County, Texas.* Cultural Resources Report Number 2010-28, AR Consultants, Inc., Dallas.

Skinner, S. Alan, R. King Harris, and Keith M. Anderson

1969 *Archaeological Investigations at the Sam Kaufman Site, Red River County, Texas*. Contributions in Anthropology No. 5, Southern Methodist University, Dallas.

Smith, Jeffrey L. and Janice V. Perino

1981 Osage Orange (*Maclura pomifera*): History and Economic Uses. *Economic Botany* 35(1):24-41.

Stahle, D. W. and M.C. Cleaveland

1994 Tree-Ring Reconstructed Rainfall over the Southeastern U.S.A. during the Medieval Warm Period and Little Ice Age. *Climatic Change* 26:194-212.

Story, Dee Ann

1990 Culture History of the Native Americans In *The Archaeology and Bioarchaeology of the Gulf Coastal Plain: Volume 1* by Dee Ann Story, Barbara A. Burnett, Martha Doty Freeman, Jerome C. Rose, D. Gentry Steele, Ben W. Olive, and Karl J. Reinhard, pp163-366 Arkansas Archaeological Survey Research Series, No. 38, University of Arkansas Printing Services, Fayetteville.

Strickland, Tex Wallace

1930 History of Fannin County, Texas, 1936-1843. *Southwestern Historical Quarterly* 33-34.

Tate, Ron

2001 *Yesterday Revisited, A Pictorial History of Fannin County, Texas*. D-Books Publishing, Inc., Marceline, Missouri.

Templin, Edward. H.

1946 *Soil survey, Fannin County, Texas*. U.S. Department of Agriculture, Washington, D.C.

Texas Archeological Sites Atlas [TASA]

2010 Search for sites listed on the Bonham, Lake Bonham, Lamasco and Selfs, Texas 7.5' USGS maps and the Fannin County map. Texas Historical Commission internet site.

Texas Department of Transportation

2011 Farm to Market Road No. 1396. Electronic Document, http://www.dot.state.tx.us /tpp/hwyfm1000/fm1396.htm, accessed September 27, 2011.

Texas Historical Commission (THC)

n.d. *Minimum Survey Standards for Projects 200 Acres or Less.* On file, Texas Historical Commission, Austin.

Thurmond, J. Peter and Don G. Wyckoff

1999 The Calf Creek Horizon in Northwestern Oklahoma. *Plains Anthropologist* 44(169):231-250.

Todd, Jesse and S. Alan Skinner

2007 *Archaeological Potential of the Proposed Lower Bois D'Arc Creek Reservoir, Fannin County, Texas.* Cultural Resources Report Number 2007-06, AR Consultants, Inc., Dallas.

United States Department of Agriculture [USDA]

1939 *Soil Map of Fannin County, Texas*. Agricultural Research Administration, Bureau of Plant Industry and Agricultural Engineering in cooperation with Texas Agricultural Experiment Station.

Vehik, Susan C.

2002 Conflict, Trade, and Political Development on the Southern Plains. *American Antiquity* 67(1):37-63.

Valley of the Caddo Archeological Society [VOCAS]

2010 Interviews at monthly meetings in Paris.

Waring, A. J., Jr. and Preston Holder

1945 A Prehistoric Ceremonial Complex in the Southeastern United States. *American Anthropologist* 5(1):1-34.

Webb, Clarence H.

1959 *The Belcher Mound, A Stratified Caddoan Site in Caddo Parish, Louisiana.* Memoir 16, Society for American Archaeology.

Wilson, Rex L.

1971 *Clay Tobacco Pipes from Fort Laramie National Historic Site and Related Locations*. Division of Archeology and Anthropology, Office of Archeology and Historic Preservation, National Park Service, U.S. Department of the Interior.

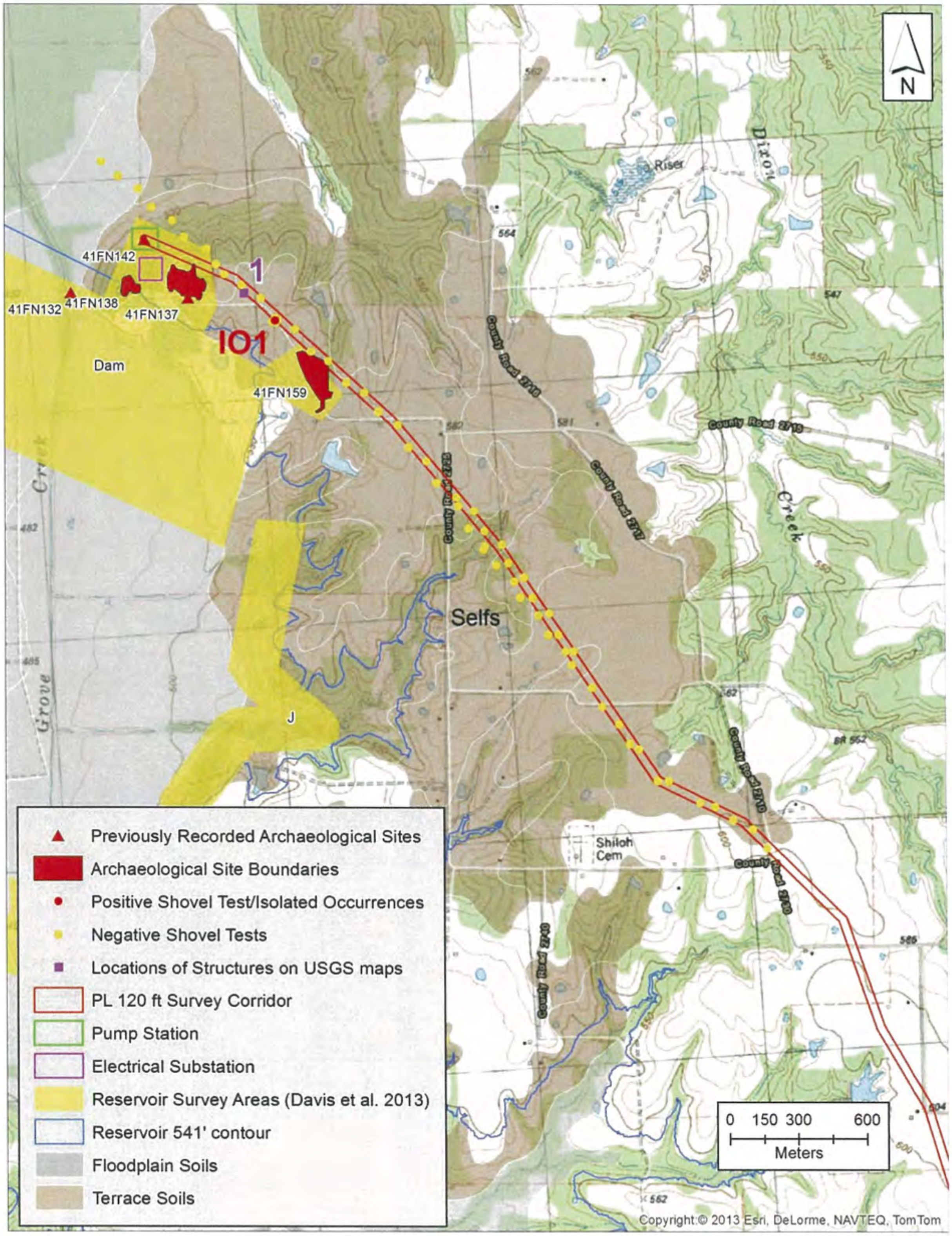
Winberry, John J.

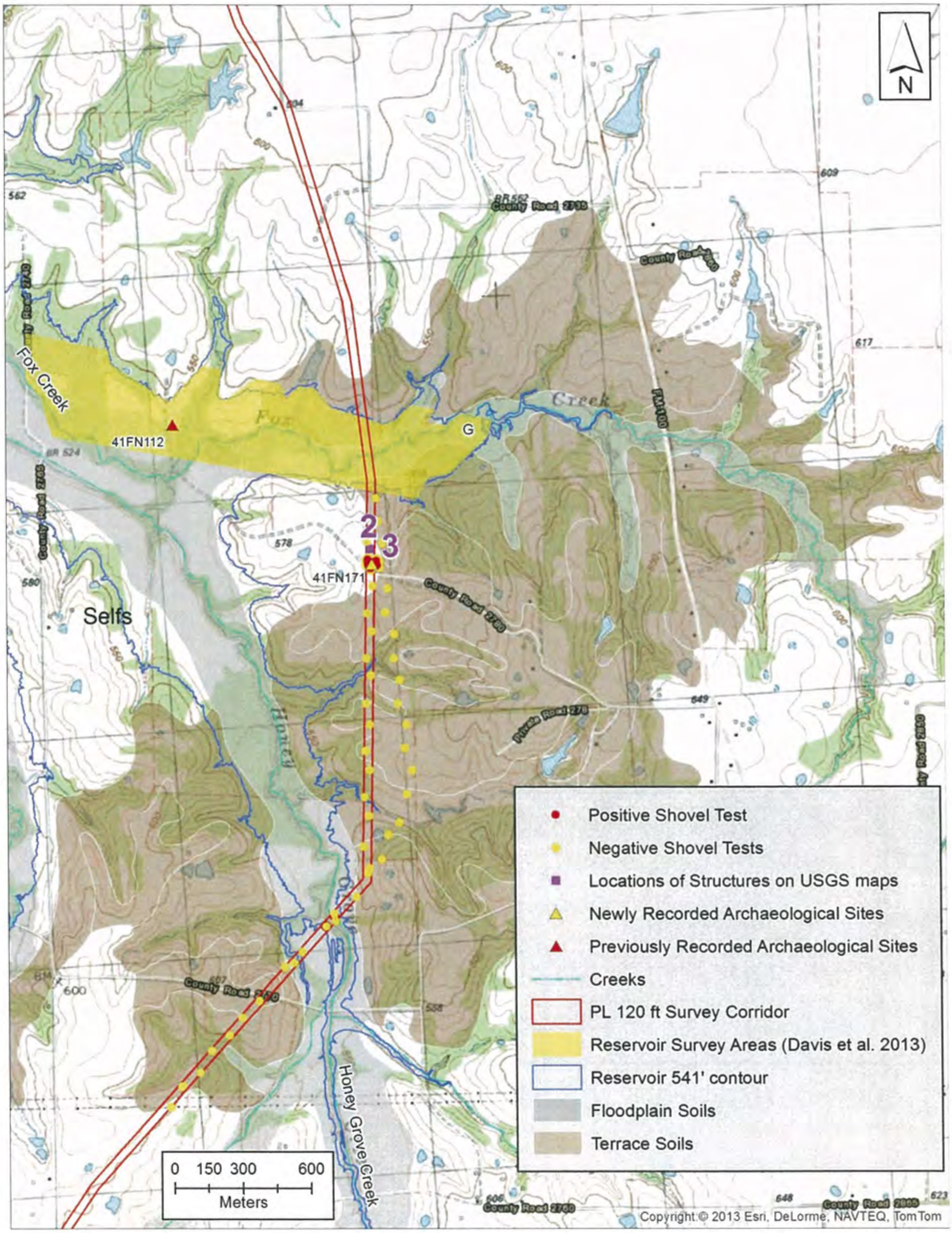
1979 The Osage Orange: A Botanical Artifact. *Pioneer America* 11(3):134-141.

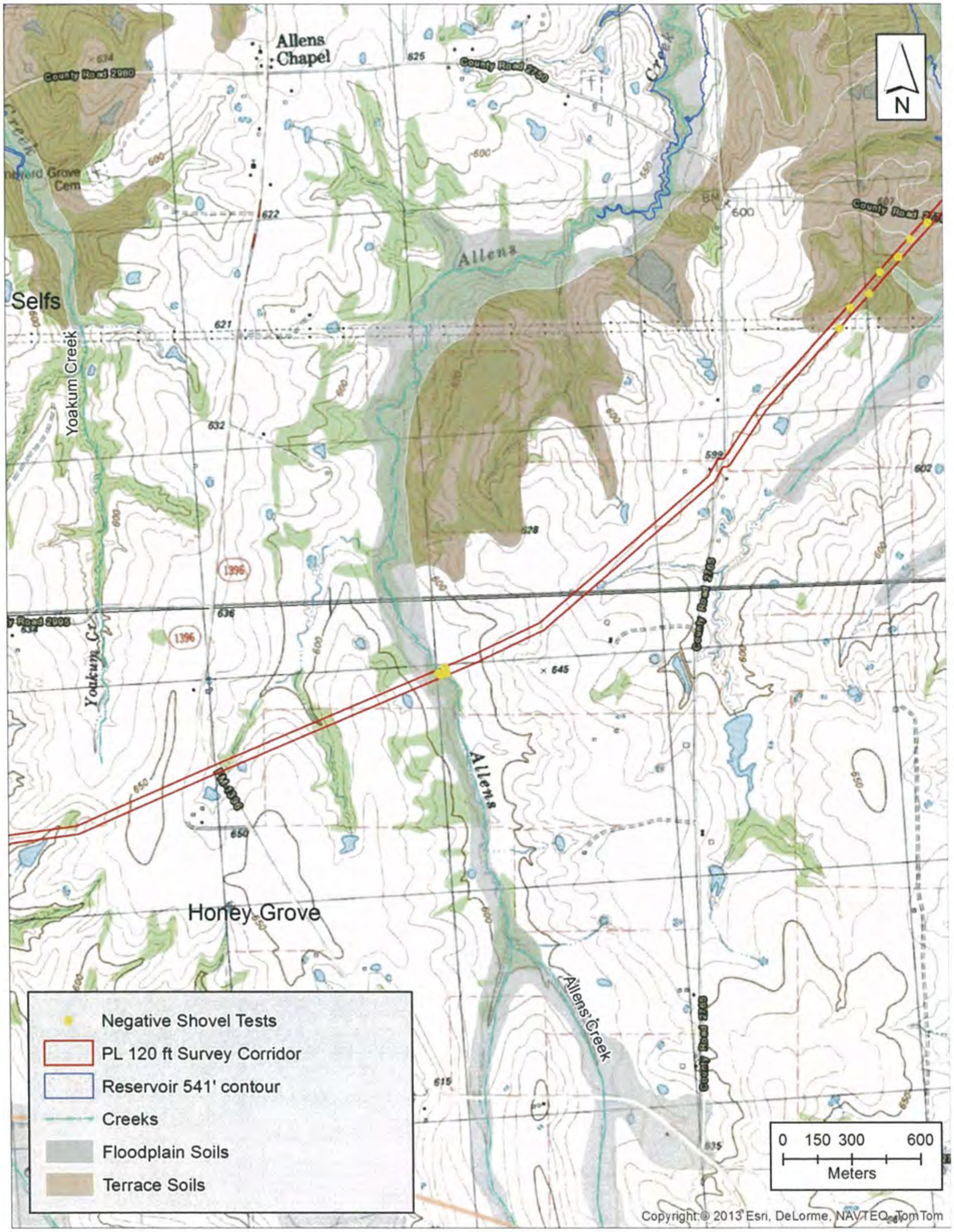
Wood, W. Ray

1981 The Poole Site, 3GA3, with a new Forward and Summary by Ann M. Early. *Arkansas Archeologist* 22:7-62.

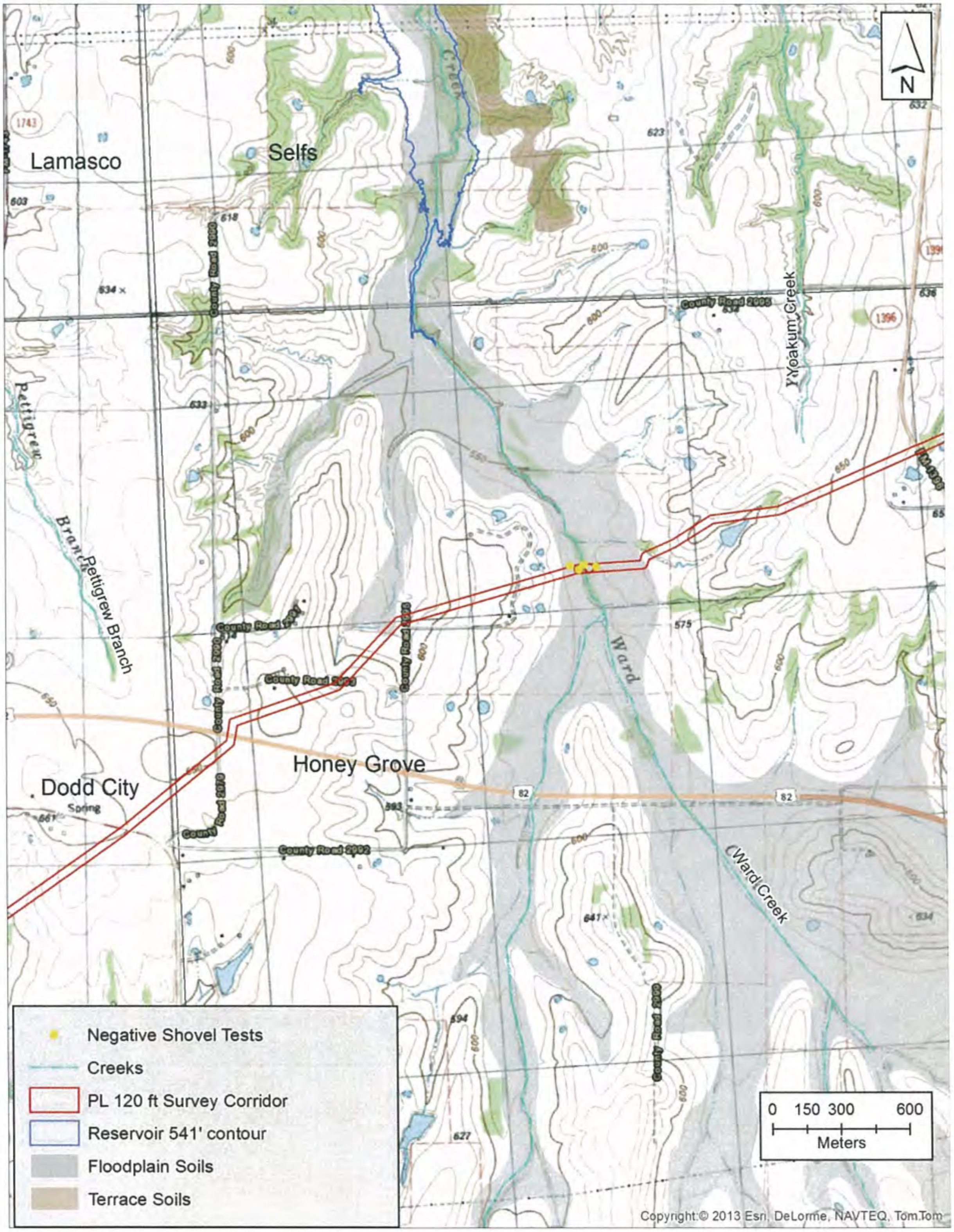
APPENDIX A: SURVEY AREAS ON USGS MAPS

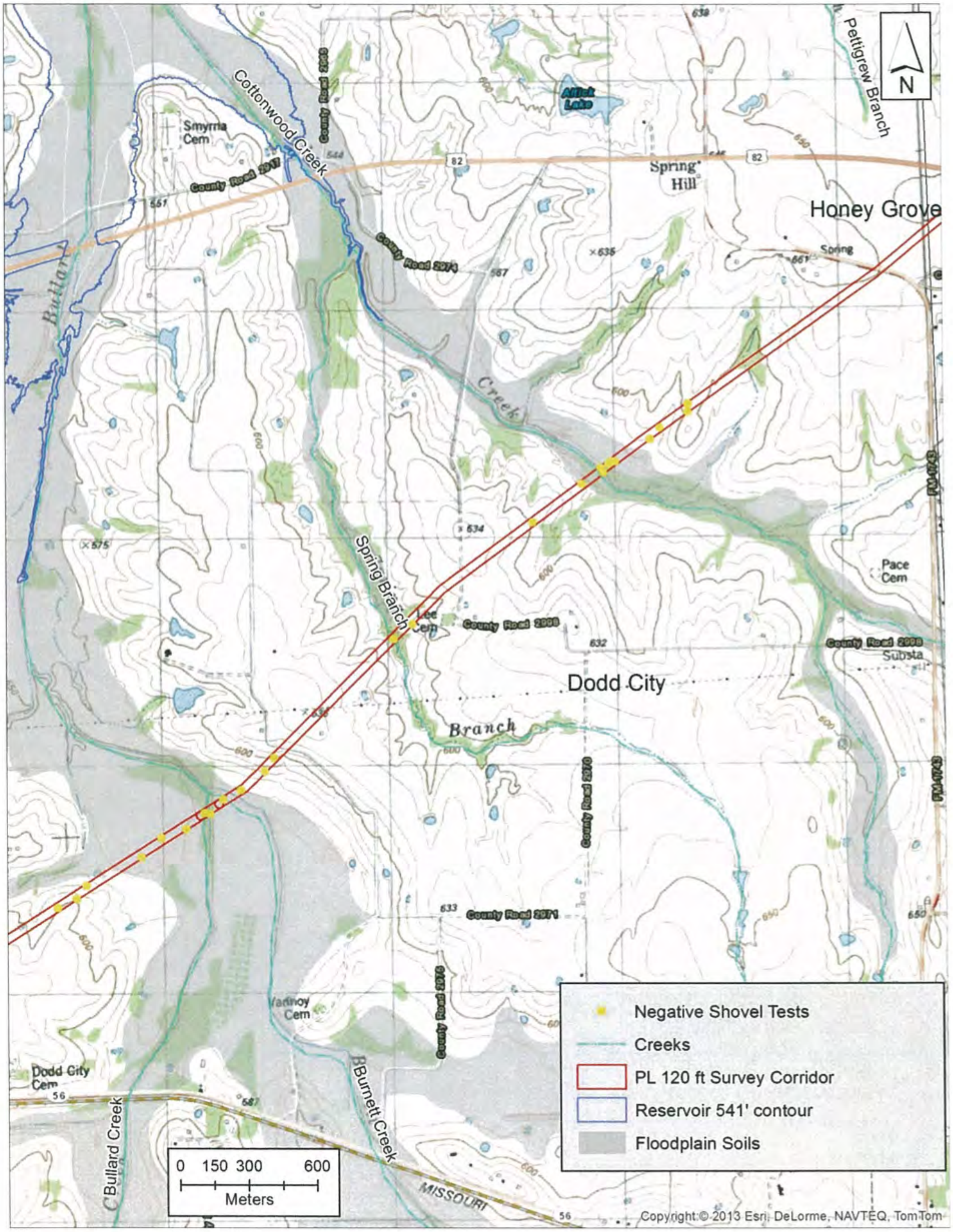

N
41FN142
41FN132
41FN138
41FN137
1
IO1
Dam
41FN159
J
Selfs
Riser
Dixon Creek
Grove Creek
Shiloh Cem
County Road 2710
County Road 2715
County Road 2717
County Road 2725
County Road 2740
▲ Previously Recorded Archaeological Sites
🟥 Archaeological Site Boundaries
● Positive Shovel Test/Isolated Occurrences
● Negative Shovel Tests
■ Locations of Structures on USGS maps
☐ PL 120 ft Survey Corridor
☐ Pump Station
☐ Electrical Substation
🟨 Reservoir Survey Areas (Davis et al. 2013)
☐ Reservoir 541' contour
▨ Floodplain Soils
▨ Terrace Soils
0 150 300 600
Meters
Copyright:© 2013 Esri, DeLorme, NAVTEQ, TomTom

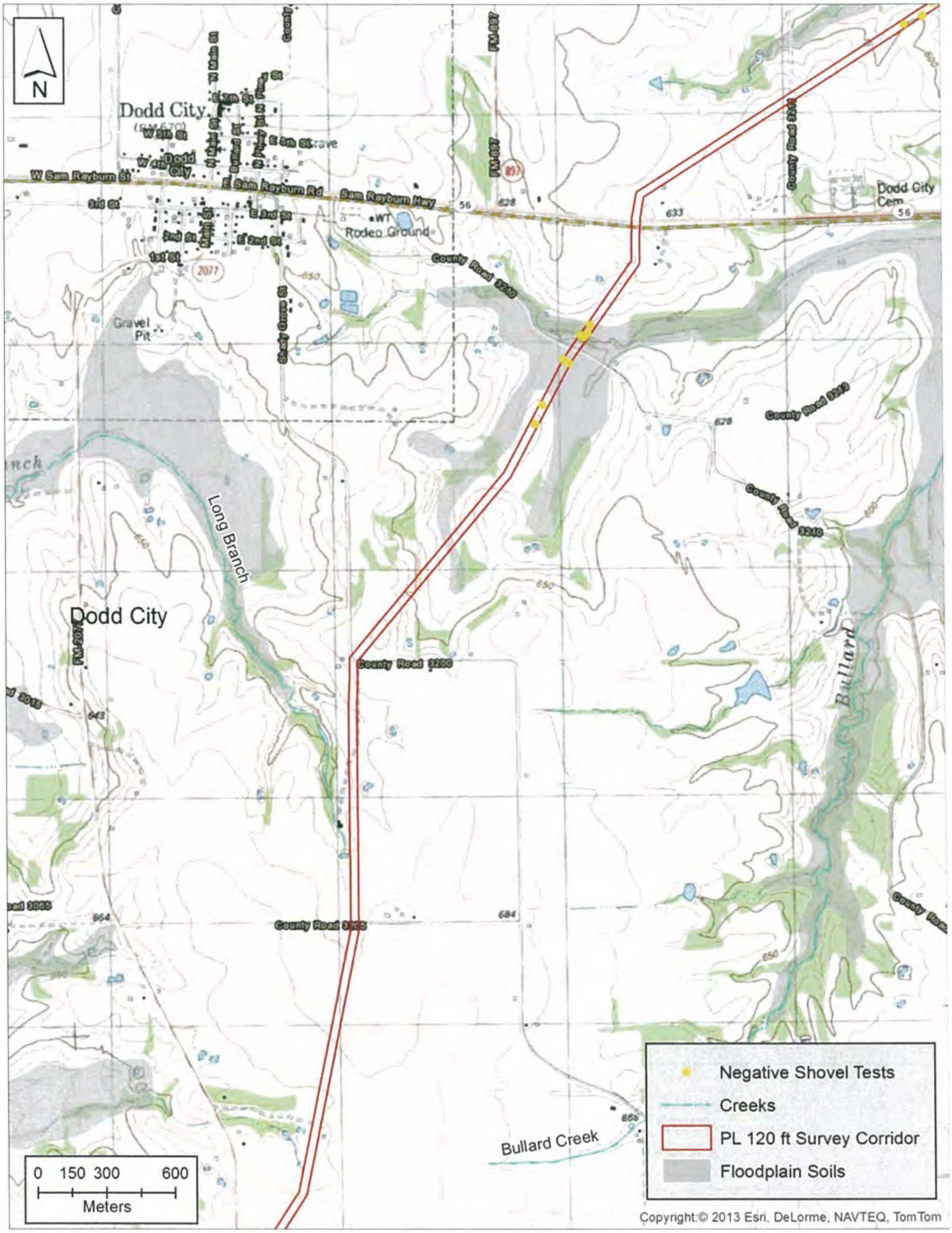

N
Fox Creek
41FN112
G
2
3
41FN171
Selfs
Honey Grove Creek
County Road 2735
County Road 2760
Private Road 278
County Road 2765
County Road 2865
FM 100
Positive Shovel Test
Negative Shovel Tests
Locations of Structures on USGS maps
Newly Recorded Archaeological Sites
Previously Recorded Archaeological Sites
Creeks
PL 120 ft Survey Corridor
Reservoir Survey Areas (Davis et al. 2013)
Reservoir 541' contour
Floodplain Soils
Terrace Soils
0 150 300 600
Meters
Copyright © 2013 Esri, DeLorme, NAVTEQ, TomTom



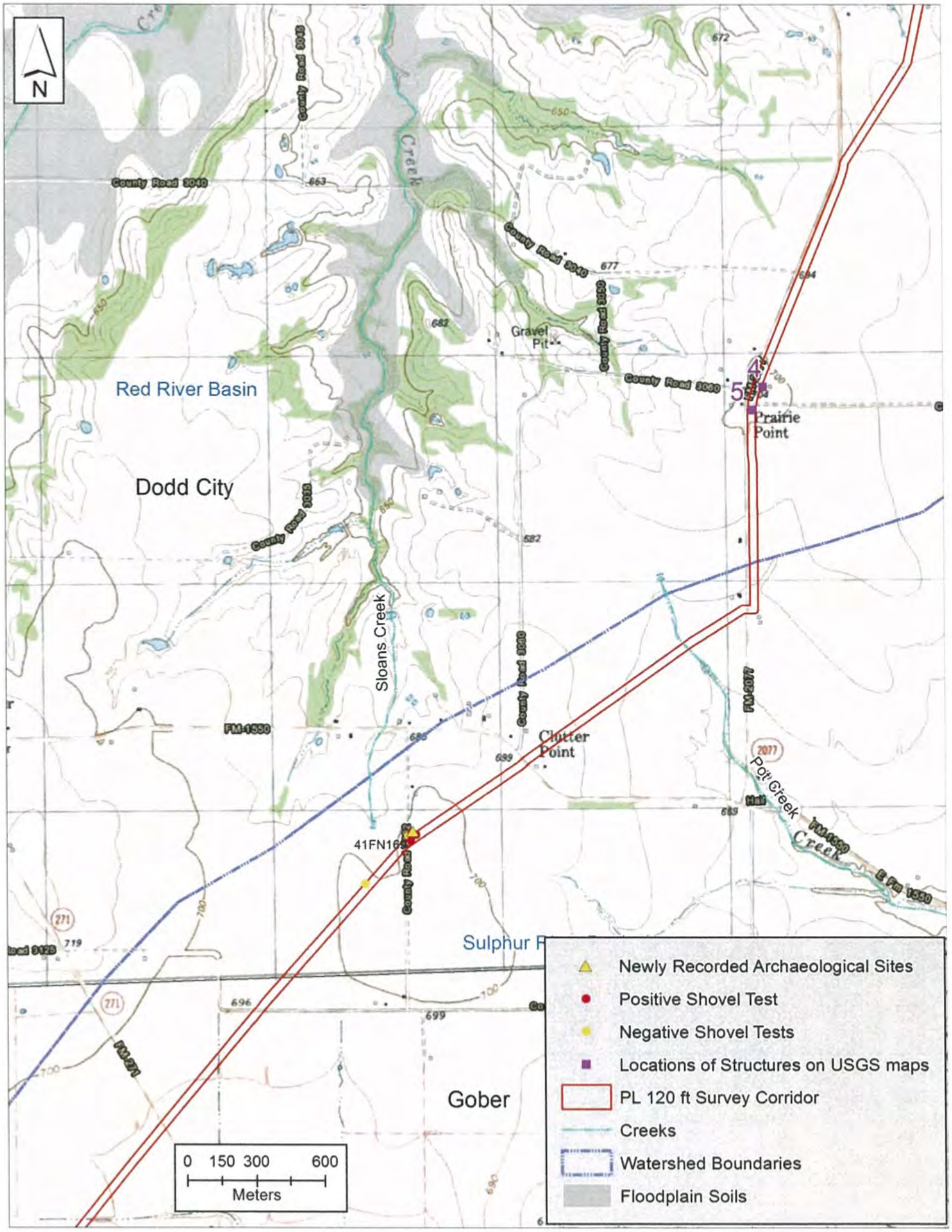
Copyright © 2013 Esri, DeLorme, NAVTEQ, TomTom

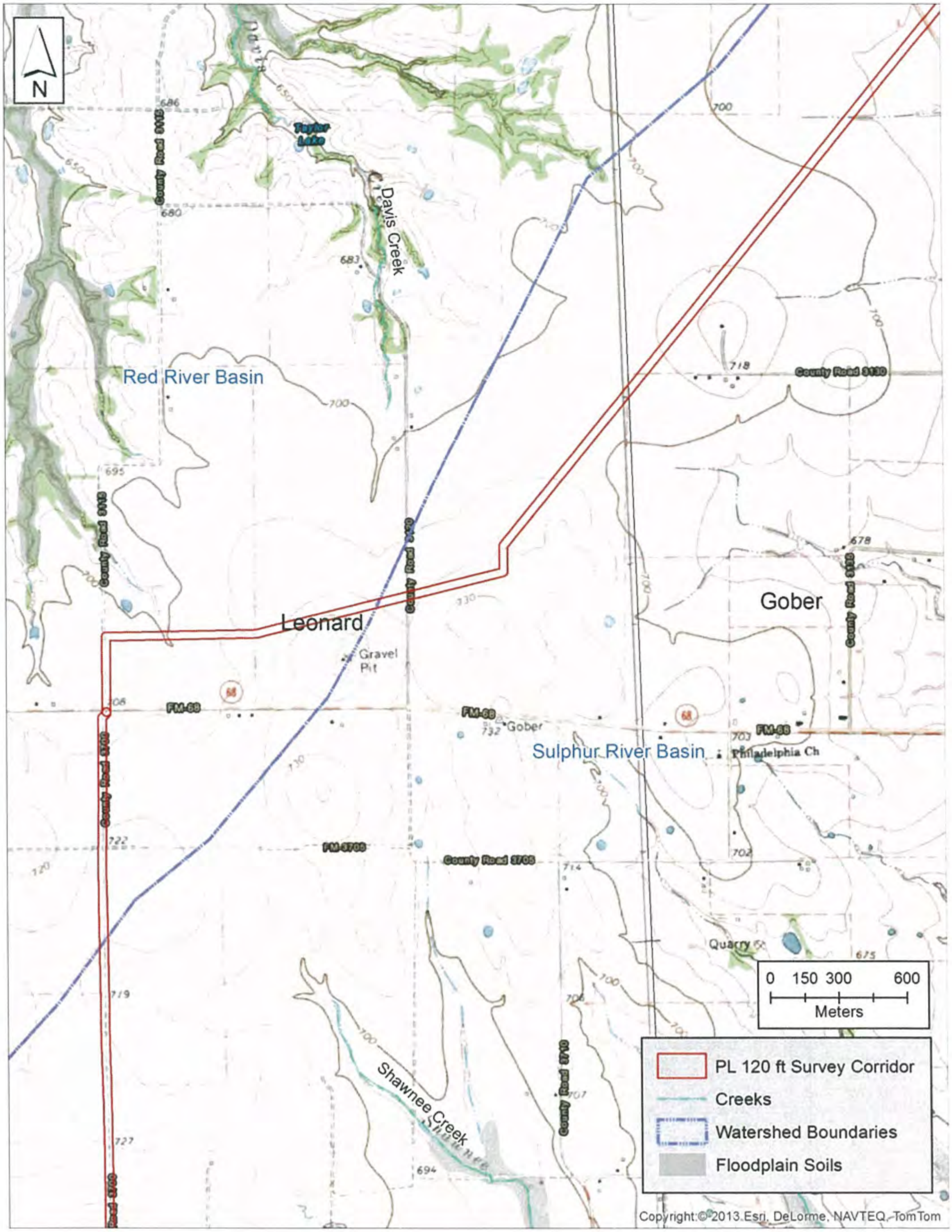

N
Lamasco
Selfs
Dodd City
Honey Grove
Pettigrew Branch
Yoakum Creek
Ward Creek
Ward
Creek
County Road 2990
County Road 2995
County Road 2991
County Road 2993
County Road 2992
County Road 2910
County Road 2990
Negative Shovel Tests
Creeks
PL 120 ft Survey Corridor
Reservoir 541' contour
Floodplain Soils
Terrace Soils
0 150 300 600
Meters
Copyright:© 2013 Esri, DeLorme, NAVTEQ, TomTom

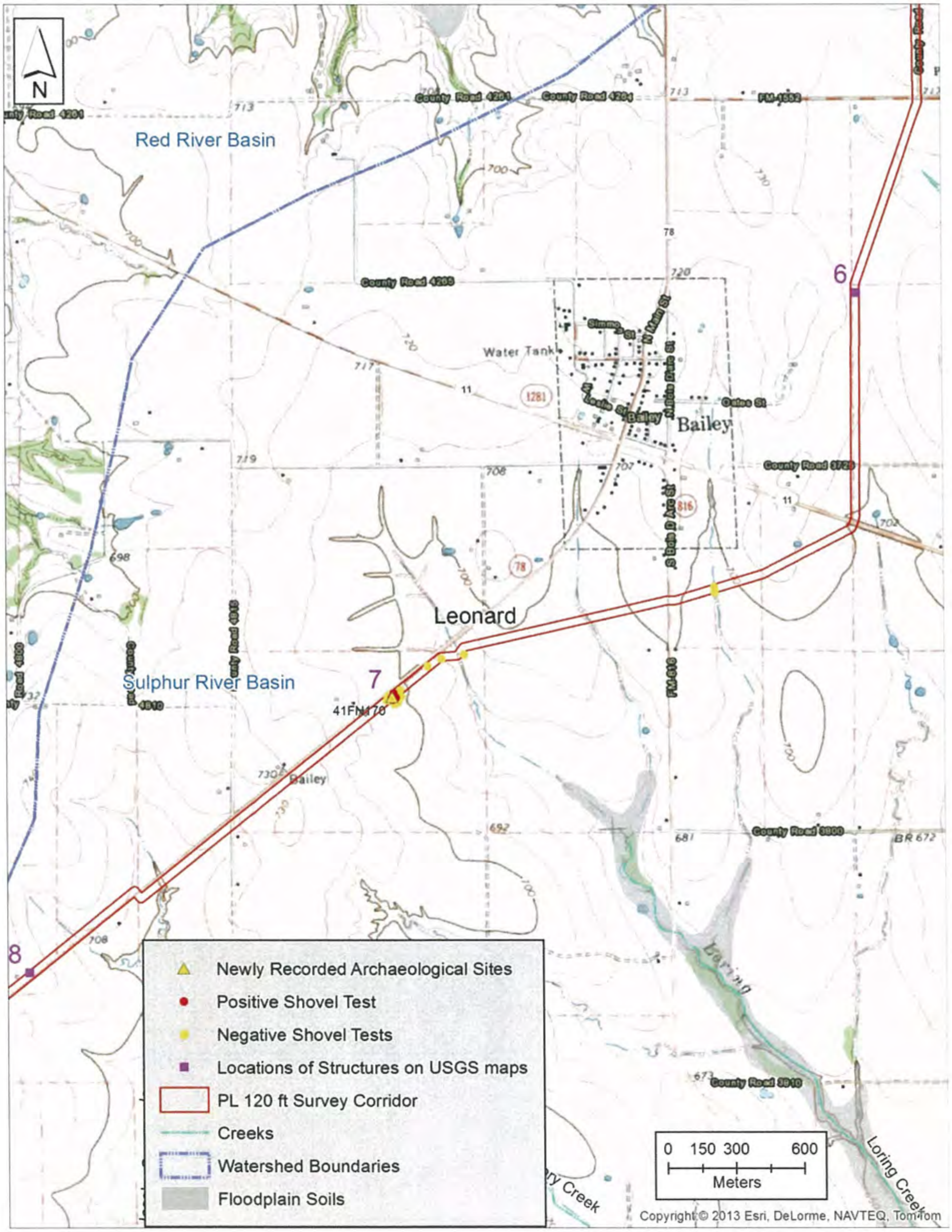

N
Pettigrew Branch
Cottonwood Creek
County Road 2985
Smyrna Cem
County Road 2917
Spring Hill
Honey Grove
County Road 2974
Creek
Spring Branch
Lee Cem
County Road 2998
Pace Cem
Substa
Dodd City
Branch
County Road 2970
County Road 2971
County Road 2975
FM 1743
Varnoy Cem
Dodd City Cem
Bullard Creek
Burnett Creek
MISSOURI
0 150 300 600
Meters
Negative Shovel Tests
Creeks
PL 120 ft Survey Corridor
Reservoir 541' contour
Floodplain Soils
Copyright:© 2013 Esri, DeLorme, NAVTEQ, TomTom

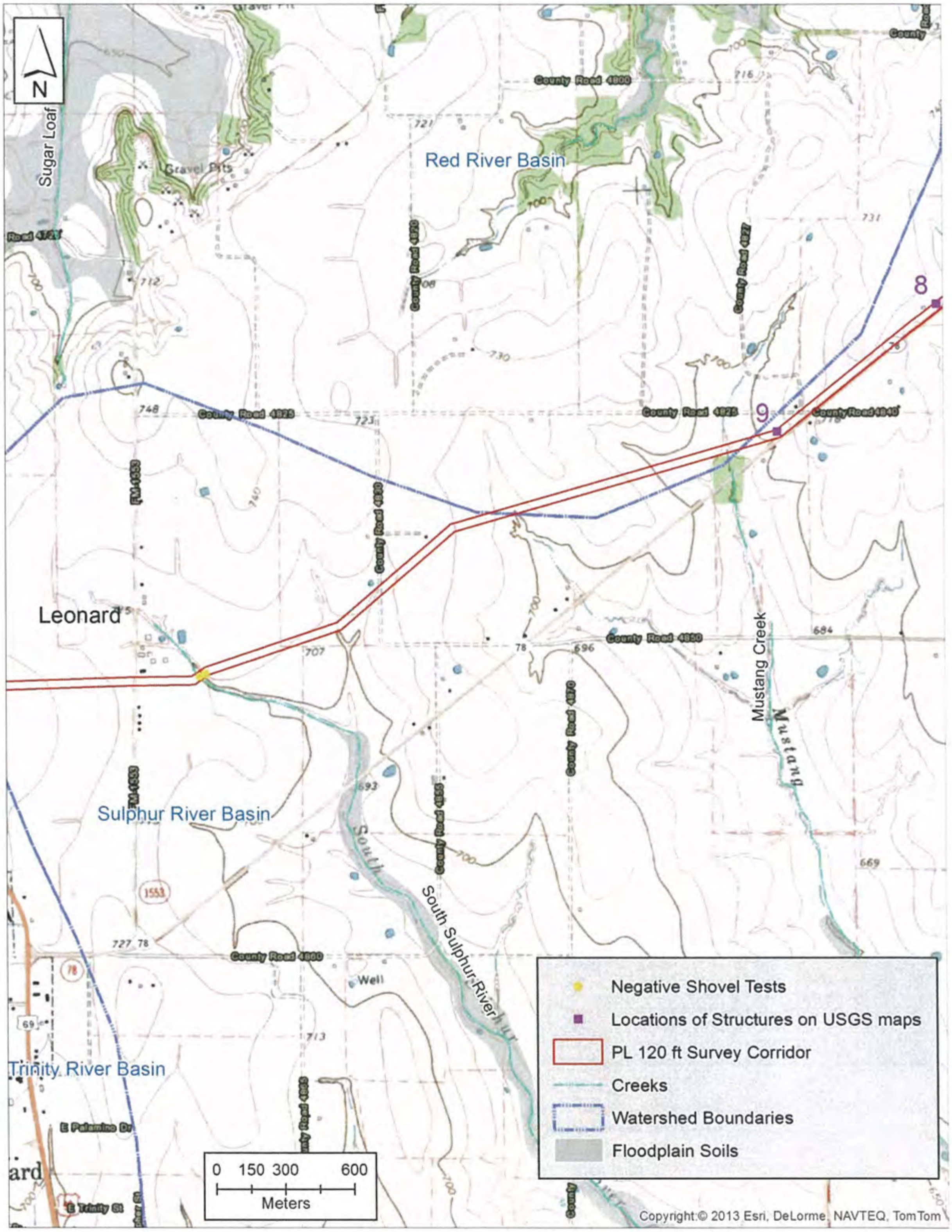


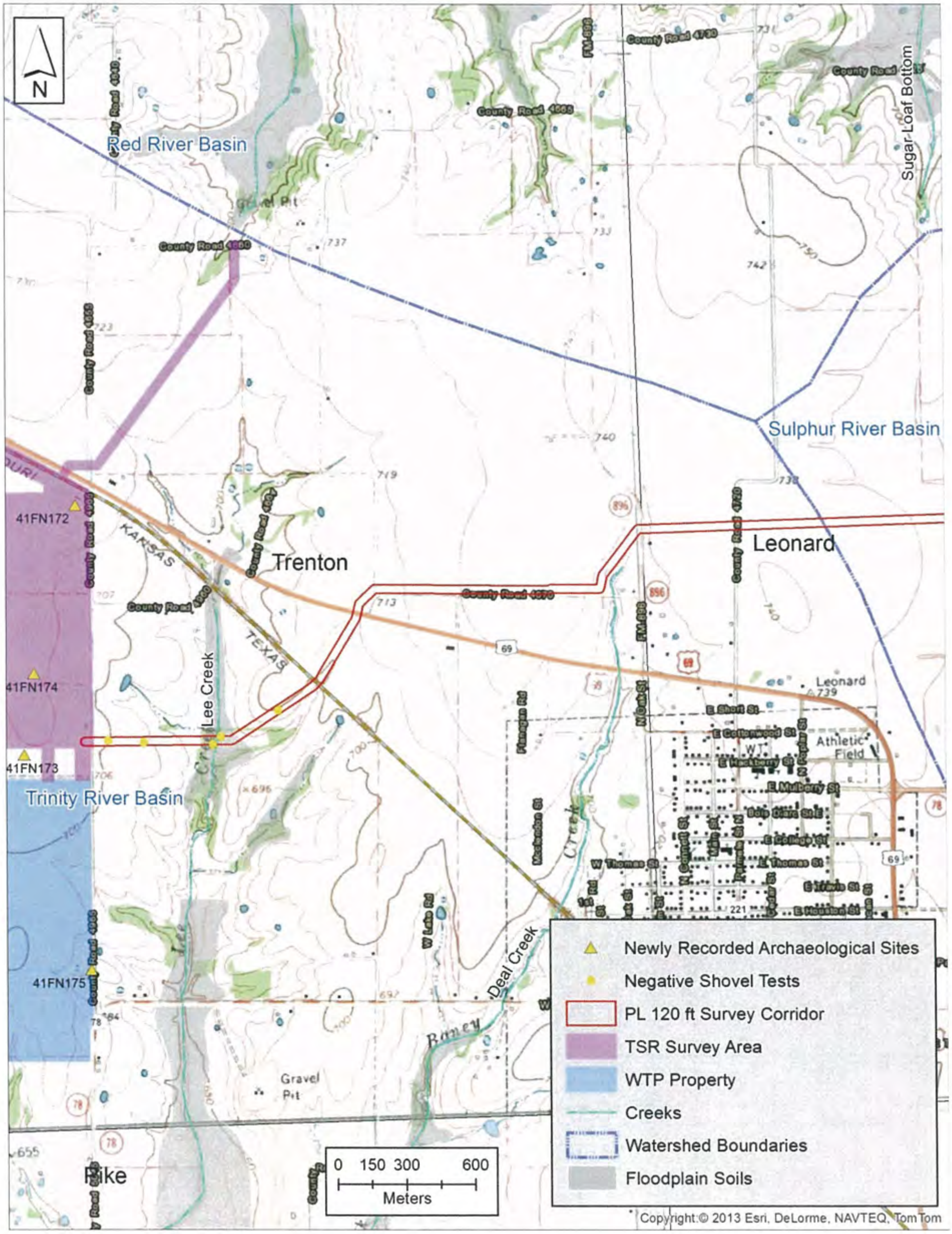
Copyright:© 2013 Esri, DeLorme, NAVTEQ, TomTom

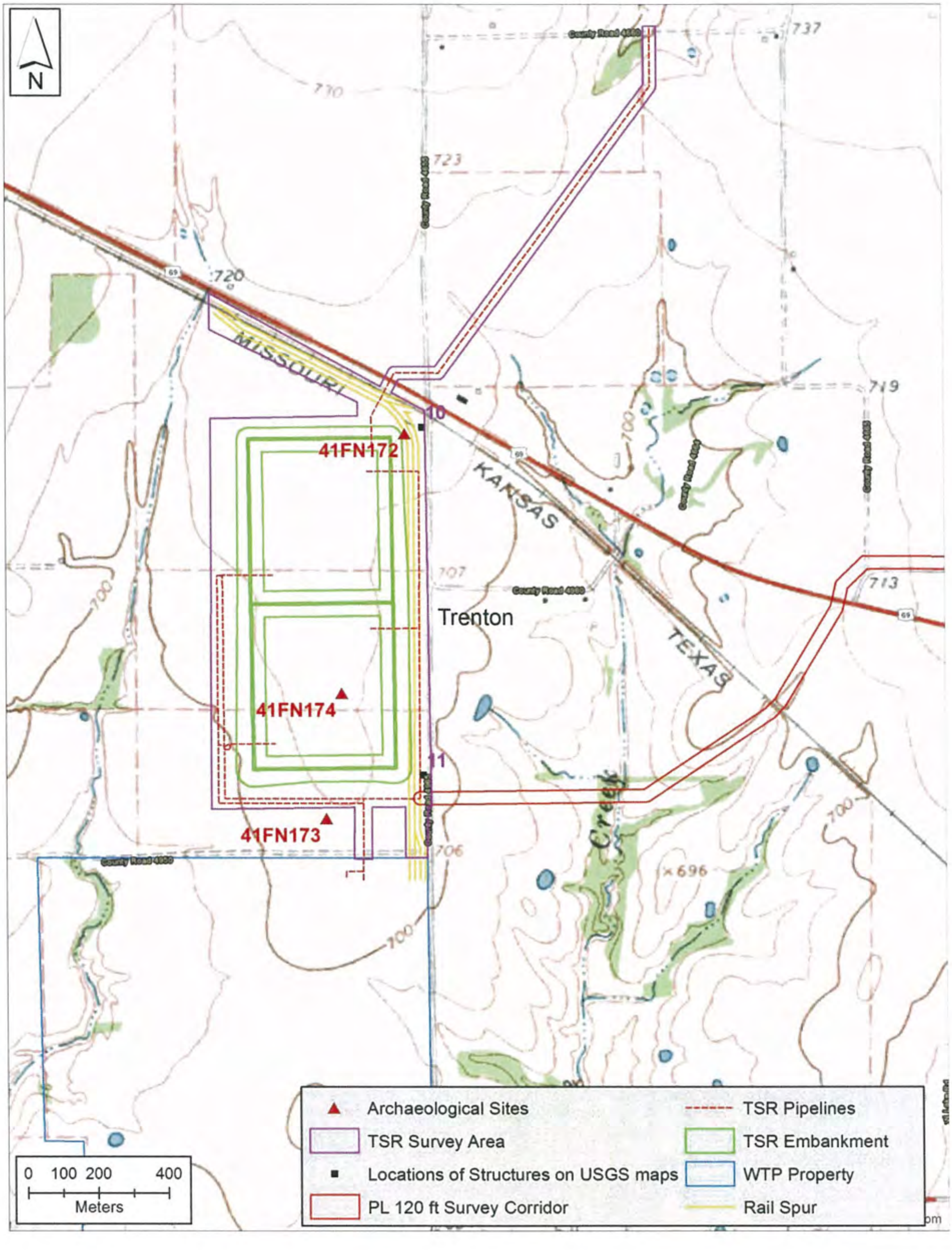

N
Red River Basin
Dodd City
Creek
Sloans Creek
County Road 3040
Gravel Pit
Prairie Point
Clutter Point
Pot Creek
FM 1550
FM 2077
4
5
41FN16
Sulphur R
Gober
0 150 300 600
Meters
Newly Recorded Archaeological Sites
Positive Shovel Test
Negative Shovel Tests
Locations of Structures on USGS maps
PL 120 ft Survey Corridor
Creeks
Watershed Boundaries
Floodplain Soils

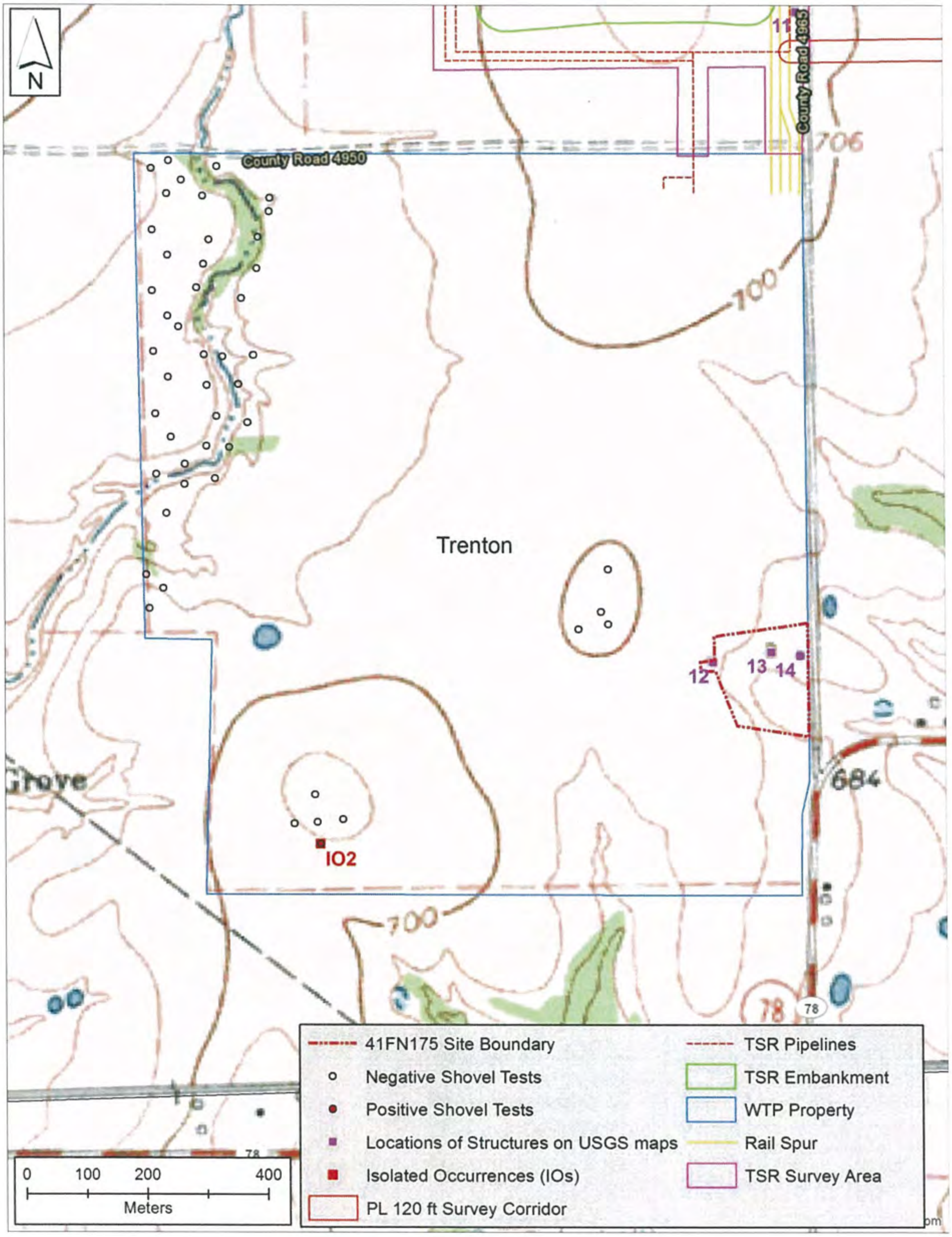

N
Taylor Lake
Davis Creek
Red River Basin
Leonard
Gravel Pit
Gober
Sulphur River Basin
Philadelphia Ch
Quarry
Shawnee Creek
FM-68
FM-3705
County Road 3705
County Road 3130
0 150 300 600
Meters
PL 120 ft Survey Corridor
Creeks
Watershed Boundaries
Floodplain Soils
Copyright:© 2013 Esri, DeLorme, NAVTEQ, TomTom


N
Red River Basin
Sulphur River Basin
County Road 4201
County Road 4204
County Road 4205
FM-1552
County Road 3720
County Road 3800
County Road 3810
County Road 4810
Water Tank
Bailey
Leonard
Simmo St
N Main St
S Bois D Arc St
FM-816
Oates St
11
78
1281
816
6
7
8
41FN170
Bailey
Loring Creek
Creek
713
700
717
719
708
707
720
730
698
692
681
673
702
BR 672
Newly Recorded Archaeological Sites
Positive Shovel Test
Negative Shovel Tests
Locations of Structures on USGS maps
PL 120 ft Survey Corridor
Creeks
Watershed Boundaries
Floodplain Soils
0 150 300 600
Meters
Copyright© 2013 Esri, DeLorme, NAVTEQ, TomTom


N
Red River Basin
Sulphur River Basin
Trinity River Basin
Leonard
Mustang Creek
South Sulphur River
Sugar Loaf
Gravel Pits
County Road 4800
County Road 4825
County Road 4840
County Road 4850
County Road 4860
County Road 4820
County Road 4827
County Road 4830
County Road 4855
County Road 4870
FM 1553
E Palamino Dr
E Trinity St
Well
8
9
Negative Shovel Tests
Locations of Structures on USGS maps
PL 120 ft Survey Corridor
Creeks
Watershed Boundaries
Floodplain Soils
0 150 300 600
Meters
Copyright:© 2013 Esri, DeLorme, NAVTEQ, TomTom


N
Red River Basin
Sulphur River Basin
Trinity River Basin
Sugar-Loaf Bottom
Trenton
Leonard
41FN172
41FN174
41FN173
41FN175
Lee Creek
Deal Creek
Pike
County Road 4670
County Road 4660
Athletic Field
Gravel Pit
Kansas
Texas
Newly Recorded Archaeological Sites
Negative Shovel Tests
PL 120 ft Survey Corridor
TSR Survey Area
WTP Property
Creeks
Watershed Boundaries
Floodplain Soils
0 150 300 600
Meters
Copyright:© 2013 Esri, DeLorme, NAVTEQ, TomTom


N
10
11
41FN172
41FN173
41FN174
Trenton
MISSOURI
KANSAS
TEXAS
Creek
County Road 4000
County Road 4800
69
737
723
720
719
713
707
706
700
696
0 100 200 400
Meters
▲ Archaeological Sites
TSR Survey Area
■ Locations of Structures on USGS maps
PL 120 ft Survey Corridor
TSR Pipelines
TSR Embankment
WTP Property
Rail Spur


N
County Road 4950
County Road 4965
11
706
700
Trenton
12
13
14
Grove
684
IO2
700
78
78
41FN175 Site Boundary
Negative Shovel Tests
Positive Shovel Tests
Locations of Structures on USGS maps
Isolated Occurrences (IOs)
PL 120 ft Survey Corridor
TSR Pipelines
TSR Embankment
WTP Property
Rail Spur
TSR Survey Area
0 100 200 400
Meters

APPENDIX B: DEED AND TITLE RECORDS

Site #: 41FN169

Grantor=Seller	Grantee=Buyer	Date	Vol.	Page	Legal Description
Perez, Elberto and Porfirio	Huerta, Juan A.	2/21/2012	1598	492	A-1130 T. Toby
Williams, Dortha M.	Perez, Elberto and Porfirio	2/23/2209	1418	355	
McCarty, Matthew & Kim	Williams, Dortha M.	12/2/2008	1407	242	
Williams, Dortha M.	McCarty, Matthew & Kim	5/10/2005	1152	192	
Williams, Homer Neal	Williams, Dortha M.	11/29/2004	1123	36	
Williams, Stella Boren/Berniece	Williams, Homer Neal	5/15/1987	694	567	
Williams, Thelma H.	Williams, Stella Boren/Berniece	1/4/1968	500	287	
Williams, George & Maggie	Williams, Thelma H.	10/28/ 1946	W	697	Civil District Court Minutes-Affidavit
Meade, J.E. & Nina	Williams, Mrs. (Maggie) Belle	12/22/1931	214	267	
Meade, G.B. & Mollie	Meade, J.E. & Nina	11/30/ 1927	200	308	
Meade, J.E. & Nina	Meade, G.B. & Mollie	11/26/ 1927	200	290	
Ragsdale, T. W.	Meade, J.E. & G.B.	11/17/ 1910	118	347	

Site #: 41FN170

Grantor=Seller	Grantee=Buyer	Date	Vol.	Page	Legal Description
Perez, Elberto and Porfirio	Huerta, Juan A.	2/21/2012	1598	492	A-1130 T. Toby
Vetran's Land Board, State of Texas	Thacker, Bobby G.	1/24/ 1978	577	321	
Davis, Jerry Lee & Elaine	Vetran's Land Board, State of Texas	1/19/ 1978	577	319	
Bevel, Raymond A. & Pauline	Davis, Jerry Lee	6/24/ 1977	573	118	
McDonald, M.K.	Bevel, Raymond A.	11/26/ 1965	484	454	
Carpenter, G.E. & Elizabeth	McDonald, M.K.	1/20/ 1947	277	372	
Clark, J.F. et al. (Heirs)	Carpenter, G.E.	1/14/ 1943	256	98	
Bowdry, D.J. & R.A.	Clark, A.A.	12/24/1920	171	447	
Tefteller, G.B.	Bowdry, D.J. & R.A.	10/4/1901	82	170	
Texas Loan Agency	Tefteller, G.B.	6/9/ 1887	48	333	

Site #: 41FN171

Grantor=Seller	Grantee=Buyer	Date	Vol.	Page	Legal Description
Lane, John R.	Lane, Thomas Bradley	4/27/ 2010	1487	48	A-0007 H.S. Allen Patent
Lane, R.D.	Lane, John R.	12/28/1946	275	207	
Newsome, J.T.	Lane, R.D.	11/8/ 1928	205	125	
Gibson, J.F. and P.H.	Newsome, J.T.	12/22/ 1909	119	118	
McDonald, J.C.	Cosner, C.D.	6/19/ 1873	Y	343	
Wright, Isom	McDonald, J.C.	6/26/ 1867	Y	342	
Allen, Anna	Wright, Isom	12/17/ 1858	M	416	

Site #: 41FN172

Grantor=Seller	Grantee=Buyer	Date	Vol.	Page	Legal Description
Neale, Mary and Lucy	James, Jimmy Roy	4/18/ 1974	548	648	A-1291 A. Morgan Patent
Neale, Roy and Lucy	Neale, Mary	1/6/ 1917	135	119	

Site #: 41FN173

Grantor=Seller	Grantee=Buyer	Date	Vol.	Page	Legal Description
Norman, Alton and Jack	Norman, Bobby Jack and Texanna	11/30/ 2005	1196	389	A-1388 Dillard L Deal Patent Date March 9, 1888. Pat No. 570, Vol. 6.
Burg, Bryan H. (Trustee of Paul Burg Trust)	Norman, Alton and Jack	5/12/ 1993	781	554	
Burg, John Parker (Trustee of Paul Burg Trust)	Burg, Bryan H. (Trustee of Paul Burg Trust)	12/11/ 1991	762	565	
Lewis, Elgin R. and Cora E.	Burg, John Parker (Trustee of Paul Burg Trust)	3/30/ 1984	643	223	
Shramm, Dale and Lois	Lewis, Elgin R. and Cora E.	11/25/ 1981	613	650	
Davis, Jerry Lee, Murrell T. Lucas and Bill D. Murphy	Shramm, Dale and Lois	12/17/ 1978	587	889	
Stevens, Barbara and Verna Wharton	Davis, Jerry Lee, Murrell T. Lucas and Bill D. Murphy	12/14/1978	584	654	
Wharton, Verna	Stevens, Barbara	11/25/ 1953	554	105	
Blackburn, Meddie Ruth (wife of H.H. Blackburn)	Wharton, Verna	7/7/ 1953	413	154	
Deel, Luther et. Al.	Wharton, Verna	4/2/1953	358	81	
Deel, Mary et. Al.	H.H. Blackburn	2/5/1944	259	607	

Site #: 41FN174

Grantor=Seller	Grantee=Buyer	Date	Vol.	Page	Legal Description
Andrew, Sid and Jimmy Page	Hendrix, Charles and Cynthia	9/9/ 2011	1573	275	A-0246 H. Cummings Patent
Lund and Livestock Trust	Andrew, Sid and Jimmy Page	6/14/ 2010	1496	50	
Property becomes a trust		10/13/ 1993	788	228	
Gaskill, Lewis and Betty	Crain, Joe Donals and Windell	4/17/ 1985	658	240	
Veterans Land Board	Gaskill, Lewis and Betty	5/27/ 1985	659	232	
Sims, W.F. and Erah Lee	Veterans Land Board	1/1/ 1955	375	330	
Sims, T.F. et. ux.	Sims, W.F and Erah Lee	6/22/ 1932	216	98	
Pigg, A.H. and Lillian	Sims, T.F. et. ux.	12/9/ 1912	130	99	
Pigg, Tom	Pigg, A.H.	10/7/ 1907	113	507	
Pigg, J.N.	Pigg, Tom	4/20/ 1903	94	161	

Site #: 41FN175

Grantor=Seller	Grantee=Buyer	Date	Vol.	Page	Legal Description
North Texas Aggregate Acquisitions	NTMWD	4/1/2009	1424	99	A-670 L. Leonard - Parcel #79106
Spurgin, Donald M.	North Texas Aggregate Acquisitions	3/27/2009	1424	84	
Sikes, Richard	Spurgin, Donald M. & Gracie	7/15/1993	783	1041	
Davis, Jerry Lee & Elaine	Sikes, Richard	5/14/1973	541	151	
Davis, Cara D.	Davis, Jerry Lee & Elaine	3/22/1973	539	349	
Davis, Leona Mae (Estate of J.D. Davis)	Davis, Cara D.	12/23/1972	536	763	
Bankers Life Company	Davis, J.D.	12/5/1939	242	666	
Hall, Bess D. (Widow of W.P. Hall)	Fowler, G. W. (V.P. of Bankers Life Company)	9/1/1926	?	630	This deed was referenced in above two deeds, but volume was listed as #27, but that is wrong when this deed was pulled, It dated to the 1880s, the real Vol. is likely in the 200s, but I pulled several like 207 and 227, but they were not the ones either, error on the county's part.
Leonard, W. H.	Hall, Willard P.	4/22/1903	92	363	

TECHNICAL MEMORANDUM 4

Local Jurisdictional Issues

PREPARED FOR: North Texas Municipal Water District

PREPARED BY: CH2M HILL
Released for the purposes of review by Edward Motley,
PE Number 48243 on September 14, 2015

Introduction

The proposed Leonard Water Treatment Plant (WTP) will be located in Fannin County west of and outside the incorporated area of Leonard, Texas (see Figure 1).

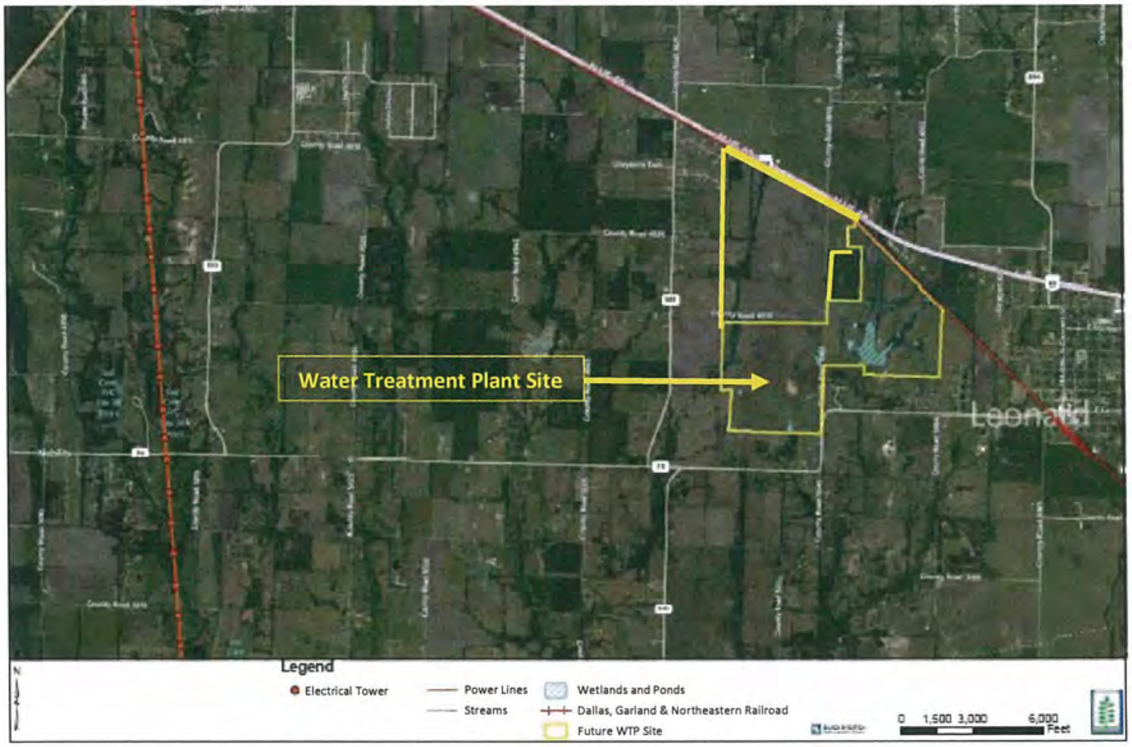


Figure 1. Site Location Map

Current Jurisdiction

Municipal Zoning and Building Codes

North Texas Municipal Water District (NTMWD) and CH2M HILL staff met with the City of Leonard staff on June 6, 2015, to determine the extent of Leonard's jurisdiction over the proposed WTP site. City staff indicated that the proposed WTP site is not within the city limits of Leonard but is within the city's extra-territorial jurisdiction.

Because the plant site is outside the city limits, Leonard has no jurisdiction over zoning or the enforcement of building codes. If the plant site were annexed into the city, Leonard's zoning ordinances and building codes will apply. The city currently recognizes International Building Code (IBC) 9 as its building code.

Future Jurisdiction

NTMWD has the option of requesting that the City of Leonard annex the WTP site into its city limits. Annexation will offer some benefits to NTMWD, but will include costs for utility extensions and will expand the city's jurisdiction over the site.

Municipal Zoning and Building Codes

If the site is annexed into the City of Leonard, the city's zoning and building codes will apply.

Under the city's current zoning ordinance, any of the following zonings will be compatible with NTMWD's desired use of the site:

- B1 – General Business
- I1 – Manufacturing / Industrial – Light
- I2 – Manufacturing / Industrial – Heavy

All three of these zoning classifications allow the following uses that are pertinent to NTMWD's intended use for the site:

- WTP
- Water storage, ground
- Water storage, elevated
- Water pumping station or well
- Sewerage pump station
- Service yards of government agencies
- Railroad track and right-of-way (ROW)
- Railroad team track and ROW
- Electrical substation
- Electrical transmission line

Alternatively, NTMWD can request that the site be zoned under a planned development ordinance. Such an ordinance would codify the exact uses and site development requirements.

The requirements for I1 and I2 zoning are essentially the same in terms of restrictions, but B1 is slightly more restrictive. The I1 and I2 zoning allows the following:

- No minimum lot area (the plant site is over 300 acres, so this should not be an issue)
- Minimum lot width, 50 feet (not an issue for the plant site)
- Minimum lot depth, 80 feet (not an issue for the plant site)
- Minimum front setback, 25 feet; 50 feet if abutting residential or commercial (not an issue at the plant site, ample room for 50-foot setback)
- Minimum side yard setback:
  - I1 – no setback unless adjoining residential or commercial, then 25 feet with a 6-foot wooden or masonry wall at the property line
  - I2 – same as I1 except 50-foot setback if adjoining residential or commercial (not an issue at the plant site, ample room for 50-foot setback)

- Minimum rear setback, no setback unless adjoining residential or commercial, then 50 feet with a 6-foot wooden or masonry wall at the property line (not an issue at the plant site, ample room for 50-foot setback)
- Building height, 45 feet, except may be as much as 80 feet provided yard setbacks are 1 vertical foot per 2 horizontal feet for height above 45 feet (70 feet for an 80-foot-high building; not an issue at the plant site, ample room for 70-foot setback)
- Noise, sound levels at the property line shall not exceed 75 A-weighted decibels

The requirements for a planned development would be as specified in the negotiated planned development ordinance. A planned development zoning requires the development of a site development plan that specifies the future development of the site in terms of what facilities will be built, their location, and the architectural features. The city council will have to approve any changes to the planned development ordinance should NTMWD's plans for the site development change in the future. Minor changes can be approved by the building official.

The benefit of the planned development is that it codifies the plan for the site and reduces the potential for a future city council to impose more stringent restrictions, but a planned development will make changing the development plan in the future subject to a city council action.

If the plant site is annexed into the city limits, all facilities will be required to comply with the city's building codes, which are IBC 9. CH2M HILL has recommended that NTMWD use IBC 12 as a building code. City officials have indicated that they will accept IBC 12.

Annexation Process

NTMWD will have to apply to the City of Leonard for annexation of the plant site. Because the plant site is not contiguous with the current city limits, a corridor connecting the site to the current city limits will have to be identified. That corridor can potentially follow a highway ROW or be through a bridging property owned by another landowner willing to be annexed.

Once the city receives the application, the council will consider the request and either approve or deny it. If the council approves the annexation, they will also concurrently determine the zoning for the annexed property.

Recommended Path Forward

It is recommended that NTMWD initiate further discussions with the City of Leonard relative to the following:

- Process, timing, and potential costs of annexation of NTMWD property into the Leonard city limits
- Available capacity, costs, and potential mutual benefits that will determine the viability of extension of city water and sanitary sewer service to the site

TECHNICAL MEMORANDUM 5

Emergency Services

PREPARED FOR:	North Texas Municipal Water District
PREPARED BY:	CH2M HILL Released for the purposes of review by Edward Motley, PE Number 48243 on September 14, 2015

Introduction

The proposed Leonard Water Treatment Plant (WTP) will be located in Fannin County, Texas, approximately 1.5 miles west of Leonard and 20 miles southwest of the county seat of Bonham (see Figure 1).

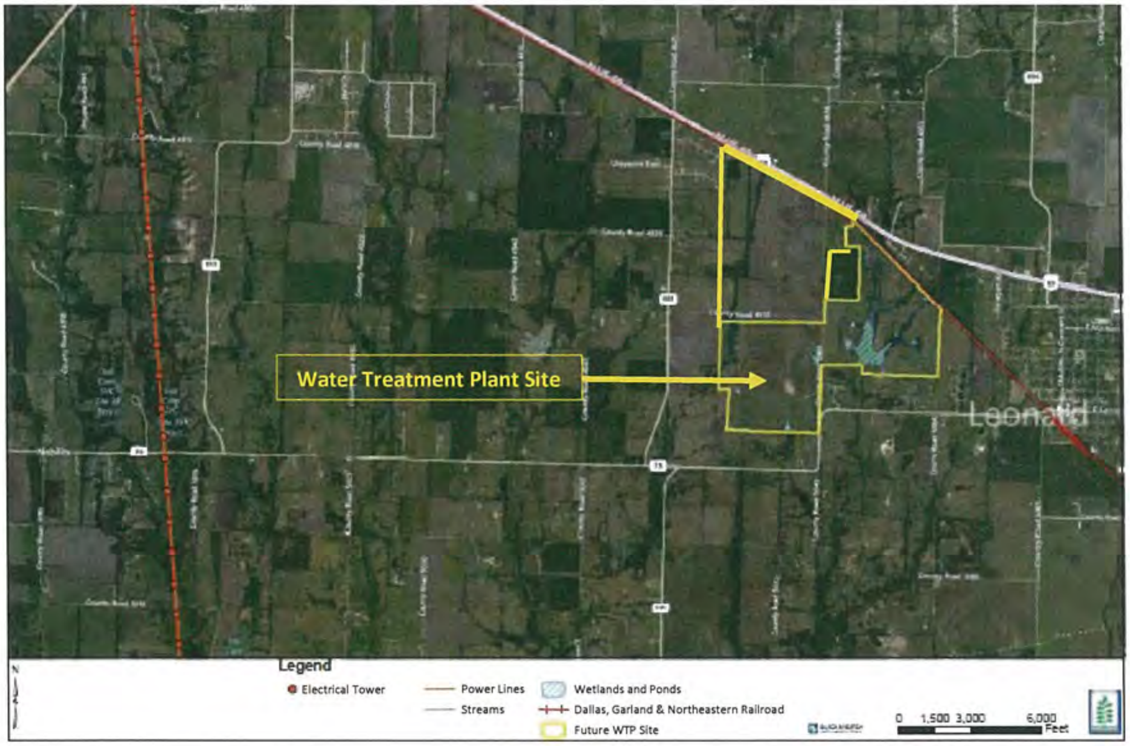


Figure 1. Site Location Map

Current Emergency Services Jurisdictions and Capabilities

The WTP site will require emergency services, law enforcement, fire protection, and medical response, both during construction and during operations. These services are currently provided by various governmental agencies.

Law Enforcement

Law enforcement first response for the WTP site is currently provided by Fannin County Sherriff's Office located in Bonham, approximately 20 miles away. Leonard can only provide first responder law enforcement if the plant site were to be annexed into the city. Annexation is discussed further in the recommendations section.

Leonard has limited law enforcement coverage with two officers on duty during day hours and one officer during nights until midnight. After midnight, officers are on call with a planned 20-minute response time.

Fire and Medical Response

Leonard Fire Department will be the first responder to the plant for fire and medical emergencies. Leonard units are also supported by Fannin County units located in Bonham. The Leonard Fire Department is less than 2 miles from the site and claims their response time can be 5 minutes.

Leonard Fire Department capabilities and equipment are as follows:

- Basic first aid
- Two mini pumpers (500-gallon capacity)
- One engine (1,000-gallon capacity)
- One rescue unit with medical and 500 gallons of water

Future Emergency Service Needs

Construction-Phase Emergency Services

Security and Law Enforcement

Since the WTP site will not be continuously manned during construction, theft and vandalism of construction equipment and materials will be a significant threat. The WTP site will need to have a robust security plan to prevent excessive loss from theft and vandalism. Neither the Fannin County Sherriff nor the Leonard Police Department can provide the level of security needed to protect the construction site. A contract security staff is recommended to maintain a secure perimeter around the construction site, and then law enforcement should be called if the perimeter is breached.

Fire and Medical Response

The nature of construction work creates a threat for either fire or emergency medical response needs during the construction period. The Leonard Fire Department should be capable of responding to and managing typical construction-magnitude fire events at the WTP during the construction phase. A robust site emergency response plan will be needed to detect, report, and contain any fire emergency long enough for the fire department to mobilize.

Given the response times for emergency medical services, the emergency response plan should also include a plan to handle medical emergencies with trained onsite personnel. These onsite first responders need to be trained to stabilize the patient until Leonard and then Bonham responders arrive.

Operational-Phase Emergency Services

Security and Law Enforcement

Once the WTP begins operations, it will likely be continuously manned, either with operations staff or at least with full-time security staff; but given the rural nature of the site, the security plan must be more robust than that for facilities in a more urban environment with a large law enforcement presence. Like the construction-phase security services, the role of plant security is to monitor a secure perimeter and then call on law enforcement if the perimeter is breached.

Fire and Medical Response

The first responders for fire will be the Leonard Fire Department, but the WTP will have some hazards that are unique and probably beyond the training and capabilities of the Leonard Fire Department and perhaps the Fannin County Fire Department. Fire responders trained for specific WTP chemical hazards could be as much as an hour away. Of particular concern are the storage chemicals, both liquid and compressed gases. Therefore, the WTP will need a robust emergency response plan and a staff trained to respond to chemical emergencies to provide sufficient containment until capable responders can mobilize.

First responders for medical emergencies will also be the Leonard Fire Department supported by ambulance service from Bonham Fire Department. Given the response time for emergency medical first responders, the WTP will need an emergency response plan that addresses the extended response times and a staff trained to respond to medical emergencies to stabilize patients until capable responders can mobilize.

Recommendations and Path Forward

It is recommended that North Texas Municipal Water District perform the following:

- Continue discussions with the City of Leonard to better understand the benefits and costs of annexation relative to emergency services and utility services. Of particular interest is the benefit of quicker first response to law enforcement needs.
- Develop robust emergency response and security plans for the construction phase of the Leonard WTP. Such plans and their execution can be a part of the construction manager at risk (CMAR) scope of services.
- Develop robust emergency response and security plans for the operation phase of the Leonard WTP.

TECHNICAL MEMORANDUM 6

Offsite Utilities

PREPARED FOR: North Texas Municipal Water District

PREPARED BY: CH2M HILL
Released for the purposes of review by Edward Motley,
PE Number 48243 on September 14, 2015

Introduction

The proposed Leonard Water Treatment Plant (WTP) will be located approximately 1.5 miles west of Leonard, Texas (see Figure 1).

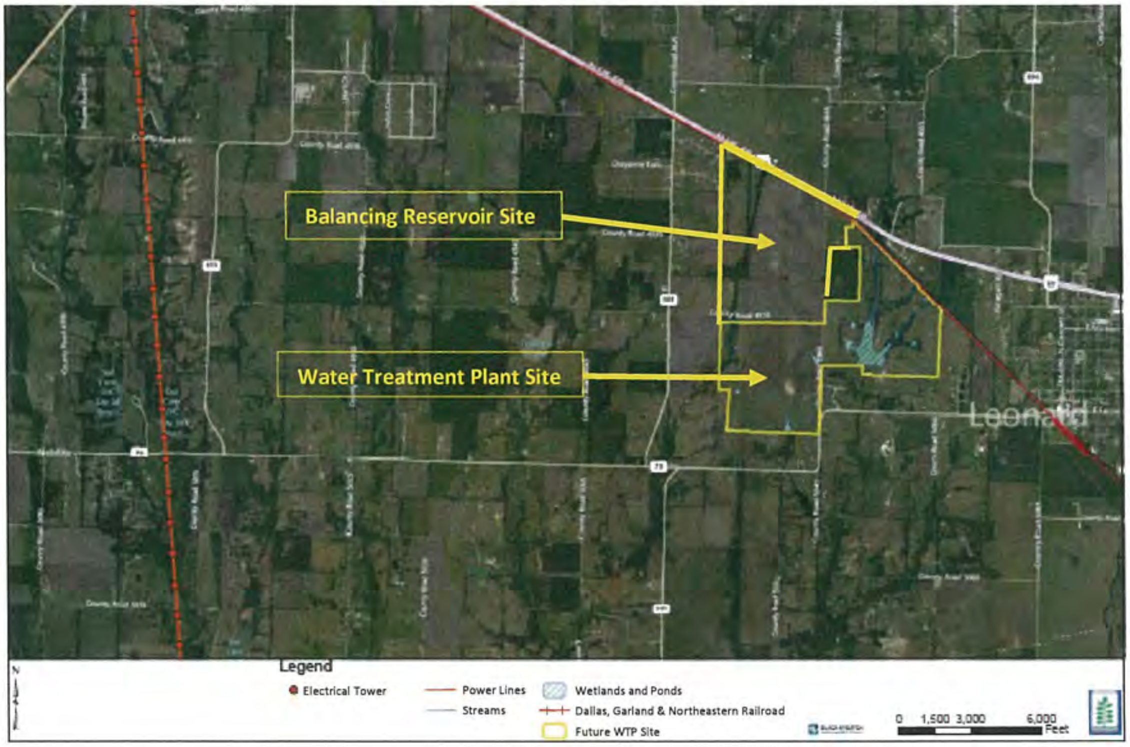


Figure 1. Site Location Map

Water Supply

Existing Conditions and Alternatives

The proposed WTP will require an external water supply for construction, and it is also recommended that North Texas Municipal Water District (NTMWD) maintain the external water connection as a backup supply to meet plant domestic and fire protection needs during periods when the plant may be shut down. Ideally, such a supplemental supply will be capable of delivering a sustained daily volume that will meet the domestic needs for the plant and a peak fire flow volume.

West Leonard Water Supply Corporation (WLWSC) holds the Certificate of Convenience and Necessity for water supply to the WTP site. WLWSC will likely have to extend a 6-inch-diameter line to provide service with capacity to meet domestic needs only. WLWSC does not have sufficient storage capacity to provide fire service. NTMWD could connect to WLWSC for domestic supply and provide its own onsite storage and pumping for fire protection.

Alternatively, if the site were to be annexed into the City of Leonard, the city could extend water service to the plant site and, under an interlocal agreement with WLWSC, provide sufficient storage and flow capacity for both domestic needs and basic fire protection. Supplemental onsite storage and pumping for fire protection might still be needed, depending on projected onsite demands. The cost to NTMWD to extend water service from Leonard to the site has not been determined.

The third alternative is for NTMWD to drill its own well to supply domestic needs and construct sufficient storage volume and pumping to provide independent onsite fire protection.

Recommendations and Path Forward

It is recommended that NTMWD continue discussions with WLWSC and the City of Leonard to quantify the costs, advantages, and disadvantages of providing domestic and fire protection water supply to the WTP site considering the following alternatives:

1. Secure domestic supply from WLWSC and provide onsite fire storage and pumping.
2. Annex the site into the City of Leonard, and through an interlocal agreement secure domestic and fire protection water supply from the City of Leonard.
3. Construct an onsite well and provide onsite storage and pumping for an independent domestic water supply and fire protection system.

Sanitary Sewer

Existing Conditions and Alternatives

The site does not currently have sanitary sewer service. NTMWD can install an onsite waste system to provide domestic sanitary sewer service. The waste system will likely be a basic treatment system with a zero discharge land application disposal system. Process water must be managed separately from domestic waste because the volumes from process waste streams (sample drains, chemical area drains, and basin blowdown drains) will overload a septic system.

If the site is annexed into the City of Leonard, the city could extend and provide sanitary sewer service to the site. A small dedicated onsite lift station will likely be required to serve the WTP site.

Recommendations and Path Forward

It is recommended that NTMWD continue discussions with the City of Leonard to quantify the costs, advantages, and disadvantages of providing municipal sanitary sewer service to the WTP site considering the following alternatives:

1. Annex the site into the City of Leonard, and obtain sanitary sewer service from the City of Leonard.
2. Construct an onsite waste disposal system.

TECHNICAL MEMORANDUM 7

Railroad Coordination and Requirements

PREPARED FOR:	North Texas Municipal Water District
PREPARED BY:	CH2M HILL Released for the purposes of review by Edward Motley, PE Number 48243 on September 14, 2015

Introduction

The proposed Leonard Water Treatment Plant (WTP) will be located approximately 1.5 miles west of Leonard, Texas. The proposed plant will use chlorination as a backup disinfection process and chlorination as a secondary disinfection process to maintain a disinfectant residual in the water transmission and distribution system. Both of these processes require significant quantities of chlorine. One potentially cost-effective source for such quantities of chlorine is compressed chlorine gas delivered in railcars carrying up to 90 tons of product. North Texas Municipal Water District's (NTMWD's) existing Wylie WTPs and several other WTPs in North Texas use chlorine delivered in railcars.

This technical memorandum discusses the availability of railroad access to the Leonard WTP site. Also, requirements to connect to the rail facilities and obtain chlorine deliveries by rail are discussed.

Leonard Water Treatment Plant Access to Railcar Delivery

The northern portion of NTMWD's property for the Leonard facilities fronts on the Dallas, Garland & Northeastern Railroad (DGNO) running adjacent to State Road 69 just northwest of Leonard. The WTP portion of the site is located approximately 1 mile south of this section of DGNO's tracks. Figure 1 illustrates the location of the plant site and DGNO. DGNO offers the closest access to railroad facilities for the Leonard WTP site.

Railroad Requirements

DGNO is operated by Genesee and Wyoming Railroad (GWRR). Connection to GWRR (DGNO) facilities will require execution of a modified Industry Track Agreement (ITA); modification to the standard GWRR ITA is required because of the hazardous cargo. Initially, GWRR can provide a standard ITA for review while the agreement modifications are being determined.

Construction Requirements

The design of the onsite railroad facilities must follow American Railway Engineering and Maintenance-of-Way Association (AREMA) and Federal Railroad Administration (FRA) requirements and recommendations. DGNO/GWRR does not have specific written design standards for private tracks. A private contractor can install NTMWD's track work, but work within the DGNO/GWRR right-of-way must be done by a DGNO/GWRR-approved contractor and under the observation and supervision of a DGNO/GWRR representative. DGNO/GWRR can share their list of approved contractors.

Figure 1. Site Location Map

Operational Requirements

DGNO/GWRR must spot the chlorine cars inside of a secured area (such as, security fence with locked gate). Hazardous material cars cannot be spotted in an unsecured area. DGNO/GWRR can spot the cars inside of the chlorine building or between the building and the gate on NTMWD property, whichever NTMWD prefers.

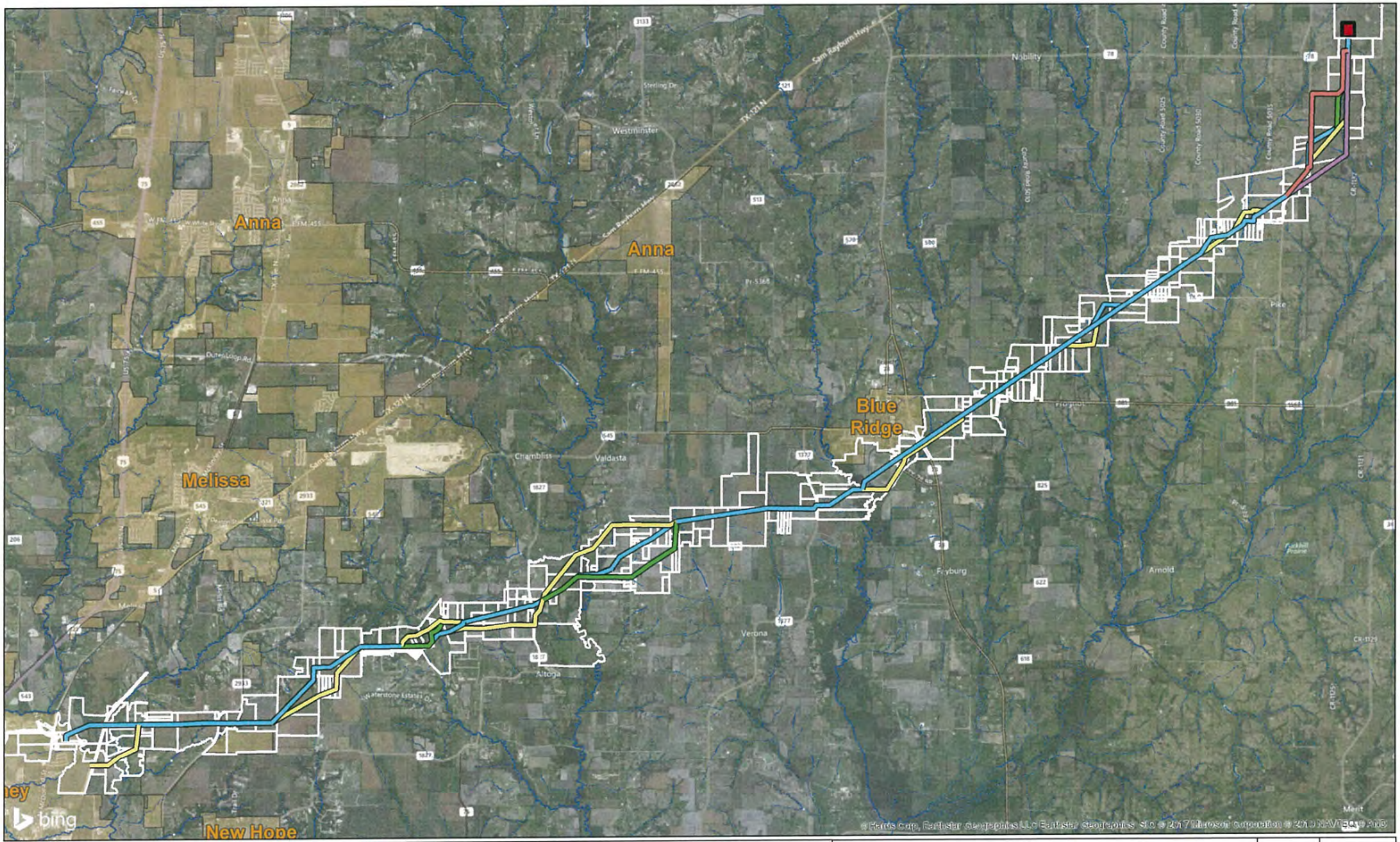
DGNO/GWRR recommends that the gate and building be "double locked," meaning two padlocks (one with a DGNO key and the other with a NTMWD key) having their shackles linked together. In this way, DGNO can deliver the cars day or night with or without NTMWD personnel present. The chlorine cars will first arrive at the DGNO rail yard in the Dallas area. Because this is a heavily populated area and the cargo is a hazardous material, DGNO will want to move the cars from their yard to the NTMWD site as soon as possible to minimize risk. This could occur on a weekend, holiday, or in the middle of the night; and train schedules can be unpredictable at times.

A track siding adjacent to the DGNO main line will not be required. The only requirement on the DGNO right-of-way is a single turnout coming off of the DGNO/GWRR track.

Other Considerations

The existing DGNO route to the proposed NTMWD site has not been approved for hazardous cargo such as chlorine. Some track upgrades (capital improvements) would be necessary because the track needs to be in better condition than average to minimize the risk of derailment with hazardous cargo. The existing rail bridges on that route are rated for 263,000-pound cars, and 90-ton chlorine cars can weigh up to 286,000 pounds. Smaller-capacity cars could be considered if available, or some upgrades to bridges could also be necessary. Tracks carrying hazardous cargo require more frequent inspection and maintenance to meet FRA requirements. Additional tariff charges will likely need to be assessed to NTMWD so that DGNO/GWRR can recoup any capital improvement investment and increased inspection and maintenance costs.

DGNO does not usually handle TIH/PIH (Toxic Inhalation Hazard/Poison Inhalation Hazard), which adds complexity. DGNO/GWRR will continue to study the project and assess what needs are to be addressed and what costs will be incurred.



FNI PROJECT: NTD14624
FILE: TWPL Alignment CEL.mxd
COORDINATE SYSTEM: NAD83 STATE PLANE TX NORTH CENTRAL (FEET)
DATE: 4/10/2017
PREPARED BY: CEL

Document Path: H:\PIPES_PUMPS\Working\TWPL Alignment CEL.mxd

FREESE NICHOLS
2711 N. Haskell Avenue
Suite 3300
Dallas, TX 75204
Phone - (214) 217-2200

NORTH TEXAS MUNICIPAL WATER DISTRICT

Leonard WTP to McKinney No. 4 Treated Water Pipeline Proposed Corridor Map

0 12,500 25,000 Feet

N

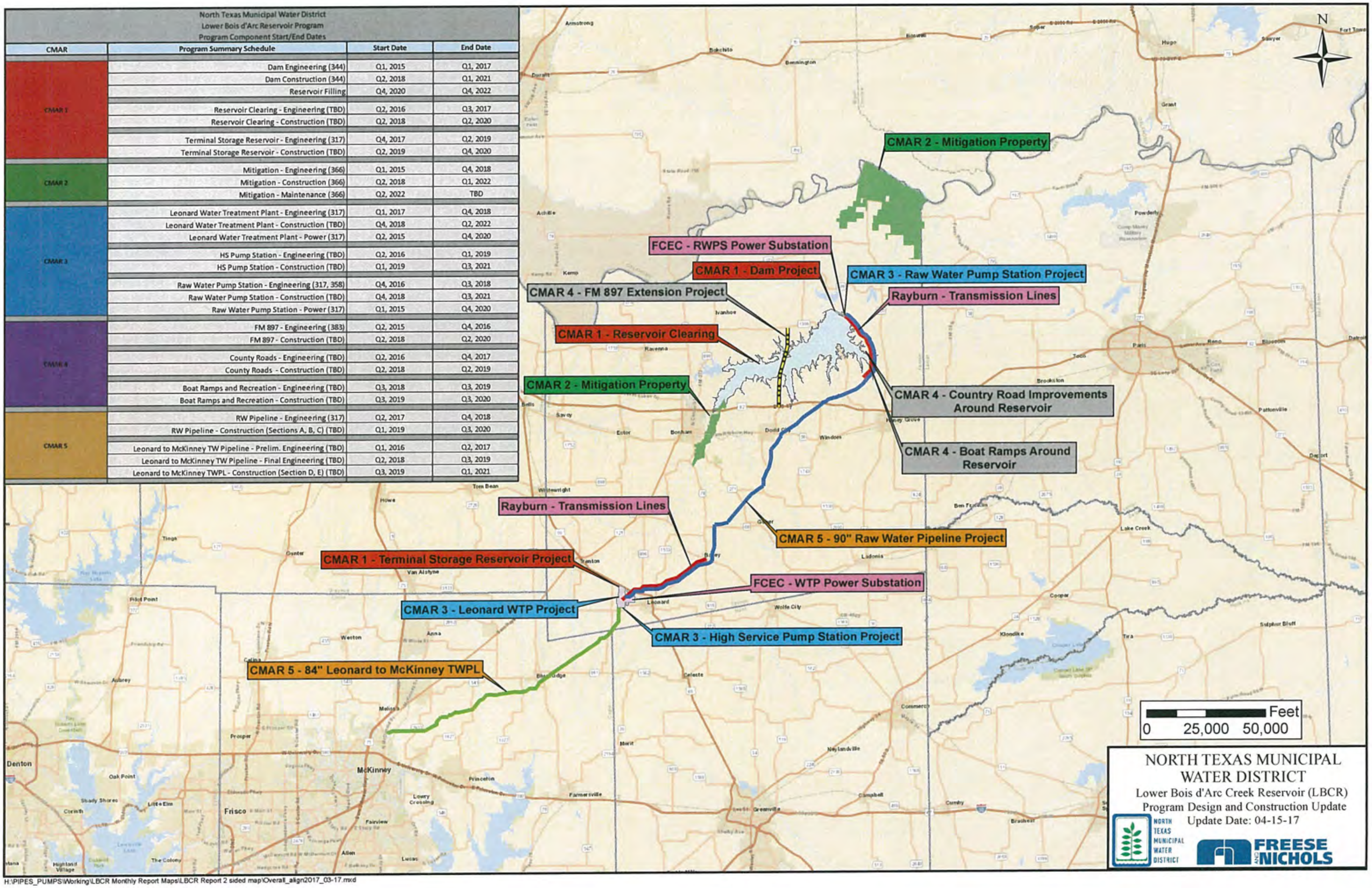
Attachment
1

Date Saved: 3/30/2017 1:32:22 PM

56. Project Location. **Please see the submitted file titled "LBCR Project Location Map.PDF" for an overall project location map.**

North Texas Municipal Water District
Lower Bois d'Arc Reservoir Program
Program Component Start/End Dates

CMAR	Program Summary Schedule	Start Date	End Date
CMAR 1	Dam Engineering (344)	Q1, 2015	Q1, 2017
	Dam Construction (344)	Q2, 2018	Q1, 2021
	Reservoir Filling	Q4, 2020	Q4, 2022
	Reservoir Clearing - Engineering (TBD)	Q2, 2016	Q3, 2017
	Reservoir Clearing - Construction (TBD)	Q2, 2018	Q2, 2020
	Terminal Storage Reservoir - Engineering (317)	Q4, 2017	Q2, 2019
	Terminal Storage Reservoir - Construction (TBD)	Q2, 2019	Q4, 2020
CMAR 2	Mitigation - Engineering (366)	Q1, 2015	Q4, 2018
	Mitigation - Construction (366)	Q2, 2018	Q1, 2022
	Mitigation - Maintenance (366)	Q2, 2022	TBD
CMAR 3	Leonard Water Treatment Plant - Engineering (317)	Q1, 2017	Q4, 2018
	Leonard Water Treatment Plant - Construction (TBD)	Q4, 2018	Q2, 2022
	Leonard Water Treatment Plant - Power (317)	Q2, 2015	Q4, 2020
	HS Pump Station - Engineering (TBD)	Q2, 2016	Q1, 2019
	HS Pump Station - Construction (TBD)	Q1, 2019	Q3, 2021
	Raw Water Pump Station - Engineering (317, 358)	Q4, 2016	Q3, 2018
	Raw Water Pump Station - Construction (TBD)	Q4, 2018	Q3, 2021
	Raw Water Pump Station - Power (317)	Q1, 2015	Q4, 2020
CMAR 4	FM 897 - Engineering (383)	Q2, 2015	Q4, 2016
	FM 897 - Construction (TBD)	Q2, 2018	Q2, 2020
	County Roads - Engineering (TBD)	Q2, 2016	Q4, 2017
	County Roads - Construction (TBD)	Q2, 2018	Q2, 2019
	Boat Ramps and Recreation - Engineering (TBD)	Q3, 2018	Q3, 2019
	Boat Ramps and Recreation - Construction (TBD)	Q3, 2019	Q3, 2020
CMAR 5	RW Pipeline - Engineering (317)	Q2, 2017	Q4, 2018
	RW Pipeline - Construction (Sections A, B, C) (TBD)	Q1, 2019	Q3, 2020
	Leonard to McKinney TW Pipeline - Prelim. Engineering (TBD)	Q1, 2016	Q2, 2017
	Leonard to McKinney TW Pipeline - Final Engineering (TBD)	Q2, 2018	Q3, 2019
	Leonard to McKinney TWPL - Construction (Section D, E) (TBD)	Q3, 2019	Q1, 2021



NORTH TEXAS MUNICIPAL WATER DISTRICT
Lower Bois d'Arc Creek Reservoir (LBCR)
Program Design and Construction Update
Update Date: 04-15-17

NORTH TEXAS MUNICIPAL WATER DISTRICT
FREESE AND NICHOLS

H:\PIPES_PUMPS\Working\LBCR Monthly Report Maps\LBCR Report 2 sided map\Overall_align2017_03-17.mxd

57. Attach census tract numbers in which the applicant's service area is within.

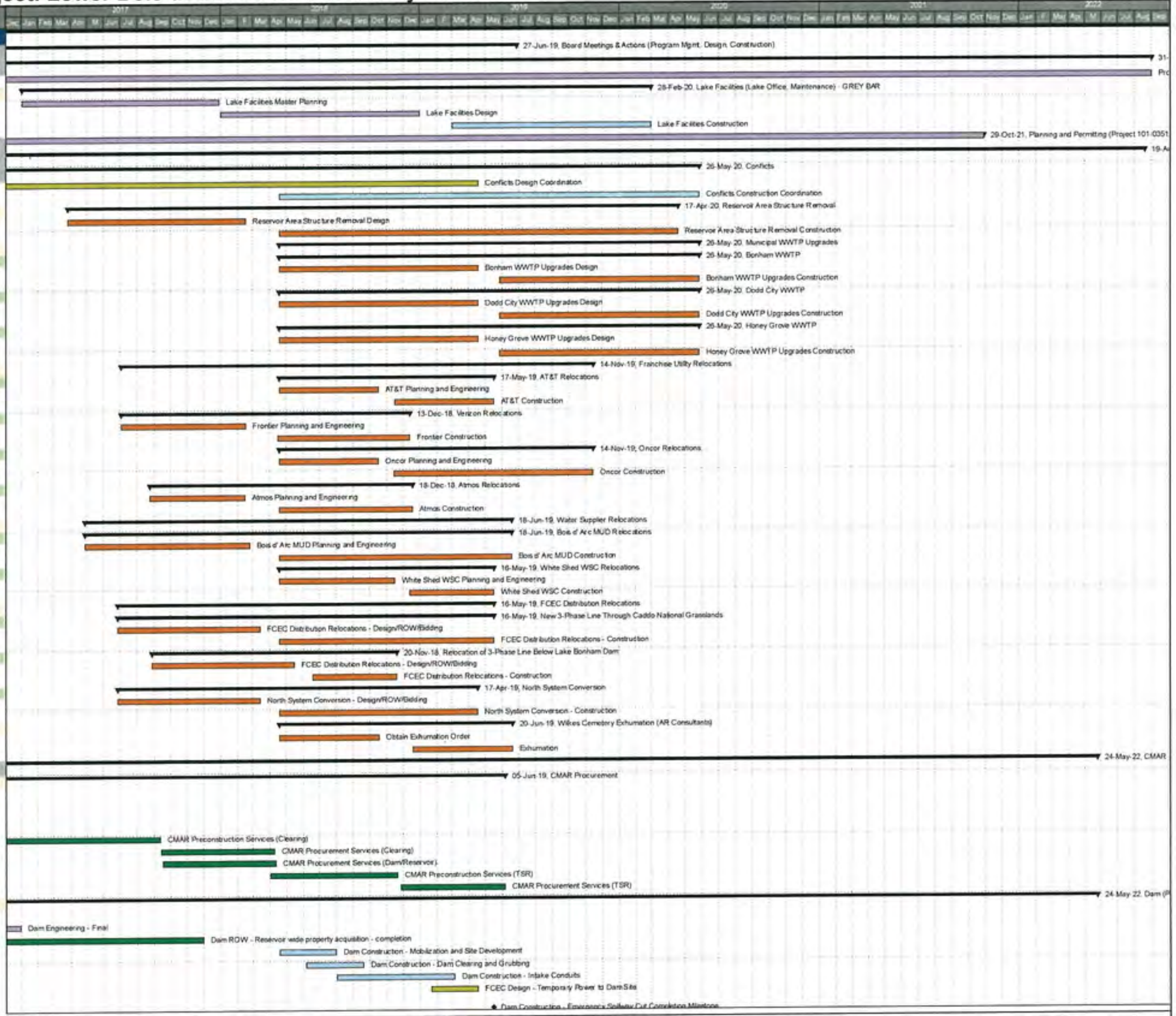
- **Census Tract Numbers – 9504.02, 9505, 9508, 9507.02, 9506, 9504.01, 9503, 216.32, 216.28, 216.27, 216.25, 215.19, 216.26, 216.29, 215.17, 215.18, 215.20, 215.21, 215.18, 215.15, 218, 215.24, 215.22, 219, 215.25, 291.05, 201.09, 201.08, 201.10, 201.11, 201.12, 201.13, 201.14, 215.26, 215.27, 181.42, 181.41, 181.35, 181.37, 181.18, 181.36, 181.34, 181.33, 181.39, 181.40, 181.24, 181.22, 401.02, 402, 404.02, 404.01, 403.02, 401.01, 403.01, 405.03, 405.05, 405.04, 405.06, 502.01, 502.05, 502.04, 503, 504, 505, 506, 507.04, 507.01, 502.03, 502.06, 507.01, 510, 511, 508, 512.02, 512.01, 507.03, 9504, 9603, 9614, 9615.01, 9615.02, 9615.03, 9607, 9611, 9613, 9612, 9609, 9610, 9608, 9502, 9501, 317.08, 317.17, 317.15, 316.49, 316.47, 316.48, 316.45, 316.46, 316.56, 316.58, 317.18, 317.20, 317.19, 317.09, 316.21, 316.55, 316.54, 316.53, 316.52, 316.64, 316.37, 316.36, 316.12, 316.13, 316.43, 316.42, 316.25, 316.27, 316.24, 316.26, 318.07, 318.06, 318.04, 318.05, 318.02, 319, 316.23, 320.03, 320.04, 320.12, 320.08, 316.22, 316.29, 316.28, 316.11, 320.13, 316.35, 316.34, 316.33, 316.31, 316.30, 316.32, 314.09, 314.11, 313.12, 313.16, 313.17, 313.13, 313.15, 313.14, 313.08, 313.09, 313.11, 313.10, 312.02, 312.01, 311, 310.04, 310.01, 310.03, 314.07, 314.08, 314.10, 315.04, 314.06, 309, 308.02, 308.01, 307.02, 306.05, 306.03, 305.27, 306.01, 305.28, 305.30, 305.15, 305.14, 305.17, 305.16, 305.31, 305.29, 305.25, 305.26, 305.13, 314.05, 315.07, 315.08, 315.04, 315.05, 315.06, 316.32, 316.31, 316.30, 316.42, 316.64, 316.59, 316. 63, 316.62, 316.61, 316.60, 316.57, 316.39, 316.38, 316.41, 316.40, 305.04, 305.05, 305.06, 305.07, 305.12, 305.11, 305.08, 305.09, 304.05, 304.06, 304.07, 304.08, 304.04, 305.10, 305.11, 305.18, 304.03, 305.20, 305.21, 305.19, 305.22, 305.23, 305.24, 203.03, 303.04, 303.02, 303.01, 303.05, 306.05, 306.04, 302.02, 307.01, 302.01, 302.03, 310.03, 301**

58. Project Schedule – **Please see the submitted file titled "LBCR Program Schedule – Permit April 2018_2017.01.16.PDF" for the current program schedule.**

16-Jan-17

Project: Lower Bois d'Arc Creek Resevoir by CMAR

Activity ID	User Text Field	Activity Name	Planned Duration	Start	Finish
LBCR Program Schedule Permit April 2018 (In-Service For Water 2022) $$ - NEW			4377	01-Aug-06 A	18-Aug-23
Board Meetings & Actions (Program Mgmt, Design, Construction)			[illegible]	25-Jan-18	27-Jun-19
Program Management (Project 101-0374-14)			1827	01-Jan-15 A	31-Aug-22
A4470	p	Program Management Administration	1827	01-Jan-15 A	31-Aug-22
Lake Facilities (Lake Office; Maintenance) - GREY BAR			825	02-Jan-17	28-Feb-20
A4720	p	Lake Facilites Master Planning	260	02-Jan-17*	29-Dec-17
A4730	p	Lake Facilites Design	261	01-Jan-18*	31-Dec-18
A4740	b	Lake Facilites Construction	261	01-Mar-19*	28-Feb-20
Planning and Permitting (Project 101-0351-14)			[illegible]	01-Aug-06 A	29-Oct-21
Outside market driver - IPL Construction			[illegible]	17-Jun-18	19-Aug-22
Conflicts			[illegible]	04-May-15 A	26-May-20
A1230	y	Conflicts Design Coordination	283	04-May-15 A	18-Apr-19
A1280	red	Conflicts Construction Coordination	550	18-Apr-18*	26-May-20
Reservoir Area Structure Removal			800	27-Mar-17	17-Apr-20
A4560	orange	Reservoir Area Structure Removal Design	235	27-Mar-17*	16-Feb-18
A4570	orange	Reservoir Area Structure Removal Construction	523	18-Apr-18*	17-Apr-20
Municipal WWTP Upgrades			550	18-Apr-18	26-May-20
Bonham WWTP			550	18-Apr-18	26-May-20
A4500	orange	Bonham WWTP Upgrades Design	262	18-Apr-18*	18-Apr-19
A4510	orange	Bonham WWTP Upgrades Construction	262	27-May-19*	26-May-20
Dodd City WWTP			550	18-Apr-18	26-May-20
A4520	orange	Dodd City WWTP Upgrades Design	262	18-Apr-18*	18-Apr-19
A4530	orange	Dodd City WWTP Upgrades Construction	262	27-May-19*	26-May-20
Honey Grove WWTP			550	18-Apr-18	26-May-20
A4540	orange	Honey Grove WWTP Upgrades Design	262	18-Apr-18*	18-Apr-19
A4550	orange	Honey Grove WWTP Upgrades Construction	262	27-May-19*	26-May-20
Franchise Utility Relocations			619	03-Jul-17	14-Nov-19
AT&T Relocations			282	18-Apr-18	17-May-19
A2200	orange	AT&T Planning and Engineering	130	18-Apr-18*	17-Oct-18
A2210	orange	AT&T Construction	130	16-Nov-18	17-May-19
Verizon Relocations			379	03-Jul-17	13-Dec-18
A2220	orange	Frontier Planning and Engineering	165	03-Jul-17*	16-Feb-18
A2230	orange	Frontier Construction	174	16-Apr-18	13-Dec-18
Oncor Relocations			411	18-Apr-18	14-Nov-19
A2240	orange	Oncor Planning and Engineering	130	18-Apr-18*	17-Oct-18
A2250	orange	Oncor Construction	261	14-Nov-18	14-Nov-19
Atmos Relocations			343	25-Aug-17	18-Dec-18
A2260	orange	Atmos Planning and Engineering	124	25-Aug-17*	14-Feb-18
A2270	orange	Atmos Construction	175	18-Apr-18*	18-Dec-18
Water Supplier Relocations			559	27-Apr-17	18-Jun-19
Bois d' Arc MUD Relocations			559	27-Apr-17	18-Jun-19
A2280	orange	Bois d' Arc MUD Planning and Engineering	217	27-Apr-17*	23-Feb-18
A2290	orange	Bois d' Arc MUD Construction	304	18-Apr-18	18-Jun-19
White Shed WSC Relocations			281	18-Apr-18	16-May-19
A2320	orange	White Shed WSC Planning and Engineering	152	18-Apr-18*	16-Nov-18
A2330	orange	White Shed WSC Construction	109	14-Dec-18	16-May-19
FCEC Distribution Relocations			493	27-Jun-17	16-May-19
New 3-Phase Line Through Caddo National Grasslands			493	27-Jun-17	16-May-19
A2340	orange	FCEC Distribution Relocations - Design/ROW/Bidding	187	27-Jun-17*	14-Mar-18
A2370	orange	FCEC Distribution Relocations - Construction	281	18-Apr-18	16-May-19
Relocation of 3-Phase Line Below Lake Bonham Dam			322	28-Aug-17	20-Nov-18
A4040	orange	FCEC Distribution Relocations - Design/ROW/Bidding	187	28-Aug-17*	15-May-18
A4050	orange	FCEC Distribution Relocations - Construction	111	18-Jun-18	20-Nov-18
North System Conversion			472	27-Jun-17	17-Apr-19
A4480	orange	North System Conversion - Design/ROW/Bidding	187	27-Jun-17*	14-Mar-18
A4490	orange	North System Conversion - Construction	260	18-Apr-18	17-Apr-19
Wilkes Cemetery Exhumation (AR Consultants)			306	18-Apr-18	20-Jun-19
A2380	orange	Obtain Exhumation Order	131	18-Apr-18*	18-Oct-18
A2390	orange	Exhumation	131	19-Dec-18	20-Jun-19
CMAR 1 - Dam and TSR			[illegible]	14-Aug-13 A	24-May-22
CMAR Procurement			1145	14-Jan-15 A	05-Jun-19
A1780		CMAR RFP Issued	0		14-Jan-15 A
A1790		CMAR Proposals Due	0		18-Feb-15 A
A1800		CMAR Board Award	0		26-Mar-15 A
A2160	g	CMAR Preconstruction Services (Dam/Reservoir)	210	13-Apr-15 A	29-Jan-16 A
A4260	g	CMAR Preconstruction Services (Clearing)	282	03-Aug-16*	12-Sep-17
A4290	g	CMAR Procurement Services (Clearing)	145	13-Sep-17*	09-Apr-18
A4270	g	CMAR Procurement Services (Dam/Reservoir)	145	18-Sep-17*	12-Apr-18
A2170	g	CMAR Preconstruction Services (TSR)	165	02-Apr-18*	21-Nov-18
A4280	g	CMAR Procurement Services (TSR)	132	28-Nov-18*	05-Jun-19
Dam (Project 101-0344-13)			2290	14-Aug-13 A	24-May-22
A1050	p	Dam Engineering - Preliminary	240	02-Dec-13 A	31-Oct-14 A
A1290	p	Dam Engineering - Final	195	03-Nov-14 A	30-Dec-16
A1040	g	Dam ROW - Reservoir wide property acquisition - completion	883	14-Aug-13 A	30-Nov-17
A1121	b	Dam Construction - Mobilization and Site Development	75	18-Apr-18*	31-Jul-18
A1131	b	Dam Construction - Dam Clearing and Grubbing	76	06-Jun-18*	19-Sep-18
A1300	b	Dam Construction - Intake Conduits	154	02-Aug-18*	05-Mar-19
A1100	y	FCEC Design - Temporary Power to Dam Site	61	22-Jan-19*	16-Apr-19
A1071		Dam Construction - Emergency Spillway Cut Completion Milestone	0	15-May-19*	

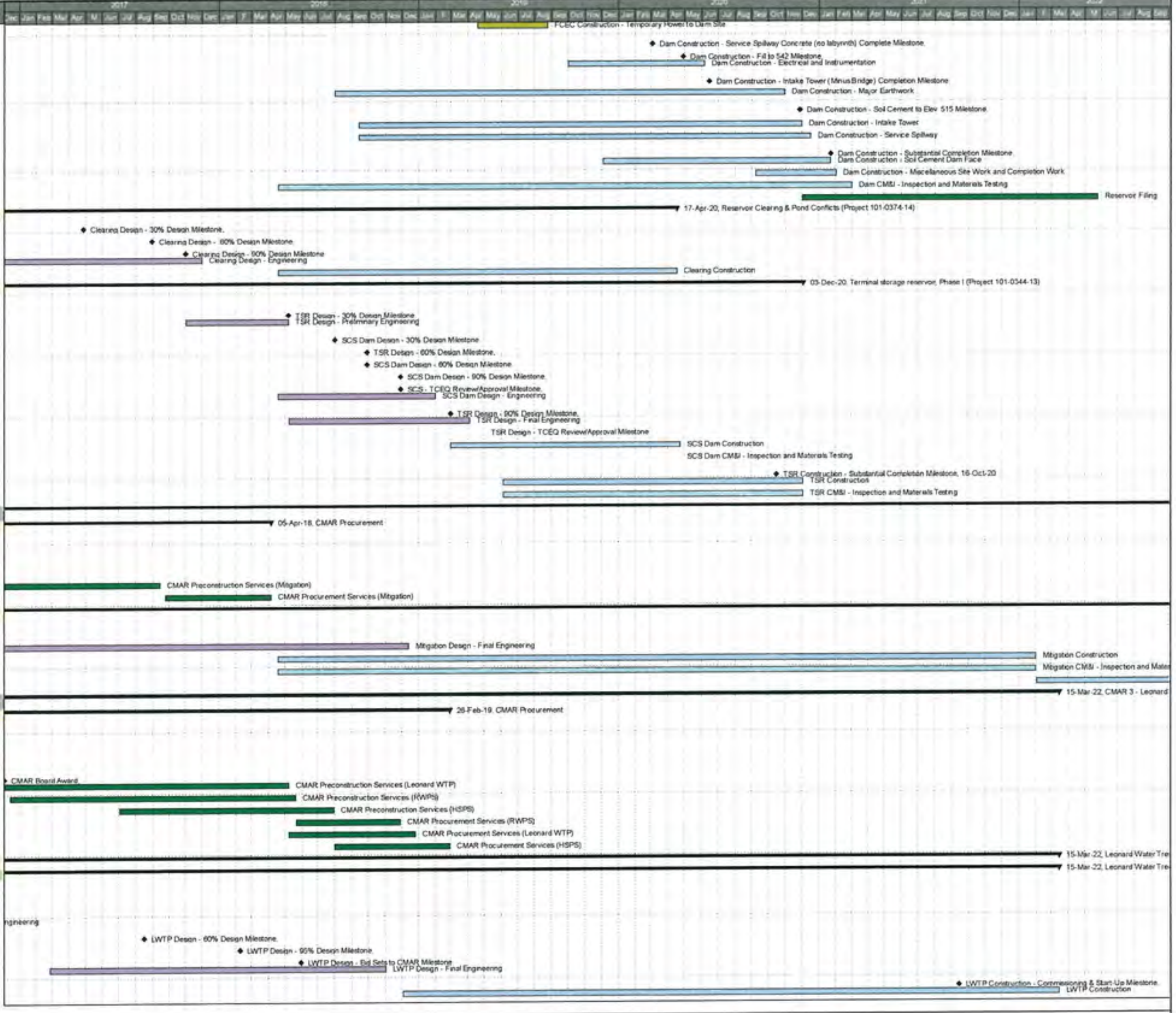


🟩 NTMWD Operations
▭ Construction
▭ Inspection ◆
◆ Milestone
▨ External Task, driver, or coordination
▨ Design
🟧 Conflicts
▼ Summary

Project: Lower Bois d'Arc Creek Resevoir by CMAR

16-Jan-17

Activity ID	User Text Field	Activity Name	Planned Duration	Start	Finish
A4000	y	FCEC Construction - Temporary Power to Dam Site	92	18-Apr-19*	23-Aug-19
A1171		Dam Construction - Service Spillway Concrete (no labyrinth) Complete Mi	0	02-Mar-20*	
A1151		Dam Construction - Fill to 542 Milestone	0	28-Apr-20*	
A1181	b	Dam Construction - Electrical and Instrumentation	180	30-Sep-19*	05-Jun-20
A1081		Dam Construction - Intake Tower (Minus Bridge) Completion Milestone	0	15-Jun-20*	
A1141	b	Dam Construction - Major Earthwork	588	01-Aug-18*	30-Oct-20
A1101		Dam Construction - Soil Cement to Elev 515 Milestone	0	27-Nov-20*	
A1310	b	Dam Construction - Intake Tower	578	13-Sep-18*	30-Nov-20
A1161	b	Dam Construction - Service Spillway	591	13-Sep-18*	17-Dec-20
A1211		Dam Construction - Substantial Completion Milestone	0	22-Jan-21*	
A1320	b	Dam Construction - Soil Cement Dam Face	298	04-Dec-19*	22-Jan-21
A1201	b	Dam Construction - Miscellaneous Site Work and Completion Work	105	08-Sep-20*	01-Feb-21
A1070	ired	Dam CM&I - Inspection and Materials Testing	749	18-Apr-18	02-Mar-21
A1080	g	Reservoir Filling	385	02-Dec-20*	24-May-22
Reservoir Clearing & Pond Conflicts (Project 101-0374-14)			980	18-Jul-16	17-Apr-20
A4580		Clearing Design - 30% Design Milestone	0	28-Apr-17*	
A4590		Clearing Design - 60% Design Milestone	0	31-Aug-17*	
A4600		Clearing Design - 90% Design Milestone	0	31-Oct-17*	
A1150	p	Clearing Design - Engineering	359	18-Jul-16*	30-Nov-17
A1160	b	Clearing Construction	522	18-Apr-18	17-Apr-20
Terminal storage reservoir, Phase I (Project 101-0344-13)			1656	31-Jul-14 A	03-Dec-20
A1630	g	TSR ROW - Land Acquisition	131	31-Jul-14 A	30-Apr-15 A
A1651		TSR Design - 30% Design Milestone	0	07-May-18*	
A1640	p	TSR Design - Preliminary Engineering	133	02-Nov-17*	07-May-18
A4630		SCS Dam Design - 30% Design Milestone	0	31-Jul-18*	
A1661		TSR Design - 60% Design Milestone	0	28-Sep-18*	
A4640		SCS Dam Design - 60% Design Milestone	0	28-Sep-18*	
A4650		SCS Dam Design - 90% Design Milestone	0	29-Nov-18*	
A4660		SCS - TCEQ Review/Approval Milestone	0	29-Nov-18*	
A4610	p	SCS Dam Design - Engineering	207	18-Apr-18*	31-Jan-19
A1681		TSR Design - 90% Design Milestone	0	28-Feb-19*	
A1641	p	TSR Design - Final Engineering	238	08-May-18	04-Apr-19
A1691		TSR Design - TCEQ Review/Approval Milestone	44	28-Feb-19*	30-Apr-19
A4620	b	SCS Dam Construction	301	28-Feb-19*	23-Apr-20
A4670		SCS Dam CM&I - Inspection and Materials Testing	301	28-Feb-19*	23-Apr-20
A2490		TSR Construction - Substantial Completion Milestone	0		16-Oct-20
A1650	b	TSR Construction	392	05-Jun-19	03-Dec-20
A1660	ired	TSR CM&I - Inspection and Materials Testing	392	05-Jun-19	03-Dec-20
CMAR 2 - Mitigation			[illegible]	[illegible]	[illegible]
CMAR Procurement			814	20-Feb-15 A	05-Apr-18
A1810		RFQ Issued	0		20-Feb-15 A
A1820		RFP Issued	0		14-Apr-15 A
A1830		Proposals Due	0	18-May-15 A	
A2000		CMAR Board Award	0	28-May-15 A	
A2180	g	CMAR Preconstruction Services (Mitigation)	393	13-Aug-15 A	15-Sep-17
A4300	g	CMAR Procurement Services (Mitigation)	135	25-Sep-17*	05-Apr-18
Mitigation/ site development (101-0366-14)			4445	03-Aug-06 A	16-Aug-23
A1170	g	Mitigation ROW - Land Acquisition	1827	03-Aug-06 A	02-Aug-13 A
A1190	p	Mitigation Design - Preliminary Engineering	120	03-Nov-14 A	06-May-15 A
A1191	p	Mitigation Design - Final Engineering	258	07-May-15 A	14-Dec-18
A1200	b	Mitigation Construction	989	18-Apr-18*	01-Feb-22
A1210	ired	Mitigation CM&I - Inspection and Materials Testing	989	18-Apr-18	01-Feb-22
A1250	b	Mitigation - Maintenance	401	02-Feb-22	16-Aug-23
CMAR 3 - Leonard WTP and PS's			[illegible]	[illegible]	[illegible]
CMAR Procurement			964	21-May-15 A	26-Feb-19
A2070		Board Authorization	0	21-May-15 A	
A1840		RFQ Issued	0	10-Jun-15 A	
A1850		RFP Issued	0	16-Nov-15 A	
A1860		Proposals Due	0	15-Mar-16*	
A2010		CMAR Board Award	0	05-Dec-16*	
A4310	g	CMAR Preconstruction Services (Leonard WTP)	362	05-Dec-16*	08-May-18
A4350	g	CMAR Preconstruction Services (RWPS)	362	16-Dec-16*	21-May-18
A4320	g	CMAR Preconstruction Services (HSPS)	273	03-Jul-17*	30-Jul-18
A4360	g	CMAR Procurement Services (RWPS)	134	22-May-18*	29-Nov-18
A4330	g	CMAR Procurement Services (Leonard WTP)	160	09-May-18*	26-Dec-18
A4340	g	CMAR Procurement Services (HSPS)	145	01-Aug-18*	26-Feb-19
Leonard Water Treatment Plant, Phase I			2262	25-Feb-13 A	15-Mar-22
Leonard Water Treatment Plant, WTP - Phase 1 (Project 101-0384-15)			2262	25-Feb-13 A	15-Mar-22
A1520	p	LWTP Design - Conceptual Engineering	216	25-Feb-13 A	23-Dec-13 A
A1535		LWTP Design - Design Criteria Development	0		01-Apr-15 A
A1540	g	LWTP ROW - Land Acquisition	88	30-Sep-14 A	01-Apr-15 A
A1530	p	LWTP Design - Preliminary Engineering	196	01-Apr-15 A	31-May-16 A
A1740		LWTP Design - 60% Design Milestone	0	17-Aug-17*	
A2300		LWTP Design - 95% Design Milestone	0	09-Feb-18*	
A2310		LWTP Design - Bid Sets to CMAR Milestone	0	31-May-18*	
A1550	p	LWTP Design - Final Engineering	440	27-Feb-17*	02-Nov-18
A2430		LWTP Construction - Commissioning & Start-Up Milestone	0	14-Sep-21	
A1560	b	LWTP Construction	855	04-Dec-18	15-Mar-22

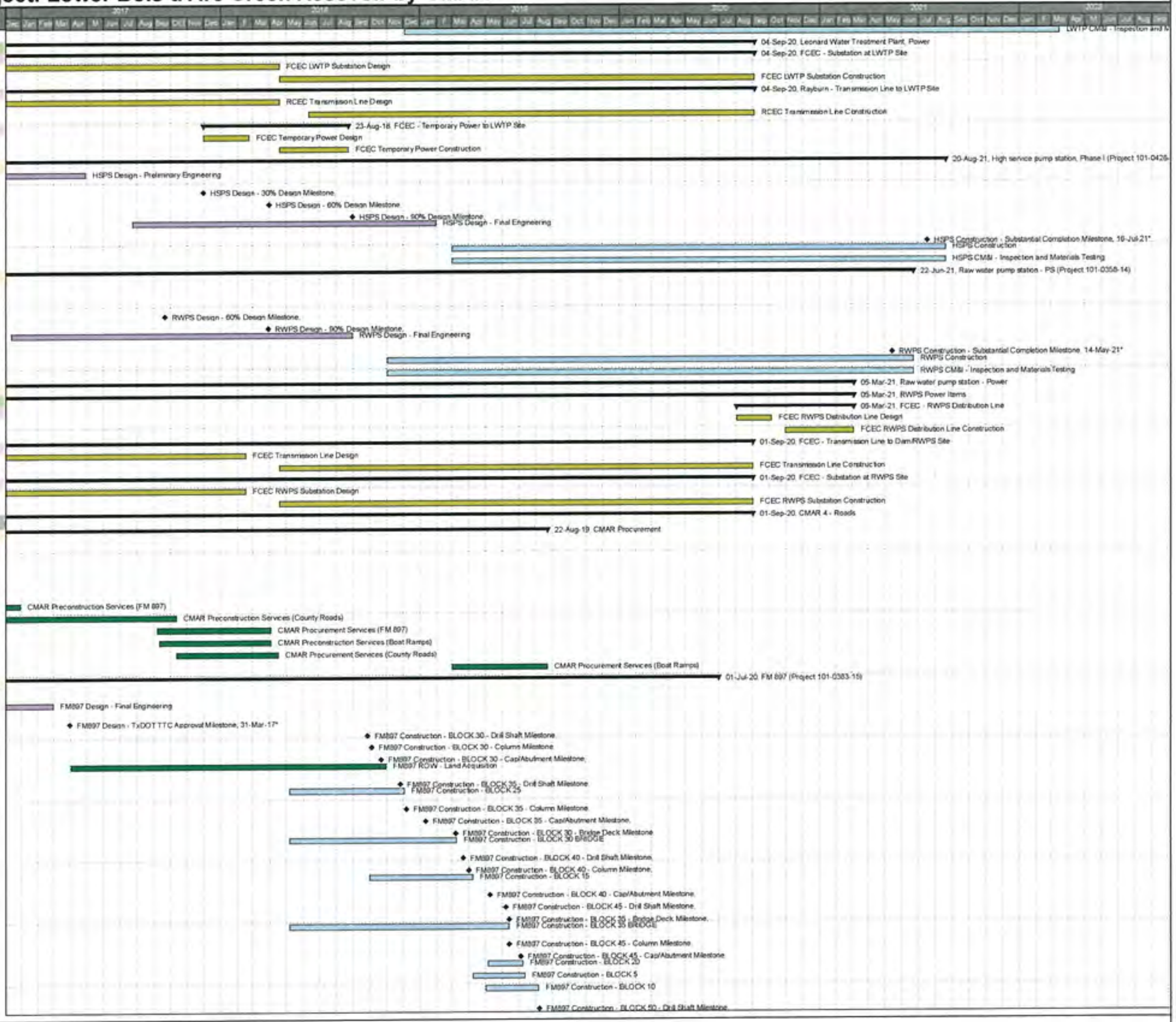


🟩 NTMWD Operations	▭ Construction	▭ Inspection ◆	◆ Milestone
🟨 External Task, driver, or coordination	▭ Design	🟧 Conflicts	▼ Summary

Project: Lower Bois d'Arc Creek Resevoir by CMAR

16-Jan-17

Activity ID	User Text Field	Activity Name	Planned Duration	Start	Finish
A1570	lred	LWTP CM&I - Inspection and Materials Testing	855	04-Dec-18	15-Mar-22
Leonard Water Treatment Plant, Power			1375	01-Jun-15 A	04-Sep-20
FCEC - Substation at LWTP Site			1375	01-Jun-15 A	04-Sep-20
A1580	y	FCEC LWTP Substation Design	219	01-Jun-15 A	18-Apr-18
A2470	y	FCEC LWTP Substation Construction	622	18-Apr-18*	04-Sep-20
Rayburn - Transmission Line to LWTP Site			1375	01-Jun-15 A	04-Sep-20
A1590	y	RCEC Transmission Line Design	546	01-Jun-15 A	18-Apr-18
A1600	y	RCEC Transmission Line Construction	585	11-Jun-18	04-Sep-20
FCEC - Temporary Power to LWTP Site			191	30-Nov-17	23-Aug-18
A1610	y	FCEC Temporary Power Design	61	30-Nov-17*	22-Feb-18
A1620	y	FCEC Temporary Power Construction	91	18-Apr-18	23-Aug-18
High service pump station, Phase I (Project 101-0428-16)			1420	01-Mar-16 A	20-Aug-21
A1670	p	HSPS Design - Preliminary Engineering	260	01-Mar-16 A	28-Apr-17
A1711		HSPS Design - 30% Design Milestone	0	30-Nov-17*	
A1721		HSPS Design - 60% Design Milestone	0	30-Mar-18*	
A1731		HSPS Design - 90% Design Milestone	0	31-Aug-18*	
A1671	p	HSPS Design - Final Engineering	398	24-Jul-17*	30-Jan-19
A2500		HSPS Construction - Substantial Completion Milestone	0		16-Jul-21*
A1680	b	HSPS Construction	645	01-Mar-19*	20-Aug-21
A1690	lred	HSPS CM&I - Inspection and Materials Testing	645	01-Mar-19	20-Aug-21
Raw water pump station - PS (Project 101-0358-14)			1884	01-May-14 A	22-Jun-21
A1369	p	RWPS Design - Siting	66	01-May-14 A	31-Jul-14 A
A1370	p	RWPS Design - Prelim Engineering	174	01-Jul-14 A	31-Aug-15 A
A1410		RWPS Design - 60% Design Milestone	0	21-Sep-17*	
A1420		RWPS Design - 90% Design Milestone	0	29-Mar-18*	
A1380	p	RWPS Design - Final Engineering	447	14-Dec-16*	30-Aug-18
A2530		RWPS Construction - Substantial Completion Milestone	0		14-May-21*
A1390	b	RWPS Construction	688	02-Nov-18*	22-Jun-21
A1400	lred	RWPS CM&I - Inspection and Materials Testing	688	02-Nov-18	22-Jun-21
Raw water pump station - Power			1319	15-Feb-16 A	05-Mar-21
RWPS Power Items			1319	15-Feb-16 A	05-Mar-21
FCEC - RWPS Distribution Line			155	03-Aug-20	05-Mar-21
A4070	y	FCEC RWPS Distribution Line Design	46	03-Aug-20*	05-Oct-20
A4080	y	FCEC RWPS Distribution Line Construction	91	30-Oct-20*	05-Mar-21
FCEC - Transmission Line to Dam/RWPS Site			1186	15-Feb-16 A	01-Sep-20
A4090	y	FCEC Transmission Line Design	524	15-Feb-16 A	16-Feb-18
A4100	y	FCEC Transmission Line Construction	619	18-Apr-18	01-Sep-20
FCEC - Substation at RWPS Site			1186	15-Feb-16 A	01-Sep-20
A4110	y	FCEC RWPS Substation Design	524	15-Feb-16 A	16-Feb-18
A4120	y	FCEC RWPS Substation Construction	619	18-Apr-18	01-Sep-20
CMAR 4 - Roads			[illegible]	[illegible]	[illegible]
CMAR Procurement			1111	21-May-15 A	22-Aug-19
A2080		Board Meeting to Authorize	0	21-May-15 A	
A1870		RFQ Issued	0	23-Jun-15 A	
A1880		RFP Issued	0	28-Dec-15 A	
A1890		Proposals Due	0	10-Mar-16*	
A2020		CMAR Board Award	0	25-May-16 A	
A4370	g	CMAR Preconstruction Services (FM 897)	153	01-Jun-16 A	30-Dec-16
A4380	g	CMAR Preconstruction Services (County Roads)	262	03-Oct-16*	12-Oct-17
A4390	g	CMAR Procurement Services (FM 897)	145	07-Sep-17*	03-Apr-18
A4410	g	CMAR Preconstruction Services (Boat Ramps)	143	11-Sep-17*	03-Apr-18
A4400	g	CMAR Procurement Services (County Roads)	129	13-Oct-17*	17-Apr-18
A4420	g	CMAR Procurement Services (Boat Ramps)	123	01-Mar-19*	22-Aug-19
FM 897 (Project 101-0383-15)			1375	26-Mar-15 A	01-Jul-20
A1970	p	FM897 Design - Preliminary Engineering	21	26-Mar-15 A	15-Jun-15 A
A1980	p	FM897 Design - Final Engineering	386	16-Jun-15 A	28-Feb-17
A1900		FM897 Design - TxDOT TTC Approval Milestone	0		31-Mar-17*
A2480		FM897 Construction - BLOCK 30 - Drill Shaft Milestone	0	27-Sep-18*	
A1110		FM897 Construction - BLOCK 30 - Column Milestone	0	04-Oct-18*	
A2480		FM897 Construction - BLOCK 30 - Cap/Abutment Milestone	0	22-Oct-18*	
A1000	g	FM897 ROW - Land Acquisition	413	03-Apr-17*	31-Oct-18
A2540		FM897 Construction - BLOCK 35 - Drill Shaft Milestone	0	26-Nov-18*	
A1430	b	FM897 Construction - BLOCK 25	151	07-May-18*	03-Dec-18
A2550		FM897 Construction - BLOCK 35 - Column Milestone	0	07-Dec-18*	
A2560		FM897 Construction - BLOCK 35 - Cap/Abutment Milestone	0	11-Jan-19*	
A2510		FM897 Construction - BLOCK 30 - Bridge Deck Milestone	0	08-Mar-19*	
A1440	b	FM897 Construction - BLOCK 30 BRIDGE	220	07-May-18*	08-Mar-19
A2600		FM897 Construction - BLOCK 40 - Drill Shaft Milestone	0	22-Mar-19*	
A2610		FM897 Construction - BLOCK 40 - Column Milestone	0	01-Apr-19*	
A2410	b	FM897 Construction - BLOCK 15	136	01-Oct-18*	08-Apr-19
A2620		FM897 Construction - BLOCK 40 - Cap/Abutment Milestone	0	09-May-19*	
A2650		FM897 Construction - BLOCK 45 - Drill Shaft Milestone	0	07-Jun-19*	
A2580		FM897 Construction - BLOCK 35 - Bridge Deck Milestone	0	13-Jun-19*	
A2520	b	FM897 Construction - BLOCK 35 BRIDGE	289	07-May-18*	13-Jun-19
A2660		FM897 Construction - BLOCK 45 - Column Milestone	0	14-Jun-19*	
A2670		FM897 Construction - BLOCK 45 - Cap/Abutment Milestone	0	05-Jul-19*	
A2440	b	FM897 Construction - BLOCK 20	46	06-May-19*	08-Jul-19
A1340	b	FM897 Construction - BLOCK 5	70	08-Apr-19*	12-Jul-19
A1350	b	FM897 Construction - BLOCK 10	69	02-May-19*	06-Aug-19
A2700		FM897 Construction - BLOCK 50 - Drill Shaft Milestone	0	08-Aug-19*	

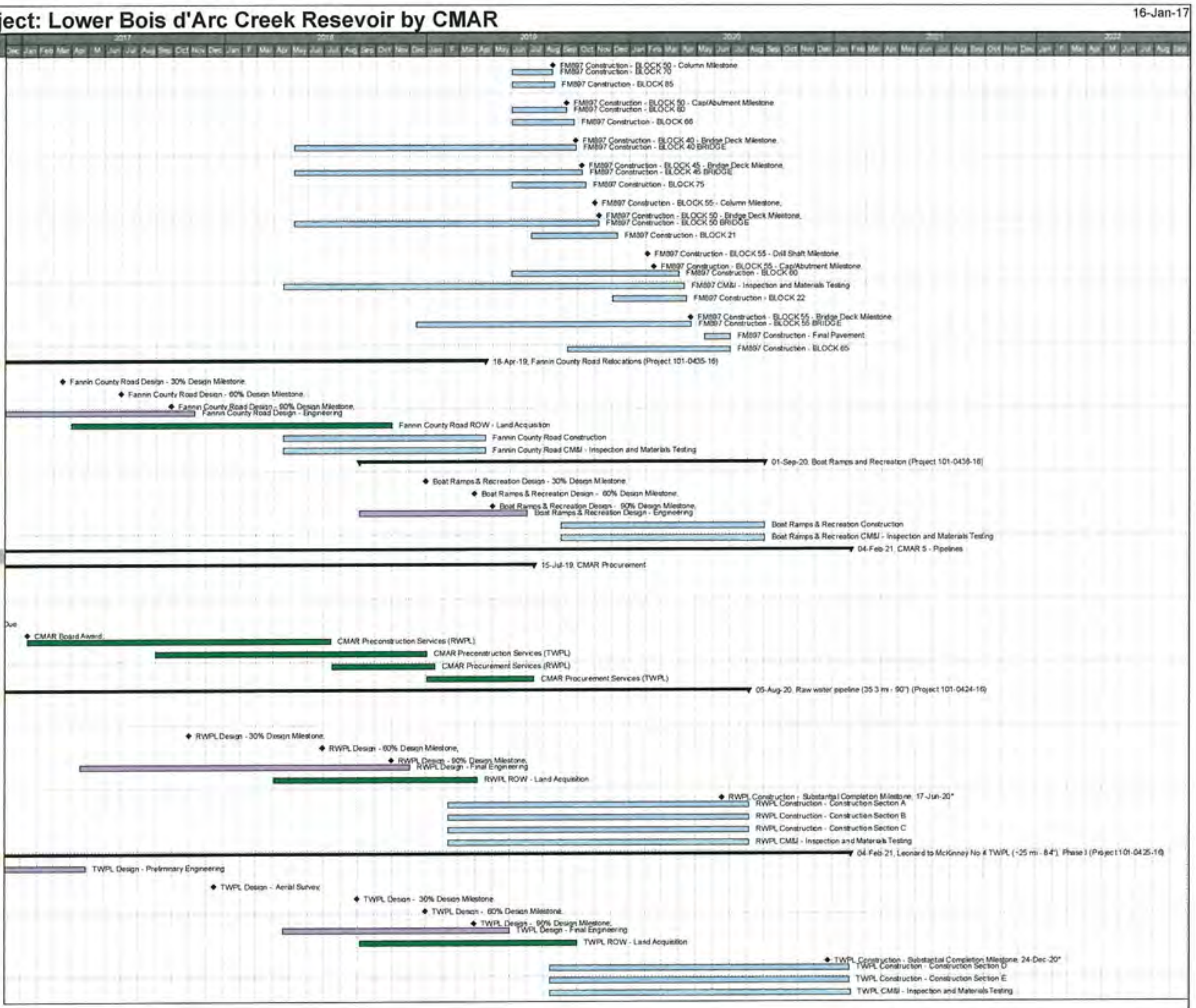


🟩 NTMWD Operations
▭ Construction
▭ Inspection ◆
◆ Milestone
🟨 External Task, driver, or coordination
🟪 Design
🟧 Conflicts
▼ Summary

Project: Lower Bois d'Arc Creek Resevoir by CMAR

16-Jan-17

Activity ID	User Text Field	Activity Name	Planned Duration	Start	Finish
A2710		FM897 Construction - BLOCK 50 - Column Milestone	0	15-Aug-19*	
A2820	b	FM897 Construction - BLOCK 70	54	03-Jun-19*	15-Aug-19
A2850	b	FM897 Construction - BLOCK 85	56	03-Jun-19*	19-Aug-19
A2720		FM897 Construction - BLOCK 50 - Cap/Abutment Milestone	0	09-Sep-19*	
A2840	b	FM897 Construction - BLOCK 80	71	03-Jun-19*	09-Sep-19
A2810	b	FM897 Construction - BLOCK 66	81	03-Jun-19*	23-Sep-19
A2630		FM897 Construction - BLOCK 40 - Bridge Deck Milestone	0	26-Sep-19*	
A2590	b	FM897 Construction - BLOCK 40 BRIDGE	364	07-May-18*	26-Sep-19
A2680		FM897 Construction - BLOCK 45 - Bridge Deck Milestone	0	07-Oct-19*	
A2640	b	FM897 Construction - BLOCK 45 BRIDGE	371	07-May-18*	07-Oct-19
A2830	b	FM897 Construction - BLOCK 75	96	03-Jun-19*	14-Oct-19
A2760		FM897 Construction - BLOCK 55 - Column Milestone	0	31-Oct-19*	
A2730		FM897 Construction - BLOCK 50 - Bridge Deck Milestone	0	07-Nov-19*	
A2690	b	FM897 Construction - BLOCK 50 BRIDGE	394	07-May-18*	07-Nov-19
A2450	b	FM897 Construction - BLOCK 21	111	09-Jul-19*	10-Dec-19
A2750		FM897 Construction - BLOCK 55 - Drill Shaft Milestone	0	03-Feb-20*	
A2770		FM897 Construction - BLOCK 55 - Cap/Abutment Milestone	0	14-Feb-20*	
A2790	b	FM897 Construction - BLOCK 60	216	03-Jun-19*	30-Mar-20
A1930	Ired	FM897 CM&I - Inspection and Materials Testing	516	18-Apr-18	09-Apr-20
A1360	b	FM897 Construction - BLOCK 22	96	02-Dec-19*	13-Apr-20
A2780		FM897 Construction - BLOCK 55 - Bridge Deck Milestone	0	21-Apr-20*	
A2740	b	FM897 Construction - BLOCK 55 BRIDGE	353	14-Dec-18*	21-Apr-20
A1330	b	FM897 Construction - Final Pavement	33	15-May-20*	30-Jun-20
A2800	b	FM897 Construction - BLOCK 65	210	12-Sep-19*	01-Jul-20
Fannin County Road Relocations (Project 101-0435-16)			729	04-Jul-16	18-Apr-19
A1220		Fannin County Road Design - 30% Design Milestone	0	17-Mar-17*	
A1240		Fannin County Road Design - 60% Design Milestone	0	30-Jun-17*	
A1260		Fannin County Road Design - 90% Design Milestone	0	29-Sep-17*	
A1120	p	Fannin County Road Design - Engineering	355	04-Jul-16*	10-Nov-17
A1180	g	Fannin County Road ROW - Land Acquisition	413	03-Apr-17*	31-Oct-18
A1130	b	Fannin County Road Construction	261	18-Apr-18	18-Apr-19
A1140	Ired	Fannin County Road CM&I - Inspection and Materials Testing	261	18-Apr-18	18-Apr-19
Boat Ramps and Recreation (Project 101-0436-16)			522	03-Sep-18	01-Sep-20
A4680		Boat Ramps & Recreation Design - 30% Design Milestone	0	31-Dec-18*	
A4690		Boat Ramps & Recreation Design - 60% Design Milestone	0	29-Mar-19*	
A4700		Boat Ramps & Recreation Design - 90% Design Milestone	0	30-Apr-19*	
A3190	p	Boat Ramps & Recreation Design - Engineering	217	03-Sep-18*	02-Jul-19
A3210	b	Boat Ramps & Recreation Construction	262	02-Sep-19	01-Sep-20
A3200	Ired	Boat Ramps & Recreation CM&I - Inspection and Materials Testing	262	02-Sep-19	01-Sep-20
CMAR 5 - Pipelines			2004	25-Feb-13 A	04-Feb-21
CMAR Procurement			891	15-Feb-16	15-Jul-19
A2420		Board Meeting to Authorize	0	15-Feb-16*	
A1900		RFQ Issued	0	16-May-16*	
A1910		RFP Issued	0	03-Aug-16*	
A1920		Proposals Due	0	16-Sep-16*	
A2030		CMAR Board Award	0	13-Jan-17*	
A4430	g	CMAR Preconstruction Services (RWPL)	382	13-Jan-17*	13-Jul-18
A4450	g	CMAR Preconstruction Services (TWPL)	337	01-Sep-17*	02-Jan-19
A4440	g	CMAR Procurement Services (RWPL)	129	16-Jul-18	17-Jan-19
A4460	g	CMAR Procurement Services (TWPL)	136	03-Jan-19	15-Jul-19
Raw water pipeline (35.3 mi - 90") (Project 101-0424-16)			1943	25-Feb-13 A	05-Aug-20
A1450	p	RWPL Design - Final alignment (part of 404 permit)	216	25-Feb-13 A	23-Dec-13 A
A2040		RWPL Design - Aerial survey	0	04-Jan-16*	
A2350		RWPL Design - 30% Design Milestone	0	31-Oct-17*	
A2380		RWPL Design - 60% Design Milestone	0	29-Jun-18*	
A2400		RWPL Design - 90% Design Milestone	0	31-Oct-18*	
A1460	p	RWPL Design - Final Engineering	424	19-Apr-17*	03-Dec-18
A1470	g	RWPL ROW - Land Acquisition	264	02-Apr-18*	04-Apr-19
A2570		RWPL Construction - Substantial Completion Milestone	0		17-Jun-20*
A1480	b	RWPL Construction - Construction Section A	388	11-Feb-19*	05-Aug-20
A1490	b	RWPL Construction - Construction Section B	388	11-Feb-19*	05-Aug-20
A1500	b	RWPL Construction - Construction Section C	388	11-Feb-19*	05-Aug-20
A1510	Ired	RWPL CM&I - Inspection and Materials Testing	388	11-Feb-19	05-Aug-20
Leonard to McKinney No.4 TWPL (~25 mi - 84"), Phase I (Project 101-0425-16)			1309	01-Feb-16 A	04-Feb-21
A1700	p	TWPL Design - Preliminary Engineering	323	01-Feb-16 A	28-Apr-17
A1709		TWPL Design - Aerial Survey	0	15-Dec-17*	
A1741		TWPL Design - 30% Design Milestone	0	31-Aug-18*	
A1751		TWPL Design - 60% Design Milestone	0	31-Dec-18*	
A1761		TWPL Design - 90% Design Milestone	0	29-Mar-19*	
A1701	p	TWPL Design - Final Engineering	292	18-Apr-18*	31-May-19
A1710	g	TWPL ROW - Land Acquisition	280	04-Sep-18*	30-Sep-19
A3220		TWPL Construction - Substantial Completion Milestone	0		24-Dec-20*
A1720	b	TWPL Construction - Construction Section D	384	13-Aug-19	01-Feb-21
A1730	b	TWPL Construction - Construction Section E	384	13-Aug-19	01-Feb-21
A1750	Ired	TWPL CM&I - Inspection and Materials Testing	387	13-Aug-19	04-Feb-21



🟩 NTMWD Operations
🟨 External Task, driver, or coordination
▭ Construction
▭ Design
▭ Inspection ◆
🟧 Conflicts
◆ Milestone
▼ Summary

SWIFT Funding Information

North Texas Municipal Water District

Lower Bois D’Arc Creek Reservoir
Project No. 317

Vol.5

-Part D #59

-Part D #60 LBCR

-Part D #60 Treatment and Treated Water Distribution

-Part D #61 LBCR

-Part D #61 Treatment and Treated Water Distribution

-Part D #63

-Part D #64

Beneficiaries of Lower Bois d'Arc Creek Reservoir and Leonard WTP, HS Pump Station, and Transmission lines

From Appendix H, Table H.23*, *2016 Region C Water Plan*

* Removed any NTWMD customers that were not allocated supply from Lower Bois d'Arc Creek Reservoir in DB17

Current Customers

Ables Springs WSC
Allen
Anna
Blackland WSC
Bonham
BHP WSC (Hunt Co portion)
Caddo Basin SUD
Cash SUD
College Mound WSC
Collin Co. Other
Copeville SUD
Crandall
Culleoka WSC
Denton County Other
East Fork SUD
Fairview
Farmersville
Fate
Forney
Forney Lake WSC
Frisco
Garland
Gastonia-Scurry SUD
Hackberry
Heath
High Point WSC
Howe
Hunt County Other
Josephine
Kaufman
Kaufman County Other
Lavon
Lavon WSC
Little Elm
Lowry Crossing
Lucas
McKinney
McLendon-Chisolm
Melissa
Mesquite

Potential Future Customers

Blue Ridge
Celina
Ector
Fannin County Other
Honey Grove
Leonard
Savoy
Southwest Fannin Co SUD
Trenton
Weston
Kaufman County Mining
Fannin County Mining

Beneficiaries of Lower Bois d'Arc Creek Reservoir and Leonard WTP, HS Pump Station, and Transmission lines

From Appendix H, Table H.23*, *2016 Region C Water Plan*

* Removed any NTWMD customers that were not allocated supply from Lower Bois d'Arc Creek Reservoir in DB17

Current Customers	**Potential Future Customers**
Milligan WSC	
Mt. Zion WSC	
Murphy	
Nevada	
North Collin WSC	
New Hope	
Oak Grove	
Parker	
Plano	
Post Oak Bend City	
Princeton	
Prosper	
RCH WSC	
Richardson	
Rockwall	
Rockwall Co. Other	
Rose Hill SUD	
Rowlett	
Royse City	
Sachse	
Saint Paul	
Scurry	
Seis Lagos UD	
Sunnyvale	
Talty	
Talty WSC	
Terrell	
The Colony	
Van Alstyne	
Wylie	
Wylie Northeast SUD	
Non-Municipal Customers	
Collin County Manufacturing	
Dallas County Manufacturing	
Denton County Manufacturing	
Fannin County Manufacturing	
Grayson County Manufacturing	
Kaufman County Manufacturing	
Kaufman County Steam Electric	
Rockwall County Manufacturing	

Part D. 59 - Population and Flows - Lower Bois d'Arc Creek Reservoir

Planning Year	**2020**	**2025**	**2030**	**2035**	**2040**
Population (Million)	**1.86**	**2.01**	**2.15**	**2.33**	**2.5**
Water Use (MGD)	**379**	**411**	**443**	**470**	**497**

Part D. 59 - Population and Flows - Treatment and Treated Water Distribution

Planning Year	2020	2025	2030	2035	2040
Population (Million)	1.86	2.01	2.15	2.33	2.5
Water Use (MGD)	379	411	443	470	497

TWDB-1201
Revised 04/17

PROJECT BUDGET - Entity Name: North Texas Municipal Water District

Project: Lower Bois d'Arc Creek Reservoir

All Costs in Millions

Uses	**TWDB Funds Series 1**	**TWDB Funds Series 2**	**TWDB Funds Series 3**	**TWDB Funds Series 4**	**TWDB Funds Series 5**	**Total TWDB Cost**	**Other Funds**	**Total Cost**
Construction								
Construction	$2.600	$427.396	$226.140	$0	$0	$656.137	$8.649	$664.786
Subtotal Construction	**$2.600**	**$427.396**	**$226.140**	**$0**	**$0**	**$656.137**	**$9**	**$664.786**
Basic Engineering Fees								
Planning +	$0.867	$0	$0	$0	$0	$0.867	$1.669	$2.536
Design	$15.829	$2.896	$0.000	$0	$0	$18.725	$45.462	$64.187
Construction Engineering	$0	$0	$1.961	$0	$0	$1.961	$2.740	$4.701
Basic Engineering Other **________________	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal Basic Engineering Fees	**$16.696**	**$2.896**	**$1.961**	**$0**	**$0**	**$21.553**	**$49.872**	**$71.425**
Special Services								
Application	$0	$0	$0	$0	$0	$0	$0	$0
Environmental	$0	$0	$0	$0	$0	$0	$0	$0
Water Conservation Plan	$0	$0	$0	$0	$0	$0	$0	$0
I/I Studies/Sewer	$0	$0	$0	$0	$0	$0	$0	$0
Surveying	$0	$0	$0	$0	$0	$0	$0	$0
Geotechnical	$0	$0	$0	$0	$0	$0	$0	$0
Testing	$0	$0	$0	$0	$0	$0	$0	$0
Permits	$0.400	$6.953	$0.366	$0	$0	$7.719	$1.863	$9.582
Inspection	$0	$6.255	$1.689	$0	$0	$7.944	$0.024	$7.968
O&M Manual	$0	$0	$0	$0	$0	$0	$0	$0
Project Management (by engineer)	$0	$0	$0	$0	$0	$0	$0	$0
Pilot Testing	$0	$0	$0	$0	$0	$0	$0	$0
Water Distribution	$0	$0	$0	$0	$0	$0	$0	$0
Special Services Other **____________	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal Special Services	**$0.400**	**$13.208**	**$2.055**	**$0**	**$0**	**$15.663**	**$1.887**	**$17.550**
Other								
Administration	$0	$0	$0	$0	$0	$0	$0	$0
Land/Easements	$0	$19.220	$0	$0	$0	$19.220	$106.152	$125.372
Water Rights Purchase (If Applicable)	$0	$0	$0	$0	$0	$0	$0	$0
Capacity Buy-In (If Applicable)	$0	$0	$0	$0	$0	$0	$0	$0
Project Legal Expenses	$0.500	$0	$0	$0	$0	$0.500	$3.556	$4.056
Other **	$0	$0	$0	$0	$0	$0	$0	$0.000
Subtotal Other Services	**$0.500**	**$19.220**	**$0.000**	**$0**	**$0**	**$19.720**	**$109.708**	**$129.428**
Fiscal Services								
Financial Advisor	$0.038	$0.429	$0.210	$0	$0	$0.676	$0	$0.676
Bond Counsel	$0.059	$0.606	$0.294	$0	$0	$0.959	$0	$0.959
Issuance Cost	$0	$0	$0	$0	$0	$0	$0	$0
Bond Insurance/Surety	$0	$0	$0	$0	$0	$0	$0	$0
Fiscal/Legal	$0.023	$0.038	$0.016	$0	$0	$0.077	$0	$0
Capitalized Interest	$0	$0	$0	$0	$0	$0	$0	$0
Bond Reserve Fund	$0.783	$23.001	$11.104	$0	$0	$34.888	$0	$34.888
Loan Origination Fee	$0	$0	$0	$0	$0	$0	$0	$0
Other **	$0.000	$0.000	$0.000	$0	$0	$0.000	$0	$0.000
Subtotal Fiscal Services	**$0.903**	**$24.073**	**$11.624**	**$0**	**$0**	**$36.600**	**$0**	**$36.600**
Contingency								
Contingency	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal Contingency	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
TOTAL COSTS	**$21.099**	**$486.793**	**$241.781**	**$0**	**$0**	**$749.673**	**$170.116**	**$919.789**
Other ** description must be entered								
+ For Planning applications under the EDAP Program, please break down Planning costs as follows:								
Category A								0
Category B								0
Category C								0
Category D								0
Total Planning Costs						0	0	0

PROJECT BUDGET - Entity Name: North Texas Municipal Water District

Project: Treatment and Treated Water Distribution

All Costs in Millions

Uses	TWDB Funds Series 1	TWDB Funds Series 2	TWDB Funds Series 3	TWDB Funds Series 4	TWDB Funds Series 5	Total TWDB Cost	Other Funds	Total Cost
Construction								
Construction	$0	$21.012	$344.627	$0	$0	$365.639	$67.776	$433.416
Subtotal Construction	**$0**	**$21.012**	**$344.627**	**$0**	**$0**	**$365.639**	**$67.776**	**$433.416**
Basic Engineering Fees								
Planning +	$0	$0	$0	$0	$0	$0	$0	$0
Design	$22.543	$7.571	$0	$0	$0	$30.114	$6.304	$36.418
Construction Engineering	$0	$0	$0	$0	$0	$0	$0	$0
Basic Engineering Other **________________	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal Basic Engineering Fees	**$22.543**	**$7.571**	**$0.000**	**$0**	**$0**	**$30.114**	**$6.304**	**$36.418**
Special Services								
Application	$0	$0	$0	$0	$0	$0	$0	$0
Environmental	$0	$0	$0	$0	$0	$0	$0	$0
Water Conservation Plan	$0	$0	$0	$0	$0	$0	$0	$0
I/I Studies/Sewer	$0	$0	$0	$0	$0	$0	$0	$0
Surveying	$0	$0	$0	$0	$0	$0	$0	$0
Geotechnical	$0	$0	$0	$0	$0	$0	$0	$0
Testing	$0	$0	$0	$0	$0	$0	$0	$0
Permits	$0	$0	$0	$0	$0	$0	$0	$0
Inspection	$0	$0.414	$3.211	$0	$0	$3.625	$0.827	$4.452
O&M Manual	$0	$0	$0	$0	$0	$0	$0	$0
Project Management (by engineer)	$0	$0	$0	$0	$0	$0	$0	$0
Pilot Testing	$0	$0	$0	$0	$0	$0	$0	$0
Water Distribution	$0	$0	$0	$0	$0	$0	$0	$0
Special Services Other **___________	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal Special Services	**$0**	**$0.414**	**$3.211**	**$0**	**$0**	**$3.625**	**$0.827**	**$4.452**
Other								
Administration	$0	$0	$0	$0	$0	$0	$0	$0
Land/Easements	$0	$4.954	$0	$0	$0	$4.954	$5.913	$10.868
Water Rights Purchase (If Applicable)	$0	$0	$0	$0	$0	$0	$0	$0
Capacity Buy-In (If Applicable)	$0	$0	$0	$0	$0	$0	$0	$0
Project Legal Expenses	$0	$0	$0	$0	$0	$0	$0.341	$0
Other **	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal Other Services	**$0**	**$4.954**	**$0.000**	**$0**	**$0**	**$4.954**	**$6.254**	**$11.208**
Fiscal Services								
Financial Advisor	$0.042	$0.031	$0.365	$0	$0	$0.439	$0	$0.439
Bond Counsel	$0.066	$0.044	$0.511	$0	$0	$0.621	$0	$0.621
Issuance Cost	$0	$0	$0	$0	$0	$0	$0	$0
Bond Insurance/Surety	$0	$0	$0	$0	$0	$0	$0	$0
Fiscal/Legal	$0.026	$0.003	$0.028	$0	$0	$0.056	$0	$0.056
Capitalized Interest	$0	$0	$0	$0	$0	$0	$0	$0
Bond Reserve Fund	$0.874	$1.688	$19.298	$0	$0	$21.859	$0	$21.859
Loan Origination Fee	$0	$0	$0	$0	$0	$0	$0	$0
Other **	$0	$0	$0	$0	$0	$0.000	$0	$0.000
Subtotal Fiscal Services	**$1.008**	**$1.766**	**$20.201**	**$0**	**$0**	**$22.976**	**$0**	**$22.976**
Contingency								
Contingency	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal Contingency	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
TOTAL COSTS	**$23.551**	**$35.717**	**$368.039**	**$0**	**$0**	**$427.307**	**$81.162**	**$508.469**
Other ** description must be entered								
+ For Planning applications under the EDAP Program, please break down Planning costs as follows:								
Category A								0
Category B								0
Category C								0
Category D								0
Total Planning Costs						0	0	0

WRD-253d
03/16/2016

Texas Water Development Board
Water Project Information

A. Project Name Lower Bois d'Arc Creek Reservoir	B. Project No. NTMWD has multiple projects under this program.	C. County Fannin	D. Regional Planning Group (A-P) C
E. Program(s) Lower Bois d'Arc Creek Reservoir Program	F. Loan ☒ : $713,072,510 w/Out COI Principal Forgiveness ☐: $ Grant ☐ : $	G. Loan Term: 30 Year	

H. Water Project Description: (Multiphase project, new or expansion; plant, well, storage, pump station, distribution system, etc)

Multiphase project consisting of a new dam, reservoir, raw water pump station, raw water pipeline, terminal storage reservoir, and compensatory mitigation.

Attach map of service area affected by Project or other documentation.

I. Is an Inter Basin Transfer potentially involved? Yes ☒ No ☐

J. Is project located in a Groundwater District (If yes, identify District by name)? Yes ☒ Red River and North Texas

K. **Service Area Projected Population** for at least a 20 year period: (if different from Planning Area, discuss in separate attachment)	Current Population		Projected Population				
	Year:	2017	2020	2025	2030	2035	2040
	Population:	1.67M	1.86M	2.01M	2.15M	2.33M	2.5M

Project Design Year: (Year for which project will be sized)	2040	Design Population: (Population served by project on the design year)	2.5M

L. Is the proposed project included in a current Regional Water Plan? Yes ☒ No ☐ Don't Know ☐
(If **Yes**, please specify on what page in the Regional Water Plan - Regional Water Plan Page Number: 5c.25

M. What type of water source is **associated directly with the proposed project?** Surface Water ☒ Groundwater ☐ Reuse ☐

N. Will the project increase the volume of water supply? Yes ☒ No ☐

O. What volume of water is the project anticipated to deliver/ treat per year? 120,665 Acre-Feet/Year

P. Current Water Supply Information

Surface Water Supply Source / Provider Names	Certificate No.	Source County	Annual Volume and Unit
North Texas Municipal Water District	See attached sheet	See attached sheet	See attached sheet
Groundwater Source Aquifer	**Well Field location**	**Source County**	**Annual Volume and Unit**
N/A	N/A	N/A	N/A

Q. Proposed Water Supply Associated Directly with the Proposed Project

Surface Water Supply Source / Provider Names	Certificate No.	Source County	Annual Volume and Unit
Lower Bois d'Arc Creek Reservoir/North Texas Municipal Water District	12151	Fannin	120,665 AF/y
Groundwater Source Aquifer	**Well Field location:**	**Source County**	**Annual Volume and Unit**
N/A	N/A	N/A	N/A

R. Consulting Engineer Name	Telephone No.	E-mail address
Freese and Nichols, Inc.	972-624-9216	jp@freese.com
S. Applicant Contact Name, Title	**Telephone No.**	**E-mail address**
Steve Long - Reservoir Project Manager	469-626-4713	slong@ntmwd.com

WRD-253d
03/16/2016

Texas Water Development Board
Water Project Information

A. Project Name Treatment and Treated Water Distribution	B. Project No. NTMWD has multiple projects under this program.	C. County Fannin	D. Regional Planning Group (A-P) C
E. Program(s) Lower Bois d'Arc Creek Reservoir Program	F. Loan ☒ : $404,331,800 w/Out COI Principal Forgiveness ☐: $ Grant ☐ : $	G. Loan Term: 30 Year	

H. Water Project Description: (Multiphase project, new or expansion; plant, well, storage, pump station, distribution system, etc)

Multiphase project consisting of a conventional water treatment plant, high service pump station, and treated water pipeline.

Attach map of service area affected by Project or other documentation.

I. Is an Inter Basin Transfer potentially involved? Yes ☒ No ☐	J. Is project located in a Groundwater District (If yes, identify District by name)? Yes☒ Red River and North Texas

K. **Service Area Projected Population** for at least a 20 year period: (if different from Planning Area, discuss in separate attachment)	Current Population		Projected Population				
	Year:	2017	2020	2025	2030	2035	2040
	Population:	1.67M	1.86M	2.01M	2.15M	2.33M	2.5M

Project Design Year: (Year for which project will be sized)	See Attached	Design Population: (Population served by project on the design year)	See Attached

L. Is the proposed project included in a current Regional Water Plan? Yes ☒ No ☐ Don't Know ☐
(If **Yes**, please specify on what page in the Regional Water Plan - Regional Water Plan Page Number: 5C.26

M. What type of water source is **associated directly with the proposed project?** Surface Water ☒ Groundwater ☐ Reuse ☐

N. Will the project increase the volume of water supply? Yes ☒ No ☐

O. What volume of water is the project anticipated to deliver/ treat per year? 120,665 Acre-Feet/Year

P. Current Water Supply Information

Surface Water Supply Source / Provider Names	Certificate No.	Source County	Annual Volume and Unit
North Texas Municipal Water District	See attached sheet	See attached sheet	See attached sheet
Groundwater Source Aquifer	**Well Field location**	**Source County**	**Annual Volume and Unit**
N/A	N/A	N/A	N/A

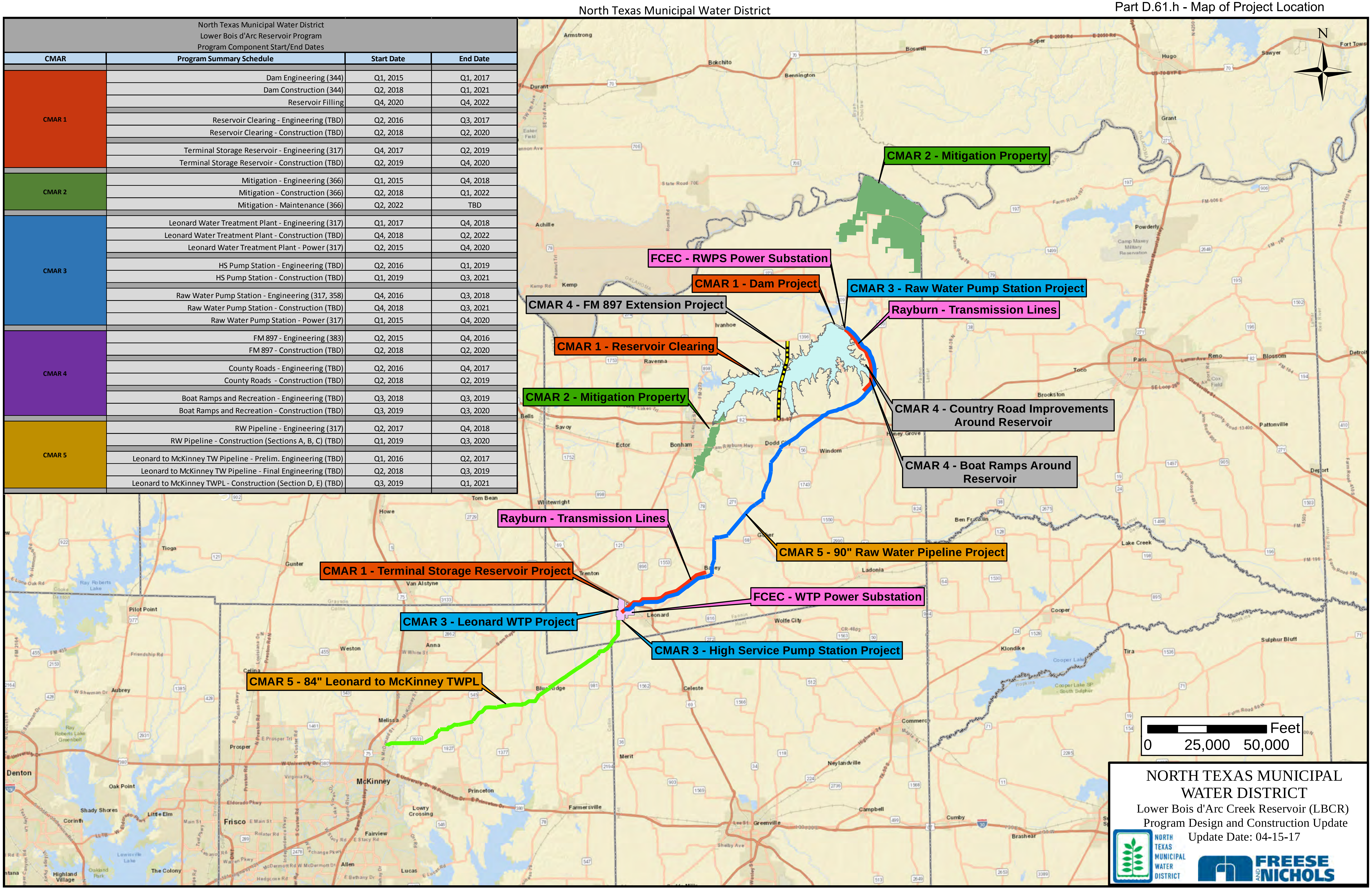
Q. Proposed Water Supply Associated Directly with the Proposed Project

Surface Water Supply Source / Provider Names	Certificate No.	Source County	Annual Volume and Unit
Lower Bois d'Arc Creek Reservoir/North Texas Municipal Water District	12151	Fannin	120,665 AF/y
Groundwater Source Aquifer	**Well Field location:**	**Source County**	**Annual Volume and Unit**
N/A	N/A	N/A	N/A

R. Consulting Engineer Name	Telephone No.	E-mail address
Freese and Nichols, Inc.	972-624-9216	jp@freese.com
S. Applicant Contact Name, Title	**Telephone No.**	**E-mail address**
Steve Long - Reservoir Project Manager	469-626-4713	slong@ntmwd.com

North Texas Municipal Water District
Lower Bois d'Arc Reservoir Program
Program Component Start/End Dates

CMAR	Program Summary Schedule	Start Date	End Date
CMAR 1	Dam Engineering (344)	Q1, 2015	Q1, 2017
	Dam Construction (344)	Q2, 2018	Q1, 2021
	Reservoir Filling	Q4, 2020	Q4, 2022
	Reservoir Clearing - Engineering (TBD)	Q2, 2016	Q3, 2017
	Reservoir Clearing - Construction (TBD)	Q2, 2018	Q2, 2020
	Terminal Storage Reservoir - Engineering (317)	Q4, 2017	Q2, 2019
	Terminal Storage Reservoir - Construction (TBD)	Q2, 2019	Q4, 2020
CMAR 2	Mitigation - Engineering (366)	Q1, 2015	Q4, 2018
	Mitigation - Construction (366)	Q2, 2018	Q1, 2022
	Mitigation - Maintenance (366)	Q2, 2022	TBD
CMAR 3	Leonard Water Treatment Plant - Engineering (317)	Q1, 2017	Q4, 2018
	Leonard Water Treatment Plant - Construction (TBD)	Q4, 2018	Q2, 2022
	Leonard Water Treatment Plant - Power (317)	Q2, 2015	Q4, 2020
	HS Pump Station - Engineering (TBD)	Q2, 2016	Q1, 2019
	HS Pump Station - Construction (TBD)	Q1, 2019	Q3, 2021
	Raw Water Pump Station - Engineering (317, 358)	Q4, 2016	Q3, 2018
	Raw Water Pump Station - Construction (TBD)	Q4, 2018	Q3, 2021
	Raw Water Pump Station - Power (317)	Q1, 2015	Q4, 2020
CMAR 4	FM 897 - Engineering (383)	Q2, 2015	Q4, 2016
	FM 897 - Construction (TBD)	Q2, 2018	Q2, 2020
	County Roads - Engineering (TBD)	Q2, 2016	Q4, 2017
	County Roads - Construction (TBD)	Q2, 2018	Q2, 2019
	Boat Ramps and Recreation - Engineering (TBD)	Q3, 2018	Q3, 2019
	Boat Ramps and Recreation - Construction (TBD)	Q3, 2019	Q3, 2020
CMAR 5	RW Pipeline - Engineering (317)	Q2, 2017	Q4, 2018
	RW Pipeline - Construction (Sections A, B, C) (TBD)	Q1, 2019	Q3, 2020
	Leonard to McKinney TW Pipeline - Prelim. Engineering (TBD)	Q1, 2016	Q2, 2017
	Leonard to McKinney TW Pipeline - Final Engineering (TBD)	Q2, 2018	Q3, 2019
	Leonard to McKinney TWPL - Construction (Section D, E) (TBD)	Q3, 2019	Q1, 2021



NORTH TEXAS MUNICIPAL WATER DISTRICT
Lower Bois d'Arc Creek Reservoir (LBCR)
Program Design and Construction Update
Update Date: 04-15-17

The design year for the ultimate capacity of Leonard WTP, HSPS and treated water pipeline matches the design year of the LBCR. However, only the initial phase of these projects are included in this SWIFT application. The next expansion of Leonard WTP and HSPS is currently scheduled for 2026 and a parallel treated water pipeline is scheduled for 2032.

NTMWD Surface Water Rights/Contracts

CA 2410 G – Lavon Lake – Collin County, Texas; NTMWD water right: 118,840 ac-ft/yr plus return flows from Wilson Creek Wastewater Treatment Plant and return flows from 16 wastewater treatment plants in the East Fork of the Trinity River

P-5003 – Lake Texoma – Grayson County, Texas; NTMWD water right: 77,300 ac-ft/yr

P-4301A – Lake Texoma – Grayson County, Texas; Purchase from Greater Texoma Utility Authority: 10,000 ac-ft/yr

P-4797 – Lake Chapman – Hopkins & Delta Counties, Texas; NTMWD water right: 54,000 ac-ft/yr

P-4798 – Lake Chapman – Hopkins & Delta Counties, Texas; Purchase from City of Cooper, Texas:

3,214 ac-ft/yr

CA – 4669C & 4670A – Lake Tawakoni & Lake Fork - Hunt, Rains, & Van Zandt Counties, Texas; Purchase from Sabine River Authority:

47,620 ac-ft/yr

Fannin County
Tammy Biggar Fannin County Clerk
101 E. Sam Rayburn Dr., #102
Bonham, Texas 75418

70 2015 00003437

Instrument Number: 2015-3437

As

Recorded On: August 03, 2015 **Recordings Real Property**

Parties: NORTH TEXAS MUNICIPAL WATER DISTRICT **Billable Pages: 9**

To **PUBLIC** **Number of Pages: 11**

Comment: WATER USE PERMIT

(Parties listed above are for Clerks reference only)

** Examined and Charged as Follows: **

Recordings Real Property	58.00
Total Recording:	**58.00**

************ DO NOT REMOVE. THIS PAGE IS PART OF THE INSTRUMENT ************

File Information: **Record and Return To:**

Document Number: 2015-3437
Receipt Number: 248095
Recorded Date/Time: August 03, 2015 11:53:04A
Book-Vol/Pg: BK-OR VL-1817 PG-135
User / Station: V Vandeventer - Cash Station #1

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

THE STATE OF TEXAS
COUNTY OF TRAVIS
I HEREBY CERTIFY THAT THIS IS A TRUE AND CORRECT COPY OF A TEXAS COMMISSION ON ENVIRONMENTAL QUALITY DOCUMENT, WHICH IS FILED IN THE PERMANENT RECORDS
JUN 29 2015
OF THE COMMISSION. GIVEN UNDER MY HAND AND THE SEAL OF OFFICE ON
Bridget C. Bohac
BRIDGET C. BOHAC, CHIEF CLERK
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

WATER USE PERMIT

PERMIT NO. 12151		TYPE	§§ 11.121, 11.085, 11.046
Permittee:	North Texas Municipal Water District	Address:	P.O. Box 2408 Wylie, TX 75098
Filed:	June 26, 2007	Granted:	June 26, 2015
Purposes:	Municipal, Industrial, Agricultural, and Recreation	Counties:	Collin, Dallas, Denton, Fannin, Hopkins, Hunt, Kaufman, Rains and Rockwall Counties
Watercourse:	Lower Bois d'Arc Creek, tributary of the Red River	Watershed:	Red, Trinity, and Sulphur River Basins

WHEREAS, North Texas Municipal Water District (NTMWD, Applicant or Permittee) seeks a Water Use Permit to construct and maintain a dam and reservoir (Lower Bois d'Arc Creek Reservoir) with a maximum normal operating capacity of 367,609 acre-feet of water and a surface area of 16,526 acres on Bois d'Arc Creek, tributary of the Red River, Red River Basin in Fannin County for recreation purposes; and

WHEREAS, Applicant also seeks authorization to divert and use not to exceed 175,000 acre-feet of water per year from any point on the perimeter of the proposed reservoir at a maximum combined diversion rate of 365.15 cfs (163,889 gpm) for municipal, industrial and agricultural purposes; and

WHEREAS, Applicant seeks authorization to reuse the return flows generated from the diversion and use of water from the proposed reservoir and until facilities are developed to reuse diverted water, such water will be returned to the Red , Sulphur, and Trinity River Basins; and

WHEREAS, Applicant also seeks an interbasin transfer authorization to use the water within the Trinity River Basin, and within that portion of Fannin County located in the Sulphur River Basin. NTMWD's service area is currently located within Collin, Dallas, Denton, Fannin, Hopkins, Hunt, Kaufman, Rains and Rockwall Counties; and

WHEREAS, Applicant indicates the proposed Lower Bois d'Arc Creek Reservoir will be located 15.2 miles in a northeast direction from City of Bonham and 9.7 miles in a north-northwest direction from the Town of Honey Grove. Station 42+33 on the centerline of the proposed dam will be S 23.2677° E, 514 feet from the southeast corner of O.H.P. Wood Survey, Abstract No. 1177, in Fannin County, Texas, also being at 33.7180° N Latitude, 95.9822° W

Longitude. The proposed dam will be located in the George W. King Original Survey, Abstract No. 604; the James Kerr Original Survey, Abstract No. 614; and the John Reynolds Original Survey, Abstract 931 in Fannin County, Texas. The proposed dam and reservoir will be located on the land of the Applicant, which will be acquired prior to construction; and

WHEREAS, Applicant indicates that diversions may overdraft the firm yield of the reservoir as part of a system operation with existing NTMWD supplies to achieve maximum conservation of limited water resources; and

WHEREAS, this application is subject to the obligations of the state of Texas pursuant to the terms of the Red River Compact; and

WHEREAS, the Texas Commission on Environmental Quality (TCEQ) finds that jurisdiction over the application is established; and

WHEREAS, Applicant submitted the *Proposed Lower Bois d'Arc Creek Reservoir Mitigation Plan*, which was accepted and approved by the Executive Director; and

WHEREAS, Applicant submitted the *North Texas Municipal Water District Reservoir Accounting Plan*, which was accepted and approved by the Executive Director; and

WHEREAS, Applicant submitted the *North Texas Municipal Water District Monitoring Plan for Proposed Lower Bois d'Arc Creek Reservoir,* which was accepted and approved by the Executive Director; and

WHEREAS, the Executive Director recommends that special conditions be included in the permit; and

WHEREAS, multiple requests for a contested case hearing on the application were granted; and

WHEREAS, as a result of negotiations with all parties, all hearing requests were withdrawn; and

WHEREAS, the Commission has complied with the requirements of the Texas Water Code and Rules of the Texas Commission on Environmental Quality in issuing this water use permit;

NOW, THEREFORE, this Water Use Permit No. 12151 is issued to North Texas Municipal Water District subject to the following terms and conditions:

1. IMPOUNDMENT

Permittee is authorized to construct and maintain a dam and reservoir (Lower Bois d'Arc Creek Reservoir) with a maximum normal operating capacity of 367,609 acre-feet of water on Bois d'Arc Creek, tributary of the Red River, Red River Basin in Fannin County located 15.2 miles in a northeast direction from City of Bonham and 9.7 miles in a north-northwest direction from the Town of Honey Grove. Station 42+33 on the centerline of the proposed dam will be S 23.2677° E, 514 feet from the southeast corner of O.H.P. Wood Survey, Abstract No. 1177, in Fannin County, Texas, also being at 33.7180° N Latitude, 95.9822° W Longitude. The proposed dam will be located in the George W. King Original Survey, Abstract No. 604 the James Kerr Original Survey, Abstract No. 614; and the John Reynolds Original Survey, Abstract 931 in Fannin County, Texas.

2. USE

A. Permittee is authorized to use the impounded water for recreation purposes.

B. Permittee is authorized to divert and use not to exceed 175,000 acre-feet of water per year for municipal, industrial and agricultural purposes within its service area in Collin, Dallas, Denton, Fannin, Hopkins, Hunt, Kaufman, Rains and Rockwall Counties.

C. Permittee is authorized an interbasin transfer to use the water appropriated hereunder within the Trinity River Basin, and within that portion of Fannin County located in the Sulphur River Basin.

D. Permittee is authorized to divert and reuse the return flows resulting from the diversion and use of water from the Lower Bois d'Arc Creek Reservoir as authorized under this permit, subject to the Permittee's compliance with Special Condition 6.Y.

3. DIVERSION

A. Permittee is authorized to divert the water authorized herein from any point on the perimeter of Lower Bois d'Arc Creek Reservoir.

B. Permittee is authorized to divert the water authorized herein at a maximum combined diversion rate of 365.15 cfs (163,889 gpm).

4. TIME PRIORITY

The time priority for this right is June 26, 2007.

5. CONSERVATION

Permittee shall fully implement water conservation plans, developed in accordance with this provision, that provide for the utilization of those reasonably available practices, techniques, and technologies that reduce the consumption of water for municipal use on a gallons per-capita per day basis within NTMWD's service area and that, for each category of use authorized by this permit not including recreation use, prevent the waste of water, prevent or reduce the loss of water, improve the efficiency in the use of water, increase the recycling and reuse of water, and prevent the pollution of water, so that a water supply is made available for future or alternative uses. Permittee shall develop, submit and implement water conservation plans as required by law. Each water conservation plan submitted to the Executive Director shall be designed to comply with relevant state conservation standards then in effect, and, at the time of submission, shall be designed to achieve, for each category of authorized uses, the highest practicable levels of water conservation and efficiency achievable within the jurisdiction of the Permittee. Permittee shall report annually to the Executive Director on the implementation of its water conservation plans and shall make both its most current water conservation plan and the annual reports on the implementation of its conservation plans easily accessible to the public through electronic and other means.

Such plans shall ensure that every water supply contract entered into, on or after the effective date of this permit, including any contract extension or renewal, requires that each successive wholesale customer shall develop and implement conservation measures that will result in the highest practicable levels of water conservation and efficiency in order to comply with TWC § 11.085 (l)(2), and that each wholesale customer will report, no less frequently than once every year, to Permittee on the implementation of those conservation measures. If Permittee enters into a water supply contract on or after the effective date of this permit that authorizes the resale of water, such contract shall require that each successive customer in the resale of the authorized water implement water conservation measures at least as stringent as those included in Permittee's approved water conservation plan.

6. SPECIAL CONDITIONS

A. Permittee shall only impound and divert water authorized by this permit in accordance with the most recently approved *North Texas Municipal Water District Reservoir Accounting Plan*. Permittee shall maintain said plan in electronic format and make the data available to the Executive Director upon request. Any modifications to the *North Texas Municipal Water District Reservoir Accounting Plan* shall be approved by the Executive Director. Only modifications that would result in a change to a permit term must be in the form of an amendment to the permit. Should Permittee fail to maintain the accounting plan or timely notify the Executive Director of any modifications to the plan, Permittee shall immediately cease impoundments and diversions authorized in Paragraph 1. IMPOUNDMENT and Paragraph 2. USE, and either apply to amend the permit, or voluntarily forfeit the permit. Permittee shall provide prior notice to the Executive Director of any proposed modifications to the accounting plan and provide copies of the appropriate documents effectuating such changes.

B. All mitigation plans and monitoring required herein shall comply with requirements set forth in 33 United States Code §1341, commonly known as the federal Clean Water Act (CWA), §401 and 30 TAC Chapter 279. Mitigation and monitoring plans shall also comply with the requirements in §404 of the CWA as implemented through the U.S. Army Corps of Engineers permit for the Lower Bois d'Arc Creek Reservoir.

C. Impoundment of water and diversion under this permit is contingent upon the initiation of implementation of the approved *Mitigation Plan for the Proposed Lower Bois d'Arc Creek Reservoir*. Permittee's continued authorization of impoundment and diversion of water under this permit is contingent on timely completion of implementation in accordance with the terms of that plan. Modifications or changes to the plan must be approved by the Executive Director. Only modifications that would result in a change to a permit term must be in the form of an amendment to the permit.

D. Permittee shall document compliance with the terms and conditions of this permit relating to environmental flow requirements, as set out in Special Conditions 6.E. through 6.R., in the most recently approved *North Texas Municipal Water District Reservoir Accounting Plan*.

E. Permittee shall determine compliance with pulse flow conditions and subsistence period freshet conditions using measured flows at USGS Gage 07332622, Bois d'Arc Creek at FM 409 near Honey Grove, TX or, in the case of deliberate releases to pass qualifying pulse flow events or qualifying subsistence period freshets, measurements of the releases from the reservoir as documented in the most recently approved *North Texas Municipal Water District Reservoir Accounting Plan.*

F. If calculated reservoir inflows, as determined in the most recently approved *North Texas Municipal Water District Reservoir Accounting Plan,* constitute a qualifying pulse flow event as defined in Special Condition 6.L., the pulse flow requirement for the season has not been met, and the flows at USGS gage 07332622 for the same time period do not exceed the pulse flow trigger requirement, the pulse shall be passed through the reservoir in a manner as close as practicable to the applicable seasonal release pattern identified in the most recently approved *North Texas Municipal Water District Reservoir Accounting Plan.* Permittee may release water to augment naturally occurring high flow events so that flows at the USGS Gage 07332622 meet or exceed the pulse flow trigger requirement, subject to the requirements of Special Condition 6.J.

G. Consistent with Special Condition 6.F., when calculated reservoir inflows, as determined in the most recently approved *North Texas Municipal Water District Reservoir Accounting Plan,* equal or exceed the pulse flow trigger requirements of Special Condition 6.R. and the pulse flow requirement for the season has not been met, inflows to the reservoir in excess of applicable base flow requirements may be temporarily impounded. Consistent with Special Condition 6.F, if the calculated volume or duration criterion for an applicable qualifying pulse flow event, as specified in Special Condition 6.L., is met, Permittee shall promptly release the temporarily impounded water in a manner as close as practicable to the applicable seasonal release pattern identified in the most recently approved *North Texas Municipal Water District Reservoir Accounting Plan.*

H. Permittee is not required to release stored water, except temporarily impounded water as described in Special Condition 6.G. or a qualifying subsistence period freshet required to be released pursuant to Special Condition 6.Q., to meet the environmental flow requirements in this permit. All requirements for pass-throughs of inflows or releases of temporarily impounded water pursuant to Special Conditions 6.E. through 6.R. are limited to the volume of calculated inflows to the reservoir.

I. Subject to compliance with the subsistence and base flow requirements of Special Conditions 6.Q and 6.R, inflows may be stored if either: (i) the pulse flow requirement for a season has been met; or (ii) inflows to the reservoir are below the applicable pulse flow trigger; or (iii) inflows equal or exceed the applicable pulse flow trigger but the calculated volume and duration criteria for a qualifying pulse flow event are both not met. If Permittee has stored water, other than temporarily stored water pursuant to Special Condition 6.G. that is part of a qualifying pulse flow event or water that is part of a qualifying subsistence period freshet required to be passed pursuant to Special Condition 6.Q., then in accordance with the terms and conditions of this permit, including any applicable environmental flow requirements in effect at the time the water was stored, Permittee may divert and use that stored water, even if the applicable environmental flow requirement is not met at the time of the subsequent diversion and use of that stored water.

J. If a naturally occurring qualifying pulse flow event is recorded at USGS gage 07332622, such pulse flow event shall satisfy a pulse flow requirement for that event within the respective season. In addition, a pulse flow requirement for an event within a season may be satisfied by a naturally occurring high flow event which has been augmented by reservoir releases as authorized in Special Condition 6.F., but only if the applicable trigger, duration and volume criteria are all met as measured at that gage.

K. Each season is independent of the preceding and subsequent seasons with respect to the pulse flow requirements of Special Condition 6.R.

L. Except as otherwise provided in Special Condition 6.J., a pulse flow is considered to be a qualifying pulse flow event if the pulse flow trigger requirement is met and either the pulse flow volume or duration requirement is met, as specified in Special Condition 6.R.

M. Permittee shall determine compliance with the requirement to pass reservoir inflows up to the applicable subsistence or base flow values of Special Condition 6.R. based on measured flows at the outlet works of the dam.

N. Seasons are defined as Fall-Winter (November - February), Spring (March – June), and Summer (July - October).

O. Reservoir storage is the trigger for determining the applicable instream flow requirements in Special Conditions 6.E. through 6.R. Subsistence flow requirements apply when storage is less than 40% of the authorized conservation storage. Base flow and pulse flow requirements apply when conservation storage is equal to or greater than 40%.

P. Pulse flow requirements are not applicable under subsistence flow conditions.

Q. When subsistence flow requirements are in effect, as provided in Special Condition 6.O., inflows into the reservoir up to 1 cfs shall be passed downstream and a subsistence period freshet pass-through requirement shall be in effect.

A qualifying subsistence period freshet is characterized by a trigger flow of at least 20 cfs and either a volume of at least 69 acre-feet or a duration of at least three days. Volume will be determined based on cumulative flows occurring over a three-day period, beginning with the day during which the trigger flow occurs. Duration will be determined based on the number of days of inflow greater than 1 cfs, beginning with the day on which the trigger flow occurs. During the time that subsistence flow requirements are in effect pursuant to Special Condition 6.O., Permittee shall track flows at USGS gage 07332622, Bois d'Arc Creek at FM 409, and inflows to the reservoir, to determine if a qualifying subsistence period freshet has occurred at either location.

If, while subsistence flow requirements are in effect pursuant to Special Condition 6.O., a 60-day period occurs without a qualifying subsistence period freshet at USGS gage 07332622, Bois d'Arc Creek at FM 409, but, during which, a qualifying subsistence period freshet has occurred as reservoir inflow, the subsistence period freshet shall be promptly passed through the dam. If a qualifying subsistence period freshet has not occurred as reservoir inflow during such 60-day period, flows will continue to be monitored to determine when a qualifying subsistence period freshet occurs at the FM 409 gage or a qualifying subsistence period freshet has occurred as inflow to the reservoir. During that period of continued monitoring, a qualifying subsistence period freshet will be passed as soon as such an event occurs as inflow into the reservoir unless a qualifying subsistence period freshet has occurred at the FM 409 gage.

As closely as practicable, the subsistence period freshet pass-through shall average 20 cfs the first day, 10 cfs the second day, and 5 cfs the third day. As long as subsistence flow requirements are in effect, once a qualifying subsistence period freshet has occurred at USGS gage 07332622, Bois d'Arc Creek at FM 409, or such flow has been passed through the dam, a new 60-day period will be started for the purpose of determining when a qualifying subsistence flow event must be passed through the dam. In passing an individual subsistence period freshet through the dam, Permittee shall never be required to pass a volume of more than 69 acre-feet.

R. Impoundment or diversion of reservoir inflows when flows are at or below the following values, at the applicable measurement points described in Special Conditions 6.E. and 6.M., is authorized only in compliance with Special Conditions 6.A. and 6.D. through 6.Q., above:

Season	**Subsistence**	**Base**	**Pulse**
Fall-Winter	1 cfs*	3 cfs	2 per season Trigger: 150 cfs Volume: 1,000 af Duration: 7 days
Spring	1 cfs*	10 cfs	2 per season Trigger: 500 cfs Volume: 3,540 af Duration: 10 days
Summer	1 cfs*	3 cfs	1 per season Trigger: 100 cfs Volume: 500 af Duration: 5 days

cfs = cubic feet per second
af = acre-feet
*A subsistence period freshet requirement with a trigger level of 20 cfs, a volume of 69 af, and a duration of 3 days, as further defined in Special Condition 6.Q., also applies.

This special condition is subject to adjustment by the commission if the commission determines, through an expedited public review process, that such adjustment is appropriate to achieve compliance with applicable environmental flow standards adopted pursuant to Texas Water Code § 11.1471. Any adjustment shall be made in accordance with the provisions of Texas Water Code § 11.147(e-1).

S. Permittee shall implement measures to minimize impacts to aquatic resources due to entrainment or impingement including, but not limited to, the installation of screens at the diversion facilities. Such measures shall include intake diversion facilities designed and operated to result in a velocity of water into the diversion facility of no greater than 1 foot-per-second. At all times that diversions are occurring, the intake diversion facilities shall be equipped with screens resulting in individual openings no larger than 1 square inch in size.

T. After commencing deliberate impoundment in the reservoir, Permittee shall conduct hydrologic and water quality monitoring in accordance with the approved North Texas Municipal Water District Monitoring Plan. Permittee shall submit a summary of hydrologic and water quality monitoring data to the Executive Director on an annual basis. Permittee shall submit to the Executive Director a summary report of hydrologic and water quality data in the fifth and tenth years following deliberate impoundment in the reservoir and every five years thereafter for as long as monitoring under Special Condition 6.U. continues. Hydrologic and water quality monitoring for all sites and parameters, other than daily flows at USGS Gage 07332622, Bois d'Arc Creek at FM 409 near Honey Grove, TX, and water quality monitoring associated with reservoir releases undertaken pursuant to Special Condition 6.W., may cease after ten years, or when instream monitoring specified in Special Condition 6.U. ceases, whichever is later.

U. Permittee shall conduct instream monitoring of Bois d'Arc Creek at the FM 409 Site and, at a minimum, one additional site within the non-channelized portion of the Creek farther downstream, in the first, third, fifth and tenth years following deliberate impoundment of water in the reservoir. In addition, if diversions from the reservoir, as calculated on an annualized basis, have not reached 100,000 acre-feet prior to the fifth year following deliberate impoundment, instream monitoring shall continue every fifth year thereafter until instream monitoring has been undertaken during two years following the year that diversions reach 100,000 acre-feet per year. Instream monitoring during any year in which it is required shall include a twice per year assessment of fish and macroinvertebrate communities and physical habitat assessment at each site, plus a twice per year analysis of water quality data collected at the USGS Gage 07332622, Bois d'Arc Creek at FM 409 near Honey Grove, TX. All aquatic biological monitoring and physical habitat assessments shall take place in the index period (March 15 – October 15) with at least one of the twice per year monitoring events taking place in the critical period (July 1 – September 15). Aquatic biological monitoring and habitat characterization shall follow TCEQ protocols set forth in the most recently approved *Surface Water Quality Monitoring Procedures, Volume 2: Methods for Collecting and Analyzing Biological Community and Habitat Data.*

V. Permittee shall submit a report to the Executive Director summarizing the twice per year monitoring activities in Special Condition 6.U. within six months after the second monitoring event in any year is completed. The report shall detail all monitoring efforts and shall include an assessment of the fish and macroinvertebrate communities and the biological metric scoring criteria used to assess aquatic life uses. Should aquatic life use not meet the water quality standards for Segment 0202A or future segment designation, Permittee shall develop and implement remedial management strategies, subject to Executive Director approval, to meet the designated aquatic life use. Permittee shall also submit summary reports to the Executive Director no later than six months after the end of the fifth and tenth year monitoring events, and any subsequent year's monitoring events, that compare all monitoring data to baseline conditions.

W. Permittee shall construct and operate a multilevel outlet tower and regulate releases to ensure that water released from the reservoir maintains DO and temperature levels that meet the surface water quality standards for Segment 0202A or future segment designation. Permittee shall monitor water quality near the outlet tower in accordance with the approved Monitoring Plan during the life of the permit.

X. Permittee shall install and maintain measuring devices which account for, within 5% accuracy, the quantity of water diverted from the points authorized above in Paragraph 3. DIVERSION. Permittee shall allow representatives of the TCEQ reasonable access to the property to inspect the measuring device.

Y. Prior to the diversion and reuse of the return flows authorized pursuant to Paragraph 2.D. USE, resulting from the diversion and use of water from the Lower Bois d'Arc Creek Reservoir as authorized under this permit, Permittee shall apply for and be granted an amendment to identify all specific points of discharge and diversion, and secure the appropriate authorizations to transfer such return flows through state watercourses pursuant to TWC §11.042, except to the extent such points of discharge, diversion, and transfer may be authorized by separate grant of authority from the Commission.

7. TIME LIMITATIONS

A. Construction of the dam for Lower Bois d'Arc Creek Reservoir must be in accordance with plans approved by the Executive Director. Construction of the dam without final approval of the construction plans is a violation of this authorization.

B. Construction shall begin within two years of issuance of this permit and be completed within seven years of the issuance of this permit, unless Permittee applies for and is subsequently granted an extension of time before the expiration of these time limitations.

This water use permit is issued subject to all superior and senior water rights in the Red River Basin.

This permit is issued subject to the obligations of the State of Texas pursuant to the terms of the Red River Compact.

Permittee agrees to be bound by the terms, conditions, and provisions contained herein and such agreement is a condition precedent to the granting of this permit.

All other matters requested in the application which are not specifically granted by this water use permit are denied.

This water use permit is issued subject to the Rules of the Texas Commission on Environmental Quality and to the right of continuing supervision of State resources exercised by the Commission.

For the Commission

ISSUED: **June 26, 2015**

Doc	Bk	Vol	Pg
3437	OR	1817	145

Filed for Record in:
Fannin County
Honorable Tammy Biggar
County Clerk
On: Aug 03,2015 at 11:53A

As a
Recordings Real Property

Document Number: 3437

Amount 58.00

Receipt Number - 248095
By
Vickie Vandeventer, Deputy

ANY PROVISION HEREIN WHICH RESTRICTS THE SALE, RENTAL, OR USE OF THE DESCRIBED REAL PROPERTY BECAUSE OF COLOR OR RACE IS INVALID AND UNENFORCEABLE UNDER FEDERAL LAW.

STATE OF TEXAS COUNTY OF FANNIN

I hereby certify that this instrument was filed on the date and time stamped hereon by me and was duly recorded in the volume and page of the named records of: Fannin County as stamped hereon by me.

Aug 03,2015

By: Vicki Vandeventer Deputy

Tammy Biggar, Fannin County Clerk
Fannin County

Bryan W. Shaw, Ph.D., P.E., *Chairman*
Toby Baker, *Commissioner*
Richard A. Hyde, P.E., *Executive Director*

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY
Protecting Texas by Reducing and Preventing Pollution

June 29, 2015

CERTIFIED MAIL

Mr. Martin C. Rochelle
Lloyd Gosselink, Attorneys at Law
816 Congress Avenue, Suite 1900
Austin, Texas 78701

RE: North Texas Municipal Water District
WRPERM 12151,CN601365448, RN105156137, RN105156145, RN105156152
Water Use Permit No. 12151
TWC §§11.121, 11.085, 11.042, and 11.046, Requiring Mailed and Published Notice
Lower Bois d'Arc Creek, Red, Sabine, Sulphur, and Trinity River Basins
Fannin County

Dear Mr. Rochelle:

Enclosed are certified copies of the above referenced document.

The applicant, North Texas Municipal Water District, is instructed to ensure that the official record of this water right is filed with the County Clerk of the county in which the appropriation is to be made.

The applicant is responsible for making payment arrangements with the **Fannin** County Clerk's Office for filing of the documents in the official records. An additional certified copy is enclosed for the purpose of filing with the appropriate County Clerk.

As proof of filing, please ensure that the enclosed card is completed by the Fannin County Clerk's Office and returned to the Water Rights Permitting & Availability Section (MC 160), Texas Commission on Environmental Quality, P.O. Box 13087, Austin, Texas 78711-3087.

This action is taken under the authority delegated by the Executive Director of the Texas Commission on Environmental Quality.

Should you have questions, please contact Mr. Chris Kozlowski of the Texas Commission on Environmental Quality's Water Rights Permitting & Availability Section at (512) 239-1801, or if by correspondence, include MC 160 in the letterhead address below.

Sincerely,

Allison Woodall for
Kevin McCalla, Acting Director
Water Availability Division

KM/ck

Enclosures

P.O. Box 13087 • Austin, Texas 78711-3087 • 512-239-1000 • tceq.texas.gov

Lloyd
Gosselink
ATTORNEYS AT LAW

816 Congress Avenue, Suite 1900
Austin, Texas 78701
Telephone: (512) 322-5800
Facsimile: (512) 472-0532
www.lglawfirm.com

Mr. Rochelle's Direct Line: (512) 322-5810
mrochelle@lglawfirm.com

July 28, 2015

Mr. Mike Rickman
Deputy Executive Director
North Texas Municipal Water District
P.O. Box 2408
Wylie, Texas 75098

VIA OVERNIGHT MAIL

Re: Lower Bois d'Arc Creek Reservoir Water Use Permit No. 12151 (446-29)

Dear Mike:

Enclosed please find an original certified copy of the above-referenced water use permit along with a recordation card. Now that the permit is final and non-appealable, please arrange for the permit to be recorded with the Fannin County Clerk and have the Clerk fill out the recordation card. Once the card is filled out, please have it forwarded to the TCEQ--the card is already addressed to the proper group at the agency.

We appreciate the opportunity to assist the District in obtaining this important permit for the Lower Bois d'Arc Creek Reservoir project. If you have any questions regarding the enclosed materials, please feel free to contact me, at your convenience.

Sincerely,

Martin C. Rochelle

ENCLOSURES

cc: Mr. Robert McCarthy
Mr. Jason Hill
Ms. Sara Thornton

4862243.1

JUL 29 2015

PERMIT NO./CERTIFICATE NO.: 12151

NAME: North Texas Municipal Water District

Date Recorded:

Volume Page No.

of the records of the

County, Texas.

By

County Clerk and/or Deputy

TNRCC-0100 (Rev. 03-13-96)

STATE OF TEXAS §

COUNTY OF Fannin §

§

SURFACE WATER AFFIDAVIT

Before me, the undersigned notary, on this day personally appeared a person Judd R. Sanderson ____ whose identity is known to me. After I administered an oath to him/her, upon his/her oath he/she said:

1. I am over 18 years of age, of sound mind, and capable of making this affidavit. The facts stated in this affidavit are within my personal knowledge and are true and correct.
2. I am an authorized representative of North Texas Municipal Water District, an entity that has filed an application for financial assistance with the Texas Water Development Board for a project that proposes the development of a new surface water supply source.
3. Does the applicant possess a Certificate of Adjudication and/or Water Rights Permit(s) issued by the Texas Commission on Environmental Quality or a predecessor agency authorizing the appropriation and use of the surface water needed for the Project?

   Yes ☒ No ☐

   Please attach a copy of the Certificate(s) of Adjudication and Water Rights Permit(s).

   Item attached: Yes ☒ No ☐
4. Does the applicant have the contractual right to use the surface water from an entity that enjoys the right to appropriate and use the surface water needed for the project?

   Yes ☐ No ☒

   Please attach a copy of any draft or executed water supply contract, lease or other legal instrument providing contractual authorization to use the surface water needed for the Project.

   Item attached: Yes ☐ No ☒

Please identify the Certificate of Adjudication(s) and Water Rights Permit(s) possessed by the wholesale water provider pursuant to which the contract, lease or other legal instrument has been or will be executed.

Certificate of Adjudications: NA

Item attached: Yes ☐ No ☒

Water Rights Permit(s): Water Use Permit #12151

Item attached: Yes ☒ No ☐

Signed the day of April 27, 2017

Name: Judd R Sanderson

Title: Deputy Director

Sworn to and subscribed before me by Judd Sanderson on April 27, 2017

Leann Bumpus

Notary Public in and for the State of Texas

[SEAL]

LEANN BUMPUS
Notary Public, State of Texas
Comm. Expires 05-18-2020
Notary ID 10188600

My Commission expires: 5/18/20

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

WATER USE PERMIT

THE STATE OF TEXAS
COUNTY OF TRAVIS
I HEREBY CERTIFY THAT THIS IS A TRUE AND CORRECT COPY OF A TEXAS COMMISSION ON ENVIRONMENTAL QUALITY DOCUMENT, WHICH IS FILED IN THE PERMANENT RECORDS
JUN 29 2015
OF THE COMMISSION. GIVEN UNDER MY HAND AND THE SEAL OF OFFICE ON
Bridget C. Bohac
BRIDGET C. BOHAC, CHIEF CLERK
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

PERMIT NO. 12151		TYPE	§§ 11.121, 11.085, 11.046
Permittee:	North Texas Municipal Water District	Address:	P.O. Box 2408 Wylie, TX 75098
Filed:	June 26, 2007	Granted:	June 26, 2015
Purposes:	Municipal, Industrial, Agricultural, and Recreation	Counties:	Collin, Dallas, Denton, Fannin, Hopkins, Hunt, Kaufman, Rains and Rockwall Counties
Watercourse:	Lower Bois d'Arc Creek, tributary of the Red River	Watershed:	Red, Trinity, and Sulphur River Basins

WHEREAS, North Texas Municipal Water District (NTMWD, Applicant or Permittee) seeks a Water Use Permit to construct and maintain a dam and reservoir (Lower Bois d'Arc Creek Reservoir) with a maximum normal operating capacity of 367,609 acre-feet of water and a surface area of 16,526 acres on Bois d'Arc Creek, tributary of the Red River, Red River Basin in Fannin County for recreation purposes; and

WHEREAS, Applicant also seeks authorization to divert and use not to exceed 175,000 acre-feet of water per year from any point on the perimeter of the proposed reservoir at a maximum combined diversion rate of 365.15 cfs (163,889 gpm) for municipal, industrial and agricultural purposes; and

WHEREAS, Applicant seeks authorization to reuse the return flows generated from the diversion and use of water from the proposed reservoir and until facilities are developed to reuse diverted water, such water will be returned to the Red , Sulphur, and Trinity River Basins; and

WHEREAS, Applicant also seeks an interbasin transfer authorization to use the water within the Trinity River Basin, and within that portion of Fannin County located in the Sulphur River Basin. NTMWD's service area is currently located within Collin, Dallas, Denton, Fannin, Hopkins, Hunt, Kaufman, Rains and Rockwall Counties; and

WHEREAS, Applicant indicates the proposed Lower Bois d'Arc Creek Reservoir will be located 15.2 miles in a northeast direction from City of Bonham and 9.7 miles in a north-northwest direction from the Town of Honey Grove. Station 42+33 on the centerline of the proposed dam will be S 23.2677° E, 514 feet from the southeast corner of O.H.P. Wood Survey, Abstract No. 1177, in Fannin County, Texas, also being at 33.7180° N Latitude, 95.9822° W

Longitude. The proposed dam will be located in the George W. King Original Survey, Abstract No. 604; the James Kerr Original Survey, Abstract No. 614; and the John Reynolds Original Survey, Abstract 931 in Fannin County, Texas. The proposed dam and reservoir will be located on the land of the Applicant, which will be acquired prior to construction; and

WHEREAS, Applicant indicates that diversions may overdraft the firm yield of the reservoir as part of a system operation with existing NTMWD supplies to achieve maximum conservation of limited water resources; and

WHEREAS, this application is subject to the obligations of the state of Texas pursuant to the terms of the Red River Compact; and

WHEREAS, the Texas Commission on Environmental Quality (TCEQ) finds that jurisdiction over the application is established; and

WHEREAS, Applicant submitted the *Proposed Lower Bois d'Arc Creek Reservoir Mitigation Plan*, which was accepted and approved by the Executive Director; and

WHEREAS, Applicant submitted the *North Texas Municipal Water District Reservoir Accounting Plan*, which was accepted and approved by the Executive Director; and

WHEREAS, Applicant submitted the *North Texas Municipal Water District Monitoring Plan for Proposed Lower Bois d'Arc Creek Reservoir,* which was accepted and approved by the Executive Director; and

WHEREAS, the Executive Director recommends that special conditions be included in the permit; and

WHEREAS, multiple requests for a contested case hearing on the application were granted; and

WHEREAS, as a result of negotiations with all parties, all hearing requests were withdrawn; and

WHEREAS, the Commission has complied with the requirements of the Texas Water Code and Rules of the Texas Commission on Environmental Quality in issuing this water use permit;

NOW, THEREFORE, this Water Use Permit No. 12151 is issued to North Texas Municipal Water District subject to the following terms and conditions:

1. IMPOUNDMENT

Permittee is authorized to construct and maintain a dam and reservoir (Lower Bois d'Arc Creek Reservoir) with a maximum normal operating capacity of 367,609 acre-feet of water on Bois d'Arc Creek, tributary of the Red River, Red River Basin in Fannin County located 15.2 miles in a northeast direction from City of Bonham and 9.7 miles in a north-northwest direction from the Town of Honey Grove. Station 42+33 on the centerline of the proposed dam will be S 23.2677° E, 514 feet from the southeast corner of O.H.P. Wood Survey, Abstract No. 1177, in Fannin County, Texas, also being at 33.7180° N Latitude, 95.9822° W Longitude. The proposed dam will be located in the George W. King Original Survey, Abstract No. 604 the James Kerr Original Survey, Abstract No. 614; and the John Reynolds Original Survey, Abstract 931 in Fannin County, Texas.

2. USE

   A. Permittee is authorized to use the impounded water for recreation purposes.

   B. Permittee is authorized to divert and use not to exceed 175,000 acre-feet of water per year for municipal, industrial and agricultural purposes within its service area in Collin, Dallas, Denton, Fannin, Hopkins, Hunt, Kaufman, Rains and Rockwall Counties.

   C. Permittee is authorized an interbasin transfer to use the water appropriated hereunder within the Trinity River Basin, and within that portion of Fannin County located in the Sulphur River Basin.

   D. Permittee is authorized to divert and reuse the return flows resulting from the diversion and use of water from the Lower Bois d'Arc Creek Reservoir as authorized under this permit, subject to the Permittee's compliance with Special Condition 6.Y.

3. DIVERSION

   A. Permittee is authorized to divert the water authorized herein from any point on the perimeter of Lower Bois d'Arc Creek Reservoir.

   B. Permittee is authorized to divert the water authorized herein at a maximum combined diversion rate of 365.15 cfs (163,889 gpm).

4. TIME PRIORITY

   The time priority for this right is June 26, 2007.

5. CONSERVATION

   Permittee shall fully implement water conservation plans, developed in accordance with this provision, that provide for the utilization of those reasonably available practices, techniques, and technologies that reduce the consumption of water for municipal use on a gallons per-capita per day basis within NTMWD's service area and that, for each category of use authorized by this permit not including recreation use, prevent the waste of water, prevent or reduce the loss of water, improve the efficiency in the use of water, increase the recycling and reuse of water, and prevent the pollution of water, so that a water supply is made available for future or alternative uses. Permittee shall develop, submit and implement water conservation plans as required by law. Each water conservation plan submitted to the Executive Director shall be designed to comply with relevant state conservation standards then in effect, and, at the time of submission, shall be designed to achieve, for each category of authorized uses, the highest practicable levels of water conservation and efficiency achievable within the jurisdiction of the Permittee. Permittee shall report annually to the Executive Director on the implementation of its water conservation plans and shall make both its most current water conservation plan and the annual reports on the implementation of its conservation plans easily accessible to the public through electronic and other means.

   Such plans shall ensure that every water supply contract entered into, on or after the effective date of this permit, including any contract extension or renewal, requires that each successive wholesale customer shall develop and implement conservation measures that will result in the highest practicable levels of water conservation and efficiency in order to comply with TWC § 11.085 (l)(2), and that each wholesale customer will report, no less frequently than once every year, to Permittee on the implementation of those conservation measures. If Permittee enters into a water supply contract on or after the effective date of this permit that authorizes the resale of water, such contract shall require that each successive customer in the resale of the authorized water implement water conservation measures at least as stringent as those included in Permittee's approved water conservation plan.

6. SPECIAL CONDITIONS

A. Permittee shall only impound and divert water authorized by this permit in accordance with the most recently approved *North Texas Municipal Water District Reservoir Accounting Plan*. Permittee shall maintain said plan in electronic format and make the data available to the Executive Director upon request. Any modifications to the *North Texas Municipal Water District Reservoir Accounting Plan* shall be approved by the Executive Director. Only modifications that would result in a change to a permit term must be in the form of an amendment to the permit. Should Permittee fail to maintain the accounting plan or timely notify the Executive Director of any modifications to the plan, Permittee shall immediately cease impoundments and diversions authorized in Paragraph 1. IMPOUNDMENT and Paragraph 2. USE, and either apply to amend the permit, or voluntarily forfeit the permit. Permittee shall provide prior notice to the Executive Director of any proposed modifications to the accounting plan and provide copies of the appropriate documents effectuating such changes.

B. All mitigation plans and monitoring required herein shall comply with requirements set forth in 33 United States Code §1341, commonly known as the federal Clean Water Act (CWA), §401 and 30 TAC Chapter 279. Mitigation and monitoring plans shall also comply with the requirements in §404 of the CWA as implemented through the U.S. Army Corps of Engineers permit for the Lower Bois d'Arc Creek Reservoir.

C. Impoundment of water and diversion under this permit is contingent upon the initiation of implementation of the approved *Mitigation Plan for the Proposed Lower Bois d'Arc Creek Reservoir*. Permittee's continued authorization of impoundment and diversion of water under this permit is contingent on timely completion of implementation in accordance with the terms of that plan. Modifications or changes to the plan must be approved by the Executive Director. Only modifications that would result in a change to a permit term must be in the form of an amendment to the permit.

D. Permittee shall document compliance with the terms and conditions of this permit relating to environmental flow requirements, as set out in Special Conditions 6.E. through 6.R., in the most recently approved *North Texas Municipal Water District Reservoir Accounting Plan*.

E. Permittee shall determine compliance with pulse flow conditions and subsistence period freshet conditions using measured flows at USGS Gage 07332622, Bois d'Arc Creek at FM 409 near Honey Grove, TX or, in the case of deliberate releases to pass qualifying pulse flow events or qualifying subsistence period freshets, measurements of the releases from the reservoir as documented in the most recently approved *North Texas Municipal Water District Reservoir Accounting Plan.*

F. If calculated reservoir inflows, as determined in the most recently approved *North Texas Municipal Water District Reservoir Accounting Plan,* constitute a qualifying pulse flow event as defined in Special Condition 6.L., the pulse flow requirement for the season has not been met, and the flows at USGS gage 07332622 for the same time period do not exceed the pulse flow trigger requirement, the pulse shall be passed through the reservoir in a manner as close as practicable to the applicable seasonal release pattern identified in the most recently approved *North Texas Municipal Water District Reservoir Accounting Plan.* Permittee may release water to augment naturally occurring high flow events so that flows at the USGS Gage 07332622 meet or exceed the pulse flow trigger requirement, subject to the requirements of Special Condition 6.J.

G. Consistent with Special Condition 6.F., when calculated reservoir inflows, as determined in the most recently approved *North Texas Municipal Water District Reservoir Accounting Plan*, equal or exceed the pulse flow trigger requirements of Special Condition 6.R. and the pulse flow requirement for the season has not been met, inflows to the reservoir in excess of applicable base flow requirements may be temporarily impounded. Consistent with Special Condition 6.F, if the calculated volume or duration criterion for an applicable qualifying pulse flow event, as specified in Special Condition 6.L., is met, Permittee shall promptly release the temporarily impounded water in a manner as close as practicable to the applicable seasonal release pattern identified in the most recently approved *North Texas Municipal Water District Reservoir Accounting Plan.*

H. Permittee is not required to release stored water, except temporarily impounded water as described in Special Condition 6.G. or a qualifying subsistence period freshet required to be released pursuant to Special Condition 6.Q., to meet the environmental flow requirements in this permit. All requirements for pass-throughs of inflows or releases of temporarily impounded water pursuant to Special Conditions 6.E. through 6.R. are limited to the volume of calculated inflows to the reservoir.

I. Subject to compliance with the subsistence and base flow requirements of Special Conditions 6.Q and 6.R, inflows may be stored if either: (i) the pulse flow requirement for a season has been met; or (ii) inflows to the reservoir are below the applicable pulse flow trigger; or (iii) inflows equal or exceed the applicable pulse flow trigger but the calculated volume and duration criteria for a qualifying pulse flow event are both not met. If Permittee has stored water, other than temporarily stored water pursuant to Special Condition 6.G. that is part of a qualifying pulse flow event or water that is part of a qualifying subsistence period freshet required to be passed pursuant to Special Condition 6.Q., then in accordance with the terms and conditions of this permit, including any applicable environmental flow requirements in effect at the time the water was stored, Permittee may divert and use that stored water, even if the applicable environmental flow requirement is not met at the time of the subsequent diversion and use of that stored water.

J. If a naturally occurring qualifying pulse flow event is recorded at USGS gage 07332622, such pulse flow event shall satisfy a pulse flow requirement for that event within the respective season. In addition, a pulse flow requirement for an event within a season may be satisfied by a naturally occurring high flow event which has been augmented by reservoir releases as authorized in Special Condition 6.F., but only if the applicable trigger, duration and volume criteria are all met as measured at that gage.

K. Each season is independent of the preceding and subsequent seasons with respect to the pulse flow requirements of Special Condition 6.R.

L. Except as otherwise provided in Special Condition 6.J., a pulse flow is considered to be a qualifying pulse flow event if the pulse flow trigger requirement is met and either the pulse flow volume or duration requirement is met, as specified in Special Condition 6.R.

M. Permittee shall determine compliance with the requirement to pass reservoir inflows up to the applicable subsistence or base flow values of Special Condition 6.R. based on measured flows at the outlet works of the dam.

N. Seasons are defined as Fall-Winter (November - February), Spring (March – June), and Summer (July - October).

O. Reservoir storage is the trigger for determining the applicable instream flow requirements in Special Conditions 6.E. through 6.R. Subsistence flow requirements apply when storage is less than 40% of the authorized conservation storage. Base flow and pulse flow requirements apply when conservation storage is equal to or greater than 40%.

P. Pulse flow requirements are not applicable under subsistence flow conditions.

Q. When subsistence flow requirements are in effect, as provided in Special Condition 6.O., inflows into the reservoir up to 1 cfs shall be passed downstream and a subsistence period freshet pass-through requirement shall be in effect.

A qualifying subsistence period freshet is characterized by a trigger flow of at least 20 cfs and either a volume of at least 69 acre-feet or a duration of at least three days. Volume will be determined based on cumulative flows occurring over a three-day period, beginning with the day during which the trigger flow occurs. Duration will be determined based on the number of days of inflow greater than 1 cfs, beginning with the day on which the trigger flow occurs. During the time that subsistence flow requirements are in effect pursuant to Special Condition 6.O., Permittee shall track flows at USGS gage 07332622, Bois d'Arc Creek at FM 409, and inflows to the reservoir, to determine if a qualifying subsistence period freshet has occurred at either location.

If, while subsistence flow requirements are in effect pursuant to Special Condition 6.O., a 60-day period occurs without a qualifying subsistence period freshet at USGS gage 07332622, Bois d'Arc Creek at FM 409, but, during which, a qualifying subsistence period freshet has occurred as reservoir inflow, the subsistence period freshet shall be promptly passed through the dam. If a qualifying subsistence period freshet has not occurred as reservoir inflow during such 60-day period, flows will continue to be monitored to determine when a qualifying subsistence period freshet occurs at the FM 409 gage or a qualifying subsistence period freshet has occurred as inflow to the reservoir. During that period of continued monitoring, a qualifying subsistence period freshet will be passed as soon as such an event occurs as inflow into the reservoir unless a qualifying subsistence period freshet has occurred at the FM 409 gage.

As closely as practicable, the subsistence period freshet pass-through shall average 20 cfs the first day, 10 cfs the second day, and 5 cfs the third day. As long as subsistence flow requirements are in effect, once a qualifying subsistence period freshet has occurred at USGS gage 07332622, Bois d'Arc Creek at FM 409, or such flow has been passed through the dam, a new 60-day period will be started for the purpose of determining when a qualifying subsistence flow event must be passed through the dam. In passing an individual subsistence period freshet through the dam, Permittee shall never be required to pass a volume of more than 69 acre-feet.

R. Impoundment or diversion of reservoir inflows when flows are at or below the following values, at the applicable measurement points described in Special Conditions 6.E. and 6.M., is authorized only in compliance with Special Conditions 6.A. and 6.D. through 6.Q., above:

Season	**Subsistence**	**Base**	**Pulse**
Fall-Winter	1 cfs*	3 cfs	2 per season Trigger: 150 cfs Volume: 1,000 af Duration: 7 days
Spring	1 cfs*	10 cfs	2 per season Trigger: 500 cfs Volume: 3,540 af Duration: 10 days
Summer	1 cfs*	3 cfs	1 per season Trigger: 100 cfs Volume: 500 af Duration: 5 days

cfs = cubic feet per second
af = acre-feet
*A subsistence period freshet requirement with a trigger level of 20 cfs, a volume of 69 af, and a duration of 3 days, as further defined in Special Condition 6.Q., also applies.

This special condition is subject to adjustment by the commission if the commission determines, through an expedited public review process, that such adjustment is appropriate to achieve compliance with applicable environmental flow standards adopted pursuant to Texas Water Code § 11.1471. Any adjustment shall be made in accordance with the provisions of Texas Water Code § 11.147(e-1).

S. Permittee shall implement measures to minimize impacts to aquatic resources due to entrainment or impingement including, but not limited to, the installation of screens at the diversion facilities. Such measures shall include intake diversion facilities designed and operated to result in a velocity of water into the diversion facility of no greater than 1 foot-per-second. At all times that diversions are occurring, the intake diversion facilities shall be equipped with screens resulting in individual openings no larger than 1 square inch in size.

T. After commencing deliberate impoundment in the reservoir, Permittee shall conduct hydrologic and water quality monitoring in accordance with the approved North Texas Municipal Water District Monitoring Plan. Permittee shall submit a summary of hydrologic and water quality monitoring data to the Executive Director on an annual basis. Permittee shall submit to the Executive Director a summary report of hydrologic and water quality data in the fifth and tenth years following deliberate impoundment in the reservoir and every five years thereafter for as long as monitoring under Special Condition 6.U. continues. Hydrologic and water quality monitoring for all sites and parameters, other than daily flows at USGS Gage 07332622, Bois d'Arc Creek at FM 409 near Honey Grove, TX, and water quality monitoring associated with reservoir releases undertaken pursuant to Special Condition 6.W., may cease after ten years, or when instream monitoring specified in Special Condition 6.U. ceases, whichever is later.

U. Permittee shall conduct instream monitoring of Bois d'Arc Creek at the FM 409 Site and, at a minimum, one additional site within the non-channelized portion of the Creek farther downstream, in the first, third, fifth and tenth years following deliberate impoundment of water in the reservoir. In addition, if diversions from the reservoir, as calculated on an annualized basis, have not reached 100,000 acre-feet prior to the fifth year following deliberate impoundment, instream monitoring shall continue every fifth year thereafter until instream monitoring has been undertaken during two years following the year that diversions reach 100,000 acre-feet per year. Instream monitoring during any year in which it is required shall include a twice per year assessment of fish and macroinvertebrate communities and physical habitat assessment at each site, plus a twice per year analysis of water quality data collected at the USGS Gage 07332622, Bois d'Arc Creek at FM 409 near Honey Grove, TX. All aquatic biological monitoring and physical habitat assessments shall take place in the index period (March 15 – October 15) with at least one of the twice per year monitoring events taking place in the critical period (July 1 – September 15). Aquatic biological monitoring and habitat characterization shall follow TCEQ protocols set forth in the most recently approved *Surface Water Quality Monitoring Procedures, Volume 2: Methods for Collecting and Analyzing Biological Community and Habitat Data.*

V. Permittee shall submit a report to the Executive Director summarizing the twice per year monitoring activities in Special Condition 6.U. within six months after the second monitoring event in any year is completed. The report shall detail all monitoring efforts and shall include an assessment of the fish and macroinvertebrate communities and the biological metric scoring criteria used to assess aquatic life uses. Should aquatic life use not meet the water quality standards for Segment 0202A or future segment designation, Permittee shall develop and implement remedial management strategies, subject to Executive Director approval, to meet the designated aquatic life use. Permittee shall also submit summary reports to the Executive Director no later than six months after the end of the fifth and tenth year monitoring events, and any subsequent year's monitoring events, that compare all monitoring data to baseline conditions.

W. Permittee shall construct and operate a multilevel outlet tower and regulate releases to ensure that water released from the reservoir maintains DO and temperature levels that meet the surface water quality standards for Segment 0202A or future segment designation. Permittee shall monitor water quality near the outlet tower in accordance with the approved Monitoring Plan during the life of the permit.

X. Permittee shall install and maintain measuring devices which account for, within 5% accuracy, the quantity of water diverted from the points authorized above in Paragraph 3. DIVERSION. Permittee shall allow representatives of the TCEQ reasonable access to the property to inspect the measuring device.

Y. Prior to the diversion and reuse of the return flows authorized pursuant to Paragraph 2.D. USE, resulting from the diversion and use of water from the Lower Bois d'Arc Creek Reservoir as authorized under this permit, Permittee shall apply for and be granted an amendment to identify all specific points of discharge and diversion, and secure the appropriate authorizations to transfer such return flows through state watercourses pursuant to TWC §11.042, except to the extent such points of discharge, diversion, and transfer may be authorized by separate grant of authority from the Commission.

7. TIME LIMITATIONS

A. Construction of the dam for Lower Bois d'Arc Creek Reservoir must be in accordance with plans approved by the Executive Director. Construction of the dam without final approval of the construction plans is a violation of this authorization.

B. Construction shall begin within two years of issuance of this permit and be completed within seven years of the issuance of this permit, unless Permittee applies for and is subsequently granted an extension of time before the expiration of these time limitations.

This water use permit is issued subject to all superior and senior water rights in the Red River Basin.

This permit is issued subject to the obligations of the State of Texas pursuant to the terms of the Red River Compact.

Permittee agrees to be bound by the terms, conditions, and provisions contained herein and such agreement is a condition precedent to the granting of this permit.

All other matters requested in the application which are not specifically granted by this water use permit are denied.

This water use permit is issued subject to the Rules of the Texas Commission on Environmental Quality and to the right of continuing supervision of State resources exercised by the Commission.

For the Commission

ISSUED: **June 26, 2015**

From: Erik Felthous
To: Daniel J. Sellars; Holly Kellen
Subject: FW: Resolution 17-16
Date: Wednesday, April 26, 2017 3:55:48 PM

From: Melisa Fuller **On Behalf Of** Tom Kula
Sent: Wednesday, April 26, 2017 3:50 PM
To: Judd Sanderson <jsanderson@NTMWD.COM>
Cc: Erik Felthous <efelthous@NTMWD.COM>; Terina Turner <tturner@NTMWD.COM>
Subject: Resolution 17-16

Judd,

Per Resolution No. 17-16, to be adopted by the Board of Directors in a regular meeting on April 27, 2017, I hereby designate you, Judd Sanderson, Deputy Director, as the authorized representative of the NTMWD for the purposes of furnishing such information and executing such documents as may be required in connection with the preparation and filing of such application for financial assistance and the rules of the Texas Water Development Board.

Please let me know if you need additional information.

Thanks,

Thomas W. Kula
Executive Director
North Texas Municipal Water District
501 E. Brown Street | Wylie, TX 75098
Office: 972.442.5405 | Cell 214.493.6167
tkula@ntmwd.com | www.ntmwd.com

PART D, No. 64 Has the applicant obtained all necessary land and easements? No.

Raw Water Pipeline Property Acquision

Property Description/Fannin County Appraisal District ID Number	Property Description LOT & BLOCK NO. OR TRACT NO.	Entity from whom the property must be acquired (property owner)	Aquired by easement	Expected acquisition date	to be funded by TWDB
82030	A0889 B PETTIT, ACRES 132	Volney Ray & Bertha Tyler	**Easement**	**Dec-18**	**YES**
78270	A0601 G W KING, ACRES 38	David Dalton	**Easement**	**Dec-18**	**YES**
70171	A0016 J C AKE, ACRES 37	Kenneth H & Janet E Jones	**Easement**	**Dec-18**	**YES**
		Janet Broadfoot Jones	**Easement**	**Dec-18**	**YES**
81889	A0878 R PETTET, ACRES 42.5, WILDLIFE MANAGEMENT	Kendall K. Brown & wife, Sharman Brown	**Easement**	**Dec-18**	**YES**
78975	A0653 P LAFLEUR, ACRES 10.5, WILDLIFE MANAGEMENT	Kendall K. Brown & wife, Sharman Brown	**Easement**	**Dec-18**	**YES**
78973	A0653 P LAFLEUR, ACRES 22.309, HOME EQUITY	Garlan Marie Holmes	**Easement**	**Dec-18**	**YES**
		Mid State Homes, Inc.	**Easement**	**Dec-18**	**YES**
78979	A0653 P LAFLEUR, ACRES 59.4	Louis O Montanio and Wife Linda F Montanio	**Easement**	**Dec-18**	**YES**
84320	A1084 L SELF, ACRES 30.356	Aitazaz A. Shah and Farah A. Shah	**Easement**	**Dec-18**	**YES**
74600	A0337 I L DOBBS, ACRES 37.452	Rubert Morgan and wife, Alice Morgan	**Easement**	**Dec-18**	**YES**
74601	A0337 I L DOBBS, ACRES 16.48	Billy Wayne Kenemore	**Easement**	**Dec-18**	**YES**
80637	A0796 M E P & P RY, ACRES 27.5	Billy Wayne Kenemore	**Easement**	**Dec-18**	**YES**
70190	A0022 D Y ALLEN, ACRES 4.0	Kevin Blake Lane	**Easement**	**Dec-18**	**YES**
70085	A0007 H S ALLEN, ACRES 100.	Thomas Bradley Lane	**Easement**	**Dec-18**	**YES**
85676	A1157 I C WILLIAMSON, ACRES 258.52	Stubbs Family Trust B c/o	**Easement**	**Dec-18**	**YES**
85682	A1157 I C WILLIAMSON, ACRES 152.9	Yvonne Butler	**Easement**	**Dec-18**	**YES**
70184	A0020 W A ALLEN, ACRES 23.5	Stanley Owen and Mary E. Owen Revocable Living Trust	**Easement**	**Dec-18**	**YES**
79760	A0726 D W MORRISON, ACRES 44.85	Stanley Owen and Mary E. Owen Revocable Living Trust	**Easement**	**Dec-18**	**YES**
70177	A0019 E J ALLEN, ACRES 108., LIFE ESTATE	A & F Land & Cattle, L.L.C	**Easement**	**Dec-18**	**YES**
76605	A0496 J W HARRISON, ACRES 64.4	Allen-Franklin Family Living Trust July 21,2011	**Easement**	**Dec-18**	**YES**
81956	A0884 D PEVELER, ACRES 25	Allen-Franklin Family Living Trust July 21,2011	**Easement**	**Dec-18**	**YES**
81961	A0884 D PEVELER, ACRES 20.	Rufus Walter Allen, Jr. and wife Treva Carole Allen	**Easement**	**Dec-18**	**YES**
81958	A0884 D PEVELER, ACRES 38.5	Eddie Hartfield, Jr. and Wallace Hartfield	**Easement**	**Dec-18**	**YES**

PART D, No. 64 Has the applicant obtained all necessary land and easements? No.

Raw Water Pipeline Property Acquision

		Michael Preston Johnson, son.	**Easement**	**Dec-18**	**YES**
86490	A1233 A ZACHARY, ACRES 25	Lisa Morse	**Easement**	**Dec-18**	**YES**
74078	A0280 J DAUGHERTY, ACRES 50	Eddie Hartfield, Jr. and Wallace James Hartfield	**Easement**	**Dec-18**	**YES**
82482	A0939 J RATTAN, ACRES 108.679	Barry Stewart and wife, Diane Stewart	**Easement**	**Dec-18**	**YES**
76579	A0493 N HARRIS, ACRES 85.297	Barry Stewart and wife, Diane Stewart	**Easement**	**Dec-18**	**YES**
76582	A0493 N HARRIS, ACRES 164.541	Alfred C. Williams and Mildred Williams	**Easement**	**Dec-18**	**YES**
100879	A0735 G MARTIN, ACRES 11.14	Hannah Kang	**Easement**	**Dec-18**	**YES**
83876	A1033 J STANDIFER, ACRES 192.33	H E and Myra Astleford	**Easement**	**Dec-18**	**YES**
110285	A1033 J STANDIFER, ACRES 4	Mark Vest and Deborah Sue Vest	**Easement**	**Dec-18**	**YES**
		E F Spelce	**Easement**	**Dec-18**	**YES**
110285	A1033 J STANDIFER, ACRES 4	H E and Myra Astleford	**Easement**	**Dec-18**	**YES**
83214	A1003 WM SAUNDERS, ACRES 257.9, LABEL# RAD1168030	Hernan Osorio	**Easement**	**Dec-18**	**YES**
83215	A1003 WM SAUNDERS, ACRES 54.75	James Donald Nichols	**Easement**	**Dec-18**	**YES**
81910	A0881 E PENNINGTON, ACRES 48.0	Douglas Kopf	**Easement**	**Dec-18**	**YES**
81908	A0881 E PENNINGTON, ACRES 20.817	Jeffrey Wayne Waller	**Easement**	**Dec-18**	**YES**
81903	A0881 E PENNINGTON, ACRES 14.728	Nejtek Family Trust	**Easement**	**Dec-18**	**YES**
81906	A0881 E PENNINGTON, ACRES 28.75	John A Pitts	**Easement**	**Dec-18**	**YES**
81919	A0882 E PENNINGTON, ACRES 25.5	John A Pitts	**Easement**	**Dec-18**	**YES**
81922	A0882 E PENNINGTON, ACRES 50	John A Pitts	**Easement**	**Dec-18**	**YES**
81921	A0882 E PENNINGTON, ACRES 24	John A Pitts	**Easement**	**Dec-18**	**YES**
75554	A0406 J M GAINER, ACRES 57., WILDLIFE MANAGEMENT	Margaret Pettengill	**Easement**	**Dec-18**	**YES**
75551	A0406 J M GAINER, ACRES 106.76, WILDLIFE MANAGEMENT	Margaret Pettengill	**Easement**	**Dec-18**	**YES**
75556	A0406 J M GAINER, ACRES 233.369, WILDLIFE MANAGEMENT	Frank & Helen Swartz	**Easement**	**Dec-18**	**YES**
75557	A0406 J M GAINER, ACRES 106.85, LABEL# TEX0458551	Mark & Sara Baker	**Easement**	**Dec-18**	**YES**
75558	A0406 J M GAINER, ACRES 44.25	Waymond L Long	**Easement**	**Dec-18**	**YES**
75542	A0406 J M GAINER, ACRES 30.056	Tyler Living Trust	**Easement**	**Dec-18**	**YES**
116606	A0406 J M GAINER, ACRES 38.642	Gina Marie Johnson	**Easement**	**Dec-18**	**YES**

PART D, No. 64 Has the applicant obtained all necessary land and easements? No.

Raw Water Pipeline Property Acquision

75539	A0406 J M GAINER, ACRES 118	Millard Doan Brent	**Easement**	**Dec-18**	**YES**
75483	A0393 W P FITZGERALD, ACRES 37.5	Millard Doan Brent	**Easement**	**Dec-18**	**YES**
83055	A0990 H SMITH, ACRES 188.375	Millard Doan Brent	**Easement**	**Dec-18**	**YES**
83077	A0990 H SMITH, ACRES 303.012	McCraw B C Family Ltd Partnership	**Easement**	**Dec-18**	**YES**
72990	A0193 N CROOM, ACRES 50.007	Larry & Brenda Lambert	**Easement**	**Dec-18**	**YES**
72997	A0193 N CROOM, ACRES 131.69	ACLJK, Ltd.	**Easement**	**Dec-18**	**YES**
72983	A0193 N CROOM, ACRES 95.85	D Lagoon Corp	**Easement**	**Dec-18**	**YES**
79736	A0724 W MERRELL, ACRES 244.39	ACLJK, Ltd.	**Easement**	**Dec-18**	**YES**
85860	A1170 W WILEY, ACRES 103	Tyler Living Trust	**Easement**	**Dec-18**	**YES**
85861	A1170 W WILEY, ACRES 28.4	J B Clements (Curly)	**Easement**	**Dec-18**	**YES**
74536	A0327 S DIXON, ACRES 53.347	Myra Astleford 1/2 Int. & Patsy Littrell 1/2 Int.	**Easement**	**Dec-18**	**YES**
74591	A0333 A DAUGHERTY, ACRES 20.436	William N White	**Easement**	**Dec-18**	**YES**
74591	A0333 A DAUGHERTY, ACRES 20.436	William N White	**Easement**	**Dec-18**	**YES**
74590	A0333 A DAUGHERTY, ACRES 28.135	James M & Betty J McCarter	**Easement**	**Dec-18**	**YES**
84692	A1130 T TOBY, ACRES 46.5	Terry K & Robin J Lowrey	**Easement**	**Dec-18**	**YES**
109082	A1130 T TOBY, ACRES 12.5	Juan A Huerta	**Easement**	**Dec-18**	**YES**
84690	A1130 T TOBY, ACRES 59.9	Edward L Robinson	**Easement**	**Dec-18**	**YES**
76359	A0474 J HART, ACRES 38	Edward L Robinson	**Easement**	**Dec-18**	**YES**
75211	A0368 L M FOSTER, ACRES 14.15	L D Shepherd III	**Easement**	**Dec-18**	**YES**
99896	A0368 I M FOSTER, ACRES 69.026	Daryl Bagley	**Easement**	**Dec-18**	**YES**
84497	A1111 S TURNER, ACRES 84.326	Roger & Nancy Hollister	**Easement**	**Dec-18**	**YES**
70896	A0073 J BECK, ACRES 323.844	Monty & Sallie Jackson	**Easement**	**Dec-18**	**YES**
70896	A0073 J BECK, ACRES 323.844	Monty & Sallie Jackson	**Easement**	**Dec-18**	**YES**
85515	A1152 WM WEBB, ACRES 134.36	Reid Family Enterprises Ltd	**Easement**	**Dec-18**	**YES**
85503	A1152 WM WEBB, ACRES 626.81	Monty & Sallie Jackson	**Easement**	**Dec-18**	**YES**
74649	A0343 E M EUBANKS, ACRES 97.57	Ronney & Laura Thompson	**Easement**	**Dec-18**	**YES**
74651	A0343 E M EUBANKS, ACRES 133.79	JCM Partners, LP	**Easement**	**Dec-18**	**YES**
74648	A0343 E M EUBANKS, ACRES 49.121	Furr Properties, Ltd.	**Easement**	**Dec-18**	**YES**
74706	A0343 E M EUBANKS, ACRES 100	David M McCollam	**Easement**	**Dec-18**	**YES**

PART D, No. 64 Has the applicant obtained all necessary land and easements? No.

Raw Water Pipeline Property Acquision

74748	A0343 E M EUBANKS, ACRES 52.88	Pittman Revocable Living Trust	**Easement**	**Dec-18**	**YES**
74686	A0343 E M EUBANKS, ACRES 56.971	Hot House Plants Limited	**Easement**	**Dec-18**	**YES**
74743	A0343 E M EUBANKS, ACRES 100.0	G B Tefteller	**Easement**	**Dec-18**	**YES**
82190	A0917 D PENEY, ACRES 76.0	R J Roberts	**Easement**	**Dec-18**	**YES**
84420	A1100 J STEPHENS, ACRES 80	R J & J F Roberts	**Easement**	**Dec-18**	**YES**
82199	A0921 T QUESENBERRY, ACRES 79.888	Beth Land & Cattle, LLC	**Easement**	**Dec-18**	**YES**
86316	A1223 F A WILLIAMS, ACRES 108.75	Raul M & Mirella Rubalcava	**Easement**	**Dec-18**	**YES**
109676	A0978 A E RAY, ACRES 23.999	BBM 5X5 Trust	**Easement**	**Dec-18**	**YES**
82746	A0978 A E RAY, ACRES 31.62	Mark & Phyllis Morgan	**Easement**	**Dec-18**	**YES**
113850	A0978 A E RAY 49.678	Jean B. Meller Subtrust	**Easement**	**Dec-18**	**YES**
86810	A1324 J W JONES, ACRES 40.	JCM Partners, LP	**Easement**	**Dec-18**	**YES**
86811	A1324 J W JONES, ACRES 28.456	Robert P & Elaine Hooper	**Easement**	**Dec-18**	**YES**
86574	A1250 J M MORRIS, ACRES 107.0	Johnny, Jo Elaine & Norma Jean Hooper	**Easement**	**Dec-18**	**YES**
86320	A1224 H B WILKERSON, ACRES 25.272	Jimmie Evans	**Easement**	**Dec-18**	**YES**
86319	A1224 H B WILKERSON, ACRES 85.18	James Evans	**Easement**	**Dec-18**	**YES**
73737	A0265 G C CLINE, ACRES 22.288	James Evans	**Easement**	**Dec-18**	**YES**
87128	A1430 F FELTY, ACRES 24.0	Rodney R & Sandra Bollinger	**Easement**	**Dec-18**	**YES**
87125	A1430 F FELTY, ACRES 266.28	Billy Gilbert	**Easement**	**Dec-18**	**YES**
71068	A0095 J J BRANTLEY, ACRES 130.0	Billy Gilbert	**Easement**	**Dec-18**	**YES**
76798	A0514 A HICKS, ACRES 281.774	Donald M Spurgin	**Easement**	**Dec-18**	**YES**
76876	A0527 J HOFFLER, ACRES 10.0., LIFE ESTATE	Denny M & Lavonna D Mitchell	**Easement**	**Dec-18**	**YES**
76877	A0527 J HOFFLER, ACRES 5.76	Donald M Spurgin	**Easement**	**Dec-18**	**YES**
76912	A0527 J HOFFLER, ACRES 67.868	Yang Huan Living Trust U/A/D April 9,2011	**Easement**	**Dec-18**	**YES**
86373	A1232 J ZEPADA, ACRES 36.5	Yang Huan Living Trust U/A/D April 9,2011	**Easement**	**Dec-18**	**YES**
86368	A1232 J ZEPADA, ACRES 169.504	Webb Living Trust	**Easement**	**Dec-18**	**YES**
86376	A1232 J ZEPADA, ACRES 52.5	Mickey D & Joey N Fuller	**Easement**	**Dec-18**	**YES**

PART D, No. 64 Has the applicant obtained all necessary land and easements? No.

Raw Water Pipeline Property Acquision

80370	A0779 M MOORE, ACRES 137.096	McCord R Spendthrift Trust	**Easement**	**Dec-18**	**YES**
80372	A0779 M MOORE, ACRES 106.5	Watson Bros Inc	**Easement**	**Dec-18**	**YES**
80343	A0778 M MOORE, ACRES 166.4	Watson Bros Inc	**Easement**	**Dec-18**	**YES**
80345	A0778 M MOORE, ACRES 38.946	Robert Norman	**Easement**	**Dec-18**	**YES**
80185	A0770 M MOORE, ACRES 138.5	Clifton & Betty Evans	**Easement**	**Dec-18**	**YES**
82304	A0927 R REDDING, ACRES 39.2 LIFE ESTATE	Margaret L Broyles	**Easement**	**Dec-18**	**YES**
82320	A0927 R REDDING, ACRES 12.3	Steve Malone	**Easement**	**Dec-18**	**YES**
82323	A0927 R REDDING, ACRES 338.166	North Texas Municipal Water District	**Easement**	**Dec-18**	**YES**
86978	A1388 D DEAL, ACRES 15.5	Bobby Jack & Texanna Norman	**Easement**	**Dec-18**	**YES**
79106	A0670 S L LEONARD, ACRES 323.286	North Texas Municipal Water District			**NO**

PART D, No. 64 Has the applicant obtained all necessary land and easements? No.

Lower Bois d'Arc Creek Reservoir Property

Property Description/ Fannin County Appraisal District ID Number	Entity from which the property must be acquired (property owner)	Full Ownership (ac)	Easement (ac)	Expected Acquisition Date	To Be Funded by TWDB
74478	ADAIR JAMES & LISA	2.035	2.762	8/1/2018	YES
109609	ALEXANDER TERRY G	0.516	2.203	8/1/2018	YES
74146	ARNOLD WILMA V	12.306	6.88	8/1/2018	YES
82972	BARRETT DAVID L	6.212	5.02	8/1/2018	YES
82975	BARRETT DAVID L			8/1/2018	YES
78179	BLAINE JAMES & MONIKA			8/1/2018	YES
73766	BLEVINS, JOHN & BECKY		0.296	8/1/2018	YES
74348	BORDERS, DAYLON & KARA formerly VERMILLION ALLEN & BILLIE	4.137	3.105	8/1/2018	YES
72004	BORDERS, DAYLON & KARA formerly VERMILLION ALLEN & BILLIE			8/1/2018	YES
99143	BOSLEY TIMOTHY			8/1/2018	YES
100017	BOSLEY TIMOTHY			8/1/2018	YES
82632	BULLOCK DAVID SAMUEL		0.099	8/1/2018	YES
85674	BUTLER NOLAN			8/1/2018	YES
74145	CHEEK LAQUILLA	35.289		8/1/2018	YES
74503	CLARK BILLY DON	3.745	5.627	8/1/2018	YES
77214	COE LILA G ET AL C/O LILA COE			8/1/2018	YES
81235	COOPER, JOYCE			8/1/2018	YES
72697	CRAWFORD KATHY	10.682	9.654	8/1/2018	YES
74482	CRIDER KELLI heir of MC CONNELL MARIE % ELLIS MC CONNELL		0.081	8/1/2018	YES
81204	DEGROOT DANIEL & ANGELA			8/1/2018	YES
75042	DEMPSEY EMILY & JAMES C			8/1/2018	YES
84941	DEWITT W C			8/1/2018	YES
75738	DUNBAR CEDRIC H & JUDY	0.767	0.375	8/1/2018	YES
108261	DUNBAR JUDY & CEDRIC			8/1/2018	YES
73529	EL-JARRAH TAISSIR F & HIND			8/1/2018	YES
77341	EL-JARRAH TAISSIR F & HIND			8/1/2018	YES
70338	EL-JARRAH TAISSIR F & HIND			8/1/2018	YES
77219	ELLISON LARRY W	1.022	0.486	8/1/2018	YES
77220	ELLISON LARRY W			8/1/2018	YES
113658	EQUITY TRUST COMPANY formerly MANUS RANDALL			8/1/2018	YES
	ESTES, GLENN			8/1/2018	YES
74022	FARMER RUEL D			8/1/2018	YES
83803	FERGUSON RICHARD A & TRACY J			8/1/2018	YES
73762	FOGLE MARY (TIM BRUCE-Deceased)			8/1/2018	YES
79842	FRANKLIN LARRY DON			8/1/2018	YES
78419	FREE NORMOUS		0.221	8/1/2018	YES
83003	GAUNT BILLY L	0.224	0.553	8/1/2018	YES
70548	GLASER DANIEL			8/1/2018	YES
74479	GOODWIN R H C/O JACKIE GOODWIN	2.182	3.145	8/1/2018	YES
81165	GRAVES, WILLIAM formerly HILL MILTON LLOYD		0.327	8/1/2018	YES
72507	HOWARD TONY		0.107	8/1/2018	YES
81200	JANSSEN BETTY P % JACK LAUGHLIN			8/1/2018	YES
81163	JOHNSON BENNY C			8/1/2018	YES
81846	JOHNSON JAMES & CARMEN C/O JAMES ANTHONY JOHNSON		0.077	8/1/2018	YES
70117	JONES, RANDY (ALMA JOYCE ESTATE)	13.956	2.404	8/1/2018	YES
81244	KAPP STEVEN GERARD	0.643	0.35	8/1/2018	YES
81147	KASBARIAN CHARLES M			8/1/2018	YES
78310	KING CHRIS DOUGLAS			8/1/2018	YES
75372	KNIGHT RONNIE & REBECCA	163.594	8.965	8/1/2018	YES
83989	KNIGHT RONNIE & REBECCA			8/1/2018	YES
82167	KNIGHT RONNIE & REBECCA			8/1/2018	YES
75785	KNOX JOHN T & BETH A			8/1/2018	YES
78324	KOS, ERIC AND JULIANNE formerly SAMFORD MAX, JR. & SABRINA	0.243	0.203	8/1/2018	YES
73494	LEDBETTER DENNIS & NANCY SCHAFFER C/O KEETON LAND DEV	26.938	3.795	8/1/2018	YES
79833	LEGACY RIDGE COUNTRY CLUB			8/1/2018	YES
82986	LILLIS ALFRED A	0.272	0.614	8/1/2018	YES
84506	LOCKE LEMUEL R	0.032	0.538	8/1/2018	YES
83134	LOCKE THOMAS R & JOHN G LOCKE (JOHN & CLARA)	8.855		8/1/2018	YES
71994	MASON HAROLD E & DARLENE	88.311	1.026	8/1/2018	YES
73759	MASON KAREN ELAINE HOLLIS		0.48	8/1/2018	YES
73486	MC CRAW BRENDA formerly ROBINSON EDWARD or RAGON MARK	0.086	1.147	8/1/2018	YES
70131	MC GEHEE, JOYCE	1.589	0.343	8/1/2018	YES
73772	MC LAIN HAROLD JR & GAIL		0.886	8/1/2018	YES
75717	MC PHAUL MARGARET O			8/1/2018	YES
74139	MC PHAUL MARGARET O			8/1/2018	YES
81202	MELTON, MARTHA (poa ROY GARZA)	69.795		8/1/2018	YES
71024	MILLER, JUSTIN, formerly SCHWARTZ BARRY & ROSE MARIE	1.093	1.649	8/1/2018	YES
75305	PARKS R BRIAN & SHARLENE ANN PARKS	1.244	0.436	8/1/2018	YES
81860	PARKS R BRIAN & SHARLENE ANN PARKS			8/1/2018	YES
73391	PEARSON J LEE	26.499		8/1/2018	YES
77390	PETTENGILL MARGARET (Bill and Margaret Mason, heirs)		0.169	8/1/2018	YES
77385	PITTS JOHN A		0.993	8/1/2018	YES
73493	RAIDEN GAYLON & KAY formerly BEWLEY MARK & SHEILA	17.558	2.797	8/1/2018	YES

PART D, No. 64 Has the applicant obtained all necessary land and easements? No.

Lower Bois d'Arc Creek Reservoir Property

79951	RAMSEY MARK ET AL C/O JOE RAMSEY	53.759	2.242	8/1/2018	YES
78533	RAMSEY MARK ET AL C/O JOE RAMSEY	47.714		8/1/2018	YES
79950	RAMSEY MATTHEW ET AL	28.629	3.344	8/1/2018	YES
82978	REED JOSEPH, JR., WESLEY REED & JOHN REED C/O WESLEY MARTIN REED	573.5	55.04	8/1/2018	YES
82978	REED JOSEPH, JR., WESLEY REED & JOHN REED C/O WESLEY MARTIN REED			8/1/2018	YES
82981	REED JOSEPH, JR., WESLEY REED & JOHN REED C/O WESLEY MARTIN REED			8/1/2018	YES
82979	REED JOSEPH, JR., WESLEY REED & JOHN REED C/O WESLEY MARTIN REED			8/1/2018	YES
74092	REED JOSEPH, JR., WESLEY REED & JOHN REED C/O WESLEY MARTIN REED			8/1/2018	YES
75782	REED JOSEPH, JR., WESLEY REED & JOHN REED C/O WESLEY MARTIN REED			8/1/2018	YES
78155	REED JOSEPH, JR., WESLEY REED & JOHN REED C/O WESLEY MARTIN REED			8/1/2018	YES
79843	ROBERTSON LLOYD B & BARBARA J LIVING TRUST	68.201	9.487	8/1/2018	YES
78378	ROBINSON FAMILY TRUST WILLIAM & DORIS ROBINSON TRUSTEES			8/1/2018	YES
70738	RYSER BILLY WAYNE			8/1/2018	YES
79613	RYSER BILLY WAYNE			8/1/2018	YES
70741	RYSER BILLY WAYNE			8/1/2018	YES
70740	RYSER BILLY WAYNE			8/1/2018	YES
75773	RYSER BILLY WAYNE			8/1/2018	YES
70187	RYSER BILLY WAYNE & PHYLLIS JANE RYSER			8/1/2018	YES
79949	RYSER BROTHERS PARTNERSHIP			8/1/2018	YES
79840	RYSER CHARLES			8/1/2018	YES
79614	RYSER CHARLES			8/1/2018	YES
78534	RYSER CHARLES			8/1/2018	YES
74265	RYSER CHARLES			8/1/2018	YES
75774	RYSER CHARLES			8/1/2018	YES
75775	RYSER CHARLES			8/1/2018	YES
79841	RYSER CHARLES			8/1/2018	YES
70088	RYSER CHARLES			8/1/2018	YES
85804	SADEGHIAN KHOSROW	51.007		8/1/2018	YES
108115	SANDERS, LOYD & KAY	30.802		8/1/2018	YES
86011	QUINN, HEIDI 1998 TRUST formerly SCHOENIG RANCH, INC		2.032	8/1/2018	YES
71993	SED PROPERTIES INC			8/1/2018	YES
78326	SMITH H Y % RAYMOND SMITH	0.001	1.427	8/1/2018	YES
86009	SMITH RUSSELL R			8/1/2018	YES
70121	SMITH RUSSELL R			8/1/2018	YES
83005	SMITH RUSSELL R			8/1/2018	YES
86010	SMITH RUSSELL R			8/1/2018	YES
86491	SMITH RUSSELL R			8/1/2018	YES
70093	STUBBS B R			8/1/2018	YES
85676	STUBBS B R			8/1/2018	YES
85677	STUBBS B R			8/1/2018	YES
81201	TAYLOR SUSAN LAUGHLIN & GREGORY	35.052	2.231	8/1/2018	YES
83136	TUBBS GERALD J	182.824		8/1/2018	YES
85799	TUBBS GERALD J			8/1/2018	YES
70186	TUBBS GERALD J			8/1/2018	YES
74464	TUCKER GRACE MARGARET C/O JARRETT LEON TUCKER	939.347	43.91	8/1/2018	YES
78416	TUCKER GRACE MARGARET C/O JARRETT LEON TUCKER			8/1/2018	YES
78417	TUCKER GRACE MARGARET C/O JARRETT LEON TUCKER			8/1/2018	YES
81144	TUCKER JARRETT			8/1/2018	YES
75979	TUCKER JARRETT			8/1/2018	YES
86348	TUCKER JARRETT LEON			8/1/2018	YES
81142	TUCKER JARRETT LEON			8/1/2018	YES
81141	TUCKER JARRETT LEON			8/1/2018	YES
79603	TUCKER JARRETT LEON			8/1/2018	YES
81139	TUCKER JARRETT LEON			8/1/2018	YES
81145	TUCKER JARRETT LEON			8/1/2018	YES
70194	WALKER CAROL MOCH	0.286	0.294	8/1/2018	YES
72688	WALKER MADA		0.265	8/1/2018	YES
100558	WALKER TRUST C/O MARGARET WALKER		0.508	8/1/2018	YES
78156	WITCHER FAMILY TRUST #1998	149.006		8/1/2018	YES
78157	WITCHER FAMILY TRUST #1998			8/1/2018	YES
83968	WITCHER FAMILY TRUST #1998	306.227		8/1/2018	YES
75843	WITCHER FAMILY TRUST #1998			8/1/2018	YES
78989	WITCHER FAMILY TRUST #1998			8/1/2018	YES
78991	WITCHER FAMILY TRUST #1998			8/1/2018	YES
109899	WITCHER FAMILY TRUST #1998			8/1/2018	YES
81161	~~WORTHEY, DAVID & SHARLEEN formerly HITCHCOCK CARLETON~~ SKAF, MARILYN & RASHID	9.963	14.335	8/1/2018	YES
70091	YARBROUGH CHARLES MICHAEL & JOHN E.			8/1/2018	YES
86006	YARBROUGH CHARLES MICHAEL & JOHN E.			8/1/2018	YES
70119	YARBROUGH CHARLES MICHAEL & JOHN E.			8/1/2018	YES
70089	YARBROUGH CHARLES MICHAEL & JOHN E. formerly WHITE ALFRED			8/1/2018	YES
70090	YARBROUGH CHARLES MICHAEL & JOHN E. formerly WHITE ALFRED			8/1/2018	YES
70084	YARBROUGH JOHN & CHARLES M			8/1/2018	YES
75776	YARBROUGH JOHN & CHARLES M			8/1/2018	YES

PART D, No. 64 Has the applicant obtained all necessary land and easements? No.					
Lower Bois d'Arc Creek Reservoir Property					
72001	Cutts, David and Jean		0.224	8/1/2018	YES
110864	Webster, Judy			8/1/2018	YES
99204	Royse, Jason & Kelly			8/1/2018	YES
86492	Allen, Jessie and Helen			8/1/2018	YES
86493	Allen, Jessie and Helen			8/1/2018	YES

The treated water pipeline is currently in preliminary design, so actual easements needed are not known at this time. However, the corridor and alignment study are underway, so the provided tables summarize the current landowners that are impacted by the study limits and the required easements will come from within this list of affected landowners.

This page is a placeholder for information submitted with the application that may contain confidential information. Please contact Cindy DePrato, Executive Assistant at (512) 463-8420 to request reviewing this information.

This page is a placeholder for information submitted with the application that may contain confidential information. Please contact Cindy DePrato, Executive Assistant at (512) 463-8420 to request reviewing this information.

This page is a placeholder for information submitted with the application that may contain confidential information. Please contact Cindy DePrato, Executive Assistant at (512) 463-8420 to request reviewing this information.

This page is a placeholder for information submitted with the application that may contain confidential information. Please contact Cindy DePrato, Executive Assistant at (512) 463-8420 to request reviewing this information.

This page is a placeholder for information submitted with the application that may contain confidential information. Please contact Cindy DePrato, Executive Assistant at (512) 463-8420 to request reviewing this information.

This page is a placeholder for information submitted with the application that may contain confidential information. Please contact Cindy DePrato, Executive Assistant at (512) 463-8420 to request reviewing this information.

This page is a placeholder for information submitted with the application that may contain confidential information. Please contact Cindy DePrato, Executive Assistant at (512) 463-8420 to request reviewing this information.

This page is a placeholder for information submitted with the application that may contain confidential information. Please contact Cindy DePrato, Executive Assistant at (512) 463-8420 to request reviewing this information.

This page is a placeholder for information submitted with the application that may contain confidential information. Please contact Cindy DePrato, Executive Assistant at (512) 463-8420 to request reviewing this information.

This page is a placeholder for information submitted with the application that may contain confidential information. Please contact Cindy DePrato, Executive Assistant at (512) 463-8420 to request reviewing this information.

This page is a placeholder for information submitted with the application that may contain confidential information. Please contact Cindy DePrato, Executive Assistant at (512) 463-8420 to request reviewing this information.

North Texas Municipal Water District

FY 17 SWIFT Multi-Year Funding Commitment

Lower Bois d'Arc Creek Reservoir & Treatment and Treated Water Distribution

Part E

Supporting Documentation and Attachments

North Texas Municipal
Water District

SWIFT - Schedule for Multi-Year Commitments

		Current Cost	Escalation	Total Cost
Total by Project				
Lower Bois d'Arc Creek Reservior				
Reimbursements (Authorized and to be Authorized)		$ 20,196,000	0%	$ 20,196,000
FY18 (12/2017 - 11/2018)		$ 449,243,000	3%	$ 462,720,290
FY19 (12/2018 - 11/2019)		$ 216,783,000	6%	$ 229,789,980
FY20 (12/2019 - 11/2020)	a	$ 109,000	9%	$ 118,810
FY21 (12/2020 - 11/2021)	a	$ 109,000	12%	$ 122,080
FY22 (12/2021 - 11/2022)	a	$ 109,000	15%	$ 125,350
		$ 686,549,000		$ 713,072,510
Treatment & Treated Water Distribution				
Reimbursements (Authorized and to be Authorized)		$ 22,543,000	0%	$ 22,543,000
FY18 (12/2017 - 11/2018)		$ 32,962,000	3%	$ 33,950,860
FY19 (12/2018 - 11/2019)		$ 328,149,000	6%	$ 347,837,940
FY20 (12/2019 - 11/2020)		$ -	9%	$ -
FY21 (12/2020 - 11/2021)		$ -	12%	$ -
FY22 (12/2021 - 11/2022)		$ -	15%	$ -
		$ 383,654,000		$ 404,331,800
Total by Project		**$ 1,070,203,000**		**$ 1,117,404,310**
Total by SWIFT Bond Year				
Reimbursements (Authorized and to be Authorized)		$ 42,739,000	0%	$ 42,739,000
FY18 (12/2017 - 11/2018)		$ 482,205,000	3%	$ 496,671,150
FY19 (12/2018 - 11/2019)		$ 544,932,000	6%	$ 577,627,920
FY20 (12/2019 - 11/2020)	a	$ 109,000	9%	$ 118,810
FY21 (12/2020 - 11/2021)	a	$ 109,000	12%	$ 122,080
FY22 (12/2021 - 11/2022)	a	$ 109,000	15%	$ 125,350
Total by SWIFT Bond Year		**$ 1,070,203,000**		**$ 1,117,404,310**
		-		-

a - To be Included in FY19 Bond Issue.

RESOLUTION AUTHORIZING THE ISSUANCE, SALE, AND DELIVERY OF NORTH TEXAS MUNICIPAL WATER DISTRICT WATER SYSTEM REVENUE BONDS, SERIES 2017; AND APPROVING AND AUTHORIZING INSTRUMENTS AND PROCEDURES RELATING THERETO

WHEREAS, North Texas Municipal Water District (the "Issuer") is a political subdivision of the State of Texas, being a conservation and reclamation district created and functioning under Article 16, Section 59 of the Texas Constitution, pursuant to Chapter 62, Acts of 1951, 52nd Legislature of Texas, Regular Session, as amended (the "Act");

WHEREAS, the Board of Directors of the Issuer is authorized to issue the bonds hereinafter authorized pursuant to the Act, Chapter 791, Texas Government Code, as amended, and other applicable laws; and

WHEREAS, by adoption of its Resolution No. 17-___ Approving an Application for Financial Assistance, dated _______, 2017, the Texas Water Development Board ("TWDB") has agreed to purchase the Issuer's hereinafter authorized bonds.

THEREFORE, BE IT RESOLVED BY THE BOARD OF DIRECTORS OF NORTH TEXAS MUNICIPAL WATER DISTRICT THAT:

Section 1. AMOUNT AND PURPOSE OF THE BONDS. The bond or bonds of North Texas Municipal Water District (the "Issuer") are hereby authorized to be issued and delivered in the aggregate principal amount of $__________, FOR THE PURPOSE OF PROVIDING FUNDS (i) FOR IMPROVING THE NORTH TEXAS MUNICIPAL WATER DISTRICT WATER SYSTEM, INCLUDING PAYING PRECONSTRUCTION COSTS RELATING TO THE LOWER BOIS D'ARC CREEK RESERVOIR, LEONARD WATER TREATMENT PLANT, AND ASSOCIATED PIPELINES, (ii) TO FUND A RESERVE FUND FOR THE BONDS, AND (iii) TO PAY COSTS OF ISSUANCE OF THE BONDS.

Section 2. DESIGNATION OF THE BONDS. Each bond issued pursuant to this Resolution shall be designated: "NORTH TEXAS MUNICIPAL WATER DISTRICT WATER SYSTEM REVENUE BOND, SERIES 2017", and initially there shall be issued, sold, and delivered hereunder a single fully registered bond, without interest coupons, payable in installments of principal (the "Initial Bond"), but the Initial Bond may be assigned and transferred and/or converted into and exchanged for a like aggregate principal amount of fully registered bonds, without interest coupons, having serial maturities, and in the denomination or denominations of $5,000 or any integral multiple of $5,000, all in the manner hereinafter provided. The term "Bonds" as used in this Resolution shall mean and include collectively the Initial Bond and all substitute bonds exchanged therefor, as well as all other substitute bonds and replacement bonds issued pursuant hereto, and the term "Bond" shall mean any of the Bonds.

Section 3. INITIAL DATE, DENOMINATION, NUMBER, MATURITIES, INITIAL REGISTERED OWNER, AND CHARACTERISTICS OF THE INITIAL BOND.

(a) The Initial Bond is hereby authorized to be issued, sold, and delivered hereunder as a single fully registered Bond, without interest coupons, dated ___________ 1, 2017, in the denomination and aggregate principal amount of $__________, numbered TR-1, payable in annual installments of principal to the initial registered owner thereof, to-wit: Texas Water Development Board, or to the registered assignee or assignees of said Bond or any portion or portions thereof (in each case, the "registered owner"), with the annual installments of principal of the Initial Bond to be payable on the dates, respectively, and in the principal amounts, respectively, stated in the FORM OF INITIAL BOND set forth in this Resolution.

(b) The Initial Bond (i) may be prepaid or redeemed prior to the respective scheduled due dates of installments of principal thereof, (ii) may be assigned and transferred, (iii) may be converted and exchanged for other Bonds, (iv) shall have the characteristics, and (v) shall be signed and sealed, and the principal of and interest on the Initial Bond shall be payable, all as provided, and in the manner required or indicated, in the FORM OF INITIAL BOND set forth in this Resolution.

Section 4. INTEREST. The unpaid principal balance of the Initial Bond shall bear interest from the date of delivery (the "Issue Date") the Initial Bond to the TWDB to the respective scheduled due dates, or to the respective dates of prepayment or redemption, of the installments of principal of the Initial Bond, and said interest shall be payable, all in the manner provided and at the rates and on the dates stated in the FORM OF INITIAL BOND set forth in this Resolution.

Section 5. FORM OF INITIAL BOND. The form of the Initial Bond, including the form of Registration Certificate of the Comptroller of Public Accounts of the State of Texas to be endorsed on the Initial Bond, shall be substantially as follows:

FORM OF INITIAL BOND

NO. TR-1 $___________

UNITED STATES OF AMERICA
STATE OF TEXAS
NORTH TEXAS MUNICIPAL WATER DISTRICT
WATER SYSTEM REVENUE BOND,
SERIES 2017

NORTH TEXAS MUNICIPAL WATER DISTRICT (the "Issuer"), being a political subdivision of the State of Texas, hereby promises to pay to TEXAS WATER DEVELOPMENT BOARD (the "TWDB"), or to the registered assignee or assignees of this Bond or any portion or portions hereof (in each case, the "registered owner") the aggregate principal amount of _______ ____________________________________ AND __/100 DOLLARS in annual installments of principal due and payable on SEPTEMBER 1 in each of the years, and in the respective principal amounts, as set forth in the following schedule:

Year	Principal Amount	Year	Principal Amount

and to pay interest, calculated on the basis of a 360-day year composed of twelve 30-day months, from the date of delivery of this Bond to the TWDB, on the balance of each such installment of principal, respectively, from time to time remaining unpaid, at the rates as follows:

Year	Rate	Year	Rate

with said interest being payable semiannually on each March 1 and September 1 commencing March 1, 2018, while this Bond or any portion hereof is outstanding and unpaid.

THE INSTALLMENTS OF PRINCIPAL OF AND THE INTEREST ON this Bond are payable in lawful money of the United States of America, without exchange or collection charges. The installments of principal and the interest on this Bond are payable to the registered owner hereof through the services of THE BANK OF NEW YORK MELLON TRUST COMPANY, NATIONAL ASSOCIATION, in Dallas, Texas, which is the "Paying Agent/Registrar" for this Bond. Payment of all principal of and interest on this Bond shall be made by the Paying Agent/ Registrar to the registered owner hereof on each principal and/or interest payment date by check dated as of such date, drawn by the Paying Agent/Registrar on, and payable solely from, funds of the Issuer required by the resolution authorizing the issuance of this Bond (the "Bond Resolution") to be on deposit with the Paying Agent/Registrar for such purpose as hereinafter provided; and such check shall be sent by the Paying Agent/Registrar by United States mail, first-class postage prepaid, on each such principal and/or interest payment date, to the registered owner hereof, at the address of the registered owner, as it appeared on the 15th day of the month next preceding each such date (the "Record Date") on the Registration Books kept by the Paying Agent/Registrar, as hereinafter described; provided that, if the TWDB is the registered owner of this Bond, at the option of the TWDB and at the expense of the Issuer, such payment shall be made by wire transfer pursuant to written directions of the TWDB. The Issuer covenants with the registered owner of this Bond that on or before each principal and/or interest payment date for this Bond it will make available to the Paying Agent/Registrar, from the "Interest and Redemption Fund" created by the Bond Resolution, the amounts required to provide for the payment, in immediately available funds, of all principal of and interest on this Bond, when due.

IF THE DATE for the payment of the principal of or interest on this Bond shall be a Saturday, Sunday, a legal holiday, or a day on which banking institutions in the City where the Paying Agent/Registrar is located are authorized by law or executive order to close, then the date for such payment shall be the next succeeding day which is not such a Saturday, Sunday, legal holiday, or day on which banking institutions are authorized to close; and payment on such date shall have the same force and effect as if made on the original date payment was due.

THIS BOND has been authorized in accordance with the Constitution and laws of the State of Texas in the principal amount of $___________ FOR THE PURPOSE OF PROVIDING FUNDS FOR IMPROVING THE NORTH TEXAS MUNICIPAL WATER DISTRICT WATER SYSTEM.

ON MARCH 1, 2028, or on any date whatsoever thereafter, the unpaid installments of principal of this Bond may be prepaid or redeemed prior to their scheduled due dates, at the option of the Issuer, with funds derived from any available source, as a whole, or in part, and, if in part, in inverse order of principal installments. If less than a whole principal installment is to be prepaid or redeemed, the portion thereof to be prepaid or redeemed shall be selected by the Paying Agent/Registrar by lot or other customary method (provided that a portion of this Bond may be redeemed only in an integral multiple of $5,000), at the prepayment or redemption price of the principal amount thereof, plus accrued interest to the date fixed for prepayment or redemption.

AT LEAST 30 days prior to the date fixed for any such prepayment or redemption a written notice of such prepayment or redemption shall be mailed by the Paying Agent/Registrar to the registered owner hereof. By the date fixed for any such prepayment or redemption due provision shall be made by the Issuer with the Paying Agent/Registrar for the payment of the required prepayment or redemption price for this Bond or the portion hereof which is to be so prepaid or redeemed, plus accrued interest thereon to the date fixed for prepayment or redemption. If such written notice of prepayment or redemption is given, and if due provision for such payment is made, all as provided above, this Bond, or the portion thereof which is to be so prepaid or redeemed, thereby automatically shall be treated as prepaid or redeemed prior to its scheduled due date, and shall not bear interest after the date fixed for its prepayment or redemption, and shall not be regarded as being outstanding except for the right of the registered owner to receive the prepayment or redemption price plus accrued interest to the date fixed for prepayment or redemption from the Paying

Agent/Registrar out of the funds provided for such payment. The Paying Agent/Registrar shall record in the Registration Books all such prepayments or redemptions of principal of this Bond or any portion hereof.

THIS BOND, to the extent of the unpaid or unredeemed principal balance hereof, or any unpaid and unredeemed portion hereof in any integral multiple of $5,000, may be assigned by the initial registered owner hereof and shall be transferred only in the Registration Books of the Issuer kept by the Paying Agent/Registrar acting in the capacity of registrar for the Bonds, upon the terms and conditions set forth in the Bond Resolution. Among other requirements for such transfer, this Bond must be presented and surrendered to the Paying Agent/Registrar for cancellation, together with proper instruments of assignment, in form and with guarantee of signatures satisfactory to the Paying Agent/Registrar, evidencing assignment by the initial registered owner of this Bond, or any portion or portions hereof in any integral multiple of $5,000, to the assignee or assignees in whose name or names this Bond or any such portion or portions hereof is or are to be transferred and registered. Any instrument or instruments of assignment satisfactory to the Paying Agent/Registrar may be used to evidence the assignment of this Bond or any such portion or portions hereof by the initial registered owner hereof. A new bond or bonds payable to such assignee or assignees (which then will be the new registered owner or owners of such new Bond or Bonds) or to the initial registered owner as to any portion of this Bond which is not being assigned and transferred by the initial registered owner, shall be delivered by the Paying Agent/Registrar in conversion of and exchange for this Bond or any portion or portions hereof, but solely in the form and manner as provided in the next paragraph hereof for the conversion and exchange of this Bond or any portion hereof. The registered owner of this Bond shall be deemed and treated by the Issuer and the Paying Agent/Registrar as the absolute owner hereof for all purposes, including payment and discharge of liability upon this Bond to the extent of such payment, and the Issuer and the Paying Agent/Registrar shall not be affected by any notice to the contrary.

AS PROVIDED above and in the Bond Resolution, this Bond, to the extent of the unpaid or unredeemed principal balance hereof, may be converted into and exchanged for a like aggregate principal amount of fully registered bonds, without interest coupons, payable to the assignee or assignees duly designated in writing by the initial registered owner hereof, or to the initial registered owner as to any portion of this Bond which is not being assigned and transferred by the initial registered owner, in any denomination or denominations in any integral multiple of $5,000 (subject to the requirement hereinafter stated that each substitute bond issued in exchange for any portion of this Bond shall have a single stated principal maturity date), upon surrender of this Bond to the Paying Agent/Registrar for cancellation, all in accordance with the form and procedures set forth in the Bond Resolution. If this Bond or any portion hereof is assigned and transferred or converted each bond issued in exchange for any portion hereof shall have a single stated principal maturity date corresponding to the due date of the installment of principal of this Bond or portion hereof for which the substitute bond is being exchanged, and shall bear interest at the rate applicable to and borne by such installment of principal or portion thereof. Such bonds, respectively, shall be subject to redemption prior to maturity on the same dates and for the same prices as the corresponding installment of principal of this Bond or portion hereof for which they are being exchanged. No such bond shall be payable in installments, but shall have only one stated principal maturity date. AS PROVIDED IN THE BOND RESOLUTION, THIS BOND IN ITS PRESENT FORM MAY BE

ASSIGNED AND TRANSFERRED OR CONVERTED ONCE ONLY, and to one or more assignees, but the bonds issued and delivered in exchange for this Bond or any portion hereof may be assigned and transferred, and converted, subsequently, as provided in the Bond Resolution. The Issuer shall pay the Paying Agent/Registrar's standard or customary fees and charges for transferring, converting, and exchanging this Bond or any portion thereof, but the one requesting such transfer, conversion, and exchange shall pay any taxes or governmental charges required to be paid with respect thereto. The Paying Agent/Registrar shall not be required to make any such assignment, conversion, or exchange (i) during the period commencing with the close of business on any Record Date and ending with the opening of business on the next following principal or interest payment date, or, (ii) with respect to any Bond or portion thereof called for prepayment or redemption prior to maturity, within 45 days prior to its prepayment or redemption date.

IN THE EVENT any Paying Agent/Registrar for this Bond is changed by the Issuer, resigns, or otherwise ceases to act as such, the Issuer has covenanted in the Bond Resolution that it promptly will appoint a competent and legally qualified substitute therefor, and promptly will cause written notice thereof to be mailed to the registered owner of this Bond.

IT IS HEREBY certified, recited, and covenanted that this Bond has been duly and validly authorized, issued, and delivered; that all acts, conditions, and things required or proper to be performed, exist, and be done precedent to or in the authorization, issuance, and delivery of this Bond have been performed, existed, and been done in accordance with law; that this Bond is a special obligation of the Issuer which, together with other bonds, are secured by and payable from a first lien on and pledge of the "Pledged Revenues" as defined in the Bond Resolution, which include the "Net Revenues of the District's Water System", as defined in the Bond Resolution, including specifically revenues derived pursuant to existing water supply contracts between the Issuer and the Cities of Allen, Farmersville, Forney, Frisco, Garland, McKinney, Mesquite, Plano, Princeton, Richardson, Rockwall, Royse City, and Wylie, Texas, which cities are currently the Member Cities constituting the territory and boundaries of the Issuer, water supply contracts relating to the District's Water System with any other cities which hereafter may become Member Cities, and water supply contracts with other cities and customers in connection with the District's Water System.

THE ISSUER has reserved the right, subject to the restrictions stated in the Bond Resolution, to issue Additional Bonds payable from and secured by a first lien on and pledge of the "Pledged Revenues" on a parity with this Bond.

THE ISSUER also has reserved the right to amend the Bond Resolution with the approval of the registered owners of 51% in principal amount of all outstanding bonds secured by and payable from a first lien on and pledge of the "Pledged Revenues".

THE REGISTERED OWNER hereof shall never have the right to demand payment of this Bond or the interest hereon out of any funds raised or to be raised by taxation or from any source whatsoever other than specified in the Bond Resolution.

BY BECOMING the registered owner of this Bond, the registered owner thereby acknowledges all of the terms and provisions of the Bond Resolution, agrees to be bound by such terms and provisions, acknowledges that the Bond Resolution is duly recorded and available for inspection in the official minutes and records of the governing body of the Issuer, and agrees that the terms and provisions of this Bond and the Bond Resolution constitute a contract between the registered owner hereof and the Issuer.

IN WITNESS WHEREOF, the Issuer has caused this Bond to be signed with the manual signature of the President of the Board of Directors of the Issuer and attested and countersigned with the manual signature of the Secretary of the Board of Directors of the Issuer, has caused the official seal of the Issuer to be duly impressed on this Bond, and has caused this Bond to be dated ___________ 1, 2017.

xxxxx	xxxxx
Secretary, Board of Directors, North Texas Municipal Water District	President, Board of Directors, North Texas Municipal Water District

(DISTRICT SEAL)

FORM OF REGISTRATION CERTIFICATE OF THE COMPTROLLER OF PUBLIC ACCOUNTS:

COMPTROLLER'S REGISTRATION CERTIFICATE: REGISTER NO.

I hereby certify that this Bond has been examined, certified as to validity, and approved by the Attorney General of the State of Texas, and that this Bond has been registered by the Comptroller of Public Accounts of the State of Texas.

Witness my signature and seal this

____
Comptroller of Public Accounts of the State of Texas

(COMPTROLLER'S SEAL)

Section 6. ADDITIONAL CHARACTERISTICS OF THE BONDS. Registration and Transfer. (a) The Issuer shall keep or cause to be kept at the principal corporate trust office of THE BANK OF NEW YORK MELLON TRUST COMPANY, NATIONAL ASSOCIATION, in Dallas, Texas (the "Paying Agent/Registrar") books or records of the registration and transfer of the Bonds (the "Registration Books"), and the Issuer hereby appoints the Paying Agent/Registrar as its registrar and transfer agent to keep such books or records and make such transfers and registrations under such reasonable regulations as the Issuer and Paying Agent/Registrar may prescribe; and the Paying Agent/Registrar shall make such transfers and registrations as herein provided. The Paying Agent/Registrar shall obtain and record in the Registration Books the address of the registered owner of each Bond to which payments with respect to the Bonds shall be mailed, as herein provided; but it shall be the duty of each registered owner to notify the Paying Agent/Registrar in writing of the address to which payments shall be mailed, and such interest payments shall not be mailed unless such notice has been given. The Issuer shall have the right to inspect the Registration Books during regular business hours of the Paying Agent/Registrar, but otherwise the Paying Agent/Registrar shall keep the Registration Books confidential and, unless otherwise required by law, shall not permit their inspection by any other entity. Registration of each Bond may be transferred in the Registration Books only upon presentation and surrender of such Bond to the Paying Agent/Registrar for transfer of registration and cancellation, together with proper written instruments of assignment, in form and with guarantee of signatures satisfactory to the Paying Agent/Registrar, evidencing (i) the assignment of the Bond, or any portion thereof in any integral multiple of $5,000, to the assignee or assignees thereof, and (ii) the right of such assignee or assignees to have the Bond or any such portion thereof registered in the name of such assignee or assignees. Upon the assignment and transfer of any Bond or any portion thereof, a new substitute Bond or Bonds shall be issued in conversion and exchange therefor in the manner herein provided. The Initial Bond, to the extent of the unpaid or unredeemed principal balance thereof, may be assigned and transferred by the initial registered owner thereof once only, and to one or more assignees designated in writing by the initial registered owner thereof. All Bonds issued and delivered in conversion of and exchange for the Initial Bond shall be in any denomination or denominations of any integral multiple of $5,000 (subject to the requirement hereinafter stated that each substitute Bond shall have a single stated principal maturity date), shall be in the form prescribed in the FORM OF SUBSTITUTE BOND set forth in this Resolution, and shall have the characteristics, and may be assigned, transferred, and converted as hereinafter provided. If the Initial Bond or any portion thereof is assigned and transferred or converted the Initial Bond must be surrendered to the Paying Agent/Registrar for cancellation, and each Bond issued in exchange for any portion of the Initial Bond shall have a single stated principal maturity date, and shall not be payable in installments; and each such Bond shall have a principal maturity date corresponding to the due date of the installment of principal or portion thereof for which the substitute Bond is being exchanged; and each such Bond shall bear interest at the single rate applicable to and borne by such installment of principal or portion thereof for which it is being exchanged. If only a portion of the Initial Bond is assigned and transferred, there shall be delivered to and registered in the name of the initial registered owner substitute Bonds in exchange for the unassigned balance of the Initial Bond in the same manner as if the initial registered owner were the assignee thereof. If any Bond or portion thereof other than the Initial Bond is assigned and transferred or converted each Bond issued in exchange therefor shall have the same principal maturity date and bear interest at the same rate as the Bond for which it is exchanged. A form of assignment shall be printed or endorsed on each Bond, excepting the Initial Bond, which shall be executed by the registered owner or its duly authorized attorney or representative to evidence an assignment thereof. Upon surrender of any Bonds or any portion or portions thereof for transfer of registration, an authorized representative of the Paying Agent/Registrar shall make such transfer in the Registration Books, and shall deliver a new fully registered substitute Bond or Bonds, having the characteristics herein described, payable to such assignee or assignees (which then will be the registered owner or owners of such new Bond or Bonds), or to the previous registered owner in case only a portion of a Bond is being assigned and transferred, all in conversion of and exchange for said assigned Bond or Bonds or any portion or portions thereof, in the same form and manner, and with the same effect, as provided in Section 6(d), below, for the conversion and exchange of Bonds by any registered owner of a Bond. The Issuer shall pay the Paying Agent/Registrar's standard or customary fees and charges for making such transfer and delivery of a substitute Bond or Bonds, but the one requesting such transfer shall pay any taxes or other governmental charges required to be paid with respect thereto. The Paying Agent/Registrar shall not be required to make transfers of registration of any Bond or any portion thereof (i) during the period commencing with the close of business on any Record Date and ending with the opening of business on the next following principal or interest payment date, or, (ii) with respect to any Bond or any portion thereof called for redemption prior to maturity, within 45 days prior to its redemption date.

(b) Ownership of Bonds. The entity in whose name any Bond shall be registered in the Registration Books at any time shall be deemed and treated as the absolute owner thereof for all purposes of this Resolution, whether or not such Bond shall be overdue, and the Issuer and the Paying Agent/Registrar shall not be affected by any notice to the contrary; and payment of, or on account of, the principal of, premium, if any, and interest on any such Bond shall be made only to such registered owner. All such payments shall be valid and effectual to satisfy and discharge the liability upon such Bond to the extent of the sum or sums so paid.

(c) Payment of Bonds and Interest. The Issuer hereby further appoints the Paying Agent/Registrar to act as the paying agent for paying the principal of and interest on the Bonds, and to act as its agent to convert and exchange or replace Bonds, all as provided in this Resolution. The Paying Agent/Registrar shall keep proper records of all payments made by the Issuer and the Paying Agent/Registrar with respect to the Bonds, and of all conversions and exchanges of Bonds, and all replacements of Bonds, as provided in this Resolution.

(d) Conversion and Exchange or Replacement; Authentication. Each Bond issued and delivered pursuant to this Resolution, to the extent of the unpaid or unredeemed principal balance or principal amount thereof, may, upon surrender of such Bond at the principal corporate trust office of the Paying Agent/Registrar, together with a written request therefor duly executed by the registered owner or the assignee or assignees thereof, or its or their duly authorized attorneys or representatives, with guarantee of signatures satisfactory to the Paying Agent/Registrar, may, at the option of the registered owner or such assignee or assignees, as appropriate, be converted into and exchanged for fully registered bonds, without interest coupons, in the form prescribed in the FORM OF SUBSTITUTE BOND set forth in this Resolution, in the denomination of $5,000, or any integral multiple of $5,000 (subject to the requirement hereinafter stated that each substitute Bond shall have a single stated maturity date), as requested in writing by such registered owner or such assignee or assignees, in an aggregate principal amount equal to the unpaid or unredeemed principal balance or principal amount of any Bond or Bonds so surrendered, and payable to the appropriate registered owner, assignee, or assignees, as the case may be. If the Initial Bond is assigned and transferred or converted each substitute Bond issued in exchange for any portion of the Initial Bond shall have a single stated principal maturity date, and shall not be payable in installments; and each such Bond shall have a principal maturity date corresponding to the due date of the installment of principal or portion thereof for which the substitute Bond is being exchanged; and each such Bond shall bear interest at the single rate applicable to and borne by such installment of principal or portion thereof for which it is being exchanged. If a portion of any Bond (other than the Initial Bond) shall be redeemed prior to its scheduled maturity as provided herein, a substitute Bond or Bonds having the same maturity date, bearing interest at the same rate, in the denomination or denominations of any integral multiple of $5,000 at the request of the registered owner, and in aggregate principal amount equal to the unredeemed portion thereof, will be issued to the registered owner upon surrender thereof for cancellation. If any Bond or portion thereof (other than the Initial Bond) is assigned and transferred or converted, each Bond issued in exchange therefor shall have the same principal maturity date and bear interest at the same rate as the Bond for which it is being exchanged. Each substitute Bond shall bear a letter and/or number to distinguish it from each other Bond. The Paying Agent/Registrar shall convert and exchange or replace Bonds as provided herein, and each fully registered Bond delivered in conversion of and exchange for or replacement of any Bond or portion thereof as permitted or required by any provision of this Resolution shall constitute one of the Bonds for all purposes of this Resolution, and may again be converted and exchanged or replaced. It is specifically provided that any Bond authenticated in conversion of and exchange for or replacement of another Bond on or prior to the first scheduled Record Date for the Initial Bond shall bear interest from the date of the Initial Bond, but each substitute Bond so authenticated after such first scheduled Record Date shall bear interest from the interest payment date next preceding the date on which such substitute Bond was so authenticated, unless such Bond is authenticated after any Record Date but on or before the next following interest payment date, in which case it shall bear interest from such next following interest payment date; provided, however, that if at the time of delivery of any substitute Bond the interest on the Bond for which it is being exchanged is due but has not been paid, then such Bond shall bear interest from the date to which such interest has been paid in full. THE INITIAL BOND issued and delivered pursuant to this Resolution is not required to be, and shall not be, authenticated by the Paying Agent/Registrar, but on each substitute Bond issued in conversion of and exchange for or replacement of any Bond or Bonds issued under this Resolution there shall be printed a Paying Agent/Registrar's Certificate, in the form set forth following the FORM OF SUBSTITUTION OF BOND. An authorized representative of the Paying Agent/Registrar shall, before the delivery of any such Bond, date and manually sign the Paying Agent/Registrar's Certificate, and no such Bond shall be deemed to be issued or outstanding unless the Paying Agent/Registrar's Certificate is so executed. The Paying Agent/Registrar promptly shall cancel all Bonds surrendered for conversion and exchange or replacement. No additional ordinances, orders, or resolutions need be passed or adopted by the governing body of the Issuer or any other body or person so as to accomplish the foregoing conversion and exchange or replacement of any Bond or portion thereof, and the Paying Agent/Registrar shall provide for the printing, execution, and delivery of the substitute Bonds in the manner prescribed herein, and said Bonds shall be of type composition printed on paper with lithographed or steel engraved borders of customary weight and strength. Pursuant to Section 1201.067, Texas Government Code, the duty of conversion and exchange or replacement of Bonds as aforesaid is hereby imposed upon the Paying Agent/Registrar, and, upon the execution of the above Paying Agent/Registrar's Authentication Certificate, the converted and exchanged or replaced Bond shall be valid, incontestable, and enforceable in the same manner and with the same effect as the Initial Bond which originally was issued pursuant to this Resolution, approved by the Attorney General, and registered by the Comptroller of Public Accounts. The Issuer shall pay the Paying Agent/Registrar's standard or customary fees and charges for transferring, converting, and exchanging any Bond or any portion thereof, but the one requesting any such transfer, conversion, and exchange shall pay any taxes or governmental charges required to be paid with respect thereto as a condition precedent to the exercise of such privilege of conversion and exchange. The Paying Agent/Registrar shall not be required to make any such conversion and exchange or replacement of Bonds or any portion thereof (i) during the period commencing with the close of business on any Record Date and ending with the opening of business on the next following principal or interest payment date, or, (ii) with respect to any Bond or portion thereof called for redemption prior to maturity, within 45 days prior to its redemption date.

(e) In General. All Bonds issued in conversion and exchange or replacement of any other Bond or portion thereof, (i) shall be issued in fully registered form, without interest coupons, with the principal of and interest on such Bonds to be payable only to the registered owners thereof, (ii) may be redeemed prior to their scheduled maturities, (iii) may be transferred and assigned, (iv) may be converted and exchanged for other Bonds, (v) shall have the characteristics, (vi) shall be signed and sealed, and (vii) the principal of and interest on the Bonds shall be payable, all as provided, and in the manner required or indicated, in the FORM OF SUBSTITUTE BOND set forth in this Resolution.

(f) Payment of Fees and Charges. The Issuer hereby covenants with the registered owners of the Bonds that it will (i) pay the standard or customary fees and charges of the Paying Agent/Registrar for its services with respect to the payment of the principal of and interest on the Bonds, when due, and (ii) pay the fees and charges of the Paying Agent/Registrar for services with respect to the transfer of registration of Bonds, and with respect to the conversion and exchange of Bonds solely to the extent above provided in this Resolution.

(g) Substitute Paying Agent/Registrar. The Issuer covenants with the registered owners of the Bonds that at all times while the Bonds are outstanding the Issuer will provide a competent and legally qualified bank, trust company, financial institution, or other agency to act as and perform the services of Paying Agent/Registrar for the Bonds under this Resolution, and that the Paying Agent/Registrar will be one entity. The Issuer reserves the right to, and may, at its option, change the Paying Agent/Registrar upon not less than 120 days written notice to the Paying Agent/Registrar, to be effective not later than 60 days prior to the next principal or interest payment date after such notice. In the event that the entity at any time acting as Paying Agent/Registrar (or its successor by merger, acquisition, or other method) should resign or otherwise cease to act as such, the Issuer covenants that promptly it will appoint a competent and legally qualified bank, trust company, financial institution, or other agency to act as Paying Agent/Registrar under this Resolution. Upon any change in the Paying Agent/Registrar, the previous Paying Agent/Registrar promptly shall transfer and deliver the Registration Books (or a copy thereof), along with all other pertinent books and records relating to the Bonds, to the new Paying Agent/Registrar designated and appointed by the Issuer. Upon any change in the Paying Agent/Registrar, the Issuer promptly will cause a written notice thereof to be sent by the new Paying Agent/Registrar to each registered owner of the Bonds, by United States mail, first-class postage prepaid, which notice also shall give the address of the new Paying Agent/Registrar. By accepting the position and performing as such, each Paying Agent/Registrar shall be deemed to have agreed to the provisions of this Resolution, and a certified copy of this Resolution shall be delivered to each Paying Agent/Registrar.

(h) Reporting Requirements of Paying Agent/Registrar. To the extent required by the Code and the regulations promulgated and pertaining thereto, it shall be the duty of the Paying Agent/Registrar, on behalf of the Issuer, to report to the owners of the Bonds and the Internal Revenue Service (i) the amount of "reportable payments", if any, subject to backup withholding during each year and the amount of tax withheld, if any, with respect to payments of the Bonds and (ii) the amount of interest or amount treating as interest on the Bonds and required to be included in gross income of the owner thereof.

Section 7. FORM OF SUBSTITUTE BONDS. The form of all Bonds issued in conversion and exchange or replacement of any other Bond or portion thereof, including the form of Paying Agent/Registrar's Certificate to be printed on each of such Bonds, and the Form of Assignment to be printed on each of the Bonds, shall be, respectively, substantially as follows, with such appropriate variations, omissions, or insertions as are permitted or required by this Resolution.

FORM OF SUBSTITUTE BOND

Unless this Bond is presented by an authorized representative of The Depository Trust Company, a New York corporation (together with any successor security depository appointed pursuant to the Indenture referred to herein, "DTC") to the Trustee named herein or its agent for registration of transfer, exchange, or payment, and any Bond issued is registered in the name of Cede & Co. or in such other name as is requested by an authorized representative of DTC (and any payment is made to Cede & Co. or to such other entity as is requested by an authorized representative of DTC), ANY TRANSFER, PLEDGE, OR OTHER USE HEREOF FOR VALUE OR OTHERWISE BY OR TO ANY PERSON IS WRONGFUL inasmuch as the registered owner hereof, Cede & Co., has an interest herein.

As provided in the Indenture, until the termination of the system of book-entry only transfers through DTC, and notwithstanding any other provision of the Indenture to the contrary, this Bond may be transferred, in whole but not in part, only to a nominee of DTC, or by a nominee of DTC to DTC or a nominee of DTC, or by DTC or a nominee of DTC to any successor securities depository or any nominee thereof.

NO. R-___ PRINCIPAL AMOUNT $______________

UNITED STATES OF AMERICA
STATE OF TEXAS
NORTH TEXAS MUNICIPAL WATER DISTRICT
WATER SYSTEM REVENUE BOND,
SERIES 2017

INTEREST RATE	MATURITY DATE	ISSUE DATE	CUSIP NO.
%	September 1, ____	____________, 2017	

ON THE MATURITY DATE specified above NORTH TEXAS MUNICIPAL WATER DISTRICT (the "Issuer"), being a political subdivision of the State of Texas, hereby promises to pay to CEDE & CO., or to the registered assignee hereof (either being hereinafter called the "registered owner") the principal amount of ____ and to pay interest thereon, calculated on the basis of a 360-day year composed of twelve 30-day months, from the Issue Date specified above to the Maturity Date specified above, or the date of redemption prior to maturity, at the interest rate per annum specified above; with interest being payable semiannually on each March 1 and September 1, commencing March 1, 2018. If the date of authentication of this Bond is later than the first Record Date (hereinafter defined), such principal amount shall bear interest from the interest payment date next preceding the date of authentication, unless such date of authentication is after any Record Date but on or before the next following interest payment date, in which case such principal amount shall bear interest from such next following interest payment date.

THE PRINCIPAL OF AND INTEREST ON this Bond are payable in lawful money of the United States of America, without exchange or collection charges. The principal of this Bond shall be paid to the registered owner hereof upon presentation and surrender of this Bond at maturity or upon the date fixed for its redemption prior to maturity, at the principal corporate trust office of THE BANK OF NEW YORK MELLON TRUST COMPANY, NATIONAL ASSOCIATION, in Dallas, Texas, which is the "Paying Agent/Registrar" for this Bond. The payment of interest on this Bond shall be made by the Paying Agent/Registrar to the registered owner hereof on each interest payment date by check dated as of such interest payment date, drawn by the Paying Agent/Registrar on, and payable solely from, funds of the Issuer required by the resolution authorizing the issuance of the Bonds (the "Bond Resolution") to be on deposit with the Paying Agent/Registrar for such purpose as hereinafter provided; and such check shall be sent by the Paying Agent/Registrar by United States mail, first-class postage prepaid, on each such interest payment date, to the registered owner hereof, at the address of the registered owner, as it appeared on the 15th day of the month next preceding each such date (the "Record Date") on the Registration Books kept by the Paying Agent/Registrar, as hereinafter described; provided, however, for Bonds, the registered owner of which is the Texas Water Development Board (the "TWDB"), at the option of the TWDB and at the expense of the Issuer, such payment shall be made by wire transfer pursuant to written directions of the TWDB. However, notwithstanding the foregoing provisions, the payment of such interest may be made by any other method acceptable to the Paying Agent/Registrar and requested by, and at the risk and expense of, the registered owner hereof. Any accrued interest due upon the redemption of this Bond prior to maturity as provided herein shall be paid to the registered owner at the principal corporate trust office of the Paying Agent/Registrar upon presentation and surrender of this Bond for redemption and payment at the principal corporate trust office of the Paying Agent/Registrar. The Issuer covenants with the registered owner of this Bond that on or before each principal payment date, interest payment date, and accrued interest payment date for this Bond it will make available to the Paying Agent/Registrar, from the "Interest and Redemption Fund" created by the Bond Resolution, the amounts required to provide for the payment, in immediately available funds, of all principal of and interest on the Bonds, when due.

IF THE DATE for the payment of the principal of or interest on this Bond shall be a Saturday, Sunday, a legal holiday, or a day on which banking institutions in the City where the Paying Agent/Registrar is located are authorized by law or executive order to close, then the date for such payment shall be the next succeeding day which is not such a Saturday, Sunday, legal holiday, or day on which banking institutions are authorized to close; and payment on such date shall have the same force and effect as if made on the original date payment was due.

THIS BOND is one of an issue of Bonds dated ___________ 1, 2017, authorized in accordance with the Constitution and laws of the State of Texas in the principal amount of $___________ FOR THE PURPOSE OF PROVIDING FUNDS FOR IMPROVING THE NORTH TEXAS MUNICIPAL WATER DISTRICT WATER SYSTEM.

ON MARCH 1, 2028, or on any date whatsoever thereafter, the Bonds of this Series may be redeemed prior to their scheduled maturities, at the option of the Issuer, with funds derived from any available and lawful source, as a whole, or in part, and, if in part, so long as the Bonds are owned by the TWDB, in inverse order of maturity, and otherwise the Issuer shall select and designate the particular maturities and amounts of Bonds to be redeemed. If less than all of the Bonds within a maturity are to be redeemed, the particular Bonds or portions thereof to be redeemed shall be selected by the Paying Agent/Registrar by lot or other customary method (provided that a portion of a Bond may be redeemed only in an integral multiple of $5,000), at the redemption price of the principal amount thereof, plus accrued interest to the date fixed for redemption.

AT LEAST 30 days prior to the date fixed for any redemption of Bonds or portions thereof prior to maturity at the option of the Issuer, a written notice of such redemption shall be sent by the Paying Agent/Registrar by United States mail, first-class postage prepaid, not less than 30 days prior to the date fixed for any such redemption, to the registered owner appearing on the Registration Books at the close of business on the day next preceding the date of mailing of such notice; provided, however, that any notice so mailed shall be conclusively presumed to have been duly given and the failure to receive such notice, or any defect therein shall not affect the validity or effectiveness of the proceedings for the redemption of any Bond at the option of the Issuer. By the date fixed for any such redemption due provision shall be made with the Paying Agent/Registrar for the payment of the required redemption price for the Bonds or portions thereof which are to be so redeemed, plus accrued interest thereon to the date fixed for redemption. If such written notice of redemption is mailed and if due provision for such payment is made, all as provided above, the Bonds or portions thereof which are to be so redeemed thereby automatically shall be treated as redeemed prior to their scheduled maturities, and they shall not bear interest after the date fixed for redemption, and they shall not be regarded as being outstanding except for the right of the registered owner to receive the redemption price plus accrued interest from the Paying Agent/Registrar out of the funds provided for such payment. If a portion of any Bond shall be redeemed a substitute Bond or Bonds having the same maturity date, bearing interest at the same rate, in any denomination or denominations in any integral multiple of $5,000, at the written request of the registered owner, and in aggregate principal amount equal to the unredeemed portion thereof, will be issued to the registered owner upon the surrender thereof for cancellation, at the expense of the Issuer, all as provided in the Bond Resolution.

THIS BOND OR ANY PORTION OR PORTIONS HEREOF IN ANY INTEGRAL MULTIPLE OF $5,000 may be assigned and shall be transferred only in the Registration Books of the Issuer kept by the Paying Agent/Registrar acting in the capacity of registrar for the Bonds, upon the terms and conditions set forth in the Bond Resolution. Among other requirements for such assignment and transfer, this Bond must be presented and surrendered to the Paying Agent/Registrar, together with proper instruments of assignment, in form and with guarantee of signatures satisfactory to the Paying Agent/Registrar, evidencing assignment of this Bond or any portion or portions hereof in any integral multiple of $5,000 to the assignee or assignees in whose name or names this Bond or any such portion or portions hereof is or are to be transferred and registered. The form of Assignment printed or endorsed on this Bond shall be executed by the registered owner or its duly authorized attorney or representative, to evidence the assignment hereof. A new Bond or Bonds payable to such assignee or assignees (which then will be the new registered owner or owners of such new Bond or Bonds), or to the previous registered owner in the case of the assignment and transfer of only a portion of this Bond, may be delivered by the Paying Agent/Registrar in conversion of and exchange for this Bond, all in the form and manner as provided in the next paragraph hereof for the conversion and exchange of other Bonds. The Issuer shall pay the Paying Agent/Registrar's standard or customary fees and charges for making such transfer, but the one requesting such transfer shall pay any taxes or other governmental charges required to be paid with respect thereto. The Paying Agent/Registrar shall not be required to make transfers of registration of this Bond or any portion hereof (i) during the period commencing with the close of business on any Record Date and ending with the opening of business on the next following principal or interest payment date, or, (ii) with respect to any Bond or any portion thereof called for redemption prior to maturity, within 45 days prior to its redemption date. The registered owner of this Bond shall be deemed and treated by the Issuer and the Paying Agent/Registrar as the absolute owner hereof for all purposes, including payment and discharge of liability upon this Bond to the extent of such payment, and the Issuer and the Paying Agent/Registrar shall not be affected by any notice to the contrary.

ALL BONDS OF THIS SERIES are issuable solely as fully registered bonds, without interest coupons, in the denomination of any integral multiple of $5,000. As provided in the Bond Resolution, this Bond, or any unredeemed portion hereof, may, at the request of the registered owner or the assignee or assignees hereof, be converted into and exchanged for a like aggregate principal amount of fully registered bonds, without interest coupons, payable to the appropriate registered owner, assignee, or assignees, as the case may be, having the same maturity date, and bearing interest at the same rate, in any denomination or denominations in any integral multiple of $5,000 as requested in writing by the appropriate registered owner, assignee, or assignees, as the case may be, upon surrender of this Bond to the Paying Agent/Registrar for cancellation, all in accordance with the form and procedures set forth in the Bond Resolution. The Issuer shall pay the Paying Agent/Registrar's standard or customary fees and charges for transferring, converting, and exchanging any Bond or any portion thereof, but the one requesting such transfer, conversion, and exchange shall pay any taxes or governmental charges required to be paid with respect thereto as a condition precedent to the exercise of such privilege of conversion and exchange. The Paying Agent/Registrar shall not be required to make any such conversion and exchange (i) during the period commencing with the close of business on any Record Date and ending with the opening of business on the next following principal or interest payment date, or, (ii) with respect to any Bond or portion thereof called for redemption prior to maturity, within 45 days prior to its redemption date.

IN THE EVENT any Paying Agent/Registrar for the Bonds is changed by the Issuer, resigns, or otherwise ceases to act as such, the Issuer has covenanted in the Bond Resolution that it promptly will appoint a competent and legally qualified substitute therefor, and promptly will cause written notice thereof to be mailed to the registered owners of the Bonds.

IT IS HEREBY certified, recited, and covenanted that this Bond has been duly and validly authorized, issued, and delivered; that all acts, conditions, and things required or proper to be performed, exist, and be done precedent to or in the authorization, issuance, and delivery of this Bond have been performed, existed, and been done in accordance with law; that this Bond is a special obligation of the Issuer which, together with other bonds, are secured by and payable from a first lien on and pledge of the "Pledged Revenues" as defined in the Bond Resolution, which include the "Net Revenues of the District's Water System", as defined in the Bond Resolution, including specifically revenues derived pursuant to existing water supply contracts between the Issuer and the Cities of Allen, Farmersville, Forney, Frisco, Garland, McKinney, Mesquite, Plano, Princeton, Richardson, Rockwall, Royse City, and Wylie, Texas, which cities are currently the Member Cities constituting the territory and boundaries of the Issuer, water supply contracts relating to the District's Water System with any other cities which hereafter may become Member Cities, and water supply contracts with other cities and customers in connection the District's Water System.

THE ISSUER has reserved the right, subject to the restrictions stated in the Bond Resolution, to issue Additional Bonds payable from and secured by a first lien on and pledge of the "Pledged Revenues" on a parity with this Bond and series of which it is a part.

THE ISSUER also has reserved the right to amend the Bond Resolution with the approval of the registered owners of 51% in principal amount of all outstanding bonds secured by and payable from a first lien on and pledge of the "Pledged Revenues".

THE REGISTERED OWNER hereof shall never have the right to demand payment of this Bond or the interest hereon out of any funds raised or to be raised by taxation or from any source whatsoever other than specified in the Bond Resolution.

BY BECOMING the registered owner of this Bond, the registered owner thereby acknowledges all of the terms and provisions of the Bond Resolution, agrees to be bound by such terms and provisions, acknowledges that the Bond Resolution is duly recorded and available for inspection in the official minutes and records of the governing body of the Issuer, and agrees that the terms and provisions of this Bond and the Bond Resolution constitute a contract between each registered owner hereof and the Issuer.

IN WITNESS WHEREOF, the Issuer has caused this Bond to be signed with the facsimile signature of the President of the Board of Directors of the Issuer and attested and countersigned with the facsimile signature of the Secretary of the Board of Directors of the Issuer, and has caused the official seal of the Issuer to be duly impressed, or placed in facsimile, on this Bond.

xxxxxx	xxxxx
Secretary, Board of Directors	President, Board of Directors
North Texas Municipal Water District	North Texas Municipal Water District

(DISTRICT SEAL)

FORM OF PAYING AGENT/REGISTRAR'S AUTHENTICATION CERTIFICATE

PAYING AGENT/REGISTRAR'S AUTHENTICATION CERTIFICATE

It is hereby certified that this Bond has been issued under the provisions of the Bond Resolution described in this Bond; and that this Bond has been issued in conversion of and exchange for or replacement of a bond, bonds, or a portion of a bond or bonds of an issue which originally was approved by the Attorney General of the State of Texas and registered by the Comptroller of Public Accounts of the State of Texas.

THE BANK OF NEW YORK MELLON TRUST
COMPANY, NATIONAL ASSOCIATION
Paying Agent/Registrar

Dated : ______________________________
Authorized Representative

FORM OF ASSIGNMENT

ASSIGNMENT

FOR VALUE RECEIVED, the undersigned sells, assigns and transfers unto

Please Insert Social Security or
Other Identifying Number of Assignee
/____________________________________/

____
(Name and Address of Assignee)
the within Bond and does hereby irrevocably constitute and appoint _________________________ to transfer said Bond on the books kept for registration thereof with full power of substitution in the premises.

Date: ______________________

____

Signature Guaranteed: _____________________________________

NOTICE: The signature to this assignment must correspond with the name as it appears upon the face of the within Bond in every particular, without alteration or enlargement or any change whatever; and

NOTICE: Signature(s) must be guaranteed by an eligible guarantor institution participating in a Securities Transfer Association recognized signature guarantee program.

Section 8. ADDITIONAL DEFINITIONS. That as used in this Resolution the following terms shall have the meanings set forth below, unless the text hereof specifically indicates otherwise:

The term "Additional Bonds" shall mean the additional parity revenue bonds permitted to be authorized in the future in this Resolution.

The term "Board" shall mean the Board of Directors of the Issuer, being the governing body of the Issuer, and it is further resolved that the declarations and covenants of the Issuer contained in this Resolution are made by, and for and on behalf of the Board and the Issuer, and are binding upon the Board and the Issuer for all purposes.

The terms "Bond Resolution" and "Resolution" mean this resolution authorizing the Bonds.

The term "Bonds" means collectively the Initial Bond as described and defined in Sections 2 and 3 of this Resolution, and all substitute bonds exchanged therefor as well as all other substitute and replacement bonds issued pursuant to this Resolution.

The term "Contracts" shall mean collectively: (a) the original separate water supply contracts between the Issuer and each of the current Member Cities, respectively, and all amendments thereto, with each of said contracts initially having been authorized at elections held in each of the current Member Cities, respectively, on December 5, 1953, except for (i) such contract with the City of Richardson, which is dated April 7, 1965, and was amended on July 2, 1973, and modified in October, 1973, (ii) such contract with the City of Allen, Texas, which is dated as of October 1, 1998 (the "Allen Contract"), and (iii) such contract with the City of Frisco, Texas, which is dated as of October 1, 2001 (the "Frisco Contract"), as all of said contracts (except the Allen Contract and the Frisco Contract, which have not been amended or modified since the respective dates thereof), as amended, have been further amended, modified, combined, consolidated, and wholly replaced by a single "North Texas Municipal Water District Regional Water Supply Facilities Amendatory Contract" dated as of August 1, 1988, executed between the Issuer and each of such Member Cities, (b) any water supply contracts relating to the System with any other cities which hereafter may become Member Cities, and (c) all water supply contracts between the Issuer and other cities and customers in connection the District's Water System.

The terms "District" and "Issuer" shall mean North Texas Municipal Water District.

The terms "District's System" and "System" shall mean all of the Issuer's existing water storage, treatment, transportation, distribution, and supply facilities, and other properties, which heretofore have been acquired or constructed with the proceeds from the sale of all bonds or other obligations ever issued by the Issuer which have been payable from or secured by a lien on or pledge of any part of the "Net Revenues of the System," or with revenues from said System, together with all future improvements, enlargements, extensions, and additions to any of the foregoing, and all future new facilities, which are acquired or constructed with the proceeds from the sale of the Parity Bonds and any Additional Bonds or money from the Contingency Fund (hereinafter described) or any water supply facilities which are deliberately and specifically, at the option of the Board, made a part of the System by resolution of the Board, and all repairs to and replacements of the System. Said terms do not include any Issuer facilities which provide waste treatment or disposal or other wastewater services of any kind. Said terms do not include any facilities acquired or constructed by the Issuer with any proceeds from the issuance of "Special Facilities Bonds," which are hereby defined as being revenue obligations of the Issuer which are not issued as Additional Bonds, and which are payable from any source, contract or revenues whatsoever other than the Pledged Revenues; and Special Facilities Bonds may be issued for any lawful purposes and made payable from any source, contract, or revenues whatsoever other than the Pledged Revenues.

The term "Gross Revenues of the System" shall mean all of the revenues, income, rentals, rates, fees, and charges of every nature derived by the Board or the Issuer from the operation and/or ownership of the System, including specifically all payments and amounts received by the Board or the Issuer from the Contracts, and all investments, interest, and income from any Fund created pursuant to this Resolution.

The term "Member Cities" shall mean collectively the Cities of Allen, Farmersville, Forney, Frisco, Garland, McKinney, Mesquite, Plano, Princeton, Richardson, Rockwall, Royse City, and Wylie, Texas, together with all cities which hereafter may become Member Cities as provided in the Act.

The terms "Net Revenues of the District’s Water System" and "Net Revenues of the System" shall mean the Gross Revenues of the System less the Operation and Maintenance Expense of the System.

The term "Operation and Maintenance Expense of the System" shall mean all costs of operation and maintenance of the System including, but not limited to, repairs and replacements, operating personnel, the cost of utilities, supervision, engineering, accounting, auditing, legal services, insurance premiums, and any other supplies, services, administrative costs, and equipment necessary for proper operation and maintenance of the System, payments to any public or private entity made for the purchase of water, storage right, or other interests in water, or for the use or operation of any property or facilities, payments to the United States of America with respect to the operation, maintenance, and use of Lavon Dam and Reservoir and/or any other reservoirs or facilities in connection with the Issuer's sources of water for the System, and payments made by the Issuer in satisfaction of judgments or other liabilities resulting from claims not covered by Issuer's insurance. Depreciation shall not be considered an item of Operation and Maintenance Expense.

The term "Parity Bonds" shall mean, (i) the Bonds, (ii) the outstanding North Texas Municipal Water District Water System Revenue Bonds, Series 2008 (the "Series 2008 Bonds"), dated as of June 15, 2008, authorized by a resolution of the Board on June 26, 2008 (the "Series 2008 Bond Resolution"), (iii) the outstanding North Texas Municipal Water District Water System Revenue Bonds, Series 2009A (the "Series 2009A Bonds"), dated as of March 1, 2009, authorized by a resolution of the Board on February 24, 2009 (the "Series 2009A Bond Resolution"), (iv) the outstanding North Texas Municipal Water District Water System Revenue Bonds, Series 2009B (the "Series 2009B Bonds"), dated as of July 15, 2009, authorized by a resolution of the Board on July 23, 2009 (the "Series 2009B Bond Resolution"), (v) the outstanding North Texas Municipal Water District Water System Revenue Refunding and Improvement Bonds, Series 2009C (the "Series 2009C Bonds"), dated as of November 15, 2009, authorized by a resolution of the Board on October 22, 2009 (the "Series 2009C Bond Resolution"), (vi) the outstanding North Texas Municipal Water

District Water System Revenue Bonds, Taxable Series 2009D (Build America Bonds - Direct Payment) (the "Series 2009D Bonds"), dated as of November 15, 2009, authorized by a resolution of the Board on October 22, 2009 (the "Series 2009D Bond Resolution"), (vii) the North Texas Municipal Water District Water System Revenue Bonds, Series 2010 (the "Series 2010 Bonds"), dated March 15, 2010, authorized by a resolution of the Board on October 28, 2010 (the "Series 2010 Bond Resolution"), (viii) the North Texas Municipal Water District Water System Revenue Bonds, Taxable Series 2010A (Build America Bonds - Direct Payment) (the "Series 2010A Bonds"), dated March 15, 2010, authorized by a resolution of the Board on October 28, 2010 (the "Series 2010A Bonds"), (ix) the North Texas Municipal Water District Water System Revenue Refunding and Improvement Bonds, Series 2012 (the "Series 2012 Bonds"), dated as of June 15, 2012, authorized by a resolution of the Board on June 28, 2012 (the "Series 2012 Bond Resolution"), (x) the North Texas Municipal Water District Water System Revenue Refunding and Improvement Bonds, Series 2014 (the "Series 2014 Bonds"), dated as of June 15, 2014, authorized by a resolution of the Board on June 26, 2014 (the "Series 2014 Bond Resolution"), (xi) the North Texas Municipal Water District Water System Revenue Refunding and Improvement Bonds, Series 2015 (the "Series 2015 Bonds"), dated as of April 15, 2015, authorized by a resolution of the Board on April 23, 2015 (the "Series 2015 Bond Resolution"), and (xii) the North Texas Municipal Water District Water System Revenue Refunding and Improvement Bonds, Series 2016 (the "Series 2016 Bonds"), dated as of October 15, 2016, authorized by a resolution of the Board on October 27, 2016 (the "Series 2016 Bond Resolution").

The term "Pledged Revenues" shall mean: (a) the Net Revenues of the System and (b) any additional revenues, income, receipts, or other resources, including, without limitation, any grants, donations, or income received or to be received from the United States Government, or any other public or private source, whether pursuant to an agreement or otherwise, which in the future may, at the option of the Issuer, be pledged to the payment of the Parity Bonds or the Additional Bonds.

The term "TWDB" shall mean the Texas Water Development Board.

The term "year" or "fiscal year" shall mean the Issuer's fiscal year, which currently begins on October 1 of each calendar year, but which subsequently may be any other 12 month period hereafter established by the Issuer as a fiscal year for the purposes of any resolution authorizing the Bonds or any Additional Bonds.

Section 9. PLEDGE. (a) The Bonds authorized by this Resolution are hereby designated as, and shall be, "Additional Bonds" as permitted by Sections 22 and 23, respectively, of the Series 2008 Bond Resolution, the Series 2009A Bond Resolution, the Series 2009B Bonds Resolution, the Series 2009C Bond Resolution, the Series 2009D Bond Resolution, the Series 2010 Bond Resolution, the Series 2010A Bond Resolution, the Series 2012 Bond Resolution, the Series 2014 Bond Resolution, the Series 2015 Bond Resolution, and the Series 2016 Bond Resolution, and it is hereby determined, declared, and resolved that all of the Parity Bonds, including the Bonds authorized by this Resolution, are and shall be secured and payable equally and ratably on a parity, and that Sections 8 through 26 of this Resolution substantially restate and are supplemental to and cumulative of the applicable and pertinent provisions of the resolutions authorizing the issuance of the previously issued Parity Bonds, respectively, with Sections 8 through 26 of this Resolution being equally applicable to all of the Parity Bonds, including the Bonds.

(b) The Parity Bonds and any Additional Bonds, and the interest thereon, are and shall be secured by and payable from a first lien on and pledge of the Pledged Revenues, and the Pledged Revenues are further pledged to the establishment and maintenance of the Interest and Redemption Fund, the Reserve Fund and the Contingency Fund as provided in this Resolution.

Section 10. REVENUE FUND. There has been created and established and there shall be maintained on the books of the Issuer, and accounted for separate and apart from all other funds of the Issuer, a special fund entitled the "North Texas Municipal Water District Water System Revenue Bonds Revenue Fund" (hereinafter called the "Revenue Fund"). All Gross Revenues of the System (excepting the investment interest and income from the Interest and Redemption Fund, the Reserve Fund, and the Contingency Fund) shall be credited to the Revenue Fund immediately upon receipt. All Operation and Maintenance Expenses of the System shall be paid from such Gross Revenues credited to the Revenue Fund, as a first charge against same.

Section 11. INTEREST AND REDEMPTION FUND. For the sole purpose of paying the principal of and interest on all outstanding Parity Bonds and any Additional Bonds, as the same come due, there has been created and established and shall be maintained at The Bank of New York Mellon Trust Company, National Association, or at the option of the Issuer at any time hereafter, established and maintained at any national bank having a capital and surplus in excess of $25,000,000, a separate fund entitled the "North Texas Municipal Water District Water System Revenue Bonds Interest and Redemption Fund" (hereinafter called the "Interest and Redemption Fund").

Section 12. RESERVE FUND. There has been created and established, and there shall be maintained at The Bank of New York Mellon Trust Company, National Association, or at the option of the Issuer at any time hereafter, established and maintained at any national bank having a capital and surplus in excess of $25,000,000, a separate fund entitled the "North Texas Municipal Water District Regional Water System Revenue Bonds Reserve Fund" (hereinafter called the "Reserve Fund"). The Reserve Fund shall be used solely for the purpose of finally retiring the last of the outstanding Parity Bonds and Additional Bonds, or for paying principal of and interest on any outstanding Parity Bonds and Additional Bonds, when and to the extent the amount in the Interest and Redemption Fund is insufficient for such purpose.

Section 13. CONTINGENCY FUND. There has been created and established, and there shall be maintained at The Bank of New York Mellon Trust Company, National Association, or at the option of the Issuer at any time hereafter, established and maintained at any national bank having a capital and surplus in excess of $25,000,000, a separate fund entitled the "North Texas Municipal Water District Water System Revenue Bonds Contingency Fund" (hereinafter called the "Contingency Fund"). The Contingency Fund shall be used solely for the purpose of paying the costs of improvements, enlargements, extensions, or additions to the System, and unexpected or extraordinary repairs or replacements of the System for which System funds are not otherwise available, or for paying unexpected or extraordinary Operation and Maintenance Expenses of the System for which System funds are not otherwise available, or for paying principal of and interest on any Parity Bonds or Additional Bonds, when and to the extent the amount in the Interest and Redemption Fund is insufficient for such purpose

Section 14. DEPOSITS OF PLEDGED REVENUES; INVESTMENTS. (a) The Pledged Revenues shall be deposited into the Interest and Redemption Fund, the Reserve Fund, and the Contingency Fund when and as required by this Resolution.

(b) Money in any Fund established or maintained pursuant to the this Resolution may, at the option of the Issuer, be placed in secured time deposits or secured certificates of deposit, or be invested in direct obligations of the United States of America, obligations guaranteed or insured by the United States of America, which, in the opinion of the Attorney General of the United States, are backed by its full faith and credit or represent its general obligations, including, but not limited to, evidences of indebtedness issued, insured, or guaranteed by such governmental agencies as the Federal Home Loan Banks, Government National Mortgage Association, Farmers Home Administration, Federal Home Loan Mortgage Association, or Small Business Administration; provided that all such deposits and investments shall be made in such manner that the money required to be expended from any Fund will be available at the proper time or times. Such investments shall be valued in terms of current market value as of the 20th day of August of each year. Interest and income derived from such deposits and investments shall be credited to the Fund from which the deposit or investment was made. Such investments shall be sold promptly when necessary to prevent any default in connection with the Parity Bonds or Additional Bonds.

Section 15. FUNDS SECURED. Money in all Funds described in this Resolution, to the extent not invested, shall be secured in the manner prescribed by law for securing funds of the Issuer.

Section 16. DEBT SERVICE REQUIREMENTS. (a) Promptly after the delivery of the Initial Bond the Issuer shall cause to be deposited to the credit of the Interest and Redemption Fund, from the proceeds received from the sale and delivery of the Initial Bond, all accrued interest, if any, to be used to pay part of the interest coming due on the Bonds.

(b) The Issuer shall transfer from the Pledged Revenues and deposit to the credit of the Interest and Redemption Fund the amounts, at the times, as follows:

> (1) such amounts, deposited in approximately equal monthly installments on or before the 25th day of each month hereafter as will be sufficient, together with other amounts, if any, then on hand in the Interest and Redemption Fund and available for such purpose, to pay the interest scheduled to accrue and come due on all of the Parity Bonds on the next succeeding interest payment date; and
>
> (2) such amounts, deposited in approximately equal monthly installments on or before the 25th day of each month hereafter as will be sufficient, together with other amounts, if any, then on hand in the Interest and Redemption Fund and available for such purpose, to pay the principal scheduled to mature and come due, and/or mandatorily required to be redeemed prior to maturity, on all of the Parity Bonds on the next succeeding principal payment date.

Section 17. RESERVE REQUIREMENTS. The Issuer is required to accumulate and maintain in the Reserve Fund an aggregate amount of money and/or investments equal in market value to the average annual principal and interest requirements on all outstanding Parity Bonds (the "Reserve Required Amount"). Immediately after the delivery of the Initial Bond, the District shall deposit to the credit of the Reserve Fund, from the proceeds from the sale and delivery of the Initial Bond, an amount of money, if any, which will cause the Reserve Fund to contain, together with the other money and/or investments then on hand therein, an amount of money and/or investments equal in market value to the Reserve Required Amount. No deposits shall be made into the Reserve Fund as long as the money and investments in the Reserve Fund are at least equal in market value to the Reserve Required Amount; but if and whenever the market value of money and investments in the Reserve Fund is reduced below said Reserve Required Amount because of a decrease in market value of investments, then the Issuer shall require the Member Cities to increase their payments under their respective Contracts as soon as practicable, and in any event within one year, in an amount sufficient to restore the amount of such decrease; and in the event the Reserve Fund is used pay the principal of or interest on the Bonds because of insufficient amounts being available in the Interest and Redemption Fund, then the Issuer shall require the Member Cities to increase their payments under the their respective Contracts as soon as practicable, and in any event within one year, in an amount sufficient to restore the Reserve Fund to the Reserve Required Amount, and the Issuer shall deposit, in the Reserve Fund, in approximately equal periodic payments, not less than annual, such amounts as are required to cause the Reserve Fund to contain the Reserve Required Amount within five years from any date of the use of the Reserve Fund to pay such principal or interest. So long as the Reserve Fund contains the Reserve Required Amount, all amounts in excess thereof shall be deposited to the credit of the Interest and Redemption Fund on or before September 1 of each year.

Section 18. CONTINGENCY REQUIREMENTS. There is now on hand in the Contingency Fund an amount of money and/or investments at least equal in market value to $500,000. No additional deposits are required to be made to the credit of the Contingency Fund unless and until such amount therein is reduced or depleted. If and when such amount in the Contingency Fund is reduced or depleted then, subject and subordinate to making the required deposits to the credit of the Interest and Redemption Fund and the Reserve Fund, such reduction or depletion shall be restored from amounts which shall be provided for such purpose in the Issuer's Annual Budget for the next ensuing fiscal year or years; provided that the Issuer is not required to budget more than $200,000 for such purpose during any one fiscal year. So long as the Contingency Fund contains money and investments not less than the amount of $500,000 in market value, any surplus in the Contingency Fund over said amount may be withdrawn and used for any lawful purpose.

Section 19. DEFICIENCIES; EXCESS PLEDGED REVENUES. (a) If on any occasion there shall not be sufficient Pledged Revenues to make the required deposits into the Interest and Redemption Fund, the Contingency Fund, and the Reserve Fund, then such deficiency shall be made up as soon as possible from the next available Pledged Revenues, or from any other sources lawfully available for such purpose.

(b) Subject to making the required deposits to the credit of the Interest and Redemption Fund, the Contingency Fund, and the Reserve Fund, when and as required by this Resolution, or any Resolution authorizing the issuance of Additional Bonds, the excess Pledged Revenues may be used for any lawful purpose; provided that at the time each Annual Budget is prepared all such excess revenues which are not pledged to the payment of junior or subordinate lien bonds or other obligations of the Issuer, and which have not been committed by formal resolution or order of the Board for a specific purpose, and which exceed twenty-five percent of the Operation and Maintenance Expenses of the Issuer for the fiscal year then ending, shall be applied to the payment of Operation and Maintenance Expenses of the Issuer for the next ensuing fiscal year, and the Annual Budget shall be prepared accordingly.

Section 20. PAYMENT OF PARITY BONDS AND ADDITIONAL BONDS. Semiannually on or before the first day of each March and September while any of the Parity Bonds or Additional Bonds are outstanding and unpaid, the Issuer shall make available to the paying agents therefor, out of the Interest and Redemption Fund, the Contingency Fund, or the Reserve Fund, if necessary, money sufficient to pay such interest on and such principal of the Parity Bonds and Additional Bonds as will accrue or mature on such March 1 or September 1, as the case may be. The paying agents shall destroy all paid Parity Bonds and Additional Bonds, and furnish the Issuer with an appropriate certificate of cancellation or destruction.

Section 21. FINAL DEPOSITS; GOVERNMENTAL OBLIGATIONS. (a) Any Parity Bond or Additional Bond shall be deemed to be paid, retired, and no longer outstanding, when payment of the principal of, redemption premium, if any, on such Parity Bond or Additional Bond, plus interest thereon to the due date thereof (whether such date be by reason of maturity, upon redemption, or otherwise) either (i) shall have been made or caused to be made in accordance with the terms thereof (including the giving of any required notice of redemption), or (ii) shall have been provided by irrevocably depositing with a paying agent therefor, (1) money sufficient to make such payment or (2) Government Obligations, as hereinafter defined in this Section, certified by an independent public accounting firm of national reputation to mature as to principal and interest in such amounts and at such times as will insure the availability, without reinvestment, of sufficient money to make such payment, and all necessary and proper fees, compensation, and expenses of such paying agent pertaining to the Parity Bonds and Additional Bonds with respect to which such deposit is made shall have been paid or the payment thereof provided for to the satisfaction of such paying agent. At such time as a Parity Bond or Additional Bond shall be deemed to be paid hereunder, as aforesaid, it shall no longer be secured by or entitled to the benefits of any Bond Resolution or a lien on and pledge of the Pledged Revenues, and shall be entitled to payment solely from such money or Government Obligations.

(b) Any moneys so deposited with a paying agent may at the direction of the Issuer also be invested in Government Obligations, maturing in the amounts and times as hereinbefore set forth, and all income from all Government Obligations in the hands of the paying agent pursuant to this Section which is not required for the payment of the Parity Bonds and Additional Bonds, the redemption premium, if any, and interest thereon, with respect to which such moneys has been so deposited, shall be turned over to the Issuer.

(c) The Issuer covenants that no deposit will be made or accepted under clause (ii) of this Section and no use made of any such deposit which would cause the Parity Bonds or any Additional Bonds to be treated as arbitrage bonds within the meaning of the Internal Revenue Code of 1986, as amended.

(d) For the purpose of this Section, the term "Government Obligations" shall mean direct obligations of the United States of America, including obligations the principal of and interest on which are unconditionally guaranteed by the United States of America, and which may be United States Treasury obligations such as its State and Local Government Series, and which may be in book-entry form.

(e) Notwithstanding any provisions of this Resolution, all money or Government Obligations set aside and held in trust pursuant to the provisions of this Section for the payment of Parity Bonds and Additional Bonds, the redemption premium, if any, and interest thereon, shall be applied to and used for the payment of Parity Bonds and Additional Bonds, the redemption premium, if any, and interest thereon.

(f) Notwithstanding the foregoing, the Issuer covenants that with respect to the Parity Bonds it will provide a paying agent/registrar to perform the services thereof provided for by this Resolution the same as if they had not been defeased, and the Issuer shall make proper arrangements to provide and pay for such paying agent and registrar services.

Section 22. ADDITIONAL BONDS. (a) The Issuer shall have the right and power at any time and from time to time, and in one or more Series or issues, to authorize, issue, and deliver additional parity revenue bonds (herein called "Additional Bonds"), in accordance with law, in any amounts, for any lawful purpose relating to the System, including the refunding of any Parity Bonds or Additional Bonds. Such Additional Bonds, if and when authorized, issued, and delivered in accordance with this Resolution, shall be secured by and made payable equally and ratably on a parity with the Parity Bonds, and all other outstanding Additional Bonds, from a first lien on and pledge of the Pledged Revenues.

(b) The Interest and Redemption Fund and the Reserve Fund, established by this Resolution shall secure and be used to pay all Additional Bonds as well as the Parity Bonds. However, each Resolution under which Additional Bonds are issued shall provide and require that, in addition to the amounts required by the provisions of this Resolution and the provisions of any other Resolution or Resolutions authorizing Additional Bonds to be deposited to the credit of the Interest and Redemption Fund, the Issuer shall deposit to the credit of the Interest and Redemption Fund at least such amounts as are required for the payment of all principal of and interest on said Additional Bonds then being issued, as the same come due; and that the aggregate amount to be accumulated and maintained in the Reserve Fund shall be increased, if and to the extent necessary, to an amount not less than the average annual principal and interest requirements of all Parity Bonds and Additional Bonds which will be outstanding after the issuance and delivery of the then proposed Additional Bonds; and that the required additional amount shall be so accumulated by the deposit in the Reserve Fund of all or any part of said required additional amount in cash immediately after the delivery of the then proposed Additional Bonds, or, at the option of the Issuer, by the deposit of said required additional amount (or any balance of said required additional amount not deposited in cash as permitted above) within five years from the date of such installment or series of Additional Bonds, and in approximately equal installments, not less than annual.

(c) All calculations of average annual principal and interest requirements made pursuant to this Section shall be made as of and from the date of the Additional Bonds then proposed to be issued.

(d) The principal of all Additional Bonds must be scheduled to be paid or mature on September 1 of the years in which such principal is scheduled to be paid or mature; and all interest thereon must be payable on March 1 and September 1.

Section 23. FURTHER REQUIREMENTS FOR ADDITIONAL BONDS. Additional Bonds shall be issued only in accordance with this Resolution, but notwithstanding any provisions of this Resolution to the contrary, no installment, Series, or issue of Additional Bonds shall be issued or delivered unless the President and the Secretary of the Board sign a written certificate to the effect that the Issuer is not in default as to any covenant, condition, or obligation in connection with all outstanding Parity Bonds and Additional Bonds, and the Resolutions authorizing same, and that the Interest and Redemption Fund and the Reserve Fund each contains the amount then required to be therein, and either (a) an independent registered professional engineer of the State of Texas or a firm of such engineers executes a certificate or report to the effect that in his or its opinion the Pledged Revenues in each complete fiscal year thereafter will be at least equal to 1.25 times the average annual principal and interest requirements of all Parity Bonds and Additional Bonds to be outstanding after the delivery of the then proposed Additional Bonds, or (b) in the alternative to (a), above, the President and Secretary of the Board sign a written certificate to the effect that, based upon an opinion of legal counsel to the Issuer, there are Contracts then in effect pursuant to which the Member Cities and others which are parties to such Contracts are obligated to make minimum payments to the Issuer at such times (including during periods when water is not available to such member Cities and others) and in such amounts as shall be necessary to provide to the Issuer Net Revenues of the System sufficient to pay when due all principal of and interest on all Parity Bonds and Additional Bonds to be outstanding after the issuance of the proposed Additional Bonds, and to make the deposits into the Reserve Fund as required under this Resolution.

Section 24. GENERAL COVENANTS. The Issuer further covenants and agrees that:

(a) PERFORMANCE. It will faithfully perform at all times any and all covenants, undertakings, stipulations, and provisions contained in this Resolution and each resolution authorizing the issuance of Additional Bonds, and in each and every Parity Bond and Additional Bond; that it will promptly pay or cause to be paid the principal of and interest on every Bond and Additional Bond, on the dates and in the places and manner prescribed in such resolutions and Parity Bonds or Additional Bonds; and that it will, at the times and in the manner prescribed, deposit or cause to be deposited the amounts required to be deposited into the Interest and Redemption Fund and the Reserve Fund; and any holder of the Parity Bonds or Additional Bonds may require the Issuer, its Board, and its officials and employees, to carry out, respect, or enforce the covenants and obligations of this Resolution or any resolution authorizing the issuance of Additional Bonds, by all legal and equitable means, including specifically, but without limitation, the use and filing of mandamus proceedings, in any court of competent jurisdiction, against the Issuer, its Board, and its officials and employees.

(b) ISSUER'S LEGAL AUTHORITY. It is a duly created and existing conservation and reclamation district of the State of Texas pursuant to Article 16, Section 59 of the Texas Constitution, and Chapter 62, Acts of the 52nd Legislature of the State of Texas, Regular Session, 1951, as amended (originally compiled as Vernon's Ann. Tex. Civ. St. Article 8280-141), and is duly authorized under the laws of the State of Texas to create and issue the Parity Bonds; that all action on its part for the creation and issuance of the Parity Bonds has been duly and effectively taken, and that the Parity Bonds in the hands of the holders and owners thereof are and will be valid and enforceable special obligations of the Issuer in accordance with their terms.

(c) TITLE. It has or will obtain lawful title to, or the lawful right to use and operate, the lands, buildings, and facilities constituting the System, that it warrants that it will defend, the title to or lawful right to use and operate, all the aforesaid lands, buildings, and facilities, and every part thereof, for the benefit of the holders and owners of the Parity Bonds and Additional Bonds against the claims and demands of all persons whomsoever, that it is lawfully qualified to pledge the Pledged Revenues to the payment of the Parity Bonds and Additional Bonds in the manner prescribed herein, and has lawfully exercised such rights.

(d) LIENS. It will from time to time and before the same become delinquent pay and discharge all taxes, assessments, and governmental charges, if any, which shall be lawfully imposed upon it, or the System, that it will pay all lawful claims for rents, royalties, labor, materials, and supplies which if unpaid might by law become a lien or charge thereon, the lien of which would be prior to or interfere with the liens hereof, so that the priority of the liens granted hereunder shall be fully preserved in the manner provided herein, and that it will not create or suffer to be created any mechanic's, laborer's, materialman's, or other lien or charge which might or could be prior to the liens hereof, or do or suffer any matter or thing whereby the liens hereof might or could be impaired; provided, however, that no such tax, assessment, or charge, and that no such claims which might be used as the basis of a mechanic's, laborer's, materialman's, or other lien or charge, shall be required to be paid so long as the validity of the same shall be contested in good faith by the Issuer.

(e) OPERATION OF SYSTEM. While the Parity Bonds or any Additional Bonds are outstanding and unpaid it will cause the System to be continuously and efficiently operated and maintained in good condition, repair, and working order, and at a reasonable cost.

(f) FURTHER ENCUMBRANCE. While the Parity Bonds or any Additional Bonds are outstanding and unpaid, it shall not additionally encumber the Pledged Revenues in any manner, except as permitted in this Resolution in connection with Additional Bonds, unless said encumbrance is made junior and subordinate in all respects to the liens, pledges, covenants, and agreements of this Resolution and any resolution authorizing the issuance of Additional Bonds; but the right of the Issuer and the Board to issue revenue bonds payable from a subordinate lien on the Pledged Revenues is specifically recognized and retained.

(g) SALE OF PROPERTY. While the Parity Bonds or any Additional Bonds are outstanding and unpaid, it will maintain its current legal corporate status as a conservation and reclamation district, and the Issuer shall not sell, convey, mortgage, or in any manner transfer title to, or lease, or otherwise dispose of the entire System, or any significant or substantial part thereof; provided that whenever it deems it necessary to dispose of any machinery, fixtures, and equipment, it may sell or otherwise dispose of such machinery, fixtures, and equipment when it has made arrangements to replace the same or provide substitutes therefor, unless it is determined by the Board that no such replacement or substitute is necessary.

(h) INSURANCE. (1) It will cause to be insured such parts of the System as would usually be insured by corporations operating like properties, with a responsible insurance company or companies, against risks, accidents, or casualties against which and to the extent insurance is usually carried by corporations operating like properties, including fire and extended coverage insurance. Public liability and property damage insurance shall also be carried unless the general counsel for Issuer, or the Attorney General of Texas, gives a written opinion to the effect that the Issuer, the Board, and its officers and employees, are not liable for claims which would be protected by such insurance. At any time while any contractor engaged in construction work shall be fully responsible therefor, the Issuer shall not be required to carry insurance on the works being constructed, but the contractor shall be required to carry appropriate insurance. All such policies shall be open to the inspection of the owners of the Parity Bonds and Additional Bonds and their representatives at all reasonable times.

(2) Upon the happening of any loss or damage covered by insurance from one or more of said causes, the Issuer shall make due proof of loss and shall do all things necessary or desirable to cause the insuring companies to make payment in full directly to the Issuer. The proceeds of insurance covering such property, together with any other funds necessary and available for such purpose, shall be used forthwith by the Issuer for repairing the property damaged or replacing the property destroyed; provided, however, that if said insurance proceeds and other funds are insufficient for such purpose, then said insurance proceeds pertaining to the System shall be used promptly as follows:

> (a) for the redemption prior to maturity of the Parity Bonds and Additional Bonds, if any, ratably in the proportion that the outstanding principal of each Series or issue of Parity Bonds or Additional Bonds bears to the total outstanding principal of all Parity Bonds and Additional Bonds; provided that if on any such occasion the principal of any such Series or issue is not subject to redemption, it shall not be regarded as outstanding in making the foregoing computation; or
>
> (b) if none of the outstanding Parity Bonds or Additional Bonds is subject to redemption, then for the purchase on the open market and retirement of said Parity Bonds and Additional Bonds, in the same proportion as prescribed in the foregoing clause (a), to the extent practicable; provided that the purchase price for any such Parity Bond or Additional Bonds shall not exceed the redemption price of such Parity Bond or Additional Bond on the first date upon which it becomes subject to redemption; or
>
> (c) to the extent that the foregoing clauses (a) and (b) cannot be complied with at the time, the insurance proceeds, or the remainder thereof, shall be deposited in a special and separate trust fund, at an official depository of the Issuer, to be designated the Insurance Account. The Insurance Account shall be held until such time as the foregoing clauses (a) and/or (b) can be complied with, or until other funds become available which, together with

the Insurance Account, will be sufficient to make the repairs or replacements originally required, whichever of said events occurs first.

(3) The annual audit hereinafter required shall contain a list of all such insurance policies carried, together with a statement as to whether or not all insurance premiums upon such policies have been paid.

(i) RATE COVENANT. It will fix, establish, maintain, and collect such rentals, rates, charges, and fees for the use and availability of the System as are necessary to produce Gross Revenues of the System sufficient, together with any other Pledged Revenues, (a) to pay all Operation and Maintenance Expenses of the System and (b) to make all payments and deposits required to be made into the Interest and Redemption Fund, and to maintain the Reserve Fund and the Contingency Fund, when and as required by the resolutions authorizing all Parity Bonds and Additional Bonds.

(j) RECORDS. Proper books of record and account will be kept in which full, true, and correct entries will be made of all dealings, activities, and transactions relating to the System, the Pledged Revenues, and all Funds described in this Resolution; and all books, documents, and vouchers relating thereto shall at all reasonable times be made available for inspection upon request of any owner of a Parity Bond or Additional Bond.

(k) AUDITS. Each year while any of the Parity Bonds or Additional Bonds is outstanding, an audit will be made of its books and accounts relating to the System and the Pledged Revenues by an independent certified public accountant or an independent firm of certified public accountants. As soon as practicable after the close of each year, and when said audit has been completed and made available to the Issuer, a copy of such audit for the preceding year shall be mailed to the Municipal Advisory Council of Texas and to any bondholders who shall so request in writing. Such annual audit reports shall be open to the inspection of the bondholders and their agents and representatives at all reasonable times.

(l) GOVERNMENTAL AGENCIES. It will comply with all of the terms and conditions of any and all agreements applicable to the System and the Parity Bonds or Additional Bonds entered into between the Issuer and any governmental agency, and the Issuer will take all action necessary to enforce said terms and conditions; and the Issuer will obtain and keep in full force and effect all franchises, permits, and other requirements necessary with respect to the acquisition, construction, operation, and maintenance of the System.

(m) CONTRACTS. It will comply with the terms and conditions of the Contracts, and any amendments thereto, and will cause the Member Cities and other cities and customers to comply with all of their obligations thereunder by all lawful means; provided that the Contracts will not be rescinded, modified, or amended in any way which would materially affect adversely the operation of the System or the rights of the owners of the Parity Bonds and Additional Bonds; provided further that, without violating this Section 24(m), the Contracts may be modified or amended to change the allocation of the Annual Requirement (as defined in the Contracts) among the Member Cities by changing the basis for determination of each Member City's minimum amount of each Annual Requirement.

(n) ANNUAL BUDGET. On or before the first day of the second calendar month prior to the beginning of each fiscal year, it will prepare the preliminary Annual Budget of Operation and Maintenance Expenses of the System for the ensuing fiscal year, and any amounts required to be deposited to the credit of the Contingency Fund during the ensuing fiscal year, and such budget shall include a showing as to the proposed expenditures for such ensuing fiscal year. In the Annual Budget for each fiscal year provisions shall be made for payment of the annual lease consideration and the Issuer's share of the cost of operation and maintenance of Lavon Dam and Reservoir and any other payments with respect to water in any other reservoir required to be made by the Issuer. If the owners of ten per centum (10%) in aggregate principal amount of the Parity Bonds and Additional Bonds then outstanding shall so request on or before the 15th day of the aforesaid month, the Board shall hold a public hearing on or before the 15th day of the following month, at which any such owner may appear in person or by agent or attorney and present any objections he may have to the final adoption of such budget. Notice of the time and place of such hearing shall be published twice, once in each of two successive weeks, in daily newspapers (and if not daily newspaper is published in any one of such cities, in a weekly newspaper published in such cities) of general circulation published in each of the Cities of Garland, McKinney, Mesquite, Richardson, and Dallas, Texas, the date of the first publication to be at least fourteen days before the date fixed for the hearing, and copies of such notice shall be mailed at least ten days before the hearing to each owner of a Parity Bond or Additional Bond who shall have filed his or her name and address with the Secretary of the Board for such purpose. The Issuer further covenants that on or before the first day of each fiscal year it will finally adopt the Annual Budget of Operation and Maintenance Expenses of the System for such fiscal year (hereinafter sometimes call the "Annual Budget") and that except as otherwise provided herein the total expenditures in any division thereof will not exceed the total expenditures in the corresponding division in the preliminary budget. If for any reason the Board shall not have adopted the Annual Budget before the first day of any fiscal year, the budget for the preceding fiscal year shall be deemed to be in force until the adoption of the Annual Budget. The Operation and Maintenance Expenses of the System incurred in any fiscal year will not exceed the reasonable and necessary amount thereof, and the Board will not expend any amount or incur any obligation for maintenance, repair, and operation in excess of the amounts provided therefor in the Annual Budget; provided, however, that if at any time the Board shall determine that the amount of the appropriation for any item in the Annual Budget is in excess of the amount which will be required for such item, the Board may by resolution reduce such appropriation and make an appropriation for any item or items not covered by the Annual Budget or increase the appropriation for any other item or items by an amount not exceeding the amount of such reduction; and provided, further, that the Board may at any time by resolution adopt an Amended or Supplemental Annual Budget for the remainder of the then current fiscal year in case of an emergency caused by some extraordinary occurrence which shall be recited in such resolution.

Section 25. AMENDMENT OF RESOLUTION. (a) The owners of Parity Bonds and Additional Bonds aggregating 51% in principal amount of the aggregate principal amount of then outstanding Parity Bonds and Additional Bonds shall have the right from time to time to approve any amendment to any resolution authorizing the issuance of any Parity Bonds or Additional Bonds, which may be deemed necessary or desirable by the Issuer, provided, however, that nothing herein contained shall permit or be construed to permit the amendment of the terms and conditions in said resolutions or in the Parity Bonds or Additional Bonds so as to:

(1) Make any change in the maturity of the outstanding Parity Bonds or Additional Bonds;

(2) Reduce the rate of interest borne by any of the outstanding Parity Bonds or Additional Bonds;

(3) Reduce the amount of the principal payable on the outstanding Parity Bonds or Additional Bonds;

(4) Modify the terms of payment of principal of or interest on the outstanding Parity Bonds or Additional Bonds, or impose any conditions with respect to such payment;

(5) Affect the rights of the holders of less than all of the Parity Bonds and Additional Bonds then outstanding;

(6) Change the minimum percentage of the principal amount of Parity Bonds and Additional Bonds necessary for consent to such amendment.

(b) If at any time the Issuer shall desire to amend a resolution under this Section, the Issuer shall cause notice of the proposed amendment to be published in a financial newspaper or journal published in the City of New York, New York, once during each calendar week for at least two successive calendar weeks. Such notice shall briefly set forth the nature of the proposed amendment and shall state that a copy thereof is on file at the principal office of each paying agent for any of the Parity Bonds or Additional Bonds for inspection by all owners of Parity Bonds and Additional Bonds. Such publication is not required, however, if notice in writing is given to each holder of Parity Bonds and Additional Bonds.

(c) Whenever at any time not less than thirty days, and within one year, from the date of the first publication of said notice or other service of written notice the Issuer shall receive an instrument or instruments executed by the owners of at least 51% in aggregate principal amount of all Parity Bonds and Additional Bonds then outstanding, which instrument or instruments shall refer to the proposed amendment described in said notice and which specifically consent to and approve such amendment in substantially the form of the copy thereof on file as aforesaid, the Issuer may adopt the amendatory resolution in substantially the same form.

(d) Upon the adoption of any amendatory resolution pursuant to the provisions of this Section, the resolution being amended shall be deemed to be amended in accordance with the amendatory resolution, and the respective rights, duties, and obligations of the Issuer and all the owners of then outstanding Parity Bonds and Additional Bonds and all future Additional Bonds shall thereafter be determined, exercised, and enforced hereunder, subject in all respects to such amendment.

(e) Any consent given by the owner of a Parity Bond or Additional Bond pursuant to the provisions of this Section shall be irrevocable for a period of six months from the date of the first publication of the notice provided for in this Section, and shall be conclusive and binding upon all future holders or owners of the same Parity Bond or Additional Bond during such period. Such consent may be revoked at any time after six months from the date of the first publication of such notice by the owner who gave such consent, or by a successor in title, by filing notice thereof with each Paying Agent for each Series of Parity Bonds and Additional Bonds, and the Issuer, but such revocation shall not be effective if the owners of 51% in aggregate principal amount of the then outstanding Parity Bonds and Additional Bonds as in this Section defined have, prior to the attempted revocation, consented to and approved the amendment.

(f) For the purpose of this Section, the ownership of and other matters relating to the Parity Bonds shall be determined from the registration books kept by the registrar therefor.

Section 26. DAMAGED, MUTILATED, LOST, STOLEN, OR DESTROYED BONDS.

(a) Replacement Bonds. In the event any outstanding Bond is damaged, mutilated, lost, stolen, or destroyed, the Paying Agent/Registrar shall cause to be printed, executed, and delivered, a new bond of the same principal amount, maturity, and interest rate, as the damaged, mutilated, lost, stolen, or destroyed Bond, in replacement for such Bond in the manner hereinafter provided.

(b) Application for Replacement Bonds. Application for replacement of damaged, mutilated, lost, stolen, or destroyed Bonds shall be made by the registered owner thereof to the Paying Agent/Registrar. In every case of loss, theft, or destruction of a Bond, the registered owner applying for a replacement bond shall furnish to the Issuer and to the Paying Agent/Registrar such security or indemnity as may be required by them to save each of them harmless from any loss or damage with respect thereto. Also, in every case of loss, theft, or destruction of a Bond, the registered owner shall furnish to the Issuer and to the Paying Agent/Registrar evidence to their satisfaction of the loss, theft, or destruction of such Bond, as the case may be. In every case of damage or mutilation of a Bond, the registered owner shall surrender to the Paying Agent/Registrar for cancellation the Bond so damaged or mutilated.

(c) No Default Occurred. Notwithstanding the foregoing provisions of this Section, in the event any such Bond shall have matured, and no default has occurred which is then continuing in the payment of the principal of, redemption premium, if any, or interest on the Bond, the Issuer may authorize the payment of the same (without surrender thereof except in the case of a damaged or mutilated Bond) instead of issuing a replacement Bond, provided security or indemnity is furnished as above provided in this Section.

(d) Charge for Issuing Replacement Bonds. Prior to the issuance of any replacement bond, the Paying Agent/Registrar shall charge the registered owner of such Bond with all legal, printing, and other expenses in connection therewith. Every replacement bond issued pursuant to the provisions of this Section by virtue of the fact that any Bond is lost, stolen, or destroyed shall constitute a contractual obligation of the Issuer whether or not the lost, stolen, or destroyed Bond shall be found at any time, or be enforceable by anyone, and shall be entitled to all the benefits of this Resolution equally and proportionately with any and all other Bonds duly issued under this Resolution.

(e) Authority for Issuing Replacement Bonds. In accordance with Section 1201.067, Texas Government Code, this Section of this Resolution shall constitute authority for the issuance of any such replacement bond without necessity of further action by the governing body of the Issuer or any other body or person, and the duty of the replacement of such bonds is hereby authorized and imposed upon the Paying Agent/Registrar, and the Paying Agent/Registrar shall authenticate and deliver such Bonds in the form and manner and with the effect, as provided in Section 6(d) of this Resolution for Bonds issued in conversion and exchange for other Bonds.

Section 27. COVENANTS REGARDING TAX-EXEMPTION. (a) Covenants. The Issuer covenants to refrain from any action which would adversely affect, or to take such action to assure, the treatment of the Bonds as obligations described in section 103 of the Code, the interest on which is not includable in the "gross income" of the holder for purposes of federal income taxation. In furtherance thereof, the Issuer covenants as follows:

(1) to take any action to assure that no more than 10 percent of the proceeds of the Bonds or the projects financed therewith (less amounts deposited into a reserve fund, if any) are used for any "private business use," as defined in section 141(b)(6) of the Code, or if more than 10 percent of the proceeds or the projects financed therewith are so used, such amounts, whether or not received by the Issuer, with respect to such private business use, do not, under the terms of this Resolution or any underlying arrangement, directly or indirectly, secure or provide for the payment of more than 10 percent of the debt service on the Bonds, in contravention of section 141(b)(2) of the Code;

(2) to take any action to assure that in the event that the "private business use" described in subsection (a) hereof exceeds five percent of the proceeds of the Bonds or the projects financed therewith (less amounts deposited into a reserve fund, if any) then the amount in excess of five percent is used for a "private business use" which is "related" and not "disproportionate," within the meaning of section 141(b)(3) of the Code, to the governmental use;

(3) to take any action to assure that no amount which is greater than the lesser of $5,000,000, or five percent of the proceeds of the Bonds (less amounts deposited into a reserve fund, if any) is, directly or indirectly, used to finance loans to persons, other than state or local governmental units, in contravention of section 141(c) of the Code;

(4) to refrain from taking any action that would otherwise result in the Bonds being treated as "private activity bonds" within the meaning of section 141(b) of the Code;

(5) to refrain from taking any action that would result in the Bonds being "federally guaranteed" within the meaning of section 149(b) of the Code;

(6) to refrain from using any portion of the proceeds of the Bonds, directly or indirectly, in a manner that would cause the Bonds to be "arbitrage bonds" within the meaning of section 148(a) of the Code and Regulations, including to acquire or to replace funds which were used, directly or indirectly to acquire Nonpurpose Investments (as defined

in the Code and Regulations) which produce yield materially higher than the yield on the TWDB's bonds that are issued to provide financing for the purchase of the Bonds, other than Nonpurpose Investments acquired with --

(A) proceeds of the Bonds invested for a reasonable temporary period of 3 years or less or, in the case of a refunding bond, for a period of 30 days or less until such proceeds are needed for the purpose for which the Bonds are issued,

(B) amounts invested in a bona fide debt service fund, within the meaning of section 1.148-1(b) of the Treasury Regulations, and

(C) amounts deposited in any reasonably required reserve or replacement fund to the extent such amounts do not exceed the least of meximum annual debt service on the Bonds, 125% of average annual debt service on the Bonds, or 10 percent of the stated principal amount (or, in the case of a discount, the issue price) of the Bonds;

(7) to otherwise restrict the use of the proceeds of the Bonds or amounts treated as proceeds of the Bonds, as may be necessary, so that the Bonds do not otherwise contravene the requirements of section 148 of the Code (relating to arbitrage), section 149(g) of the Code (relating to hedge bonds), and, to the extent applicable, section 149(d) of the Code (relating to advance refundings); and

(8) to take all necessary steps to comply with the requirement that certain amounts earned on investment of gross proceeds of the Bonds be rebated to the federal government in order to satisfy the requirements of section 148 of the Code. The District will:

(A) account for all Gross Proceeds, as defined in the Code and Regulations (including all receipts, expenditures and investments thereof) on its books of account separately and apart from all other funds (and receipts, expenditures and investments thereof) and retain all records of such accounting for a least six years after the final Computation Date, as defined in the Code and Regulations. The Issuer may, however, to the extent permitted by law, commingle Gross Proceeds of its loan with other money of the Issuer, provided that the Issuer separately accounts for each receipt and expenditure of such Gross Proceeds and the obligations acquired therewith;

(B) calculate the Rebate Amount as defined in the Code and Regulations, with respect to the Bonds, not less frequently than each Computation Date, in accordance with rules set forth in section 148(f) of the Code, section 1.148-3 of the Regulations, and the rulings thereunder. The Issuer shall maintain a copy of such calculations for a least six years after the final Computation Date;

(C) as additional consideration for the purchase of the Bonds by the TWDB, and in order to induce the purchase of the Bonds by the TWDB, by measures designed to ensure the excludability of the interest on the Source Series Bonds from the gross income of the owners thereof for federal income tax purposes, pay to the United States, the amount described in paragraph (b) above within 30 days after each Computation Date; and

(D) exercise reasonable diligence to assure that no errors are made in the calculations required by paragraph (b) and, if such error is made, to discover and promptly to correct such error within a reasonable amount of time thereafter, including payment to the United States of any interest and any penalty required by the Regulations.

For purposes of the foregoing (a)(1) and (a)(2), the Issuer understands that the term "proceeds" includes "disposition proceeds" as defined in the Treasury Regulations and, in the case of refunding bonds, transferred proceeds (if any) and proceeds of the refunded bonds expended prior to the date of issuance of the Bonds.

(b) Compliance with Code. It is the understanding of the Issuer that the covenants contained herein are intended to assure compliance with the Code and any regulations or rulings promulgated by the U.S. Department of the Treasury pursuant thereto. In the event that regulations or rulings are hereafter promulgated which modify or expand provisions of the Code, as applicable to the Bonds, the Issuer will not be required to comply with any covenant contained herein to the extent that such failure to comply, in the opinion of nationally-recognized bond counsel, will not adversely affect the exemption from federal income taxation of interest on the Bonds under section 103 of the Code. In the event that regulations or rulings are hereafter promulgated which impose additional requirements which are applicable to the Bonds, the Issuer agrees to comply with the additional requirements to the extent necessary, in the opinion of nationally-recognized bond counsel, to preserve the exemption from federal income taxation of interest on the Bonds under section 103 of the Code. In furtherance of such intention, the Issuer hereby authorizes and directs its President or Executive Director to execute any documents, certificates or reports required by the Code and to make such elections, on behalf of the Issuer, which may be permitted by the Code as are consistent with the purpose for the issuance of the Bonds. The Issuer covenants to comply with the covenants contained in this section after defeasance of the Bonds.

(c) Rebate Fund. In order to facilitate compliance with the above covenant (a)(8), a "Rebate Fund" is hereby established by the Issuer for the sole benefit of the United States of America, and such fund shall not be subject to the claim of any other person, including without limitation, the bondholders. The Rebate Fund is established for the additional purpose of compliance with section 148 of the Code.

(d) Written Procedures. Unless superseded by another action of the Issuer to ensure compliance with the covenants contained herein regarding private business use, remedial actions, arbitrage and rebate, the Issuer hereby adopts and establishes the instructions attached hereto as Exhibit A as their written procedures applicable to Bonds issued pursuant to the Contract.

Section 28 ALLOCATION OF, AND LIMITATION ON, EXPENDITURES FOR THE PROJECT; DISPOSITION OF THE PROJECT. (a) The Issuer covenants to account for the expenditure of Bond proceeds and investment earnings to be used for the construction or acquisition of the property constituting the project financed with proceeds of the sale of the Bonds on its books and records by allocating proceeds to expenditures within 18 months of the later of the date that (1) the expenditure is made or (2) such construction or acquisition is completed. The foregoing notwithstanding, the Issuer shall not expend proceeds of the Bonds or investment earnings thereon more than 60 days after the earlier of (1) the fifth anniversary of the delivery of the Bonds or (2) the date the Bonds are retired, unless the Issuer obtains an opinion of nationally-recognized bond counsel that such expenditure will not adversely affect the tax-exempt status of the Bonds. For purposes hereof, the Issuer shall not be obligated to comply with this covenant if it obtains an opinion that such failure to comply will not adversely affect the excludability for federal income tax purposes from gross income of the Bonds on the Bonds.

(b) The Issuer covenants that the property constituting the project financed with proceeds of the Bonds will not be sold or otherwise disposed in a transaction resulting in the receipt by the Issuer of cash or other compensation, unless the Issuer obtains an opinion of nationally-recognized bond counsel that such sale or other disposition will not adversely affect the tax-exempt status of the Bonds. For purposes of the foregoing, the portion of the property comprising personal property and disposed in the ordinary course shall not be treated as a transaction resulting in the receipt of cash or other compensation. For purposes hereof, the Issuer shall not be obligated to comply with this covenant if it obtains an opinion that such failure to comply will not adversely affect the excludability for federal income tax purposes from gross income of the interest.

Section 29 CUSTODY, APPROVAL, AND REGISTRATION OF BONDS; BOND COUNSEL'S OPINION, CUSIP NUMBERS, AND PREAMBLE. The President of the Board of Directors of the Issuer is hereby authorized to have control of the Initial Bond issued hereunder and all necessary records and proceedings pertaining to the Initial Bond pending its delivery and its investigation, examination, and approval by the Attorney General of the State of Texas, and its registration by the Comptroller of Public Accounts of the State of Texas. Upon registration of the Initial Bond said Comptroller of Public Accounts (or a deputy designated in writing to act for said Comptroller) shall manually sign the Comptroller's Registration Certificate on the Initial Bond, and the seal of said Comptroller shall be impressed, or placed in facsimile, on the Initial Bond. The approving legal opinion of the Issuer's Bond Counsel and the assigned CUSIP numbers may, at the option of the Issuer, be printed on the Initial Bond or on any Bond issued and delivered in conversion of and exchange or replacement of any Bond, but neither shall have any legal effect, and shall be solely for the convenience and information of the registered owners of the Bonds. The preamble to this Resolution is hereby adopted and made a part hereof for all purposes.

Section 30. INTEREST EARNINGS ON BOND PROCEEDS. Interest earnings derived from the investment of proceeds from the sale of the Initial Bond, other than proceeds deposited in accordance with Section 16 hereof, shall be used as provided in Section 34(c) hereof; provided that after such use, if any of such interest earnings remain on hand, such interest earnings on bond proceeds which are required to be rebated to the United States of America pursuant to Section 27 hereof in order to prevent the Bonds from being arbitrage bonds shall be so rebated and not considered as interest earnings for the purposes of this Section.

Section 31. DTC REGISTRATION. The Bonds initially shall be issued and delivered in such manner that no physical distribution of the Bonds will be made to the public, and the Depository Trust Company ("DTC"), New York, New York, initially will act as depository for the Bonds. DTC has represented that it is a limited purpose trust company incorporated under the laws of the State of New York, a member of the Federal Reserve System, a "clearing corporation" within the meaning of the New York Uniform Commercial Code, and a "clearing agency" registered under Section 17A of the federal Securities Exchange Act of 1934, as amended, and the Issuer accepts, but in no way verifies, such representations. The Initial Bond authorized by this Resolution shall be delivered to and registered in the name of the Purchaser. However, it is a condition of delivery and sale that the Purchaser, immediately after such delivery, shall cause the Paying Agent/Registrar, as provided for in this Resolution, to cancel said Initial Bond and deliver in exchange therefor a substitute Bond for each maturity of such Initial Bond, with each such substitute Bond to be registered in the name of CEDE & CO., the nominee of DTC, and it shall be the duty of the Paying Agent/Registrar to take such action. It is expected that DTC will hold the Bonds on behalf of the Purchaser and/or the DTC Participants, as defined and described in the Official Statement referred to and approved in Section 32 hereof (the "DTC Participants"). So long as each Bond is registered in the name of CEDE & CO., the Paying Agent/Registrar shall treat and deal with DTC in all respects the same as if it were the actual and beneficial owner thereof. It is expected that DTC will maintain a book entry system which will identify beneficial ownership of the Bonds by DTC Participants in integral amounts of $5,000, with transfers of ownership being effected on the records of DTC and the DTC Participants pursuant to rules and regulations established by them, and that the substitute Bonds initially deposited with DTC shall be immobilized and not be further exchanged for substitute Bonds except as hereinafter provided. The Issuer is not responsible or liable for any functions of DTC, will not be responsible for paying any fees or charges with respect to its services, will not be responsible or liable for maintaining, supervising, or reviewing the records of DTC or the DTC Participants, or protecting any interests or rights of the beneficial owners of the Bonds. It shall be the duty of the Purchaser and the DTC Participants to make all arrangements with DTC to establish this book-entry system, the beneficial ownership of the Bonds, and the method of paying the fees and charges of DTC. The Issuer does not represent, nor does it in any way covenant that the initial book-entry system established with DTC will be maintained in the future. The Issuer reserves the right and option at any time in the future, in its sole discretion, to terminate the DTC (CEDE & CO.) book-entry only registration requirement described above, and to permit the Bonds to be registered in the name of any owner. If the Issuer exercises its right and option to terminate such requirement, it shall give written notice of such termination to the Paying Agent/ Registrar and to DTC, and thereafter the Paying Agent/Registrar shall, upon presentation and proper request, register any Bond in any name as provided for in this Resolution. Notwithstanding the initial establishment of the foregoing book-entry system with DTC, if for any reason any of the originally delivered substitute Bonds is duly filed with the Paying Agent/Registrar with proper request for transfer and substitution, as provided for in this Resolution, substitute Bonds will be duly delivered as provided in this Resolution, and there will be no assurance or representation that any book-entry system will be maintained for such Bonds.

Section 32. SALE OF BONDS; USE OF PROCEEDS.

(a) Sale to TWDB. The Bonds are hereby sold to TWDB (the "Purchaser"), acting through the TWDB's designated trustee, for the price of par, less an origination fee of ____% of the principal amount of the Bonds. The Bonds have been purchased by the TWDB pursuant to its Resolution No. 17-___ adopted on ________, 2017 ("TWDB Resolution No. 17-___"). The Bonds initially delivered shall be registered in the name of the Texas Water Development Board. The Private Placement Memorandum prepared in connection with the sale of the Bonds to the TWDB is approved. The Issuer has determined, based upon the advice provided by its financial advisors, that acceptance of the purchase price for the Bonds is on terms advantageous to, and in the best interests of, the Issuer.

(b) Notice from TWDB of Sale of Bonds. It is the intent of the parties to the sale of the Bonds that if TWDB ever determines to sell all or a part of the Bonds, it shall notify the Issuer at least 60 days prior to the sale of the Bonds of the decision to so sell the Bonds

(c) Proceeds. The proceeds from the sale of the Bonds shall be used in the manner described in the letter of instructions executed by the Issuer, or on behalf of the Issuer by its financial advisor.

(d) Payment by Wire Transfer. Payment of amounts due and owing on the Bonds to the TWDB shall be made by wire transfer, at no expense to the TWDB, as provided in the FORM OF INITIAL BOND and the FORM OF SUBSTITUTE BOND.

(e) Investment of Bond Proceeds. Proceeds from the sale of the Bonds shall be held at a designated state depository or other properly chartered and authorized institution in accordance with Chapter 2256, Texas Government Code, and Chapter 2257, Texas Government Code.

Section 33. ESCROW AGREEMENT. The President, any Vice President, the Secretary, and/or the Executive Director/General Manager are each authorized to execute and deliver an escrow agreement in substantially the form attached as Exhibit B. The TWDB agrees that proceeds of the Bonds required to be deposited under the Escrow Agreement shall be disposed of and released in accordance with TWDB Rules Relating to Financial Programs or as otherwise authorized and directed by the TWDB.

Section 34. PROJECT FUND.

(a) Project Fund Created. There is hereby created, established and maintained on the books of the Issuer, a separate fund to be entitled the "North Texas Municipal Water District Water System Revenue Bonds, Series 2017 Project Fund" (hereinafter called the "Project Fund"). Monies in the Project Fund shall be maintained at a official depository bank of the Issuer.

(b) Use of Funds. Except as otherwise may be provided in Sections 17, 32(c), and 33 hereof, the proceeds of the Bonds shall be deposited in the Project Fund and used by the Issuer for payment of the costs of construction, improvements, and extensions of the System, and the payment of costs associated therewith, including any costs for engineering, financing, financial consultation, administrative, auditing and legal expenses. Amounts in the Project Fund shall be timely and expeditiously used to pay such costs, in compliance with applicable federal and State law.

(c) Surplus Proceeds. Any surplus proceeds, including the investment earnings derived from the investment of monies on deposit in the Project Fund, from the Bonds remaining on deposit in the Project Fund after completing the improvements and extensions to the System and upon the completion of the final accounting as described in Section 35(c) hereof, shall be transferred to the Interest and Redemption Fund to redeem, in inverse order of maturity, the Bonds owned by TWDB, unless the Executive Administrator of TWDB approves the use of such surplus proceeds to pay eligible costs of improving or extending the System by funding projects that are part of the State Water Plan.

Section 35. TWDB REQUIREMENTS. The Issuer covenants and agrees, so long as the TWDB owns any of the Bonds, as follows:

(a) Compliance with the TWDB's Rules and Regulations. The Issuer covenants to comply with the rules and regulations of the TWDB.

(b) Audits. The Issuer shall mail a copy of the Issuer's audit required by Section 24(k) hereof to the TWDB within 120 days after the close of the fiscal year. In addition, monthly operating statements for the System shall be maintained by the Issuer and made available, on request, to the TWDB, and the monthly operating statement shall be in such detail as requested by the Development Fund Manager of the TWDB until this requirement is waived thereby. Upon request by the Executive Administrator of the TWDB, the Issuer shall provide or cause the Member Cities to provide, to the Executive Administrator, the most recent audits of such Member Cities as are requested by the Executive Administrator.

(c) Final Accounting. The Issuer shall render a final accounting to the TWDB in reference to the total cost incurred by the Issuer for construction, improvements, and extensions to the System which were financed by the issuance of the Bonds, together with a copy of "as built" plans of such construction, improvements, and extensions upon completion.

(d) Defeasance. Should the Issuer exercise its right under this Resolution to effect the defeasance of the Bonds, the Issuer agrees that it will provide the TWDB with written notice of any such defeasance.

(e) Segregation of Funds. The Issuer covenants that proceeds of the Bonds (except for amounts deposited into the Reserve Fund) shall remain separate and distinct from other sources of funds from the date of closing of the Bonds through final disbursement of the proceeds thereof.

(f) Environmental Indemnity. Proceeds from the Bonds shall not be used by the Issuer when sampling, testing, removing, or disposing of contaminated soils and/or media at the project site. To the extent permitted by law, the Issuer agrees to indemnify, hold harmless, and protect the TWDB from any and all claims, causes of action, or damages to the person or property of third parties arising from the sampling, analysis, transport, storage, treatment, recycling, and disposition of any contaminated sewage sludge, contaminated sediments, and/or contaminated media that may be generated by the Issuer, its contractors, agents, officials, and employees as a result of activities relating to the project funded with proceeds of the Bonds.

(g) Environmental Determination. In connection with the project financed with the Bonds, the Issuer agrees to implement any environmental determination issued by the Executive Administrator of TWDB to satisfy the environmental review requirements set forth in 31 Texas Administrative Code 371.

(h) Insurance. The Issuer agrees that it will maintain insurance on the System in an amount determined by the TWDB to be sufficient to protect TWDB's interest in the project financed with the proceeds of the Bonds. The Issuer may satisfy this covenant with self-insurance.

(i) Water Conservation Program. The Issuer has implemented or will implement an approved water conservation program in compliance with 31 Texas Administrative Code 371.71(a)(2)(F).

(j) No Purchase of TWDB Bonds. The Issuer agrees that it, nor any related party to the issuer, will not purchase, as a investment or otherwise, bonds issued by TWDB including, without limitation, bonds issued by TWDB, the proceeds of which were used by TWDB to purchase the Bonds.

(k) Compliance with Federal Contracting Law. The Issuer acknowledges that it has a legal obligation to comply with any applicable requirements of federal law relating to contracting with disadvantaged business enterprises.

(l) Compliance with State Contracting Law. The Issuer acknowledges that it has a legal obligation to comply with any applicable requirements of State law relating to contacting with historically underutilized businesses and the Issuer shall report to the TWDB the amount of proceeds of the Bonds used to compensate historically underutilized businesses that worked on the project.

(m) TWDB Remedies. The TWDB may exercise all remedies available to it in law or equity, and any provision of this Resolution that restricts on limits the full exercise of such remedies by the TWDB shall be of no force or effect.

(n) Limitation on Conveyances of Bonds. Prior to any action by the Issuer to convey the Bonds of the Issuer held by the TWDB to another entity, the conveyance and assumption of the Bonds must be approved by the TWDB.

(o) Accounting. The Issuer shall maintain current, accurate and complete records and accounts in accordance with generally accepted accounting principles necessary to demonstrate compliance with financial assistance related legal and contractual provisions.

Section 36. CONTINUING DISCLOSURE UNDERTAKING.

(a) Annual Reports

The Issuer shall provide or cause to be provided annually to the MSRB, (1) within six months after the end of each fiscal year ending in or after 2017, financial information and operating data of the general type included in the final Official Statement with respect to the Series 2016 Bonds, (i) with respect to the Issuer, in tables numbered 1 through 5, and (ii) with respect to each Significant Obligated Persons in Appendix C, and (2) when and if available, audited financial statements of the Issuer and each Significant Obligated Person. Any financial statements so to be provided shall be prepared in accordance with generally accepted accounting principles or such other accounting principles as the Issuer or any such Significant Obligated Person may be required to employ from time to time pursuant to state law or regulation. If the audit of such financial statements of the Issuer or a Significant Obligated Person is not complete within 12 months after the respective fiscal year end, then the Issuer shall provide or cause to be provided by each Significant Obligated Person unaudited financial statements within such 12-month period and audited financial statements when and if the audit report on such statements become available.

If the Issuer or any such Significant Obligated Person changes its fiscal year, the Issuer will notify or cause the Significant Obligated Person to notify the MSRB of the change (and of the date of the new fiscal year end) prior to the next date by which the Issuer or any such Significant Obligated Person otherwise would be required to provide financial information and operating data pursuant to this Section.

The financial information and operating date to be provided pursuant to this Section may be set forth in full in one or more documents or may be included by specific reference to any document (including an official statement or other offering document, if it is available from the MSRB) that theretofore has been provided to the MSRB or filed with the SEC

(b) Event Notices.

The Issuer shall notify the MSRB, in a timely manner, of any of the following events with respect to the Bonds, not in excess of ten Business Days after occurrence of the event:

1. Principal and interest payment delinquencies;
2. Non-payment related defaults, if material;
3. Unscheduled draws on debt service reserves reflecting financial difficulties;
4. Unscheduled draws on credit enhancements reflecting financial difficulties;
5. Substitution of credit or liquidity providers, or their failure to perform;
6. Adverse tax opinions, the issuance by the Internal Revenue Service of proposed or final determinations of taxability, Notices of Proposed Issue (IRS Form

5701-TEB) or other material notices or determinations with respect to the tax status of the security, or other material events affecting the tax status of the security;

7. Modifications to the rights of security holders, if material;

8. Bond calls, if material, and tender offers;

9. Defeasances;

10. Release, substitution or sale of property securing repayment of the securities, if material;

11. Rating changes;

12. Bankruptcy, insolvency, receivership or similar event of the Issuer or a Significant Obligated Person;

13. The consummation of a merger, consolidation, or acquisition involving the Issuer or a Significant Obligated Person or the sale of all or substantially all of the assets of the Issuer or a Significant Obligated Person, other than in the ordinary course of business, the entry into a definitive agreement to undertake such an action or the termination of a definitive agreement relating to any such actions, other than pursuant to its terms, if material; and

14. Appointment of a successor or additional trustee or the change of name of a trustee, if material.

The Issuer shall notify the MSRB, in a timely manner, of any failure by the Issuer to provide financial information or operating data in accordance with Section 36(c) of this Resolution by the time required by such Section. As used in clause 12 above, the phrase "bankruptcy, insolvency, receivership or similar event" means the appointment of a receiver, fiscal agent, or similar officer for the Issuer in a proceeding under the U.S. Bankruptcy Code or in any other proceeding under state or federal law in which a court or governmental authority has assumed jurisdiction over substantially all of the assets or business of the Issuer, or if jurisdiction has been assumed by leaving the Board of Directors and official or officers of the Issuer in possession but subject to the supervision and orders of a court or governmental authority, or the entry of an order confirming a plan of reorganization, arrangement or liquidation by a court or governmental authority having supervision or jurisdiction over substantially all of the assets or business of the Issuer.

(c) Limitations, Disclaimers, and Amendments.

The Issuer shall be obligated to observe and perform or cause a Significant Obligated Person to observe and perform the covenants specified in this Section for so long as, but only for so long as, such Significant Obligated persons remains a "Significant Obligated Person" with respect to the Bonds, except that the Issuer in any event will give notice of any deposit made in accordance with Section 21 hereof that causes Bonds no longer to be Outstanding.

The provisions of this Section are for the sole benefit of the Holders and beneficial owners of the Bonds, and nothing in this Section, express or implied, shall give any benefit or any legal or equitable right, remedy, or claim hereunder to any other person. The Issuer undertakes to provide or cause to be provided only the financial information, operating data, financial statements, and notices which it has expressly agreed to provide pursuant to this Section and does not hereby undertake to provide or cause to be provided any other information that may be relevant or material to a complete presentation of the Issuer's or any Significant Obligated Person's financial results, condition or prospects or hereby undertake to update any information provided in accordance with this Section or otherwise, except as expressly provided herein. The Issuer does not make any representation or warranty concerning such information or its usefulness to a decision to invest in or sell Bonds at any future date.

UNDER NO CIRCUMSTANCES SHALL THE ISSUER BE LIABLE TO THE HOLDER OR BENEFICIAL OWNER OF ANY BOND OR ANY OTHER PERSON, IN CONTRACT OR TORT, FOR DAMAGES RESULTING IN WHOLE OR IN PART FROM ANY BREACH BY THE ISSUER, WHETHER NEGLIGENT OR WITHOUT FAULT ON ITS PART, OF ANY COVENANT SPECIFIED IN THIS SECTION, BUT EVERY RIGHT AND REMEDY OF ANY SUCH PERSON, IN CONTRACT OR TORT, FOR OR ON ACCOUNT OF ANY SUCH BREACH SHALL BE LIMITED TO AN ACTION FOR MANDAMUS OR SPECIFIC PERFORMANCE.

No default by the Issuer in observing or performing its obligations under this Section shall comprise a breach of or default under this Resolution for purposes of any other provision of this Resolution.

Nothing in this Section is intended or shall act to disclaim, waive, or otherwise limit the duties of the Issuer under federal and state securities laws.

Should the Rule be amended to obligate the Issuer to make filings with or provide notices to entities other than the MSRB, the Issuer hereby agrees to undertake such obligation with respect to the Bonds in accordance with the Rule as amended. The provisions of this Section may be amended by the Issuer from time to time to adapt to changed circumstances that arise from a change in legal requirements, a change in law, or a change in the identify, nature, status, or type of operations of the Issuer or any Significant Obligated Person, but only if (1) the provisions of this Section, as so amended, would have permitted an underwriter to purchase or sell Bonds in the primary offering of the Bonds in compliance with the Rule, taking into account any amendments or interpretations of the Rule since such offering as well s such changed circumstances and (2) either (a) the Holders of a majority in aggregate principal amount (or any greater amount required by any other provision of this Resolution that authorizes such an amendment) of the outstanding Bonds consent to such amendment or (b) a Person that is unaffiliated with the Issuer (such as nationally recognized bond counsel) determined that such amendment will not materially impair the interest of the Holders and beneficial owners of the Bonds. If the Issuer so amends the provisions of this Section, it shall include with any amended financial information or operating data next provided in accordance with Subsection (a) hereof an explanation, in narrative form, of the reason for the amendment and of the impact of any change in the type of financial information or operating data so provided. The Issuer may also amend or repeal the provisions of this continuing disclosure agreement if the SEC amends or repeals the applicable provision of the Rule or a court of final jurisdiction enters judgment that such provisions of the Rule are invalid, but only if and to the extent that the provisions of this sentence would not prevent an underwriter from lawfully purchasing or selling Bonds in the primary offering of the Bonds.

(d) Definitions.

As used in this Section, the following terms have the meanings ascribed to such terms below:

"*MSRB*" means the Municipal Securities Rulemaking Board.

"*Rule*" means SEC Rule 15c2-12, as amended from time to time.

"*SEC*" means the United States Securities and Exchange Commission and any successor to its duties.

"*Significant Obligated Person*" means, at any point in time, any Member City or other party contracting with the Issuer, in either case whose payments to the Issuer for the use of or service from the System in the calendar year preceding any such determination exceeded 10% of the Gross Revenues of the System.

Section 37. ATTORNEY GENERAL FEES. The District hereby authorizes and directs payment, from legally available funds of the District, of the nonrefundable examination fee of the Attorney General of the State of Texas required by Section 1202.004, Texas Government Code, as amended.

Section 38. FURTHER PROCEDURES. The President, Vice President, and/or the Secretary of the Board of Directors of the Issuer, the Executive Director and General Manager of the Issuer, and all other officers, employees, and agents of the Issuer, and each of them, shall be and they are hereby expressly authorized, empowered, and directed from time to time and at any time to do and perform all such acts and things and to execute, acknowledge, and deliver in the name and on behalf of the Issuer all such instruments, whether or not herein mentioned, as may be necessary or desirable in order to carry out the terms and provisions of this Resolution, the Bond Purchase Agreement, the Bonds, the sale and delivery of the Initial Bond and the Bonds, and all details in connection therewith. In case any officer whose signature shall appear on any Bond shall cease to be such officer before the delivery of such Bond, such signature shall nevertheless be valid and sufficient for all purposes the same as if such officer had remained in office until such delivery.

Section 39. REPEAL OF CONFLICTING RESOLUTIONS. All resolutions and all parts of any resolutions which are in conflict or inconsistent with this Resolution are hereby repealed and shall be of no further force or effect to the extent of such conflict or inconsistency.

****

EXHIBIT "A"

WRITTEN PROCEDURES RELATING TO CONTINUING COMPLIANCE WITH FEDERAL TAX COVENANTS

A. Arbitrage. With respect to the investment and expenditure of the proceeds of the Bonds and any Additional Bonds (the "Obligations") the Issuer's Executive Director and Director of Finance (the "Responsible Persons") will :

For Obligations issued for newly acquired property or constructed property:

- instruct the appropriate person or persons that the construction, renovation or acquisition of the facilities must proceed with due diligence and that binding contracts for the expenditure of at least 5%of the proceeds of the Obligations will be entered into within 6 months of the date of delivery of the Obligations ("Issue Date");

- monitor that at least 85% of the proceeds of the Obligations to be used for the construction, renovation or acquisition of any facilities are expended within 3 years of the Issue Date;

- restrict the yield of the investments (other than those in the Reserve Fund) to the yield on the Obligations after 3 years of the Issue Date;

- monitor all amounts deposited into a sinking fund or funds, e.g., the Interest and Redemption Fund and the Reserve Fund, to assure that the maximum amount invested at a yield higher than the yield on the Obligations does not exceed an amount equal to the debt service on the Obligations in the succeeding 12 month period plus a carryover amount equal to one-twelfth of the principal and interest payable on the Obligations for the immediately preceding 12-month period;

- assure that no more than 50% of the proceeds of the Obligations are invested in an investment with a guaranteed yield for 4 years or more;

- assure that the maximum amount of the Reserve Fund invested at a yield higher than the yield on the Obligations will not exceed the lesser of (1) 10% of the original principal amount of the Obligations, (2) 125% of the average annual debt service on the Obligations measured as of the Issue Date, or (3) 100% of the maximum annual debt service on the Obligations as of the Issue Date;

For Obligations issued for refunding purposes:

- monitor the actions of the escrow agent (to the extent an escrow is funded with proceeds) to assure compliance with the applicable provisions of the escrow agreement, including with respect to reinvestment of cash balances;

For all Obligations:

- maintain any official action of the Issuer (such as a reimbursement resolution) stating its intent to reimburse itself with the proceeds of the Obligations any amount expended prior to the Issue Date for the acquisition, renovation or construction of the facilities;

- assure that the applicable information return (e.g., IRS Form 8038-G, 8038-GC, or any successor forms) is timely filed with the IRS;

- assure that, unless excepted from rebate and yield restriction under section 148(f) of the Code, excess investment earnings are computed and paid to the U.S. government at such time and in such manner as directed by the IRS (i) at least every 5 years after the Issue Date and (ii) within 30 days after the date the Obligations are retired.

B. Private Business Use. With respect to the use of the facilities financed or refinanced with the proceeds of the Obligations the Responsible Persons will:

- monitor the date on which the facilities are substantially complete and available to be used for the purpose intended;

- monitor whether, at any time the Obligations are outstanding, any person, other than the Issuer, the employees of the Issuer, the agents of the Issuer or members of the general public has any contractual right (such as a lease, purchase, management or other service agreement) with respect to any portion of the facilities;

- monitor whether, at any time the Obligations are outstanding, any person, other than the Issuer, the employees of the Issuer, the agents of the Issuer or members of the general public has a right to use the output of the facilities (e.g., water, gas, electricity);

- monitor whether, at any time the Obligations are outstanding, any person, other than the Issuer, the employees of the Issuer, the agents of the Issuer or members of the general public has a right to use the facilities to conduct or to direct the conduct of research;

- determine whether, at any time the Obligations are outstanding, any person, other than the Issuer, has a naming right for the facilities or any other contractual right granting an intangible benefit;

- determine whether, at any time the Obligations are outstanding, the facilities are sold or otherwise disposed of; and

- take such action as is necessary to remediate any failure to maintain compliance with the covenants contained in the resolution authorizing the Obligations.

C. Record Retention. The Responsible Persons will maintain or cause to be maintained all records relating to the investment and expenditure of the proceeds of the Obligations and the use of the facilities financed or refinanced thereby for a period ending three (3) years after the complete extinguishment of the Obligations. If any portion of the Obligations is refunded with the proceeds of another series of tax-exempt obligations, such records shall be maintained until the three (3) years after the refunding obligations are completely extinguished. Such records can be maintained in paper or electronic format.

D. Responsible Persons. Each Responsible Person shall receive appropriate training regarding the Issuer's accounting system, contract intake system, facilities management and other systems necessary to track the investment and expenditure of the proceeds and the use of the facilities financed with the proceeds of the Obligations. The foregoing notwithstanding, the Responsible Persons are authorized and instructed to retain such experienced advisors and agents as may be necessary to carry out the purposes of these instructions.

EXHIBIT "B"

FORM OF ESCROW AGREEMENT

PRIVATE PLACEMENT MEMORANDUM DATED _______________, 2017

NEW ISSUE BOOK-ENTRY-ONLY

On the date of initial delivery of the Obligations (defined below), Issuer Bond Counsel (defined on page 2) will render its opinion substantially in the form attached in APPENDIX C - FORM OF OPINION OF BOND COUNSEL.

$44,650,000
NORTH TEXAS MUNICIPAL WATER DISTRICT, WATER SYSTEM REVENUE BONDS, SERIES 2017
(the "Obligations")

Dated: July 1, 2017 **Due: September 1**

Interest Date:	Interest on the Obligations will be payable on March 1, 2018, and on each September 1 and March 1 each year thereafter until maturity or prior redemption (each an "Interest Payment Date"). The Obligations will bear interest at the rates per annum set forth in "APPENDIX A - MATURITY SCHEDULE."
Record Date:	The close of business on the fifteenth business day of the calendar month immediately preceding the applicable Interest Payment Date.
Date Interest Accrues:	Each Obligation shall bear interest from the Delivery Date thereof or the most recent Interest Payment Date to which interest has been paid or provided for.
Redemption:	The Obligations are subject to redemption prior to maturity as provided herein. See "THE OBLIGATIONS - Redemption Provisions" herein.
Authorized Denominations:	The Obligations are being issued as fully registered bonds in denominations of $5,000, or any integral multiple thereof.
Paying Agent/Registrar/Registrar:	The paying agent ("Paying Agent/Registrar/Registrar") for the Obligations is The Bank of New York Mellon Trust Company, National Association, Dallas, Texas.
Book-Entry-Only System	Upon initial issuance, the ownership of the Obligations will be registered in the registration books of North Texas Municipal Water District (the "Issuer") kept by the Paying Agent/Registrar, in the name of Cede & Co., as nominee of The Depository Trust Company, New York, New York ("DTC") to which principal, redemption premium, if any, and interest payments on the Obligations will be made. The purchasers of the Obligations will not receive physical delivery of bond certificates. Principal of, interest, and premium if any, on the Obligations will be payable at the designated office of the Paying Agent/Registrar in, Texas as the same become due and payable.
Issuer:	North Texas Municipal Water District, created and functioning under Article 16, Section 59, of the Texas Constitution, pursuant to the general laws of the State of Texas, including Chapters 49 and 51, Texas Water Code, and pursuant to the provisions of Chapter 268, Acts of 1957, 55th Legislature of Texas, Regular Session, as amended (collectively, the "District Act").
Official Action:	Resolution Authorizing the Issuance, Sale and Delivery of North Texas Municipal Water District, Water System Revenue Bonds, Series 2017, dated September __, 2017.
Purpose:	The Obligations are being issued for the purpose of (i) to pay for construction, improvements, and extensions to the District's Water System, including design, acquisition, and construction relating to the Lower Bois d'Arc Reservoir Project; (ii) to fund a debt service reserve fund and (iii) to pay costs of issuance of the Series 2017 Bonds.
Security for the Obligations:	See "SECTION 9 PLEDGE" OF "APPENDIX B – FORM OF OFFICIAL ACTION."
Ratings:	See "OTHER INFORMATION - Ratings"
Delivery Date:	______________, 2017.

See "APPENDIX A - MATURITY SCHEDULE" for Principal Amounts,

Maturities, Interest Rates, Prices or Yields, and Initial CUSIP Numbers

NORTH TEXAS MUNICIPAL WATER DISTRICT

BOARD OF DIRECTORS

Terry Sam Anderson, Mesquite, President
Robert Thurmond, Jr., Wylie, Vice President
John F. Sweeden, Richardson, Secretary

ALLEN
Joe Farmer
James Kerr

FARMERSVILLE
Wayne May

FORNEY
Don Cates
Michael Lopez

FRISCO
Richard Peasley
Lynn Shuyler

GARLAND
Don Gordon
Jack May

McKINNEY
Joe Joplin
Charles McKissick

MESQUITE
Bobby Robinson

PLANO
Phil Dyer
James R. Hogan

RICHARDSON
John Murphy

ROCKWALL
Bill Lofland
Larry Parks

ROYSE CITY
Jim Mellody
Bill Forbus

WYLIE
Marvin Fuller

PRINCETON
Richard Sheehan
Bill Glass

Executive Director/General Manager	Thomas W. Kula
Deputy Director of Finance & Personnel	Judd R. Sanderson
Deputy Director of Engineering & CIP	Joseph M. Stankiewicz
Deputy Director of Operations & Maintenance	Mike Rickman
Assistant Deputy Director of Engineering	Ceasar Baptista
Assistant Deputy Director of CIP	Richard Muraski
Assistant Deputy Director of Water	Billy George
Assistant Deputy Director of Wastewater	Jennafer Covington
Assistant Deputy Director of Solid Waste	Jeff Mayfield
Information Technology Officer	Jim Shirley
Environmental Services Officer	Elizabeth Turner
Finance Manager	Erik Felthous
Human Resources Manager	John Montgomery
Accounting Manager	Teresa Wigington
Records Manager	Kelly O'Brian
Engineering Manager	Jeff Ray
Real Estate Manager	Jennifer Flippo

McCall, Parkhurst & Horton L.L.P., Bond Counsel

FirstSouthwest, a Division of Hilltop Securities Inc., Financial Advisor

The Bank of New York Mellon Trust Company, National Association, Paying Agent/Registrar

TABLE OF CONTENTS

Page

Private Placement Memorandum
relating to

$44,650,000

NORTH TEXAS MUNICIPAL WATER DISTRICT
WATER SYSTEM REVENUE BONDS, SERIES 2017
(the "Obligations")

INTRODUCTION

This Private Placement Memorandum, including the cover page and appendices, contains brief descriptions of the Issuer, provides certain information with respect to the issuance by the Issuer, and summaries of certain provisions of the "Obligations" pursuant to the Official Action. Except as otherwise set forth herein, capitalized terms used but not defined in this Private Placement Memorandum have the meanings assigned to them in the Official Action. See "APPENDIX B – "FORM OF OFFICIAL ACTION" attached hereto.

APPENDIX A contains the maturity schedule for the Obligations. APPENDIX B contains the Official Action and a description of the purpose for the proceeds of the Obligations. APPENDIX C contains a copy of the proposed opinion of Bond Counsel with respect to the Obligations. The summaries of the documents contained in the forepart of this Private Placement Memorandum are not complete or definitive, and every statement made in this Private Placement Memorandum concerning any provision of any document is qualified by reference to such document in its entirety.

THE OBLIGATIONS

General Description

The Obligations are being issued in the aggregate principal amount set forth in APPENDIX A of this Private Placement Memorandum and will mature and be subject to redemption prior to maturity as described therein. The Obligations are being issued as fully registered bonds in denominations of $5,000**,** or any integral multiple thereof. The Obligations will be dated as of the stated date of issue and will mature on the dates referenced thereon, and will bear interest at the rates per annum set forth in "APPENDIX A - MATURITY SCHEDULE."

Interest on the Obligations is payable semiannually on each Interest Payment Date, and will be calculated on the basis of a 360-day year consisting of twelve 30-day months. Principal of and the redemption price with respect to the Obligations will be payable to the Owners upon presentation and surrender at the principal office of the Paying Agent/Registrar.

Purpose

See "APPENDIX B - FORM OF OFFICIAL ACTION."

Authority for Issuance

The Obligations are special obligations of the North Texas Municipal Water District (the "District") secured by and payable, both as to principal and interest, solely from and secured by a first lien on and pledge of the "Pledged Revenues" as defined in the Resolution authorizing the issuance of the Obligations.

Security for the Obligations

See "APPENDIX B - FORM OF OFFICIAL ACTION."

Redemption Provisions

On March 1, 2028, or on any date thereafter, the Obligations maturing on and after September 1, 2028 may be redeemed prior to their scheduled maturities, upon the written direction of the Issuer, with funds provided by the Issuer, at par plus accrued interest to the date fixed for redemption as a whole, or in part, and if less than all of a maturity is to be redeemed the Paying Agent/Registrar will determine by lot the Obligations, or portions thereof within such maturity to be redeemed (provided that a portion of an Obligation may be redeemed only in Authorized Denominations).

Notice of Redemption; Selection of Obligations to Be Redeemed

See "APPENDIX B - FORM OF OFFICIAL ACTION."

The Paying Agent/Registrar, so long as a Book-Entry-Only System is used for the Obligations, will send any notice of redemption of the Obligations, notice of any proposed amendment to the Official Action or other notices with respect to the Obligations only to DTC. Any failure by DTC to advise any DTC Participant (defined below), or of any DTC participant to notify the beneficial owner, shall not affect the validity of the redemption of the Obligations called for redemption or any other action premised on any such notice. Redemption of portions of the Obligations by the Issuer will reduce the outstanding principal amount of such Obligations held by DTC.

Book-Entry-Only System

The information in this caption concerning The Depository Trust Company, New York, New York ("DTC") and DTC's book entry system has been obtained from DTC and the Issuer makes no representation or warranty nor takes any responsibility for the accuracy or completeness of such information.

DTC will act as securities depository for the Obligations. The Obligations will be issued as fully-registered securities registered in the name of Cede & Co. (DTC's partnership nominee) or such other name as may be requested by an authorized representative of DTC. One fully-registered certificate will be issued for each maturity of the Obligations and deposited with DTC. See APPENDIX B - "FORM OF OFFICIAL ACTION."

DTC is a limited-purpose trust company organized under the New York Banking Law, a "banking organization" within the meaning of the New York Banking Law, a member of the Federal Reserve System, a "clearing corporation" within the meaning of the New York Uniform Commercial Code, and a "clearing agency" registered pursuant to the provisions of Section 17A of the Securities Exchange Act of 1934. DTC holds and provides asset servicing for over 3.5 million issues of U.S. and non-U.S. equity, corporate and municipal debt issues, and money market instrument (from over 100 countries) that DTC's participants (the "Direct Participants") deposit with DTC. DTC also facilitates the post-trade settlement among Direct Participants of sales and other securities transactions, in deposited securities, through electronic computerized book entry transfers and pledges between Direct Participants' accounts. This eliminates the need for physical movement of securities certificates. Direct Participants include both U.S. and non-U.S. securities brokers and dealers, banks, trust companies, clearing corporations, and certain other organizations. DTC is a wholly-owned subsidiary of The Depository Trust & Clearing Corporation ("DTCC"). DTCC is the holding company for DTC, National Securities Clearance Corporation, and Fixed Income Clearance Corporation, all of which are registered clearing agencies. DTCC is owned by the users of its regulated subsidiaries. Access to the DTC system is also available to others such as both U.S. and non-U.S. securities brokers and dealers, banks, trust companies, and clearing corporations that clear through or maintain a custodial relationship with a Direct Participant, either directly or indirectly ("Indirect Participants"). Direct Participants and Indirect Participants are referred to herein collectively as "Participants". DTC has a Standard & Poor's rating of "AA+". The DTC Rules applicable to its Participants are on file with the Securities and Exchange Commission. More information about DTC can be found at www.dtcc.com and www.dtc.org.

Purchases of Obligations under the DTC system must be made by or through Direct Participants, which will receive a credit for the Obligations on DTC's records. The ownership interest of each actual purchaser of each Obligation ("Beneficial Owner") is in turn to be recorded on the Participants' records. Beneficial Owners will not receive written confirmation from DTC of their purchase. Beneficial Owners are, however, expected to receive written confirmations providing details of the transaction, as well as periodic statements of their holdings, from the Participant through which the Beneficial Owner entered into the transaction.

Transfers of ownership interests in the Obligations are to be accomplished by entries made on the books of Participants acting on behalf of Beneficial Owners. Beneficial Owners will not receive Obligations representing their ownership interests in Obligations, except in the event that use of the book-entry system for the Obligations is discontinued.

To facilitate subsequent transfers, all Obligations deposited by Direct Participants with DTC are registered in the name of DTC's partnership nominee, Cede & Co., or such other name as may be requested by an authorized representative of DTC. The deposit of Obligations with DTC and their registration in the name of Cede & Co. or such other DTC nominee do not effect any change in beneficial ownership. DTC has no knowledge of the actual Beneficial Owners of the Obligations; DTC's records reflect only the identity of the Direct Participants to whose accounts such Obligations are credited, which may or may not be the Beneficial Owners. The Participants will remain responsible for keeping account of their holdings on behalf of their customers.

Conveyance of notices and other communications by DTC to Direct Participants, by Direct Participants to Indirect Participants, and by Direct Participants and Indirect Participants to Beneficial Owners will be governed by arrangements among them, subject to any statutory or regulatory requirements as may be in effect from time to time.

Redemption notices shall be sent to DTC. If less than all of the Obligations within a maturity are being redeemed, DTC's practice is to determine by lot the amount of the interest of each Direct Participant in such maturity to be redeemed.

Neither DTC nor Cede & Co. (nor any other DTC nominee) will consent or vote with respect to Obligations unless authorized by a Direct Participant in accordance with DTC's Money Market Instrument Procedures. Under its usual procedures, DTC mails an Omnibus Proxy to the Issuer as soon as possible after the record date. The Omnibus Proxy assigns Cede & Co.'s consenting or voting rights to those Direct Participants to whose accounts Obligations are credited on the record date (identified in a listing attached to the Omnibus Proxy).

All payments on the Obligations will be made to Cede & Co., or such other nominee as may be requested by an authorized representative of DTC. DTC's practice is to credit Direct Participants' accounts upon DTC's receipt of funds and corresponding detail information from the Issuer or the Paying Agent/Registrar, on payable date in accordance with their respective holdings shown on DTC's records. Payments by Participants to Beneficial Owners will be governed by standing instructions and customary practices, as is the case with Obligations held for the accounts of customers in bearer form or registered in "street name," and will be the responsibility of such Participant and not of DTC, the Paying Agent/Registrar, or the Issuer, subject to any statutory or regulatory requirements as may be in effect from time to time. All payments to Cede & Co. (or such other nominee as may be requested by an authorized representative of DTC) are the responsibility of the Issuer or the Paying Agent/Registrar, disbursement of such payments to Direct Participants will be the responsibility of DTC, and disbursement of such payments to the Beneficial Owners will be the responsibility of Participants.

DTC may discontinue providing its services as depository with respect to the Obligations at any time by giving reasonable notice to the Issuer or the Paying Agent/Registrar. Under such circumstances, in the event that a successor depository is not obtained, Obligations are required to be printed and delivered.

With the consent of the Texas Water Development Board, the Issuer may decide to discontinue use of the system of book-entry-only transfers through DTC (or a successor securities depository). In that event, Obligations will be printed and delivered to DTC or successor securities depository.

TAX MATTERS

Opinion

Bond Counsel will deliver its opinion on the date of delivery of the Obligations substantially in the form as attached in "APPENDIX C - FORM OF OPINION OF BOND COUNSEL."

OTHER INFORMATION

Forward Looking Statements

The statements contained in this Private Placement Memorandum, including the cover page, appendices, and any other information or documents provided by the Issuer, that are not purely historical, are forward-looking statements, including statements regarding the Issuer's assumptions, expectations, hopes, intentions, or strategies regarding the future. Any of such assumptions, expectations or hopes could be inaccurate and, therefore, there can be no assurance that the forward-looking statements included herein will prove to be accurate. Holders of the Obligations should not place undue reliance on forward-looking statements. All forward-looking statements included in this Private Placement Memorandum are based on information available to the Issuer on the date hereof, and the Issuer assumes no obligation to update any such forward-looking statements. It is important to note that the Issuer's actual results could differ materially from those in such forward-looking statements.

Ratings

The existing outstanding water system revenue bonds of the District are rated "AAA" by Standard & Poor's Ratings Services, a Standard & Poor's Financial Services LLC business, and "Aa2" by Moody's Investors Service, Inc. An explanation of the significance of such ratings may be obtained from the company furnishing the rating. The ratings reflect only the respective views of such rating companies, and the District makes no representation as to the appropriateness of the ratings. There is no assurance that such ratings will continue for any given period of time, or that they will not be revised downward or withdrawn entirely by either or both of such rating companies, if in the judgment of either or both companies, circumstances so warrant. Any such downward revision or withdrawal of such ratings, by either of them, may have an adverse effect on the market price of the Obligations. **No application has been made to any rating agency or municipal bond insurance company for qualification of the Obligations for ratings or municipal bond insurance, respectively.**

LITIGATION

At the time of the initial delivery of the Bonds, the District will provide the Initial Purchaser with a certificate to the effect that no litigation of any nature has been filed or is then pending challenging the issuance of the Bonds or that affects the payment and security of the Bonds or in any other manner questioning the issuance, sale or delivery of said Bonds.

CONTINUING DISCLOSURE OF INFORMATION

In the Official Action, the Issuer has made the following agreement for the benefit of the holders and beneficial owners of the Obligations. The Issuer is required to observe the agreement for so long as it remains obligated to advance funds to pay the Obligations. Under the agreement, the Issuer will be obligated to provide certain updated financial information and operating data, and timely notice of specified material events, to certain other information vendors. SEE APPENDIX B - "FORM OF OFFICIAL ACTION."

Compliance with Prior Undertakings

During the last five years, the District believes it has complied in all material respects with its previous continuing disclosure undertakings, entered into pursuant to the Rule, except as follows:

In fiscal year ending 2010, the City of Forney ("Forney") became, and in fiscal year ending 2011 the City continued to be, a Significant Obligated Person with respect to its Buffalo Creek Wastewater Interceptor System (the "Buffalo Creek System"), because Forney's payments to the District for use of, or service from, the Buffalo Creek System exceeded 10% of the Gross Revenues of the Buffalo Creek System. However, due to an administrative oversight, the required financial information and operating data for Forney was not timely filed at the State Information Depository ("SID") or the MSRB for fiscal years ending 2010 and 2011. All financial information has since been filed, including a notice of late filing. The District has implemented procedures to ensure timely filing of all future financial information.

The District became obligated to file annual reports with the nationally recognized municipal securities information repository ("NRMSR") and any SID in an offering for the Panther Creek Regional Wastewater System ("Panther Creek System") that took place in 2006. However, due to an administrative oversight that resulted from additional requirements relating to the Panther Creek System's 2009 bond issue, certain of the required information and operating data for the District was not timely filed at the SID or MSRB for fiscal years ending 2009 through 2011. The District has since filed the required information. The District has implemented procedures to ensure timely filing of all future financial information.

In its Water Transmission Facilities Contract Revenue Bonds (City of Terrell Project), Series 2005, the District agreed that it would provide or cause the Significant Obligated Person to provide certain updated financial information and operating data annually to each NRMSIR and any SID, which information would include audited financial statements, provided an audit is commissioned and the audit is completed in time. The District further agreed that if audited financial statements were not available by the required time, the District would provide or cause to be provided unaudited financial statements within the required time, which is six months after the end of each fiscal year of the Significant Obligated Person (March 31 in each year) and would provide or cause to be provided audited financial statements when and if such audited financial statements became available. For fiscal years ending 2009-2013, the Significant Obligated Person, the City of Terrell, Texas ("Terrell"), filed its audited financial statements between 4 and 10 months after March 31 in each year. Terrell filed certain financial information and statements of the type included in Appendix A and C of the 2014 City of Terrell Project Official Statement through its other filings.

In its Water System Revenue Bonds Series 2010, the District agreed that it would provide or cause Significant Obligated Persons to provide certain updated financial information and operating data annually to the MSRB, which information would include audited financial statements, provided an audit is commissioned and the audit is completed in time. The District further agreed that if audited financial statements were not available by the required time, the District would provide or cause to be provided unaudited financial statements within the required time, which is six months after the end of each fiscal year of the Significant Obligated Person ending in or after 2010, and would provide or cause to be provided audited financial statements when and if such audited financial statements became available. In the fiscal years ending 2011 and 2012, a Significant Obligated Person, the City of Garland ("Garland"), filed its audited financial statements on April 17, 2012 and May 1, 2013, respectively. However, Garland did file certain unaudited financial statements, financial information and quantitative data in the form of certain tables identified for each of the respective debt issuances within six months after the end of its 2011 and 2012 fiscal years (March 31).

Due to an administrative oversight, the current investments table was not included in the 2012-2015 filings for the District's Water Transmission Facilities Contract Revenue Refunding Bonds (City of Plano Project), Series 2009. The investments table due in 2016 was timely filed, but the District believes it is neither reasonably feasible nor material to create such Tables for prior years. The District has implemented procedures to ensure timely filing of all future information.

Due to an administrative oversight, the ten largest wastewater customers was not included in the 2012-2013 filings for the District's City of Rockwall 2007 Sewage Treatment and Disposal Service Contract (Buffalo Creek Plant) Revenue Bonds, Series 2008 (the "2008 Bonds"). The City of Rockwall, through its disclosure filings, had filed this information and the information was publically available. This information is now linked to the 2008 Bonds 2012-2013 filings.

The ratings on municipal bond insurers have been downgraded with frequency at various times in recent years. Information about the downgrades of municipal bond insurers has been publicly reported. During the previous five years, the District and Significant Obligated Persons have filed notices of downgrades of municipal bond insurers that insured the District or Significant Obligated Person's outstanding obligations, but no assurances can be made that all the filings have been made or made in a timely manner.

On March 18, 2014, Standard and Poor's upgraded Assured Guaranty's rating from "AA-" to "AA", and the District did not timely file a material event notice related to the rating change, by virtue of the insurance policy provided by Assured Guaranty, for the District's Mustang Creek Wastewater Interceptor System Contract Revenue Bonds, Series 2012. The material event notice has now been filed, including a notice of late filing.

On August 4, 2015, Moody's downgraded from "Aa3" to "A1" the District's Water Facilities Installment Sale Contract Revenue Bonds (City of Rockwall Pump Station Project), Series 2006 and the District's City of Rockwall 2007 Sewage Treatment and Disposal Service Contract (Buffalo Creek Plant) Revenue Bonds, Series 2008, and a material event notice was not timely filed. The material event notice has now been filed, including a notice of late filing.

In its Regional Wastewater System Revenue Bonds Series 2009, the District agreed that it would provide or cause Significant Obligated Persons to provide certain updated financial information and operating data annually to the MSRB, which information would include audited financial statements, provided an audit is commissioned and the audit is completed in time. The District further agreed that if audited financial statements were not available by the required time, the District would provide or cause to be provided unaudited financial statements within the required time, which is six months after the end of each fiscal year of the Significant Obligated Person ending in or after 2009, and would provide or cause to be provided audited financial statements when and if such audited financial statements became available. In the fiscal year ending 2011, a Significant Obligated Person, the City of Mesquite ("Mesquite"), filed unaudited financial statements by the required time, on March 30, 2012, and these unaudited financial statements were available on EMMA under Mesquite's CUSIP. However, these unaudited financial statements were not linked to the District's outstanding CUSIP numbers where Mesquite is a Significant Obligation Person.

MISCELLANEOUS

Any statements made in this Private Placement Memorandum involving matters of opinion or of estimates, whether or not so expressly stated, are set forth as such and not as representations of fact, and no representation is made that any of the estimates will be realized. Neither this Private Placement Memorandum nor any statement that may have been made verbally or in writing is to be construed as a contract with the owners of the Obligations.

The information contained above is neither guaranteed as to accuracy or completeness nor to be construed as a representation by the Issuer. The information and expressions of opinion herein are subject to change without notice and neither the delivery of this Private Placement Memorandum nor any sale made hereunder is to create, under any circumstances, any implication that there has been no change in the affairs of the Issuer or the Issuer from the date hereof.

The Private Placement Memorandum is submitted in connection with the sale of the securities referred to herein and may not be reproduced or used, as a whole or in part, for any other purpose.

ADDITIONAL INFORMATION

The Private Placement Memorandum speaks only as of its date and the information contained herein is subject to change. Descriptions of the Obligations and the Official Action and any other agreements and documents contained herein constitute summaries of certain provisions thereof and do not purport to be complete.

APPENDIX A

MATURITY SCHEDULE

(Due September 1)

CUSIP Prefix: 662903 (1)

Amount	Maturity September 1	Rate	Initial Yield	CUSIP Suffix (1)	Amount	Maturity September 1	Rate	Initial Yield	CUSIP Suffix (1)
$ 940,000	2018				$ 1,460,000	2033			
965,000	2019				1,505,000	2034			
995,000	2020				1,550,000	2035			
1,025,000	2021				1,600,000	2036			
1,055,000	2022				1,645,000	2037			
1,090,000	2023				1,695,000	2038			
1,120,000	2024				1,745,000	2039			
1,155,000	2025				1,800,000	2040			
1,190,000	2026				1,850,000	2041			
1,225,000	2027				1,910,000	2042			
1,260,000	2028				1,965,000	2043			
1,300,000	2029				2,025,000	2044			
1,340,000	2030				2,085,000	2045			
1,380,000	2031				2,145,000	2046			
1,420,000	2032				2,210,000	2047			

---

(1) CUSIP is a registered trademark of the American Bankers Association. CUSIP data herein is provided by CUSIP Global Services, managed by S&P Global Market Intelligence on behalf of the American Bankers Association. This data is not intended to create a database and does not serve in any way as a substitute for the CUSIP Services. CUSIP numbers are provided for convenience of reference only. Neither the Issuer nor the Financial Advisor take any responsibility for the accuracy of CUSIP numbers.

APPENDIX B

FORM OF OFFICIAL ACTION

APPENDIX C

FORM OF OPINION OF BOND COUNSEL

___________, 2017

NORTH TEXAS MUNICIPAL WATER DISTRICT
WATER SYSTEM REVENUE BONDS,
SERIES 2017
DATED ________ 1, 2017
$__________

AS BOND COUNSEL for the North Texas Municipal Water District (the "Issuer"), we have examined into the legality and validity of the bond issue initially evidenced by the bond described above (the "Initial Bond"), which Initial Bond originally has been issued and delivered as a single fully registered bond, without interest coupons, with the principal amount thereof payable in installments due on September 1 in each of the years ____ through ____, and with the unpaid balance of each installment of principal, respectively, bearing interest from the date hereof to the scheduled maturity, or to the date of prepayment or redemption, of each installment of principal, at the following rates per annum for each maturity, respectively:

Year	Rate	Year	Rate

with interest, calculated on the basis of a 360-day year composed of twelve 30-day months, payable semiannually on each March 1 and September 1, commencing March 1, 2018, and with the then outstanding principal of the Initial Bond being subject to prepayment or redemption, as a whole, or in part, prior to scheduled maturity, at the option of the Issuer, on September 1, 2028, or on any date whatsoever thereafter, all in accordance with the terms and conditions stated on the face of the Initial Bond. The Initial Bond may, at the request of the registered owner, be transferred and converted into, and/or exchanged for, fully registered bonds, without interest coupons, in the denomination of $5,000 or any integral multiple of $5,000, and such bonds again may be transferred and/or exchanged, all subject to the conditions stated and in the manner provided in the Resolution authorizing the issuance of the Initial Bond (the "Bond Resolution"), with any such bonds which are registered, authenticated, and delivered in accordance with the Bond Resolution being hereinafter called "Definitive Bonds".

WE HAVE EXAMINED the applicable and pertinent provisions of the Constitution and laws of the State of Texas, and have examined and relied upon a transcript of certified proceedings of the Issuer, and other pertinent instruments furnished by the Issuer relating to the authorization of the Initial Bond and Definitive Bonds and the issuance and delivery of the Initial Bond, including the executed Initial Bond and a printed specimen of the form for Definitive Bonds initially made available by the Issuer for completion and exchange for the Initial Bond.

BASED ON SAID EXAMINATION, IT IS OUR OPINION that the Initial Bond and Definitive Bonds have been duly authorized and the Initial Bond has been duly issued and delivered, all in accordance with law, and that, except as may be limited by laws relating to sovereign immunity and to bankruptcy, reorganization, and other similar matters affecting creditors' rights, (i) the covenants and agreements in the Bond Resolution constitute valid and binding obligations of the Issuer, and the Initial Bond constitutes and Definitive Bonds will constitute valid and legally binding special obligations of the Issuer, which, together with other bonds, are secured by and payable from a first lien on and pledge of the "Pledged Revenues" as defined in the Bond Resolution, including specifically revenues derived pursuant to existing water supply contracts between the Issuer and the Cities of Allen, Farmersville, Forney, Frisco, Garland, McKinney, Mesquite, Plano, Princeton, Richardson, Rockwall, Royse City, and Wylie, Texas, which cities are currently the Member Cities constituting the territory and boundaries of the Issuer, water supply contracts relating to the District=s Water System with any other cities which hereafter may become Member Cities, and water supply contracts with other cities and customers in connection the District=s Water System, and (ii) each of the aforesaid Contracts is authorized by law, has been duly executed, is valid, and is legally binding upon and enforceable by the parties thereto in accordance with their respective terms and provisions.

THE ISSUER has reserved the right, subject to the restrictions stated in the Bond Resolution, to issue additional parity revenue bonds which also may be secured by and made payable from a first lien on and pledge of the Pledged Revenues.

THE ISSUER also has reserved the right, subject to the restrictions stated in the Bond Resolution, to amend the Bond Resolution with the approval of the holders or owners of fifty-one percent in principal amount of all outstanding bonds which are secured by and payable from a first lien on and pledge of the Pledged Revenues.

THE REGISTERED OWNERS of the Initial Bond and the Definitive Bonds shall never have the right to demand payment of the principal thereof or interest thereon out of any funds raised or to be raised by taxation, or from any source whatsoever other than specified in the Bond Resolution.

IN OUR OPINION, that, except as discussed below, under the statutes, regulations, published rulings, and court decisions existing on the date of this opinion, for federal income tax purposes, the interest on the Initial Bond and the Definitive Bonds (collectively, the "Bonds") (i) is excludable from the gross income of the owners thereof and (ii) is not includable in an owner's alternative minimum taxable income under section 55 of the Internal Revenue Code of 1986 (the "Code"). In expressing the aforementioned opinions, we have relied on, and assume compliance by the Issuer with, certain representations, the accuracy of which we have not independently verified, and assume compliance with certain and covenants regarding the use and investment of the proceeds of the Bonds and the use of the property financed therewith. We call your attention to the fact if such representations are determined to be inaccurate or if the Issuer fails to comply with such covenants, interest on the Bonds may become includable in gross income retroactively to the date of issuance of the Bonds.

OUR OPINIONS ARE BASED ON EXISTING LAW, which is subject to change. Such opinions are further based on our knowledge of facts as of the date hereof. We assume no duty to update or supplement our opinions to reflect any facts or circumstances that may thereafter come to our attention or to reflect any changes in any law that may thereafter occur or become effective. Moreover, our opinions are not a guarantee of result and are not binding on the Internal Revenue Service (the "Service"); rather, such opinions represent our legal judgment based upon our review of existing law and in reliance upon the representations and covenants referenced above that we deem relevant to such opinions. The Service has an ongoing audit program to determine compliance with rules that relate to whether interest on state or local obligations is includable in gross income for federal income tax purposes. No assurance can be given whether or not the Service will commence an audit of the Bonds. If an audit is commenced, in accordance with its current published procedures the Service is likely to treat the Issuer as the taxpayer. We observe that the Issuer has covenanted not to take any action, or omit to take any action within its control, that if taken or omitted, respectively, may result in the treatment of interest on the Bonds as includable in gross income for federal income tax purposes.

EXCEPT AS STATED ABOVE, we express no opinion as to any other tax consequences of acquiring, carrying, owning, or disposing of the Bonds. In particular, but not by way of limitation, we express no opinion with respect to the federal, state or local tax consequences arising from the enactment of any pending or future legislation.

WE HAVE ACTED AS BOND COUNSEL for the Issuer for the sole purpose of rendering an opinion with respect to the legality and validity of the Bonds under the Constitution and laws of the State of Texas, and with respect to the exemption of the interest on the Bonds from federal income taxes, and for no other reason or purpose. We have not been requested to investigate or verify, and have not investigated or verified, any records, data, or other material relating to the financial condition or capabilities of the Issuer or its Member Cities, or the adequacy of the "Pledged Revenues," and have not assumed any responsibility with respect thereto. The foregoing opinions represent our legal judgment based upon a review of existing legal authorities that we deem relevant to render such opinions and are not a guarantee of a result.

Respectfully,