Nacogdoches

the oldest town in Texas

FLOOD CONTROL STUDY

for the

CITY OF NACOGDOCHES, TEXAS

STATE OF TEXAS
KARL TRACY LEEDY
98254
LICENSED
PROFESSIONAL ENGINEER

Karl [signature]
03-04-10

Prepared by:

Klotz Associates, Inc.
2716 South Medford Drive
Lufkin, Texas 75901

Texas P.E. Firm Registration No. F-929

Klotz Associates Project No. 0836.004.000
March, 2010

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klotz associates

TABLE OF CONTENTS

TABLES

EXHIBITS

APPENDICES

EXECUTIVE SUMMARY

The City of Nacogdoches and surrounding areas are drained by two watersheds, LaNana watershed on the east side of town and Banita watershed on the west side of town. The LaNana watershed is served by LaNana Creek with several tributaries and the Banita watershed is served by Banita Creek with several tributaries. Banita Creek flows into LaNana Creek at the south side of town. Increased development throughout the city has exacerbated the creek's capacities causing substantial damage during moderate storm events. Because of the increase development and already short times of concentrations due to extreme elevation changes throughout the city, the City of Nacogdoches must implement a comprehensive plan to decrease the likelihood of property damage in such a storm event. Historical flood damage data provided by the City of Nacogdoches was compared to the HEC-RAS model that was created with this study. This comparison identified potential problem areas throughout the city.

In this study, the following flood control alternatives were evaluated and considered as methods to mitigate flood problems throughout the City of Nacogdoches:

1. Do nothing.
2. Purchase of flood prone structures that lie within the 100-year storm flood plain.
3. Create floodplain greenbelts.
4. Intensive floodplain management.
5. Flood proofing.
6. Construct channel improvements and enlarge stream crossing such as bridges and culverts to allow the peak 100-year storm events to pass more freely throughout the system.
7. Construct regional detention ponds to detain the peak flow downstream of ponds.
8. Combination of regional detention ponds, channel improvements, and floodplain management.
9. Tunneling flood waters.

These alternatives were evaluated with consideration to economic means as well as the protection of public health and safety.

Alternate #1 has no cost involved however will continue to put the citizens of Nacogdoches at risk of danger and flooding.

Alternate #2 has an estimated cost of ($23,000,000). A 10-year buy-out program could be put in place to buy-out structures currently in the 100-year flood plain at an estimated annual cost of $2.3 million. This alternate would mean implementing no improvements to the existing drainage system, accepting the 100-year flood plain as is and moving all structures out of the flood plain's path. With continuous development, the flood plain will expand with time making it necessary to purchase additional structures in the future. This is not a viable, comprehensive solution.

Alternate #3 would involve re-zoning areas inside the 100-year flood plain to "Floodplain Greenbelt". The City would have first right to buy property as it became available. A "Greenbelt Creation Fund" could be established to purchase these properties. Budgeting $1 million dollars annually would allow the city to purchase approximately12 properties per year.

Alternate #4, would involve adopting stringent regulations to reduce damage from flooding and protect the public. FEMA Grants could be used to transition repetitive flood structures from residential and business to properties which are compatible with flooding.

Alternate #5 would involve improving existing structures inside the 100-year floodplain to make them water proof for businesses only. This alternative would be feasible only to buildings that flooded three feet or less.

Alternate #6 at an estimated cost of $85,349,400, would provide much needed channel and infrastructure improvements throughout the area, allowing the 100-year storm event to flow more freely, which in return will reduce the area of the 100-year flood plain. Channel improvements for LaNana Creek are estimated at $22,110,000.00. Channel improvements for Banita Creek are estimated at $8,374,000.00. Bridge improvements on LaNana Creek are estimated at $16,821,400.00. Bridge improvements on Banita Creek are estimated at $38,004,000.00. These improvements can be broken down into phases as described in Section 6.

Alternate #7, at an estimated cost of $67,157,000, would provide storm detention for the system which would delay the storms' peak flow rate. This would cause the water surface elevations in the creeks downstream of the detention facilities to decrease, therefore reducing the extent of the 100-year flood plain. There are four detention ponds proposed to reduce the amount of run-off reaching the city. Detention pond #1 has an estimated cost of $13,105,000.00. Detention pond #2 has an estimated cost of $10,744,000.00. Detention pond #3 has an estimated cost of $31,758.000.00. Detention pond #4 has an estimated cost of $11,550,000.00.

Alternate #8, at an estimated cost of $152,506,400, would be the combination of Alternate #6 and Alternate #7.

Alternate #9, at an estimated cost of $599,093,750, would capture the storm water just upstream of Loop 224 on the north side of town and tunnel the water to just down stream of Loop 224 on the south side of town on both LaNana and Banita Creeks. Due to cost, this alternative has been dismissed.

Klotz Associates, Inc. recommends constructing Alternate #6 in phases that will accommodate the City's budget. This phasing sequence is outlined in Section 6 of this report. This would be the most advantageous option for improving the flooding problems in the area, in respect to the protection of the public's health and safety. Once the channel improvements are complete, the City can concentrate on building the proposed detention ponds.

SECTION 1

INTRODUCTION

Banita Creek and LaNana Creek provide drainage for the City of Nacogdoches and significant areas north of the City. A large section of each stream passes through the most densely developed sections of the City and through the middle of the Stephen F. Austin State University Campus (SFASU). In the past ten years, there have been over 32 recorded flooding events that have occurred within the City limits. When flooding events occur, almost every sector of town is at risk. With the combination of tropical moisture from the Gulf of Mexico and the dry hot air from the Rockies, thunderstorms can spring up at a moment's notice and drop large amounts of rain within a relatively brief period of time. Flash flooding occurs with little or no warning and can reach full peak in only a few minutes. The area on the east side of Banita Creek has several low income trailer parks, H.U.D. housing, and high density residential apartments located within the 100-year flood zone. This area has been evacuated several times within the last five years due to extreme rainfall events. Shelters were opened by the Red Cross and water rescue teams mobilized to rescue citizens trapped in the rising water at these locations.

Historically, significant flooding events have occurred in the City at least once every two years. These flood events range from road closures to structure flooding. An estimated 312 structures are currently located in the 100-year floodplain and are subject to repetitive damages from flooding. Atmospheric conditions, combined with the location of LaNana and Banita Creeks in the planning area, create an environment conducive to flooding and subsequent damage to property. Fortunately, there has been no reported loss of life due to flooding in the planning area since 1975, when eight people lost their lives.

Inadequate and insufficient drainage infrastructure also contributes to the planning area's risk of flooding. These drainage systems have not grown or been replaced at the same pace as the growth of the town. In the past ten years, the development of "big box" stores and several residential neighborhoods have sprung up within the City as well as the County. The existing Flood Insurance Rating Maps date back to 1977 and do not include much of the new development and do not accurately define the current 100-year floodplain. Many flood-prone properties do not have flood insurance and are not protected from flooding losses.

The planning area is growing and has the most potential for growth within the upper reaches of the proposed watershed area. The City/County must have a current flood protection plan and accurate flood models to use in planning and controlling the existing and future growth. This issue is not confined to just the City of Nacogdoches. It has become a regional issue where the County is experiencing unprecedented residential growth and must insure that infrastructure improvements meet the future needs of the area and do not adversely impact downstream assets such as SFASU and the downtown business district. SFASU has exceeded enrollment projections over the past several years and has added millions of dollars in facility improvements along with additional on campus housing. LaNana Creek runs through the heart of the campus. The downtown area is located at the convergence of LaNana Creek and Banita Creek. Upstream improvements directly impact the campus as well as the downtown business district.

The City is currently beginning a regional detention program to help control flooding in the watershed area. The proposed flood protection plan will ensure this program meets the future needs of the watershed area. The City will continue to apply for federal assistance for this project which will augment their budget and allow them to implement more mitigation projects identified in the proposed flood protection plan.

As the "Oldest Town in Texas", Nacogdoches has many infrastructure needs that demand huge shares of the budget. Nacogdoches is a relatively small town and has a relatively small budget. The City is currently in the process of TCEQ mandated wastewater collection and treatment improvements, as well as expanding the City's water supply capabilities. These multi-year and multi-million dollar projects have not left much in the budget for drainage improvements.

Even though the City does not have funds available to address all of their drainage needs, they have addressed all issues that were possible. In 1996, the City utilized funding from the TWDB to conduct a Flood Control Study. This study yielded many recommendations for improving flood control. Among these recommendation were widening the existing channels, stream crossing improvements, and detention reservoir's

In 1995, the City approved a Regional Flood Control Plan that recommends over $28 million in flood control improvements needed over the next 20 to 30 years. The City has begun preliminary design of the most downstream LaNana Creek detention facility. Additionally, the City must include channel improvements, bridge widening, and storm collector system upgrades.

This flood study concludes that channel improvements and stream crossing improvements will yield the most benefit. In order for the detention system to have any significant effect, all four detention facilities on LaNana Creek would need to be constructed. Constructing the most downstream detention facility first has little or no effect on the flood plain due to the large outlet pipes needed to pass the flows received from upstream. Once detention facilities are constructed upstream, these outlet pipe sizes could be reduced to achieve lower water surface elevations downstream. Near the same results can be achieved with extensive channel widening and stream crossing improvements. The improvements mentioned above have an estimated cost exceeding $25,000,000.

The City has an extensive system of inlets and conveyance piping to minimize street flooding. In addition, all new developments are required to provide onsite storm water detention based on a 25-year storm frequency. The City budget typically includes $200,000 - $300,000 annually for construction/reconstruction of local drainage projects in known problem areas.

The City must have state-funding assistance for the Flood Protection Planning in order to leverage the funding resources available. The savings in the City budget, which could be realized from state-funding assistance for the planning study, can be applied towards final engineering design and actual implementation of the recommended mitigation measures developed by the study.

SECTION 2

PHYSICAL CONDITIONS AND TOPOGRAPHY

The City of Nacogdoches is located near the center of Nacogdoches County in the piney woods of East Texas. The current estimated population for Nacogdoches County is 59,203 (32,843 within the planning area).

The LaNana and Banita Creek watersheds include all of the City of Nacogdoches and a very large unincorporated area within the County just north of the City. Most of the unincorporated area is undeveloped and heavily wooded.

The area is very hilly outside the floodplain and ranges in elevations from an excess of 610 feet in the northerly limits to approximately 220 feet in the southerly area. The approximate 38,000 acres of drainage area is conveyed by natural streams and creek tributaries to either Banita Creek or LaNana Creek. The entire watershed consists of approximately 52 miles of channels. Internal drainage improvements to serve improved areas consist of curb and gutter streets with underground storm sewers or roadways with roadside ditch drainage. Drainage from the improved areas is typically directed to one of the main tributaries through underground trunk storm sewers, small natural channels or man made ditches.

The 100-year flood zone covers over 4,000 acres within the City limits and nearly 5,000 acres outside the City limits. The planning area boundaries were selected mainly due to the watershed limits matching the proximity of the City limits to the east and west. The southern boundary will be just downstream of convergence of Banita Creek and LaNana Creek outside of the city limits. The northern boundary is dictated by the reach of the two watersheds. The northern boundary includes the area with the fastest developing residential growth that has the potential to have the most future impact on adverse changes to the flood planning area.

SECTION 3

ENVIRONMENTAL ASSESSMENT

3.1 Description of Study Area

The regional flood protection study area for this project consists mostly within the City of Nacogdoches, including a considerable area along the LaNana Creek watershed. This area extends south of the city limits of Nacogdoches and north to the headwaters of LaNana Creek and Banita Creek, LaNana Creek's main tributary. The estimated population for Nacogdoches is 29,914.

Other communities included inside the study area are: a large portion of the city of Appleby, the unincorporated community of Central Heights, and the unincorporated community of Mahl.

3.2 Currently Existing Environment Without the Proposed Project

3.2.1. Geological Elements

3.2.1.a. Topography: The Piney Woods of East Texas encompasses the study area, this area is characterized by pine and hardwood forested hills. The ground surface varies from level or gently rolling hills to hillside inclines of 25% or more with elevation variation from 220 feet above sea level to 610 feet above sea level. The study area as well as the entire county lies within the Neches River drainage basin.

3.2.1.b. Soil Types: The 1980 Soil Survey of Nacogdoches, Texas developed by the USDA defines four separate mapping units inside the study area: The dominantly loamy upland soil Nacogdoches-Trawick, the dominantly sandy upland soils Lilbert-Darco and Cuthbert-Tenaha, and finally the dominantly loamy bottom land soil Tuscosso-Hannahatchee.

The upland soils are predominantly sandy or loamy at the surface, with gravel occurring in reoccurring levels and areas. The bottomland surface and sub-soils throughout the area are mainly clay and loam. Almost all surface soils and sub-soils have varying degrees of acidity. The soils are noted by the USDA as well drained or moderately well drained during their formation with a moderate or moderately slow permeability.

There are a number of detailed soil mapping units categorized as being prime farmland by the USDA that are scattered extensively throughout the portion of the planning area north of Nacogdoches. Within the City, they occur only in limited areas, and some of these areas may be excluded because of urbanization. South of the City, some prime farmland can be found, mainly on the fringes of the LaNana Creek floodplain.

The prime soils for farmland occur in topography ranging from floodplains to broad interstream divides, these do not generally fall immediately adjacent to major streams such as LaNana Creek.

Prime farmland occasionally falls within the general areas of the detention basins, but only small areas are subject to impact from the basins. Most prime farmland does not extend close enough to the streams to be included in the work areas proposed for channel or stream crossing improvements.

The Nacogdoches-Trawick and Cuthbert-Tenaha general mapping units are noted by the USDA as eroding easily. Also, the Nacogdoches and Trawick soils, as well as the Hannahatchee bottomland soils, have been noted as being unstable in pits and road banks because of low shear strength.

The Tuscosso-Hannahatchee unit covers all project elements along LaNana and Banita Creeks. The basins extend away from the creeks into the Nacogdoches-Trawick unit and possibly into the Libert-Darco unit. Most elements along tributary streams will be in the Libert-Darco, with some possibly in the other two units. No work falls into the Cuthbert-Tenaha unit.

3.2.1.c. Geologic Structures: The principal sub-surface rocks in the study area are classified Cenozoic, within the Cenozoic subclass. Predominant surface rocks in the area are of the Claiborne Group, including in descending order the Stone City Formation, the Sparta Sand, the Therill Formation, and the Weches Formation.

East Texas lies within a structural province known as the Gulf of Mexico Basin. The geological structures are represented by two major elements, the East Texas Embayment and the Sabine Uplift. Nacogdoches lies within the East Texas Embayment, which covers approximately 90% of East Texas with a north-south axis running through Cherokee County (west of Nacogdoches).

The Elkhart-Jarvis-Mount Enterprise fault, a major fault system in the Nacogdoches vicinity, runs east and west approximately twenty miles north of Nacogdoches. Just east and in the northeastern portion of the study area more localized fault lines occur.

3.2.2 Hydrological Elements

3.2.2.a. Streams: The two major streams within the study area are LaNana Creek and its main tributary, Banita Creek. Both of these streams begin in northern Nacogdoches County at the beginning of the study area and flow south. Banita Creek flows into LaNana Creek in Nacogdoches. LaNana Creek continues southward to the Angelina River. Several miles of the LaNana Creek channel within the City of Nacogdoches were straightened during the 1970's.

Other named streams within the study area are Toliver Branch, Mill Branch, and Egg Nog Branch.

Stream flow in LaNana Creek at the Nacogdoches wastewater treatment plant (south of the City) averages 56.8 cfs, with monthly averages as low as 1.5 cfs during dry years. Instantaneous flows up to 26,650 cfs have occurred.

The Nacogdoches wastewater treatment plant receives flows from the entire City including local industries. The streams within the study area are not affected by any significant wastewater discharges until they reach the Nacogdoches wastewater treatment plant. The area north of Nacogdoches is affected to some extent by natural erosion and some agricultural runoff, and possibly by timber clear cutting operations. The streams within and downstream from Nacogdoches are also affected by urban runoff.

3.2.2.b. Lakes: The existing lakes cover only a negligible portion of the study area and have little effect on flood control. There are several small lakes on minor tributary streams in the study area, none of which covers over 15 acres.

3.2.2.c. Aquifers: The Carrizo Sand supplies all of the ground water used by the City of Nacogdoches. This aquifer outcrops in a band across the northern and northeastern parts of Nacogdoches County. The top of the formation in the immediate Nacogdoches area varies from 400 to 500 feet below ground, and the aquifer is generally 60 to 90 feet thick in this area. This aquifer contains water of a generally good quality that is generally soft from Nacogdoches southward, including the City's south well field. The portion of the aquifer north of Nacogdoches, including the city's north well field, contains significant amounts of iron, which can be removed for domestic use of the water.

It was noted several years ago that Nacogdoches pumped an average of 4.5 mgd of ground water, representing approximately 55% of the City's water usage. The remainder comes from Lake Nacogdoches ten miles west of town (outside the study area). Ground water pumpage is expected to diminish in the future, with an increase in surface water use.

The Wilcox Group and Sparta Sand are also aquifers that are favorable for producing water for small users within the study area. Other aquifers in the area include the Reklaw Formation, the Queen City Sand, the Weches Formation, and the Alluvium along LaNana Creek. The aquifers other than the Carrizo contain a number of small shallow wells, but are not used for major water supplies.

3.2.2.d. Springs: Near the fringes of the study area at least two springs are known to exist in the immediate Nacogdoches area.

3.2.3 Floodplains and Wetlands: Within the City of Nacogdoches, where a detailed floodplain study has been performed, the 100 year floodplain along LaNana Creek generally varies between 1000 and 2000 feet wide. The Banita Creek floodplain generally varies between 700 and 1000 feet wide within the City. Floodplains occur as relatively narrow strips along streams in the study area.

Within the City, 100 year flood elevations along LaNana Creek vary from 255 to 316 feet. Banita Creek has flood elevations up to 354 feet.

The study area does not contain significant amounts of wetlands outside the immediate vicinity of streams.

3.2.4. Climatic Elements

3.2.4.a. General: The study area is located in the humid sub-tropical region of Central East Texas. The average rainfall as shown in the Texas Almanac is 47.5 inches. Average maximum temperature in July is 94 degrees F, with an average minimum temperature of 39 degrees F in January. Record high and low temperatures are 100 degree temperatures F and -4 degrees F.

The study area has a growing season of approximately 243 days which, coupled with the generous amounts of rainfall, makes the area highly suitable for agriculture.

The winter months are mainly characterized by winds from the northerly direction resulting from the influence of Arctic or Pacific cool fronts. The prevailing wind direction for the area during the summer months is influenced mainly by the warm Gulf air currents from the south and southeast. The region experiences quite rapid fluctuations in both temperature and wind direction during the fall, winter, and summer months because of the interaction of the continental weather systems with warm, moist air from the Gulf.

3.2.4.b Air Quality: The nearest air monitoring stations to the study area are at Tyler, Texas and Shreveport, Louisiana. The Tyler and Shreveport areas, similar to the study area, are in attainment for ozone concentration. Because of the lesser amount of industrialization and the large rural areas in the Nacogdoches area, it is not expected that there are any major air pollution violations.

3.2.5. Biological Elements

3.2.5.a. Plant Communities: The Piney Woods covers most of East Texas, Nacogdoches falls into this vegetational area. Most underdeveloped land within the study area is forested, largely with second growth pines. Hardwoods are also found in the area, including sycamore, black walnut, sweet gum, eastern cottonwood, green ash, and several oaks.

Understory vegetation varies with the many soil types contained within the study area. This vegetation includes longleaf uniola, Indiangrass, sedge various bluestems and panicums, purpletop, three awn, giant cane, switchgrass, Canada wildrye, carpetgrass, holly and paspalum. The understory sometimes supports grazing in wooded areas.

3.2.5.b. Animal Communities: Mammal life in the Nacogdoches area varies from small animals such as rats and mice to larger animals such as bobcats, coyotes and white tailed deer. Various species of bird, reptile, and aquatic life are also found in the area.

The U.S. Fish and Wildlife Service has identified two federally listed endangered species found in Nacogdoches County, the bald eagle and the red-cockaded woodpecker. The bald eagle is found along major rivers and reservoirs and is expected to be well away from the study area. The red-cockaded woodpecker tends to nest in stands of pine timber over sixty years old. This type of timber is found in a number of locations within the study area. Preliminary observations do not indicate such woodpecker habitat to be within or near the basin sites.

3.2.5.c. Habitats of Endangered Species: The habitat of the bald eagle mentioned above is believed to be outside the study area. No specific information is available on local woodpecker nest locations.

Several species of endangered plants are listed by the University of Texas as occurring in Nacogdoches County, but no specific habitats are listed.

3.2.5.d. Preserves in Area: Pioneer Park, a city park in the southern part of Nacogdoches, is a type of natural preserve which is barely developed. Channel and stream crossing improvements are proposed for the stream running through the park. However, the area affected by the project should be small in comparison to the entire park area.

3.2.6. Cultural Resources: Several agencies were contacted in October of 1995 regarding cultural or historic resources and given a chance to comment on the flood study performed. Very little cultural change has occurred in the passed 15 years so these agencies were not contacted again. The Nacogdoches area is noted for many historic sites, since Nacogdoches is the oldest town in the state. Previous correspondence from the Texas Antiquities Committee for a wastewater project also indicated a high potential for archeological sites within the Nacogdoches area.

3.2.7. Economic Conditions: The City of Nacogdoches, one of the oldest towns in Texas, is both a university town and a diversified industrial center. Stephen F. Austin State University (fall 2008 enrollment of 11,756) is by far the largest employer in the community. Its students living on campus make up over 11% of the City's population.

Local industries include manufacturers of valves, outdoor furniture, feed and fertilizer, processed poultry, transformers, business forms, motor homes, industrial sealing products, poultry coops, cooling coils, oriented strand board, millwork and commercial fixtures, soft drinks, candy, flanges, and various wood products. Other significant employers include the U.S. Postal Service; city and county governments; the school district; two hospitals; large retailers; and a construction company. Unemployment within the City Limits of Nacogdoches is relatively low in comparison with the East Texas area.

Nacogdoches County has considerable timber resources, with 2/3 of the county covered by commercial timber. Many county residents are employed in timber production, livestock production, oil and gas production, and tourism.

For Nacogdoches County, the per capita income for 2000 was $15,437. Average weekly wage rate was $544.25 in 2000, with retail sales over $600 million and tax value over $1.5 billion.

Nacogdoches has many opportunities for cultural and recreational activities, including theater groups, art galleries, museums, libraries, parks, swimming pools, golf courses, and tennis courts. Several lakes in the region offer fishing and water sports, including Lake Nacogdoches, Sam Rayburn Reservoir, and Lake Stryker. The surrounding timber land offers considerable hunting opportunities.

Nacogdoches residents tend to have a higher level of education than the nation as a whole. The 2000 census showed that over 25% of all residents 18 to 24 years old had completed at least one year of college. For residents 25 years and older, the percentage was over 14%.

Nacogdoches has an estimated present (2000) population of 29,914, with a projected population of 40,053 in the design year 2020.

Education through high school is provided by the Nacogdoches Independent School District and by the Central Heights ISD. Medical facilities include two general hospitals.

3.2.8. Land Use: Nacogdoches has had zoning within the City since 1970. Zoning designations include several categories of residential, business, and industrial use, as well as medical, agricultural, planned development, and floodplain zones. Applicable City ordinances, including the Floodplain Ordinance, place significant restrictions on further development within floodplains.

In the event of annexation of some land within the study area, zoning for the annexed area is expected to be similar to existing zoning patterns.

Land in the study outside Nacogdoches is primarily covered with timber, with some agricultural use including crops, pasture, and chicken houses. A small portion of the study area includes portions of the city of Appleby as well as residential communities and commercial development. At least one industry is located in the study area outside Nacogdoches, a creosote plant at Mahl.

Population within floodplains within the study area is reported at 284 within Nacogdoches, with an estimated 120 additional residents outside the City.

3.2.9. Other Programs: The most significant public and private programs are those which encourage industrial and business growth. The general effect of these various programs in Nacogdoches is to promote continued growth in the area. These programs include industrial revenue bonds issued by several nonprofit organizations managed by the Nacogdoches County Chamber of Commerce.

Small businesses may obtain financial assistance through the Small Business Administration and the Deep East Texas Regional Certified Development Corporation. Technical assistance is available through the Small Business Institute at SFA University.

The Nacogdoches Area Industrial Park, a nonprofit organization, has property at the north end of the city to help facilitate industrial development.

The City of Nacogdoches had a comprehensive study of its water system performed in 1985, with a further analysis reflected in a plan prepared for the City in 1994. The study outlined a twenty year program for upgrading water storage and distribution facilities. The City also plans to expand the capacity of its surface water intake and distribution facilities on Lake Nacogdoches.

The City has also been implementing a major improvement program for its wastewater collection and treatment facilities. Portions of the program are covered by SRF funding, with some portions funded by TDHCA grants.

3.3 Primary Impacts of Various Alternatives

3.3.1. Short Term Impacts

3.3.1.a. Alterations to Land Forms, Streams, Drainage Patterns

(1) Detention Basins: Each detention basin will involve levee construction, with the land forms within the width of the base of the levee permanently altered by up to 15 feet of fill. The source of the fill material will also be permanently altered, whether the material comes from excavation within the basin or from an outside borrow pit. However, some material may possibly come from area construction sites unrelated to the project, thus reducing the direct effects of the project itself.

The project should have no significant effect on landforms in portions of the impoundment other than levees and excavation areas. However, depending on the levee design, the drainage facilities for flows in excess of the 100-year flood may alter landforms in the areas just downstream from the levees.

The streams within the basin areas may possibly be affected by periodic siltation and sedimentation on a permanent basis as discussed below. Since the impounded water will normally exit through the regular stream channel after runoff subsides, no changes in drainage patterns should occur (except in floods approaching or exceeding the 100 year flood). All water over a designated level will flow out through a spillway or similar structure rather than through the stream channel, in extremely severe flood conditions.

(2) Channel Improvements: Improvements to existing stream channels will involve widening, deepening, and/or riprap in the channels. In some cases, the channel may be realigned. In any case, the alteration in landforms due to channel improvements would be permanent. Drainage patterns would not be affected except for realignments.

(3) Road or Railroad Crossing Improvements: Alterations to landforms would include channel widening and/or deepening at crossings, removal of existing road fill for a distance on each side of the stream, and/or possible increases in the width or height of the fill. Such alterations would be permanent. However, in the case of removal of road fill and replacement with increased bridge length, the project would, to a slight extent, restore the area to its natural condition prior to the original road crossing construction.

Drainage patterns would not be altered for road crossing improvements, unless the improvements include additional culverts or bridges serving as relief structures to supplement existing structures.

(4) Storm Sewers: Any linework (except boring or tunneling) will temporarily alter the ground surface. Local drainage patterns will often be disturbed, including temporary impediments to small ditches and streams. However, contractors will normally be required to restore existing conditions, with little permanent impact.

3.3.1.b. Siltation and Sedimentation: Siltation and sedimentation are expected to occur temporarily in all construction areas. For basin construction, some fill material can be expected to erode during construction (prior to re-vegetation) and wash into the stream on both the upstream and downstream sides of the levee. For channel improvements, considerable siltation would occur from channel excavation. For road crossing improvements, siltation would occur from any channel widening, from any culvert or bridge construction, and possibly from removing or adding road fill. For storm sewer work, siltation would occur in ditches and streams for a distance downstream from any given work area.

Some siltation may occur periodically after project completion in stream channels within the basin impoundment areas. However, any riprap constructed within channels would reduce the amount of siltation in the affected streams by eliminating a source of erosion.

Control measures will be covered to a large extent by a Pollution Prevention Plan (if required for the project) and may include silt hay bales, curtains, reseeding, salvaging/replacing topsoil, and scheduling operations for favorable weather. For any bridge supports or culverts located within channels, possible control measures include scheduling the work for times of low stream flow and/or temporarily sandbagging the stream flow. Construction equipment should be located outside the stream if possible, with the next best course of action being the use of mats for the equipment to rest on.

Measures for the storm sewer work will be similar. Additionally, ditch crossings will be sodded and/or covered with riprap as necessary. Headwalls will be placed around outfall lines if necessary.

3.3.1.c. Injury to Cover Vegetation: Vegetation must be removed from construction areas, but the areas will be restored when not covered by permanent improvements such as basin levees, roadways, etc. For storm sewer work, care will be taken to minimize destruction to adjacent tree roots.

Any rare or endangered species found in a construction area will be considered for preservation by transplanting or design modifications.

3.3.1.d. Herbicides, Defoliants, Cutting, Burning: Clearing will not involve herbicides or defoliants. Significant amounts of cutting is expected within the basin levee areas to the extent that the levees fall in wooded areas. Cutting may also be required for the borrow sources and some channel improvements, and to a lesser extent for storm sewers. However, the areas which will be impounded will not generally require cutting.

Burning, if applicable, will be conducted according to TCEQ regulations for areas within and outside cities.

3.3.1.e. Disposal of Soil and Vegetative Spoil. Any channel excavation or removed road fill must be removed from the site, although in some cases it may be used to refill abandoned channels. Likewise, any excess linework excavation which cannot be spread along the route must be removed. Some of this material may possibly be placed on nearby vacant land or construction sites.

Vegetative spoil, if not placed within channels to be refilled, can be disposed of in the City landfill.

3.3.1.f. Land Acquisition.

(1) Amount to be Acquired. The recommended project is not expected to involve relocation of people, since the areas for the basin sites appear to be vacant. (*One alternative, not recommended, involves a buyout of all floodplain residents in the City in lieu of drainage improvements. That alternative does not appear to be cost effective*.)

The project will require title or other rights to an estimated 2090 acres of land for the four basin sites, including actual construction areas and impoundment areas. The City will need to purchase virtually all construction areas, but it may prove more feasible to purchase flood control easements for the untouched impoundment areas, similar to the Corps of Engineers easement around the boundaries of Sam Rayburn Reservoir. (*Such easements would prohibit most types of structures within the impoundment areas.)* Additionally, the City may need to compensate some land owners for impaired access to land adjacent to basin sites, or for reducing their tracts of land to unusable sizes.

Only minimal easement requirements are expected for channel improvements. Channel easements may already exist along some portions of LaNana Creek which were improved in the 1970's.

Road crossing improvements (*exclusive of associated upstream and downstream channel improvements)* can be constructed within existing highway and road right-of-way. Likewise, the two extensions of railroad trestles can be constructed within existing railroad ROW, although temporary working easements may be required.

Storm sewers can probably be located within existing street and highway ROW in most cases, but may require easements in a few areas.

(2) Method of Acquisition. The construction sites and/or easements will be acquired according to the Uniform Relocation and Assistance Act of 1970. Eminent domain will

be exercised only if necessary. Some existing improvements may remain undisturbed, such as fences or roads within the impoundment areas. However, any existing buildings within impoundment areas are expected to be (a) purchased and removed or demolished or (b) relocated on the owner's property outside the impoundment area.

(3) Effects on Adjacent Land Values. The value of any unpurchased land within impoundment areas would diminish because of periodic flooding in excess of that which would occur naturally. Also, most all types of structures within such areas would be necessarily prohibited. However, the easement payments would be sufficient to compensate the owner for the reduction in value.

The land value outside but adjacent to the impoundment areas should not be affected except for possible impaired access or in cases where the remaining portion of the tract is too small or narrow to be usable. Land values in areas now subject to periodic severe flooding could be improved significantly.

Land values adjacent to channel or stream crossing improvements should not be affected other than by lowered flood levels. Land adjacent to storm sewer routes should not be affected in value except for possible improvements if an existing local drainage problem is relieved.

3.3.1.g. Abandonment of Facilities. Abandonment of existing facilities will primarily be limited to road crossing structures to be removed to allow construction of improved structures. Some existing channels may be abandoned in favor for relocated channels, while some storm sewer lines may be removed for replacement with a larger size.

3.3.1.h. Bypassing of Sewage. In the event that channel improvements or other work require temporary or permanent relocation of sanitary sewer lines, the plans and specifications will include measures to prevent any bypassing or temporary spills. Possible measures include temporary pumping until a relocated line can be constructed. Stream crossings of sewer lines will be reconstructed if necessary in a manner which will prevent any future spills.

3.3.1.i. Construction in Waterways. The Corps of Engineers has been contacted regarding the possible need for Section 10 and Section 404 permits in the 1995 study. Some or all of the construction may be covered under a nationwide permit rather than requiring an individual permit.

3.3.1.j. Noise. Normal construction noise will be a short term nuisance in the immediate vicinity. Noise will occur in residential and commercial areas, along streets and highways, and also in remote areas. OSHA requirements, including mufflers, should protect residents and wildlife.

3.3.1.k. Dust Control. Dust problems may occur as a result of earth moving for basin construction and for road reconstruction associated with stream crossing improvements. Some dust problems may occur from storm sewer construction. If necessary, construction areas can be watered in dry weather.

3.3.1.l. Blasting. There is a slight chance that rock excavation could be required for some storm sewer work, it is anticipated that a rock bucket or similar equipment would be used. No blasting should be required.

3.3.1.m. Safety Provisions. If heavy construction traffic causes problems on roads leading to the sites, or in cases of linework or reconstruction of road crossings, standard safety precautions will be taken such as barricades, warning signs, etc. Parking of construction vehicles will be kept away from heavy traffic or sensitive areas as much as possible. Construction within basin sites and at most channel improvement sites will not interfere with vehicular or pedestrian traffic.

Storm sewer work as well as some road crossings may result in temporary street closures where the work crosses a street.

Any open trenches will be closed as soon as possible or barricaded to prevent accidental entry. If necessary, pedestrian walkways will be provided.

Safety measures for extension of railroad trestles will be in accordance with accepted railroad safety standards.

The relatively inaccessible locations of some construction sites will tend to keep the public away. Other measures such as warning signs, fences, and locked gates will be used as needed.

3.3.1.n. Night Work. Night work is not anticipated except in unusual situations. One possibility may be the need to restore railway traffic when a railroad trestle is being extended in length. Effects of the resulting noise will be minimized by noise control measures or remote locations as appropriate.

3.3.1.o. Effects on Existing Utilities. Owners of all utilities affected by construction will be notified well in advance of construction. Pipeline owners will be contacted to determine pipeline depths, avert damage, and arrange for any necessary adjustments. Consideration will be given to relocating some or all utilities within impoundment areas, according to the expected effects on each facility.

3.3.1.p. Effects on Railroad Traffic. No determination has been made as to how long rail traffic would be curtailed at the two trestles to be lengthened. No local detour routes are available. However, every effort would be made to consult (*during project design)* with the railroad's engineering department as to construction methods which would minimize interference with rail traffic.

Most railroad crossing improvements involve only channel improvements under existing trestles. In the event that the existing substructure requires some type of upgrading as a result of the improvements, every effort will be made to avoid prolonged closure of the trestles.

3.3.2. Long Term Impacts

3.3.2.a. Land Affected, Beneficial Areas. Amounts of land and/or easements required for various construction elements are discussed in subsection C.1.f (1) above.

Away from construction sites, land uses may be affected by slight improvement in developability as a result of reduction of the flooding level. This future development is not expected to affect wetlands or prime agricultural land, and should not affect floodplains other than through infilling. Some existing residential land may increase in value from lowered flood hazard.

Existing usage of the basin areas appears to be primarily for pasture, along with some timber production. The areas covered by the levees and related structures will be necessarily taken out of these permanently. However, if the City and the property owners should negotiate agreements for flood control easement, the impounded areas could continue to enjoy their present uses, subject to interruption during impoundment episodes.

3.3.2.b. Scenic Views. No scenic views should be affected. No landscaping, other than fine grading of embankment and restoring existing surface conditions where applicable is needed.

3.3.2.c. Wind Patterns. Prevailing winds are from the south and southeast in the summer and from a northerly direction in the winter.

3.3.2.d. Effects on Aquatic Life. The only effect of the project on aquatic life would be a possible improvement in stream quality from construction of riprap within channels and thus reducing erosion and siltation.

3.3.2.e. Effects on Water Uses. By reducing the amount of siltation where riprap is constructed in channels, the project may be of slight benefit to any immediate downstream recreational usage of the waters.

3.3.2.f. Diversion of Flows. No diversion of flows between river basins or local watershed is included in the project.

3.3.2.g. Historical, Cultural, and Archeological Resources. Although no special investigation of any of the potential work areas has been made, the City and the Engineer are not immediately aware of any historical or archeological resources within the work sites. However, the City and the Engineer recognize that such resources have been found in some areas of the town and that Nacogdoches has a high potential for such resources, having been a Caddo Indian settlement several hundred years ago.

The TWDB archeological staff may wish to conduct on-site surveys in connection with any state loan funding.

If any archeological resources are discovered during construction, work at the immediate site will be suspended pending archeological investigation.

3.3.2.h. Recreational Areas and Preserves. No known recreational areas or preserves will be adversely affected by the project except for minor effects of channel widening and road crossing improvements in city parks located along streams, such as Pioneer Park. Any parks within floodplains could benefit slightly by reducing the depth and frequency of flooding.

3.3.2.i. Noise Levels. No permanent noise sources will be created.

3.3.2.j. Access Control. No special measures are proposed for any of the channel, road crossing, and storm sewer improvements, since the nature of these areas will be unchanged from their present state. If necessary, the levee sites can be surrounded by fences with lockable gates. The impoundment areas can likewise be enclosed, or (if a flood control easement is used) they can remain under their existing fences. In either event, special warning signs should be installed around the perimeter of each impoundment area to warn the public of sudden rises in the water level.

3.3.2.k. Insect Nuisance. Because of the nature of the project, no insect nuisance will be created or aggravated.

3.3.2.l. Floodplains. The project will be of benefit to all existing floodplain areas within the portion of Nacogdoches inside the study area, as well as portions of the area immediately to the south, with the exception of the areas covered by detention basins. Those areas will be impacted permanently on the levee sites, and the impoundment areas will suffer increased flooding effects on a periodic basis. However, the impacts on those areas will be far outweighed by the benefits to other floodplain areas.

3.3.2.m. Air Quality. The project should have no effect on air quality.

3.3.2.n. Energy and Chemical Consumption. Because of the nature of this project, no energy or chemicals will be involved in operation.

3.3.2.o. Effects on Wildlife. Long-term effects on wildlife should be minimized by leaving the impoundment areas in their natural state. Channel, road crossing, and storm sewer improvements should have no effect on wildlife.

3.3.3.p. Effect on Utilities. Detention Basins will be designed to minimize any problems for existing pipelines and power lines crossing the sites. All existing rights of protection contained in easement agreements will be honored, or alternate arrangements will be made. Channel, road crossing, and storm sewer improvements will be designed to minimize effects on any utilities crossing or paralleling the channels or storm sewers. Coordination would be made with utility owners during construction.

3.4 Secondary Impacts of Various Alternatives

3.4.1. Land Uses. The project may facilitate residential growth in a few marginal areas on the edge of the floodplain by lowering the flood level and thus removing these areas from the floodplain. Similarly, the project may encourage some existing residents to remain in their homes rather than vacating them because of flood problems. Otherwise, no impact on land use is expected.

3.4.2. Air Quality. No secondary effects on air quality through increased automobile usage are expected, since total population growth should not be affected.

3.4.3. Water Quality. Since population growth and thus water usage will not be affected, the project should have no effect on water quality in the Carrizo aquifer or Lake Nacogdoches.

3.4.4. Effect on Public Services. Since the population growth will not be affected, the project should not affect the total demand for public services such as water, gas, and electric power supply; wastewater collection/treatment; solid waste collection/disposal; fire and police protection; and education.

3.4.5. Economic Impacts. Scheduling and financing of the project will require serious consideration by the City. First, the magnitude of the project (*approximately $165.5 million in construction)* is very substantial in comparison with other ongoing capital improvements programs such as water and sewer projects. This represents a capital cost of approximately $5259 per capita for City residents. Second, the project is of a nature which does not normally generate revenue as do water and sewer service.

It is anticipated that the City will follow the recommendation of a report prepared by others to address the issue of financing major drainage improvements. This report, which is attached as an appendix, discusses a means of collecting fees from customers served by the improvements. Such fees, which could be added as a separate line item to monthly water/sewer bills, would be based on the amount of peak runoff generated from a piece of property. (*The peak runoff is a function of various factors such as lot size, vegetation, amount of impervious area such as buildings and pavement, and any detention volume which may be provided on site.*)

Other potential alternatives to drainage fees include property and sales taxes.

Initial financing for the project, or for one or more phases, could come from a bond issue on the open market or from a loan from the Texas Water Development Board. Debt service could come from various sources discussed above.

SECTION 4

DESIGN CRITERIA AND METHODOLOGY

4.1 Design Criteria

This flood study and mitigation alternatives were derived using advanced GIS modeling along with other widely accepted hydrologic and hydraulic practices. The City of Nacogdoches implemented a drainage criteria manual in October of 1999 to mitigate the drainage runoff of new development. Using the 2005 city aerials, new development areas were identified and their impacts were estimated using the City of Nacogdoches drainage criteria manual. The City of Nacogdoches Drainage Criteria Manual states that for watershed areas of greater than 200 acres, the Regional Regression Equations as described in the Texas Department of Highways Hydraulic Manual shall be used.

The Natural Resources Conservation Service (NRCS) Methods produce the direct runoff for a storm, either real or fabricated, by subtracting infiltration and other losses from the total rainfall using a method sometimes termed the Runoff Curve Number Method. The NRCS Runoff Curve Number Method was used to calculate stormwater runoff for the design of drainage improvements on this project since the watershed area greatly exceeds 200 acres (Exhibit 1)

The primary input variables for the NRCS methods are as follows:

- Drainage area size in square miles
- Time of concentration
- Weighted runoff curve number
- Rainfall Distribution
- Total design rainfall

4.2 Design Storm Frequency

TYPE OF FACILITY	DESCRIPTION OF AREA TO BE DETAINED	MINIMUM DESIGN FREQUENCY (YRS)
Streets and Storm Sewers or Side Ditches Combined	Residential Commercial and Industrial	Local – 10 Collector -10 Arterial -10
Culverts, Bridges, Channels and Creeks	Less than 200 Acres	25
Culverts, Bridges, Channel	Greater than 200 Acres	100

4.3 Methodology

For flooding sources studied in detail in the community, standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for this study. Floods having recurrence intervals of 2, 5, 10, 25, 50, 100, and 500 years have been selected as having special significance for flood plain management and for flood insurance premium rates.

4.4 Time of Concentration

The Time of Concentration (Tc) is the time required for a drop of water to travel from the most hydraulically remote point in the sub-area to the point of collection, each sub-area has its own Tc. Technical Release 55 (TR-55) worksheet was used to calculate the time of concentration in this analysis. The TR-55 worksheet is divided up into three flow segments: sheet flow, shallow concentrated flow, and channel flow. The travel time for each of these three flows are added together to form a total Tc for the sub-area.

Sheet Flow

$$Tt = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5} S^{0.4}}$$

Tt = travel time (hour),
n = Manning's roughness coefficient (Table below)
L = Length of sheet flow (≤ 300 feet)
P_2 = 2-year, 24-hour rainfall (inches) and
S = slope of hydraulic grade line (land slope, feet/feet)

Table 4-1: Roughness Coefficients (Manning's n) for sheet flow

Ground Cover	Roughness Coefficient, n
Smooth surfaces (Concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated Soils:	
Residue cover less than 20%	0.06
Residue cover greater than 20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses	0.24
Bermuda grass	0.41
Range (natural)	0.13
Woods:	
Light underbrush	0.40
Dense underbrush	0.80

Shallow Concentrated Flow

After a maximum of 300 feet, sheet flow will act as shallow concentrated flow. Watercourse slope is determined by collecting elevations at both the upstream and downstream ends of the shallow concentrated flow and dividing the elevation difference by the flow length. The velocity for shallow concentrated flow is calculated by using the equation below:

If paved surface, $V = 20.3282\ S^{0.5}$ Unpaved: $V = 16.1345\ S^{0.5}$

$$T_t = \frac{L}{V}$$

T_t= Travel Time (hours)
L= Length of shallow concentrate flow ($\leq$800 feet)
V= Velocity (feet/second)
S= Watercourse Slope (ft/ft)

Channel Flow

After a maximum of 800 feet, shallow flow will generally act as channel flow.

$$T_t = \frac{L}{V}$$

T_t= Travel Time (hours)
L= Length of channel flow (feet)
V= Velocity (feet/second)

4.5 Weighted Runoff Curve Numbers

The NRCS has developed a rainfall runoff index called the runoff curve number (CN), which takes into account factors including soil characteristics and, land use/land condition, and antecedent soil moisture to derive a generalized rainfall/runoff relationship for a given area (Exhibits 2 thru 4). Table 3 provides the runoff curve number calculations for each sub-basin. Table 4 provides a reference to the Texas Department of Transportation Hydraulic Design Manual which was used to develop Table 4-2.

$$CN_{composite} = (1 - impervious\%) \times \frac{\sum A_i CN_i}{A_T} + (100 \times impervious\%)$$

$CN_{composite}$ = the composite CN used for runoff volume computations

i = an index of watersheds subdivisions of uniform land use and soil type

CN_i = the CN for subdivision i

A_i = the area of subdivision i

A_T = the total drainage area

Table 4-2: NRCS Curve Number Equivalent

Land Use	Curve Number of NRCS Group			
	A	B	C	D
Open Water	100	100	100	100
Developed - Open Space	49	69	79	84
Developed - Low Intensity	57	72	81	86
Developed - Med Intensity	61	75	83	87
Developed - High Intensity	77	85	90	92
Barren Land	63	77	85	88
Deciduous Forest	30	55	70	77
Evergreen Forest	36	60	73	79
Mixed Forest	36	60	73	79
Shrub/Scrub	35	56	70	77
Grassland/Herbaceous	49	69	79	84
Pasture/Hay	49	69	79	84
Cultivated Crops	72	81	88	91
Woody Wetlands	98	98	98	98
Emergent Herbaceous Wetlands	98	98	98	98

4.6 Rainfall Distribution

The NRCS Storm method was used to compute the hyetographs for the 24-hour rainfall durations. There are several rainfall distributions that may be applied to the hydrologic model. The National Resources Conservation Service (NRCS) Type II and NRCS Type III are both accepted for a 24-hour rainfall event in the state of Texas and the differences are minimal. Table 4-3 and Figure 1 below show two design dimensionless rainfall distributions for Texas. The distribution represents the fraction of accumulated rainfall accrued with respect to time. Figure 2 on page 4-8 shows the areas in Texas to which these distribution types apply.

Table 4-3: NRCS 24-Hour Rainfall Distributions

Time, t (hr***)	Fraction of 24-hour Rainfall	
	Type II	Type III
0	0.000	0.000
2	0.022	0.020
4	0.048	0.043
6	0.080	0.072
7	0.098	0.089
8	0.120	0.115
8.5	0.133	0.130
9	0.147	0.148
9.5	0.163	0.167
9.75	0.172	0.178
10	0.181	0.189
10.5	0.204	0.216
11	0.235	0.250
11.5	0.283	0.298
11.75	0.357	0.339
12	0.663	0.500
12.5	0.735	0.702
13	0.772	0.751
13.5	0.799	0.785
14	0.820	0.811
16	0.880	0.886
20	0.952	0.957
24	1.000	1.000

Figure 1: Rainfall Distributions For Texas

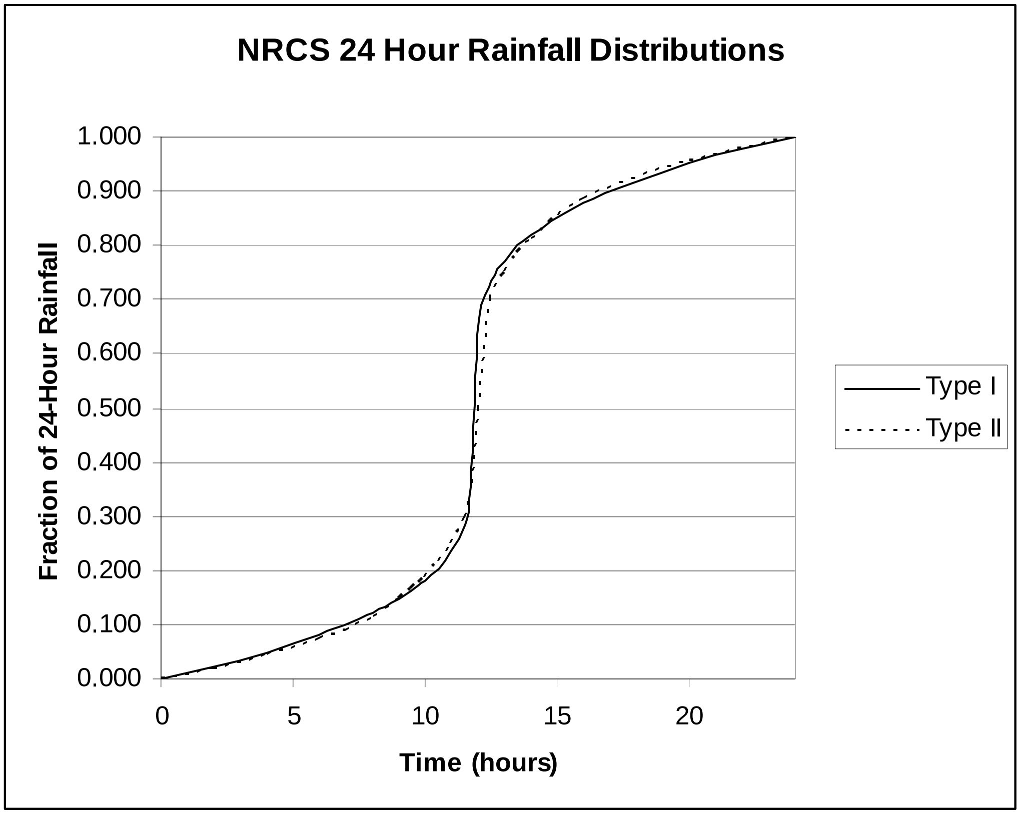
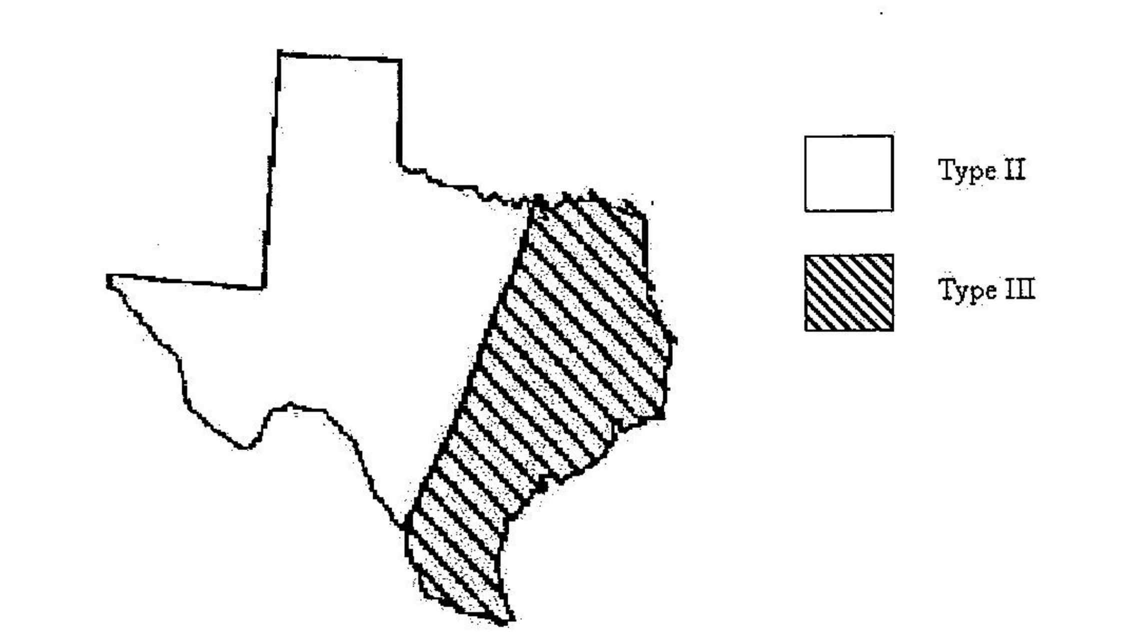


Figure 2: Soil Conservation Service 24-Hour Rainfall Distributions- Adapted from TR55 (1986, pp. B-1)



4.7 Total Design Rainfall

Accumulated rainfall may be obtained from Technical Paper 40 for a 24-hour storm for the relevant frequency. The data for 24-hour two, five, 10, 25, 50, and 100 year frequencies for Texas counties are presented in the 24-hour Rainfall Depth vs. Frequency Values for Texas Counties.

4.8 Hydrologic Analyses

Hydrologic analyses were carried out to establish peak discharge-frequency relationships for floods of the selected recurrence intervals for each flooding source studied in detail in the community.

Peak discharges for LaNana Creek, Banita Creek, Eggnog Creek, and the six tributaries studied were estimated by applying unit hydrograph methodology to a rainfall=runoff mathematical model developed by the U.S. Army COE, Hydrologic Engineering Center Hydrologic Modeling System (Reference 3). The unit hydrograph computations considered rainfall depth-duration-frequency data, rainfall losses, percentage of watershed developed, and other pertinent watershed characteristics as determined from published documents and field and office investigation.

Rainfall data developed by the U.S. Department of Commerce NOAA were used in development of the 2, 5, 10, 25, 50, and 100 year storm events (Reference 6).

The 500 year flood discharges were determined by a straight line extrapolation of log-probability plots of the 2, 5, 10, 25, 50 and 100 year flood discharges.

The peak discharges, that were developed using the methods listed above, are provided in Table 1 for the following categories:

- Values obtained from FEMA Report (where available)
- S&P HEC-2 model using present 100 yr – 24 hr storm
- Current HEC-RAS model values using present 100 yr – 6 hr storm
- Current HEC-RAS model values using present 100 yr – 24 hr storm
- Current HEC-RAS model values using future 100 yr – 24 hr storm
- Current HEC-RAS model values using proposed 100 yr – 24 hr storm

4.9 Hydraulic Analyses

Analyses of the hydraulic characteristics of the streams in the community were carried out to provide estimates of the elevations of floods of the selected recurrence intervals along each stream studied in detail.

Water-surface elevations of the 2, 5, 10, 25, 50, 100, and 500 year floods were computed using a computer program developed by the U.S. Army COE, Hydrologic Engineering Center River Analysis System (Reference 4).

The water-surface elevations, that were computed using the program listed above, are provided in Table 2 for the following categories:

- Current HEC-RAS model values using present 100 yr – 6 hr storm
- Current HEC-RAS model values using present 100 yr – 24 hr storm
- Current HEC-RAS model values using future 100 yr – 24 hr storm
- Current HEC-RAS model values using proposed 100 yr – 24 hr storm

Channel and valley cross sections of streams studied in detail were obtained by either field surveys, United States Geological Survey (USGS) 15-minute topographic quadrangle maps, or available data from the City of Nacogdoches. Locations of cross sections used in the hydraulic analyses are shown on the Cross Section Location Map (Appendix B).

Coefficients of roughness (Mannings "n") were assigned to elements of the valley on the basis of field inspections, aerial photos, and topographical maps depicting the channels and flood plains of the streams. The selected coefficients varied from .015 to .08 for the channels and from .08 to .15 for the overbank areas for the streams studied in detail.

The hydraulic analyses were based on existing conditions. Calculated flood elevations are valid only if the waterway structures and the channel and overbank characteristics remain in essentially the same conditions as defined for the time period covered under the scope of this study.

Flood profiles were drawn, for existing and future conditions, using the computed water-surface elevations for floods having the selected recurrence intervals of 2, 5, 10, 25, 50, 100 and 500 years (Appendix B). All elevations used in this study are measured from NAD 83 Central Texas State Plane Coordinate System. Elevation reference marks are shown on the Flood Insurance Rate Map using NGVD 29. The NAD 83 elevations were measured by field surveys and compared against the NGVD 29 elevations at the same point. There was a fairly good correlation between the NGVD 29 data and the NAD 83 data. When the differences were averaged, the NAD 83 data was 0.30 feet lower that the NGVD 29 data.

SECTION 5

EVALUATION OF DRAINAGE AREAS AND STREAMS

The total watershed was initially divided into 20 separate drainage areas for the purpose of isolating the individual tributaries to Eggnog Creek, Banita Creek and LaNana Creek. Subsequently, eight of these drainage areas were sub-divided to further assist analysis.

Using GIS, with aerial photos and two foot contours, the entire watershed and its limits were developed. The limits of each drainage area were defined by outlining the high-point ridge line between tributaries to the intersections with other tributaries or major stream. The area enclosed within each outline defines the surface from which the tributary would receive run-off during a rain event. These individual drainage areas are listed below and shown on Exhibit 1:

Watershed	Drainage Area	Acres
LaNana	A	6265
LaNana	B	4571
LaNana	C	2446
LaNana	D-Tributary E	1167
LaNana	D1-Tributary E	783
LaNana	E	1461
LaNana	E1	1243
LaNana	F	1803
LaNana	F1	48
LaNana	G	1594
LaNana	H	517
LaNana	R	1755
LaNana	S	226
LaNana	T	1663
	Total Area (Acres) =	25,542
Eggnog	I	1527
Eggnog	I1	194
	Total Area (Acres) =	1,721
Banita	J	2699
Banita	K	1549
Banita	L-Tributary G	504
Banita	L1-Tributary G	696
Banita	M	1310
Banita	N-Tributary C	706
Banita	N1-Tributary C	397
Banita	O	665
Banita	P-Tributary B	684

Banita	P1-Tributary B	236
Banita	Q-Tributary A	674
Banita	Q1-Tributary A	706
	Total Area in (Acres) =	10,826
	Total Watershed in (Acres) =	38,089

The 1976 Flood Study published by the Federal Emergency Management Agency (FEMA) and the 1995 Flood Study by Schaumburg and Polk performed a detailed analysis of all of the streams and Tributaries listed above except tributaries E and G. Comparison of FEMA data and this study found the area of comparable drainage areas to be approximately the same with a few minor variations.

Each drainage area was evaluated and values assigned for run-off, sheet flow, shallow flow and channel flow coefficients and factors. This input data combined with the rainfall intensity coefficients and storm duration definition, as previously described, provided flood hydrographs for each drainage area. These flood hydrographs were then routed and combined along the entire channel route(s) to develop peak flows that could be expected to occur at various points along the stream(s).

As previously discussed, the 100-year, 6-hour duration storm was evaluated in addition to the 100-year, 24-hour duration storm. The 6-hour duration is significant because that is the approximate time for run-off generated at the uppermost reaches of the watershed to pass through the entire watershed. This condition can result in the worst case storm event in terms of instantaneous peak flows to be transported and therefore merits analysis. However, this study found the 24-hour storm to result in the greater flows and thus used as the design storm.

Flood hydrographs for the design storm under present development, and the design storm under future development are provided in Appendix B. The peak flows from these hydrographs are shown in Table 1 and are the flow rates used in the HEC-RAS 3.1.3 stream modeling program for this study.

Field surveys were performed during previous studies to collect data for the HEC-RAS program and included the following:

- Channel cross-sections
- Bridge Data
    - Width
    - Length
    - Depth of Deck Structure
    - Piling
- Culvert Data
    - Size: Diameter, width, depth
    - Inlet/Outlet conditions
- Elevations

For bridge analysis, four separate cross-sections of the channel were taken; one at each face of the structure plus one each up/downstream of the structure. Cross sections were also taken at the up/downstream faces of other crossings and at various intermittent points between crossings.

To check for accuracy and validity, several cross-sections were generated from USGS 15-minute topographic quadrangle maps. The cross-sections were then compared to the cross-section data from the previous studies at the same location. These comparisons were very favorable and additional cross-sections at selected points along the channels were developed from the USGS quadrangles where existing data was not available. These cross-sections were used infrequently and mainly on the outer limits of drainage areas. Although not as accurate as field surveys, the USGS cross-sections were sufficiently accurate for their intended purpose.

The City of Nacogdoches provided 2 foot contour maps for the studied area within the city limits. This data proved to be very accurate and was used to map the 100-year 24-hour floodplain maps. These maps were compared with the FEMA 100-year 24-hour floodplain maps and the results were very comparable.

The USGS quadrangle maps and the existing data were all provided on the same datum (NGVD 27). However, the City of Nacogdoches contour maps were provided on a different datum (NAD 83). In order to adjust the elevations, to the more accurate City of Nacogdoches contour data, bench mark loops were performed using existing benchmarks with known elevations. After comparing several benchmarks with known existing elevations and with the new survey elevations, it was determined that the difference in datum was 0.3 feet. The elevations in the HEC-RAS stream model were then adjusted to match the more accurate contours.

With the channel cross-sections, bridge and culvert data, channel lengths, roughness coefficients and flow rates, a HEC-RAS (hydraulic) model was constructed for the following channels.

1. LaNana Creek
2. Banita Creek
3. Eggnog Creek
4. Tributary A
5. Tributary B
6. Tributary C
7. Tributary D
8. Tributary E
9. Tributary G

Other than the flow roughness coefficient, the raw input data for the HEC-RAS model is fairly precise and definitive. The Manning coefficients however, were reviewed through visual observation of the channel or structure and compared with the channel conditions provided (Table 4).

The hydrologic models for the LaNana and Banita Creek Watersheds were compared for reasonableness with previous hydrologic studies conducted in the watersheds and in comparison to records for Stream Gaging Station 08037050 on LaNana Creek at Nacogdoches, Texas, operated from 1965 to 1993 by the United States Geological Survey (USGS).

The peak flows predicted in this study compared favorably with results from the 1995 and 1996 studies completed for LaNana and Banita Creeks. The modeled flows in this study were within one to five percent of each other with the current study reflecting the urbanization of the watersheds.

The USGS gage records are for a period of 27 years and the maximum peak flow recorded at the site was 13,500 cfs and is within the range of peak flows estimated by the HEC-HMS model developed for the project. The USGS gaging station had a drainage area of 31.3 square miles and was located on LaNana Creek near East Starr Avenue in Nacogdoches, Texas.

SECTION 6

EVALUATION OF PROPOSED IMPROVEMENTS

6.1 Introduction

Identification and evaluation of potential methods to mitigate the impacts and damage from flood events up through the 100-year return period is a primary objective of this study. The wide-spread flooding that occurs along LaNana and Banita Creeks in Nacogdoches can impact over three hundred structures, inundate 17 bridges, severely disrupt commerce and endanger lives. Mitigation measures are needed to reduce flooding and produce benefits that are commensurate with cost.

Non-structural and structural methods were considered and evaluated as flood mitigation measures. In addition, combinations of non-structural and structural measures were evaluated.

Exhibit 6 illustrates a Water Surface Floodplain Map using water surface elevations calculated in the hydraulic model. The illustration shows flood mitigation provided by a combination of structures compared to the existing conditions during a 24 hour duration and 100 year frequency storm event. As shown, a large amount of flooding occurs in the center of the city. Flood mitigation with a combination of structures, including channels, would produce the greatest flood relief towards the center of the city along both LaNana Creek and Banita Creek.

The mitigation measures studied included:

Alternative 1 - Do Nothing
Alternative 2 - Property Buy-Outs
Alternative 3 - Floodplain Greenbelts
Alternative 4 - Intensive Floodplain Management
Alternative 5 - Floodproofing
Alternative 6 - Stream Channel Modifications
Alternative 7 - Floodwater Retarding Structures
Alternative 8 - Combination of Floodwater Retarding Structures, Stream Channel Modifications and Intensive Floodplain Management
Alternative 9 - Tunnels

Tables 6.1, 6.2 and 6.3 present peak flows at selected locations along LaNana and Banita Creeks for the 100-, 25- and 10-year, 24-hour rainfall future development conditions flood events.

As table 6.1, 6.2, and 6.3 show, the flow will remain constant for non-structural alternatives and will likely result in no change to the existing flood plain. Other than the "Do Nothing" alternative, the non-structural alternatives are intended to protect existing development or to prevent future development in the floodplain areas.

For the channel modifications alternative, little flow change is expected. However, channel modifications will allow a higher channel velocity and as a result will reduce the water surface elevation for that particular storm which reduces the floodplain area.

The data presented in the tables for flood water retarding structure alternatives shows very little to no impact on the peak discharges. Areas that do experience a significant decrease in peak flow are more toward the north of the city limits and not in the downtown area where the most damage occurs. These tables tell us that adding floodwater retarding structures alone will do very little to reduce flooded areas during a significant rainfall event.

TABLE 6.1
100-YEAR PEAK DISCHARGES FOR FLOOD MITIGATION ALTERNATIVES

ALTERNATIVE	100-YEAR, 24-HOUR RAINFALL PEAK DISCHARGE IN CUBIC FEET PER SECOND, FUTURE DEVELOPMENT CONDITIONS									
	LaNana Creek						**Banita Creek**			
	North Loop 224	Norma Street	College Street	**Above Confluence with Banita Creek**	**Below Confluence with Banita Creek**	**South Loop 224**	Austin Street	Pearl Street	MLK Jr. Street	**Above Confluence with LaNana Creek**
DO NOTHING	14,800	11,400	11,400	**14,600**	**23,700**	**23,000**	7,000	7,000	8,600	**9,200**
PROPERTY BUY-OUTS	14,800	11,400	11,400	**14,600**	**23,700**	**23,000**	7,000	7,000	8,600	**9,200**
FLOODPLAIN GREENBELTS	14,800	11,400	11,400	**14,600**	**23,700**	**23,000**	7,000	7,000	8,600	**9,200**
INTENSIVE FLOODPLAIN MANAGEMENT	14,800	11,400	11,400	**14,600**	**23,700**	**23,000**	7,000	7,000	8,600	**9,200**
FLOODPROOFING	14,800	11,400	11,400	**14,600**	**23,700**	**23,000**	7,000	7,000	8,600	**9,200**
TUNNELS	0	3,500	6,200	**11,400**	**18,700**	**17,800**	3,800	3,800	6,000	**7,300**
CHANNEL MODIFICATIONS AND INTENSIVE FLOODPLAIN MANAGEMENT	14,800	11,400	11,400	**14,600**	**23,700**	**23,000**	7,000	7,000	8,600	**9,200**
FLOODWATER RETARDING STRUCTURE 1, CHANNEL MODIFICATIONS, INTENSIVE FLOODPLAIN MANAGEMENT	13,000	9,800	10,000	**14,600**	**23,800**	**23,000**	7,000	7,000	8,600	**9,200**
FLOODWATER RETARDING STRUCTURES 1 AND 2, CHANNEL MODIFICATIONS, INTENSIVE FLOODPLAIN MANAGEMENT	11,000	8,300	10,000	**15,000**	**23,700**	**23,000**	7,000	7,000	8,600	**9,200**
FLOODWATER RETARDING STRUCTURES 1, 2 AND 3, CHANNEL MODIFICATIONS, INTENSIVE FLOODPLAIN MANAGEMENT	5,300	7,100	10,000	**14,600**	**23,700**	**22,900**	7,000	7,000	8,600	**9,200**
FLOODWATER RETARDING STRUCTURES 1, 2, 3 AND 4, CHANNEL MODIFICATIONS, INTENSIVE FLOODPLAIN MANAGEMENT	5,300	7,100	6,800	**12,300**	**23,700**	**22,900**	7,000	7,000	8,600	**9,200**

TABLE 6.2
25-YEAR PEAK DISCHARGES FOR FLOOD MITIGATION ALTERNATIVES

ALTERNATIVE	25-YEAR, 24-HOUR RAINFALL PEAK DISCHARGE IN CUBIC FEET PER SECOND, FUTURE DEVELOPMENT CONDITIONS									
	LaNana Creek						Banita Creek			
	North Loop 224	Norma Street	College Street	Above Confluence with Banita Creek	Below Confluence with Banita Creek	South Loop 224	Austin Street	Pearl Street	MLK Jr. Street	Above Confluence with LaNana Creek
DO NOTHING	10,300	8,400	8,500	11,700	18,300	17,500	5,100	5,100	6,200	6,700
PROPERTY BUY-OUTS	10,300	8,400	8,500	11,700	18,300	17,500	5,100	5,100	6,200	6,700
FLOODPLAIN GREENBELTS	10,300	8,400	8,500	11,700	18,300	17,500	5,100	5,100	6,200	6,700
INTENSIVE FLOODPLAIN MANAGEMENT	10,300	8,400	8,500	11,700	18,300	17,500	5,100	5,100	6,200	6,700
FLOODPROOFING	10,300	8,400	8,500	11,700	18,300	17,500	5,100	5,100	6,200	6,700
TUNNELS	0	2,600	4,500	8,400	13,700	12,500	2,800	2,800	4,500	5,400
CHANNEL MODIFICATIONS AND INTENSIVE FLOODPLAIN MANAGEMENT	10,300	8,400	8,500	11,700	18,300	17,500	5,100	5,100	6,200	6,700
FLOODWATER RETARDING STRUCTURE 1, CHANNEL MODIFICATIONS, INTENSIVE FLOODPLAIN MANAGEMENT	9,100	7,400	8,300	11,700	18,300	17,500	5,100	5,100	6,200	6,700
FLOODWATER RETARDING STRUCTURES 1 AND 2, CHANNEL MODIFICATIONS, INTENSIVE FLOODPLAIN MANAGEMENT	7,900	6,100	8,300	11,700	18,300	17,500	5,100	5,100	6,200	6,700
FLOODWATER RETARDING STRUCTURES 1, 2 AND 3, CHANNEL MODIFICATIONS, INTENSIVE FLOODPLAIN MANAGEMENT	3,800	6,100	8,300	11,700	17,500	22,900	5,100	5,100	6,200	6,700
FLOODWATER RETARDING STRUCTURES 1, 2, 3 AND 4, CHANNEL MODIFICATIONS, INTENSIVE FLOODPLAIN MANAGEMENT	3,800	6,100	5,700	9,800	15,900	16,400	5,100	5,100	6,200	6,700

TABLE 6.3
10-YEAR PEAK DISCHARGES FOR FLOOD MITIGATION ALTERNATIVES

ALTERNATIVE	10-YEAR, 24-HOUR RAINFALL PEAK DISCHARGE IN CUBIC FEET PER SECOND, FUTURE DEVELOPMENT CONDITIONS									
	LaNana Creek						Banita Creek			
	North Loop 224	Norma Street	College Street	Above Confluence with Banita Creek	Below Confluence with Banita Creek	South Loop 224	Austin Street	Pearl Street	MLK Jr. Street	Above Confluence with LaNana Creek
DO NOTHING	8,000	6,700	7,400	10,200	15,500	15,000	4,100	4,100	5,000	5,500
PROPERTY BUY-OUTS	8,000	6,700	7,400	10,200	15,500	15,000	4,100	4,100	5,000	5,500
FLOODPLAIN GREENBELTS	8,000	6,700	7,400	10,200	15,500	15,000	4,100	4,100	5,000	5,500
INTENSIVE FLOODPLAIN MANAGEMENT	8,000	6,700	7,400	10,200	15,500	15,000	4,100	4,100	5,000	5,500
FLOODPROOFING	8,000	6,700	7,400	10,200	15,500	15,000	4,100	4,100	5,000	5,500
TUNNELS	0	2,100	3,600	6,500	10,800	9,900	2,300	2,300	3,600	4,300
CHANNEL MODIFICATIONS AND INTENSIVE FLOODPLAIN MANAGEMENT	8,000	6,700	7,400	10,200	15,500	15,000	4,100	4,100	5,000	5,500
FLOODWATER RETARDING STRUCTURE 1, CHANNEL MODIFICATIONS, INTENSIVE FLOODPLAIN MANAGEMENT	7,000	5,900	7,400	10,200	15,500	15,000	4,100	4,100	5,000	5,500
FLOODWATER RETARDING STRUCTURES 1 AND 2, CHANNEL MODIFICATIONS, INTENSIVE FLOODPLAIN MANAGEMENT	6,400	5,700	7,400	10,200	15,500	15,000	4,100	4,100	5,000	5,500
FLOODWATER RETARDING STRUCTURES 1, 2 AND 3, CHANNEL MODIFICATIONS, INTENSIVE FLOODPLAIN MANAGEMENT	3,100	5,700	7,400	10,200	15,500	15,000	4,100	4,100	5,000	5,500
FLOODWATER RETARDING STRUCTURES 1, 2, 3 AND 4, CHANNEL MODIFICATIONS, INTENSIVE FLOODPLAIN MANAGEMENT	3,100	5,700	5,200	8,500	13,900	13,100	4,100	4,100	5,000	5,500

6.2 Do Nothing

The “Do Nothing” Alternative assumes that there will be little, if any, effort made to reduce flooding along the creeks and tributaries. Floodplain management will be used to prevent additional structures from being unsafely constructed in the floodplains but no additional effort will be made to reduce damages to existing structures. The impact of 100-year event includes floodwaters entering 312 existing structures with an estimated value of $23,450,000. In addition, 17 bridges will be overtopped by floodwater and significant other property damage will occur (such as land erosion, utility disruptions, damage to roads and parking lots).

6.3 Property Buy-Out

The “Buy-Out” Alternative is based on a long term plan to systematically buy the structures that are flood prone and remove them from the floodplain. A property buy-out plan would be developed that targets the buy-out of the most frequently flooded structures during the early phases of the program followed by the other structures in the floodplain in the later years.

If a 10-year buy-out program is adopted, the annual funding need would be about $2.3 million. On the average, this would buy about 30 structures each year. Funding from FEMA to assist in buy-outs is available based on applying for and receiving competitive grants.

Buy-outs are not always a preferred alternative because of the social impacts associated with relocating people and their lives, the loss of value of the bought property from tax rolls, and buying-out property does not remove it from the floodplain. In addition, the bridges subject to flooding remain as hazards during floods. Advantages of this approach include removal of structures from the floodplain without using structural measures.

Buy-out of the structures subject to the most frequent flooding combined with other flood mitigation alternatives is probably the most desirable mitigation strategy.

6.4 Floodplain Greenbelts

The “Floodplain Greenbelt” Alternative can be described as re-zoning the area within the floodplain limits as a “Floodplain Greenbelt” and prohibiting all future construction within the greenbelt. In addition, as properties become available for purchase, the City would have the right of first refusal to purchase based on fair market value.

The City could establish a “Greenbelt Creation Fund” for use in making opportunistic purchases of property in the floodplain. If $1 million per year is budgeted annually, about 12 properties per year could be purchased. This program would be a long-term approach to flood mitigation without structural improvements.

Funding from FEMA to assist in buying flood-prone property is available based on applying for and receiving competitive grants. In addition, if the project is described as a linear park, funding for property purchase and park development may be available from agencies such as Texas Parks and Wildlife.

Greenbelts are not always a preferred alternative because of the social impacts associated with relocating people and their lives, the loss of value of the property from tax rolls, and buying property does not remove it from the floodplain. In addition, the bridges subject to flooding remain as hazards during floods. Advantages of this approach include removal of structures from the floodplain without using structural measures.

6.5 Intensive Floodplain Management

The City of Nacogdoches, as a home rule city in Texas, has the ability to adopt stringent regulations to minimize and reduce damage from flooding and to protect the lives of citizens.

Developing and adopting regulations that prevent any additional construction in floodplains and when appropriate, require removal of structures from the floodplain. The City would not take fee simple ownership of the property but the use of property would be limited to activities that do not include the potential for loss of life or damage to inhabitable property.

The City could consider and implement innovative approaches to the transition of property in the floodplain from residences and businesses to uses which are compatible with flooding. Funding may be available from FEMA for innovative approaches to intensive floodplain management based on applying for and receiving competitive grants.

Intensive floodplain management may not be a preferred alternative because of the social impacts associated with relocating people and their lives, the loss of value of the property from tax rolls, and buying property does not remove it from the floodplain. In addition, the bridges subject to flooding remain as hazards during floods. Advantages of this approach include removal of structures from the floodplain without using structural measures.

6.6 Floodproofing

Floodproofing is a combination of adjustments and/or additions of features to individual buildings that are designed to eliminate or reduce the potential for flood damage. Some examples of floodproofing include the placement of walls or levees around individual buildings; elevation of buildings on fill, posts, piers, walls, or pilings; anchorage of buildings to resist flotation and lateral movement; watertight closures for doors and windows; reinforcement of walls to resist water pressure and floating debris; use of paints, membranes, and other sealants to reduce seepage of water; installation of pumps to control water levels; installation of check valves to prevent entrance of floodwaters at utility and sewer wall penetrations; and location of electrical equipment and circuits above expected flood levels.

Floodproofing is available primarily for non-residential buildings. Dry floodproofing seals a building by coating its walls with waterproofing compounds or impermeable sheeting. Openings such as doors, windows, sewer lines, and vents are blocked off with permanent closures or removable shields, sandbags, valves, or other barriers.

Wet floodproofing is often used when dry floodproofing is either not possible or too expensive. This form of protection can be employed on structures with basements. Wet floodproofing modifies a building to allow floodwaters inside while ensuring minimal damage to the structure and contents. To use this form of mitigation, there must be an area available above the Base Flood Elevation (BFE) where damageable items can be relocated or temporarily stored. Additionally, utilities and furnaces must either be protected or relocated to an area above the BFE.

There are three main components to wet floodproofing a structure: design elements (such as openings in foundation walls and other construction techniques), flood-resistant materials (such as impervious construction materials and insulation), and protection of contents (by elevating mechanical, electrical, and HVAC systems or placing them in waterproof containers).

Relocating flood prone structures to higher ground is one of the safest ways to protect against flooding and reduce the liability and cost to the community. Although relocation can be expensive initially, in the long run moving can be less costly than paying for repetitive flood damages or high flood insurance premiums. In addition, relocating buildings to areas with reduced flood risk allows flood prone property to be used for open space, wetlands, or recreation.

One of the most common retrofitting methods is to elevate a building above the expected flood level. When a house is properly elevated, the living area will be above all but the most severe floods. Elevation to or above the BFE allows a substantially damaged or substantially improved house to be brought into compliance with the floodplain management ordinance or law adopted by the community.

A building can be raised above the BFE by placing it on a crawlspace or compacted fill, or by elevating it on piles or piers. The elevation method used is dependent on the condition of the structure, the source of flood hazard putting the building at risk, local floodplain regulations, and the owner's financial resources. By raising a building so its lowest habitable floor is above the BFE, not only is this structure protected from floodwaters, but the owner can add parking and (limited) storage space beneath the building.

FEMA has approved three techniques for elevating buildings. Property owners may extend the walls of the building upward and raise the lowest habitable floor; convert the existing lower area of the house to non-habitable space and build a new second story for living space; or lift the entire house (with the floor slab attached) and build a new, elevated foundation for the building.

When elevating, it is essential for all utilities (air conditioner, water heater, furnace, etc.) to be elevated at or above the BFE. After a building is elevated, the need to move vulnerable contents to areas above the water level during flooding is eliminated, except where a lower floor is used for storage.

By covering the costs for demolition and debris removal of lost buildings insured by the NFIP, FEMA allows residents to move permanently out of harm's way. Buyout and demolition is voluntary, and the homeowner receives the fair market value of the home before the disaster struck. Under a FEMA buyout agreement, the structure is removed and the city maintains the land as open space. In many cases, after the acquired building has been demolished, the land has been flooded again.

Floodproofing may be a preferred alternative for some structures where flooding depths are three feet or less or where the structures can be elevated above the BFE. Floodproofing is primarily for non-residential structures and not all structures can be practically floodproofed. In addition, the bridges subject to flooding remain as hazards during floods. Thus, floodproofing has some benefit for select structures but overall, it does not mitigate flooding to the extent desired for protection of the public.

6.7 Channel Modifications

6.7.1 LaNana Creek

A review of flooding patterns and associated damages indicate that the reach of LaNana Creek from Norma Street to the confluence of LaNana Creek and Banita Creek is where a significant portion of flood damages can occur. In addition, the reach of Banita Creek from Austin Street to the confluence of Banita Creek and LaNana Creek is where significant flood damages can occur. Thus, channel modification to convey floodwaters and reduce flood damages was investigated for these reaches.

Channel Modifications for the 100-year, 25-year and 10-year events were investigated to assist in comparing the cost of improvements to benefits. Table 6.4 presents the proposed channel improvements for the 100-year design event while Table 6.5 presents the same information for the 25-year design event and Table 6.6 presents the information for the 10-year design event.

TABLE 6.4 PROPOSED LANANA CREEK CHANNEL MODIFICATIONS – 100-YEAR FUTURE DESIGN FLOWS					
REACH	Design Flow, cfs	Bottom Width, Feet	Side Slopes, Horizontal: Vertical	Approximate Depth of Channel, Feet	Reach Length, Feet
Norma Street to College Street	11,400	140	3:1	10	8,585
College Street to 300 Feet Upstream of East Main Street	14,600	200	3:1	10	8,761
From 300 Feet Upstream of East Main Street to 300 Feet Downstream of East Main Street	14,600	70	3:1	15	600
From 300 Feet Downstream of East Main Street to Confluence of LaNana and Banita Creeks	14,600	200	3:1	15	3,072

TABLE 6.5 PROPOSED LANANA CREEK CHANNEL MODIFICATIONS – 25-YEAR FUTURE DESIGN FLOWS					
REACH	Design Flow, cfs	Bottom Width, Feet	Side Slopes, Horizontal: Vertical	Approximate Depth of Channel, Feet	Reach Length, Feet
Norma Street to College Street	8,500	120	3:1	8	8,585
College Street to 300 Feet Upstream of East Main Street	11,700	160	3:1	10	8,761
From 300 Feet Upstream of East Main Street to 300 Feet Downstream of East Main Street	11,700	90	3:1	12	600
From 300 Feet Downstream of East Main Street to Confluence of LaNana and Banita Creeks	11,700	200	3:1	8	3,072

TABLE 6.6 PROPOSED LANANA CREEK CHANNEL MODIFICATIONS – 10-YEAR FUTURE DESIGN FLOWS					
REACH	Design Flow, cfs	Bottom Width, Feet	Side Slopes, Horizontal: Vertical	Approximate Depth of Channel, Feet	Reach Length, Feet
Norma Street to College Street	7,400	130	3:1	7	8,585
College Street to 300 Feet Upstream of East Main Street	10,200	180	3:1	8	8,761
From 300 Feet Upstream of East Main Street to 300 Feet Downstream of East Main Street	10,200	95	3:1	11	600
From 300 Feet Downstream of East Main Street to Confluence of LaNana and Banita Creeks	10,200	200	3:1	7	3,072

The Engineer's Opinion of Probable Construction Cost for the improvements to the LaNana Creek Channel for each return period is presented in detail in Appendix A (A-3, A-4, A-5) and are summarized as follows:

LaNana Creek 100-Year Design Event – $22,110,000
LaNana Creek 25-Year Design Event – $19,866,000
LaNana Creek 10-Year Design Event - $17,970,000

In addition to the channel improvements, bridge modifications will be needed to pass the flood flows safely. Table 6.7 lists the proposed bridge improvements and the estimated cost to make the improvements is $16,821,400 (Appendix A-6).

TABLE 6.7
PROPOSED LANANA CREEK BRIDGE IMPROVEMENTS

BRIDGE	NEW BRIDGE LENGTH, FEET
Austin Street	175
College Street	160
Starr	220
Martinsville	220
Park Street	220
Main Street	370
MLK Jr.	770

LaNana Creek downstream of its confluence with Banita Creek will not be improved but will be proactively managed to prevent new structures from being constructed in the floodplain and to remove existing structures when possible.

6.7.2 Banita Creek

Investigations completed as part of the study determined that the preferred flood mitigation alternative for Banita Creek would consist of channel modifications through the densely developed portions of Banita Creek and modifications to bridges.

Starting at Austin Street, the Banita Creek channel will be modified downstream to the confluence of Banita Creek and LaNana Creek. Table 6.8 contains data on the proposed channel modifications for Banita Creek.

TABLE 6.8
PROPOSED BANITA CREEK CHANNEL MODIFICATIONS – 100-YEAR FUTURE DESIGN FLOWS

REACH	Design Flow, cfs	Bottom Width, Feet	Side Slopes, Horizontal: Vertical	Approximate Depth of Channel, Feet	Reach Length, Feet
Austin Street to 1,400’ North of Powers Street	7,000	90	3:1	8	8,083
1,400’ South of Powers Street to MLK, Jr. Street	8,600	80	3:1	9	8,357
MLK Jr. Street to Confluence with LaNana Creek	9,200	140	3:1	11	1,825

TABLE 6.9
PROPOSED BANITA CREEK CHANNEL MODIFICATIONS – 25-YEAR FUTURE DESIGN FLOWS

REACH	Design Flow, cfs	Bottom Width, Feet	Side Slopes, Horizontal: Vertical	Approximate Depth of Channel, Feet	Reach Length, Feet
Austin Street to 1,400’ North of Powers Street	5,100	95	3:1	7	8,083
1,400’ South of Powers Street to MLK, Jr. Street	6,200	100	3:1	7	8,357
MLK Jr. Street to Confluence with LaNana Creek	6,700	140	3:1	10	1,825

TABLE 6.10
PROPOSED BANITA CREEK CHANNEL MODIFICATIONS – 10-YEAR FUTURE DESIGN FLOWS

REACH	Design Flow, cfs	Bottom Width, Feet	Side Slopes, Horizontal: Vertical	Approximate Depth of Channel, Feet	Reach Length, Feet
Austin Street to 1,400' North of Powers Street	4,100	100	3:1	6	8,083
1,400' South of Powers Street to MLK, Jr. Street	5,000	100	3:1	6	8,357
MLK Jr. Street to Confluence with LaNana Creek	5,400	150	3:1	8	1,825

The Engineer's Opinion of Probable Construction Cost for the improvements to the Banita Creek Channel for each return period is presented in detail in Appendix A (A-7, A-8, A-9) and are summarized as follows:

Banita Creek 100-Year Design Event – $8,374,000
Banita Creek 25-Year Design Event – $8,270,000
Banita Creek 10-Year Design Event - $8,321,000

In addition to the channel improvements, bridge modifications will be needed to pass the flood flows safely. Table 6.11 lists the proposed bridge improvements and the estimated cost to make the improvements is $38,004,000 (Appendix A-10).

TABLE 6.11
PROPOSED BANITA CREEK BRIDGE IMPROVEMENTS

BRIDGE	NEW BRIDGE LENGTH, FEET
Powers Street	420
East Main	900
Pilar Street	145
South Street	1150
South Pecan	1200
Fredonia	1155
Church Street	680

6.8 Floodwater Retarding Structures

6.8.1 LaNana Creek

Installation of Floodwater Retarding Structures (FWRS) in the LaNana Creek Watershed upstream of the City of Nacogdoches was investigated as a measure to mitigate flooding in the City of Nacogdoches. Four FWRS structures were incrementally added and the flood reduction impact of each added structure was measured (Exhibit 5). Existing site conflicts (roads, railroads, structures) prevented placing of one large structure on LaNana Creek to control flooding immediately above the City.

Table 6.12 presents data regarding the floodwater retarding structures and the cost estimates are detailed in Appendix A. In evaluating the structures, it should be remembered that FWRS 1 or 2 could be built without FWRS 3 and 4, but FRWS 3 is not recommended to be built without FWRS 1 and 2. In addition, FRWS 4 is not recommended to be built without FWRS 1, 2 and 3 in place.

TABLE 6.12
FLOODWATER RETARDING STRUCTURE DATA – CAPTURE 100-YEAR RUNOFF

STRUCTURE NUMBER	Drainage Area, Square Miles	Top of Dam Elevation, Feet	Overflow Spillway Crest Elevation, Feet	Floodwater Storage, Acre-Feet	Maximum Low Flow Outlet Discharge, cfs	Area at Top of Dam, Acres	Overflow Spillway Width, Feet	Engineer's Opinion of Probable Construction Cost
1	4.64	398	392	1,850	50.5	215	500	$13,105,000
2	4.59	402	394	1,825	61.3	183	500	$10,744,000
3	20.73	352	341	8,815	412	610	500	$31,758,000
4	25.82	828	318	2,715	3,272	180	500	$11,550,000

The total estimated cost for the four FWRS is estimated as $67,157,000. The individual cost estimates are in Appendix A-11, A-12, A-13 and A-14.

6.9 Combination of Floodwater Retarding Structures, Channel Modifications and Intensive Floodplain Management

The long, relatively narrow watersheds of LaNana and Banita Creeks impact how flooding can be structurally mitigated within the City of Nacogdoches. Appendix B illustrates the hydrograph for the 100-year, 24-hour rainfall flood event on LaNana Creek just above its confluence with Banita Creek. As shown on the hydrograph, the peak runoff rate is reached in about three hours after runoff starts to increase but the flow recedes slowly with flooding still occurring for over 12 hours after the peak is reached. This pattern is indicative of a long narrow watershed where runoff is delivered to the creek and passed through the system over a relatively long period of time. This indicates that a single flood control measure will probably not mitigate all flooding.

6.9.1 LaNana Creek

An alternative investigated as part of the study combined the four FWRS for LaNana Creek with the channel modifications through the densely developed portions of LaNana Creek and Intensive Floodplain Management on the lower portion of the watershed.

Exhibits 5 and 6 illustrate the location of each element of the flood mitigation plan and the modified floodplains resulting from implementation of the plan.

Based on the results of the investigations, it was found that the FWRS do not materially reduce the need for channel modifications to achieve the desired protection against flooding. Thus, the FWRS and channel modifications are not as cost effective as the channel modifications alone.

6.9.2 Banita Creek

An alternative investigated as part of the study was to locate a site or sites for FWRS in the Banita Creek Watershed. However, sites could not be found that would materially reduce the peak flows downstream of the dam and thus no FWRS were studied in detail in the Banita Creek Watershed.

6.10 Tunnels

One method to reduce flooding is to capture floodwaters upstream of the City and bypass the developed portions of the City and release the floodwaters downstream past the developed City.

Using this concept, tunnels were designed to capture flows from Banita Creek and LaNana Creek just upstream of Loop 224 on the north side of the City and release the stormwater downstream of Loop 224 on the south side of the City. Table 6.1 illustrates the flows that would be experienced in the channels with the tunnels in place.

The design flow (100-year, 24-hour rainfall, future development conditions) for the LaNana Creek Tunnel would be 14,800 cfs and for Banita Creek the tunnel would convey 5,200 cfs. Each tunnel would be approximately 28,000 feet long and include an upstream inlet and vertical flow shaft and a downstream vertical flow shaft and outlet structure. The tunnel for LaNana Creek would be 30 feet in diameter and the tunnel for Banita would be 20 feet in diameter.

The runoff occurring downstream of each tunnel inlet would need to conveyed through the existing creek channels. Table 6.1 shows the remaining flows in the channels.

Appendix A-1 and A-2 present the Opinion of Probable Construction Cost (OPCC) prepared for each tunnel and these are $234 million for the Banita Tunnel and $365 million for the LaNana Tunnel. These costs total over $600 million and exceed the property value to be protected by over 20 times and thus this alternative was dismissed from further consideration.

6.11 Benefits

The cost of any proposed improvements need to be evaluated with respect to any benefits that would be gained by the proposed improvements. For purposes of evaluating the cost-effectiveness of the proposed improvements, the number of structures and acreage removed from the floodplain by each alternative were determined.

Estimates were made of the annual damage to structures prevented by removing the structures from the floodplain and added to the annual ad-valorem taxes generated by new development on recovered land in the floodplain to estimate annual benefits that might be generated by the proposed improvements. The cost of bridge modifications were excluded for the cost because their primary benefit is to reduce the possibility of loss of life from water flowing over bridges and to increase mobility during flood events.

6.11.1 LaNana Creek

Table 6.13 below presents a summary of the structures removed from the floodplain and area recovered from the floodplain by the alternatives considered for structural improvements.

TABLE 6.13
BENEFITS PROVIDED BY ALTERNATIVES ON LANANA CREEK (100-YEAR FUTURE CONDITIONS)

ALTERNATIVE	Structures Remaining in Floodplain	Structures Removed From 100-Year Floodplain	Area Remaining in 100-Year Floodplain, Acres	Area Removed from 100-Year Floodplain, Acres	Estimated Annual Cost of Improvements, Million $ [1]	Estimated Annual Benefits , Million $ [2]	Benefit/Cost Ratio	Engineer's Opinion of Probable Project Cost for Improvements Named [3]
DO NOTHING (ALTERNATIVE 1)	57	0	710	0	0	0	-	$0
CHANNEL MODIFICATIONS (ALTERNATIVE 6)	20	37	415	195	1.128	1.364	1.2	$22,110,000
CHANNEL MODIFICATIONS AND FWRS 1 (ALTERNATIVE 6 & 7)	18	39	410	300	1.800	1.428	0.8	$35,215,000
CHANNEL MODIFICATIONS AND FWRS 1 and 2 (ALTERNATIVE 6 & 7)	17	40	400	310	2.326	1.456	0.6	$45,959,000
CHANNEL MODIFICATIONS AND FWRS 1, 2 and 3 (ALTERNATIVE 6 & 7)	18	39	400	310	3.965	1.436	0.4	$77,717,000
CHANNEL MODIFICATIONS AND FWRS 1, 2, 3 and 4 (ALTERNATIVE 6 & 7)	16	41	400	310	4.554	1.496	0.3	$89,267,000

[1] – Based on Cost Amortized for 30 Years at 3% Interest
[2] – Based on Damage Prevented to Structures Plus New Ad-Valorem Taxes
[3] – Does Not Include Cost of Bridges

The Benefit Cost Ratios illustrated in Table 6.13 indicate that the channel modification alternative is the preferred alternative if the largest ratio is the selection criteria. The maximum annual benefit is with all FWRS in place and the channel modifications completed but the Benefit Cost Ratio is less than 1.0. Consideration was given to construction of channels providing protection of either the 10-year or 25-year recurrence intervals. Comparison of the project cost for these events compared to the 100-year event indicated that the benefits from the 100-year return period design event would yield the most return.

6.11.2 Banita Creek

Table 6.14 presents a summary of the structures removed from the floodplain and area recovered from the floodplain by the alternatives considered for structural improvements.

TABLE 6.14
BENEFITS PROVIDED BY ALTERNATIVES ON BANITA CREEK (100-YEAR FUTURE CONDITIONS)

ALTERNATIVE	Structures Remaining in Floodplain	Structures Removed From 100-Year Floodplain	Area Remaining in 100-Year Floodplain, Acres	Area Removed from 100-Year Floodplain, Acres	Estimated Annual Cost of Improvements, Million $ [1]	Estimated Annual Benefits, Million $ [2]	Benefit/Cost Ratio	Engineer's Opinion of Probable Project Cost for Improvements Named [3]
DO NOTHING (ALTERNATIVE 1)	153	0	490	0	0	0	-	$0
CHANNEL MODIFICATIONS (ALTERNATIVE 6)	97	56	340	150	0.427	0.902	2.1	$8,374,000

[1] – Based on Cost Amortized for 30 Years at 3% Interest
[2] – Based on Damage Prevented to Structures Plus New Ad-Valorem Taxes
[3] – Does Not Include Cost of Bridges

The Benefit Cost Ratios illustrated in Table 6.14 indicate that the channel modification alternative has a positive Benefit Cost Ratio.

Consideration was given to construction of channels providing protection of either the 10-year or 25-year recurrence intervals. Comparison of the project cost for these events compared to the 100-year event indicated that the benefits from the 100-year return period design event would yield the most return.

6.12 Phasing

The preferred alternative of channel modifications for LaNana and Banita Creeks has a total estimated project cost of $30,484,000 (not including bridge replacement cost). Capital investments of this size can be phased such that the impacts to tax rates are controlled and the needed improvements can be made over a reasonable period of time.

The following phasing is recommended to assist in investing funds to provide the greatest immediate return.

Phase 1 – Banita Creek (starting at LaNana Creek confluence) – 9,100 Linear Feet - $4,187,000

Phase 2 – Banita Creek (upper end to Austin Street) - 9,165 Linear Feet - $4,187,000

Phase 3 – LaNana Creek (starting at Banita Creek confluence) - 7,000 Linear Feet - $7,370,000

Phase 4 – LaNana Creek (middle reach) - 7,000 Linear Feet - $7,370,000

Phase 5 – LaNana Creek (Upper Reach to Norma Street) - 7,018 Linear Feet - $7,370,000

Bridge replacement cost will be in addition to the cost presented above.

The time interval between phases can be based on the long-term financing plan of the City, potential grants and securing of matching funds.

6.13 Context Sensitive and Sustainable Channel Design

Traditional channel modification projects have incorporated straight channels with linings to efficiently and effectively collect floodwater and pass it downstream. Channelization projects normally remove natural riparian habitat and change the natural character of the stream.

It is recommended that the design criteria for the proposed channels include natural channel design features. Natural sinuosity, pools and riffles, rock linings, stepped side slopes and parallel trails would be adopted. Sustainable design concepts would be used and sensitivity to the surrounding environment would be incorporated in designs.

SECTION 7

WATERSHED MANAGEMENT PLAN

The City of Nacogdoches existing drainage infrastructure is currently inadequate to pass the 100-year, 24-hour storm event safely. Major flooding causing property damage and endangerment to public health and safety will result from a storm event of this magnitude. In 1975, there was an estimated 30-year storm event that occurred in Nacogdoches County, causing an estimated $20,000,000 in damages.

The City of Nacogdoches adopted ordinance No. 1168-9-99 in 1999, which outlined drainage criteria for future development within the city limits. The criteria in this ordinance will help damper flooding problems cause by new development however it does nothing to alleviate the current flooding problems. In order to lessen the impact of current flood problems, the City will need to improve the existing drainage infrastructure throughout the city.

It is recommended that the City of Nacogdoches implement the alternative of constructing reservoirs, stream crossing improvements, and channel improvements proposed in this study.

For the City of Nacogdoches to implement a plan for drainage infrastructure improvements, the following steps and procedures should be taken:

1. Public Meeting.

   Before initiating a drainage project, one or more public meetings should be held to inform the public on the intent of the project. The meeting should provide an overview of the project, exhibits that are detailed enough for the public to have a clear understanding of the project, and an explanation as to what the project will accomplish. Public involvement should be encouraged and any comments and recommendations should be given due consideration.

2. Develop and implement drainage criteria for current and future development.

   The City of Nacogdoches adopted a drainage criteria ordinance in 1999, which does a sufficient job of limiting the flood impact of future development. The ordinance requires any construction involving 14,000 square feet to provide onsite detention for the 25-year storm event.

3. Coordinate planned improvements with private and governmental agencies that have jurisdiction within the watershed. Joint-Ventures may be arranged. The following are agencies within the flood plain:

    - Nacogdoches County
    - City of Appleby
    - Texas Department of Transportation
    - Southern Pacific Railroad

4. Funding.

    Everett Griffith and Associates prepared a report, “Evaluation of the Feasibility to Establish a Municipal Utility System for Nacogdoches, Texas” in 1995. This report provides detailed analysis of the financial considerations for improvement and proposes a detailed plan and rate structure that will support proposed improvements. Since the improvements recommended in this study are similar to the recommendation in the 1995 study, the above mentioned report can be utilized with adjustments due to inflation.

5. Phased Improvement Plan.

    - Construct Regional detention ponds
    - Construct improvements to Major Stream Crossings
    - Construct channel improvements
    - Construct improvements to minor stream crossings
    - Improvements to internal storm sewer system

TABLE 1

PEAK FLOW RATES

City of Nacogdoches
Flood Control Study

Table - Peak Flow Rates

LaNana Creek

Location	River Station	A	B	C	D	E	F	G
Eggnog Creek	0.6	21830		24280	13463	22042	22259	21050
Loop 224 (S)	1	19500		22960	14462	21881	22092	20605
Trib A	6	18480		22630	14731	21838	22048	20507
Banita Creek	7	16800		17500	11962	17857	18012	21124
Butt St.	9	16300		16990	9550	14463	14572	12385
RailRoad Bridge	16	15800		16800	8735	13337	13430	12275
Main St.	21	15300		16600	8513	13225	13323	12011
Park St.	26	14940		16540	8254	13096	13198	11704
Martinsville St.	30	14920		16510	8022	12980	13085	11428
Starr	35	14900		16480	7751	12845	12954	11106
College	40	14840		16400	7636	12692	12794	6429
Austin	45	14200		15840	7595	12325	12390	5012
Loop 224 (N)	51	12430		15430	9113	14254	14270	1676

*Catergory Description

A. Values obtained from FEMA Report
B. S&P HEC-2 model using FEMA based flow rates
C. S&P HEC-2 model using present 100 yr - 24 hr storm
D. Current HEC-RAS model values using present 100 yr - 6 hr storm
E. Current HEC-RAS model values using present 100 yr - 24 hr storm
F. Current HEC-RAS model values using future 100 yr - 24 hr storm
G. Curent HEC-RAS model values using proposed 100 yr - 24 hr storm

Banita Creek

Location	River Station	A	B	C	D	E	F	G
LaNana	1	7880		8330	6185	9091	9179	9179
Butt	4	7780		8230	6185	9091	9179	9179
RailRoad Bridge	7	7340		8230	5731	8470	8553	8553
Church	15	9300		8230	5693	8438	8517	8517
Fredonia	17	9290		8230	5682	8429	8506	8506
Pecan	20	9280		8230	5674	8423	8499	8499
North	24	8800		8230	5659	8410	8484	8484
Pilar	28	8800		8200	5625	8382	8452	8452
Main	33	8800		8100	5613	8372	8440	8440
Powers	39	8300		8000	5553	8322	8384	8384
Tib C	41	7900		7910	4631	6967	7009	7009
Trib G	44	6400		7380	4505	7212	7261	7261
Loop 224	47	5880		6900	3288	4929	4946	4946

Eggnog Branch

Location	River Station	A	B	C	D	E	F	G
LaNana	21	3500		3890	1618	2789	2802	2802
Hwy 1275	21.1	3240		3600	1247	2152	2162	2162
Loop 224	21.2	2380		2650	931	1608	1615	1615
Hwy 2259	21.3	1800		2000	771	1334	1341	1341
Eastwood Terrace	21.4	1800		2000	744	1287	1294	1294
Hwy 21	21.5	770		850	457	793	797	797
Stallings	21.6	190		200	236	414	417	417

Tributary A

Location	River Station	A	B	C	D	E	F	G
LaNana	19	3060		3130	2394	3240	3276	3276
RailRoad Bridge	19.1	3025		3000	2231	3063	3099	3099
Press Rd.	19.2	3015		3000	2198	3028	3064	3064
Park Ent.	19.5	2690		2470	1788	2582	2618	2618
North St.	19.6	2510		2220	1532	2304	2340	2340
Fredonia	19.8	2220		1630	1143	1881	1918	1918

Tributary B

Location	River Station	A	B	C	D	E	F	G
Banita	16	2800		1870	1508	2235	2264	2264
Pk. Lot	16.1	2800		1870	1455	2161	2189	2189
Fredonia	16.2	2800		1790	1275	1910	1935	1935
RailRoad Bridge	16.3	2800		1790	1225	1841	1865	1865
South	16.4	2800		1700	1150	1737	1760	1760
Virginia	16.41	2800		1700	1112	1684	1706	1706
Sunset	16.5	2780		1420	913	1407	1426	1426
Burk	16.6	2500		1420	839	1303	1321	1321
Durst	16.7	1800		930	545	894	907	907
Perry	16.8	1200		650	334	601	610	610

Tributary C

Location	River Station	A	B	C	D	E	F	G
Banita	14	3200		2070	1757	2645	2700	2700
RailRoad Bridge	14.1	3200		2070	1699	2559	2614	2614
Old Tyler Road	14.2	3020		2010	1652	2487	2541	2541
Dam	14.26	2590		1700	1390	2095	2145	2145

Tributary D

Location	River Station	A	B	C	D	E	F	G
University Drive	9	3930		4400	1538	4185	4228	4228
FM 1411	9.1	2990		4200	1330	3617	3653	3653
FM 1878	9.2	2880		3940	1033	2803	2831	2831
Loop 224	9.5	600		340	69	164	164	164

Tributary E

Location	River Station	A	B	C	D	E	F	G
LaNana	7			3100	3384	5063	5083	5083
Loveless Rd.	7.1			2360	2184	3071	3086	3086

Tributary G

Location	River Station	A	B	C	D	E	F	G
Banita	12.1			2350	1548	2444	2462	2462
Stallings	12.3			1410	1105	1713	1733	1733

TABLE 2

WATER SURFACE ELEVATIONS

City of Nacogdoches
Flood Control Study

Table - Water Surface Elevations

<u>LaNana Creek</u>

Location	River Station	Top of Crossing	A	B	C	D	E	F	G
Loop 224 (S)	2.5	262.37				258.98 259.70	260.16 262.41	260.2 262.48	260.18 262.36
Trib A	6	-				261.89	263.82	263.89	263.32
Banita Creek	7	-				262.66	264.43	264.5	263.68
Butt St.	9.5	266.07				264.92 266.21	266.29 267.63	266.33 267.65	263.07 263.07
RailRoad Bridge	15.5	278.07				267.57 267.57	269.4 269.4	269.43 269.43	265.01 265.01
Main St.	20.5	270.77				272.61 272.61	273.88 273.88	273.91 273.91	265.97 266.48
Park St.	25.5	276.97				277.97 278.17	279.33 279.98	279.36 280.01	268.77 268.77
Martinsville St.	30.5	282.57				280.10 280.10	283.14 283.93	283.19 283.98	272.07 272.07
Starr	35.5	280.77				283.39 283.39	285.26 285.24	285.31 285.28	276.24 276.24
College	40.5	291.57				287.88 287.88	289.67 289.67	289.67 289.67	279.31 279.31
Austin	45.5	299.67				293.84 293.84	296.45 296.77	296.5 296.77	285.89 285.89
Loop 224 (N)	51.5	300.87				311.64 312.40	315.95 316.02	315.94 316.02	316.9 316.91

*Catergory Description

A. Values obtained from FEMA Report
B. S&P HEC-2 model using FEMA based flow rates
C. S&P HEC-2 model using present 100 yr - 24 hr storm
D. Current HEC-RAS model values using present 100 yr - 6 hr storm
E. Current HEC-RAS model values using present 100 yr - 24 hr storm
F. Current HEC-RAS model values using future 100 yr - 24 hr storm
G. Curent HEC-RAS model values using proposed 100 yr - 24 hr storm

Banita Creek

Location	River Station	Top of Crossing	A	B	C	D	E	F	G
LaNana	1	-				263.9	263.9	263.9	263.9
Butt	3.5	266.17				267.03 267.08	267.95 268	267.99 268.04	264.59 264.43
RailRoad Bridge	8.5	274.77				268.91 268.91	270.28 270.28	270.33 270.33	266.13 266.13
Church	13.5	272.87				270.47 271.00	271.66 271.66	271.66 271.66	270.44 270.48
Fredonia	17.5	272.17				273.74 274.24	274.37 274.71	274.39 274.75	272.35 273.92
Pecan	20.5	273.57				273.10 273.10	275.68 275.91	275.7 275.94	274.42 274.64
North	23.5	276.67				275.60 275.60	276.72 277.42	276.76 277.45	275.54 275.60
Pilar	28.5	277.47				279.42 279.66	280.25 280.12	280.27 280.14	279.60 279.63
Main	32.5	278.37				279.64 281.36	280.95 282.6	280.98 282.63	280.23 282.34
Powers	37.5	284.57				287.24 287.97	288.06 288.87	288.08 288.9	287.70 288.70
Tib C	41	-				292.57	293.43	293.44	290.58
Trib G	44	-				331.42	332.33	332.36	332.57
Loop 224	46.5	382.47				351.98 351.98	353.5 353.39	353.51 353.4	353.81 353.70

Eggnog Branch

Location	River Station	Top of Crossing	A	B	C	D	E	F	G
LaNana	21	-				243.14	243.8	244.14	244.14
Hwy 1275	21.1	265.47				267.56 267.19	268.17 267.41	268.50 267.75	268.50 267.75
Loop 224	21.2	301.97				290.02 290.84	292.43 296.84	292.78 296.65	292.78 296.65
Hwy 2259	21.3	310.07				310.35 310.95	313.27 312.82	313.64 313.18	313.64 313.18
Eastwood Terrace	21.4	313.27				311.05 312.88	313.18 313.87	313.54 314.18	313.54 314.18

Hwy 21	21.5	346.77				343.58 344.28	349.27 349.47	349.65 349.84	349.65 349.84
Stallings	21.6	393.57				378.69 381.73	378.7 386.69	379.03 387.14	379.03 387.14

Tributary A

Location	River Station	Top of Crossing	A	B	C	D	E	F	G
LaNana	19	-				259.19	259.39	259.73	259.73
RailRoad Bridge	19.1	260.67				264.17 263.04	265.37 263.71	265.79 264.11	265.79 264.11
Press Rd.	19.2	260.67				264.82 266.34	265.96 268.16	266.35 268.56	266.35 268.56
Park Ent.	19.5	275.37				270.39 270.69	275.67 275.67	276.04 276.04	276.04 276.04
South St.	19.6	288.67				281.56 283.45	281.33 285.94	281.71 286.48	281.71 286.48
South St.	19.61	288.67				283.42 289.51	285.97 289.43	286.51 289.75	286.51 289.75
Fredonia	19.8	307.07				305.57 308.51	306.56 309.94	306.93 310.42	306.93 310.42

Tributary B

Location	River Station	Top of Crossing	A	B	C	D	E	F	G
Banita	16	-				264.02	265.95	266.33	266.33
Pk. Lot	16.1	266.07				266.43 266.50	267.46 267.33	267.84 267.69	267.84 267.69
Fredonia	16.2	271.57				273.55 273.96	273.81 274.56	274.14 274.92	274.14 274.92
RailRoad Bridge	16.3	276.07				273.40 273.40	276.2 276.2	276.55 276.55	276.55 276.55
South	16.4	281.37				279.22 280.20	282.04 282.04	282.43 282.43	282.43 282.43
Virginia	16.41	281.37				283.18 284.08	283.85 284.94	284.22 285.32	284.22 285.32
Sunset	16.5	294.77				296.27 296.27	297.57 297.72	298.20 298.39	298.20 298.39
Burk	16.6	298.47				299.16 299.16	300.61 301.27	301.07 301.65	301.07 301.65

Durst	16.7	332.27				332.25 331.90	332.8 333.74	333.16 334.21	333.16 334.21
Perry	16.8	348.67				347.09 348.76	348.25 350.28	349.78 350.64	349.78 350.64

Tributary C

Location	River Station	Top of Crossing	A	B	C	D	E	F	G
Banita	14	-				291.45	291.73	292.09	292.09
RailRoad Bridge	14.1	293.37				294.27 294.27	294.56 294.52	294.93 294.88	294.93 294.88
Old Tyler Road	14.2	296.37				298.25 299.70	299.29 300.78	299.70 301.19	299.70 301.19
Dam	14.26	-				327.44	329.26	328.07	328.07

Tributary D

Location	River Station	Top of Crossing	A	B	C	D	E	F	G
University Drive	9	287.97				287.33 288.06	286.04 289.57	286.41 289.90	286.41 289.90
FM 1411	9.1	298.17				295.13 298.22	295.85 299.04	296.21 299.39	296.21 299.39
FM 1878	9.2	305.47				306.11 307.96	307.96 309.44	308.31 309.82	308.31 309.82
Loop 224	9.5	392.47				386.43 387.08	386.82 387.41	387.15 387.74	387.15 387.74

Tributary E

Location	River Station	Top of Crossing	A	B	C	D	E	F	G
LaNana	7	-				313.77	314.02	314.36	314.36
Loveless Rd.	7.1	354.87				351.64 352.20	351.87 351.87	352.20 352.20	352.20 352.20

Tributary G

Location	River Station	Top of Crossing	A	B	C	D	E	F	G
Banita	12.1	-				333.99	334.6	334.94	334.94
Stallings	12.3	379.97				372.66 376.99	373.88 379.81	374.25 380.14	374.25 380.14

TABLE 3

CN CALCULATIONS

CITY OF NACOGDOCHES
NACOGDOCHES FLOOD STUDY
KLOTZ PROJECT NO.: 0836.004.000
CURVE NUMBER CALCULATIONS

Sub_A	Total Area =	9.7863 mi.2
	Impervious Area =	0.4020 mi.2
	Impervious CN=	100
	Pervious CN=	76.09
	Fraction of Pervious Cover=	0.9589
	Fraction of Impervious Cover=	0.0411
	Weighted Pervious CN=	72.9648
	Weighted Impervious CN=	4.1078
	Total CN =	77
Sub_B	Total Area =	7.1431 mi.2
	Impervious Area =	0.2510 mi.2
	Impervious CN=	100
	Pervious CN=	77.30
	Fraction of Pervious Cover=	0.9649
	Fraction of Impervious Cover=	0.0351
	Weighted Pervious CN=	74.59
	Weighted Impervious CN=	3.5139
	Total CN =	78
Sub_C	Total Area =	3.8227 mi.2
	Impervious Area =	0.0830 mi.2
	Impervious CN=	100
	Pervious CN=	77.67
	Fraction of Pervious Cover=	0.9783
	Fraction of Impervious Cover=	0.0217
	Weighted Pervious CN=	75.98
	Weighted Impervious CN=	2.1712
	Total CN =	78
Sub_D	Total Area =	1.8231 mi.2
	Impervious Area =	0.1600 mi.2
	Impervious CN=	100
	Pervious CN=	75.25
	Fraction of Pervious Cover=	0.9122
	Fraction of Impervious Cover=	0.0878
	Weighted Pervious CN=	68.64
	Weighted Impervious CN=	8.7763
	Total CN =	77

CITY OF NACOGDOCHES
NACOGDOCHES FLOOD STUDY
KLOTZ PROJECT NO.: 0836.004.000
CURVE NUMBER CALCULATIONS

Sub_D1	Total Area =	1.2234	mi.2
	Impervious Area =	0.0940	mi.2
	Impervious CN=	100	
	Pervious CN=	76.70	
	Fraction of Pervious Cover=	0.9232	
	Fraction of Impervious Cover=	0.0768	
	Weighted Pervious CN=	70.81	
	Weighted Impervious CN=	7.68	
	Total CN =	78	
Sub_E	Total Area =	2.2833	mi.2
	Impervious Area =	0.4614	mi.2
	Impervious CN=	100	
	Pervious CN=	71.71	
	Fraction of Pervious Cover=	0.80	
	Fraction of Impervious Cover=	0.2021	
	Weighted Pervious CN=	57.22	
	Weighted Impervious CN=	20.21	
	Total CN =	77	
Sub_E1	Total Area =	1.9400	mi.2
	Impervious Area =	0.2069	mi.2
	Impervious CN=	100	
	Pervious CN=	72.62	
	Fraction of Pervious Cover=	0.89	
	Fraction of Impervious Cover=	0.1066	
	Weighted Pervious CN=	64.88	
	Weighted Impervious CN=	10.66	
	Total CN =	76	
Sub_F	Total Area =	2.8159	mi.2
	Impervious Area =	0.1751	mi.2
	Impervious CN=	100	
	Pervious CN=	61.00	
	Fraction of Pervious Cover=	0.9400	
	Fraction of Impervious Cover=	0.0622	
	Weighted Pervious CN=	57.31	
	Weighted Impervious CN=	6.22	
	Total CN =	64	
Sub_F1	Total Area =	0.0757	mi.2
	Impervious Area =	0.0010	mi.2

CITY OF NACOGDOCHES
NACOGDOCHES FLOOD STUDY
KLOTZ PROJECT NO.: 0836.004.000
CURVE NUMBER CALCULATIONS

Impervious CN=	100
Pervious CN=	69.00
Fraction of Pervious Cover=	0.9900
Fraction of Impervious Cover=	0.0132
Weighted Pervious CN=	68.43
Weighted Impervious CN=	1.32
Total CN =	70

Sub_G	Total Area =	2.4954	mi.2
	Impervious Area =	0.5280	mi.2
	Impervious CN=	100	
	Pervious CN=	71.24	
	Fraction of Pervious Cover=	0.7884	
	Fraction of Impervious Cover=	0.2116	
	Weighted Pervious CN=	56.17	
	Weighted Impervious CN=	21.16	
	Total CN =	77	
Sub_H	Total Area =	0.8226	mi.2
	Impervious Area =	0.1490	mi.2
	Impervious CN=	100	
	Pervious CN=	60.99	
	Fraction of Pervious Cover=	0.82	
	Fraction of Impervious Cover=	0.1811	
	Weighted Pervious CN=	49.94	
	Weighted Impervious CN=	18.11	
	Total CN =	68	
Sub_I	Total Area =	2.6896	mi.2
	Impervious Area =	0.1530	mi.2
	Impervious CN=	100	
	Pervious CN=	60.38	
	Fraction of Pervious Cover=	0.94	
	Fraction of Impervious Cover=	0.0569	
	Weighted Pervious CN=	56.94	
	Weighted Impervious CN=	5.69	
	Total CN =	63	
Sub_I1	Total Area =	0.3036	mi.2
	Impervious Area =	0.0230	mi.2
	Impervious CN=	100	
	Pervious CN=	58.45	
	Fraction of Pervious Cover=	0.92	
	Fraction of Impervious Cover=	0.0758	
	Weighted Pervious CN=	54.03	
	Weighted Impervious CN=	7.58	
	Total CN =	62	

CITY OF NACOGDOCHES
NACOGDOCHES FLOOD STUDY
KLOTZ PROJECT NO.: 0836.004.000
CURVE NUMBER CALCULATIONS

Sub_J	Total Area =	4.2163	mi.2
	Impervious Area =	0.2460	mi.2
	Impervious CN=	100	
	Pervious CN=	71.26	
	Fraction of Pervious Cover=	0.94	
	Fraction of Impervious Cover=	0.0583	
	Weighted Pervious CN=	67.10	
	Weighted Impervious CN=	5.83	
	Total CN =	73	
Sub_K	Total Area =	2.4189	mi.2
	Impervious Area =	0.2530	mi.2
	Impervious CN=	100	
	Pervious CN=	74.35	
	Fraction of Pervious Cover=	0.90	
	Fraction of Impervious Cover=	0.1046	
	Weighted Pervious CN=	66.57	
	Weighted Impervious CN=	10.46	
	Total CN =	77	
Sub_L	Total Area =	0.7883	mi.2
	Impervious Area =	0.0590	mi.2
	Impervious CN=	100	
	Pervious CN=	71.46	
	Fraction of Pervious Cover=	0.93	
	Fraction of Impervious Cover=	0.0748	
	Weighted Pervious CN=	66.12	
	Weighted Impervious CN=	7.48	
	Total CN =	74	
Sub_L1	Total Area =	1.0879	mi.2
	Impervious Area =	0.0870	mi.2
	Impervious CN=	100	
	Pervious CN=	68.93	
	Fraction of Pervious Cover=	0.92	
	Fraction of Impervious Cover=	0.0800	
	Weighted Pervious CN=	63.42	
	Weighted Impervious CN=	8.00	
	Total CN =	71	

Sub_M	Total Area =	2.0464 mi.2
	Impervious Area =	0.2390 mi.2
	Impervious CN=	100
	Pervious CN=	82.02
	Fraction of Pervious Cover=	0.88
	Fraction of Impervious Cover=	0.1168
	Weighted Pervious CN=	72.44
	Weighted Impervious CN=	11.68
	Total CN =	84
Sub_N	Total Area =	1.1341 mi.2
	Impervious Area =	0.1070 mi.2
	Impervious CN=	100
	Pervious CN=	70.18
	Fraction of Pervious Cover=	0.91
	Fraction of Impervious Cover=	0.0943
	Weighted Pervious CN=	63.56
	Weighted Impervious CN=	9.43
	Total CN =	73
Sub_N1	Total Area =	0.5886 mi.2
	Impervious Area =	0.1090 mi.2
	Impervious CN=	100
	Pervious CN=	67.34
	Fraction of Pervious Cover=	0.81
	Fraction of Impervious Cover=	0.1852
	Weighted Pervious CN=	54.87
	Weighted Impervious CN=	18.52
	Total CN =	73
Sub_O	Total Area =	1.0307 mi.2
	Impervious Area =	0.2560 mi.2
	Impervious CN=	100
	Pervious CN=	67.86
	Fraction of Pervious Cover=	0.75
	Fraction of Impervious Cover=	0.2484
	Weighted Pervious CN=	51.00
	Weighted Impervious CN=	24.84
	Total CN =	76

Sub_P	Total Area =	1.0684	mi.2
	Impervious Area =	0.1155	mi.2
	Impervious CN=	100	
	Pervious CN=	65.00	
	Fraction of Pervious Cover=	0.89	
	Fraction of Impervious Cover=	0.1081	
	Weighted Pervious CN=	58.36	
	Weighted Impervious CN=	10.81	
	Total CN =	69	
Sub_P1	Total Area =	0.3691	mi.2
	Impervious Area =	0.0515	mi.2
	Impervious CN=	100	
	Pervious CN=	56.00	
	Fraction of Pervious Cover=	0.86	
	Fraction of Impervious Cover=	0.1395	
	Weighted Pervious CN=	47.99	
	Weighted Impervious CN=	13.95	
	Total CN =	62	
Sub_Q	Total Area =	1.0538	mi.2
	Impervious Area =	0.1120	mi.2
	Impervious CN=	100	
	Pervious CN=	76.30	
	Fraction of Pervious Cover=	0.89	
	Fraction of Impervious Cover=	0.1063	
	Weighted Pervious CN=	67.76	
	Weighted Impervious CN=	10.63	
	Total CN =	78	
Sub_Q1	Total Area =	1.1029	mi.2
	Impervious Area =	0.1210	mi.2
	Impervious CN=	100	
	Pervious CN=	61.62	
	Fraction of Pervious Cover=	0.89	
	Fraction of Impervious Cover=	0.1097	
	Weighted Pervious CN=	54.86	
	Weighted Impervious CN=	10.97	
	Total CN =	66	

CITY OF NACOGDOCHES
NACOGDOCHES FLOOD STUDY
KLOTZ PROJECT NO.: 0836.004.000
CURVE NUMBER CALCULATIONS

Sub_R	Total Area =	2.7435 mi.2
	Impervious Area =	0.3230 mi.2
	Impervious CN=	100
	Pervious CN=	74.06
	Fraction of Pervious Cover=	0.88
	Fraction of Impervious Cover=	0.1177
	Weighted Pervious CN=	65.35
	Weighted Impervious CN=	11.77
	Total CN =	77
Sub_S	Total Area =	0.3530 mi.2
	Impervious Area =	0.0060 mi.2
	Impervious CN=	100
	Pervious CN=	66.47
	Fraction of Pervious Cover=	0.98
	Fraction of Impervious Cover=	0.0170
	Weighted Pervious CN=	65.34
	Weighted Impervious CN=	1.70
	Total CN =	67
Sub_T	Total Area =	2.5436 mi.2
	Impervious Area =	0.0960 mi.2
	Impervious CN=	100
	Pervious CN=	70.93
	Fraction of Pervious Cover=	0.96
	Fraction of Impervious Cover=	0.0377
	Weighted Pervious CN=	68.26
	Weighted Impervious CN=	3.77
	Total CN =	72

TABLE 4

RUN-OFF AND FLOW COEFFICIENTS

RUNOFF COEFFICIENTS

DESCRIPTION	COEFFICIENT
Paved Areas	0.95
Shopping Centers	0.90
Business Centers	0.80
Industrial Areas	0.85
Residential Areas:	
Less than 2 lot per acre	0.40
Greater than 2 lots per acre but less than 4 lots per acre	0.50
Greater than 4 lots per acre but less than 8 lots per acre	0.60
Greater than 8 lots per acre	0.75
Apartments	0.75
Parks and Open Space	0.30

Source: City of Nacogdoches Dainage Criteria Manual

PERVIOUS AREAS

SLOPE	SCS SOILS			
	A	B	C	D
0% - 2%	0.04	0.07	0.11	0.15
2% - 6%	0.09	0.12	0.16	0.20
OVER 6%	0.13	0.18	0.23	0.28

Manning's Roughness Coefficients

Channel Material	Manning's Coefficient N
Plastic (PVC and ABS)	0.009
Clean, uncoated cast iron	0.013 - 0.015
Clean coated cast iron	0.012 - 0.014
Dirty, tuberculated cast iron	0.015 - 0.035
Riveted steel	0.015 - 0.017
Lock-bar and welded steel pipe	0.012 - 0.013
Galvanized iron	0.015 - 0.017
Brass and glass	0.009 - 0.013
Wood stave	
Small Diameter	0.011 - 0.012
Large diameter	0.012 - 0.013
Concrete	
Average value used	0.013
Typical commercial, ball and spigot rubber gasketed end connections	
Full (pressurized and wet)	0.01
Partial full	0.0085
With rough joints	0.016 - 0.017
Dry mix, rough forms	0.015 - 0.016
Wet mix steel forms	0.012 - 0.014
Very smooth, finish	0.011 - 0.012
Vitrified sewer	0.013 - 0.015
Common-clay drainage tile	0.012 - 0.014
Asbestos	0.011
Planed timber (flume)	0.012 (0.010 - 0.014)
Canvas	0.012
Unplanned timber (flume)	0.013 (0.011 - 0.015)
Brick	0.016
Rubber masonry	0.017
Smooth earth	0.018
Firm Gravel	0.023
Corrugated metal pipe (CMP)	0.024
Natural channels, good condition	0.025
Rip rap	0.035
Natural channels with stones and weeds	0.035
Very poor natural channels	0.06
Cultivated soils	
Residue cover < or = 20%	0.06
Residue cover > 20%	0.17
Grasses	
Short prairie grass	0.15
Dense grass	0.24
Bermuda grass	0.41
Range, natual woods	
Light underbrush	0.4
Dense underbrush	0.8

Source: Civil Engineering Reference Manual, Ninth Edition, Michael R. Lindeburg, PE

Manning's Roughness Coefficients for Conduits

Description	Manning's "N" Value
Reinforced concrete pipe	0.013
Reinforced concrete box	0.013
Vitrified clay pipe	0.013
Coated cast iron pipe	0.011
Uncoated cast iron pipe	0.012
Commercial wrought-iron, black pipe	0.013
Commercial wrought-iron, galvanized pipe	0.014
Smooth lockbar and welded "OD" pipe	0.011
Riveted and spiral steel pipe	0.015
Corrugated metal pipe	0.0225
Corrugated aluminum pipe	0.0225
Corrugated metal pipe (paved invert)	0.02
Corrugated metal multi-plate pipe	0.035
Polyvinyl chloride (PVC) pipe	0.01

Entrance Loss Coefficiemnts Ke

Concrete pipe	Ce
Projecting from fill, socket end (groove end)	0.2
Projecting from fill, square cut end	0.5
Headwall or headwall and wingwalls:	
socket end of pipe (groove end)	0.2
Square-edge	0.5
Rounded (radius 1/12 D)	0.2
Mitered to conform to fill slope	0.7
End section conforming to fill slope	0.5
Beveled edges, 33.7°, or 45° bevels	0.2
Slide or slope-tapered inlet	0.2
Corrugated Metal Pipe or Pipe Arch	
Projecting from fill (no headwall)	0.9
Headwall or headwall and wingwalls square-edge	0.5
Mitered to conform to fill slope, paved or unpaved slope	0.7
End section conforming to fill slope	0.5
Beveled edges, 33.7°, or 45° bevels	0.2
Side or slope-tapered inlet	0.2
Reinforced Concrete Box	
Headwall parallel to embankment (no wingwalls):	
Square-edged on 3 edges	0.5
Rounded on 3 edges to radius of 1/12 barrel dimension, or beveled edges on 3 sides	0.2
Wingwalls at 30° to 75° to barrel:	
Square edged at crown	0.4
Crown edge rounded to radius of 1/12 barrel dimension, or beveled to edge	0.2
Wingwall at 10° to 25° to barrel:	
Square edged at crown	0.5
Wingalls parallel(extension of sides):	
Square edged at crown	0.7
Side or slope-tapered inlet	0.2

Source: Hydraulic Design Manual, Texas Department of Transportation, Revised March 2004

Soil Groups

Soil properties influence the relationship between rainfall and runoff by affecting the rate of infiltration. NRCS divides soils into four hydrologic soil groups based on infiltration rates (Groups A-D). Remember to consider effects of urbanization on soil groups as well.

Group A. Group A soils have a low runoff potential due to high infiltration rates even when saturated (0.30 in/hr to 0.45 in/hr or 7.6 mm/hr to 11.4 mm/hr). These soils primarily consist of deep sands, deep loess, and aggregated silts.

Group B. Group B soils have a moderately low runoff potential due to moderate infiltration rates when saturated (0.15 in/hr to 0.30 in/hr or 3.8 mm/hr to 7.6 mm/hr). These soils primarily consist of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures (shallow loess, sandy loam).

Group C. Group C soils have a moderately high runoff potential due to slow infiltration rates (0.05 in/hr to 0.5 in/hr or 1.3 mm/hr to 3.8 mm/hr if saturated). These soils primarily consist of soils in which a layer near the surface impedes the downward movement of water or soils with moderately fine to fine texture such as clay loams, shallow sandy loams, soils low in organic content, and soils usually high in clay.

Group D. Group D soils have a high runoff potential due to very slow infiltration rates (less than 0.05 in./hr or 1.3 mm/hr if saturated). These soils primarily consist of clays with high swelling potential, soils with permanently high water tables, soils with a claypan or clay layer at or near the surface, shallow soils over nearly impervious parent material such as soils that swell significantly when wet or heavy plastic clays or certain saline soils.

Effects of Urbanization. Consider the effects of urbanization on the natural hydrologic soil group. If heavy equipment can be expected to compact the soil during construction or if grading will mix the surface and subsurface soils, you should make appropriate changes in the soil group selected.

Runoff Curve Numbers for Urban Areas

Cover Type and Hydrologic Condition	Average Percent Impervious Area	A	B	C	D
Open space (lawns, parks, golf courses, cemeteries, etc.)					
♦ Poor condition (grass cover < 50%)		68	79	86	89
♦ Fair condition (grass cover 50% to 75%)		49	69	79	84
♦ Good condition (grass cover > 75%)		39	61	74	80
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
♦ Paved; curbs and storm drains (excluding right-of-way)		98	98	98	98
♦ Paved; open ditches (including right-of-way)		83	89	92	93
♦ Gravel (including right-of-way)		76	85	89	91
♦ Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
♦ Natural desert landscaping (pervious areas only)		63	77	85	88
♦ Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
♦ Commercial and business	85	89	92	94	95
♦ Industrial	72	81	88	91	93
Residential districts by average lot size:					
♦ 1/8 acre or less (town houses)	65	77	85	90	92
♦ 1/4 acre	38	61	75	83	87
♦ 1/3 acre	30	57	72	81	86
♦ 1/2 acre	25	54	70	80	85
♦ 1 acre	20	51	68	79	84
♦ 2 acres	12	46	65	77	82
Developing urban areas:					
Newly graded areas (pervious areas only, no vegetation)		77	86	91	94

Notes: Values are for average runoff condition, and $I_a = 0.2S$.
The average percent impervious area shown was used to develop the composite RCNs.
Other assumptions are: impervious areas are directly connected to the drainage system, impervious areas have a RCN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition.

Runoff Curve Numbers for Cultivated Agricultural Land[1]

Cover Type	Treatment[2]	Hydrologic Condition[3]	A	B	C	D
Fallow	Bare soil		77	86	91	94
	Crop residue	Poor	76	85	90	93
	cover (CR)	Good	74	83	88	90
Row Crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded	SR	Poor	66	77	85	89
or broadcast		Good	58	72	81	85
Legumes or C		Poor	64	75	83	85
Rotation		Good	55	69	78	83
Meadow	C&T	Poor	63	73	80	83
		Good	51	67	76	80

Notes. [1] Values are for average runoff condition, and $I_a = 0.2S$.

[2] Crop residue cover applies only if residue is on at least 5 percent of the surface throughout the year.

[3] Hydrologic condition is based on a combination of factors affecting infiltration and runoff: density and canopy of vegetative areas, amount of year-round cover, amount of grass or closed-seeded legumes in rotations, percent of residue cover on land surface (good > 20 percent), and degree of roughness.

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better infiltration and tend to decrease runoff.

Runoff Curve Numbers for Other Agricultural Lands

Cover Type	Hydrologic Condition	A	B	C	D
Pasture, grassland, or range-continuous forage for grazing	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow – continuous grass, protected from grazing and generally mowed for hay		30	58	71	78
Brush – brush-weed-grass mixture, with brush the major element	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods – grass combination (orchard or tree farm)	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads – buildings, lanes, driveways, and surrounding lots		59	74	82	86

Notes: Values are for average runoff condition, and $I_a = 0.2S$.

Pasture: Poor is < 50% ground cover or heavily grazed with no mulch, Fair is 50% to 75% ground cover and not heavily grazed, and Good is >75% ground cover and lightly or only occasionally grazed.

Meadow: Poor is <50% ground cover, Fair is 50% to 75% ground cover, Good is >75% ground cover.

Woods/grass: RCNs shown were computed for areas with 50 percent grass (pasture) cover. Other combinations of conditions may be computed from RCNs for woods and pasture.

Woods: Poor is forest litter, small trees, and brush destroyed by heavy grazing or regular burning. Fair is woods grazed but not burned and with some forest litter covering the soil. Good is woods protected from grazing and with litter and brush adequately covering soil.

Runoff Curve Numbers for Arid and Semi Arid Rangelands

Cover Type	Hydrologic Condition	A	B	C	D
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both; grass understory	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
saltbush, greasewood, creosote-bush, blackbrush, bursage, palo verde, mesquite, and cactus	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

Notes. Values are for average runoff condition, and $I_a = 0.2S$.
Hydrologic Condition: Poor is <30% ground cover (litter, grass, and brush overstory), Fair is 30% to 70% ground cover, Good is >70% ground cover.
Curve numbers for Group A have been developed only for desert shrub.

EXHIBIT 1

DRAINAGE AREA MAP

EXHIBIT 1
(DRAINAGE AREA MAP)

1 inch equals 5,000 feet

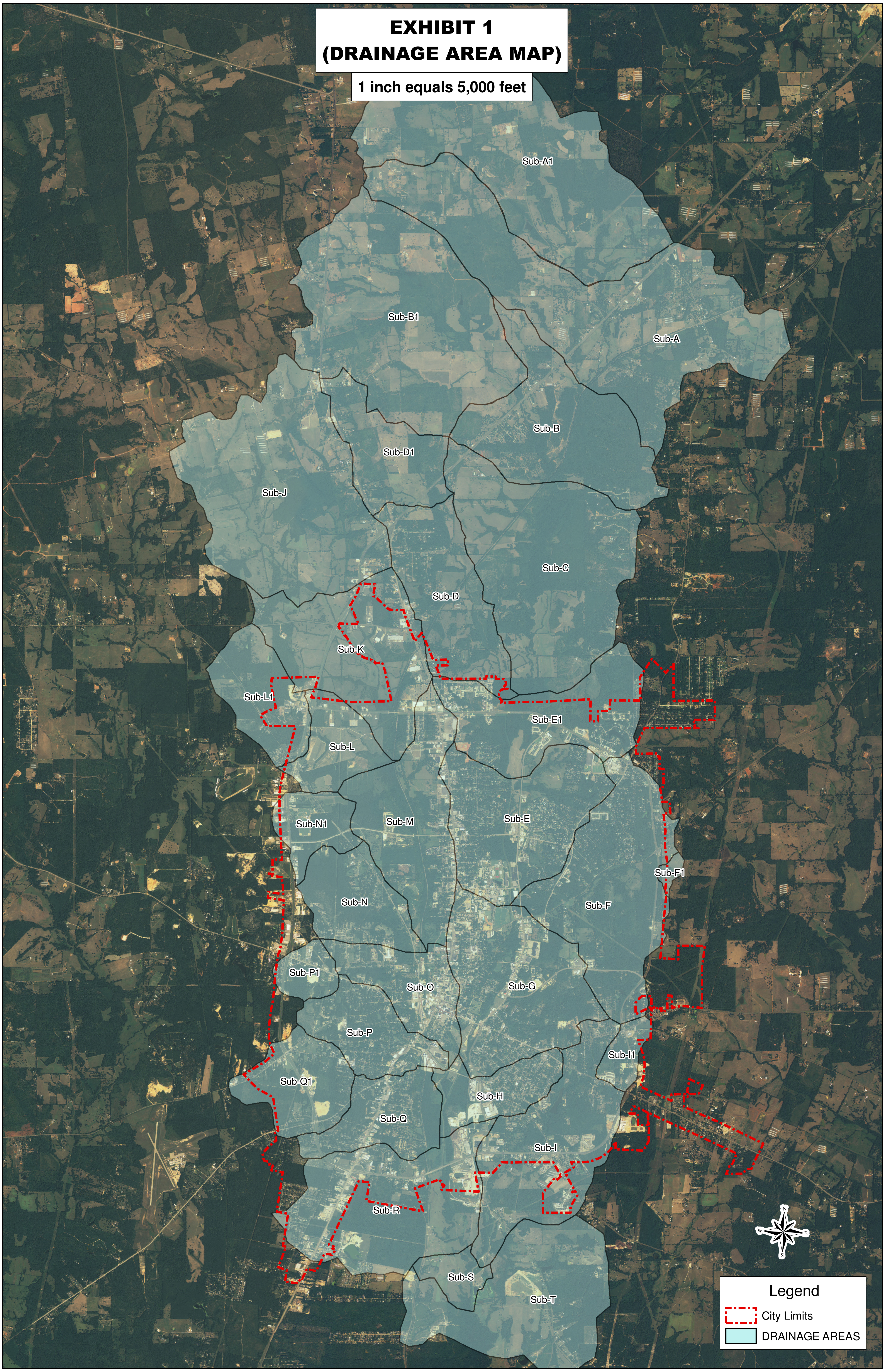


EXHIBIT 2

HYDROLOGICAL SOIL GROUP MAP

EXHIBIT 2
(HYDROLOGIC SOIL GROUP MAP)

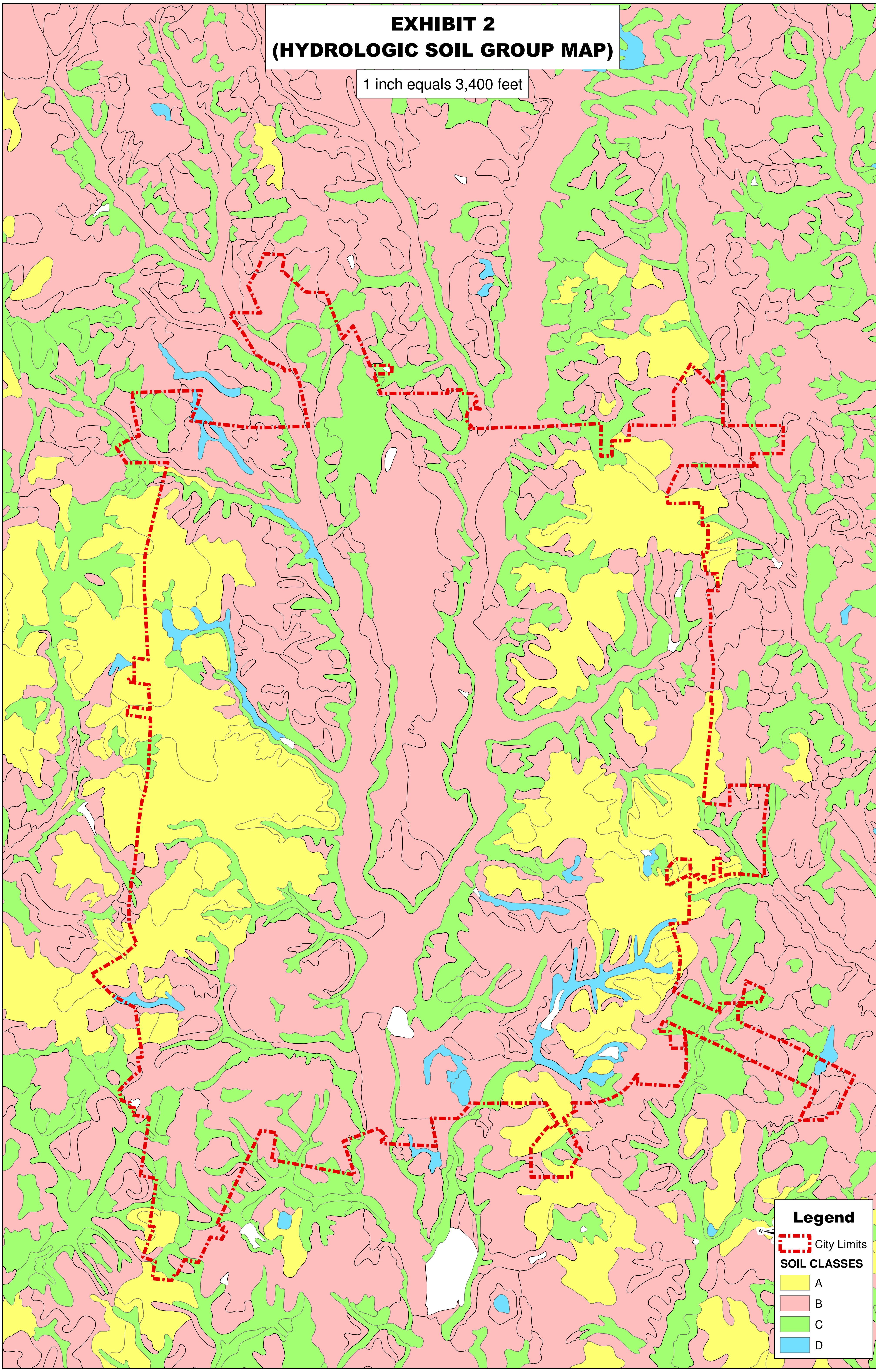


EXHIBIT 3

PRE-DEVELOPMENT LAND USE MAP

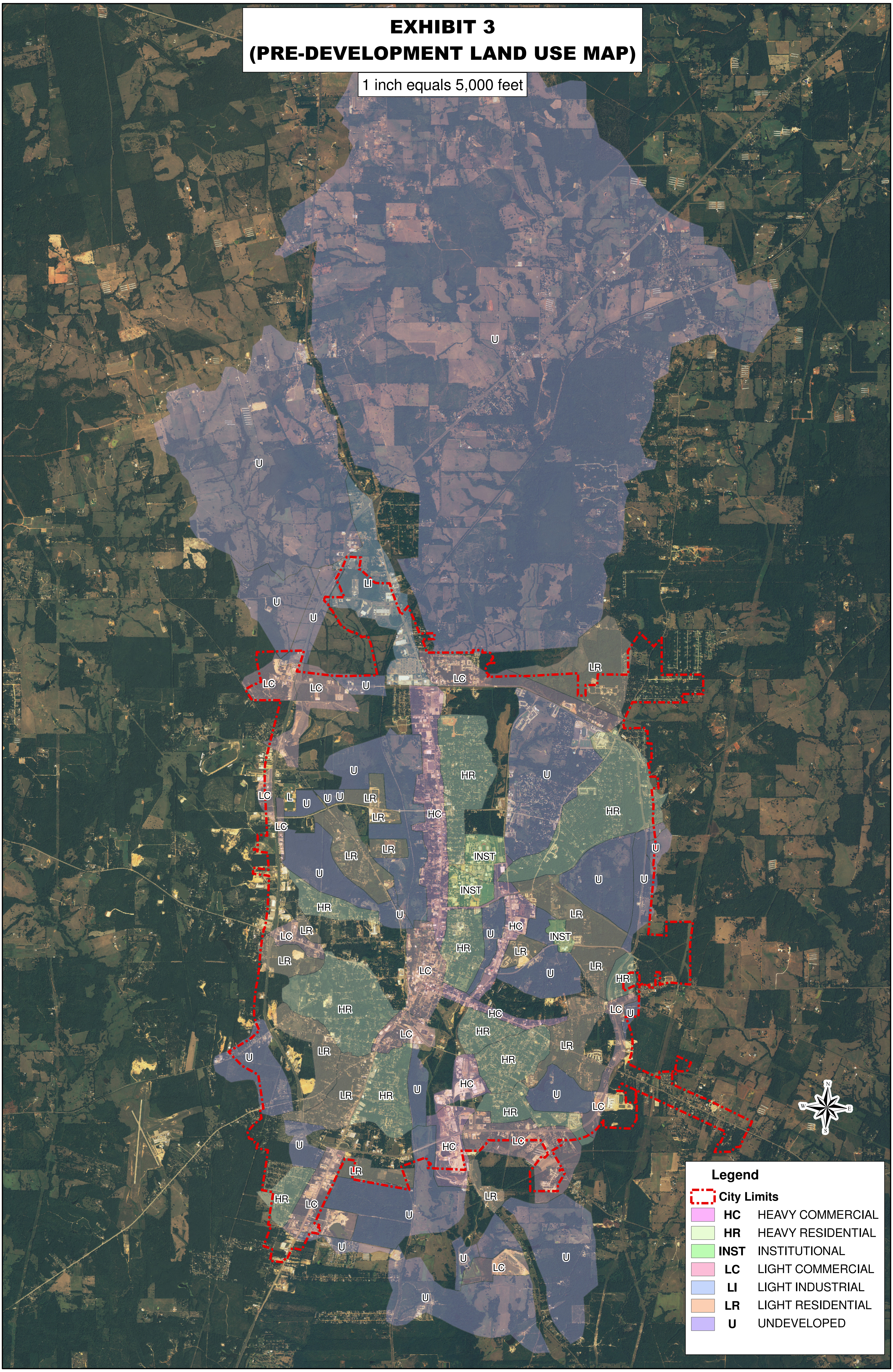


EXHIBIT 3
(PRE-DEVELOPMENT LAND USE MAP)
1 inch equals 5,000 feet
Legend
City Limits
HC HEAVY COMMERCIAL
HR HEAVY RESIDENTIAL
INST INSTITUTIONAL
LC LIGHT COMMERCIAL
LI LIGHT INDUSTRIAL
LR LIGHT RESIDENTIAL
U UNDEVELOPED

klotz associates

EXHIBIT 4

POST DEVELOPMENT LAND USE MAP

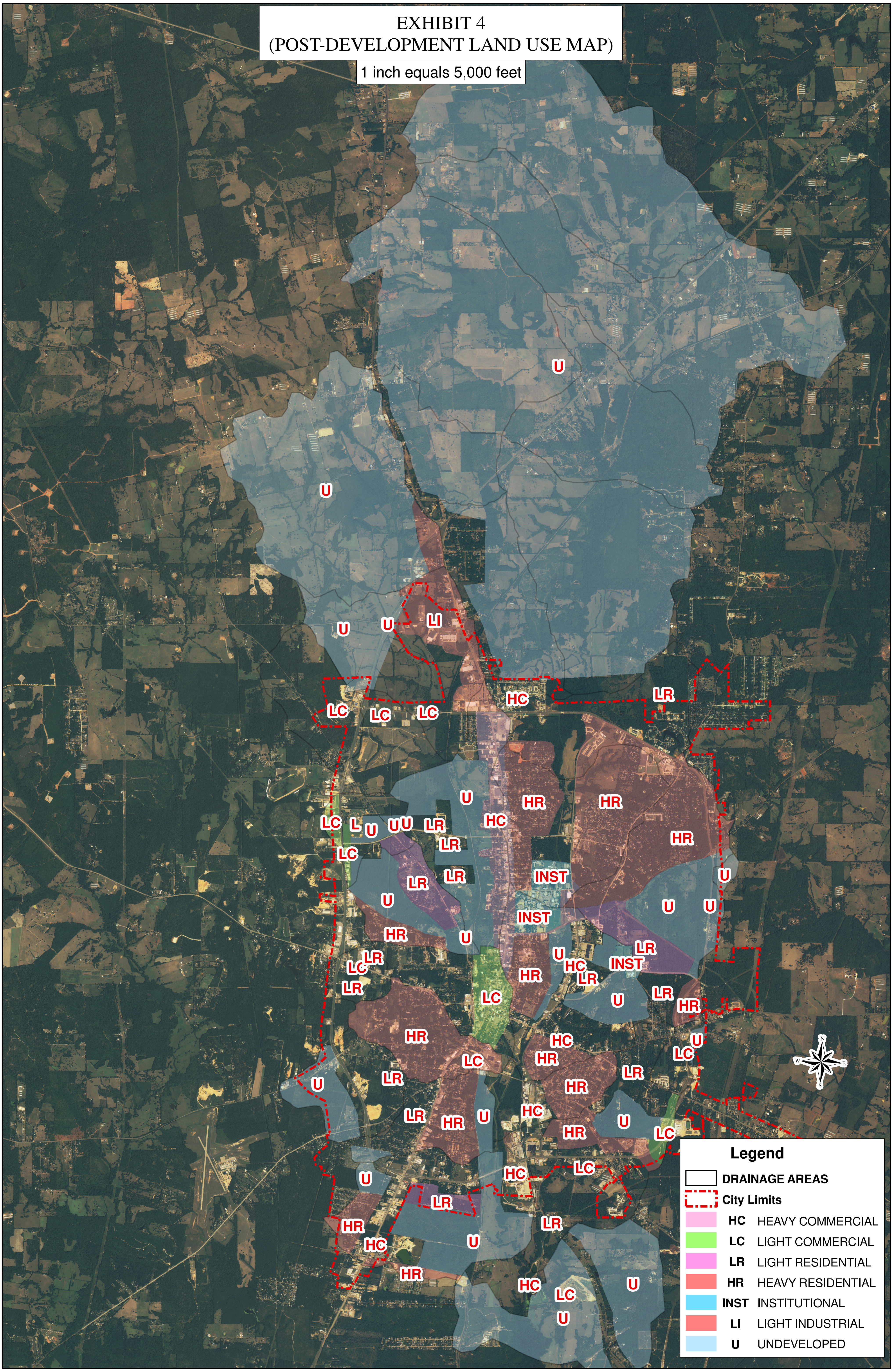


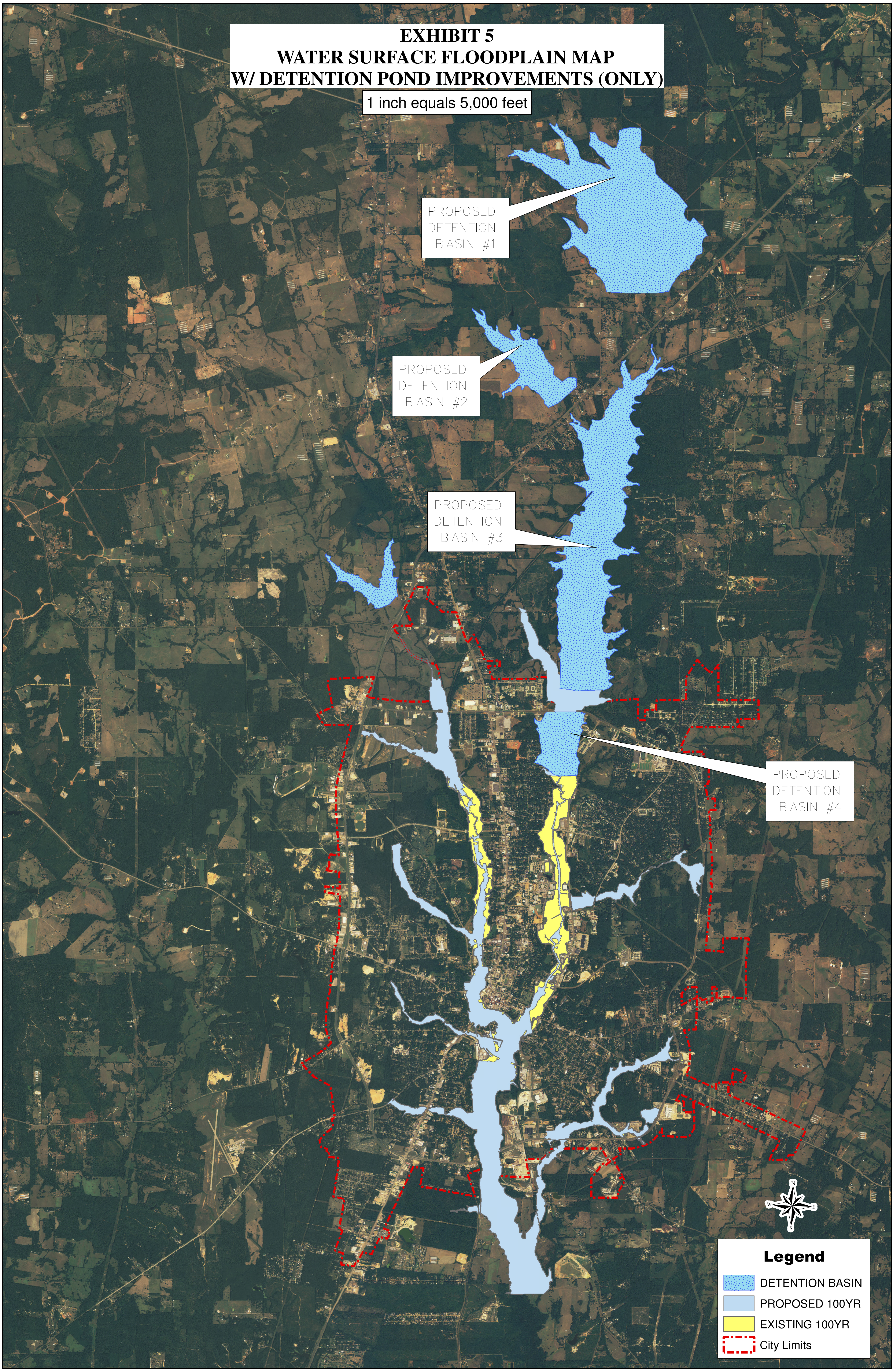
EXHIBIT 4
(POST-DEVELOPMENT LAND USE MAP)
1 inch equals 5,000 feet
Legend
DRAINAGE AREAS
City Limits
HC HEAVY COMMERCIAL
LC LIGHT COMMERCIAL
LR LIGHT RESIDENTIAL
HR HEAVY RESIDENTIAL
INST INSTITUTIONAL
LI LIGHT INDUSTRIAL
U UNDEVELOPED

EXHIBIT 5

WATER SURFACE FLOOD PLAIN MAP
W/DETENTION POND IMPROVEMENTS (ONLY)

EXHIBIT 5
WATER SURFACE FLOODPLAIN MAP W/ DETENTION POND IMPROVEMENTS (ONLY)

1 inch equals 5,000 feet



klotz associates

EXHIBIT 6

WATER SURFACE FLOOD PLAIN MAP
CHANNEL IMPROVEMENTS (ONLY)

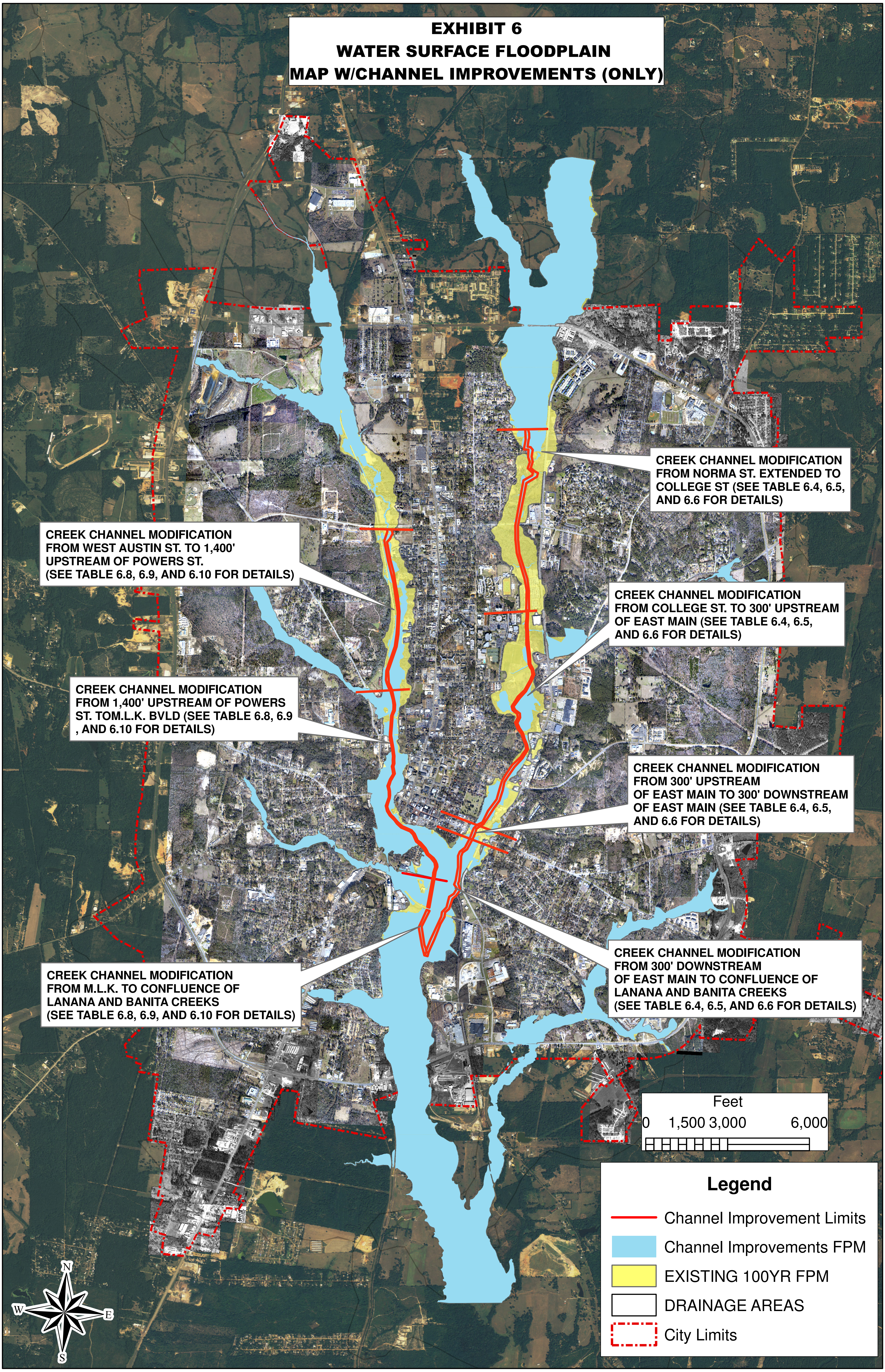


EXHIBIT 6
WATER SURFACE FLOODPLAIN
MAP W/CHANNEL IMPROVEMENTS (ONLY)
CREEK CHANNEL MODIFICATION FROM NORMA ST. EXTENDED TO COLLEGE ST (SEE TABLE 6.4, 6.5, AND 6.6 FOR DETAILS)
CREEK CHANNEL MODIFICATION FROM WEST AUSTIN ST. TO 1,400' UPSTREAM OF POWERS ST. (SEE TABLE 6.8, 6.9, AND 6.10 FOR DETAILS)
CREEK CHANNEL MODIFICATION FROM COLLEGE ST. TO 300' UPSTREAM OF EAST MAIN (SEE TABLE 6.4, 6.5, AND 6.6 FOR DETAILS)
CREEK CHANNEL MODIFICATION FROM 1,400' UPSTREAM OF POWERS ST. TOM.L.K. BVLD (SEE TABLE 6.8, 6.9 , AND 6.10 FOR DETAILS)
CREEK CHANNEL MODIFICATION FROM 300' UPSTREAM OF EAST MAIN TO 300' DOWNSTREAM OF EAST MAIN (SEE TABLE 6.4, 6.5, AND 6.6 FOR DETAILS)
CREEK CHANNEL MODIFICATION FROM M.L.K. TO CONFLUENCE OF LANANA AND BANITA CREEKS (SEE TABLE 6.8, 6.9, AND 6.10 FOR DETAILS)
CREEK CHANNEL MODIFICATION FROM 300' DOWNSTREAM OF EAST MAIN TO CONFLUENCE OF LANANA AND BANITA CREEKS (SEE TABLE 6.4, 6.5, AND 6.6 FOR DETAILS)
Feet
0 1,500 3,000 6,000
Legend
Channel Improvement Limits
Channel Improvements FPM
EXISTING 100YR FPM
DRAINAGE AREAS
City Limits
N
E
S
W

APPENDIX A

COST ESTIMATES

APPENDIX A-1					
ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST					
CONCEPTUAL PLANNING STAGE					
BANITA FLOOD CONTROL TUNNEL					
January 20, 2009					
ITEM NUMBER	DESCRIPTION	UNITS	QUANTITY	UNIT COST	AMOUNT
1	Land Rights	Lump Sum	1	$ 100,000	$ 100,000
2	Tunnel Boring Machine	Lump Sum	1	$ 9,000,000	$ 9,000,000
3	Banita Inlet Structure	Lump Sum	1	$ 1,000,000	$ 1,000,000
4	Banita Inlet Shaft	Lump Sum	1	$ 2,000,000	$ 2,000,000
5	Banita Tunnel	Linear Feet	27,800	$ 4,400	$ 122,320,000
6	Banita Outlet Shaft	Each	1	$ 2,000,000	$ 2,000,000
7	Banita Outlet Structure	Each	1	$ 1,000,000	$ 1,000,000
8	Banita Maintenance Shafts	Each	5	$ 2,000,000	$ 10,000,000
9	Banita Vent Shafts	Each	5	$ 500,000	$ 2,500,000
SUBTOTAL					$ 149,920,000
Engineering and Permitting - 15%					$ 22,488,000
Administration - 10%					$ 14,992,000
SUBTOTAL					$ 187,400,000
Contingency - 25%					$ 46,850,000
TOTAL					$ 234,250,000

APPENDIX A-2					
ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST					
CONCEPTUAL PLANNING STAGE					
LANANA FLOOD CONTROL TUNNEL					
January 20, 2009					
ITEM NUMBER	DESCRIPTION	UNITS	QUANTITY	UNIT COST	AMOUNT
1	Land Rights	Lump Sum	1	$ 100,000	$ 100,000
2	Tunnel Boring Machine	Lump Sum	1	$ 14,400,000	$ 14,400,000
3	Banita Inlet Structure	Lump Sum	1	$ 2,000,000	$ 2,000,000
4	Banita Inlet Shaft	Lump Sum	1	$ 4,000,000	$ 4,000,000
5	Banita Tunnel -30' Diameter	Linear Feet	28,000	$ 6,500	$ 182,000,000
6	Banita Outlet Shaft	Each	1	$ 4,000,000	$ 4,000,000
7	Banita Outlet Structure	Each	1	$ 2,000,000	$ 2,000,000
8	Banita Maintenance Shafts	Each	5	$ 4,000,000	$ 20,000,000
9	Banita Vent Shafts	Each	5	$ 1,000,000	$ 5,000,000
SUBTOTAL					$ 233,500,000
Engineering and Permitting - 15%					$ 35,025,000
Administration - 10%					$ 23,350,000
SUBTOTAL					$ 291,875,000
Contingency - 25%					$ 72,968,750
TOTAL					$ 364,843,750

APPENDIX A-3					
ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST					
CONCEPTUAL PLANNING STAGE					
LANANA CHANNEL MODIFICATIONS -100-YEAR FUTURE DESIGN FLOWS					
February 16, 2009					
ITEM NUMBER	DESCRIPTION	UNITS	QUANTITY	UNIT COST	AMOUNT
1	Mobilization/Demobilization	Lump Sum	1	$ 100,000	$ 100,000
2	Clearing	Acres	76	$ 1,500	$ 114,000
3	Clearing and Grubbing	Acres	76	$ 2,500	$ 190,000
4	Fill	Cubic Yards	32,000	$ 6	$ 192,000
5	Excavation	Cubic Yards	1,984,000	$ 4	$ 7,936,000
6	Side Drainage Structures	Each	170	$ 10,000	$ 1,700,000
7	Revegetation	Acres	152	$ 2,500	$ 380,000
8	Erosion Control Measures	Lump Sum	1	$ 250,000	$ 250,000
SUBTOTAL					$ 10,862,000
Utility Conflict Resolution - 25%					$ 2,720,000
Engineering and Permitting - 25%					$ 2,716,000
Administration - 10%					$ 1,086,000
SUBTOTAL					$ 17,384,000
Contingency - 25%					$ 4,346,000
SUBTOTAL					$ 21,730,000
Land Acquisition		Acres	152	$ 2,500	$ 380,000
TOTAL					$ 22,110,000

APPENDIX A-4					
ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST					
CONCEPTUAL PLANNING STAGE					
LANANA CHANNEL MODIFICATIONS -25-YEAR FUTURE DESIGN FLOWS					
February 16, 2009					
ITEM NUMBER	DESCRIPTION	UNITS	QUANTITY	UNIT COST	AMOUNT
1	Mobilization/Demobilization	Lump Sum	1	$ 100,000	$ 100,000
2	Clearing	Acres	76	$ 1,500	$ 114,000
3	Clearing and Grubbing	Acres	76	$ 2,500	$ 190,000
4	Fill	Cubic Yards	41,000	$ 6	$ 246,000
5	Excavation	Cubic Yards	1,690,000	$ 4	$ 6,760,000
6	Side Drainage Structures	Each	170	$ 10,000	$ 1,700,000
7	Revegetation	Acres	152	$ 2,500	$ 380,000
8	Erosion Control Measures	Lump Sum	1	$ 250,000	$ 250,000
SUBTOTAL					$ 9,740,000
Utility Conflict Resolution - 25%					$ 2,440,000
Engineering and Permitting - 25%					$ 2,435,000
Administration - 10%					$ 974,000
SUBTOTAL					$ 15,589,000
Contingency - 25%					$ 3,897,000
SUBTOTAL					$ 19,486,000
Land Acquisition		Acres	152	$ 2,500	$ 380,000
TOTAL					$ 19,866,000

APPENDIX A-5					
ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST					
CONCEPTUAL PLANNING STAGE					
LANANA CHANNEL MODIFICATIONS -10-YEAR FUTURE DESIGN FLOWS					
February 16, 2009					
ITEM NUMBER	DESCRIPTION	UNITS	QUANTITY	UNIT COST	AMOUNT
1	Mobilization/Demobilization	Lump Sum	1	$ 100,000	$ 100,000
2	Clearing	Acres	76	$ 1,500	$ 114,000
3	Clearing and Grubbing	Acres	76	$ 2,500	$ 190,000
4	Fill	Cubic Yards	52,000	$ 6	$ 312,000
5	Excavation	Cubic Yards	1,437,000	$ 4	$ 5,748,000
6	Side Drainage Structures	Each	170	$ 10,000	$ 1,700,000
7	Revegetation	Acres	152	$ 2,500	$ 380,000
8	Erosion Control Measures	Lump Sum	1	$ 250,000	$ 250,000
SUBTOTAL					$ 8,794,000
Utility Conflict Resolution - 25%					$ 2,200,000
Engineering and Permitting - 25%					$ 2,199,000
Administration - 10%					$ 879,000
SUBTOTAL					$ 14,072,000
Contingency - 25%					$ 3,518,000
SUBTOTAL					$ 17,590,000
Land Acquisition		Acres	152	$ 2,500	$ 380,000
TOTAL					$ 17,970,000

APPENDIX A-6					
ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST					
CONCEPTUAL PLANNING STAGE					
LANANA BRIDGE MODIFICATIONS					
January 20, 2009					
ITEM NUMBER	DESCRIPTION	UNITS	QUANTITY	UNIT COST	AMOUNT
1	Austin	Lump Sum	1	$ 756,000	$ 756,000
2	College	Lump Sum	1	$ 691,200	$ 691,200
3	Starr	Lump Sum	1	$ 950,400	$ 950,400
4	Martinsville	Lump Sum	1	$ 528,000	$ 528,000
5	Park	Lump Sum	1	$ 528,000	$ 528,000
6	Main	Lump Sum	1	$ 1,598,400	$ 1,598,400
7	MLK Jr.	Lump Sum	1	$ 3,326,400	$ 3,326,400
SUBTOTAL					$ 8,378,400
Utility Conflict Resolution - 25%					$ 2,090,000
Engineering and Permitting - 25%					$ 2,095,000
Administration - 10%					$ 838,000
SUBTOTAL					$ 13,401,400
Contingency - 25%					$ 3,350,000
SUBTOTAL					$ 16,751,400
Land Acquisition		Acres	28	$ 2,500	$ 70,000
TOTAL					$ 16,821,400

APPENDIX A-7
ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST
CONCEPTUAL PLANNING STAGE
BANITA CHANNEL MODIFICATIONS -100-YEAR FUTURE DESIGN FLOWS
February 16, 2009

ITEM NUMBER	DESCRIPTION	UNITS	QUANTITY	UNIT COST	AMOUNT
1	Mobilization/Demobilization	Lump Sum	1	$ 100,000	$ 100,000
2	Clearing	Acres	42	$ 1,500	$ 63,000
3	Clearing and Grubbing	Acres	42	$ 2,500	$ 105,000
4	Fill	Cubic Yards	103,000	$ 6	$ 618,000
5	Excavation	Cubic Yards	379,000	$ 4	$ 1,516,000
6	Side Drainage Structures	Each	122	$ 10,000	$ 1,220,000
7	Revegetation	Acres	84	$ 2,500	$ 210,000
8	Erosion Control Measures	Lump Sum	1	$ 250,000	$ 250,000
SUBTOTAL					$ 4,082,000
Utility Conflict Resolution - 25%					$ 1,020,000
Engineering and Permitting - 25%					$ 1,021,000
Administration - 10%					$ 408,000
SUBTOTAL					$ 6,531,000
Contingency - 25%					$ 1,633,000
SUBTOTAL					$ 8,164,000
Land Acquisition		Acres	84	$ 2,500	$ 210,000
TOTAL					$ 8,374,000

APPENDIX A-8					
ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST					
CONCEPTUAL PLANNING STAGE					
BANITA CHANNEL MODIFICATIONS - 25-YEAR FUTURE DESIGN FLOWS					
February 16, 2009					
ITEM NUMBER	DESCRIPTION	UNITS	QUANTITY	UNIT COST	AMOUNT
1	Mobilization/Demobilization	Lump Sum	1	$ 100,000	$ 100,000
2	Clearing	Acres	42	$ 1,500	$ 63,000
3	Clearing and Grubbing	Acres	42	$ 2,500	$ 105,000
4	Fill	Cubic Yards	132,000	$ 6	$ 792,000
5	Excavation	Cubic Yards	322,000	$ 4	$ 1,288,000
6	Side Drainage Structures	Each	122	$ 10,000	$ 1,220,000
7	Revegetation	Acres	84	$ 2,500	$ 210,000
8	Erosion Control Measures	Lump Sum	1	$ 250,000	$ 250,000
SUBTOTAL					$ 4,028,000
Utility Conflict Resolution - 25%					$ 1,010,000
Engineering and Permitting - 25%					$ 1,007,000
Administration - 10%					$ 403,000
SUBTOTAL					$ 6,448,000
Contingency - 25%					$ 1,612,000
SUBTOTAL					$ 8,060,000
Land Acquisition		Acres	84	$ 2,500	$ 210,000
TOTAL					$ 8,270,000

APPENDIX A-9					
ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST					
CONCEPTUAL PLANNING STAGE					
BANITA CHANNEL MODIFICATIONS - 10-YEAR FUTURE DESIGN FLOWS					
February 16, 2009					
ITEM NUMBER	DESCRIPTION	UNITS	QUANTITY	UNIT COST	AMOUNT
1	Mobilization/Demobilization	Lump Sum	1	$ 100,000	$ 100,000
2	Clearing	Acres	42	$ 1,500	$ 63,000
3	Clearing and Grubbing	Acres	42	$ 2,500	$ 105,000
4	Fill	Cubic Yards	169,000	$ 6	$ 1,014,000
5	Excavation	Cubic Yards	274,000	$ 4	$ 1,096,000
6	Side Drainage Structures	Each	122	$ 10,000	$ 1,220,000
7	Revegetation	Acres	84	$ 2,500	$ 210,000
8	Erosion Control Measures	Lump Sum	1	$ 250,000	$ 250,000
SUBTOTAL					$ 4,058,000
Utility Conflict Resolution - 25%					$ 1,010,000
Engineering and Permitting - 25%					$ 1,015,000
Administration - 10%					$ 406,000
SUBTOTAL					$ 6,489,000
Contingency - 25%					$ 1,622,000
SUBTOTAL					$ 8,111,000
Land Acquisition		Acres	84	$ 2,500	$ 210,000
TOTAL					$ 8,321,000

APPENDIX A-10					
ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST					
CONCEPTUAL PLANNING STAGE					
BANITA BRIDGE MODIFICATIONS					
January 20, 2009					
ITEM NUMBER	DESCRIPTION	UNITS	QUANTITY	UNIT COST	AMOUNT
1	Powers	Lump Sum	1	$ 1,008,000	$ 1,008,000
2	East Main	Lump Sum	1	$ 3,888,000	$ 3,888,000
3	Pilar	Lump Sum	1	$ 950,400	$ 348,000
4	South	Lump Sum	1	$ 528,000	$ 6,440,000
5	Pecan	Lump Sum	1	$ 528,000	$ 2,880,000
6	Fredonia	Lump Sum	1	$ 1,598,400	$ 2,772,000
7	Church	Lump Sum	1	$ 3,326,400	$ 1,632,000
SUBTOTAL					$ 18,968,000
Utility Conflict Resolution - 25%					$ 4,740,000
Engineering and Permitting - 25%					$ 4,742,000
Administration - 10%					$ 1,897,000
SUBTOTAL					$ 30,347,000
Contingency - 25%					$ 7,587,000
SUBTOTAL					$ 37,934,000
Land Acquisition		Acres	28	$ 2,500	$ 70,000
TOTAL					$ 38,004,000

APPENDIX A-11					
ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST					
CONCEPTUAL PLANNING STAGE					
FLOODWATER RETARDING STRUCTURE 1					
January 20, 2009					
ITEM NUMBER	DESCRIPTION	UNITS	QUANTITY	UNIT COST	AMOUNT
1	Mobilization/Demobilization	Lump Sum	1	$ 100,000	$ 100,000
2	Clearing	Acres	360	$ 500	$ 180,000
3	Clearing and Grubbing	Acres	14	$ 1,000	$ 14,000
4	Foundation Preparation	Cubic Yards	30,000	$ 4	$ 120,000
5	Cutoff Excavation	Cubic Yards	50,000	$ 4	$ 200,000
6	Embankment Fill	Cubic Yards	300,000	$ 6	$ 1,800,000
7	Roller Compacted Concrete	Cubic Yards	27,000	$ 150	$ 4,050,000
8	Concrete Headwalls/Basin	Cubic Yards	250	$ 500	$ 125,000
9	Inlet Riser	Each	1	$ 100,000	$ 100,000
10	Outlet Pipe	Linear Feet	400	$ 240	$ 96,000
11	Pipe Outlet Basin	Each	1	$ 100,000	$ 100,000
12	Rock Riprap	Cubic Yards	4,000	$ 50	$ 200,000
13	Revegetation	Acres	28	$ 1,000	$ 28,000
14	Fencing	Linear feet	6,000	$ 10	$ 60,000
15	Trash Rack	Each	1	$ 10,000	$ 10,000
16	Erosion Control Measures	Lump Sum	1	$ 50,000	$ 50,000
SUBTOTAL					$ 7,233,000
Engineering and Permitting - 25%					$ 1,808,000
Administration - 10%					$ 723,000
SUBTOTAL					$ 9,764,000
Contingency - 25%					$ 2,441,000
SUBTOTAL					$ 12,205,000
Land Acquisition		Acres	360	$ 2,500	$ 900,000
TOTAL					$ 13,105,000

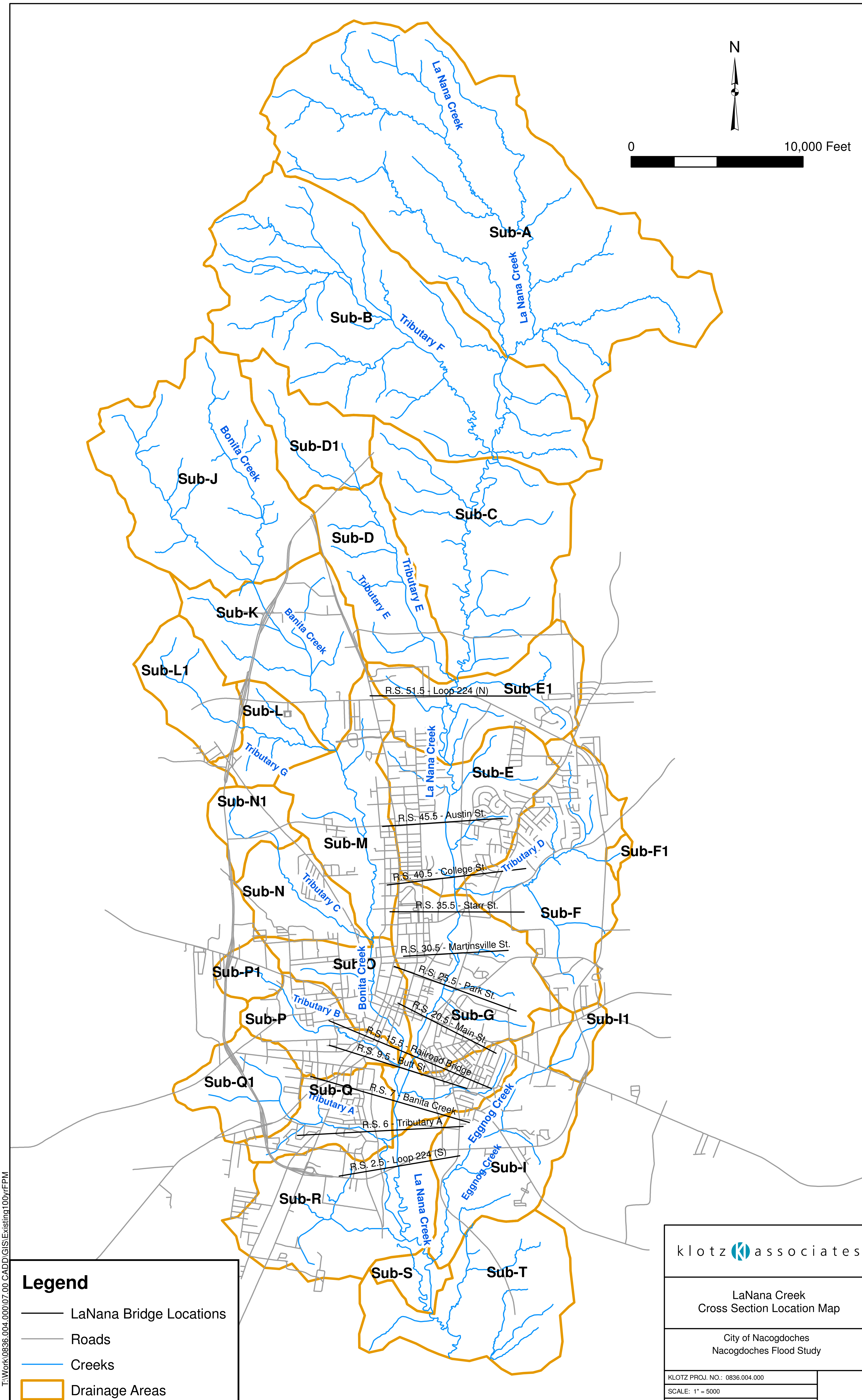
APPENDIX A-12					
ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST					
CONCEPTUAL PLANNING STAGE					
FLOODWATER RETARDING STRUCTURE 2					
January 20, 2009					
ITEM NUMBER	DESCRIPTION	UNITS	QUANTITY	UNIT COST	AMOUNT
1	Mobilization/Demobilization	Lump Sum	1	$ 100,000	$ 100,000
2	Clearing	Acres	270	$ 500	$ 135,000
3	Clearing and Grubbing	Acres	16	$ 1,000	$ 16,000
4	Foundation Preparation	Cubic Yards	27,000	$ 4	$ 108,000
5	Cutoff Excavation	Cubic Yards	46,000	$ 4	$ 184,000
6	Embankment Fill	Cubic Yards	275,000	$ 6	$ 1,650,000
7	Roller Compacted Concrete	Cubic Yards	20,000	$ 150	$ 3,000,000
8	Concrete Headwalls/Basin	Cubic Yards	250	$ 500	$ 125,000
9	Inlet Riser	Each	1	$ 100,000	$ 100,000
10	Outlet Pipe	Linear Feet	400	$ 240	$ 96,000
11	Pipe Outlet Basin	Each	1	$ 100,000	$ 100,000
12	Rock Riprap	Cubic Yards	4,000	$ 50	$ 200,000
13	Revegetation	Acres	32	$ 1,000	$ 32,000
14	Fencing	Linear feet	6,000	$ 10	$ 60,000
15	Trash Rack	Each	1	$ 10,000	$ 10,000
16	Erosion Control Measures	Lump Sum	1	$ 50,000	$ 50,000
SUBTOTAL					$ 5,966,000
Engineering and Permitting - 25%					$ 1,492,000
Administration - 10%					$ 597,000
SUBTOTAL					$ 8,055,000
Contingency - 25%					$ 2,014,000
SUBTOTAL					$ 10,069,000
Land Acquisition		Acres	270	$ 2,500	$ 675,000
TOTAL					$ 10,744,000

APPENDIX A-13					
ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST					
CONCEPTUAL PLANNING STAGE					
FLOODWATER RETARDING STRUCTURE 3					
January 20, 2009					
ITEM NUMBER	DESCRIPTION	UNITS	QUANTITY	UNIT COST	AMOUNT
1	Mobilization/Demobilization	Lump Sum	1	$ 100,000	$ 100,000
2	Clearing	Acres	970	$ 500	$ 485,000
3	Clearing and Grubbing	Acres	84	$ 1,000	$ 84,000
4	Foundation Preparation	Cubic Yards	133,000	$ 4	$ 532,000
5	Cutoff Excavation	Cubic Yards	382,000	$ 4	$ 1,528,000
6	Embankment Fill	Cubic Yards	1,800,000	$ 6	$ 10,800,000
7	Roller Compacted Concrete	Cubic Yards	20,000	$ 150	$ 3,000,000
8	Concrete Headwalls/Basin	Cubic Yards	250	$ 500	$ 125,000
9	Inlet Riser	Each	1	$ 100,000	$ 100,000
10	Outlet Pipe	Linear Feet	400	$ 240	$ 96,000
11	Pipe Outlet Basin	Each	1	$ 100,000	$ 100,000
12	Rock Riprap	Cubic Yards	4,000	$ 50	$ 200,000
13	Revegetation	Acres	32	$ 1,000	$ 32,000
14	Fencing	Linear feet	14,000	$ 10	$ 140,000
15	Trash Rack	Each	1	$ 10,000	$ 10,000
16	Erosion Control Measures	Lump Sum	1	$ 50,000	$ 50,000
SUBTOTAL					$ 17,382,000
Engineering and Permitting - 25%					$ 4,346,000
Administration - 10%					$ 1,738,000
SUBTOTAL					$ 23,466,000
Contingency - 25%					$ 5,867,000
SUBTOTAL					$ 29,333,000
Land Acquisition		Acres	970	$ 2,500	$ 2,425,000
TOTAL					$ 31,758,000

APPENDIX A-14					
ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST					
CONCEPTUAL PLANNING STAGE					
FLOODWATER RETARDING STRUCTURE 4					
January 20, 2009					
ITEM NUMBER	DESCRIPTION	UNITS	QUANTITY	UNIT COST	AMOUNT
1	Mobilization/Demobilization	Lump Sum	1	$ 100,000	$ 100,000
2	Clearing	Acres	210	$ 500	$ 105,000
3	Clearing and Grubbing	Acres	24	$ 1,000	$ 24,000
4	Foundation Preparation	Cubic Yards	39,000	$ 4	$ 156,000
5	Cutoff Excavation	Cubic Yards	53,000	$ 4	$ 212,000
6	Embankment Fill	Cubic Yards	316,000	$ 6	$ 1,896,000
7	Roller Compacted Concrete	Cubic Yards	13,000	$ 150	$ 1,950,000
8	Concrete Headwalls/Basin	Cubic Yards	250	$ 500	$ 125,000
9	Inlet Riser	Each	1	$ 100,000	$ 100,000
10	Outlet Pipe	Linear Feet	400	$ 1,000	$ 400,000
11	Pipe Outlet Basin	Each	1	$ 100,000	$ 100,000
12	Rock Riprap	Cubic Yards	4,000	$ 50	$ 200,000
13	Revegetation	Acres	32	$ 1,000	$ 32,000
14	Fencing	Linear feet	14,000	$ 10	$ 140,000
15	Trash Rack	Each	1	$ 10,000	$ 10,000
16	Erosion Control Measures	Lump Sum	1	$ 50,000	$ 50,000
SUBTOTAL					$ 5,600,000
Engineering and Permitting - 25%					$ 1,400,000
Administration - 10%					$ 560,000
SUBTOTAL					$ 7,560,000
Contingency - 25%					$ 1,890,000
SUBTOTAL					$ 9,450,000
Land Acquisition		Acres	210	$ 10,000	$ 2,100,000
TOTAL					$ 11,550,000

APPENDIX B

EXISTING AND FUTURE FLOOD HYDROGRAPHS
AND
CHANNEL PROFILES



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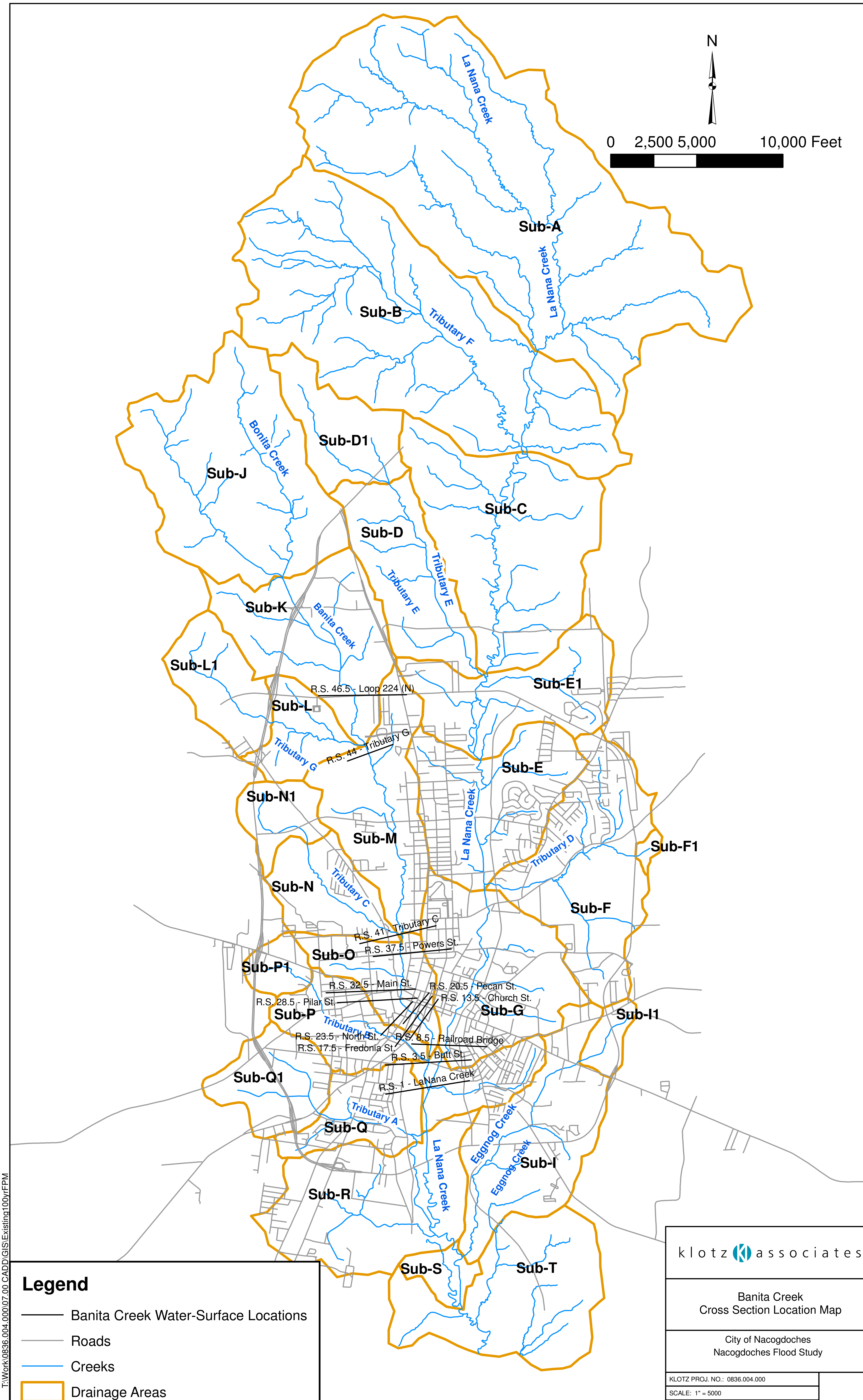

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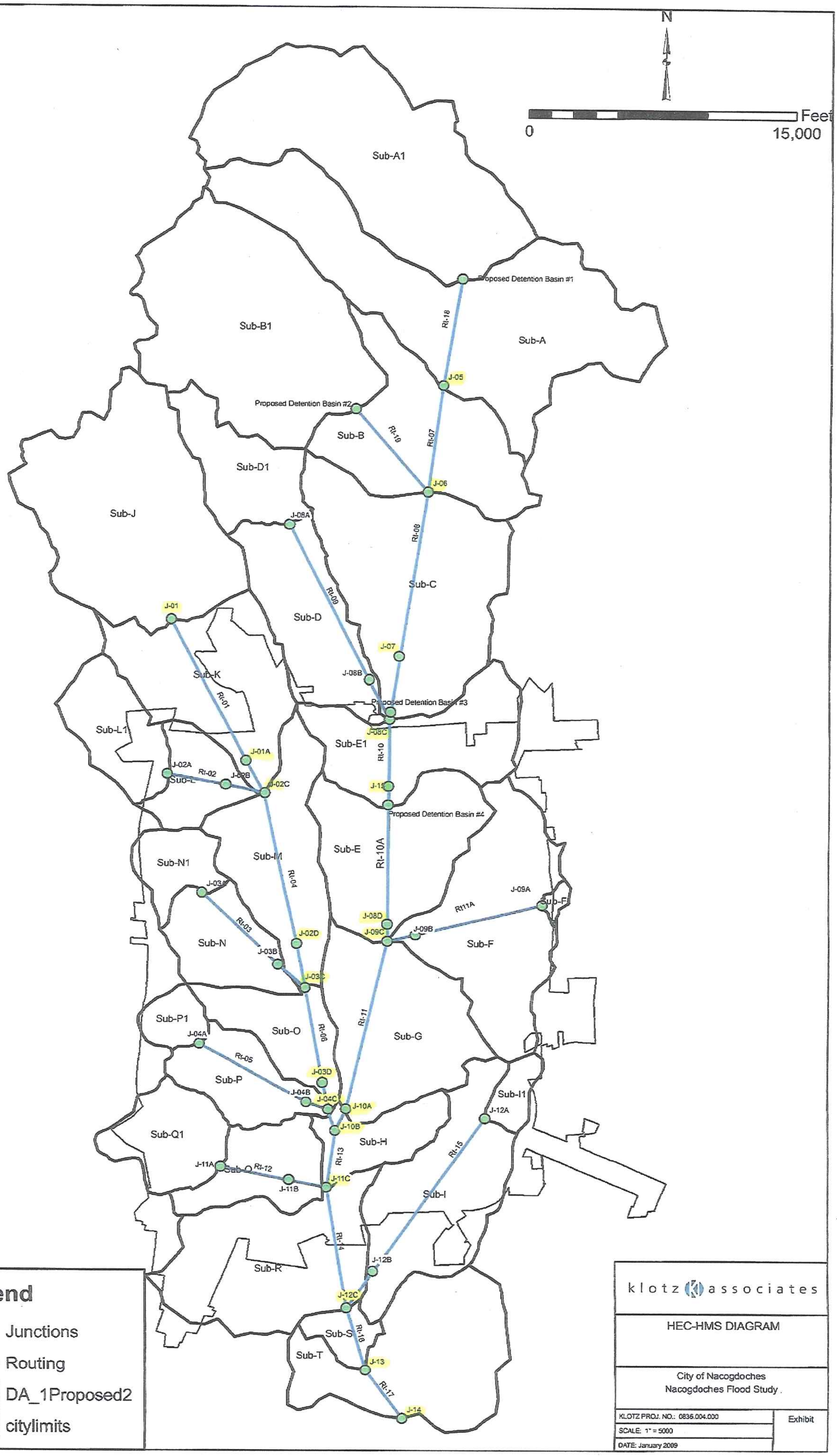


Legend

- Junctions
- Routing
- DA_1Proposed2
- citylimits

klotz associates

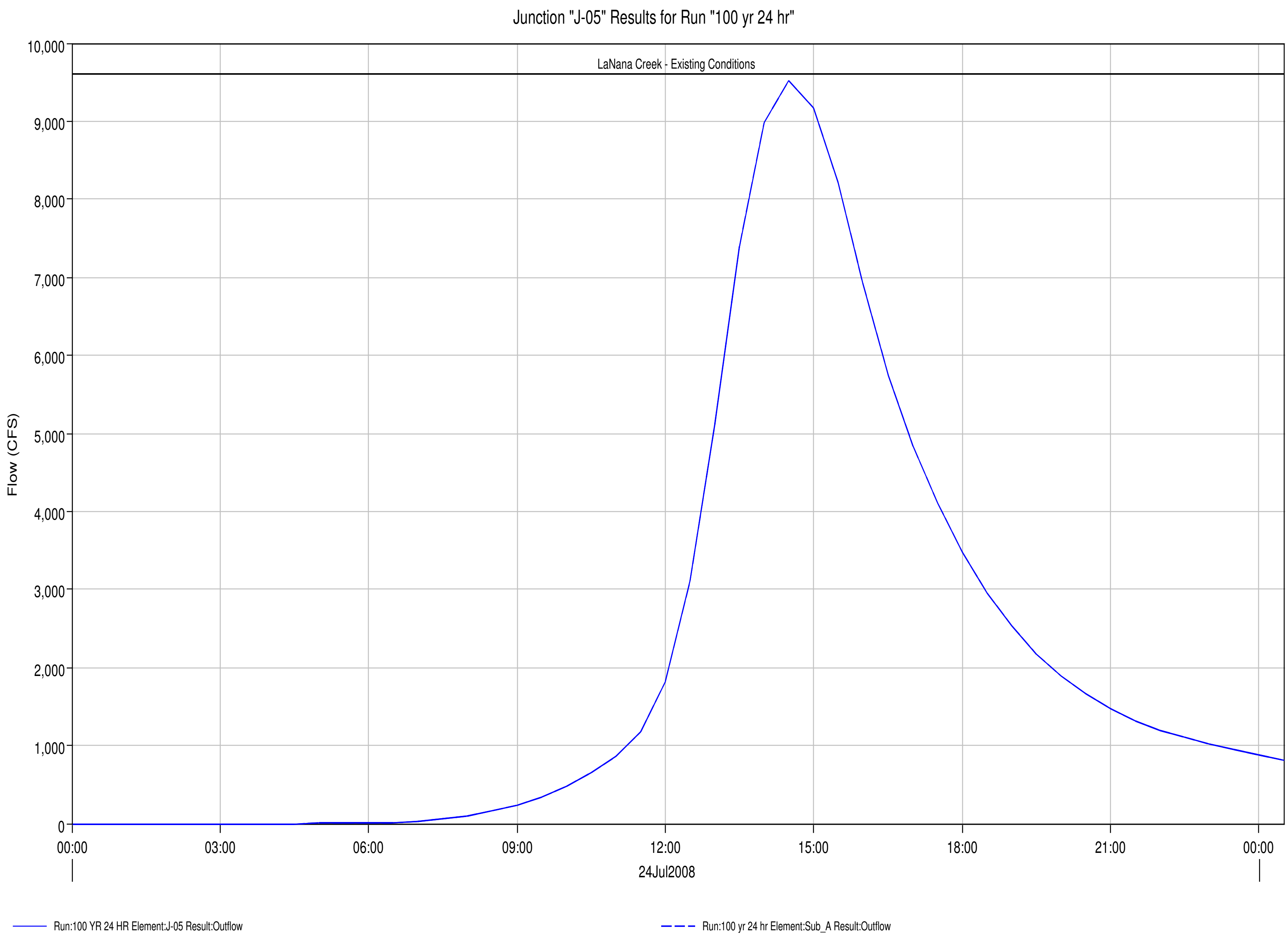
HEC-HMS DIAGRAM

City of Nacogdoches
Nacogdoches Flood Study

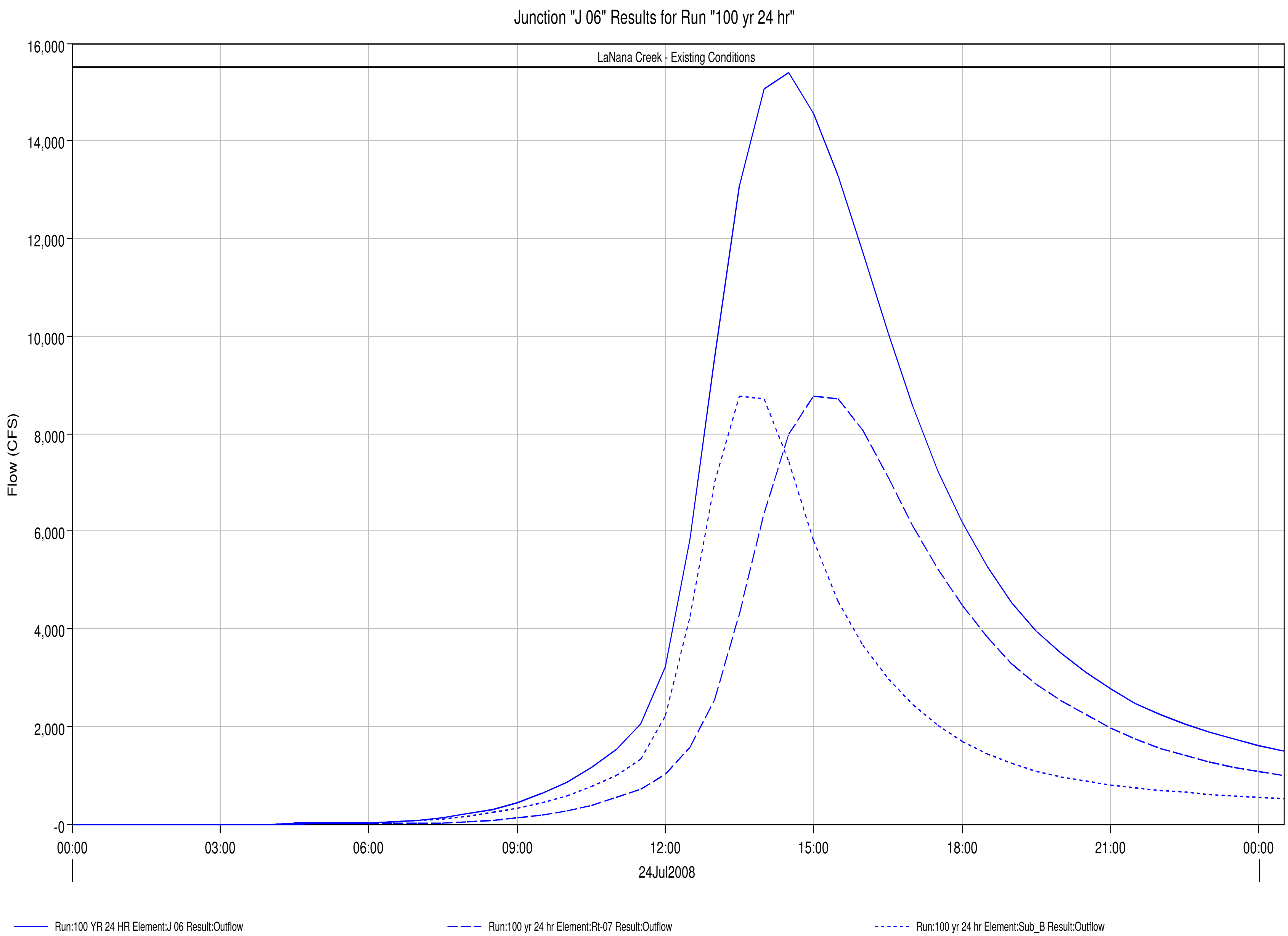
KLOTZ PROJ. NO.: 0836.004.000	Exhibit
SCALE: 1" = 5000	
DATE: January 2009	

T:\Work\0836.004.000\07.00 CADD\GIS\HEC-HMS DIAGRAM

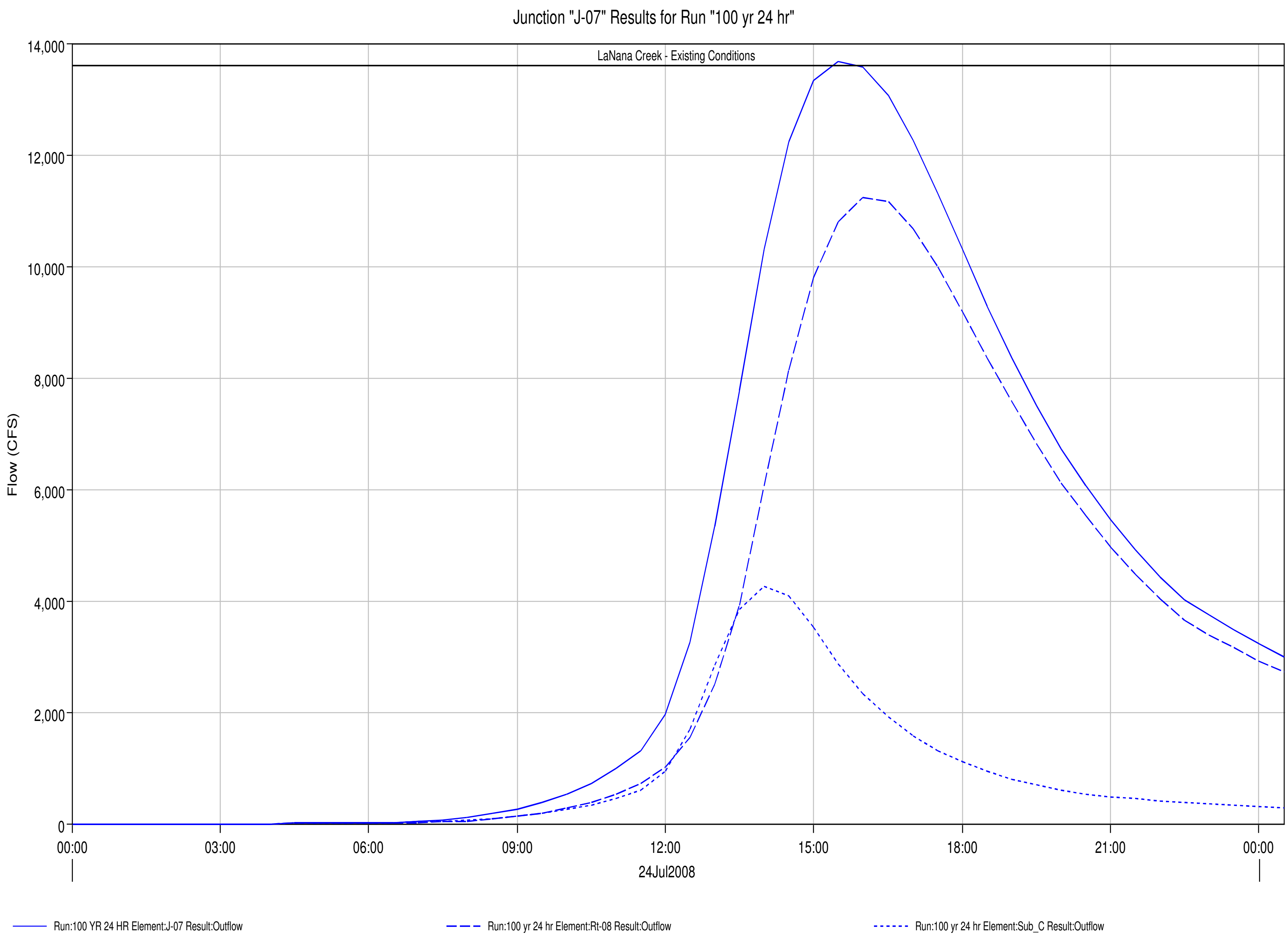
EXISTING FLOOD HYDROGRAPHS

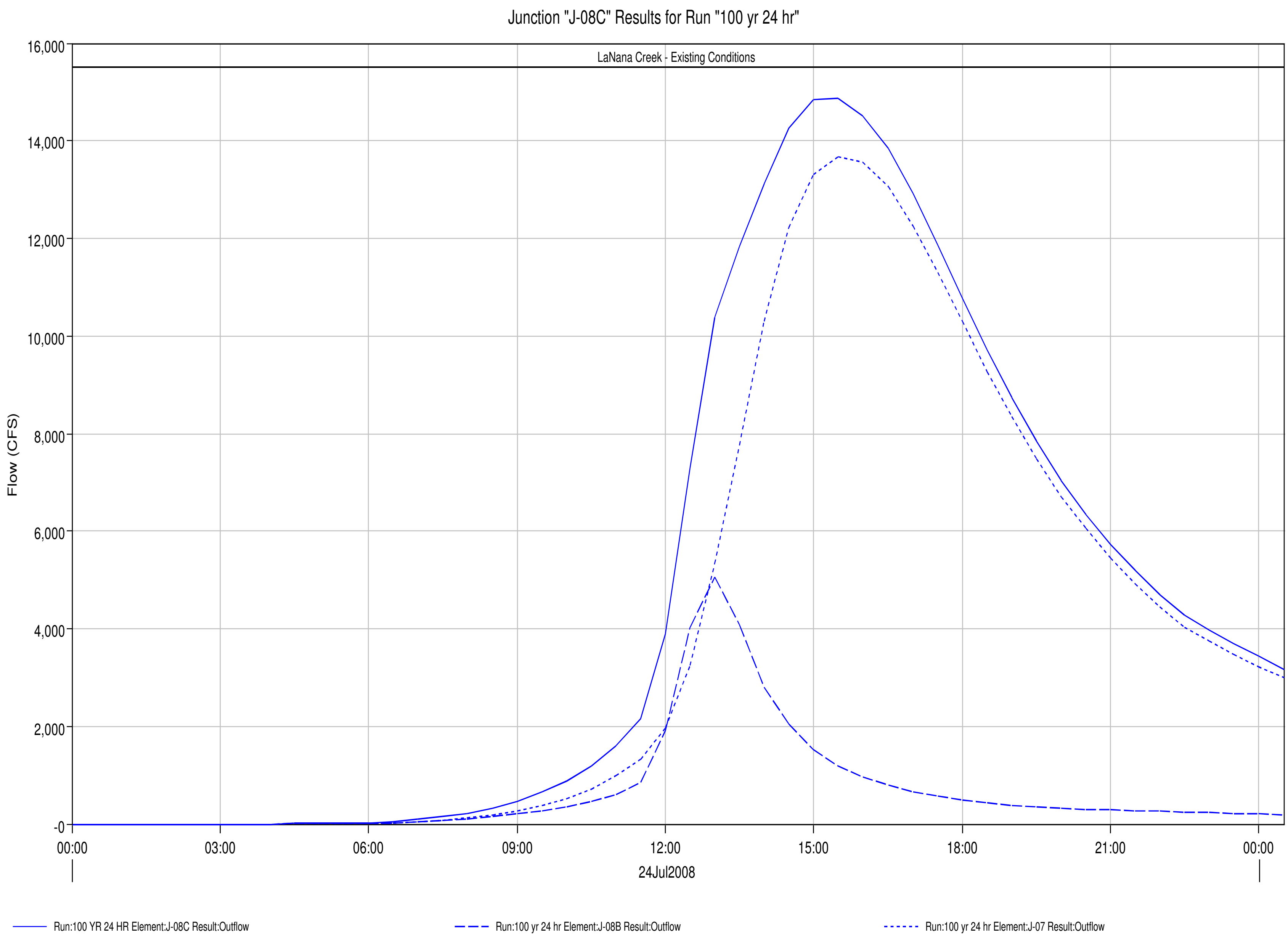


Junction "J-05" Results for Run "100 yr 24 hr"
LaNana Creek - Existing Conditions
Flow (CFS)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-05 Result:Outflow
Run:100 yr 24 hr Element:Sub_A Result:Outflow



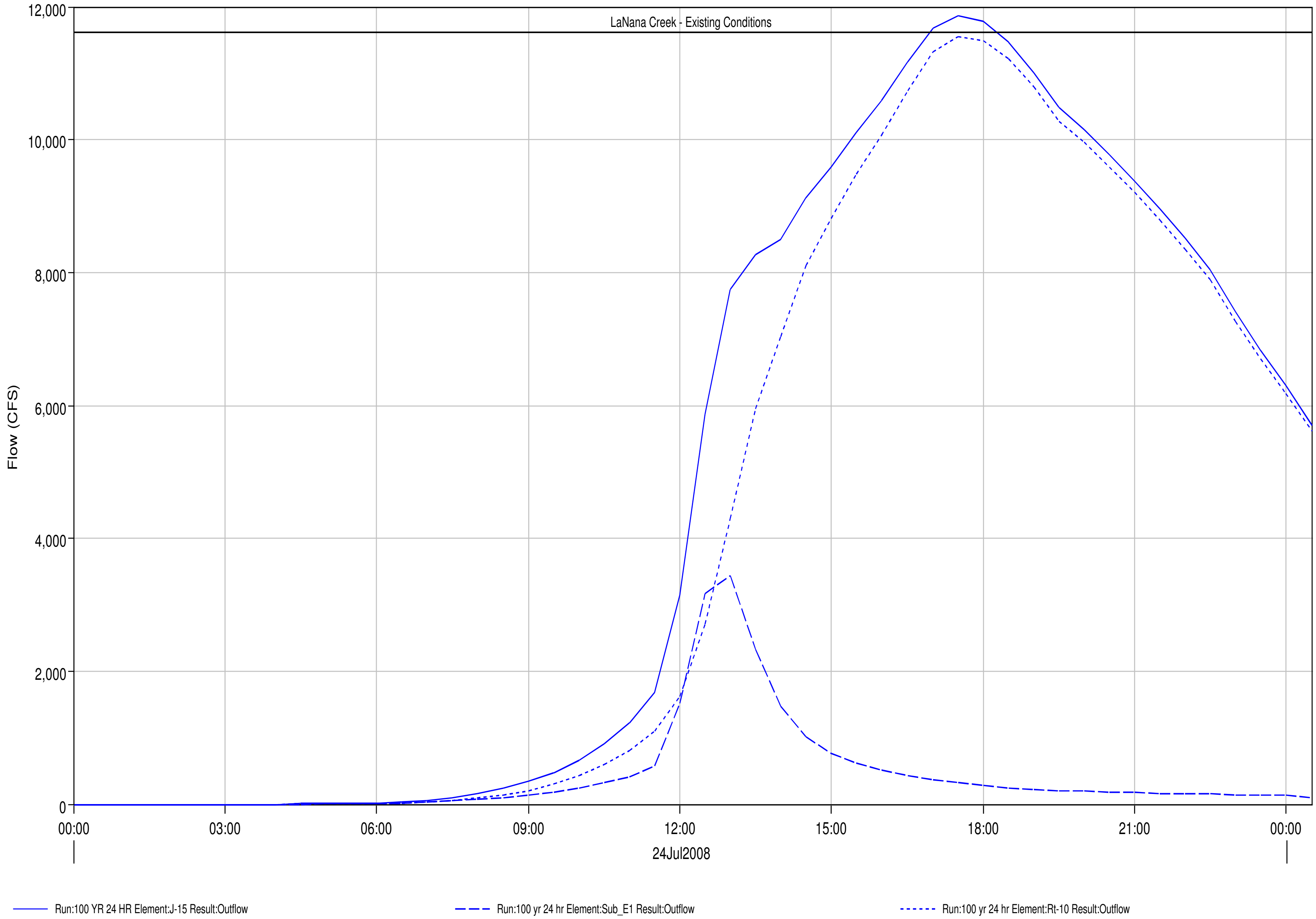
Junction "J 06" Results for Run "100 yr 24 hr"
LaNana Creek - Existing Conditions
Flow (CFS)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J 06 Result:Outflow
Run:100 yr 24 hr Element:Rt-07 Result:Outflow
Run:100 yr 24 hr Element:Sub_B Result:Outflow

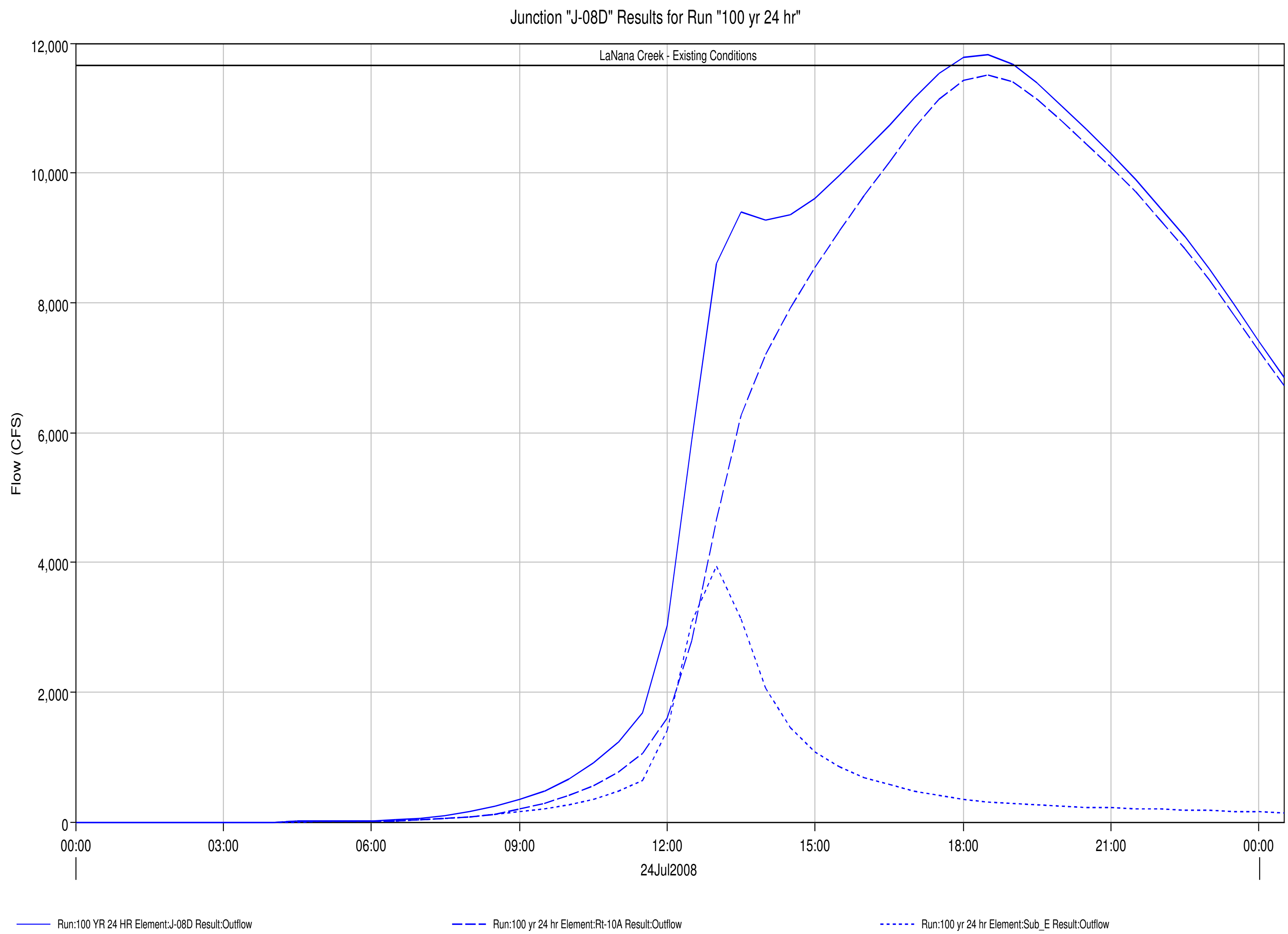

Junction "J-07" Results for Run "100 yr 24 hr"
LaNana Creek - Existing Conditions
Flow (CFS)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-07 Result:Outflow
Run:100 yr 24 hr Element:Rt-08 Result:Outflow
Run:100 yr 24 hr Element:Sub_C Result:Outflow

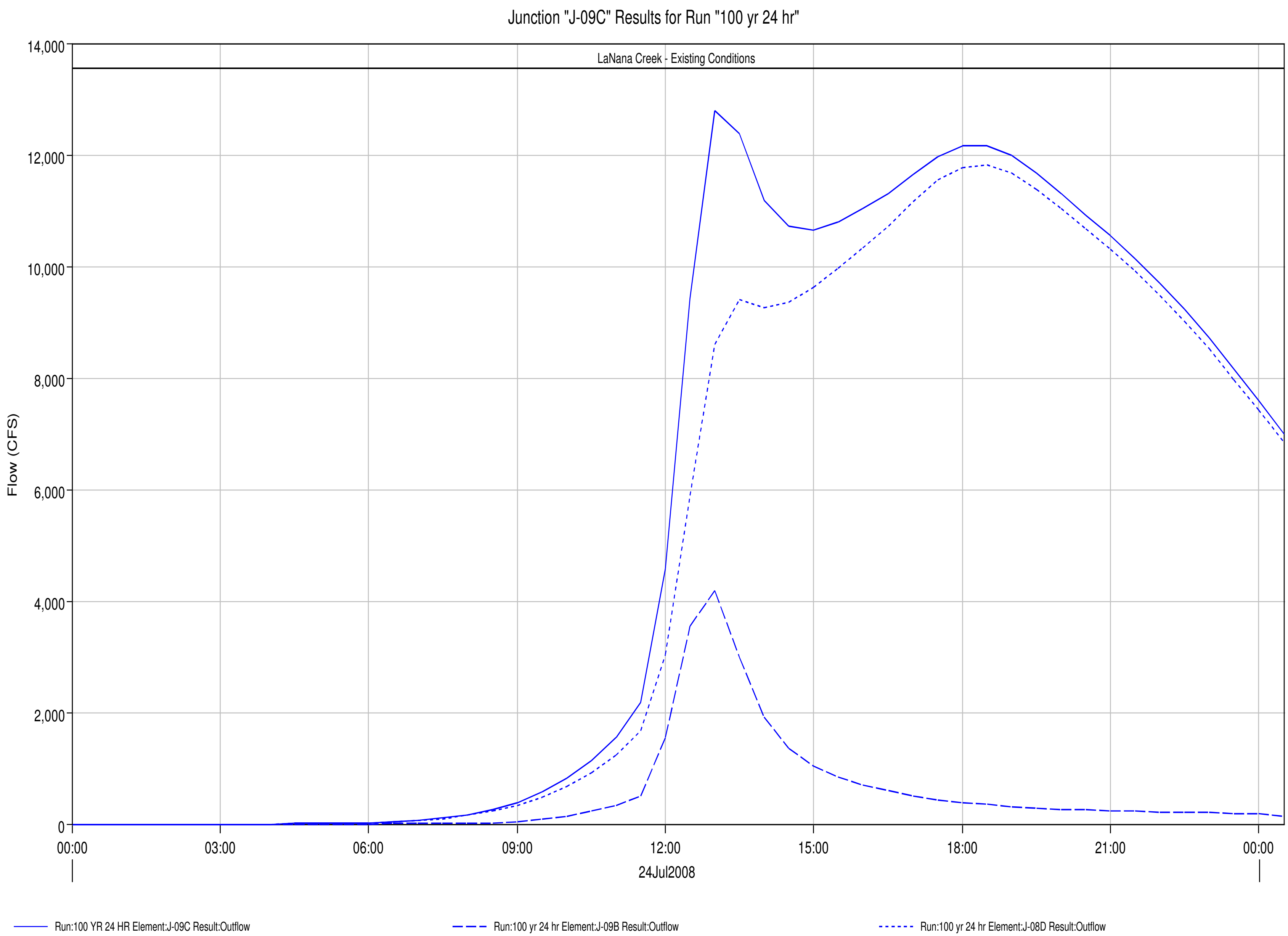


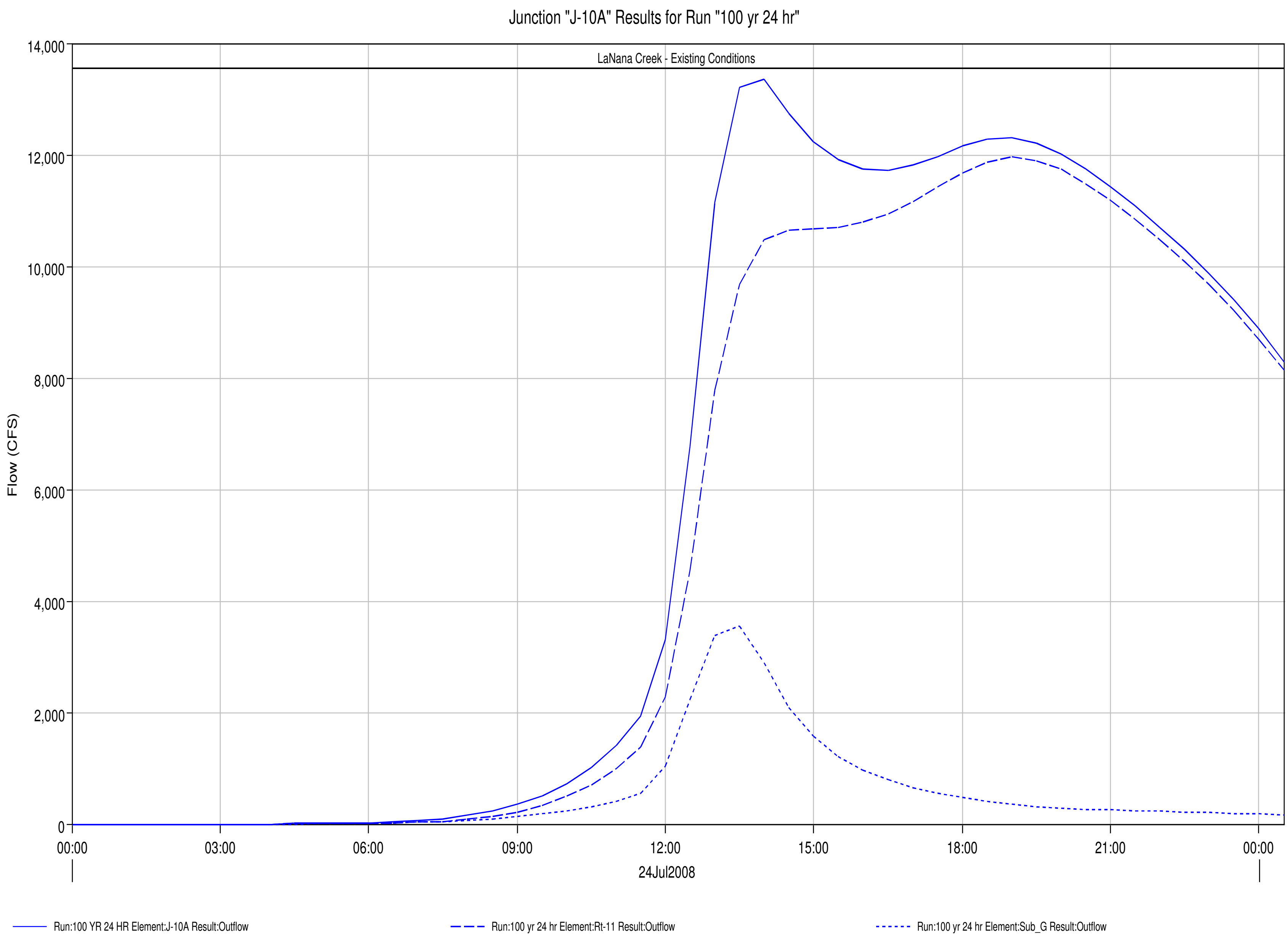
Junction "J-08C" Results for Run "100 yr 24 hr"
LaNana Creek - Existing Conditions
Flow (CFS)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-08C Result:Outflow
Run:100 yr 24 hr Element:J-08B Result:Outflow
Run:100 yr 24 hr Element:J-07 Result:Outflow

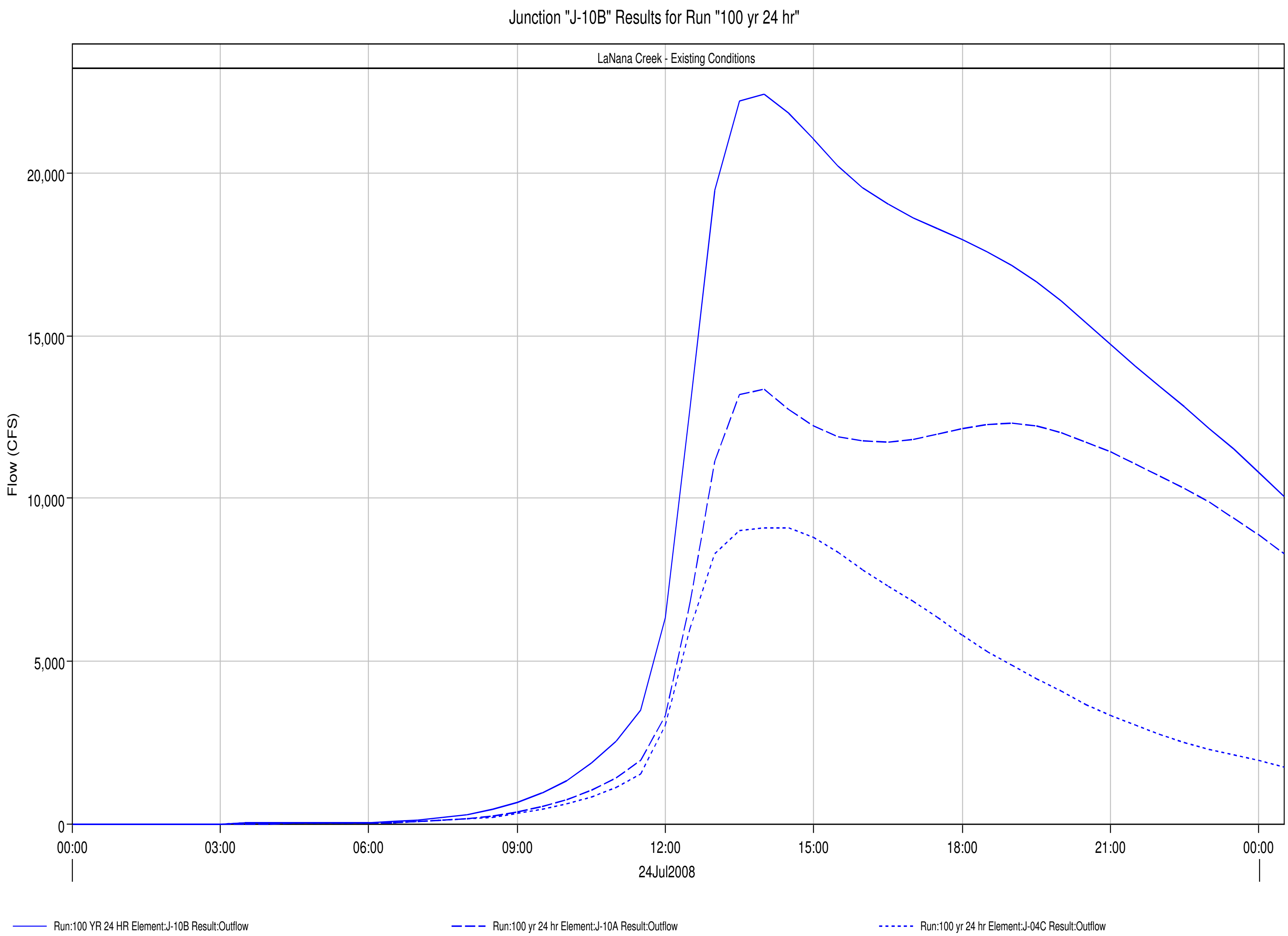
Junction "J-15" Results for Run "100 yr 24 hr"

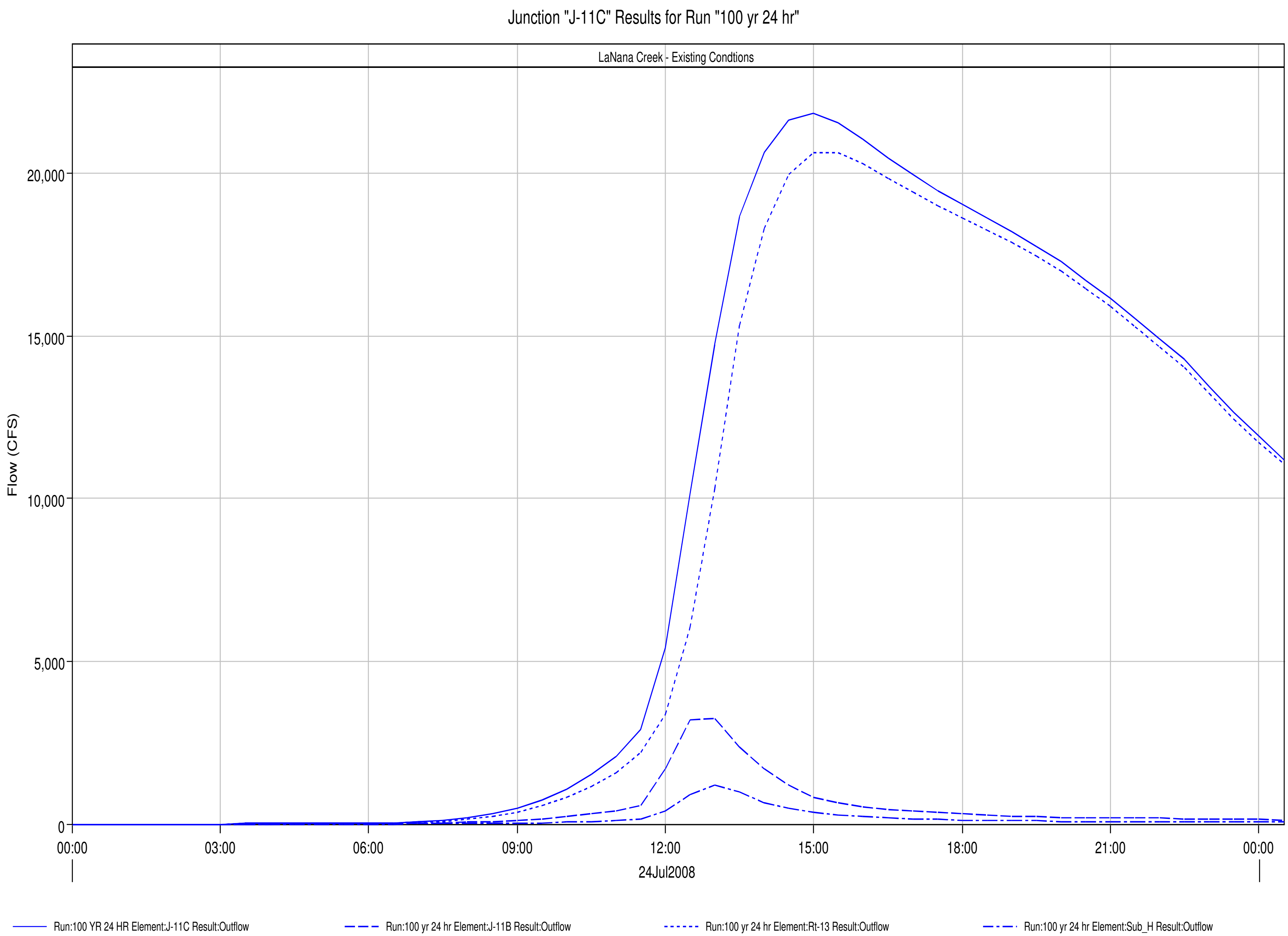



Junction "J-08D" Results for Run "100 yr 24 hr"
LaNana Creek - Existing Conditions
Flow (CFS)
12,000
10,000
8,000
6,000
4,000
2,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-08D Result:Outflow
Run:100 yr 24 hr Element:Rt-10A Result:Outflow
Run:100 yr 24 hr Element:Sub_E Result:Outflow


Junction "J-09C" Results for Run "100 yr 24 hr"
LaNana Creek - Existing Conditions
Flow (CFS)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-09C Result:Outflow
Run:100 yr 24 hr Element:J-09B Result:Outflow
Run:100 yr 24 hr Element:J-08D Result:Outflow

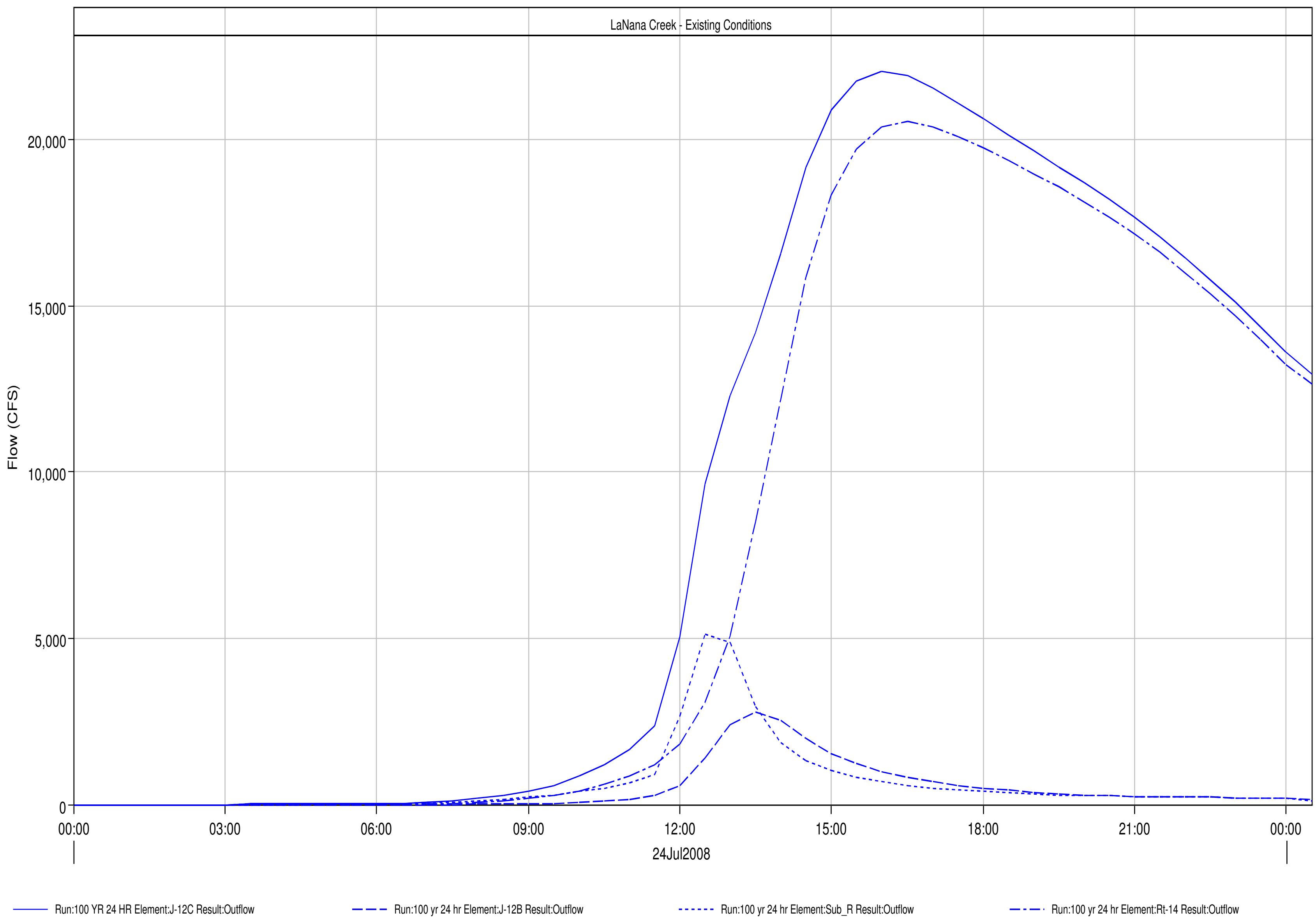

Junction "J-10A" Results for Run "100 yr 24 hr"
LaNana Creek - Existing Conditions
Flow (CFS)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-10A Result:Outflow
Run:100 yr 24 hr Element:Rt-11 Result:Outflow
Run:100 yr 24 hr Element:Sub_G Result:Outflow

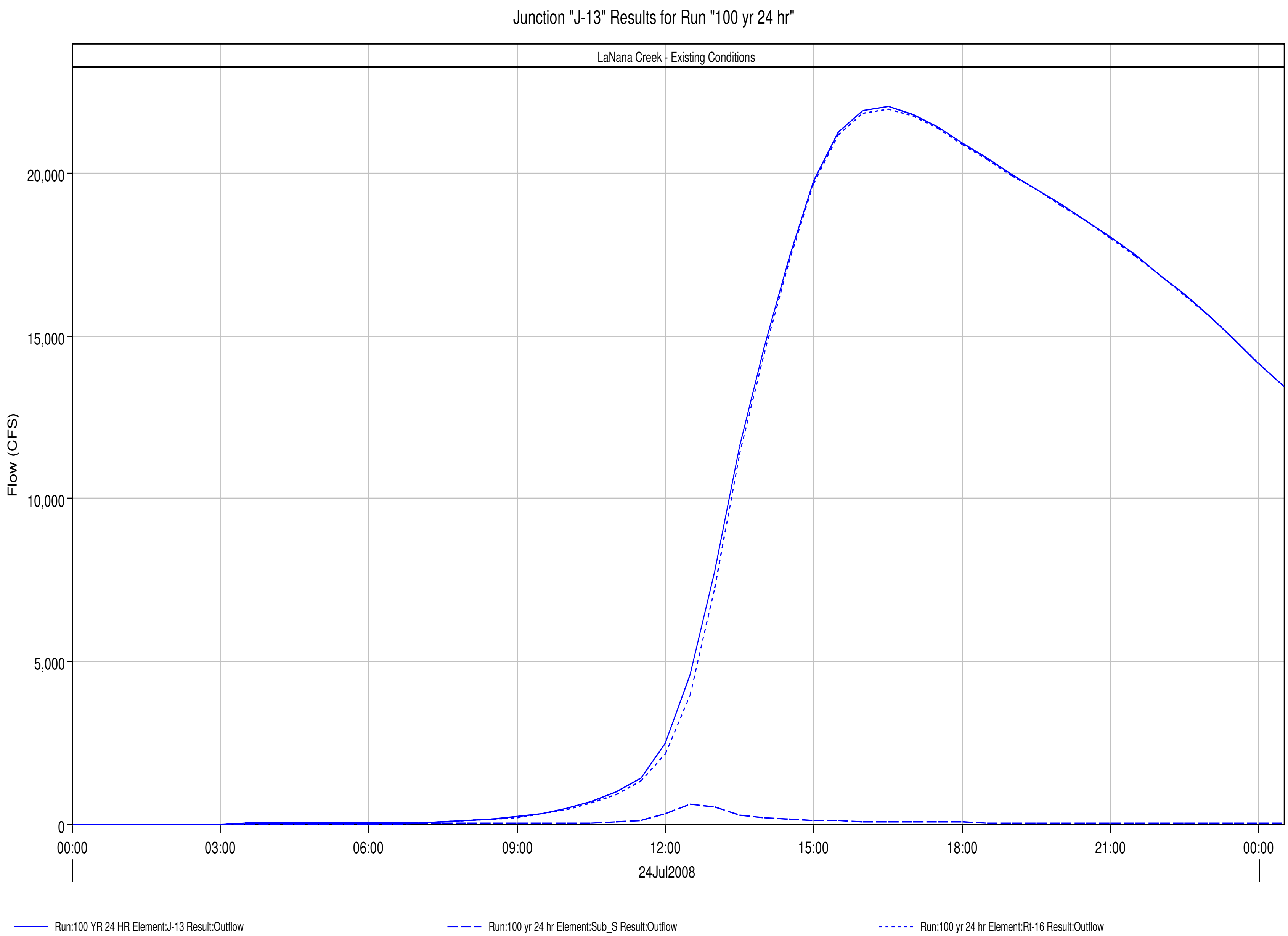

Junction "J-10B" Results for Run "100 yr 24 hr"
LaNana Creek - Existing Conditions
Flow (CFS)
20,000
15,000
10,000
5,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-10B Result:Outflow
Run:100 yr 24 hr Element:J-10A Result:Outflow
Run:100 yr 24 hr Element:J-04C Result:Outflow



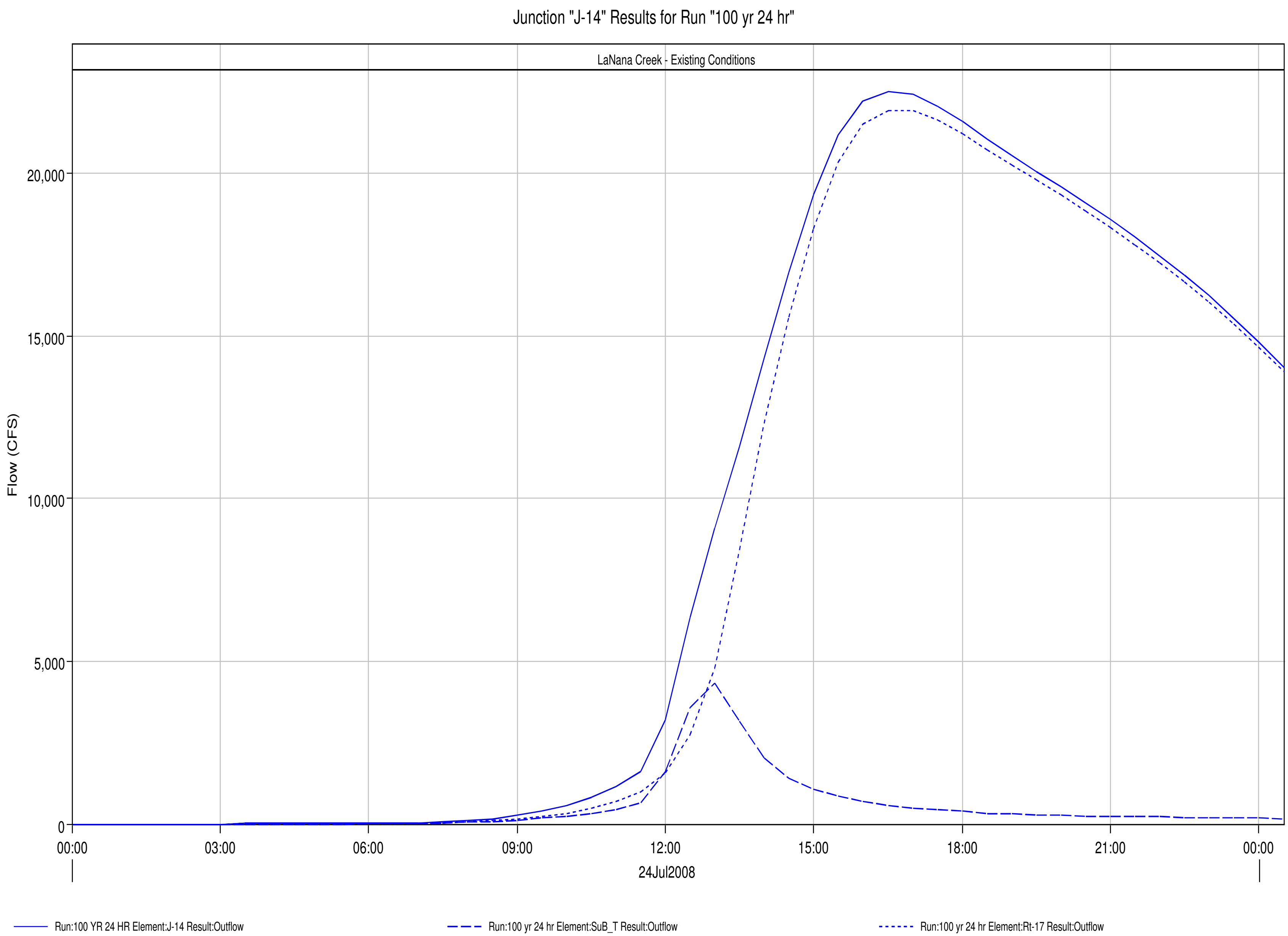
Junction "J-11C" Results for Run "100 yr 24 hr"
LaNana Creek - Existing Condtions
Flow (CFS)
20,000
15,000
10,000
5,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-11C Result:Outflow
Run:100 yr 24 hr Element:J-11B Result:Outflow
Run:100 yr 24 hr Element:Rt-13 Result:Outflow
Run:100 yr 24 hr Element:Sub_H Result:Outflow

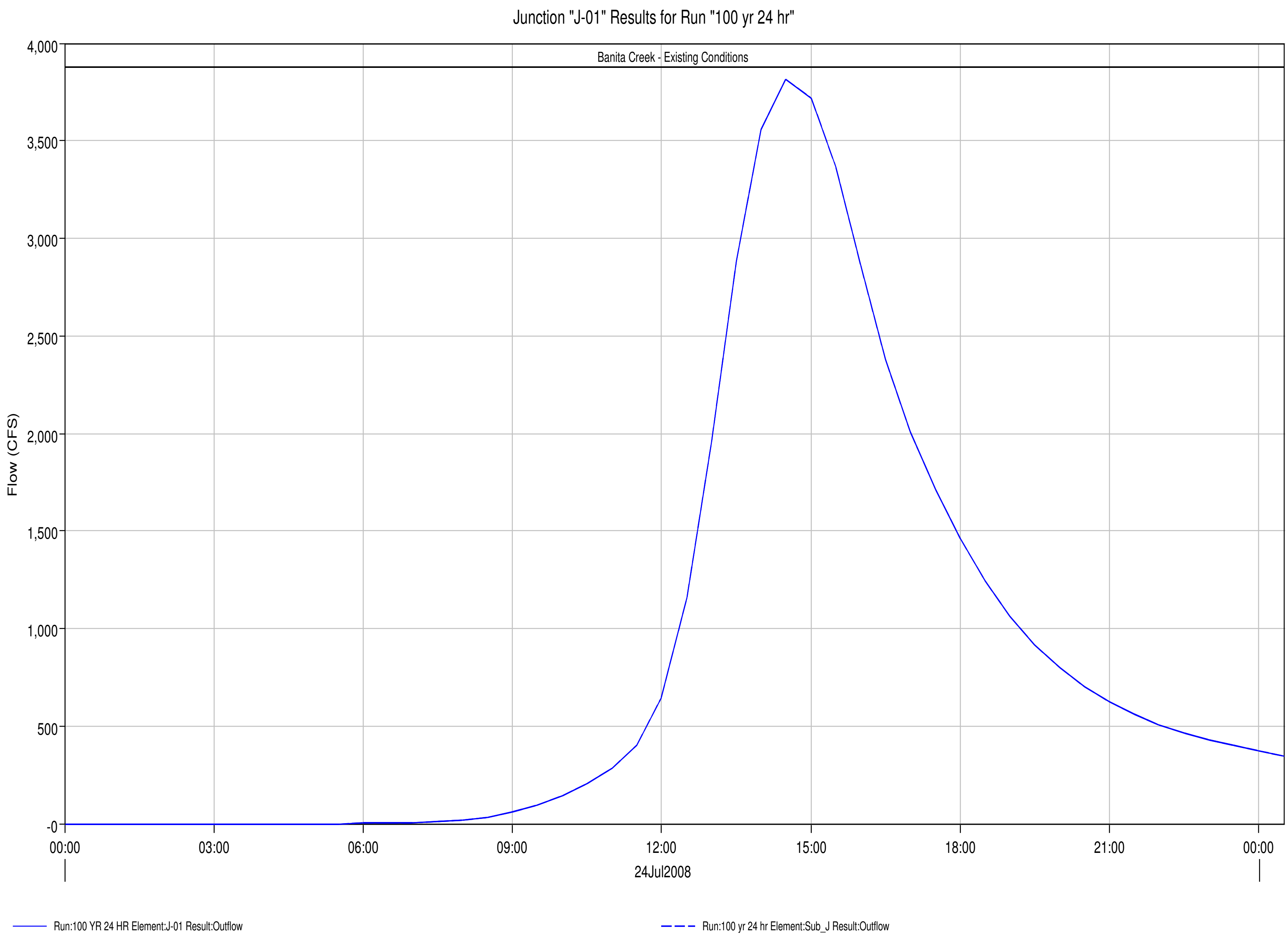
Junction "J-12C" Results for Run "100 yr 24 hr"





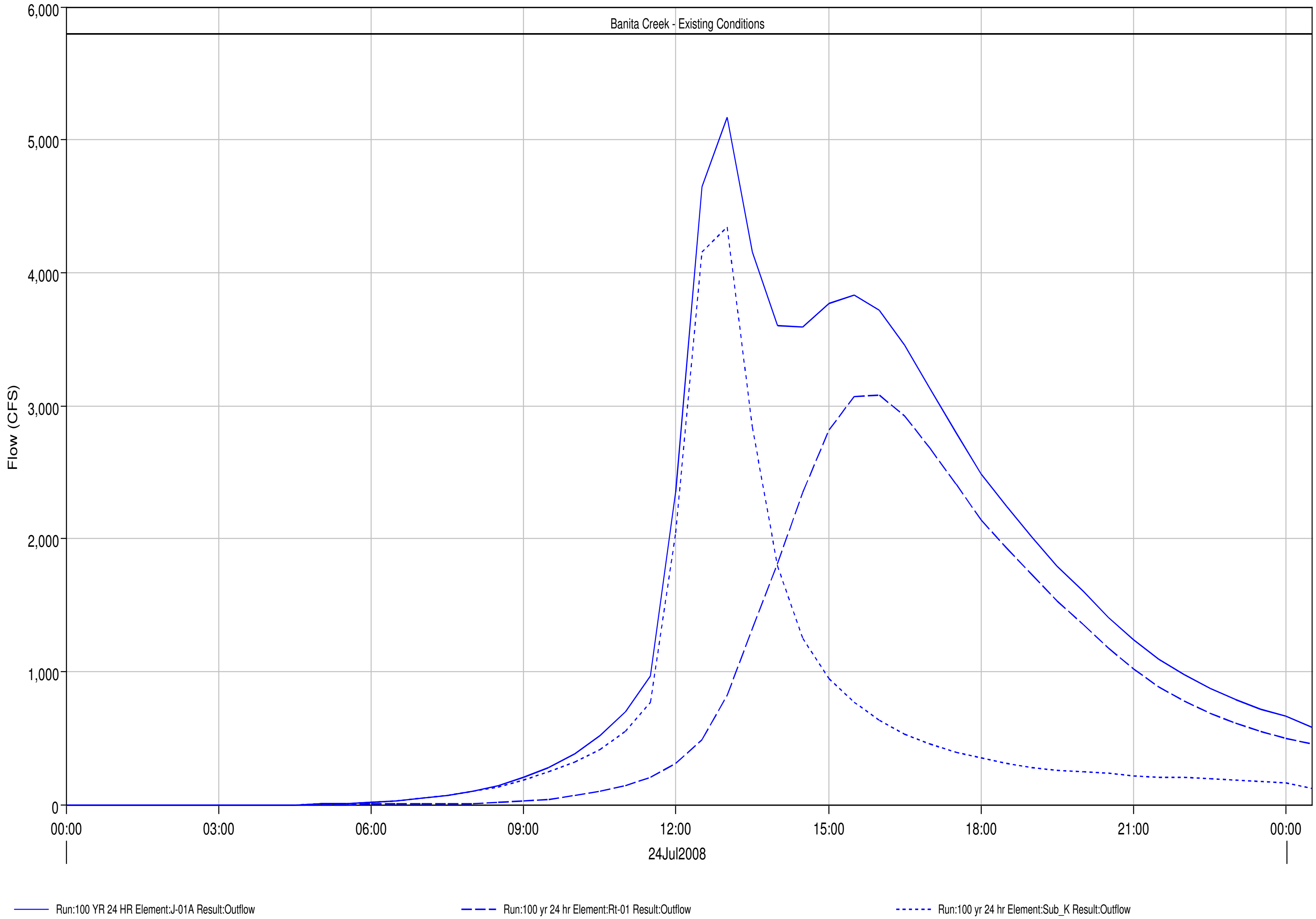
Junction "J-13" Results for Run "100 yr 24 hr"
LaNana Creek - Existing Conditions
Flow (CFS)
20,000
15,000
10,000
5,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-13 Result:Outflow
Run:100 yr 24 hr Element:Sub_S Result:Outflow
Run:100 yr 24 hr Element:Rt-16 Result:Outflow

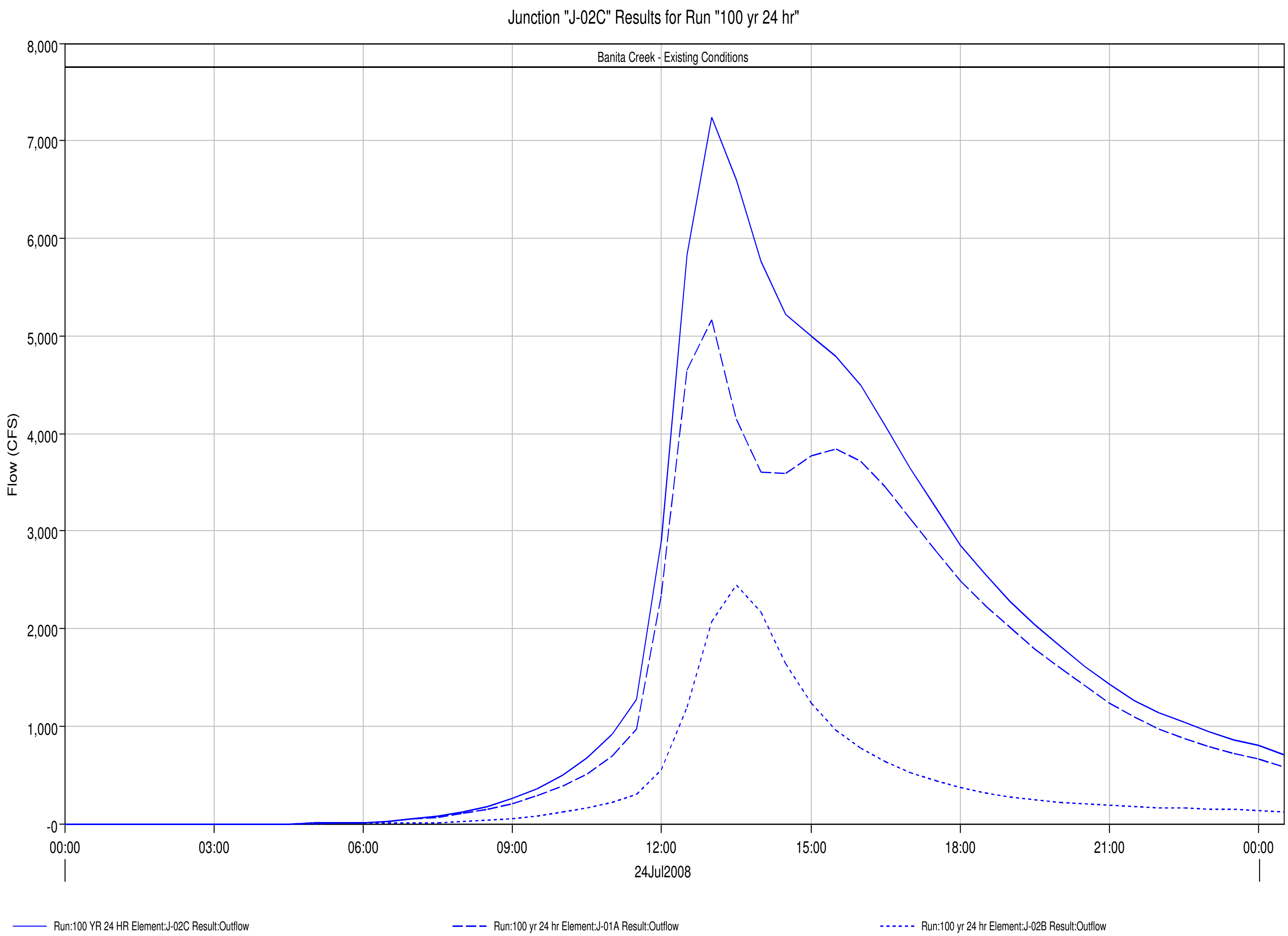

Junction "J-14" Results for Run "100 yr 24 hr"
LaNana Creek - Existing Conditions
Flow (CFS)
20,000
15,000
10,000
5,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-14 Result:Outflow
Run:100 yr 24 hr Element:SuB_T Result:Outflow
Run:100 yr 24 hr Element:Rt-17 Result:Outflow

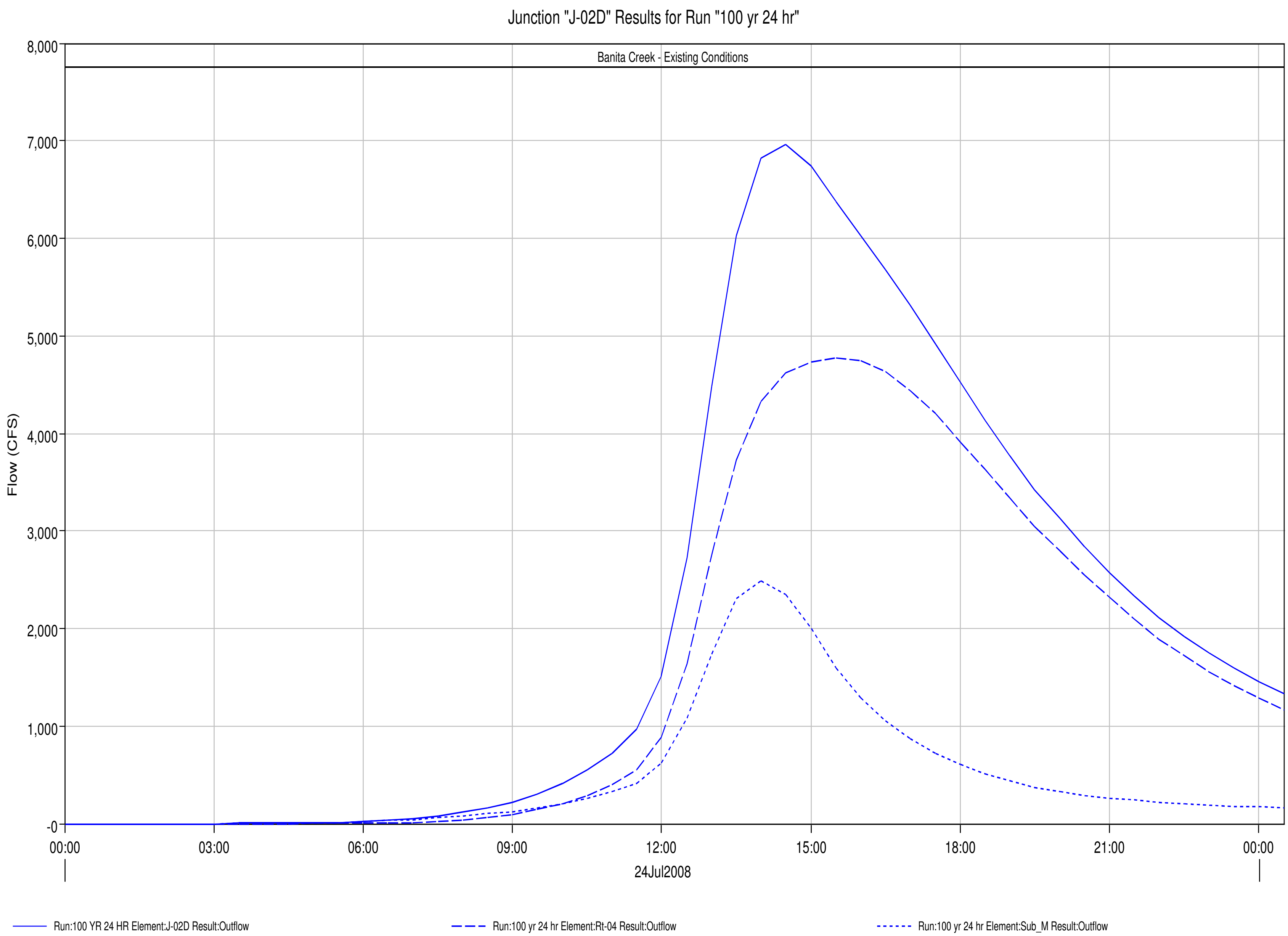


Junction "J-01" Results for Run "100 yr 24 hr"
Banita Creek - Existing Conditions
Flow (CFS)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
-0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-01 Result:Outflow
Run:100 yr 24 hr Element:Sub_J Result:Outflow

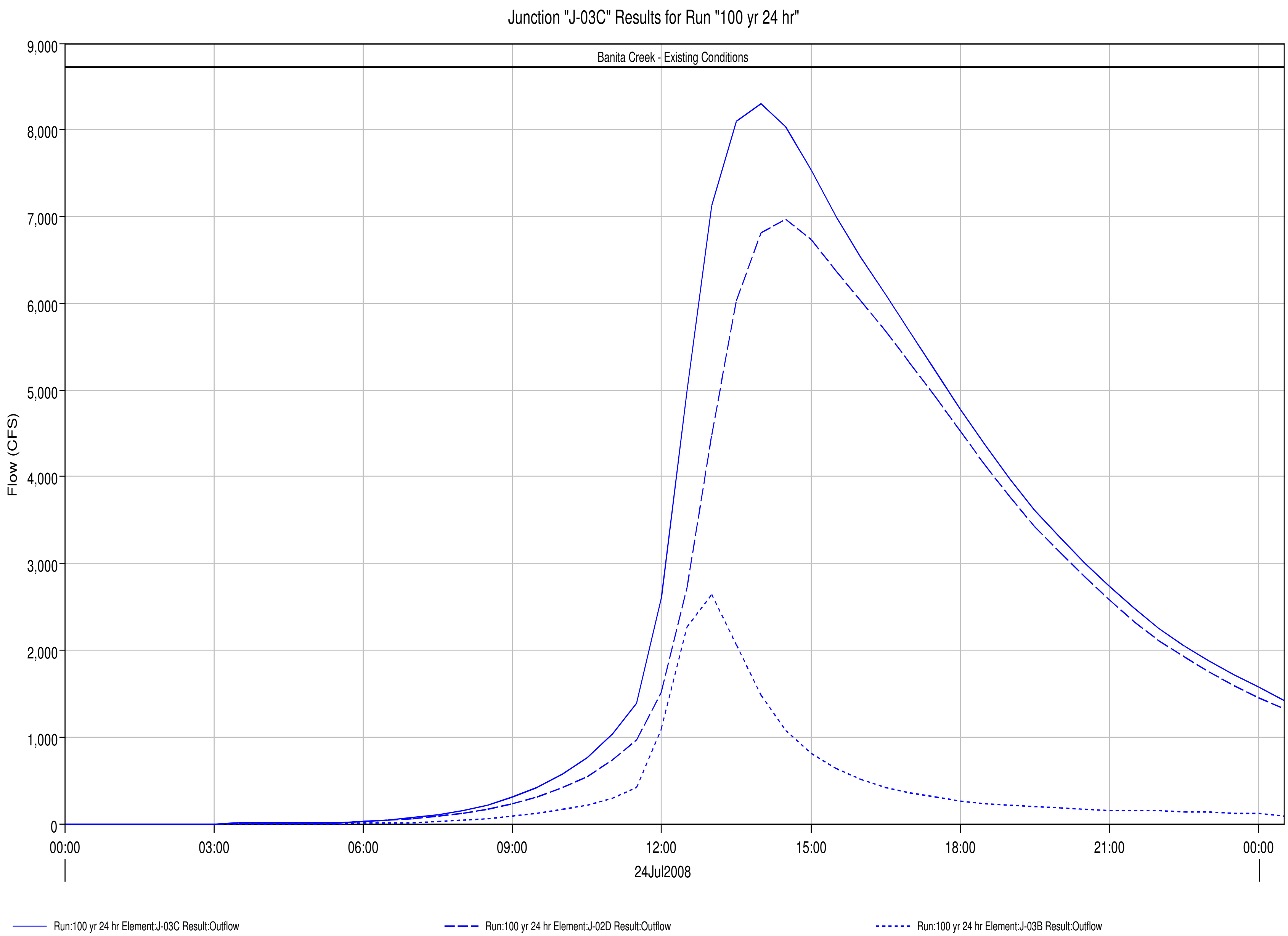
Junction "J-01A" Results for Run "100 yr 24 hr"

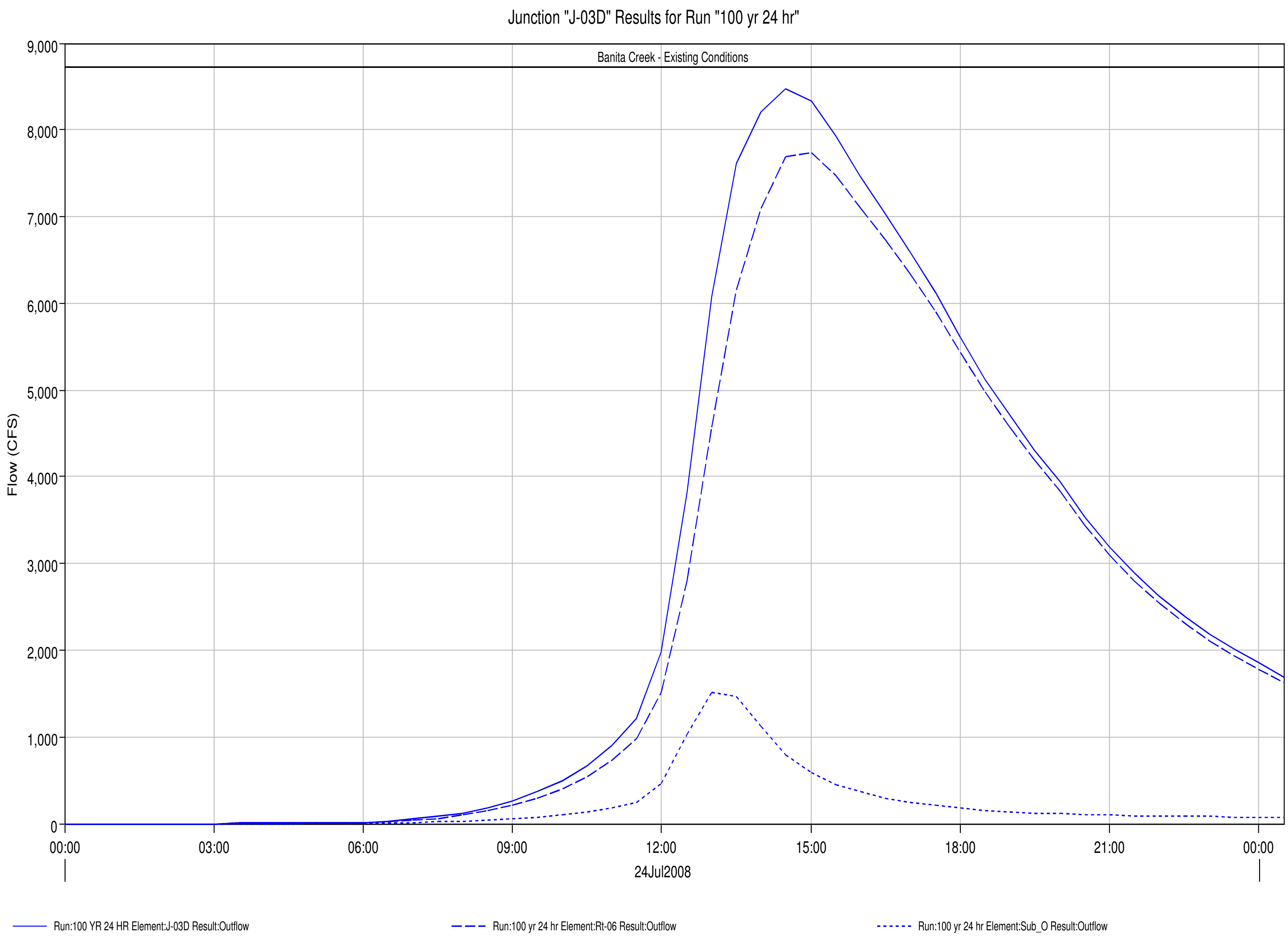


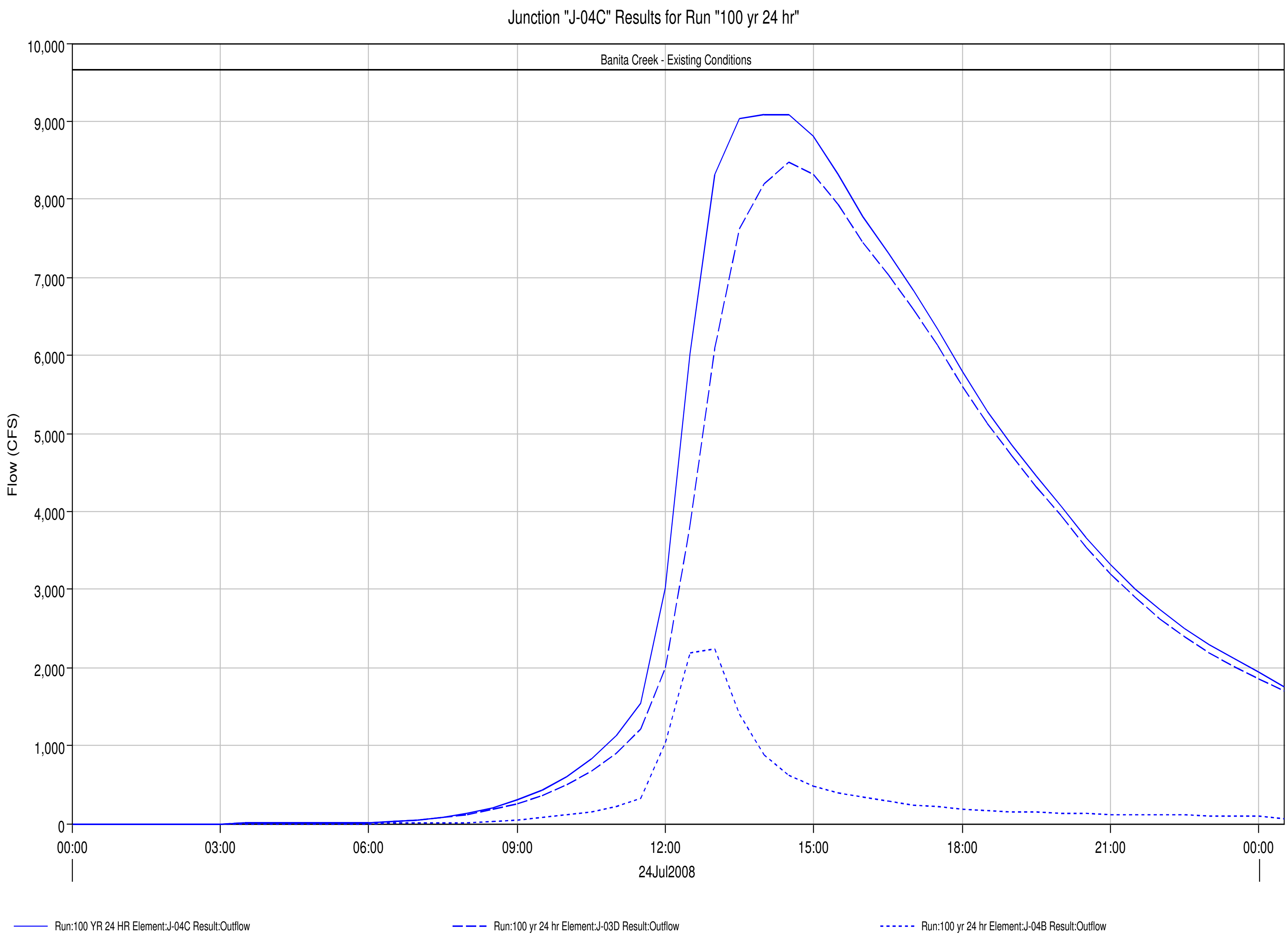

Junction "J-02C" Results for Run "100 yr 24 hr"
Banita Creek - Existing Conditions
Flow (CFS)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
-0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-02C Result:Outflow
Run:100 yr 24 hr Element:J-01A Result:Outflow
Run:100 yr 24 hr Element:J-02B Result:Outflow



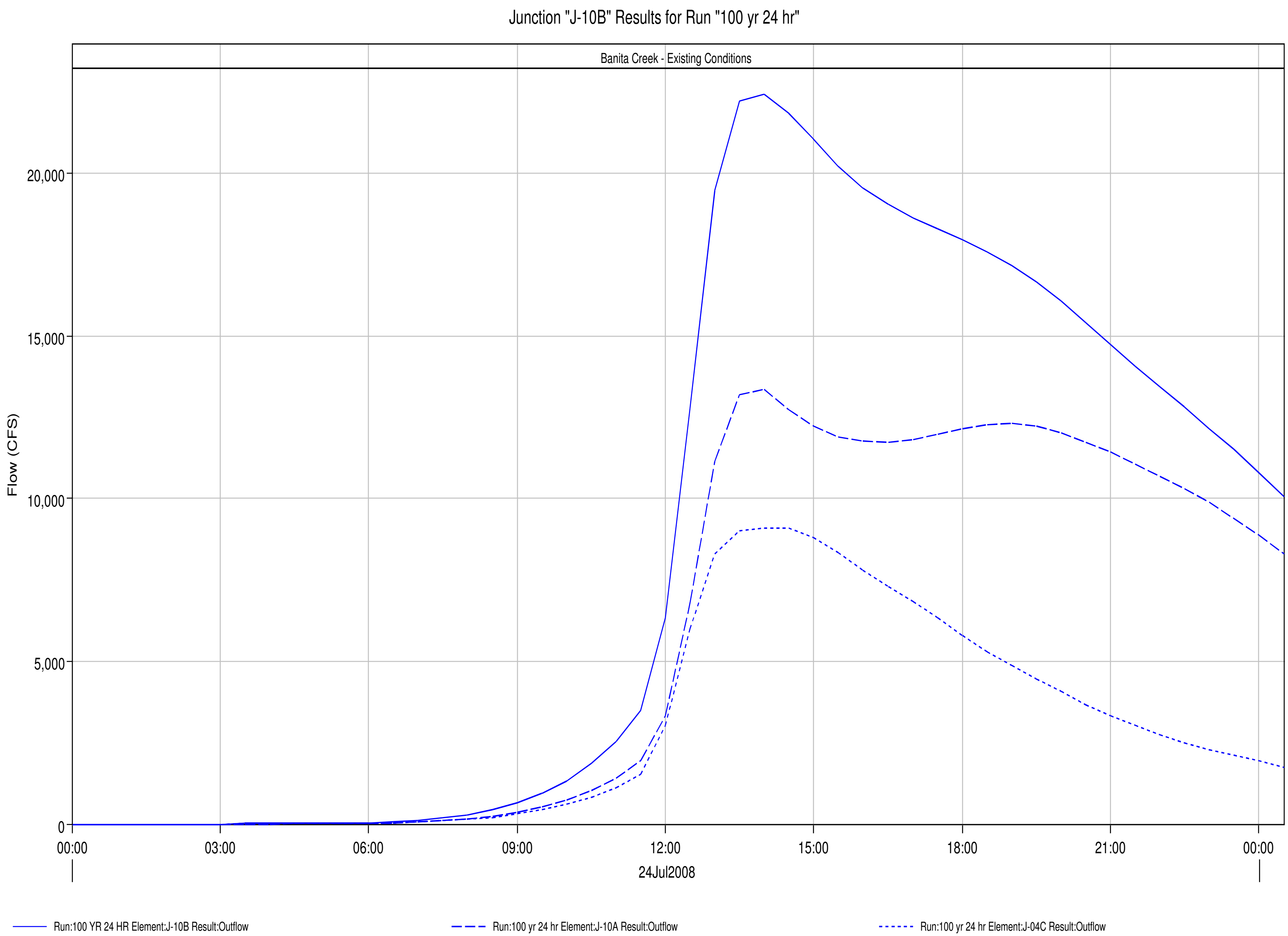
Junction "J-02D" Results for Run "100 yr 24 hr"
Banita Creek - Existing Conditions
Flow (CFS)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
-0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-02D Result:Outflow
Run:100 yr 24 hr Element:Rt-04 Result:Outflow
Run:100 yr 24 hr Element:Sub_M Result:Outflow


Junction "J-03C" Results for Run "100 yr 24 hr"
Banita Creek - Existing Conditions
Flow (CFS)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 yr 24 hr Element:J-03C Result:Outflow
Run:100 yr 24 hr Element:J-02D Result:Outflow
Run:100 yr 24 hr Element:J-03B Result:Outflow


Junction "J-03D" Results for Run "100 yr 24 hr"
Banita Creek - Existing Conditions
Flow (CFS)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-03D Result:Outflow
Run:100 yr 24 hr Element:Rt-06 Result:Outflow
Run:100 yr 24 hr Element:Sub_O Result:Outflow

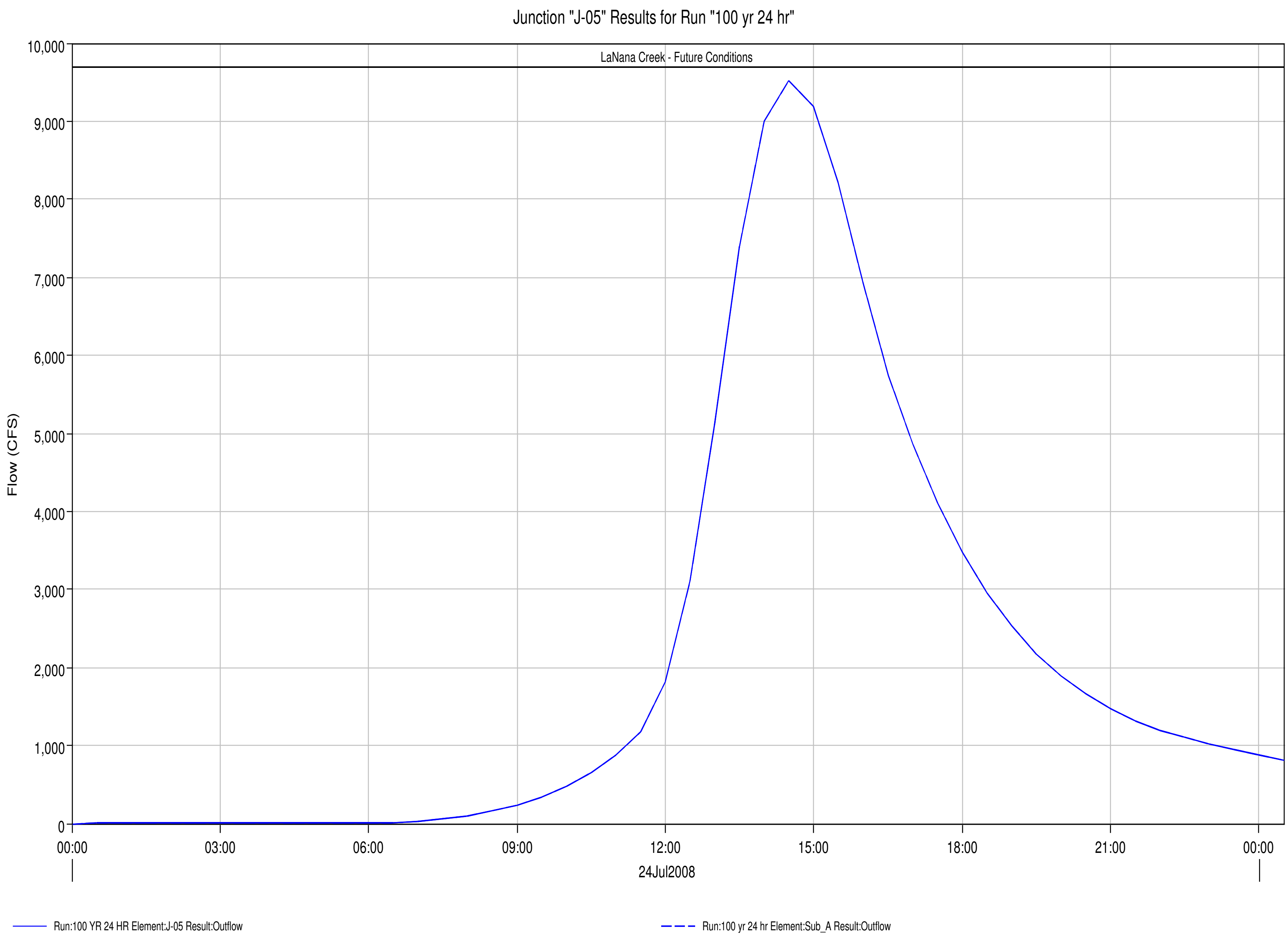


Junction "J-04C" Results for Run "100 yr 24 hr"
Banita Creek - Existing Conditions
Flow (CFS)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-04C Result:Outflow
Run:100 yr 24 hr Element:J-03D Result:Outflow
Run:100 yr 24 hr Element:J-04B Result:Outflow

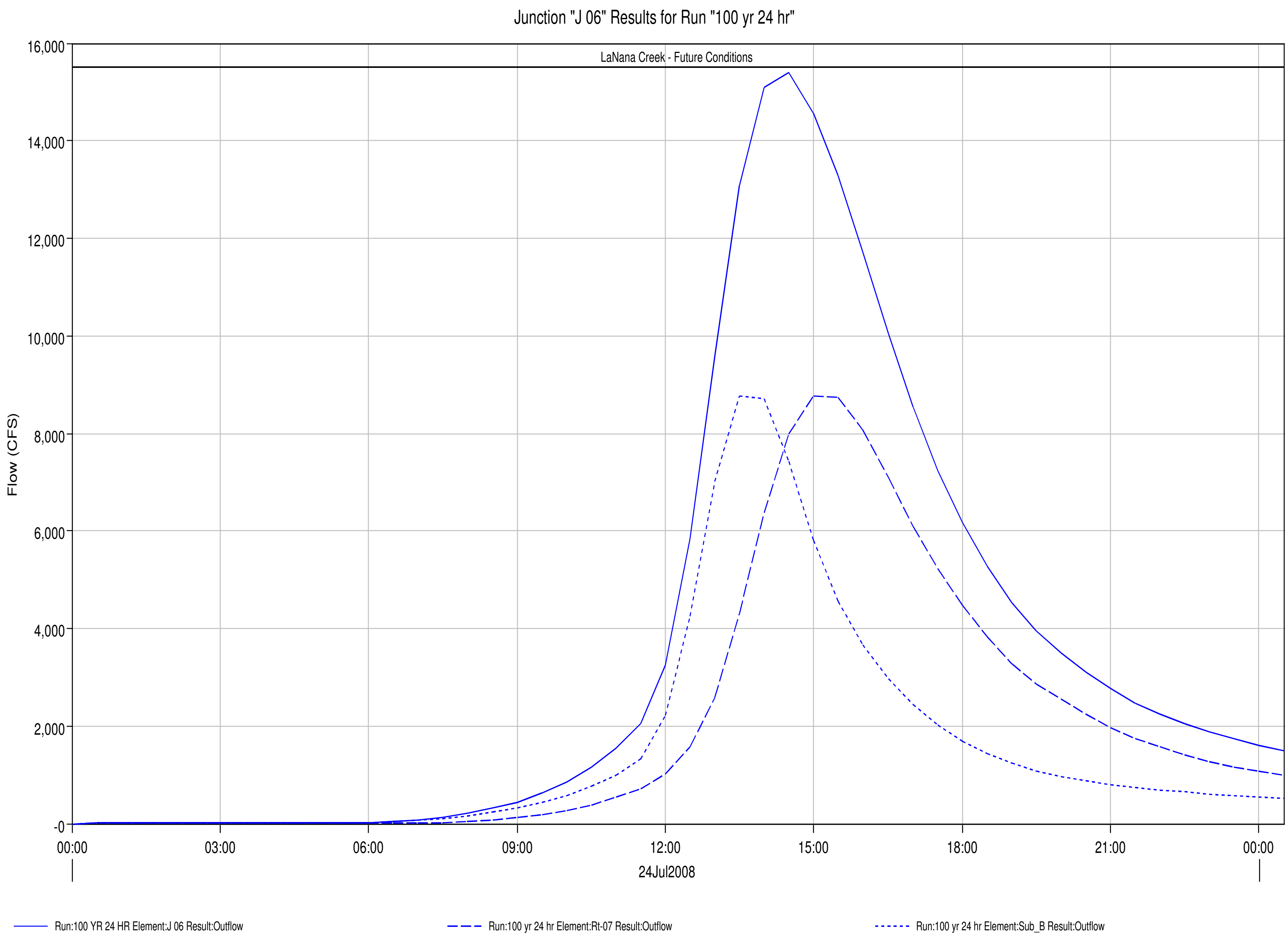


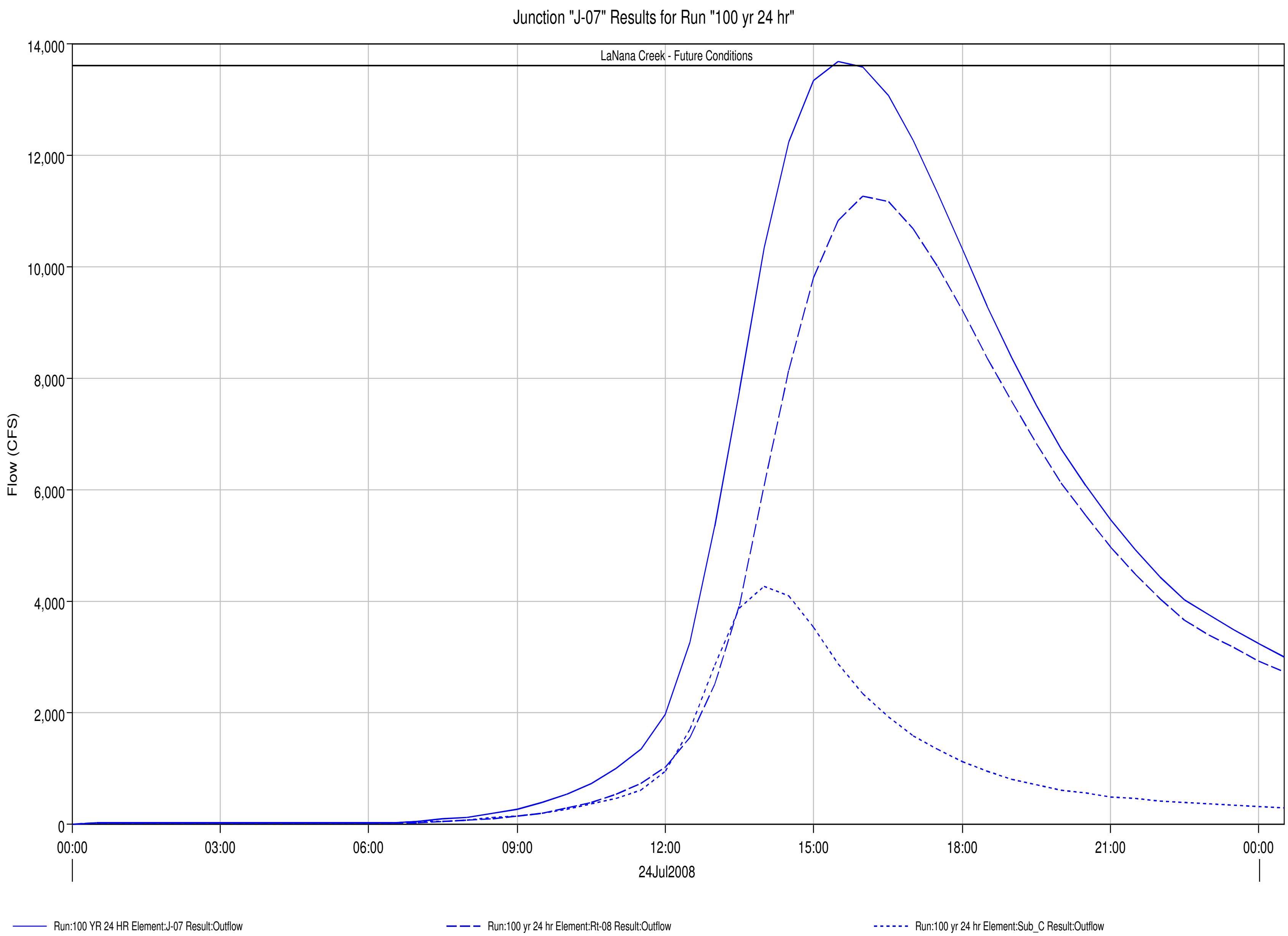
Junction "J-10B" Results for Run "100 yr 24 hr"
Banita Creek - Existing Conditions
Flow (CFS)
20,000
15,000
10,000
5,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-10B Result:Outflow
Run:100 yr 24 hr Element:J-10A Result:Outflow
Run:100 yr 24 hr Element:J-04C Result:Outflow

FUTURE FLOOD HYDROGRAPHS



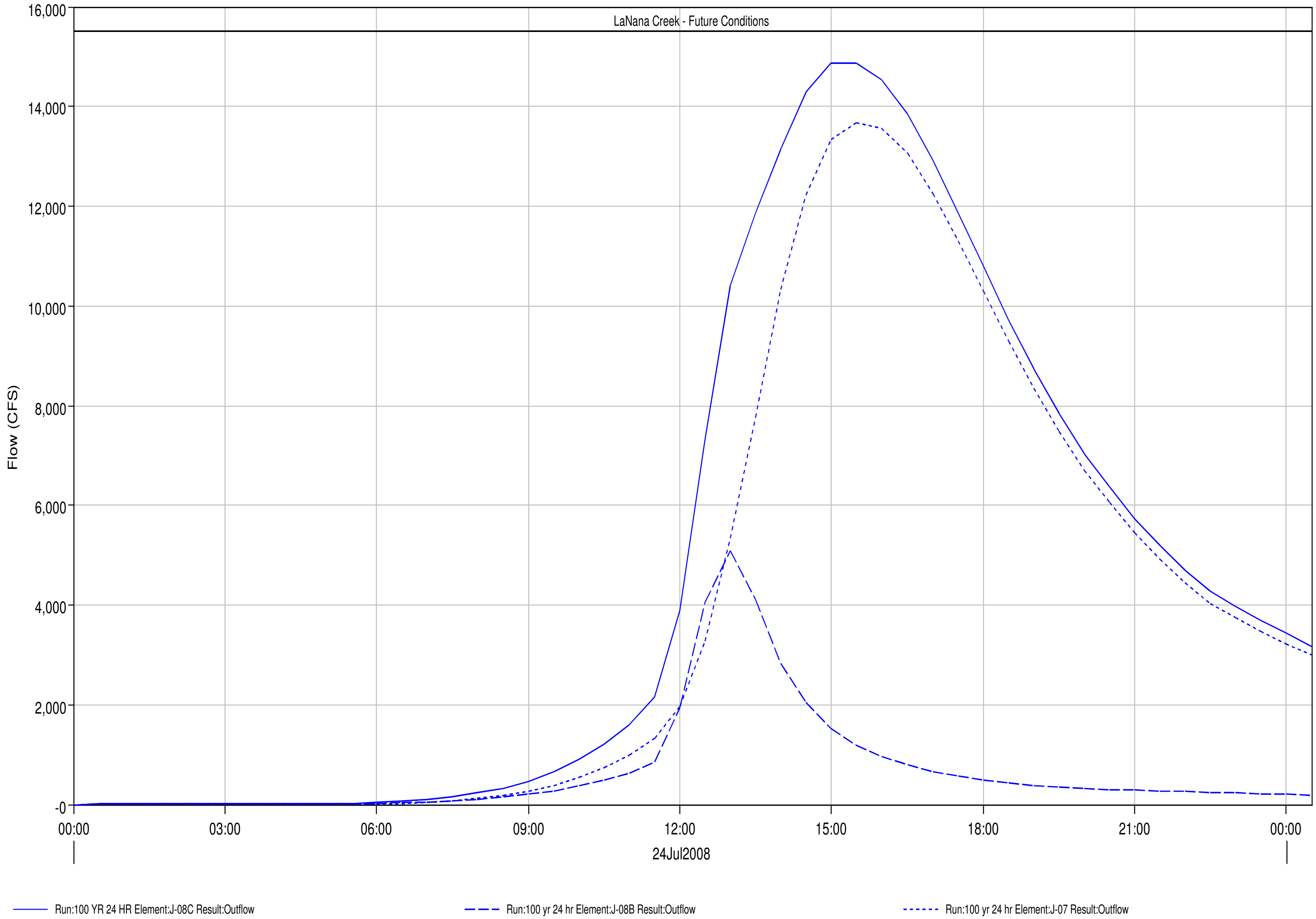
Junction "J-05" Results for Run "100 yr 24 hr"
LaNana Creek - Future Conditions
Flow (CFS)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-05 Result:Outflow
Run:100 yr 24 hr Element:Sub_A Result:Outflow

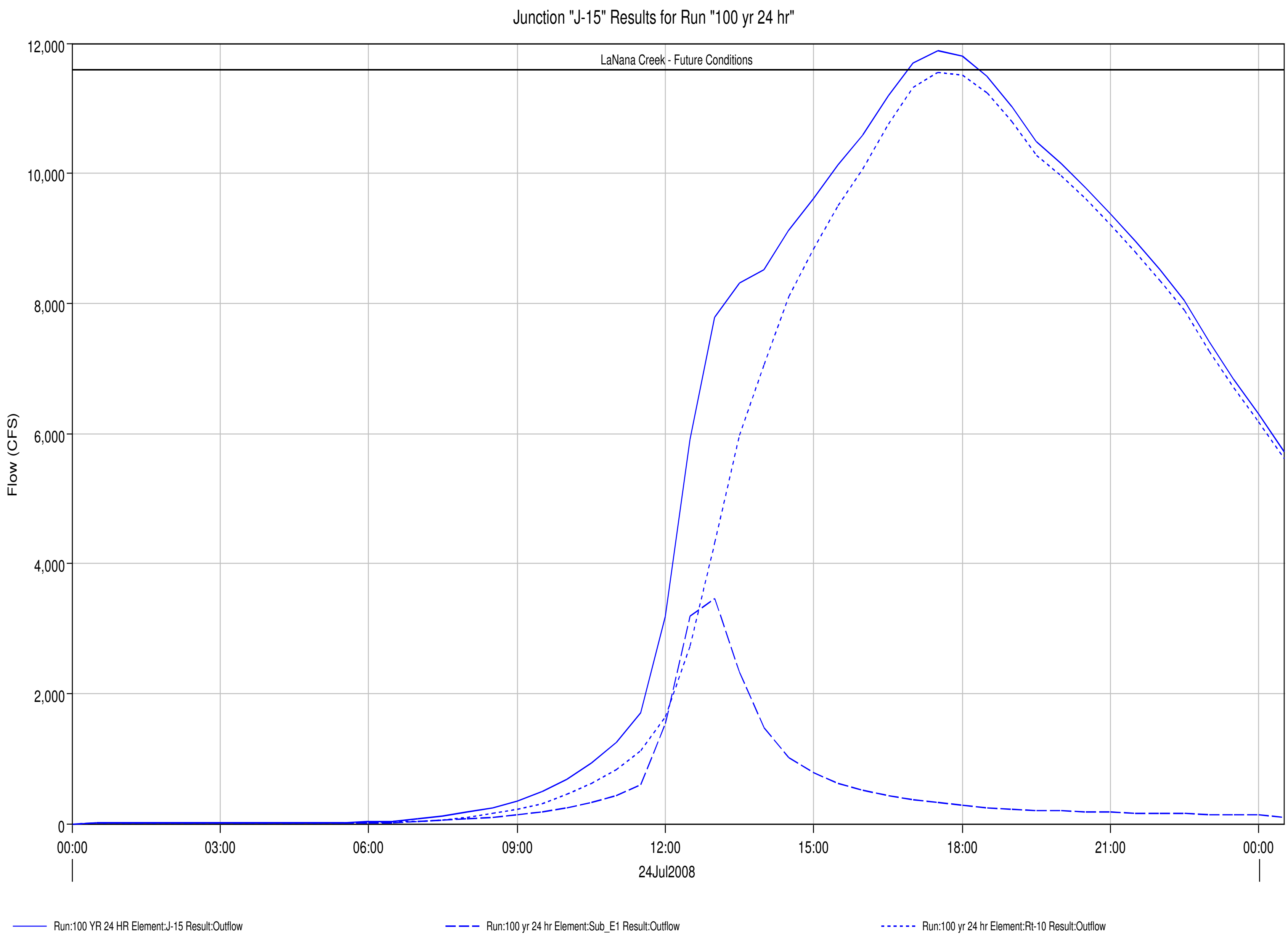

Junction "J 06" Results for Run "100 yr 24 hr"
LaNana Creek - Future Conditions
Flow (CFS)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J 06 Result:Outflow
Run:100 yr 24 hr Element:Rt-07 Result:Outflow
Run:100 yr 24 hr Element:Sub_B Result:Outflow



Junction "J-07" Results for Run "100 yr 24 hr"
LaNana Creek - Future Conditions
Flow (CFS)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-07 Result:Outflow
Run:100 yr 24 hr Element:Rt-08 Result:Outflow
Run:100 yr 24 hr Element:Sub_C Result:Outflow

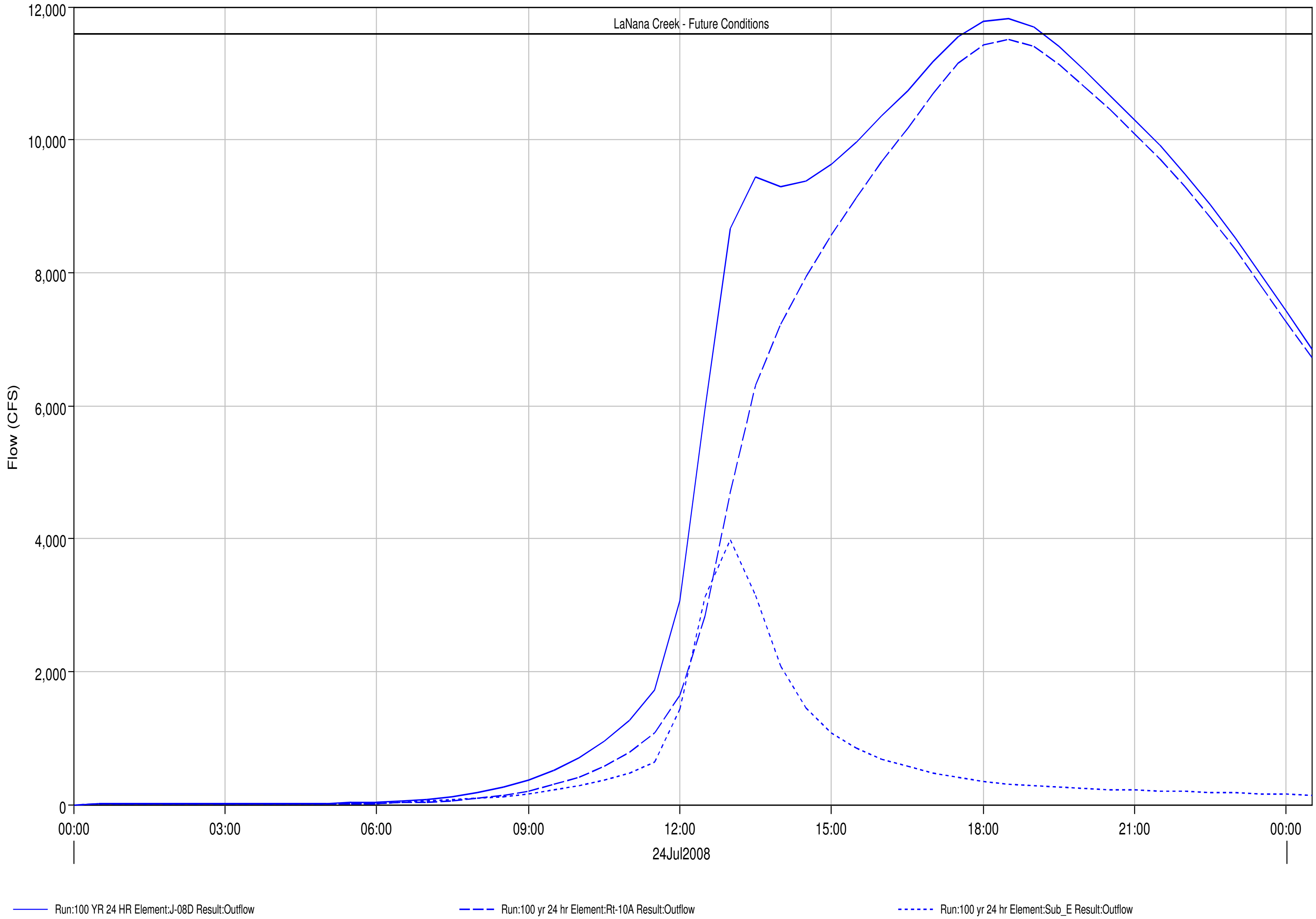
Junction "J-08C" Results for Run "100 yr 24 hr"

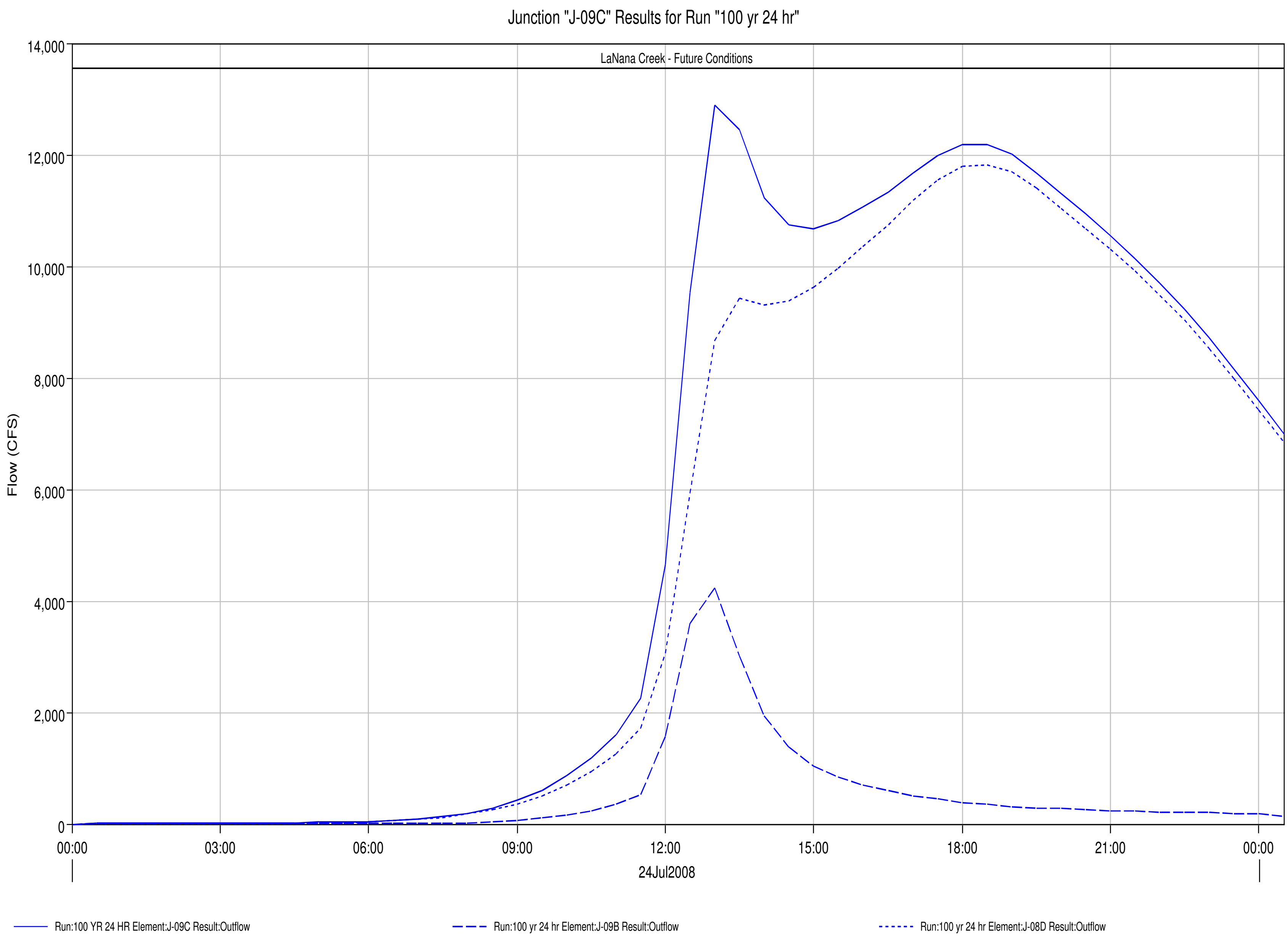




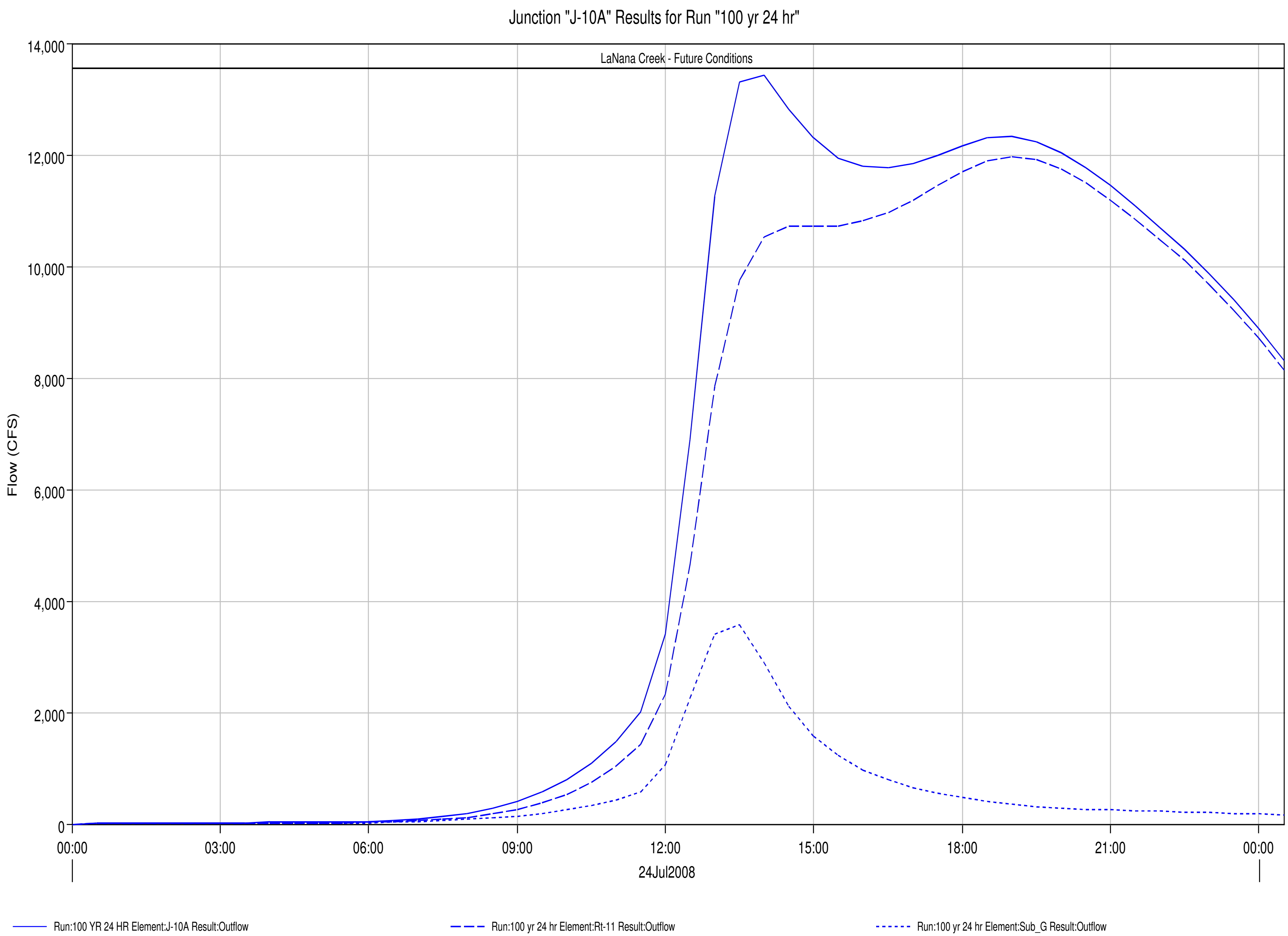
Junction "J-15" Results for Run "100 yr 24 hr"
LaNana Creek - Future Conditions
Flow (CFS)
12,000
10,000
8,000
6,000
4,000
2,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-15 Result:Outflow
Run:100 yr 24 hr Element:Sub_E1 Result:Outflow
Run:100 yr 24 hr Element:Rt-10 Result:Outflow

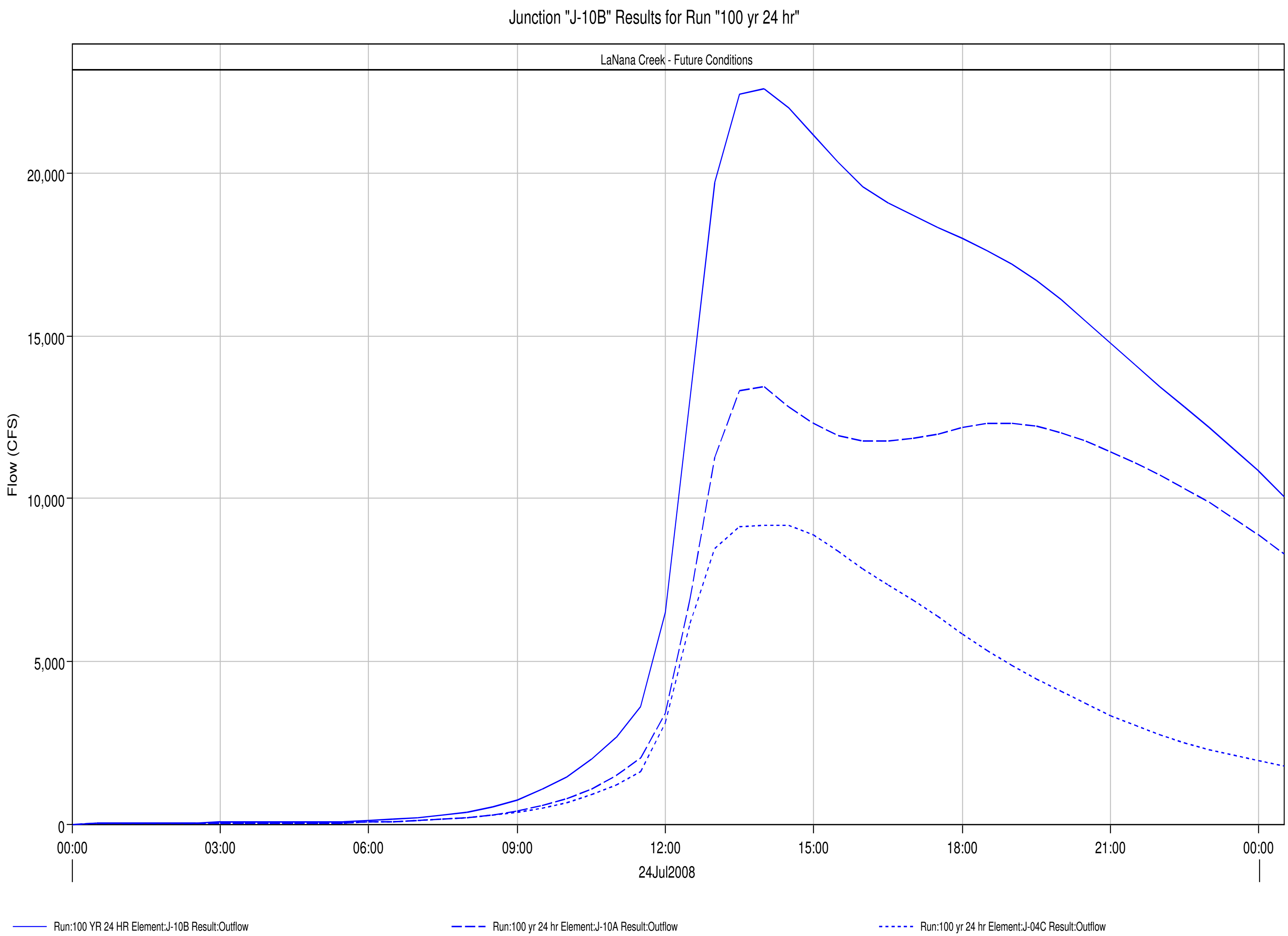
Junction "J-08D" Results for Run "100 yr 24 hr"



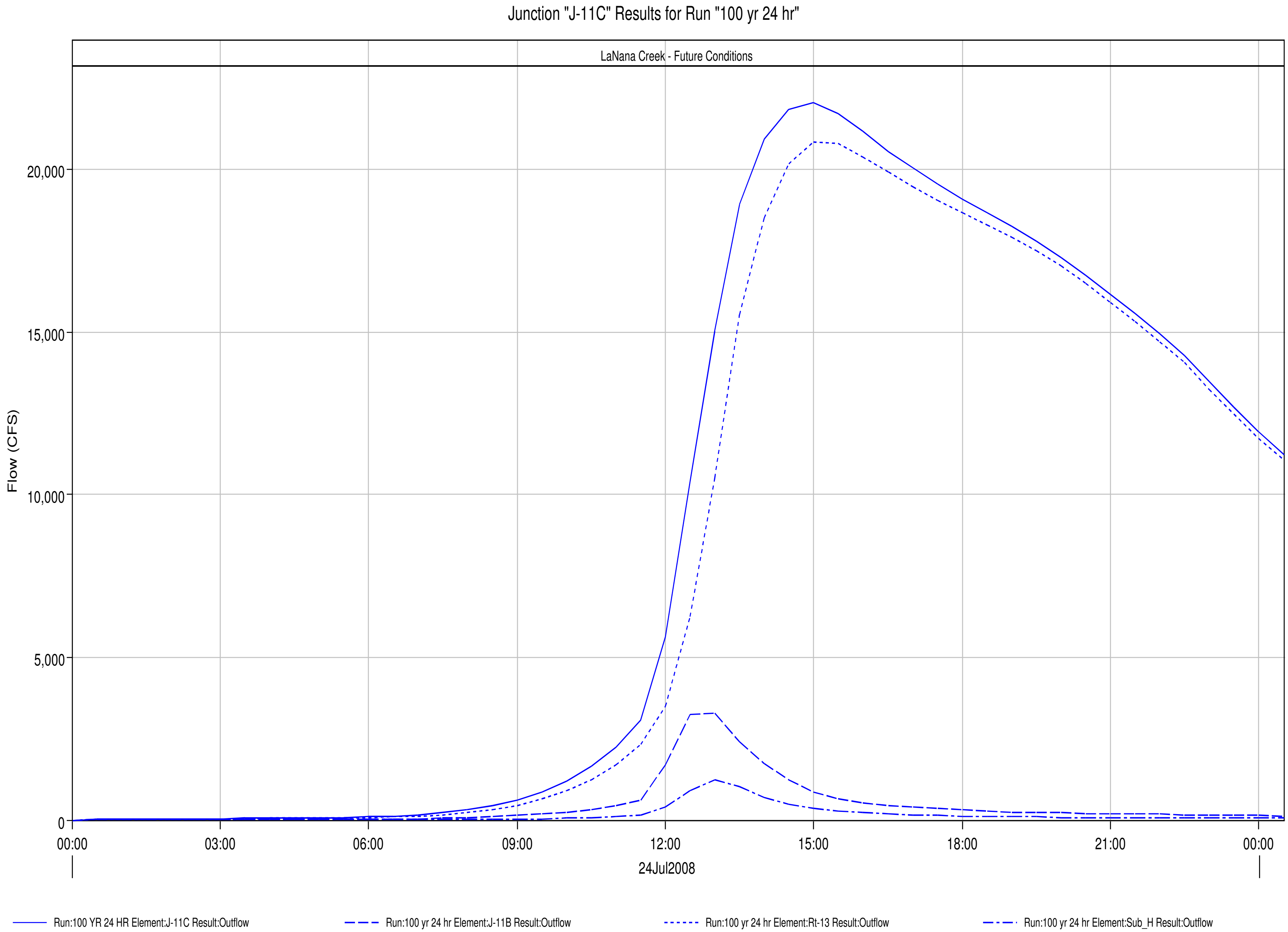


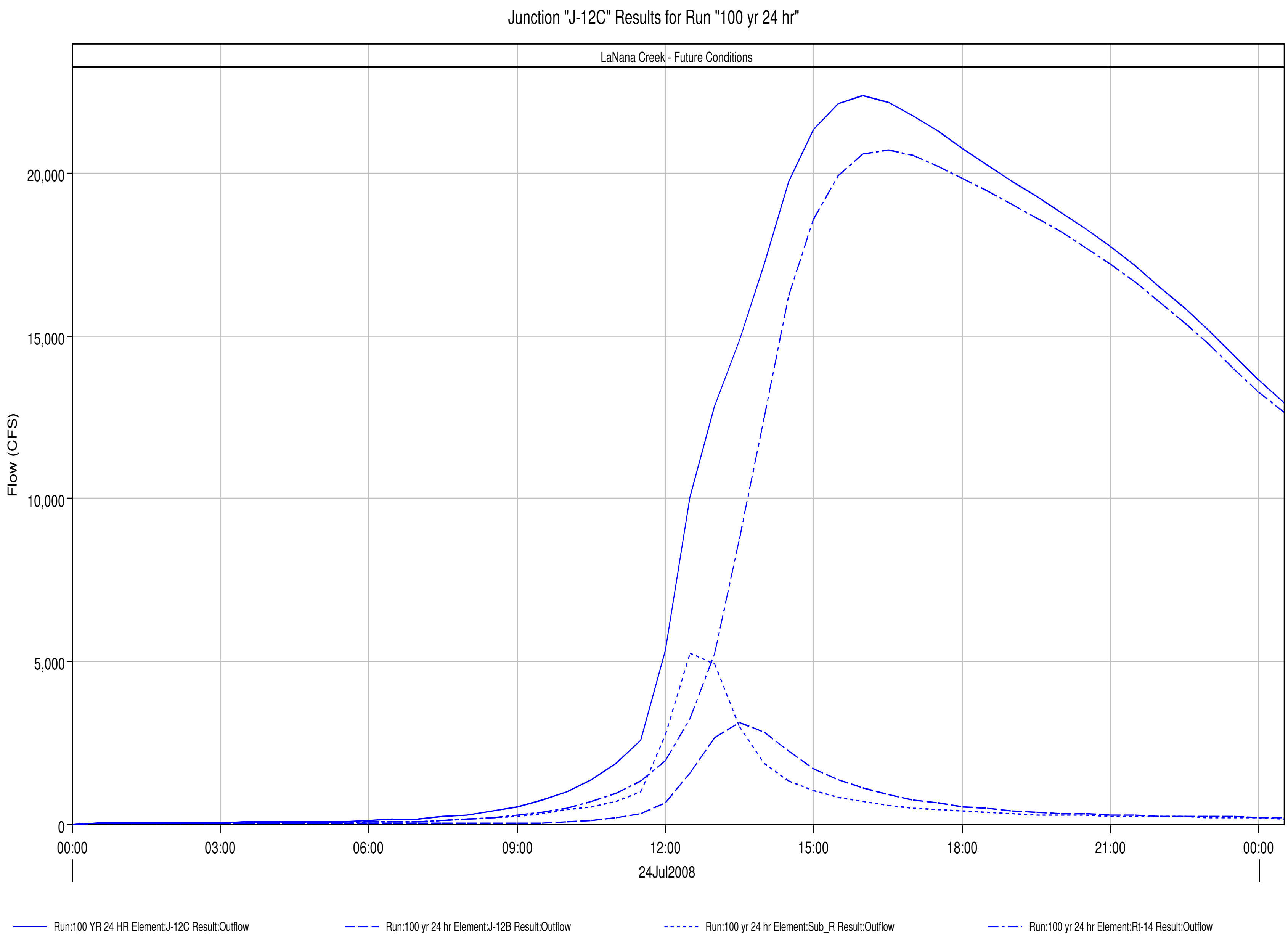
Junction "J-09C" Results for Run "100 yr 24 hr"
LaNana Creek - Future Conditions
Flow (CFS)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-09C Result:Outflow
Run:100 yr 24 hr Element:J-09B Result:Outflow
Run:100 yr 24 hr Element:J-08D Result:Outflow

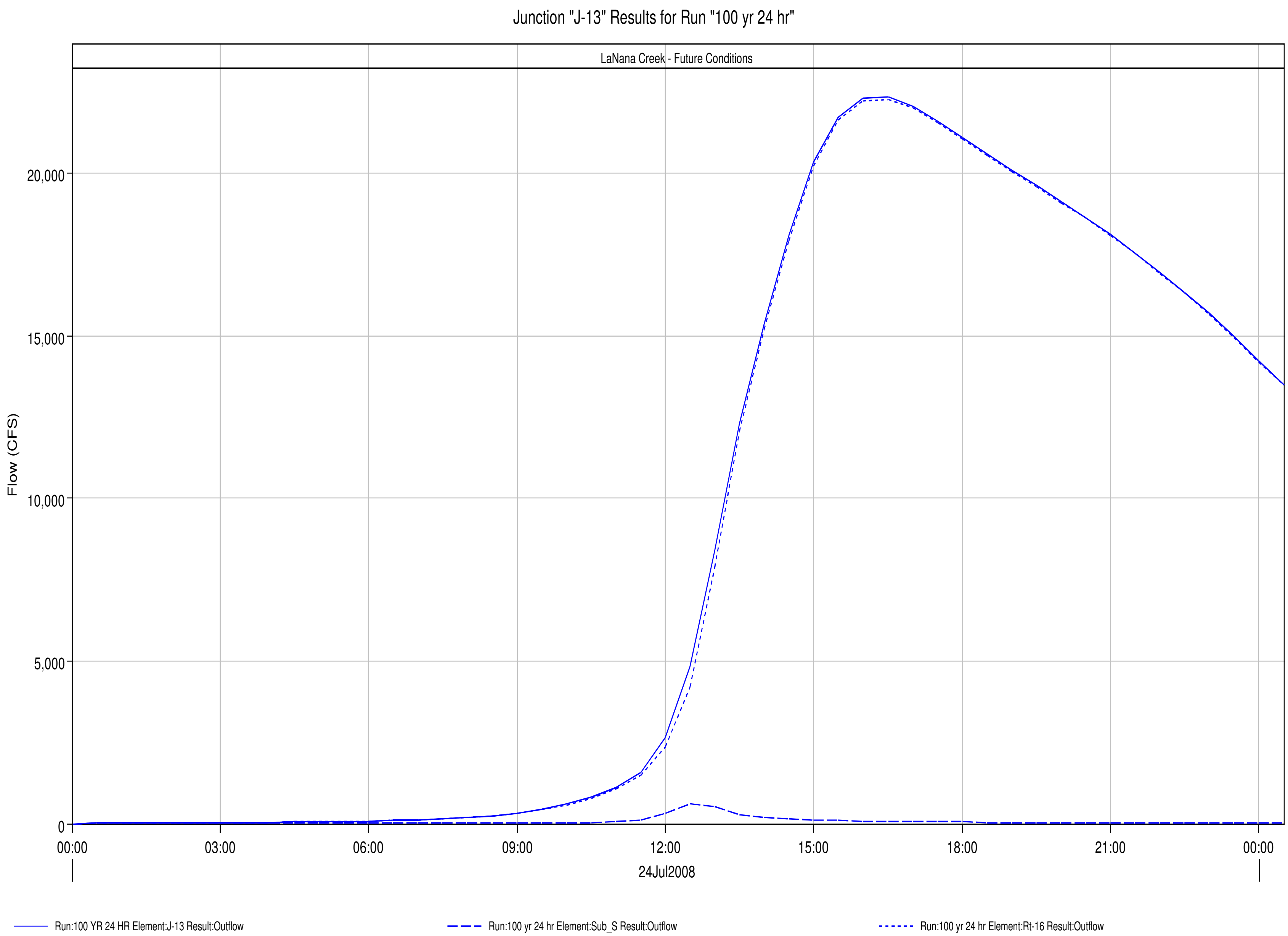

Junction "J-10A" Results for Run "100 yr 24 hr"
LaNana Creek - Future Conditions
Flow (CFS)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-10A Result:Outflow
Run:100 yr 24 hr Element:Rt-11 Result:Outflow
Run:100 yr 24 hr Element:Sub_G Result:Outflow



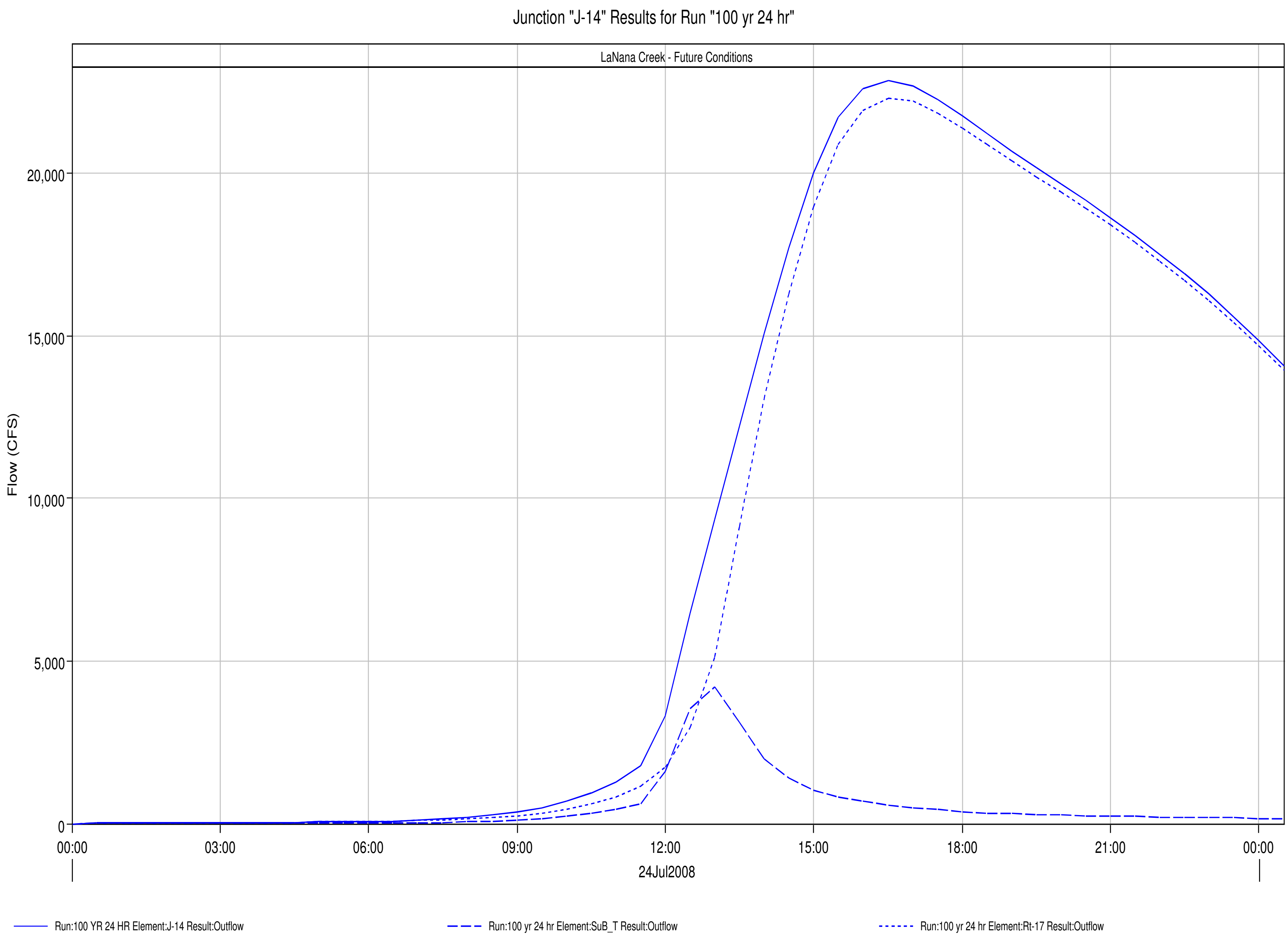
Junction "J-10B" Results for Run "100 yr 24 hr"
LaNana Creek - Future Conditions
Flow (CFS)
20,000
15,000
10,000
5,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-10B Result:Outflow
Run:100 yr 24 hr Element:J-10A Result:Outflow
Run:100 yr 24 hr Element:J-04C Result:Outflow

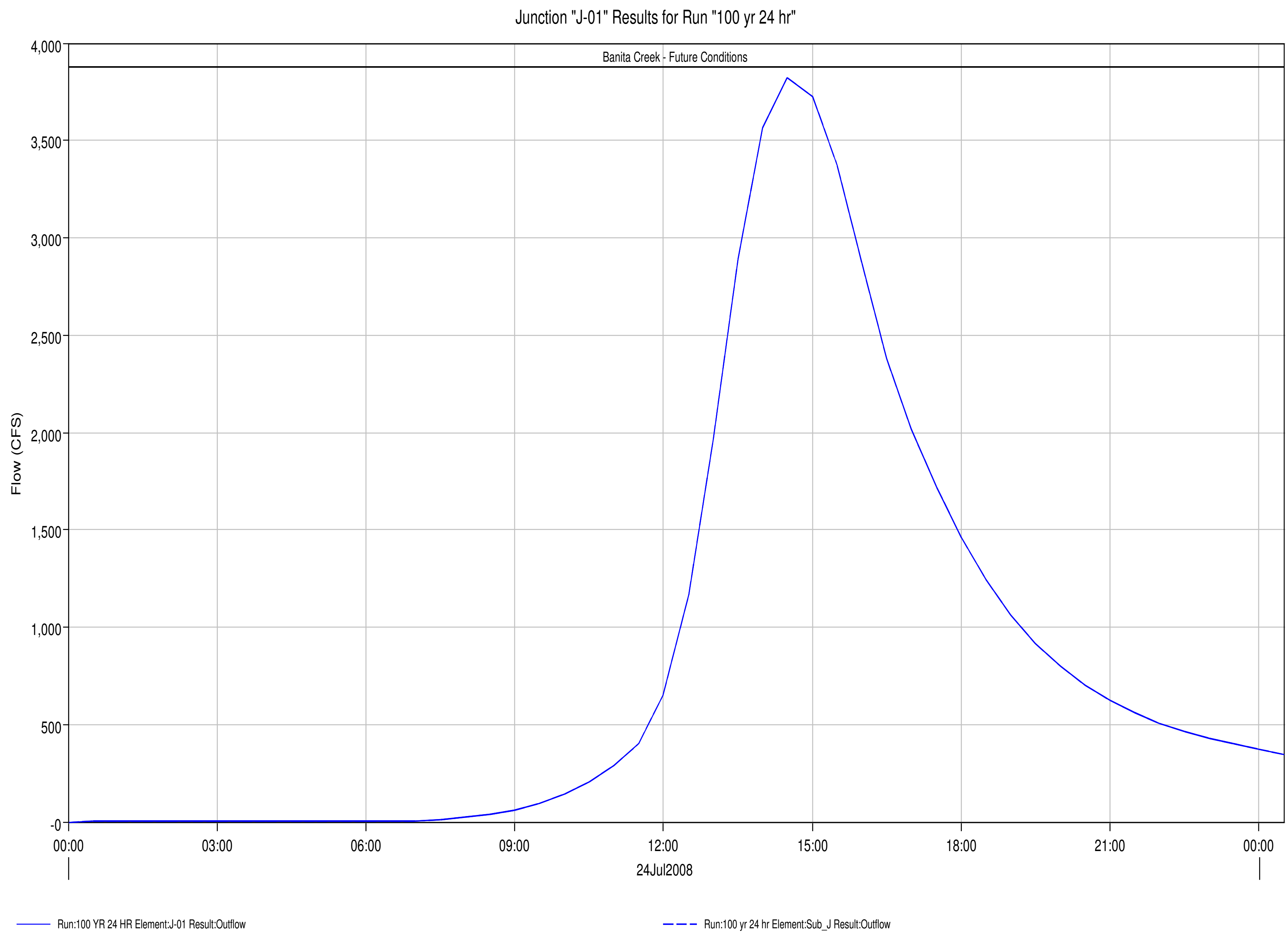

Junction "J-11C" Results for Run "100 yr 24 hr"
LaNana Creek - Future Conditions
Flow (CFS)
20,000
15,000
10,000
5,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-11C Result:Outflow
Run:100 yr 24 hr Element:J-11B Result:Outflow
Run:100 yr 24 hr Element:Rt-13 Result:Outflow
Run:100 yr 24 hr Element:Sub_H Result:Outflow


Junction "J-12C" Results for Run "100 yr 24 hr"
LaNana Creek - Future Conditions
Flow (CFS)
20,000
15,000
10,000
5,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-12C Result:Outflow
Run:100 yr 24 hr Element:J-12B Result:Outflow
Run:100 yr 24 hr Element:Sub_R Result:Outflow
Run:100 yr 24 hr Element:Rt-14 Result:Outflow



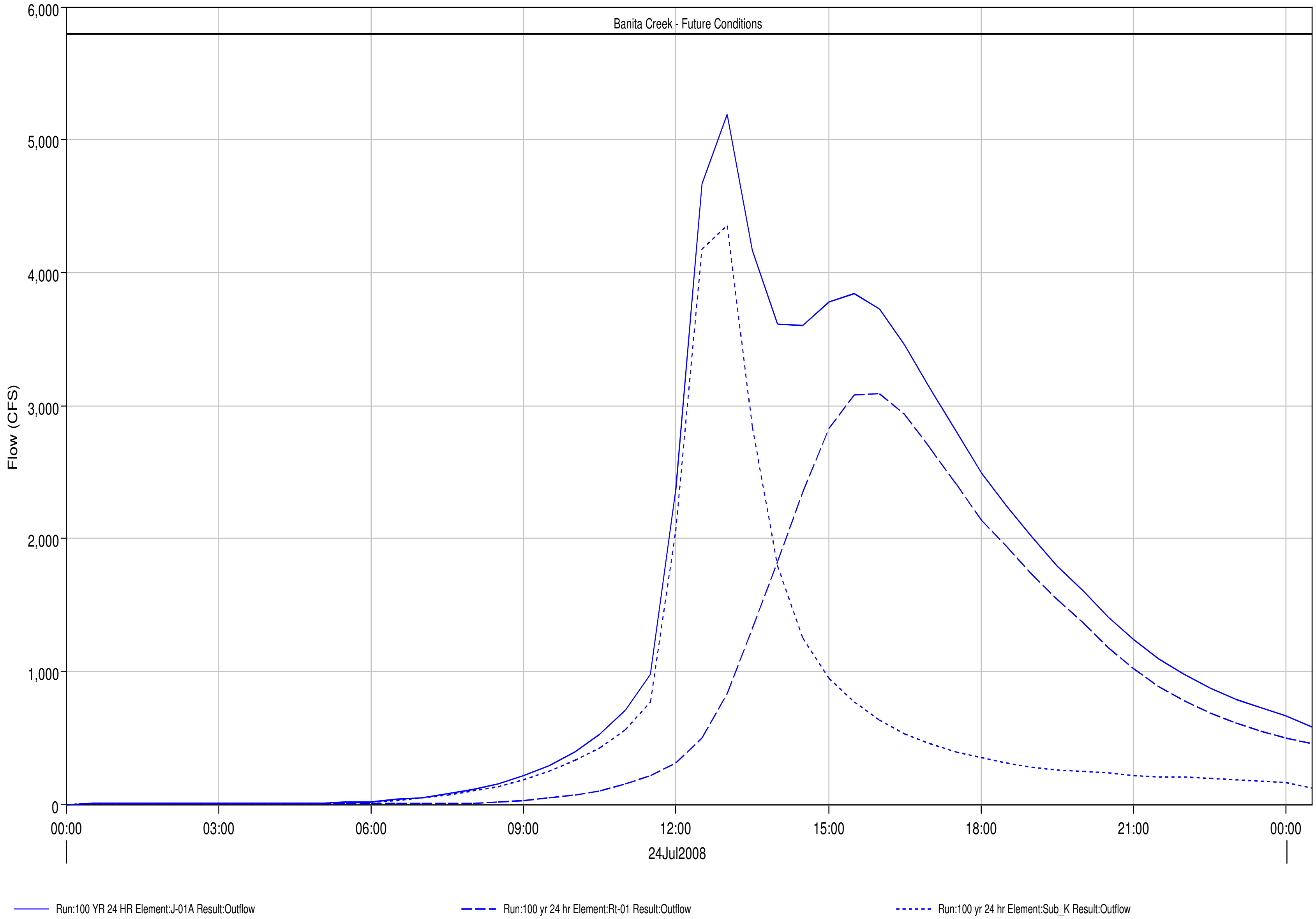
Junction "J-13" Results for Run "100 yr 24 hr"
LaNana Creek - Future Conditions
Flow (CFS)
20,000
15,000
10,000
5,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-13 Result:Outflow
Run:100 yr 24 hr Element:Sub_S Result:Outflow
Run:100 yr 24 hr Element:Rt-16 Result:Outflow

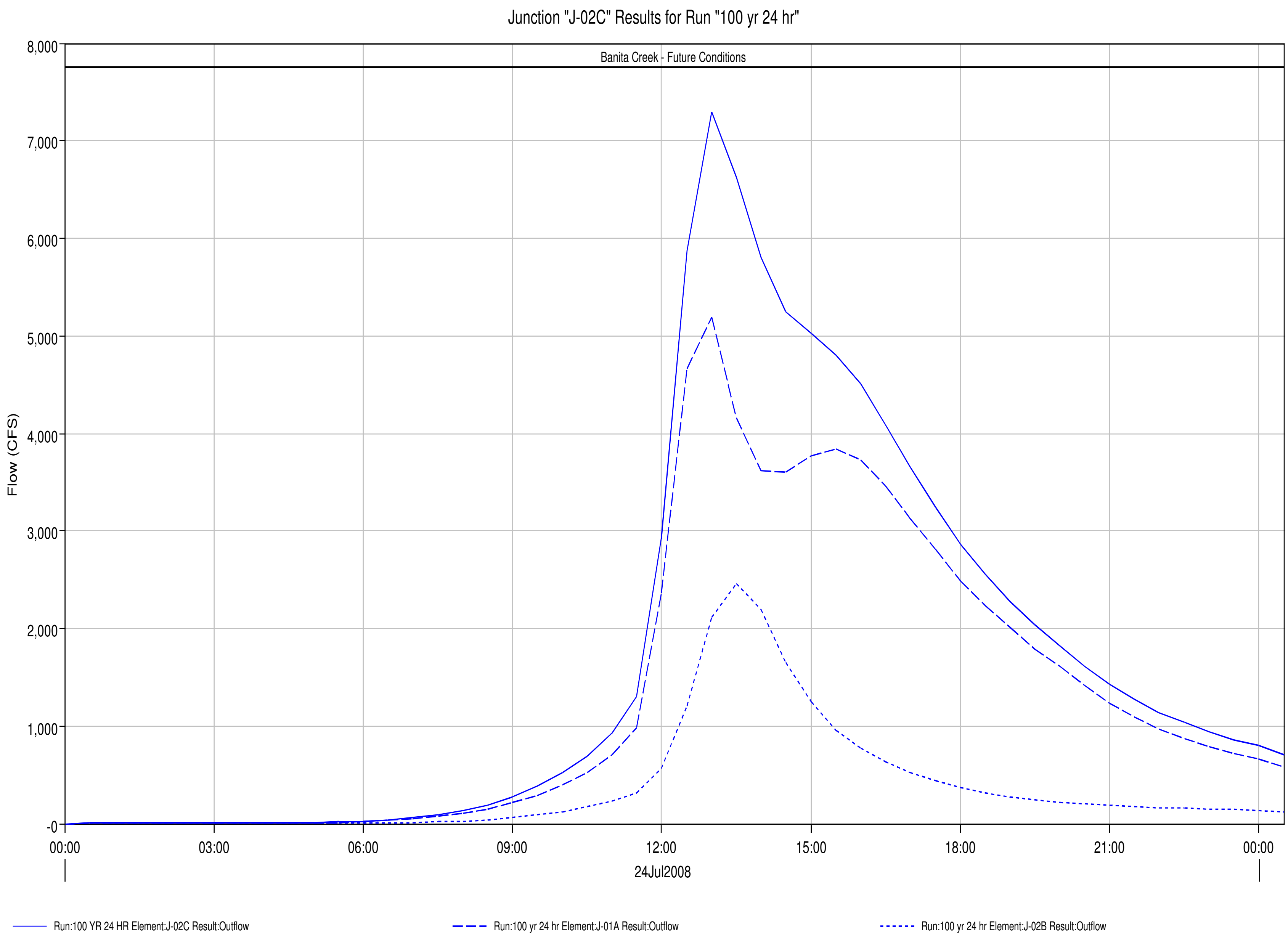

Junction "J-14" Results for Run "100 yr 24 hr"
LaNana Creek - Future Conditions
Flow (CFS)
20,000
15,000
10,000
5,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-14 Result:Outflow
Run:100 yr 24 hr Element:SuB_T Result:Outflow
Run:100 yr 24 hr Element:Rt-17 Result:Outflow



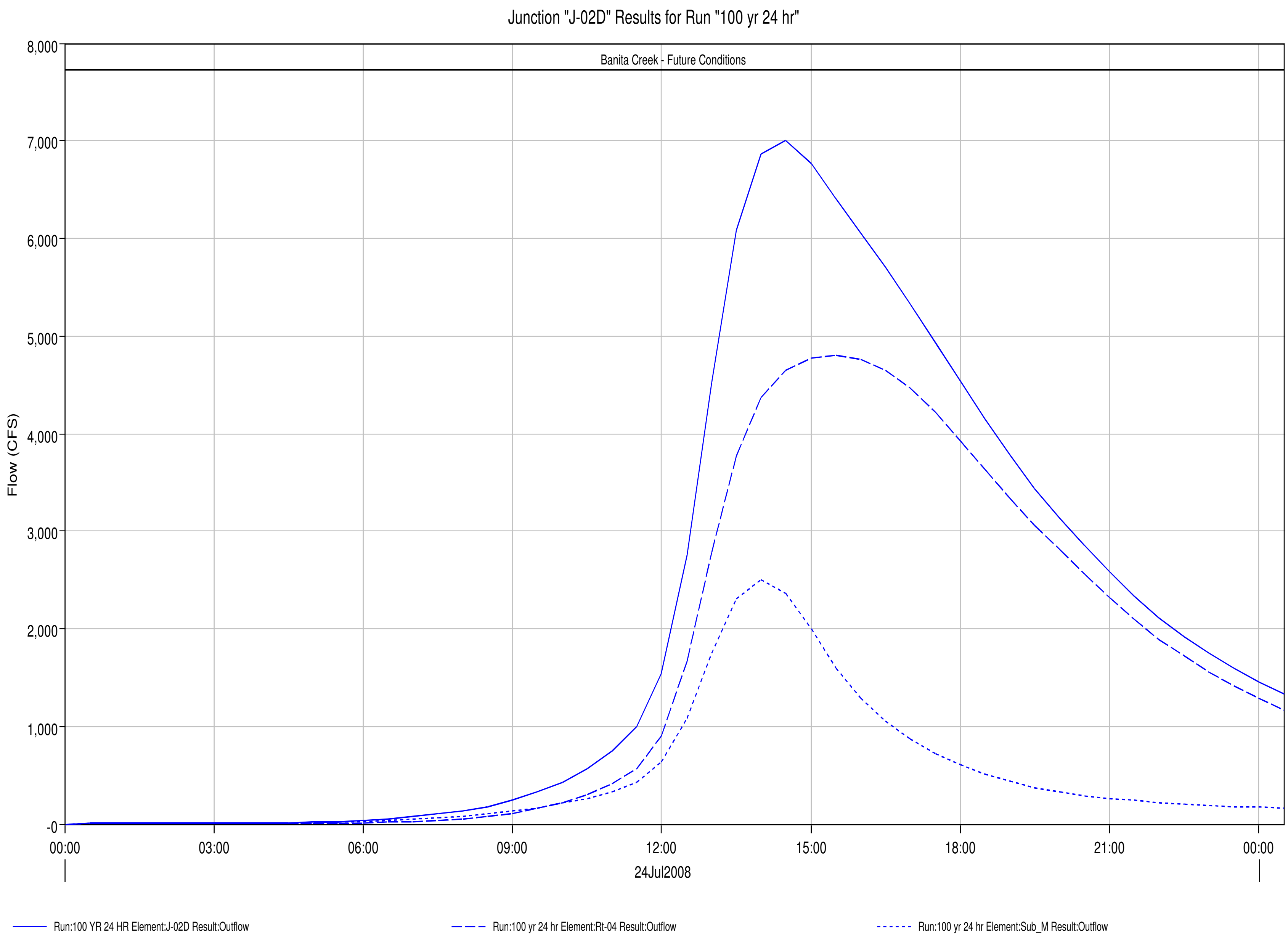
Junction "J-01" Results for Run "100 yr 24 hr"
Banita Creek - Future Conditions
Flow (CFS)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-01 Result:Outflow
Run:100 yr 24 hr Element:Sub_J Result:Outflow

Junction "J-01A" Results for Run "100 yr 24 hr"

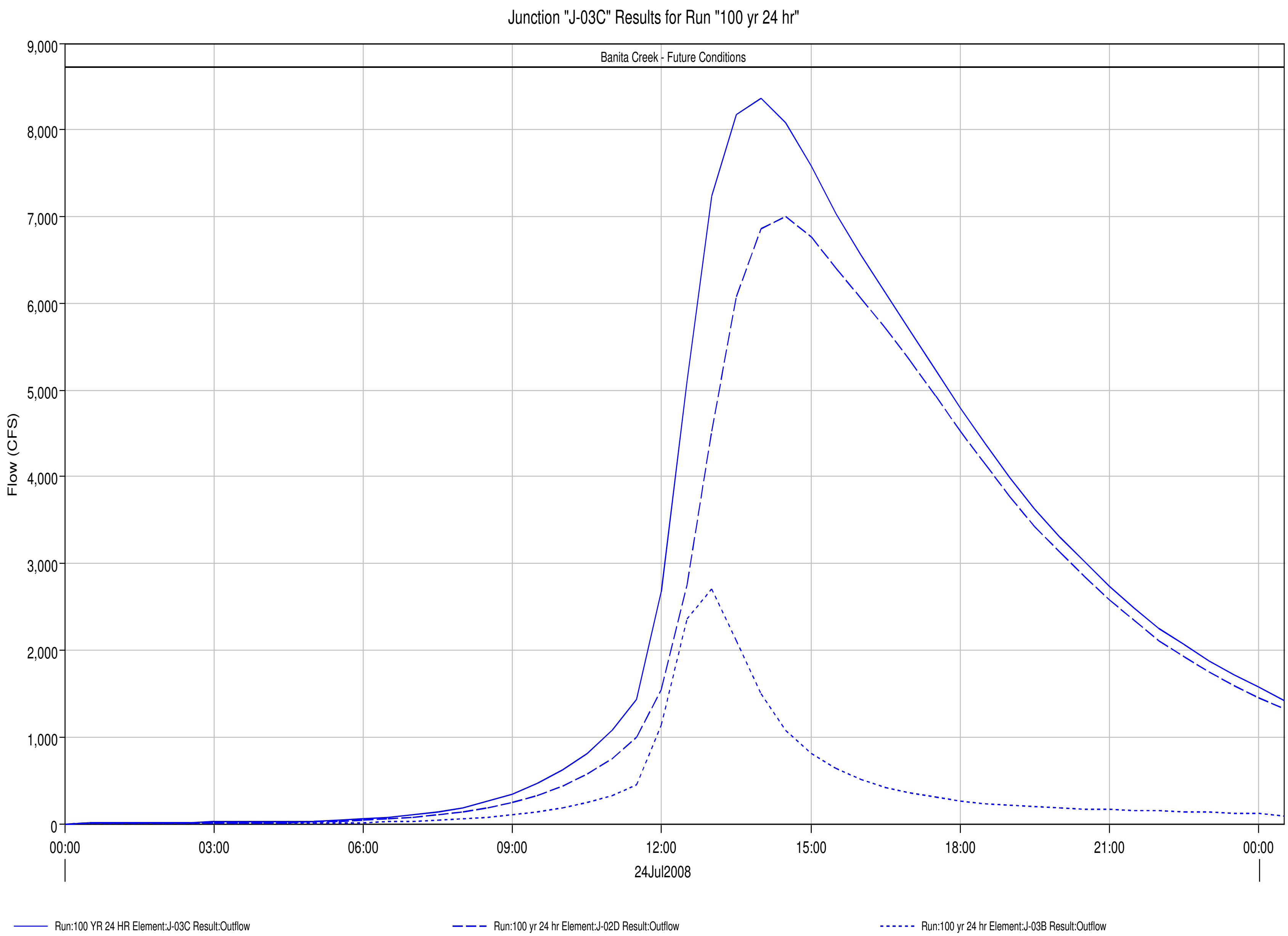


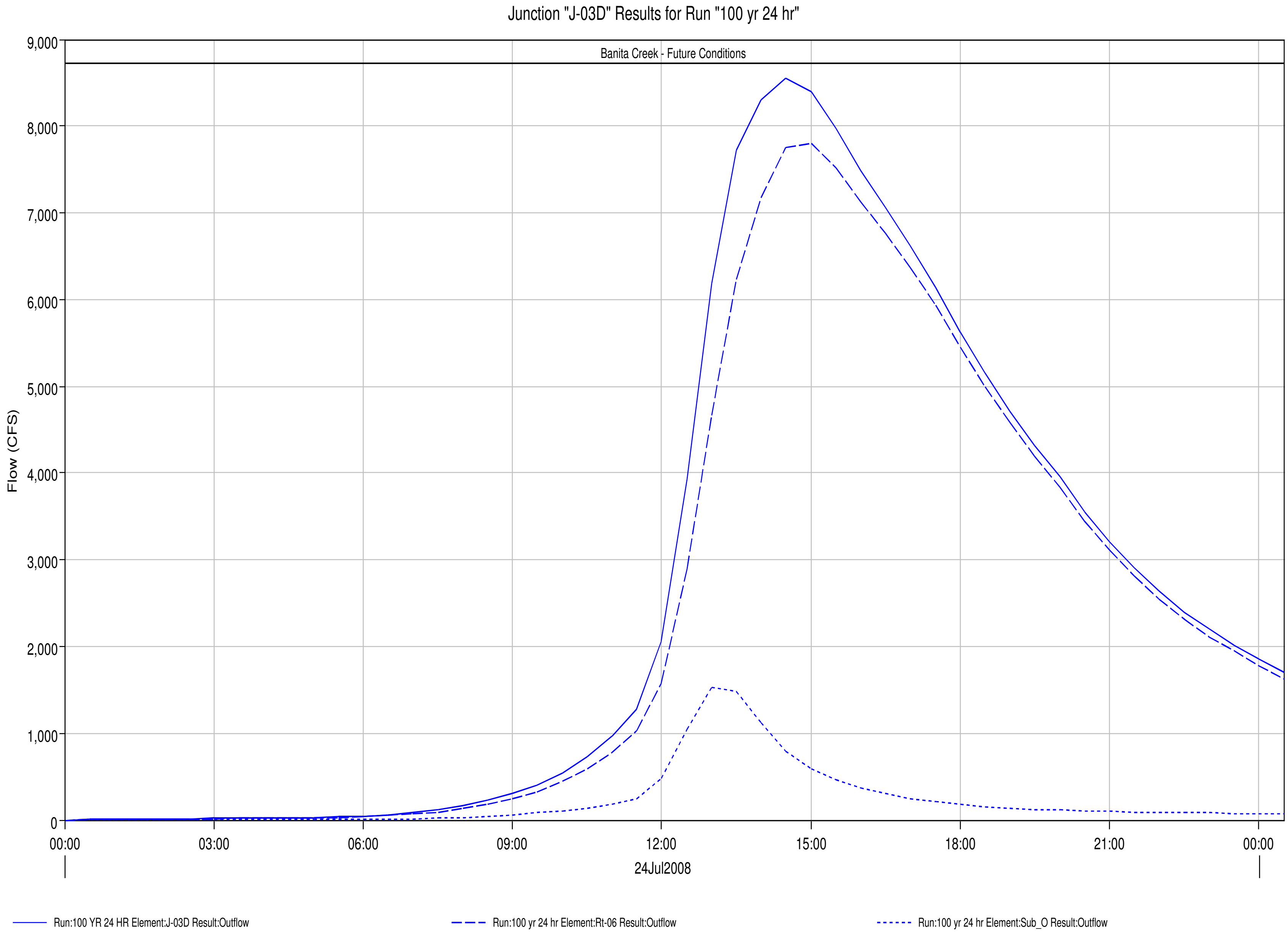


Junction "J-02C" Results for Run "100 yr 24 hr"
Banita Creek - Future Conditions
Flow (CFS)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
-0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-02C Result:Outflow
Run:100 yr 24 hr Element:J-01A Result:Outflow
Run:100 yr 24 hr Element:J-02B Result:Outflow

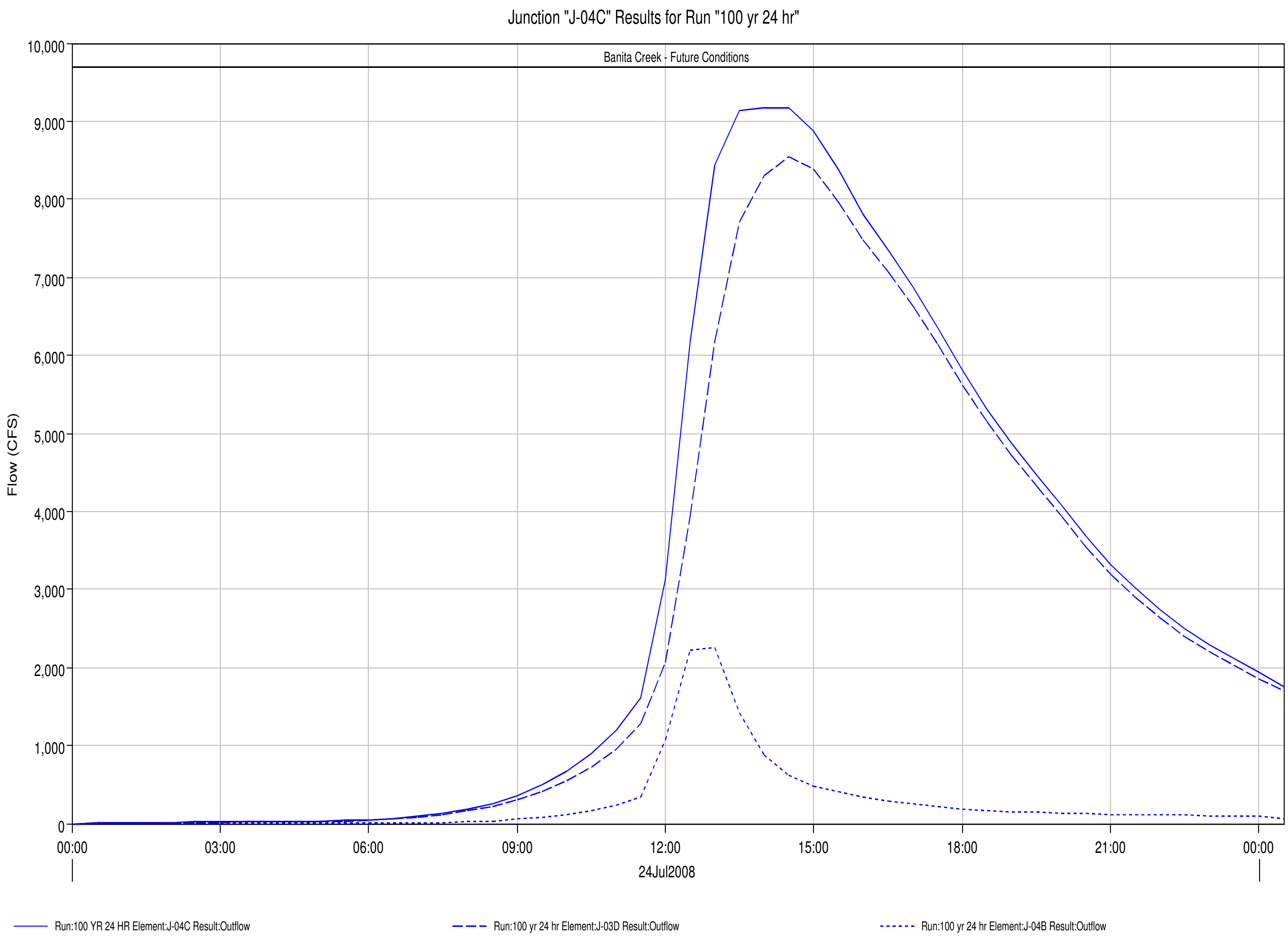


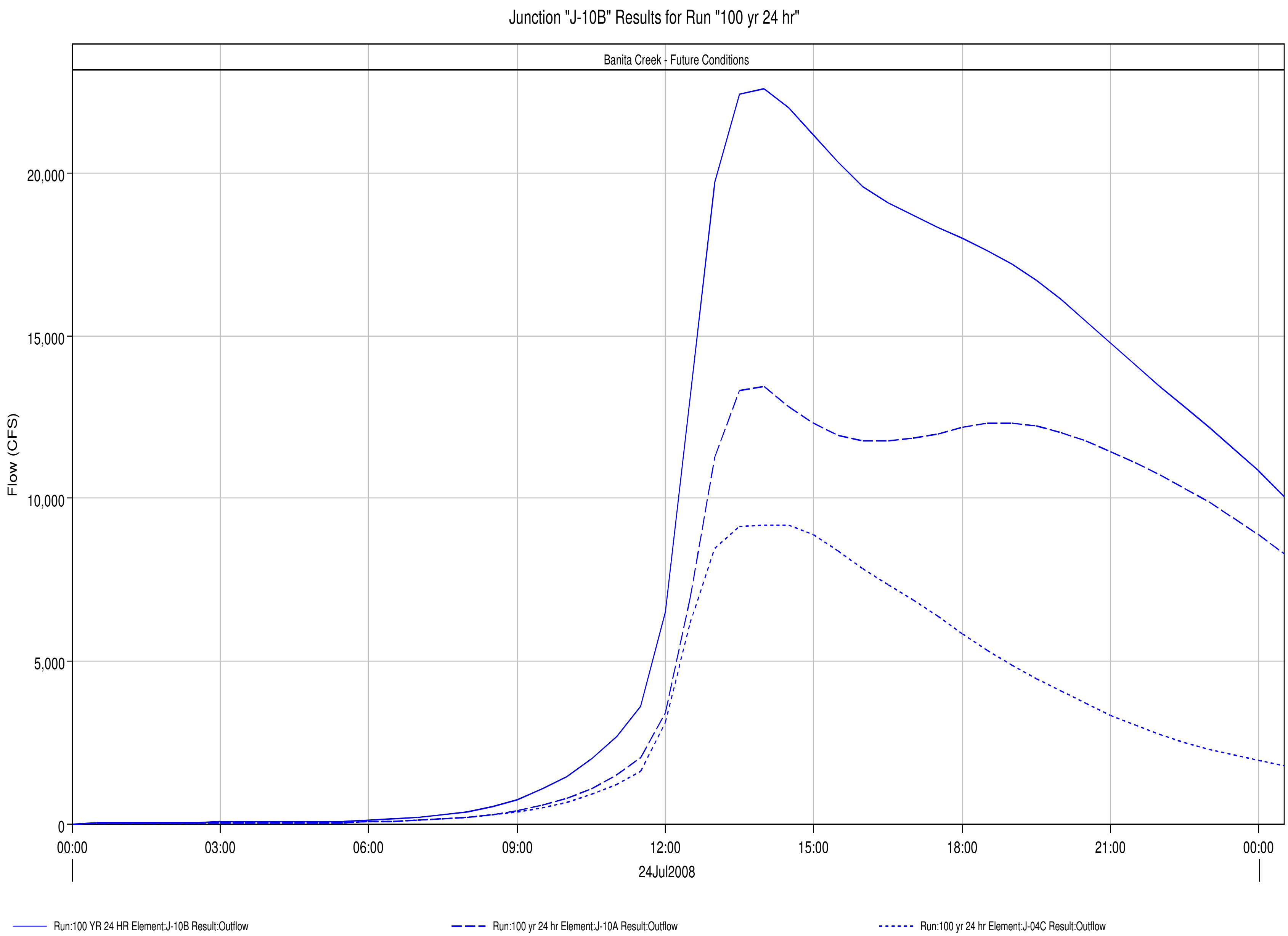
Junction "J-02D" Results for Run "100 yr 24 hr"
Banita Creek - Future Conditions
Flow (CFS)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
-0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-02D Result:Outflow
Run:100 yr 24 hr Element:Rt-04 Result:Outflow
Run:100 yr 24 hr Element:Sub_M Result:Outflow


Junction "J-03C" Results for Run "100 yr 24 hr"
Banita Creek - Future Conditions
Flow (CFS)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-03C Result:Outflow
Run:100 yr 24 hr Element:J-02D Result:Outflow
Run:100 yr 24 hr Element:J-03B Result:Outflow

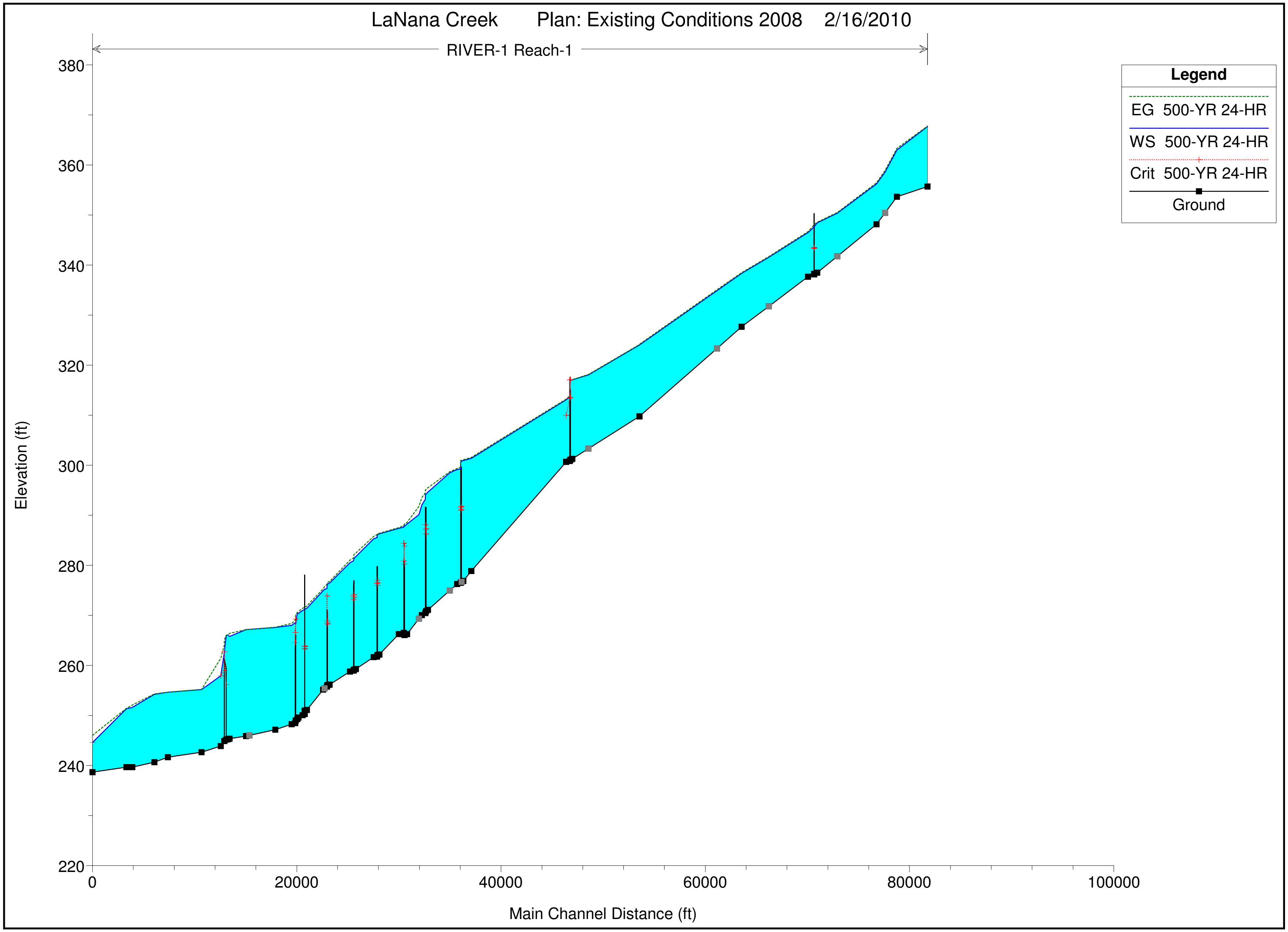


Junction "J-03D" Results for Run "100 yr 24 hr"
Banita Creek - Future Conditions
Flow (CFS)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-03D Result:Outflow
Run:100 yr 24 hr Element:Rt-06 Result:Outflow
Run:100 yr 24 hr Element:Sub_O Result:Outflow

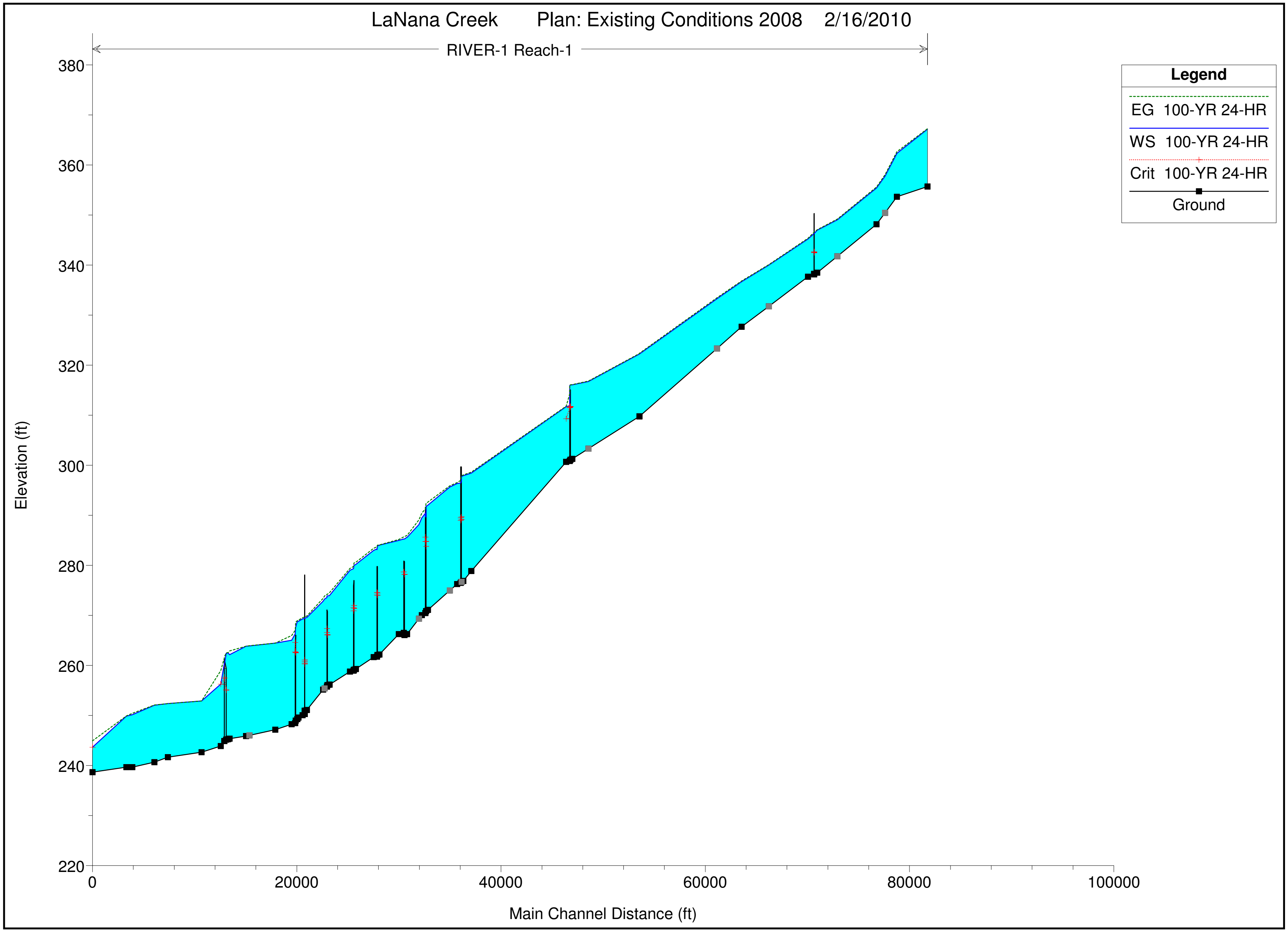

Junction "J-04C" Results for Run "100 yr 24 hr"
Banita Creek - Future Conditions
Flow (CFS)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-04C Result:Outflow
Run:100 yr 24 hr Element:J-03D Result:Outflow
Run:100 yr 24 hr Element:J-04B Result:Outflow


Junction "J-10B" Results for Run "100 yr 24 hr"
Banita Creek - Future Conditions
Flow (CFS)
20,000
15,000
10,000
5,000
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
24Jul2008
Run:100 YR 24 HR Element:J-10B Result:Outflow
Run:100 yr 24 hr Element:J-10A Result:Outflow
Run:100 yr 24 hr Element:J-04C Result:Outflow

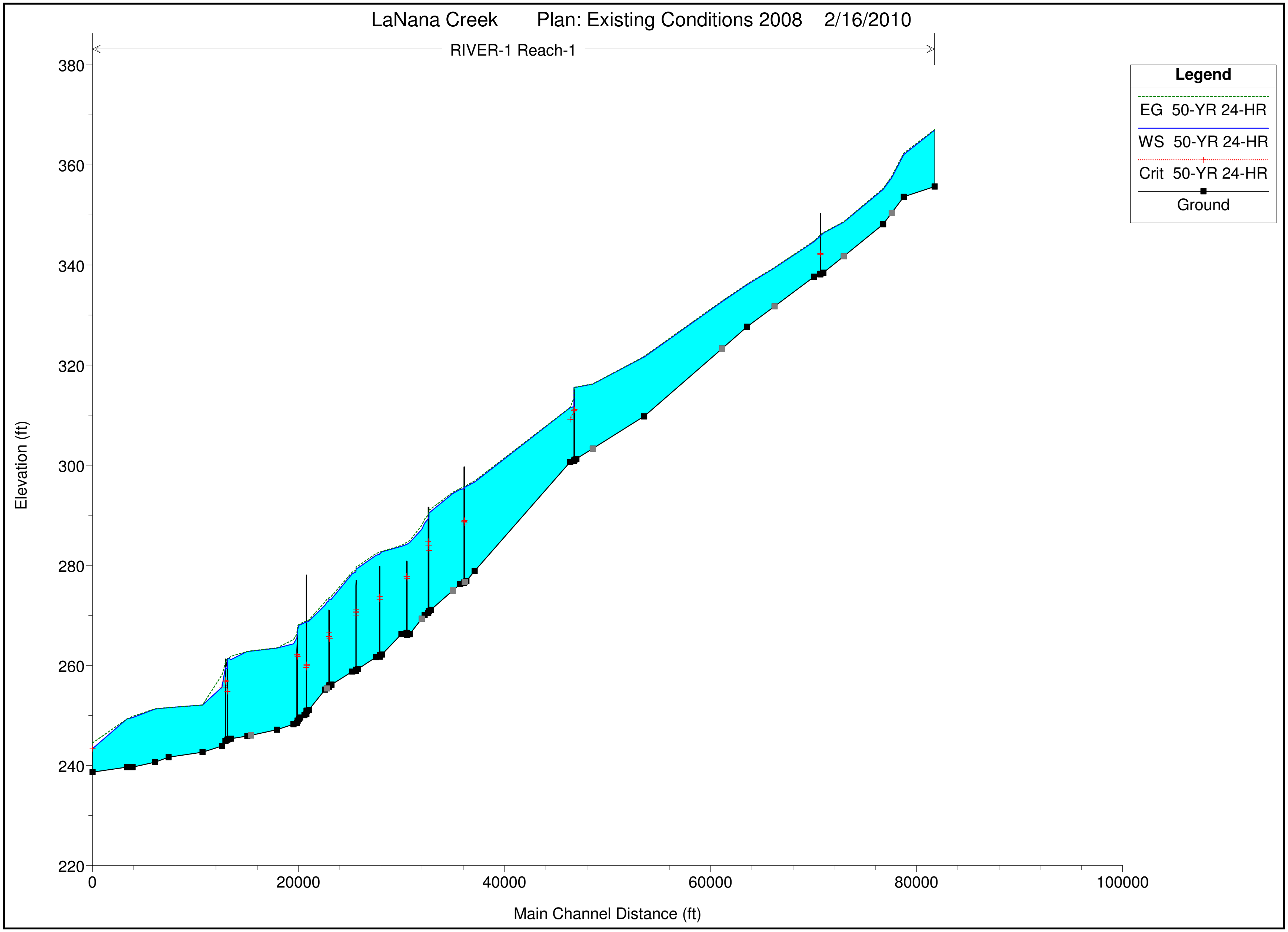
EXISTING CHANNEL PROFILES

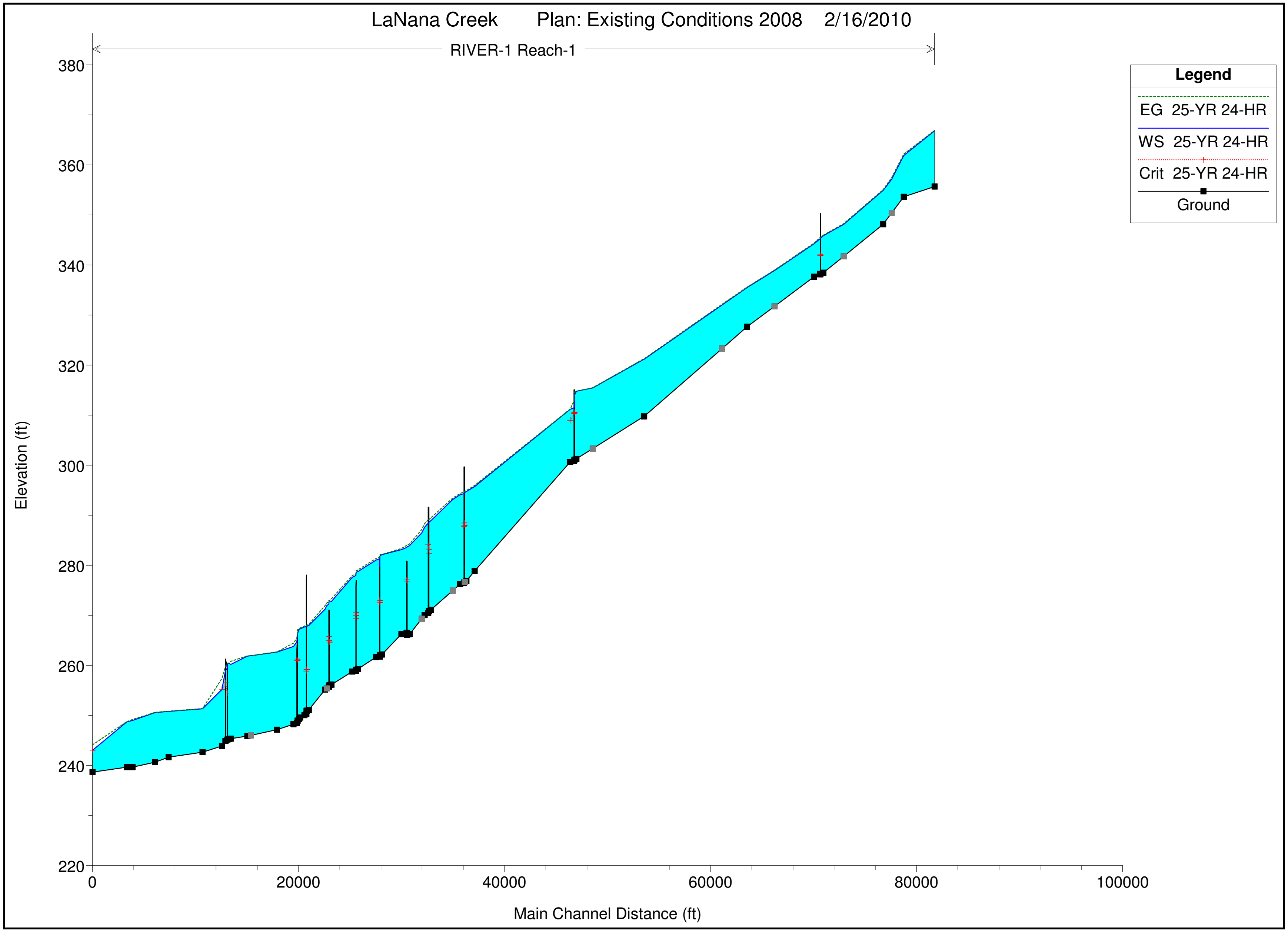


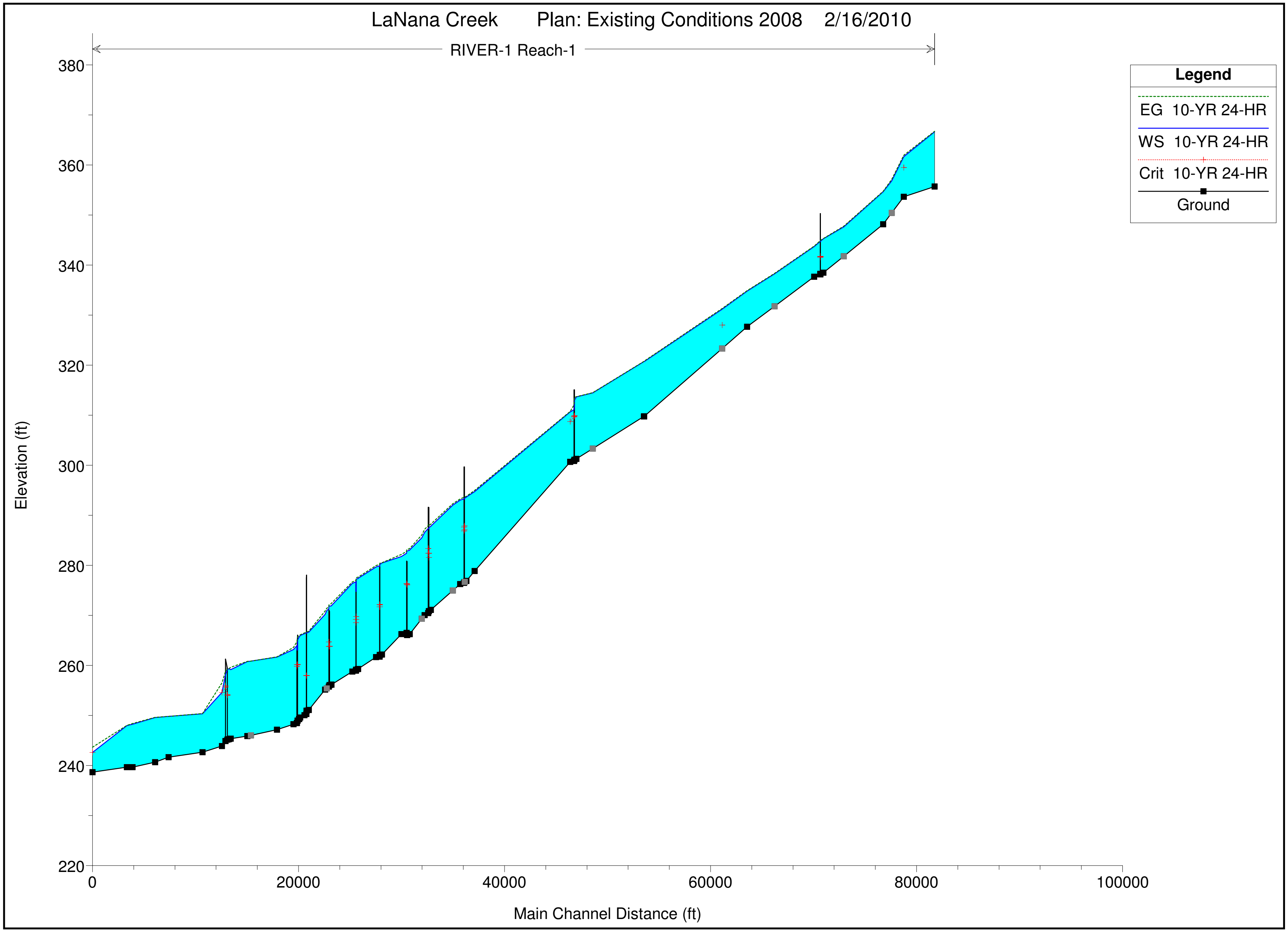
LaNana Creek Plan: Existing Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 500-YR 24-HR
WS 500-YR 24-HR
Crit 500-YR 24-HR
Ground
Elevation (ft)
Main Channel Distance (ft)
380
360
340
320
300
280
260
240
220
0
20000
40000
60000
80000
100000

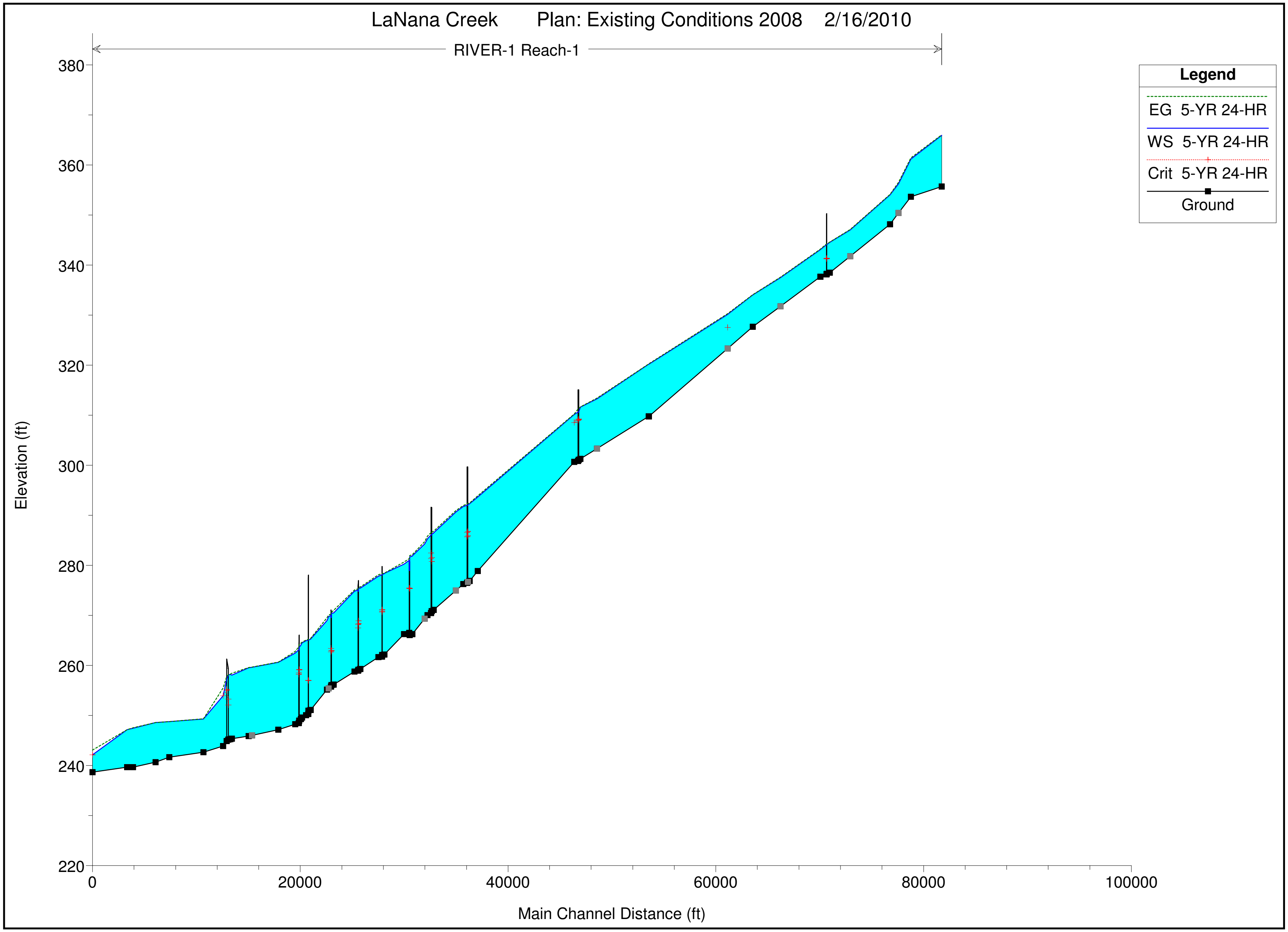


LaNana Creek Plan: Existing Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 100-YR 24-HR
WS 100-YR 24-HR
Crit 100-YR 24-HR
Ground
Elevation (ft)
380
360
340
320
300
280
260
240
220
0
20000
40000
60000
80000
100000
Main Channel Distance (ft)

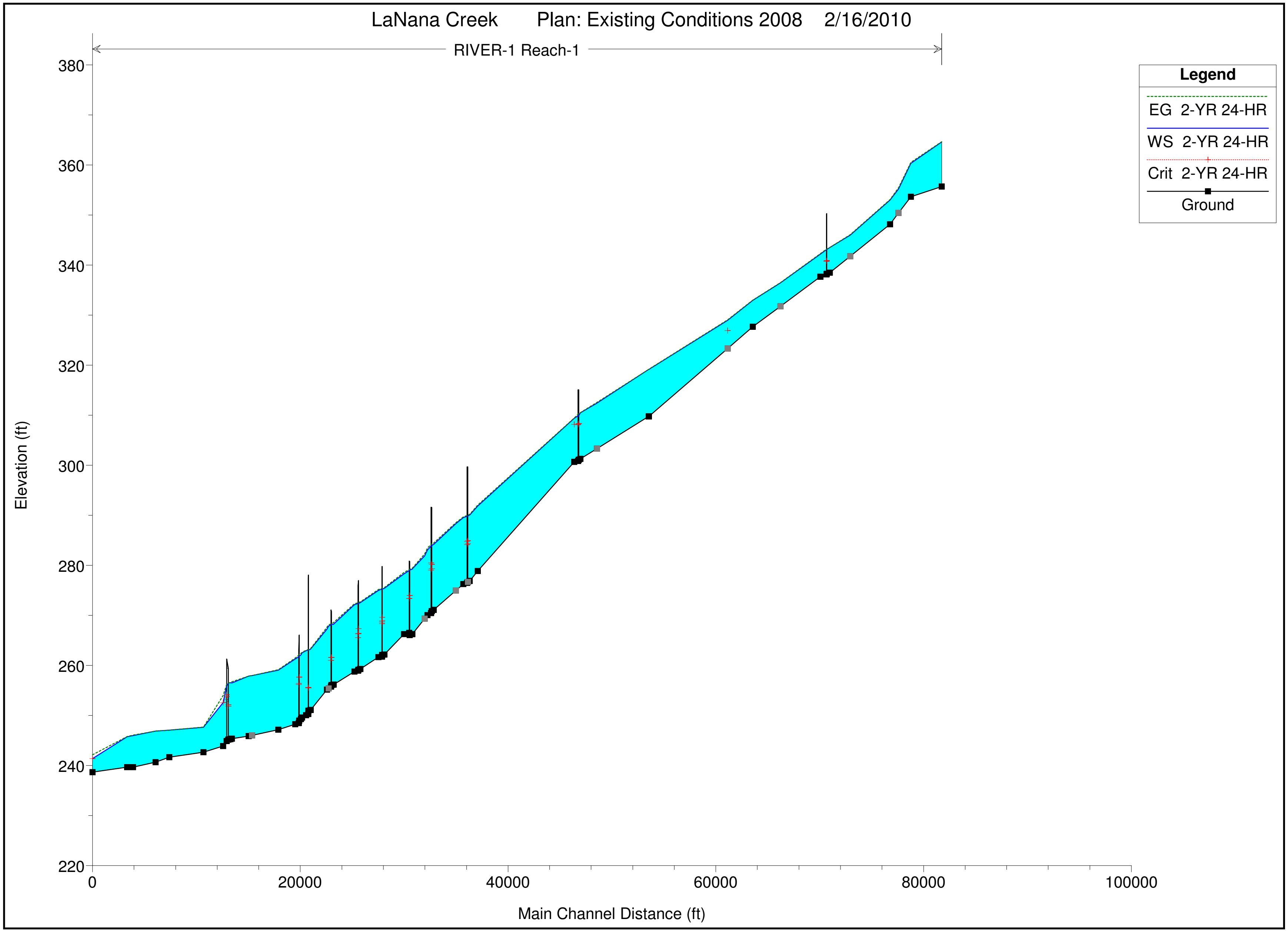

LaNana Creek Plan: Existing Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 50-YR 24-HR
WS 50-YR 24-HR
Crit 50-YR 24-HR
Ground
Elevation (ft)
Main Channel Distance (ft)
380
360
340
320
300
280
260
240
220
0
20000
40000
60000
80000
100000


LaNana Creek Plan: Existing Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 25-YR 24-HR
WS 25-YR 24-HR
Crit 25-YR 24-HR
Ground
Elevation (ft)
380
360
340
320
300
280
260
240
220
0
20000
40000
60000
80000
100000
Main Channel Distance (ft)

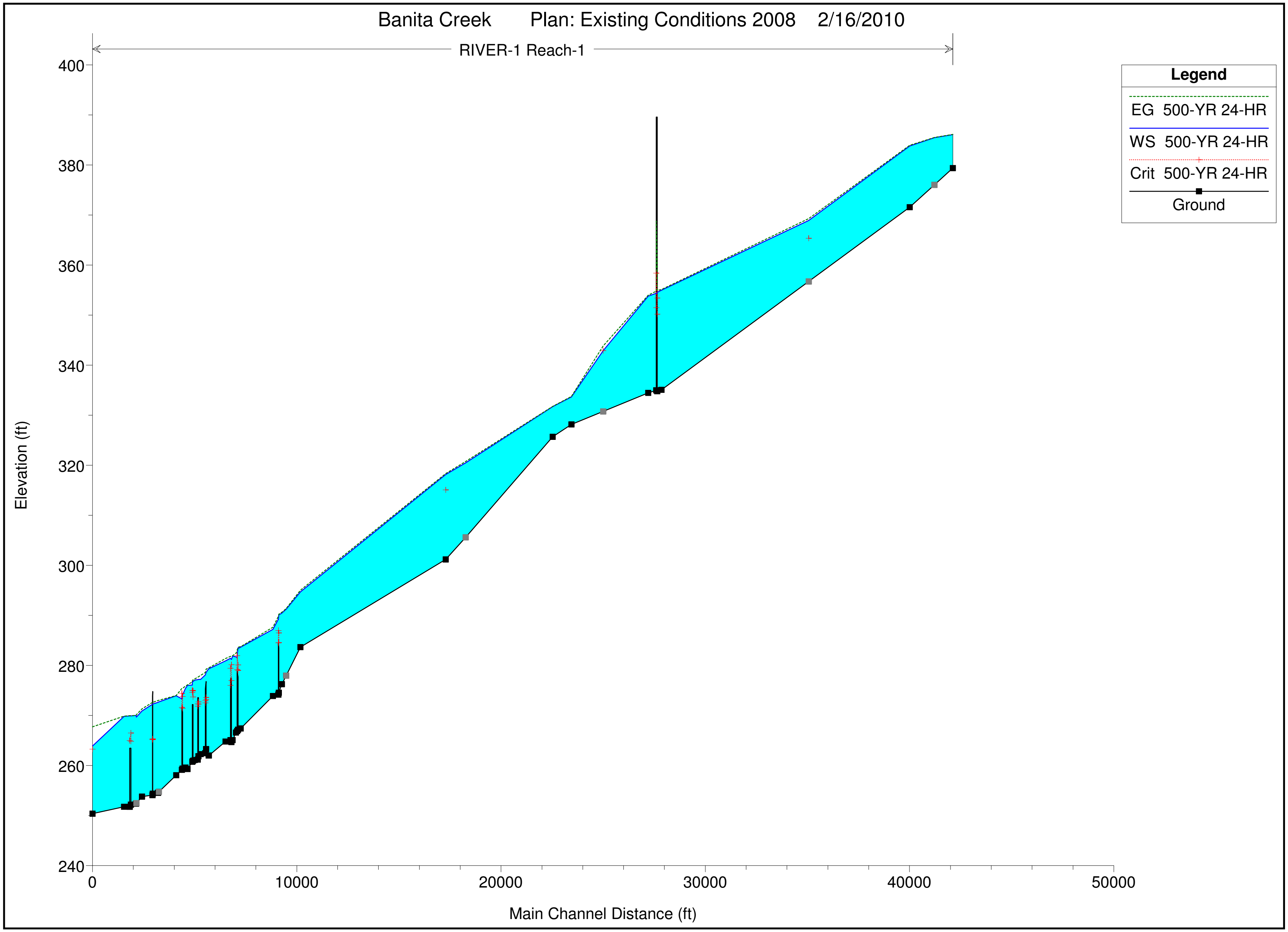

LaNana Creek Plan: Existing Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 10-YR 24-HR
WS 10-YR 24-HR
Crit 10-YR 24-HR
Ground
Elevation (ft)
Main Channel Distance (ft)
380
360
340
320
300
280
260
240
220
0
20000
40000
60000
80000
100000

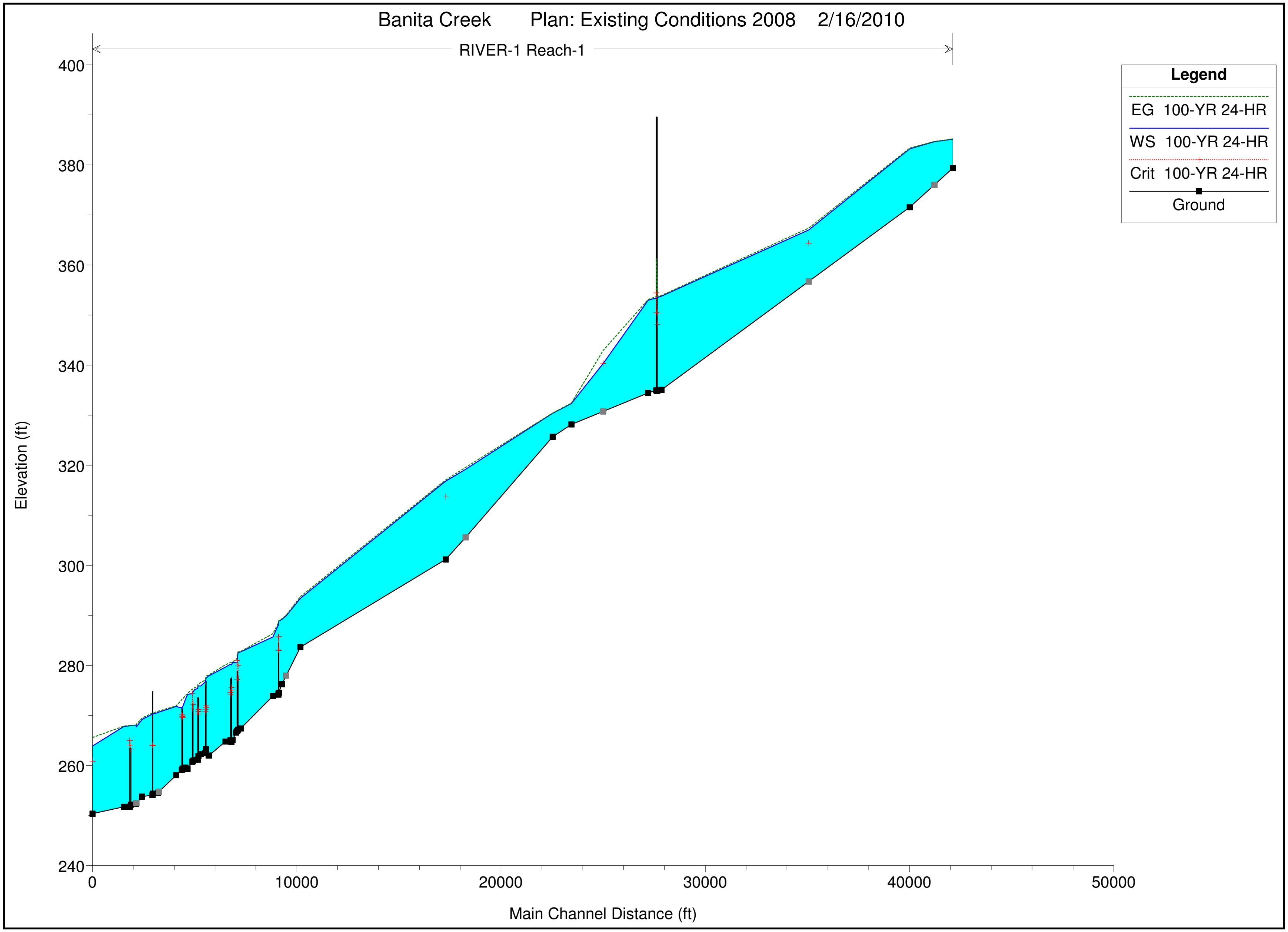


LaNana Creek Plan: Existing Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 5-YR 24-HR
WS 5-YR 24-HR
Crit 5-YR 24-HR
Ground
Elevation (ft)
Main Channel Distance (ft)
380
360
340
320
300
280
260
240
220
0
20000
40000
60000
80000
100000

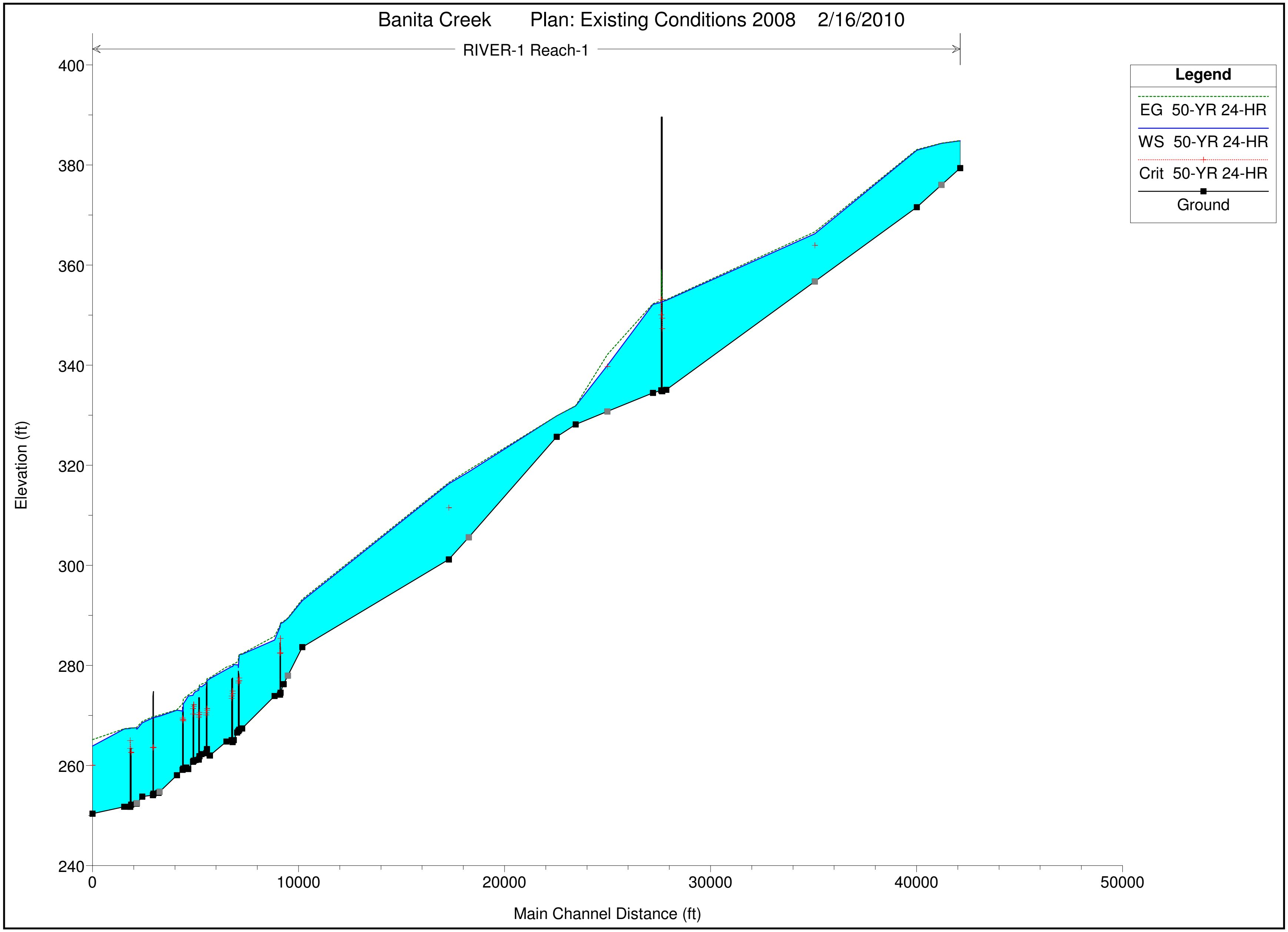


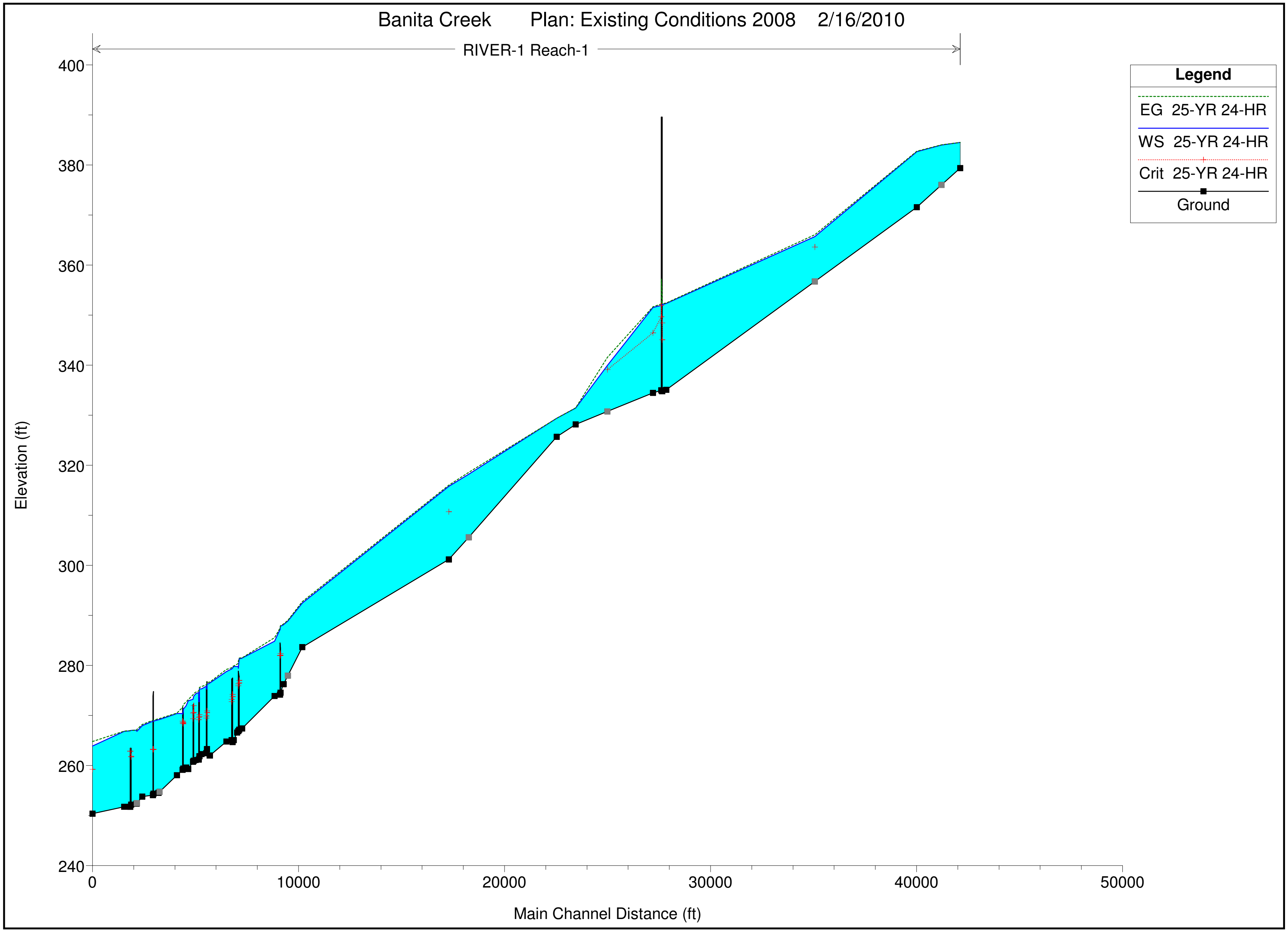
LaNana Creek Plan: Existing Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 2-YR 24-HR
WS 2-YR 24-HR
Crit 2-YR 24-HR
Ground
Elevation (ft)
Main Channel Distance (ft)
380
360
340
320
300
280
260
240
220
0
20000
40000
60000
80000
100000


Banita Creek Plan: Existing Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 500-YR 24-HR
WS 500-YR 24-HR
Crit 500-YR 24-HR
Ground
Elevation (ft)
400
380
360
340
320
300
280
260
240
0
10000
20000
30000
40000
50000
Main Channel Distance (ft)

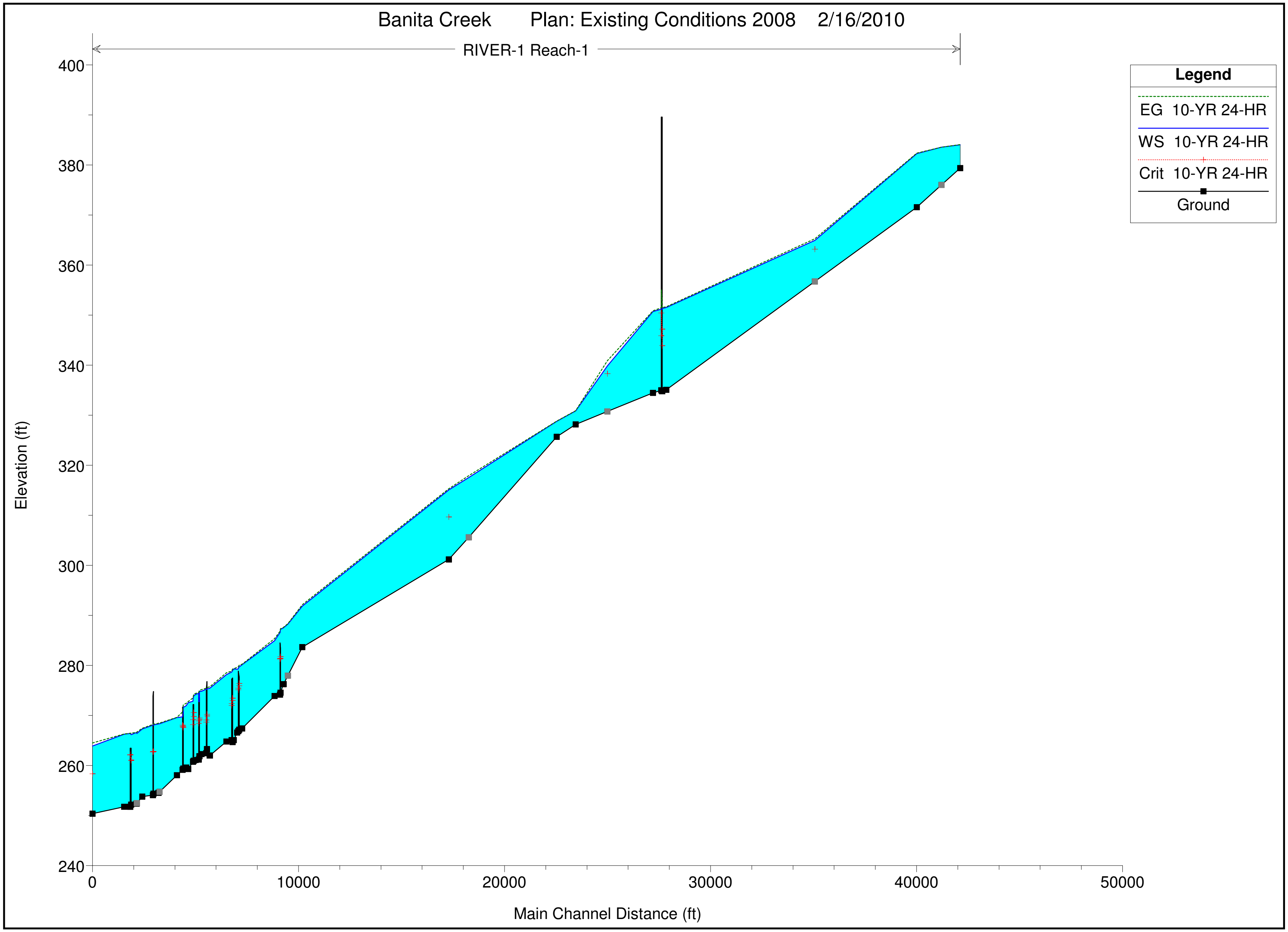


Banita Creek Plan: Existing Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 100-YR 24-HR
WS 100-YR 24-HR
Crit 100-YR 24-HR
Ground
Elevation (ft)
400
380
360
340
320
300
280
260
240
0
10000
20000
30000
40000
50000
Main Channel Distance (ft)

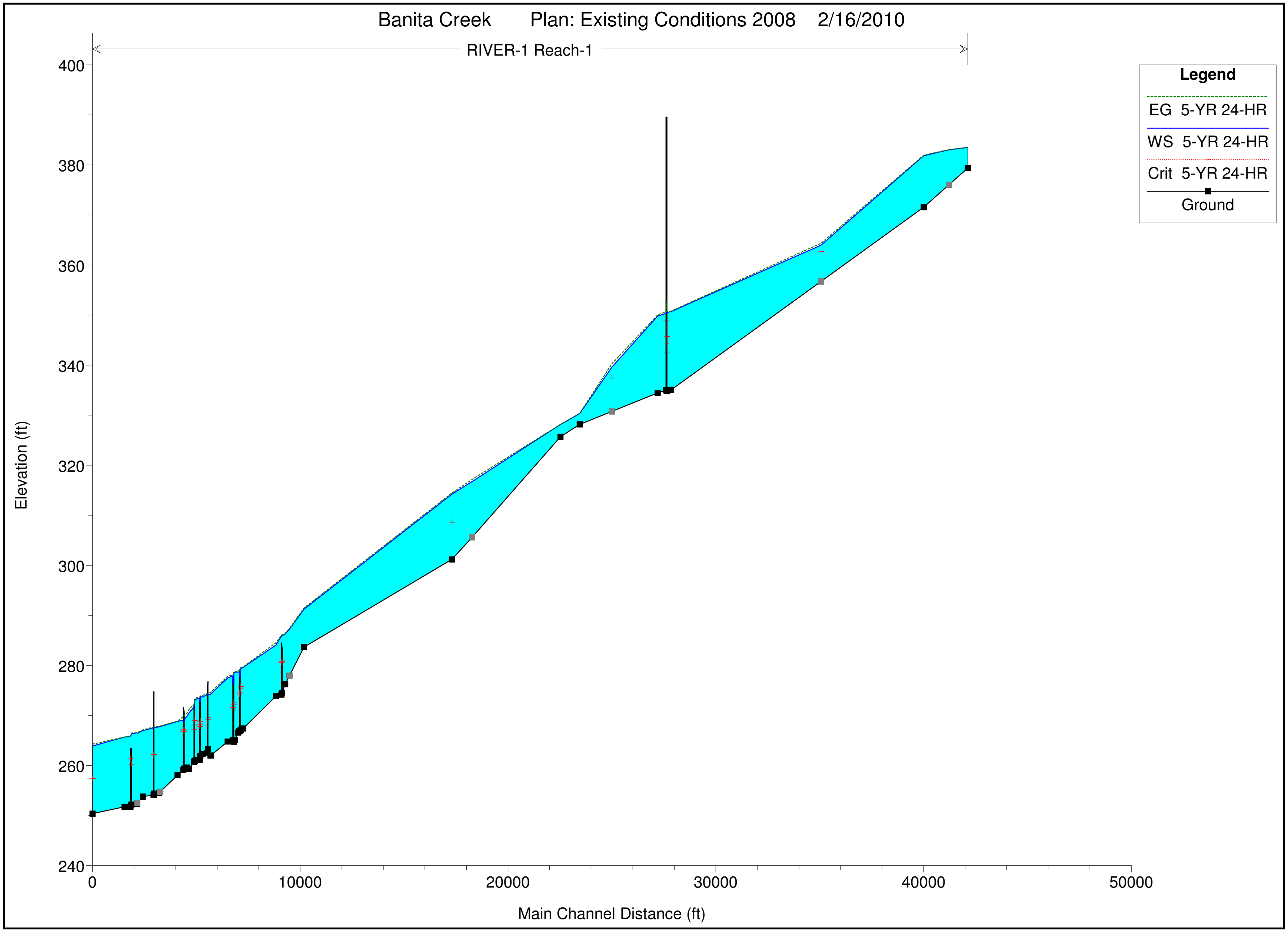

Banita Creek Plan: Existing Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 50-YR 24-HR
WS 50-YR 24-HR
Crit 50-YR 24-HR
Ground
Elevation (ft)
Main Channel Distance (ft)
400
380
360
340
320
300
280
260
240
0
10000
20000
30000
40000
50000



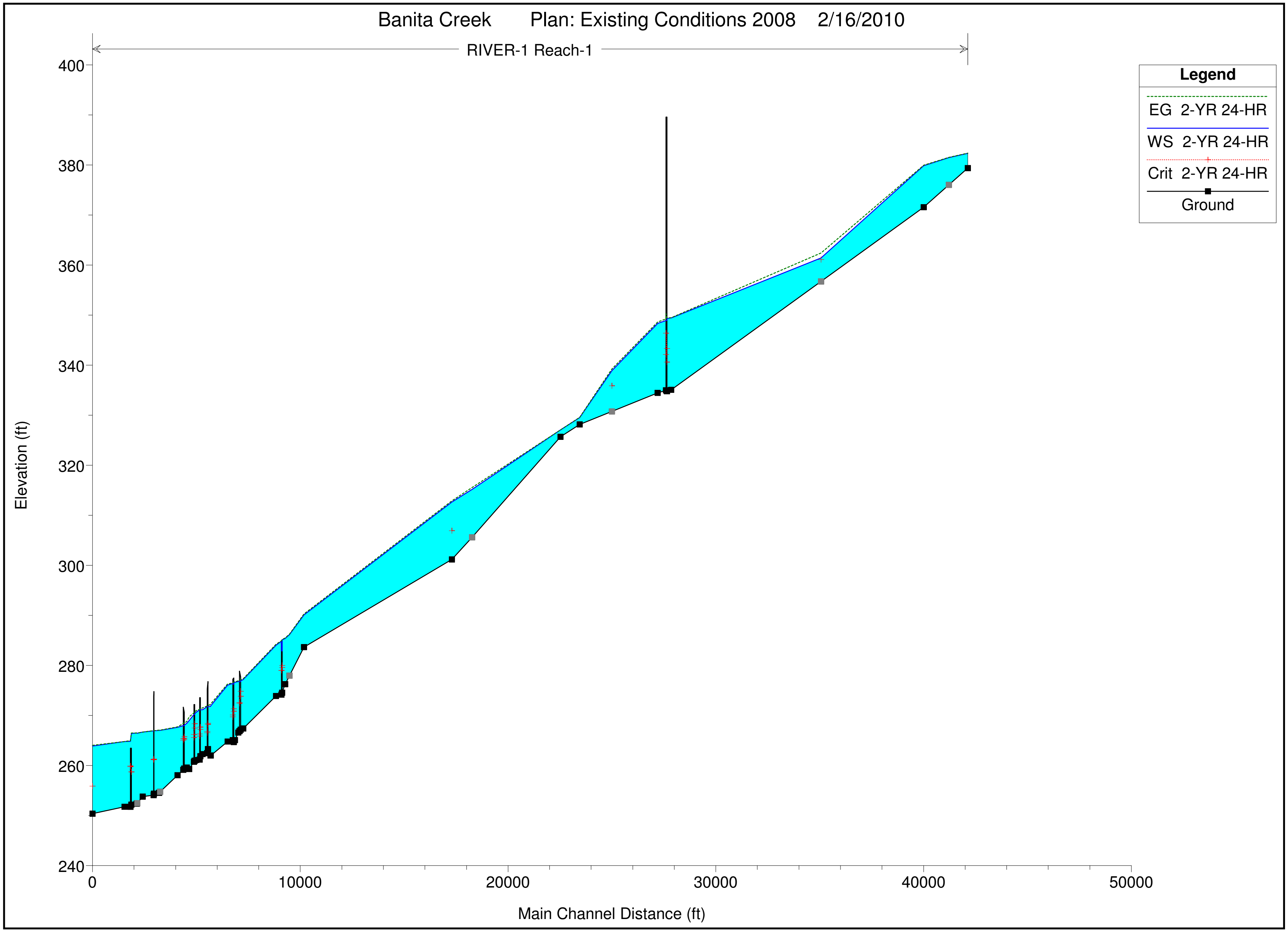
Banita Creek Plan: Existing Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 25-YR 24-HR
WS 25-YR 24-HR
Crit 25-YR 24-HR
Ground
Elevation (ft)
Main Channel Distance (ft)
400
380
360
340
320
300
280
260
240
0
10000
20000
30000
40000
50000



Banita Creek Plan: Existing Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 10-YR 24-HR
WS 10-YR 24-HR
Crit 10-YR 24-HR
Ground
Elevation (ft)
Main Channel Distance (ft)
400
380
360
340
320
300
280
260
240
0
10000
20000
30000
40000
50000

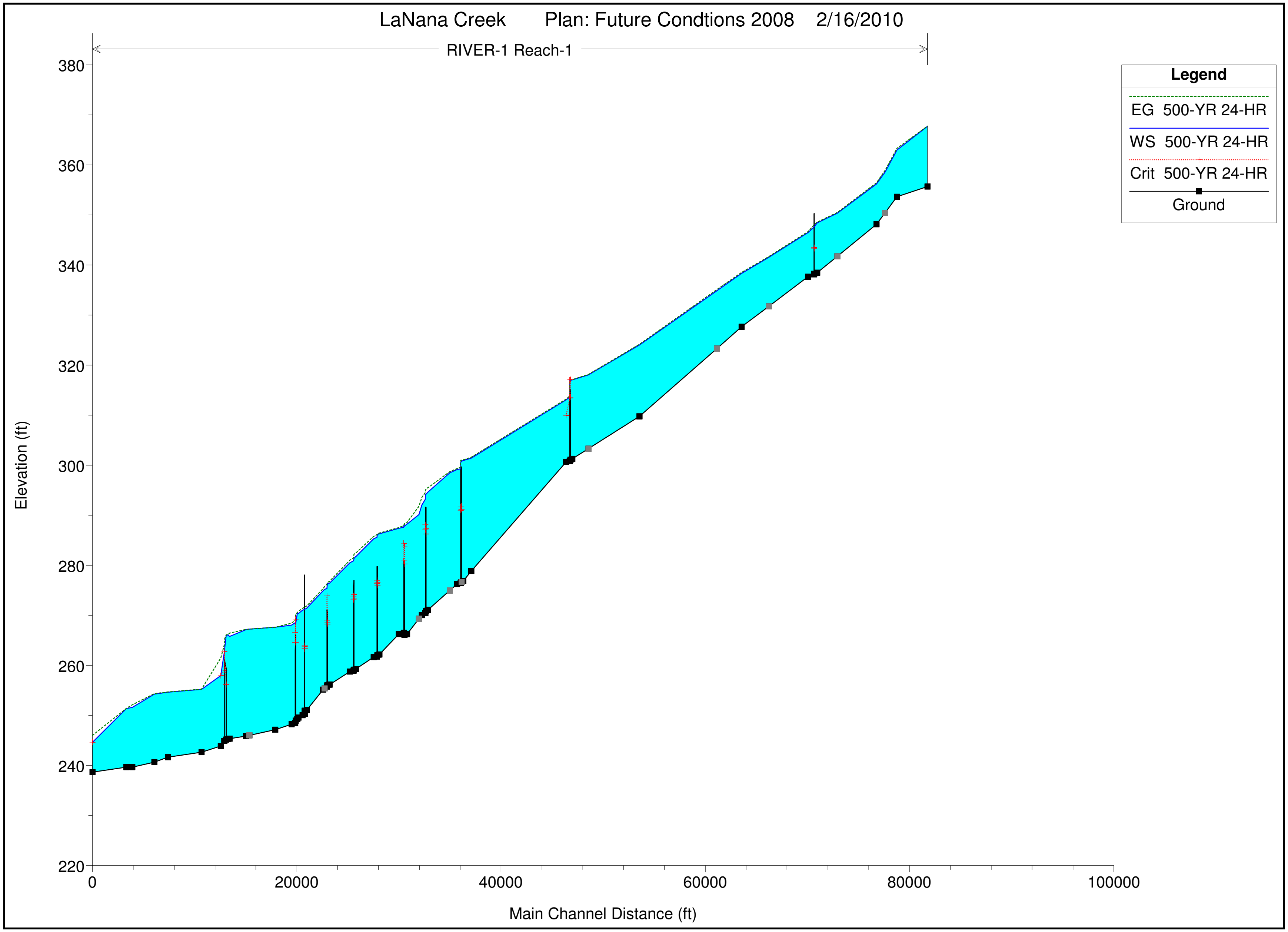


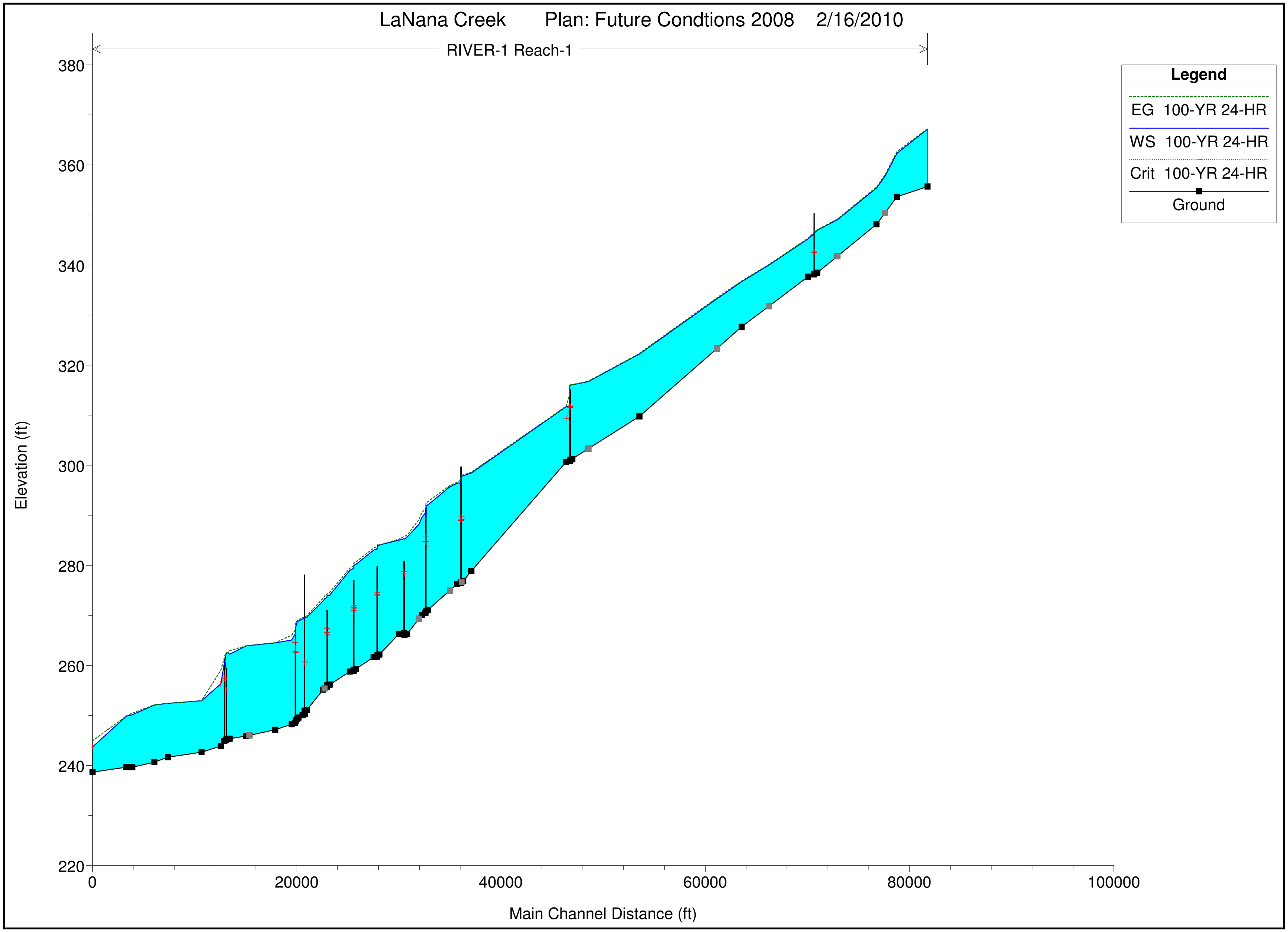
Banita Creek Plan: Existing Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 5-YR 24-HR
WS 5-YR 24-HR
Crit 5-YR 24-HR
Ground
Elevation (ft)
400
380
360
340
320
300
280
260
240
0
10000
20000
30000
40000
50000
Main Channel Distance (ft)



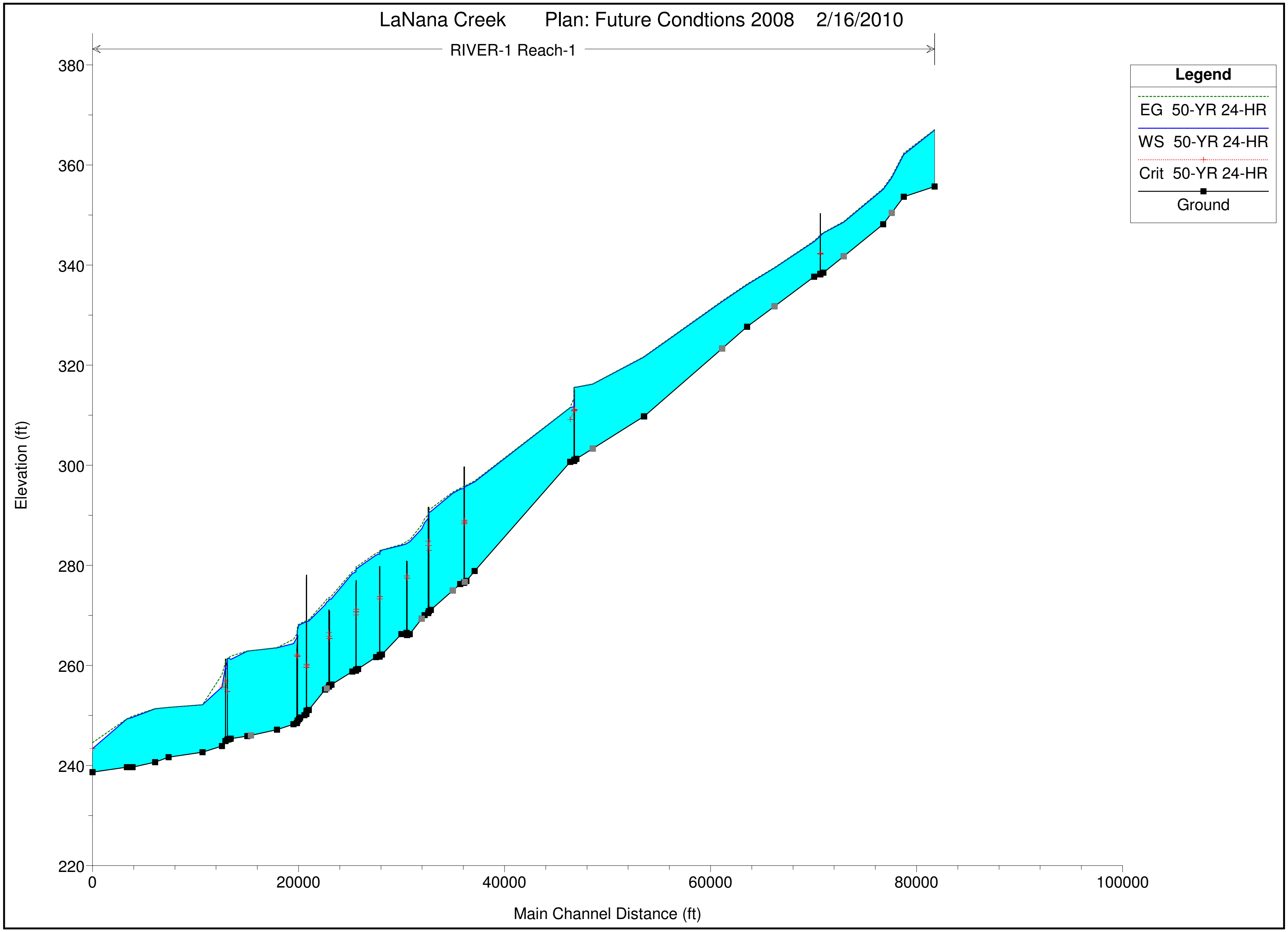
Banita Creek Plan: Existing Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 2-YR 24-HR
WS 2-YR 24-HR
Crit 2-YR 24-HR
Ground
Elevation (ft)
400
380
360
340
320
300
280
260
240
0
10000
20000
30000
40000
50000
Main Channel Distance (ft)

FUTURE CHANNEL PROFILES

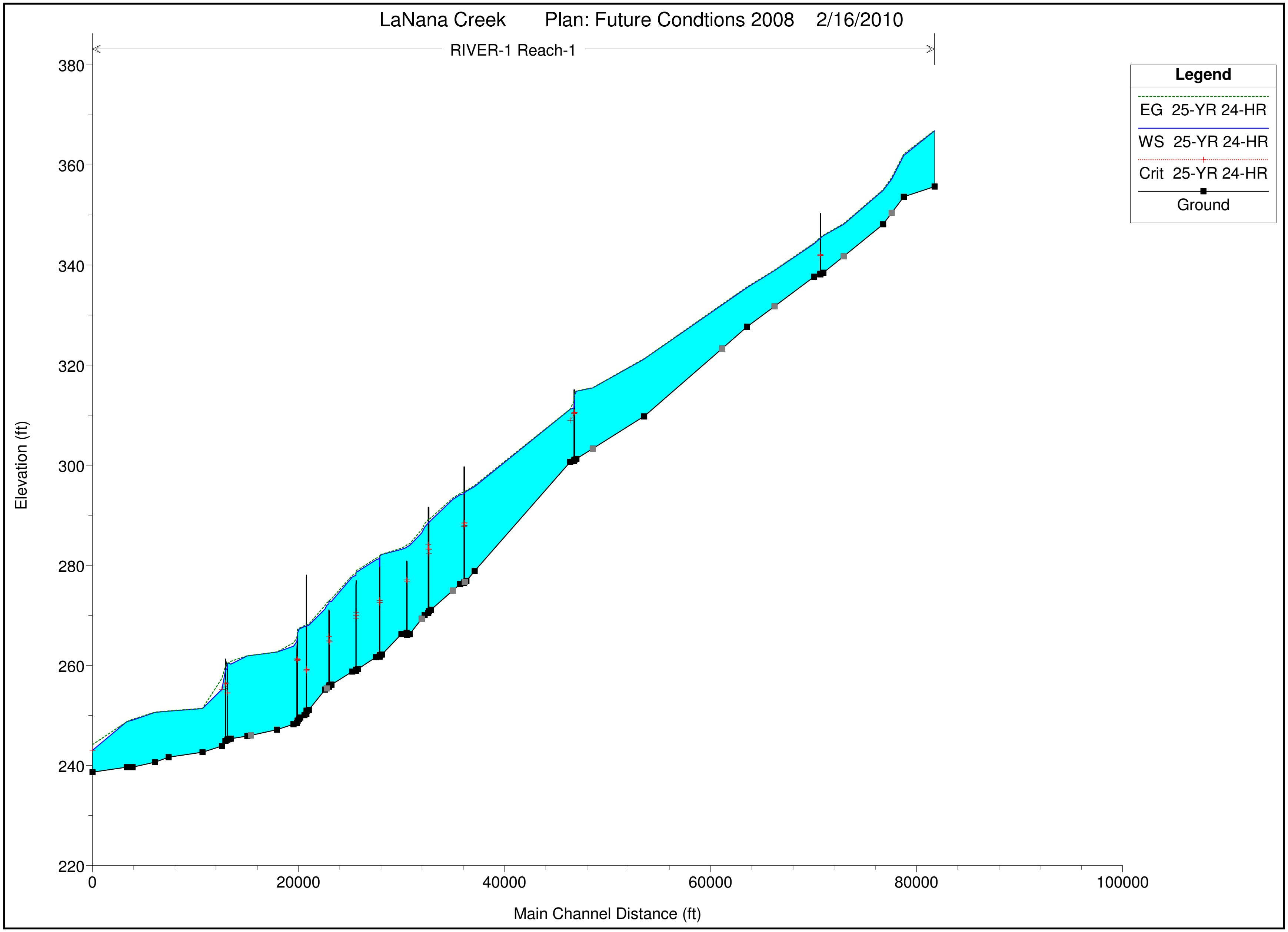

LaNana Creek Plan: Future Condtions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 500-YR 24-HR
WS 500-YR 24-HR
Crit 500-YR 24-HR
Ground
Elevation (ft)
Main Channel Distance (ft)
380
360
340
320
300
280
260
240
220
0
20000
40000
60000
80000
100000

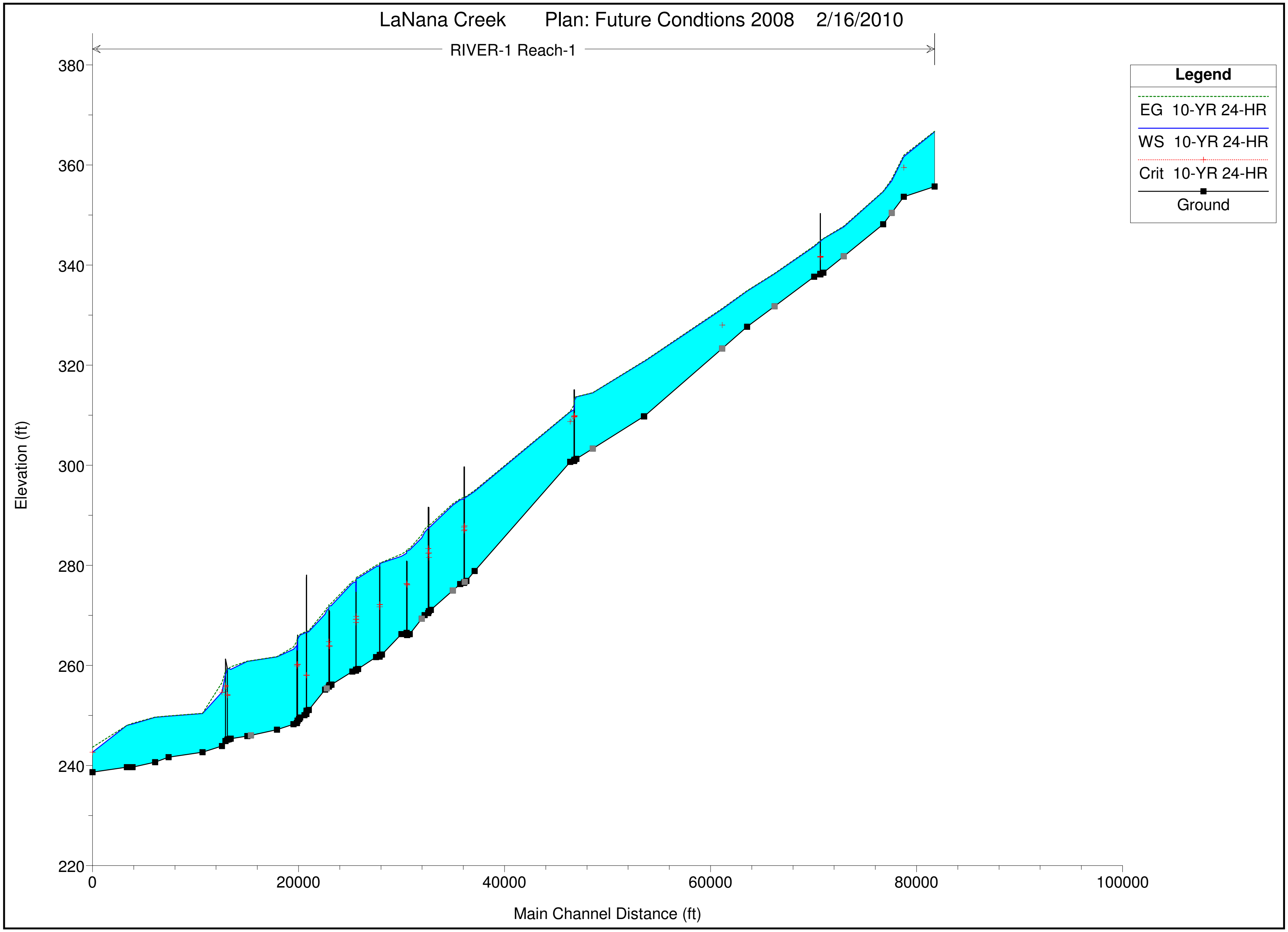


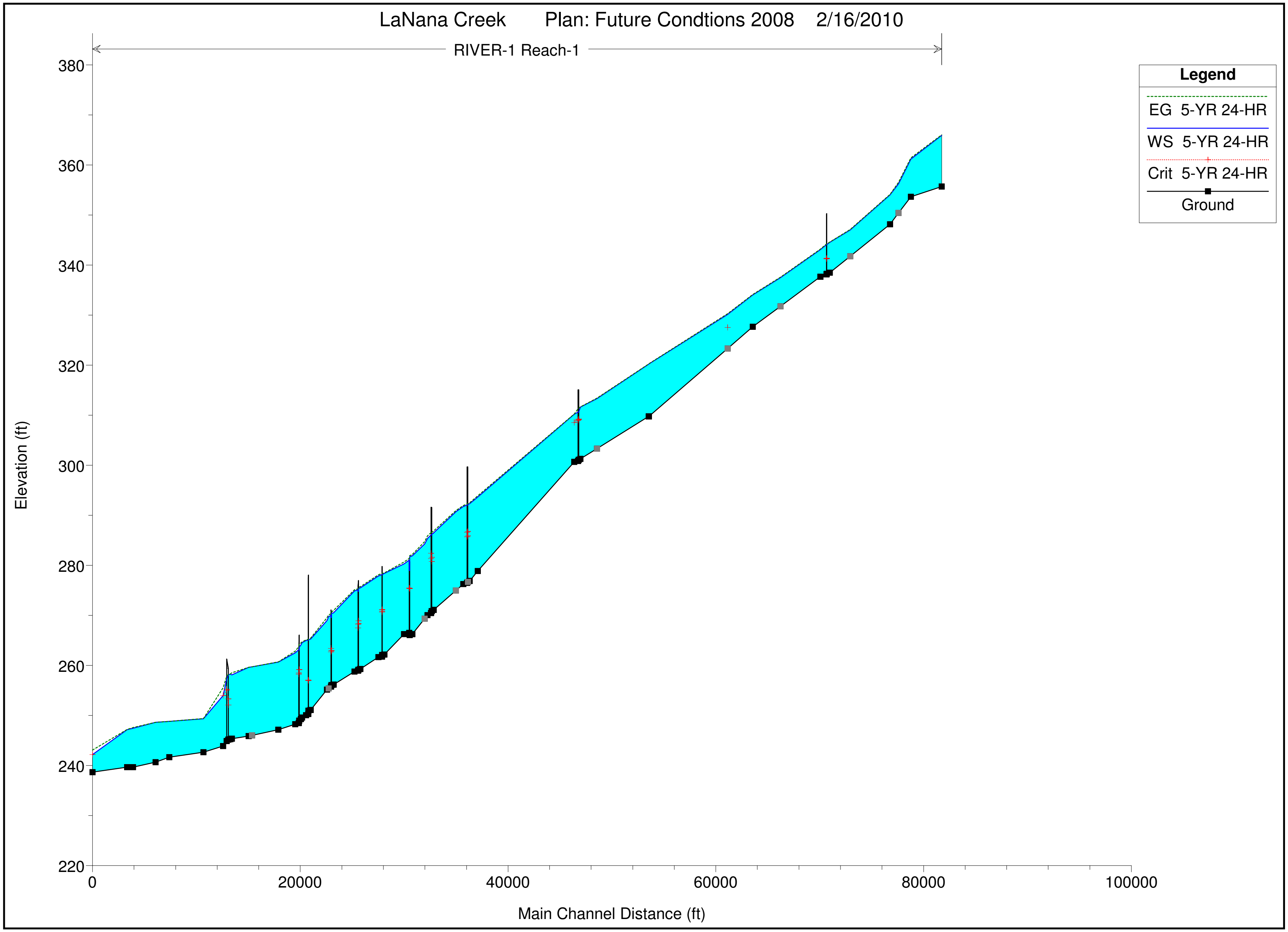
LaNana Creek Plan: Future Condtions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 100-YR 24-HR
WS 100-YR 24-HR
Crit 100-YR 24-HR
Ground
Elevation (ft)
380
360
340
320
300
280
260
240
220
0
20000
40000
60000
80000
100000
Main Channel Distance (ft)



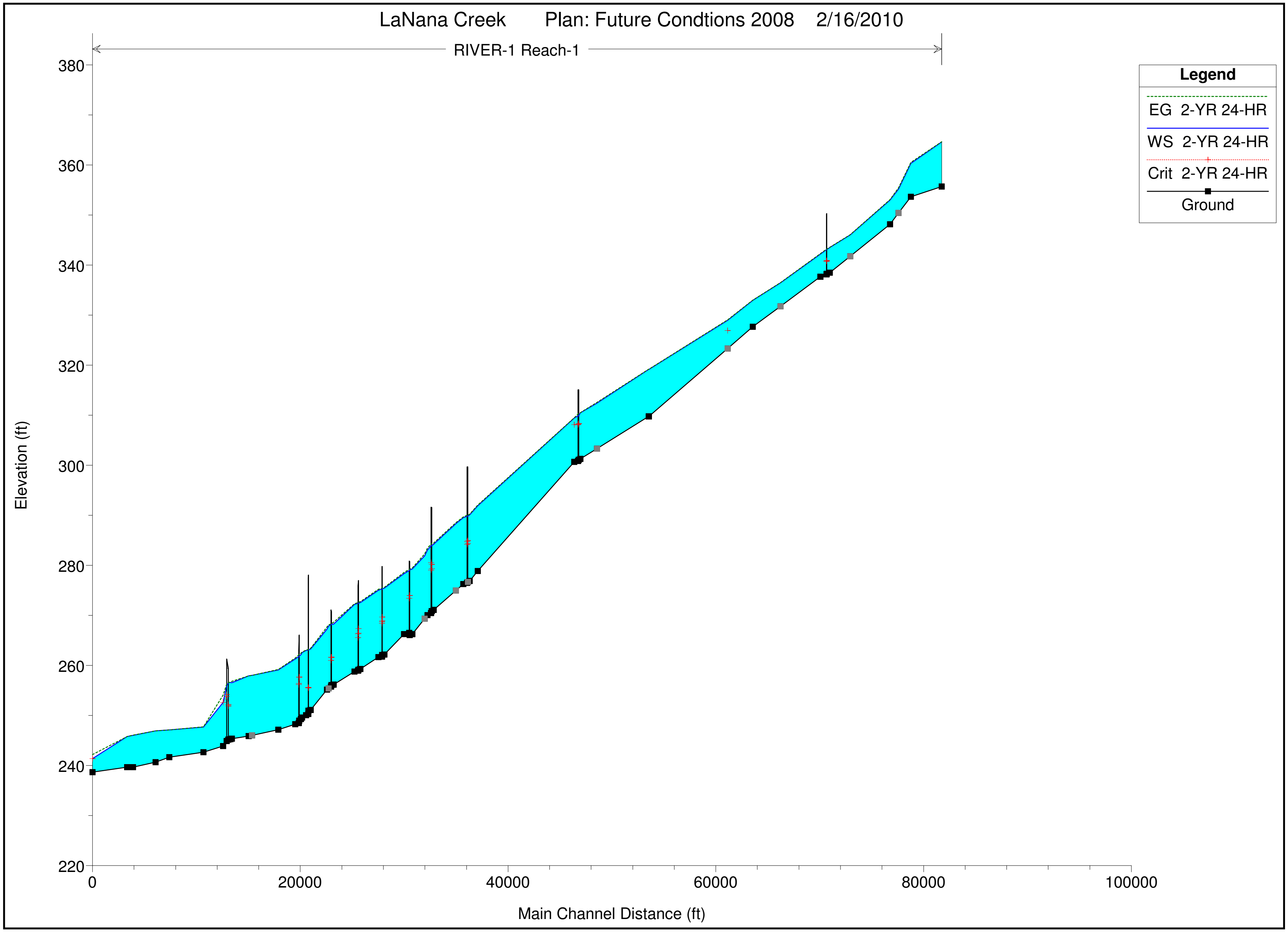
LaNana Creek Plan: Future Condtions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 50-YR 24-HR
WS 50-YR 24-HR
Crit 50-YR 24-HR
Ground
Elevation (ft)
Main Channel Distance (ft)
380
360
340
320
300
280
260
240
220
0
20000
40000
60000
80000
100000

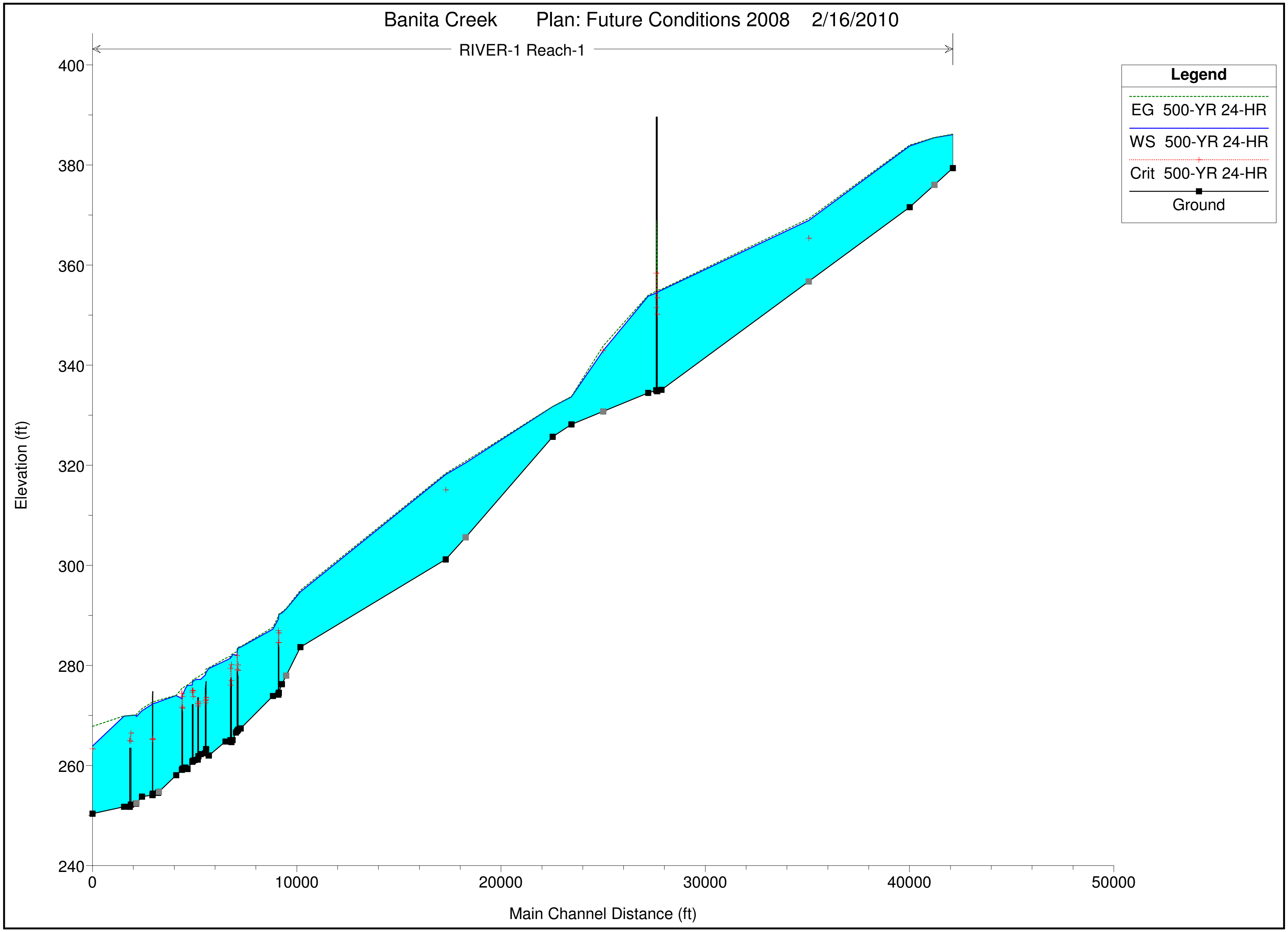

LaNana Creek Plan: Future Condtions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 25-YR 24-HR
WS 25-YR 24-HR
Crit 25-YR 24-HR
Ground
Elevation (ft)
Main Channel Distance (ft)
380
360
340
320
300
280
260
240
220
0
20000
40000
60000
80000
100000

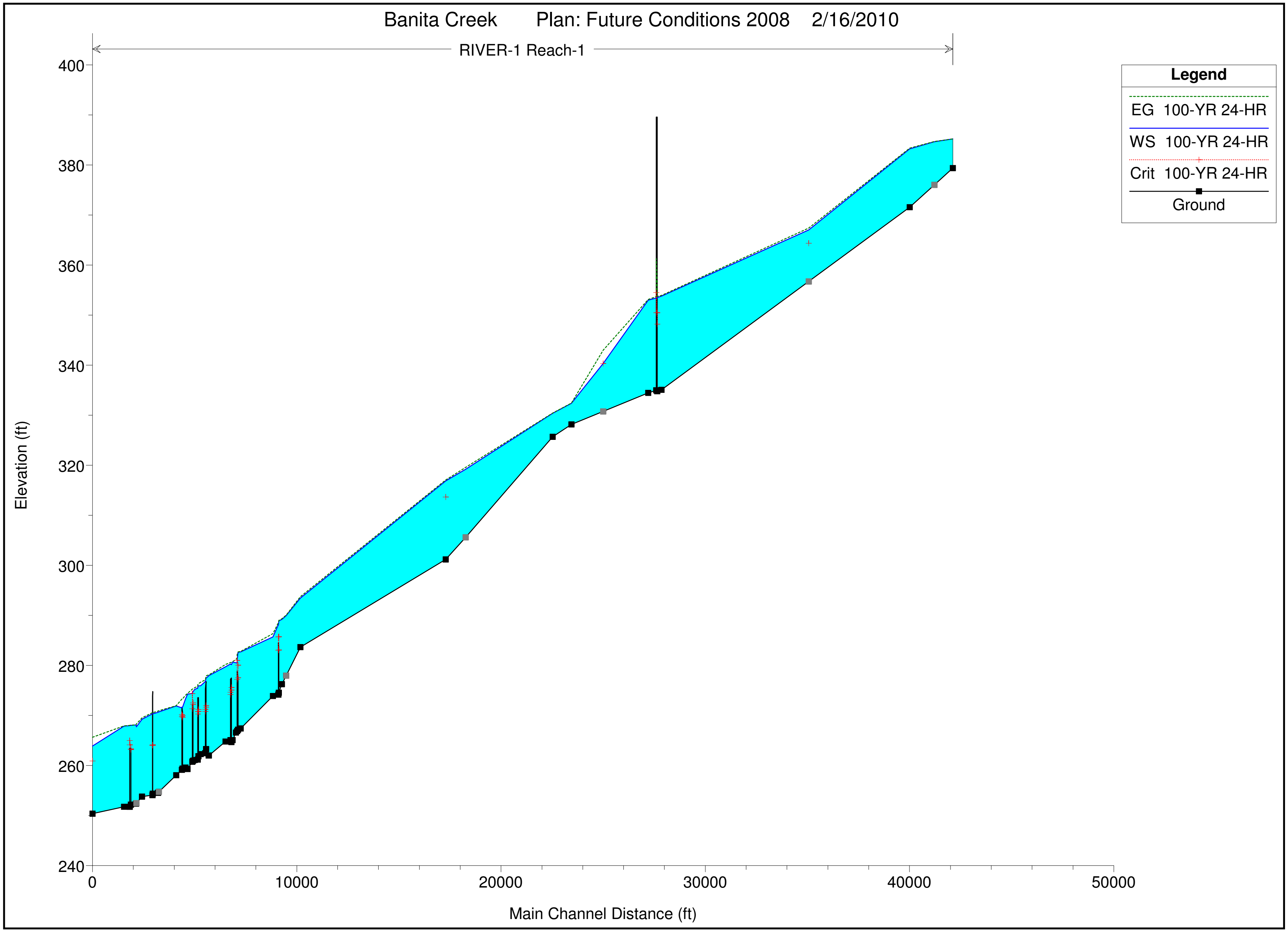

LaNana Creek Plan: Future Condtions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 10-YR 24-HR
WS 10-YR 24-HR
Crit 10-YR 24-HR
Ground
Elevation (ft)
380
360
340
320
300
280
260
240
220
0
20000
40000
60000
80000
100000
Main Channel Distance (ft)



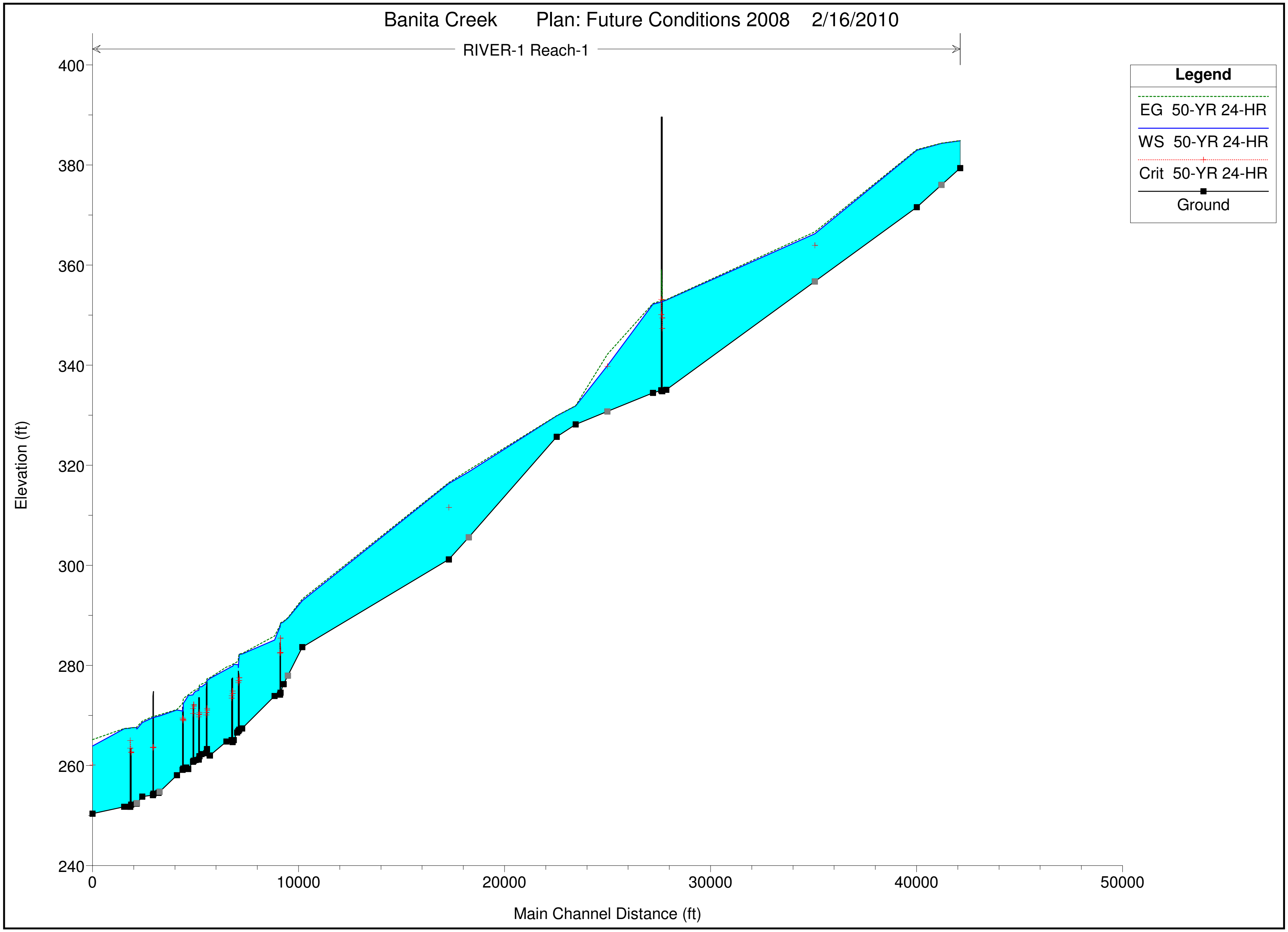
LaNana Creek Plan: Future Condtions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 5-YR 24-HR
WS 5-YR 24-HR
Crit 5-YR 24-HR
Ground
Elevation (ft)
Main Channel Distance (ft)
380
360
340
320
300
280
260
240
220
0
20000
40000
60000
80000
100000


LaNana Creek Plan: Future Condtions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 2-YR 24-HR
WS 2-YR 24-HR
Crit 2-YR 24-HR
Ground
Elevation (ft)
380
360
340
320
300
280
260
240
220
0
20000
40000
60000
80000
100000
Main Channel Distance (ft)

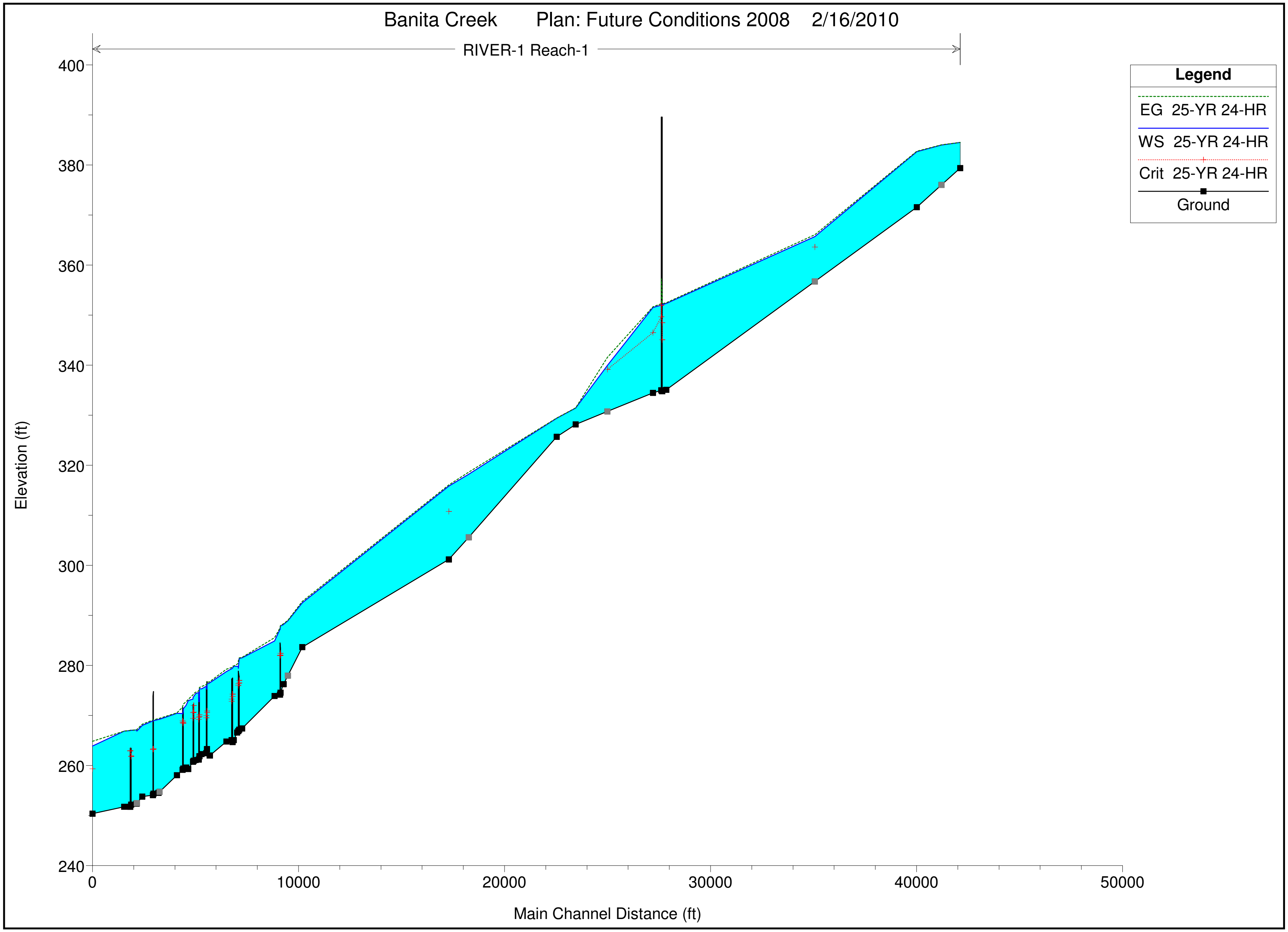

Banita Creek Plan: Future Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 500-YR 24-HR
WS 500-YR 24-HR
Crit 500-YR 24-HR
Ground
Elevation (ft)
Main Channel Distance (ft)
400
380
360
340
320
300
280
260
240
0
10000
20000
30000
40000
50000

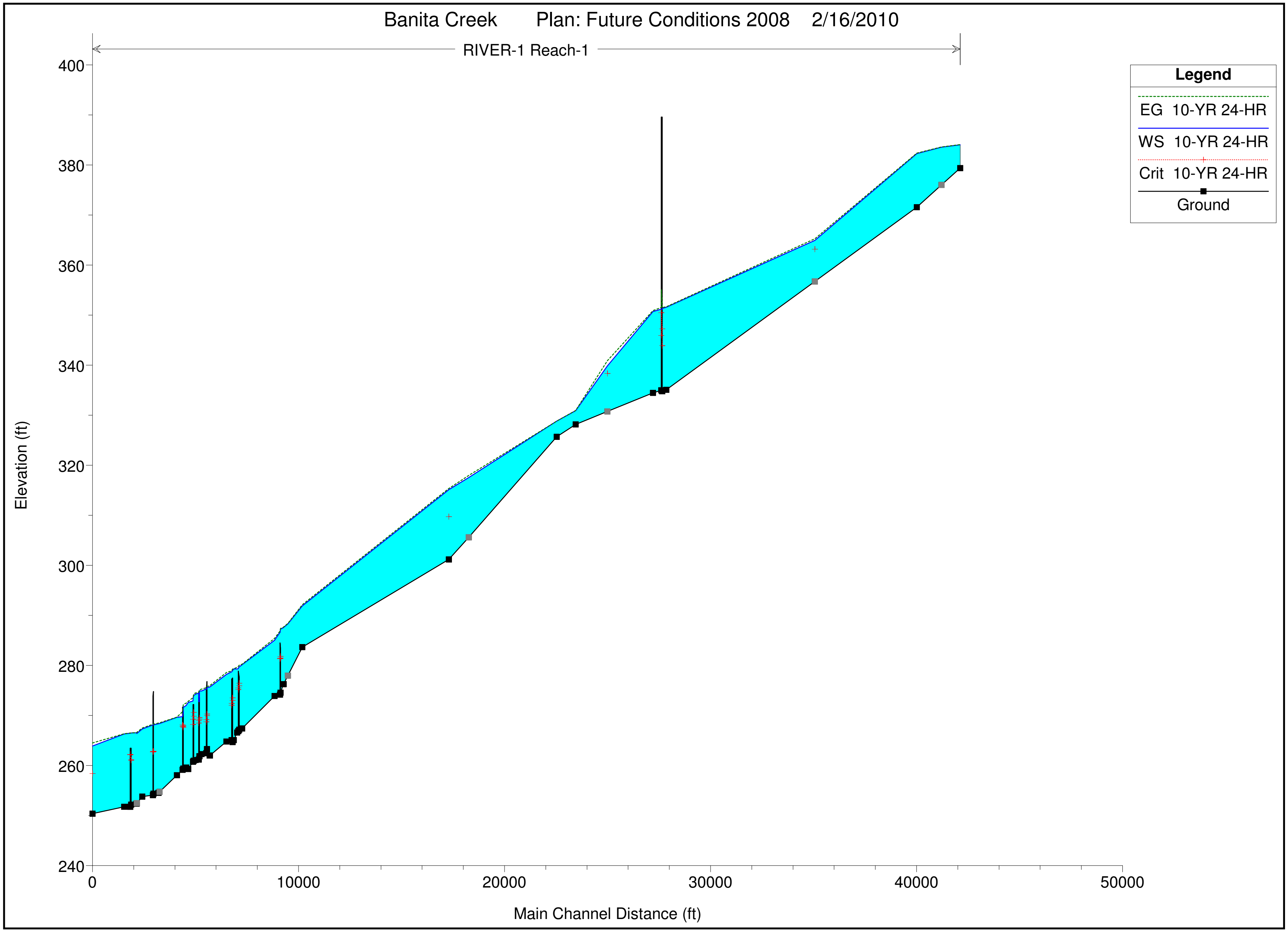


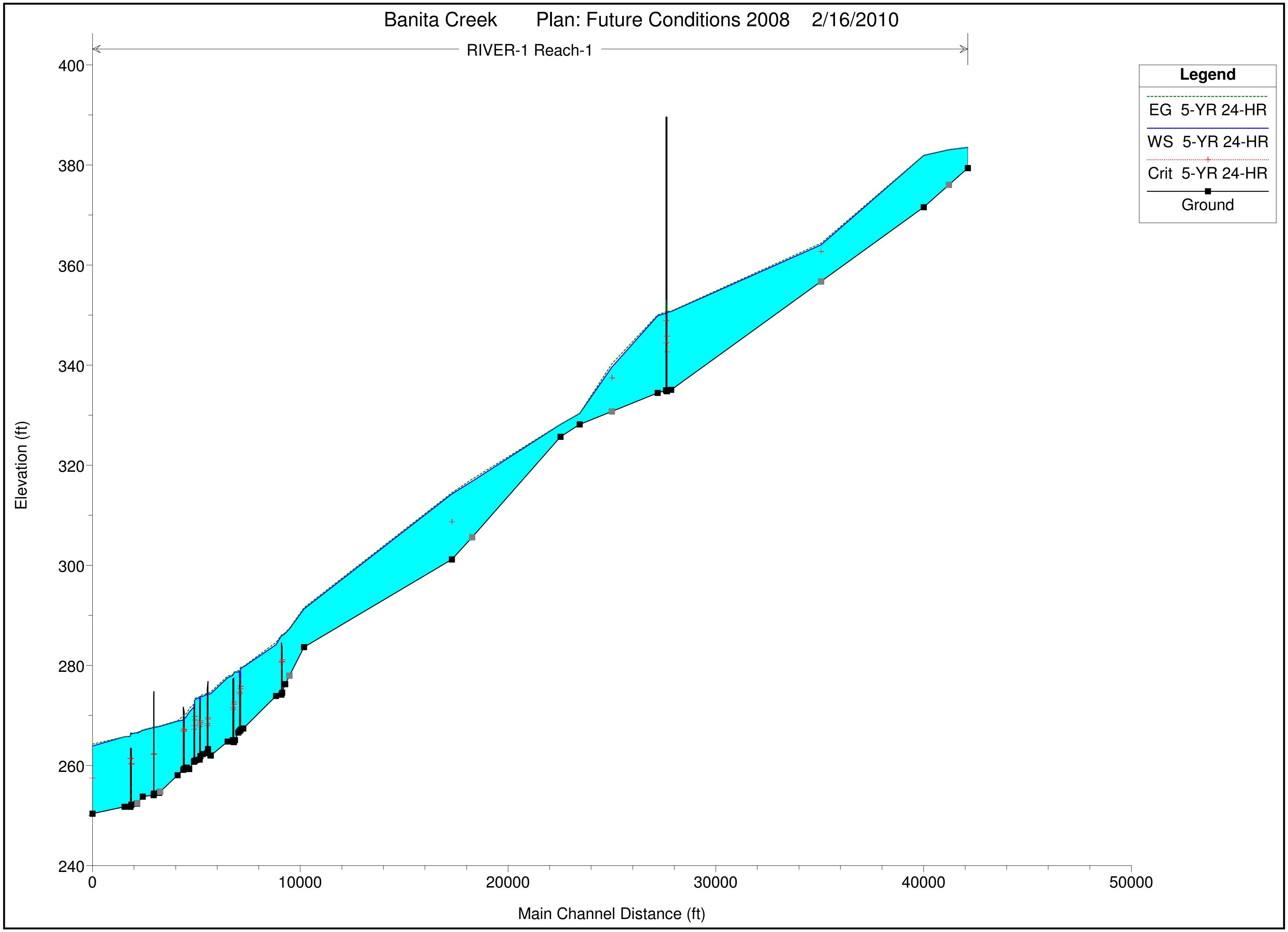
Banita Creek Plan: Future Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 100-YR 24-HR
WS 100-YR 24-HR
Crit 100-YR 24-HR
Ground
Elevation (ft)
400
380
360
340
320
300
280
260
240
0
10000
20000
30000
40000
50000
Main Channel Distance (ft)



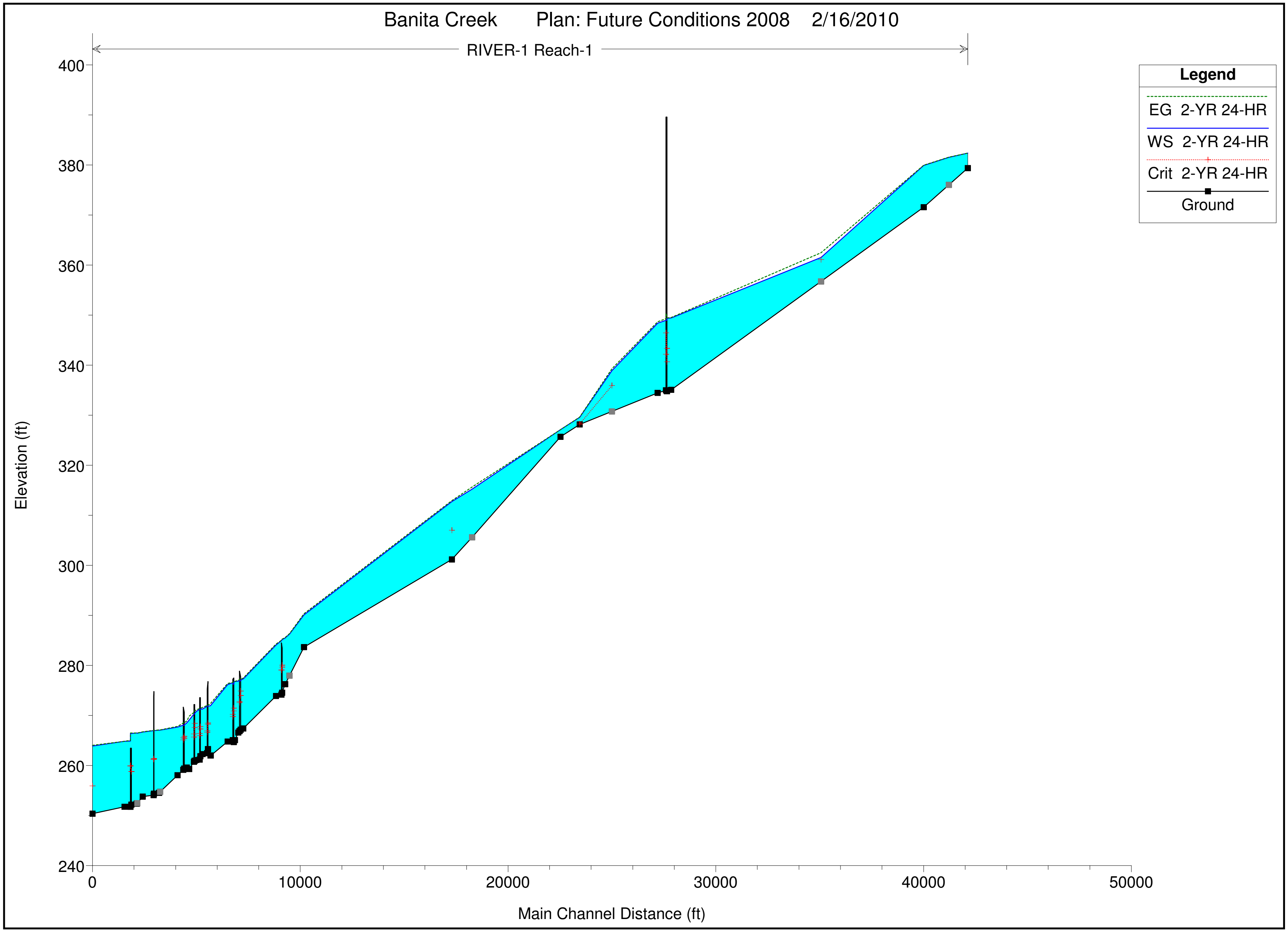
Banita Creek Plan: Future Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 50-YR 24-HR
WS 50-YR 24-HR
Crit 50-YR 24-HR
Ground
Elevation (ft)
400
380
360
340
320
300
280
260
240
0
10000
20000
30000
40000
50000
Main Channel Distance (ft)


Banita Creek Plan: Future Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 25-YR 24-HR
WS 25-YR 24-HR
Crit 25-YR 24-HR
Ground
Elevation (ft)
400
380
360
340
320
300
280
260
240
0
10000
20000
30000
40000
50000
Main Channel Distance (ft)


Banita Creek Plan: Future Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 10-YR 24-HR
WS 10-YR 24-HR
Crit 10-YR 24-HR
Ground
Elevation (ft)
400
380
360
340
320
300
280
260
240
0
10000
20000
30000
40000
50000
Main Channel Distance (ft)



Banita Creek Plan: Future Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 5-YR 24-HR
WS 5-YR 24-HR
Crit 5-YR 24-HR
Ground
Elevation (ft)
Main Channel Distance (ft)
400
380
360
340
320
300
280
260
240
0
10000
20000
30000
40000
50000



Banita Creek Plan: Future Conditions 2008 2/16/2010
RIVER-1 Reach-1
Legend
EG 2-YR 24-HR
WS 2-YR 24-HR
Crit 2-YR 24-HR
Ground
Elevation (ft)
Main Channel Distance (ft)
400
380
360
340
320
300
280
260
240
0
10000
20000
30000
40000
50000

APPENDIX C

PHOTOGRAPHS

Lanana Creek @ Main St.

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Lanana Creek @ Starr Street

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Lanana St. @ Park St.

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Lanana Creek @ Martinsville Rd.

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Lanana Creek @ Martin Luther King Blvd.

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Banita Creek @ Martin Luther King Blvd.

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Banita Creek @ South St.

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Banita Creek @ Fredonia

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Banita Creek @ Main St.

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Banita Creek @ Powers

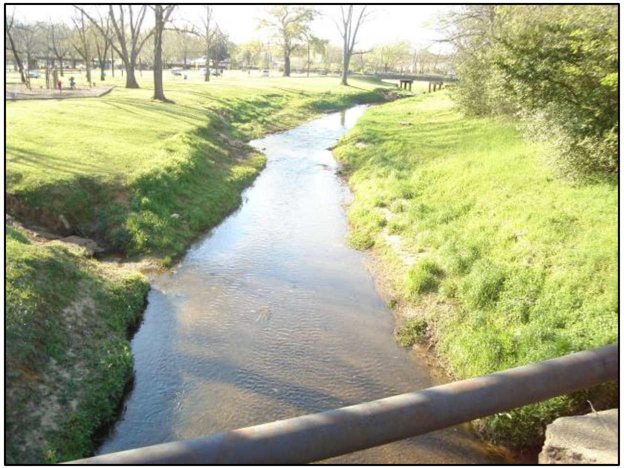
Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Banita Creek @ Church St.



Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Banita Creek @ Pilar St.

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Banita Creek @ South Pecan

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bride crossing

Looking downstream at bridge crossing

Eggnog Br. @ Loop 224

Looking upstream from bridge deck

Looking downstream from bridge deck

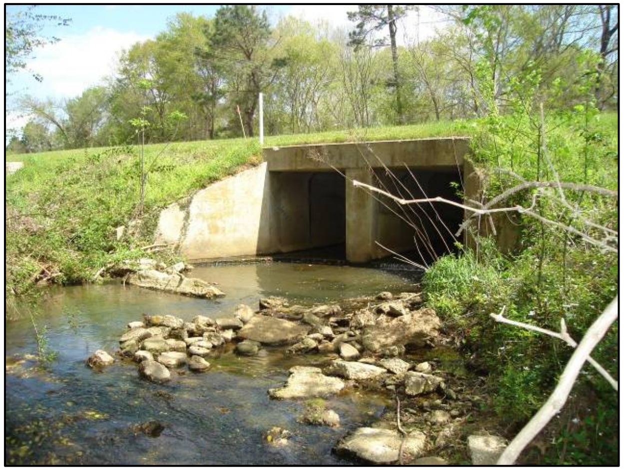
Looking upstream at bridge crossing

Looking downstream at bridge crossing

Eggnog Br. @ Hwy 1275

Looking upstream from bridge deck

Looking downstream from bridge deck



Looking upstream at bridge crossing

Looking downstream at bridge crossing

Eggnog Br. @ F.M. 2259

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Eggnog Br. @ Eastwood Terrace

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Tributary A @ Pioneer Park Entrance

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Tributary A @ Press Rd.

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Tributary A @ R.R. Trestle.

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Tributary A @ South St.

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Tributary B. @ South St.

Looking upstream from bridge deck

Looking downstream from under Boles Feed Co

Looking upstream at Boles Feed Co.

Looking downstream at bridge crossing

Tributary B. @ Virginia Ave.

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Profile view of culvert

Tributary A. @ Fredonia St.

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Tributary B @ Burk St.

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Tributary B @ Sunset St.

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Tributary B @ Fredonia St.

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Tributary B. @ R.R. Trestle

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Tributary B @ NIBCO Parking Driveway

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Tributary D @ F.M. 1411

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Tributary D-2 @ F.M. 1878

Looking upstream from road deck

Looking downstream from road deck

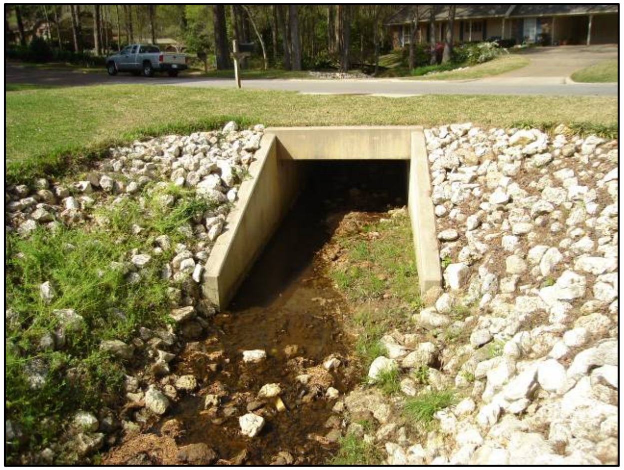
Looking upstream at culvert crossing

Looking downstream at culvert crossing

Tributary D-2 @ Briar Grove

Looking upstream from headwall

Looking downstream from headwall



Looking upstream at culvert crossing

Looking downstream at culvert crossing

Tributary D @ F.M. 1878

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Tributary D @ University Dr.

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking upstream at bridge crossing

Looking downstream at bridge crossing

Tributary B. @ Perry Dr.

Looking upstream from bridge deck

Looking downstream from bridge deck

Looking at upstream profile view

Looking at downstream profile view

Tributary B. @ Durst St.

Looking upstream from bridge deck

Looking downstream from bridge deck

Upstream profile view

Downstream profile view

APPENDIX D

REFERENCES

APPENDIX D

REFERENCES

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