SAN JACINTO RIVER AUTHORITY

WATER RESOURCES DEVELOPMENT PLAN

PATE ENGINEERS, INC.

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WATER RESOURCES DEVELOPMENT PLAN
WATER SUPPLY PLAN

PREPARED BY:

PATE ENGINEERS, INC.
WITH MATCHING FUNDS PROVIDED BY
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SECTION I

INTRODUCTION

PURPOSE

The effective use of water resources is a growing concern of Texas citizens. A reliable water supply is an essential prerequisite for economic growth, and the way we use water significantly affects the quality of the environment and is a prime determinent of the type and quality of urban growth. In addition, State policy has been re-shaped in recent years to place more emphasis on total water resource management. The Texas Water Plan adopted by the voters in 1985 not only revitalized State water financial assistance programs, but also broadened those programs to cover regional water and wastewater projects and flood control projects for growing urban areas. State policy was also changed to promote conservation of water resources through reuse and reduction of consumption.

The existing institutional framework within the State reserves authority for planning and implementing specific water resource projects to local units of government, including river authorities. In many instances, an existing river authority may be the only local entity capable of long-term planning and implementation to meet changing needs as urban growth occurs in previously rural areas. These changing local circumstances as well as policy changes at the State level represent a challenge to local government, particularly entities with regional scope such as river authorities, to provide for effective water resource management programs that meet the needs of local areas and that reflect current State water policy.

Responding to that challenge, the San Jacinto River Authority authorized this study to define a comprehensive water resources development plan. The purpose of the study is to define a plan that 1) addresses the water supply, water quality, and flood control needs of the rapidly urbanizing service area of the Authority; 2) provides guidance for implementing specific water resource projects within the service area; 3) examines the relationship of the Authority to the larger metropolitan region of which it is part and evaluates broader regional projects in which the Authority may play a productive role; and 4) is consistent with State policy.

AUTHORIZATION

This study was authorized by the San Jacinto River Authority by contract dated December 1, 1986. Matching funds were provided by the Texas Water Development Board.

SCOPE

The Water Resources Development Plan is presented in three volumes. Volume I presents the Water Supply Plan, Volume II presents the Flood Control Plan and Volume III presents the Water Quality Plan.

The scope of work of the Water Supply Plan addressed in this volume has been defined as follows:

- o Define population and water demands through the year 2030.
- o Determine groundwater availability and the need for surface water within the study area.
- o Identify existing and potential surface water supply sources.
- o Analyze the cost of obtaining surface water, including raw water conveyance and treatment facilities, from both in-basin and out-of-basin reservoirs, and analyze the cost of future groundwater supply facilities that may be required.
- o Define alternative water supply projects and associated costs.

- Develop criteria for screening alternative projects and rank the alternatives based on these criteria.

- Recommend a water supply program and develop an implementation plan.

SAN JACINTO RIVER AUTHORITY: THE FIRST FIFTY YEARS

The San Jacinto River Authority was created by the Texas Legislature in 1937 and is one of 15 major river authorities in the State of Texas. Over the past fifty years, the Authority has implemented soil conservation, water supply, wastewater treatment, flood control, and recreation programs. The SJRA's watershed area includes all of Montgomery County and portions of Waller, Grimes, San Jacinto, and Liberty Counties and contains approximately 1,200 square miles. It is empowered to and does operate facilities both within and outside of these boundaries as shown on Exhibit No. 1. The SJRA first implemented its soil conservation and reclamation program in 1946 in cooperation with agencies of the U.S. Department of Agriculture. The Authority purchased heavy equipment and provided interim financing for the construction of improvements to prevent erosion, reduce flooding, and restore soil fertility. More than $1.5 million was invested in individual projects which included over 400 small lakes and stock tanks, 150 miles of field terracing, 75 miles of water diversion channels, and the leveling of hundreds of acres of gullied land in preparation for reforestation or pasture use.

The Authority's first water supply project was the purchase in 1945 of the Highlands Canal System serving industrial and agricultural customers in southeast Harris County with water supply contracts currently totaling 66.5 million gallons per day (MGD). The canal system facilities presently include a 100 MGD pump station at Lake Houston Dam, 38 miles of canal, and the 1,400 acre Highlands Reservoir. In 1970, the San Jacinto River Authority constructed Lake Conroe in conjunction with the City of Houston and the Texas Water Development Board. Located in northwest Montgomery County, the 22,000 acre Lake Conroe has a firm yield of 89.3 MGD. Although its primary purpose is water supply, it also provides recreation benefits.

In 1975, the Authority entered into contractual agreements with The Woodlands Corporation and the associated municipal utility districts (MUDs) whereby the Authority owns and operates the regional water supply and wastewater treatment facilities serving The Woodlands. The Authority acts as a wholesaler of water and wastewater services to the nine existing MUDs encompassing 9,000 acres and an existing resident population of approximately 23,000. Currently, the regional water supply facilities include seven wells and two storage and pumping plants capable of producing 20 MGD at peak demand. The regional wastewater collection and treatment system has a total treatment capacity of 6.1 MGD in two plants. These water and wastewater facilities will be expanded to serve a projected population of approximately 140,000 people at ultimate development of The Woodlands.

In recent years, SJRA has continued to pursue regional planning to address the long-term needs of the basin. In 1982, the SJRA sponsored the Bureau of Reclamation's San Jacinto Project investigation which has resulted in the Bureau's preliminary recommendation for construction of the Lake Creek reservoir. The Bureau's study is on-going. In cooperation with the Texas Department of Water Resources, SJRA prepared a Water Quality Management Plan for the San Jacinto River Basin in 1982 and a San Jacinto Upper Watershed Drainage Improvement and Flood Control Planning Study in 1985. In 1986, the Authority commissioned a feasibility study of the purchase of water from Toledo Bend Reservoir and its conveyance to Lake Houston.

This planning study is the SJRA's response to the problems of the next fifty years and beyond. The primary focus of the plan should be the SJRA's service area as legally defined. There is a clear need for regional solutions to insure water supply for future urbanization in Montgomery County, and the SJRA is the only regional entity in existence at this time which could implement needed projects. This certainly does not preclude other entities from forming for that purpose, but the SJRA does have an opportunity to provide leadership by defining cost-effective solutions which are capable of implementation and which are recognized by responsible community leaders in Montgomery County as necessary to provide for the sustainable economic growth of the County. The plan should also take into account the broader region, so that out-of-basin projects which may enhance solutions required for the SJRA service area and which solve regional water supply problems can be considered. This aspect of the planning effort must be consistent with other planning entities because most out-of-basin projects are either larger in scale than required for SJRA needs, or involve areas where other entities such as the City of Houston exercise legal planning jurisdiction.

COORDINATION WITH OTHER REGIONAL WATER SUPPLY PLANNING

A number of other planning efforts are currently on-going in which coordination is required to avoid duplication of efforts. These planning efforts are primarily focused in north Harris County and involve surface water conversion studies by the North Harris County Water Supply Corporation, the West Harris County Water Supply Corporation and the Northeast Harris County Water Supply Corporation, all partially funded by planning grants from the Texas Water Development Board. The geographic relationship of each of these corporations is illustrated in Exhibit No. 2. Also of importance is the City of Houston Water Master Plan which is nearing completion. The scope, available data, and relevant planning conclusions are summarized for each of these plans below:

North Harris County Water Supply Corporation

The North Harris County Water Supply Corporation (NHCWSC) was formed in 1986 to address groundwater problems in the F.M. 1960/Cypress Creek area. These problems include decreasing well production due to declining water levels and natural gas intrusion. In addition, most of the area is required to convert to 80 percent surface water by the year 2005 in accordance with the plan of the Harris-Galveston Coastal Subsidence District adopted in 1985. A surface water conversion planning study was recently performed by the NHCWSC with financial assistance provided by the Texas Water Development Board. The 38,000 acre service area of the NHCWSC is in the City of Houston extraterritorial jurisdiction and has a current water demand of approximately 19 MGD. This demand is projected to grow to 30 MGD by the year 2010.

The feasibility of obtaining surface water from Millican Reservoir, Bedias Reservoir, Toledo Bend, Lake Creek, Lake Conroe, and Lake Houston was evaluated. Based on factors including raw water costs, conveyance costs, adequate available yield, timing, and predictability (some reservoirs are only in preliminary planning phase), the NHCWSC study concluded that Lake Houston was the most cost effective and reliable surface water source for its needs. City of Houston officials have indicated that supply of the NHCWSC service area with treated surface water from Lake Houston is consistent with the City's previous and on-going master planning.

The City of Houston has also expressed an interest in cooperating with the NHCWSC in constructing the first phase of the Northeast Water Purification Plant in lieu of constructing the previously proposed upgrade and expansion of the Intercontinental Airport well field. The City's 1988 Capital Improvement Plan reflects this position with funding for design and construction of the Northeast Plant. In addition, the City has expressed a willingness to participate with the NHCWSC in the construction of a portion of the water transmission line from Lake Houston.

West Harris County Water Supply Corporation

The West Harris County Water Supply Corporation (WHCWSC) was created in 1987 on behalf of the Coastal Water Authority to develop a regional implementation plan for surface water conversion in West Harris County consistent with the HGCSD Plan and the City of Houston's Water Master Plan in order to provide a reliable supply of surface water and minimize subsidence. The WHCWSC has obtained financial assistance from the Texas Water Development Board to perform the necessary engineering studies. The service area contains 283,500 acres, the majority of which is in the City of Houston's extraterritorial jurisdiction.

Six alternative surface water supply plans were defined to serve the West Harris County area. Four alternatives rely on various combinations of water from Lake Houston in the northeast and the Brazos River in the southwest portion of the service area. Lake Houston, as referenced in these alternatives, includes water from Lake Conroe as well as ultimately Lake Livingston and Toledo Bend. Two alternatives rely on surface water from the north including Lake Millican and Lake Bedias. The Lake Bedias water was assumed to be delivered to Lake Conroe and thence due south into north Harris County.

Although no final plan has been selected, public presentations of study results indicate that the final plan will likely involve some combination of supply from Lake Houston and the Brazos River. The two supply alternatives from the north were not carried forward into the detailed evaluation process. Final evaluations are focused on a definition of the split of service to north and west Harris County between the proposed Northeast Water Purification Plant supplied by Lake Houston and the proposed Southwest Water Purification Plant supplied by the Brazos River.

Northeast Harris County Water Supply Corporation

The Northeast Harris County Water Supply Corporation was formed in late 1987 and obtained financial assistance from the Texas Water Development Board to prepare a surface water conversion plan. The service area containing approximately 33,000 acres is located east of I-45 and north of Greens Bayou, all of which is in the City of Houston's extraterritorial jurisdiction, as shown on Exhibit No. 2. Although planning has just begun, the Corporation has expressed an interest in participating with the NHCWSC and the City of Houston in the treated surface water transmission line from the Northeast Water Purification Plant on Lake Houston.

City of Houston Water Master Plan

The City of Houston's Water Master Plan addresses the long term water supply needs for the City and the surrounding eight county area. The study addresses such things as area growth, water use, groundwater availability, subsidence, existing and potential future surface water sources and water distribution. Much of the study effort has been completed and published in interim draft reports, and the final City of Houston Water Master Plan Report is anticipated to be published in June, 1988.

The final screening of water supply alternatives yielded three candidates: (1) Toledo Bend Alternative, (2) Western Water Alternative (including the Bedias and Millican Reservoirs), and (3) Toledo Bend and Wallisville Alternative. The City has stated that the Western Water alternative has been eliminated and one of the two Toledo Bend Alternatives will be finally selected. The Western Water alternative envisioned supplying water from Millican and Bedias to north Harris County similar to the analysis conducted in the plan for the West Harris County Water Supply Corporation. The Toledo Bend alternative proposes the import of 606 MGD of Toledo Bend and Lake Livingston water into Lake Houston via Luce Bayou. Combined with the yields of Lake Conroe (90 MGD) and Lake Houston (129 MGD), a total of 825 MGD of surface water would be available in Lake Houston to supply 625 MGD to the proposed Northeast Water Purification Plant and 200 MGD to the existing East Water Purification Plant. The master plan also includes a Southwest Water Purification Plant near Sugarland supplied by the Brazos River.

The distribution plan conceptualized in Appendix L includes a major transmission line which would convey treated surface water from the Northeast Water Purification Plant along an east-west alignment in the vicinity of North Belt. North and northwestern Harris County will be served by smaller line conveying water north and south of this transmission line. The distribution plans developed by the NHCWSC and the WHCWSC are consistent with this concept.

PLANNING EMPHASIS

The focus of SJRA water supply activities in the past has been largely out of its service area because that is where surface water-users have been located in the past. The SJRA participated in construction of Lake Conroe and planning for Lake Creek, but groundwater has generally been assumed to be the source of future water supply for in-basin users, and as a result the SJRA has focused attention on out-of-basin delivery of surface water (Highlands

Canal System) and consideration of out-of-basin projects in which it might participate such as the Toledo Bend project.

Two factors combine to suggest that the SJRA reconsider this emphasis. First is the fact that Montgomery County is now undergoing rapid urbanization with population expected to reach nearly 800,000 within the planning period of this study. This would result in significant increases in demand for water in the coming years. Second, there is strong evidence developed through this study that groundwater supplies in the area served by the Gulf Coast aquifer system including Montgomery County are limited, and that a surface water system will be needed in Montgomery County to replace groundwater systems as that resource is depleted.

Fortunately, other areas dependent on the Gulf Coast aquifer such as Harris County have a well-established agenda for surface water conversion in various stages of implementation as indicated in the previous section. A change in the status of the aquifer may, at worst, accelerate final planning and implementation of conversion projects, but would not require a significant change in the direction of current water supply planning. On the other hand, there is no plan to meet the future water supply needs of Montgomery County if groundwater supplies are in fact depleted. Therefore, this study should be organized to emphasize planning for the long-term water supply needs of the 800,000 future residents of Montgomery County. Development of a water supply plan for the SJRA will, therefore, include the evaluation of three scenarios: Base Scenario, Import Scenario, and Export Scenario. These scenarios, described in the following paragraphs, define the range of possible scenarios needed to evaluate the least cost water supply plan.

Base Scenario

The planning objective of the Base Scenario is to define the most cost-effective project or combination of projects that meets the projected water supply needs of the SJRA service area (primarily Montgomery County) from in-basin supply sources. Financial feasibility will be determined by the impact on future users (ratepayers).

Import Scenario

The planning objective of the Import Scenario is to determine if it is less costly to the future in-basin ratepayers to supply water from other river basins.

Export Scenario

The planning objective of the Export Scenario is to examine the feasibility of scaling up the most probable project selected for implementation to provide surface water supply to users adjacent to the SJRA service area. The feasibility of projects considered in this scenario should be based on reducing the financial impact on ratepayers in the SJRA service area.

All of the possible alternatives will be evaluated using criteria which reflect this basis of organization. Section II of this report describes existing and future water demands. Section III describes the evaluation of the Gulf Coast Aquifer leading to the conclusion that groundwater supply in the area is limited, and Section IV describes the sources of surface water considered in the study. Section V defines the methodology developed to assess the impact of project alternatives on the ratepayer, other criteria used to rank alternatives and the formulation of the recommended water supply plan. Section VI presents the recommended water supply plan and implementation considerations. The final section, Section VII, summarizes the conclusions and recommendations made in this report.

SECTION II

EXISTING AND PROJECTED WATER DEMAND

PLANNING AREA

The planning area used for the development of the Base Scenario coincides with Montgomery County. This planning area takes into account urban growth projected to occur throughout southern Montgomery County as well as the urban growth along the I-45 corridor up to and including the City of Conroe. No water demand projections were included in this analysis for areas of concentrated urban development in north Harris County. Export Scenarios will be evaluated utilizing water use projections developed as a part of the on-going studies of surface water conversion for north Harris County referenced in the previous section. Population and water use projections were included for small portions of San Jacinto, Liberty and Harris Counties to facilitate groundwater modeling efforts.

The planning, permitting, and construction of large reservoirs has historically taken up to 20 years to complete. It is, therefore, necessary in regional water supply planning to evaluate water needs from a long term perspective. For the purposes of this study, the planning horizon was established as the year 2030, which corresponds with the State's Water Plan and the City of Houston Water Master Plan. The water supply plan will focus on meeting projected water demands between 1990 and 2030, although the ability to continue to provide water supply beyond the planning horizon of 2030 will also be an important consideration in the evaluation of alternatives.

EXISTING WATER USE

All water currently used in Montgomery County for public and private purposes is groundwater with the exception of Gulf States Utilities and a few minor diversions for irrigation or recreation uses from the West Fork of the San

Jacinto River. Gulf States Utilities uses surface water from its Lewis Creek Reservoir, which is adjacent to and supplemented by pumping water from Lake Conroe. The rapid growth of the planning area is illustrated by the population and water use figures for Montgomery County shown in Table No.\1. The total water use in Montgomery County grew at an average annual compounded growth rate of 8 percent over the 19 year period from 1966 to 1985. Of the total water used in 1985, approximately 78 percent was municipal and rural domestic, 21 percent was industrial, and 1 percent was irrigation and livestock. Per capita consumption also increased over this period from 150 gallons per capita per day (gpcd) to 155 gpcd showing the effects of the somewhat higher usage of urban development. Unlike many of the neighboring counties in the region, Montgomery County has a relatively small irrigation water use. As its rural land is urbanized, the net increase in total water use will be greater than the net increase in a county in which urban development replaces irrigated land and irrigation water use is thereby reduced.

PROJECTED WATER DEMAND

Future water use for the planning area will be directly related to population growth. Population projections were obtained from local municipalities, the City of Houston, the Houston-Galveston Area Council, the Texas Water Commission and the Texas Water Development Board. These projections generally correlate well through the year 2000, and present a range of estimates through the 2030. Actual population growth through the planning period will depend in part on the availability of adequate public water supplies, and so the long term planning for water supplies should be based on population projection estimates which represent a reasonable upside potential growth rather than a downside projected growth. The Texas Water Development Board county population projections (1986, High Series) were selected for use in this study and are shown in Exhibit No. 3 along with City of Houston, the Harris-Galveston Area Council and the Texas Water Development Board low series projections for comparison purposes.

The total county population projection, as projected by the Texas Water Development Board, was apportioned to census tracts in the planning area using existing census tract data, the City of Houston's Water Master Plan population study, and population projections provided by local entities including the City of Conroe and The Woodlands. The Texas Water Development Board population projections used for this study apportioned to each census tract in the planning area are shown in Table No. 2. Exhibit No. 4 shows the location and delineation of these census tracts.

Water demands by census tract for the planning area were projected by multiplying the projected population by an average per capita water demand which includes all residential, commercial, and light industrial uses. Current levels of agricultural and heavy industrial (e.g. GSU) water uses are provided for in the 1985 base demand. No significant increases in either agricultural or heavy industrial demand are expected in Montgomery County. The planning area was rural up to the 1970's, and with the exception of the City of Conroe and the urban corridor along I-45 in south Montgomery County, it still is largely rural. In addition, many of its residents still work outside of the County. As the economic base within the County develops, a larger percentage of the County's residents will work inside the County. The development of this diversified employment base is occurring in the Conroe area and The Woodlands area. These business activities will increase the nonresidential component of average per capita water use, and thus, the average per capita water consumption is expected to increase over current levels reflecting the growth in in-county commercial activity. This does not necessarily imply an increase in per capita residential water use.

The trend of increase in per capita water use will be mitigated to some degree by water conservation. It is the current policy of the San Jacinto River Authority and the Texas Water Development Board to encourage and promote water conservation. Water conservation plans will involve a range of voluntary and involuntary measures, many of which will rely on an effective public education program. Increased prices of water to the customer is one of the most effective methods to promote water conservation. As will be shown, surface water supplies will be required in the planning area, and since the cost of transporting and treating surface water is higher than groundwater, future increases in water rates are expected in the planning area. In Montgomery County, increasing water rates are expected to reduce the increases in discretionary residential water use, but not to significantly impact commercial and industrial water use growth.

The current average per capita water use for Montgomery County is in the range of 155 gallons per day (gpd). The average per capita water use, including all categories of non-residential use, is 167 gpd for The Woodlands, 190 gpd for the City of Conroe, and 205 gpd for the City of Houston (not including the industrial water supplied by the Coastal Water Authority). These numbers confirm that the average overall consumption increases as the commercial base develops. For purposes of this study, the per capita water demand was projected to increase to 170 gpd by the year 2000, and then remain constant through 2030 with any increase in the non-residential component being balanced by decreases in the residential component due to water conservation.

Applying the assumed per capita water demands as described above to the population projections presented in Table No. 2, the total estimated average daily demand in the study area increases from 38.0 MGD in 1990 to 147.1 MGD in 2030. Table No. 3 presents a breakdown of this projected water demand by census tract. The projected growth in water use represents an average annual increase of 3.4 percent, a significantly slower rate than observed over the last 20 years. Approximately 50 percent of this ultimate demand occurs in the urban corridor along I-45 from the Harris County line to just north of and including the City of Conroe. This area of increasing urban concentration represents only 20 percent of the land area of the county. Other areas of significant water demand include the areas around Lake Conroe and south Montgomery County between I-45 and the Waller County line which when added to the I-45 corridor represents 65 to 70 percent of ultimate water demand for Montgomery County.

The projection of water demands for the service area show continuous and significant increases over the planning period due to continued urbanization and increased commercial and industrial development in Montgomery County. The projections also show continued increase in the concentration of demands as significant portions of Montgomery County are urbanized.

SECTION III

GROUNDWATER SUPPLY

GENERAL

In Water for Texas - A Comprehensive Plan for the Future prepared by the Texas Department of Water Resources and adopted in 1984, the total available groundwater in the San Jacinto Basin (including Harris County) was estimated to be approximately 300 MGD as compared to a 1980 pumpage of 416 MGD. "This extremely large overdraft has caused significant water level declines, compaction of clays within the Gulf Coast aquifer, and consequently, an increase in the rate of land surface subsidence and probably fault movement in the western and southwestern portions of Harris County." The water plan concluded: "Based on existing surface water supply sources [including Lake Livingston and the proposed Luce Bayou diversion], shortages are expected in the San Jacinto Basin beginning around the year 2010."

The development of a long term strategy for water supply in the SJRA service area requires a reliable definition of the quantity of groundwater available to meet future demands. Past evaluations of this aquifer system as a whole have been based on the assumption that there are no significantd limitations to groundwater recharge. The aquifer was viewed as a renewable resource recharged by rainfall infiltrating surface soils. The recharge zones include most of Montgomery County, and as a result, groundwater production has never been viewed as a problem there because of the proximity to the supposed source.

The analysis of the Gulf Coast Aquifer system conducted as a part of this study suggests that recharge to the aquifer is very small and may be considered negligible relative to current and proposed groundwater pumpages in the Houston region. In this system concept, nearly all available groundwater is in storage, within both the sands and the clays. It is essentially a finite resource and withdrawal results initially in reducing artesian pressure and subsequently in the watering or mining of the aquifer with production dependent on the thickness and artesian pressure of the water bearing formation under any specific well or well field. The work done in this study, described in more detail in the paragraphs which follow, strongly supports this premise and suggests that fundamentally different conclusions should be drawn regarding the amount of groundwater available and the management of its consumption to meet future demands.

GULF COAST AQUIFER SYSTEM

Groundwater is available in almost all areas of Montgomery County from what is referred to as the Gulf Coast Aquifer System. This system is composed of three principal water bearing units: the Chicot, the Evangeline, and the Jasper aquifers. These hydrologic units dip in a southeasterly direction toward the Gulf at an angle greater than the slope of the land surface, and become thicker towards the coast, as shown in profile on Exhibit No. 5.

The Chicot aquifer outcrops throughout all but the northwest corner of Montgomery County and has been delineated by the United States Geological Survey. Exhibit No. 6 shows the outcrop area of the Chicot aquifer. From its updip limit the aquifer thickness increases to approximately 300 feet in the southeastern part of the county where a few large capacity wells have been developed. Although the Chicot is not a major source of municipal water supply in Montgomery County, it supplies many small private residential wells. Water from the Chicot is generally soft and fresh, however, in some areas corrosive (acidic) or iron-bearing waters are produced.

The Evangeline Aquifer underlies most of Montgomery County outcropping in the northwest corner of the County, immediately north of the Chicot recharge zone also delineated on Exhibit No. 6. The Evangeline is under artesian conditions except in the outcrop area. It lies just under the Chicot and is differentiated by higher artesian pressures and lower hydraulic conductivity. Thickness of the aquifer ranges from less than 50 feet in the northwest to approximately 1000 feet in the southeastern corner of Montgomery County. The Evangeline aquifer provides portions of the municipal water supply in Conroe, south Montgomery County, and major portions of Harris County. Large capacity wells can generally be developed except in areas near the outcrop. The water is fresh although some limited areas do produce corrosive or iron-bearing waters.

The Jasper aquifer underlies essentially all of Montgomery County outcropping to the north in Walker County. It is differentiated into upper and lower units, with the lower unit potentially more productive with a thickness of 1,100 feet in the northwest part of the county and a thickness of 2,200 feet in the southwest part. The upper Jasper has a thickness of 100 feet in the northwest and 400 feet in the southeast part of the county. Increasing salinity as the aquifer dips to the south inhibits its use as a source of municipal water supply. In Conroe, both the upper and lower units of the Jasper are being used for municipal water supply. In southern Montgomery County only the upper unit of the Jasper is being used for municipal water supply due to salinity, and in Harris County, with a few exceptions, neither the upper or lower unit of the Jasper are being pumped.

PREVIOUS STUDIES

The Gulf Coast aquifer has been the subject of studies and evaluations for years, although most of this work has been concentrated in Harris County and relatively little data is available in Montgomery County. These studies generally were directed toward defining the response of the system to demand and developing a plausible explanation for the steady decline of artesian pressure and associated land subsidence. These studies include "Geology and Groundwater Resources of the Houston District" by Land, Winslow and White (1950); "Development of Groundwater in the Houston District, 1961-1965" by R. K. Gabrysch (1967); "Groundwater Resources of Montgomery County" by B. P. Popkin (1971); "Analog-Model Studies of Groundwater Hydrology in the Houston District, Texas" by G. D. Jorgensen (1975); and "Groundwater Availability in Texas Estimates and Projections through 2030" by Mueller and Price (1979). The more recent studies depend on complex computer models for answers and this work is continuing.

The past studies have created a picture of the aquifer and its operation in which the aquifer is considered to be a large hydraulic system through which water is moving continuously from recharge zones (places where the aquifers reach the land surface) toward the Texas coastline. The difference in elevation between the recharge zone and the coast creates pressure in the aquifer and provides the energy needed to move the water downstream through the aquifer. The amount of water moving through the aquifer is assumed to be quite large because of the extensive recharge zones and plentiful rainfall. The average rainfall in the planning area is approximately 47 inches per year, and if only a fraction of this rainfall actually entered the aquifer, then substantial annual pumpage would be balanced by recharge. The earliest studies concluded that the sources of all groundwater production were recharge (96%) and artesian storage (4%). This is the "underground river" concept and suggests that wells developed in the aquifer merely withdraw a portion of the flow as it passes by.

Groundwater pumping has caused dramatic artesian pressure declines in the Chicot and Evangeline aquifers over large areas. These declines were first noted in the early 1900's and have progressed steadily on a regional basis with the exception of periods in which well production was limited by economic depression (1930-1936) or the introduction of surface water (Lake Houston, 1954-1959, and Brazos River water to Texas City, 1948 - 1951). Public water supply wells when first developed in Houston flowed at the surface at rates as high as 750 gallons per minute. Water levels have been subsequently drawn down 300 to 400 feet below ground surface.

These declines in artesian pressure forming a bowl-like shape around areas of high groundwater withdrawal were associated with land subsidence (the actual reduction of land elevations) in eastern Harris County along the Houston Ship Channel and in the Texas City area of Galveston County, and began to result in actual flooding or threats of flooding in low lying portions of these areas. Flooding and the threat of flooding stimulated a large number of studies and analyses to explain the reason for the decline in artesian pressure and the land subsidence that seemed to be associated with it and led to the creation of the Harris-Galveston Coastal Subsidence District in 1975.

The principal cause of land subsidence was quickly defined as the consolidation of underground clay layers releasing water to wells as the artesian pressure was reduced. While this explained the technical reason for land subsidence, it shed no light on why artesian pressure in the aquifer was falling if the underground flow of water was such a substantial amount.

Mathematical models of the aquifer were developed to analyze this problem. The earliest work was done by the USGS using an analog model. Later a digital computer model was developed for the Subsidence District and numerous other studies were conducted. These studies determined that the water released from clay storage was a substantial amount representing up to 22 percent of all the groundwater pumped from 1890 to the present. These studies did not contradict the assumption of large flows in the "underground river", but suggested that this flow was relatively slow and was uniformly distributed over a very large area, and that large concentrated withdrawals of groundwater could exceed the rate of flow in the aquifer in the immediate vicinity of the area of concentrated withdrawal, thus reducing artesian pressure, triggering the release of water from clay formations, and causing land subsidence. This theory fit the facts at that time and could be used to explain the large declines in artesian pressure and the cone of subsidence centered on the Houston Ship Channel, since the rate of groundwater pumpage in that area was very large (126 mgd) and very concentrated (0.76 mgd/square mile), and resulted in an average rate of artesian decline of 11 feet/year.

It was still believed that large quantities of groundwater could be pumped indefinitely as long as the over-concentration of wells such as had occurred along the Ship Channel was avoided in the future. Current studies are generally based on this concept of the aquifer system - that the quantity of "flow" in the aquifer is substantial but slow moving and that large quantities can be pumped indefinitely as long as wells are properly located and spaced. This concept assumes that ultimately the regional gradient (the slope of the artesian pressure level) will be increased over the area and that net new flow will move from the recharge zone toward areas of withdrawal so that a significant steady-state pumpage rate can be projected indefinitely.

REASSESSMENT OF AQUIFER RECHARGE

The initial scope of the groundwater portion of the SJRA water supply plan was based on the conventional concept of the aquifer system discussed above. It was assumed that some level of long-term steady-state groundwater pumpage would be defined, and that probably Montgomery County had an advantage because of its location near the recharge zones of the principal aquifers. Simultaneously, planning of a surface water conversion project in North Harris County had focused attention on the performance of wells in that area. The original premise was that gas intrusion into wells in this area was affecting the production of individual wells but that the production potential over-all was stable.

However, data collected on well performance in the course of these studies revealed some troublesome inconsistencies with the expected system behavior. Significant declines in artesian pressure have been observed in the Evangeline aquifer even for relatively moderate pumping rates in areas close to the recharge zone. For example, in the report entitled "Surface Water Conversion Plan" prepared for the North Harris County Water Supply Corporation, a detailed analysis of pumping was made and it was found that the aggregate pumpage in a 59.4 square mile area of north Harris County was 19 mgd or 0.32 mgd/square mile, but the levels in wells had declined at an average rate of 8 feet/year since 1975, a rate of decline that is similar to areas further south in Harris County even though the pumpage rates are much lower. To illustrate this graphically, the historic artesian declines of six representative Evangeline wells in north Harris County are shown in Exhibit No. 7. Similar historic declines have been recorded in the I-45 growth corridor in southern Montgomery County, based in part on data collected by the SRJA's Groundwater Monitoring Program, as evidenced by water levels in the five Evangeline wells shown in Exhibit No. 8. Although the aggregate pumpage in this area was only 6.2 MGD in 1984, or 0.11 MGD/square mile, the average rate of decline is about 8.5 feet/year since 1975.

These observations caused a critical review of the basic assumptions about the recharge capacity of the aquifer system which led to a redefinition of the scope of work to include an examination of why such significant declines would occur near the recharge zone with such small pumpage rates. Included in this effort was an evaluation of available data on the surficial soils and water levels in the recharge zones in Harris and Montgomery Counties. Since the aquifer outcrops are so large and annual rainfall so abundant, the infiltration capacity of the surficial soils was not investigated in the past. A review of the soil stratigraphy and properties published by the Soil Conservation Service clearly shows that infiltration of rainfall is inhibited from readily entering the aquifer sands in the Chicot and Evangeline recharge zones because of an overlying clay layer on the surface. The familiar silty/sandy top soils of Montgomery County are usually underlain by clay strata which resist the absorption of precipitation falling on the aquifer recharge zones. In contradiction to what might be expected, the Soil Conservation Service "Soil Survey of Montgomery County" indicates that the least permeable surface soils in the County overlie the Evangeline recharge zone as shown in Exhibit No. 9. Although varying in total thickness and degree of impermeability, surficial clay soils are generally found throughout Montgomery and Harris Counties. McBride-Ratcliff & Associates selected representative soil borings shown in Exhibit No. 10 from their files along I-45 alignment from south Harris County to south Walker County which show the prevelance of clays in the surficial soils.

In addition to the surficial constraint, the ability of groundwater to move through the aquifer is limited by the relatively lower permeabilities characteristic of Gulf Coast aquifer sands due to the presence of silt and clay. The Chicot, Evangeline and Jasper aquifers were formed over geologic time as layer after layer of sediments were laid down in the shallow marine waters and river floodplains of the Texas Coast. What is seen in profile is not a single, thick water bearing sand (an "underground river"), but dozens of relatively thin sand and clay layers, as illustrated in Exhibit No. 11. Aquifer boundaries are difficult to define, and within an aquifer individual sand layers are under different pressures. The low permeability results in very slow rates of travel in the range of 25 feet per year, which means that it takes approximately 3,000 years for water to flow from the Evangeline recharge zone in northern Montgomery County in a southerly direction across the County.

Previous models have assumed no limitations on recharge through the surface. That is, as groundwater withdrawals increase, water levels in the recharge area remain constant (a constant head boundary), thereby increasing the system hydraulic gradient and delivering higher underground flows. The surficial stratigraphy suggests that the Gulf Coast aquifer may not recharge at a significant rate which would explain why artesian water levels in wells near the recharge zone are rapidly declining. This interpretation is corroborated by the fact that the sands in the Chicot recharge zone are being dewatered, and wells which were once artesian are now under gravity conditions. In Jorgensen's analog model analysis (1975), it was calculated that 37 percent of all groundwater pumped in the Houston district between 1890 and 1970 was derived from the depletion of water table storage in the Chicot aquifer.

Although the Chicot outcrop was essentially saturated in the early 1900's, the dewatering of the recharge zone was already evident by 1941 during a time when total groundwater withdrawal was still small, and has continued to the present. Exhibit No. 12 shows the water level declines of four Chicot wells in north Harris County. The average rate of decline in these wells since 1960 is about 1.6 feet/year. Table No. 4 presents water levels in some 23 relatively shallow wells in north Harris County in the Chicot outcrop area where historical records exist. The first 20 are wells within the Chicot aquifer (including the four displayed in Exhibit No. 12) and all are constantly declining over the period of record. The three very shallow surface wells showing relatively constant levels indiciate that the surficial soils are saturated but little or no infiltration is occurring to the aquifer sands below. These wells appear to indicate a perched water table above the Chicot sands, which are being dewatered. These declines indicate that the recharge capacity of the Chicot has been inadequate to replenish the groundwater withdrawal for some time and the deficit has been met by dewatering the sands and clays.

Relative to the Evangeline, the Chicot recharge zone is both larger in area and more permeable in surficial soils, and so water table declines in the Evangeline recharge zone would also be expected. Available TWDB data indicates that water levels decreased up to 20 feet from 1942 to 1966 in the recharge zone, which is located approximately 50 miles north of the concentrated areas of pumpage. There is insufficient available data to determine if further declines in the Evangeline recharge zone have occurred since 1966.

The Jasper aquifer is similar in nature to the Chicot and Evangeline and is expected to behave in a similar manner. All large wells in the northern half of Montgomery County are completed in the Jasper, whereas virtually no wells are completed in the Jasper in Harris County. Although pumpages has been rather small, steady declines in some areas have been recorded. Exhibit No. 13 illustrates the historical declines for five Jasper wells in the City of Conroe area. The declines shown represent an average of 7.0 feet/year from 1967 to 1985.

These facts suggest that recharge to the aquifer is very small and may be considered negligible with respect to the large current and proposed groundwater pumpages in the Houston region. In this system concept, most of the available groundwater is in storage within the sands and the clays. The fresh water in the Gulf Coast aquifer, because of the slow rate of recharge and low aquifer permeability, has probably taken tens of thousands of years to accumulate and displace the mostly seawater originally laid down when the sediments were formed. It is essentially a finite resource and withdrawal results in mining of the aquifer with production dependent on the sand thickness and artesian pressure of the water bearing formation under any specific well or well field. Montgomery County's proximity to the recharge zone is thus a disadvantage since aquifer sand thicknesses decreases from south to north, and for a given density of pumpage well level declines will be greater in Montgomery County than in central and southern Harris County. The work done in this study, and described further in the geotechnical report, submitted as Appendix E, strongly supports this premise and suggests that fundamentally different conclusions must be drawn regarding the amount of groundwater available and the management of its consumption to meet future demands.

METHODOLOGY

Based on the preceding discussion, recharge is assumed to be negligible and groundwater availability is defined as the amount of groundwater withdrawn from storage as aquifer water levels are lowered. Regional water level drawdowns were determined with a two-dimensional hydrologic model applying the Theis equation for artesian conditions and the Thiem equation for water table conditions, both of which assume uniform aquifer thickness and permeability. Although more recent groundwater studies of the Gulf Coast Aquifer are complex, three-dimensional models encompassing larger areas, the principal difference in this report's model is that withdrawals are supplied only from storage and not from recharge across a constant head boundary.

Variations in aquifer thickness and permeability were accounted for by subdividing the county into the thirteen groundwater analysis sectors shown in Exhibit No. 14. Due to the limited extent and thickness of the Chicot aquifer in the study area and its stratigraphic similarity to the Evangeline, it has been assumed that these two aquifers can be represented in the model as a single aquifer system. The Upper and Lower Jasper units were treated individually due to different locations of the fresh water/saline water interfaces. In all three aquifers modeled recharge was assumed to be negligible.

For each aquifer in each sector, values of the percent sand, saturated thickness, permeability, and storage coefficient were determined. The groundwater yields for each sector were calculated which produced a defined drawdown in the center of the sector. Aquifer conditions were checked in each sector to assure that the defined drawdown did not cause a well to lose artesian condition or to produce saline water due to upconing from a lower layer. The average drawdown in each aquifer across the county was next calculated by superimposing the individual sector drawdowns, and the desired regional drawdown was obtained by adjusting the individual sector yields.

The model assumes that wells are evenly spaced on a grid pattern in each sector, however, actual well spacing will follow the patterns of development and be more closely spaced or clustered than an idealized distribution. This would also be true for remote well fields. Groundwater yields were adjusted to reflect the estimated reduction due to realistic well spacing. The model also accounts for the future Chicot/Evangeline water level decline expected to occur in south Montgomery County as a result of on-going pumpage in north Harris County. The magnitude of this decline was provided by the Harris-Galveston Coastal Subsidence District and assumes implementation of the current District Plan requiring conversion to surface water.

Subsidence due to future water level declines was estimated by evaluating the historical rates of subsidence in Montgomery and northern Harris Counties and took into account the preconsolidation stress of each aquifer's clays. Since the Chicot/Evangeline in southern Montgomery County has already exceeded its preconsolidation stress, its future rate of subsidence will be approximately three times greater than the rate of subsidence for all of the Upper and Lower Jasper as well as the Chicot/Evangeline in northern Montgomery County.

MODELING RESULTS

Based on the assumption that recharge is negligible, the groundwater model was set up to estimate the volume of groundwater available in storage assuming aquifer water levels are lowered to just below the top of the aquifer sands. At this point, gravity well conditions will occur in which well production will be reduced rather abruptly by approximately 50 percent, and further pumpage will result in dewatering of the aquifer sands. The estimated available volumes from each aquifer in each sector are presented in Table No. 5. The geographic distribution of the available groundwater is not uniform. Most of the available groundwater is yielded by the Jasper aquifer (72%), and the majority of this yield is in the northern half of the planning area defined as Sections 1 through 8 (80%). The total available groundwater volume is approximately 1,257,798 million gallons.

These results must be compared to projected water demand volumes by sector in order to evaluate their significance. The cumulative volumes of the projected water demands for the planning period were calculated by first allocating the demands by census tract to each groundwater analysis sector. The results of this allocation by sector is presented in Table No. 6. Table No. 7 then presents for each sector the estimated available groundwater volume, the projected water demand volume through the year 2030, and the approximate year of groundwater depletion. If the current dependence on local groundwater for virtually all water supply in Montgomery County continues, then projected water demands in Sectors 10, 11 and 13 located in south Montgomery County will deplete available in-sector groundwater supply about the year 2000, as illustrated in Exhibit No. 15. Sectors 6, 7 and 12 are projected to deplete available in-sector supplies around 2020, and Sector 8 and 9 by the year 2030. These sectors in southern and central Montgomery County have higher projected water demands due to concentrated urban development but lower groundwater availability than the sectors in the north and northwest. Finally, even assuming the use of remote groundwater wells in sectors with a surplus, the planning area as a whole will deplete the available groundwater by the year 2030.

Intermediate pumping scenarios were initially evaluated which placed more restrictive limits on aquifer drawdowns in order to minimize subsidence. These limits significantly reduced groundwater availability. Although land surface subsidence in Galveston and Harris Counties has caused significant property damage due to flooding in low lying coastal areas, the effect of subsidence on upland flooding in Harris County has been determined to be minimal as reported in "A Study of the Relationship Between Subsidence and Flooding", funded by the Harris County Flood Control District, the Harris-Galveston Coastal Subsidence District, the City of Houston and the Fort Bend County Drainage District. The impact of subsidence on flooding in Montgomery County is expected to be even less significant due to the steeper overland and channel slopes compared to Harris County. Therefore, the groundwater availability defined is based on the maximum aquifer drawdowns described above not limited by any specific subsidence criteria.

CONCLUSIONS

The Gulf Coast Aquifer system underlying the SJRA planning area is not being recharged to a significant degree in relation to the withdrawals imposed in the metropolitan Houston area. As a result, the available groundwater is a finite rather than renewable resource, and its utilization over time results in depletion. This conclusion differs from previous studies of the Gulf Coast Aquifer system which have not found recharge to be a limiting factor in groundwater production estimates. The rate of depletion of the artesian system at a given pumpage is greater in areas where aquifer thicknesses are less than in areas to the south where aquifer thicknesses are greater. Thus, groundwater availability will be impacted to a greater degree in Montgomery County than in counties to the south.

The available groundwater is not located where the majority of the water demands are projected to be in the planning area. This geographic imbalance results in the local depletion of available groundwater in the areas of concentrated urban demand as early as the year 2000 and will require remote well fields and water transmission facilities to deliver surplus available groundwater located in the north and northwest to the users unless surface water supplies are made available.

The available groundwater will be depleted by projected planning area demands in the year 2030. Therefore, the available groundwater is not adequate for the long term needs of the planning area and acquisition of surface water supplies will be required to meet water demands. Rapid depletion of the groundwater resource entails public policy risk and suggests that surface water supplies should be introduced as early as possible in the planning period in order to conserve available groundwater supplies and provide for conjunctive use of ground and surface supplies.

SECTION IV

SURFACE WATER SUPPLY

GENERAL

The amount of water needed for existing population and commercial enterprise and to provide for sustainable economic expansion in the San Jacinto River Authority planning area was defined in Section II. Groundwater will continue to play a major role with regard to water supply in Montgomery County; however, surface water supplies will be required for any long term plan as established in Section III. In this Section, potential surface water sources which could serve the planning area located both inside and outside of the San Jacinto River basin were identified. These potential sources are screened for the best candidates to include in the water supply plan.

The amount of surface water supply required for Montgomery County by the end of the planning period is estimated to be approximately 90 MGD assuming a phased conversion to surface water beginning prior to the year 2000. This estimate recognizes that most individuals in low density rural areas will continue to rely on private wells. Surface water will be provided primarily to public water supply systems serving the areas of concentrated urban development previously described in Section II. Areas with relatively high population density, low groundwater availability, and central location will rely predominantly on surface water prior to the year 2030. Areas with relatively low population density and surplus available groundwater will probably remain on groundwater throughout the planning period.

SCREENING CRITERIA

For the Base Scenario, potential surface water sources will be screened on the basis of adequate yield and raw water cost per thousand gallons. In the case of the Import Scenario, potential surface water sources will be screened primiarly based on a comparison of delivered raw water cost to the cost of the selected in-basin sources. State policy prohibits the export of water from a river basin unless the projected fifty year in-basin needs can be met, and so the availability of surface water for transfer into the San Jacinto must also be considered.

In surveying the potential surface water supply sources, information was obtained through visits and discussions with the Brazos River Authority, Trinity River Authority, City of Houston, Texas Water Development Board, Texas Water Commission, Army Corps of Engineers, and the Bureau of Reclamation. Existing engineering and planning reports were reviewed to ensure a comprehensive data base and avoid duplication of effort. These include the Bureau's San Jacinto Project and Bon Weir Project reports, the City of Houston's Water Master Plan Reports, the SJRA's Preliminary Feasibility Report of Surface Water - Sabine River to Lake Houston, and the Texas Department of Water Resource's "Water for Texas - A Comprehensive Plan for the Future".

The potential sources identified for evaluation and screening are shown in Exhibit No. 16 and include Bedias Reservoir, Lake Creek, Lake Livingston, Millican Reservoir, Rockland Reservoir, San Rayburn Reservoir, Spring Creek Lake and Toledo Bend Reservoir. The owner or potential owner in the case of proposed reservoirs, construction status, yield, availability for interbasin transfer, approximate price of water in the reservoir, and estimated conveyance costs for each of the potential surface water sources are summarized in Table No. 8. An evaluation of each of these potential sources in the development of a Base Scenario and Import Scenario is presented below.

BASE SCENARIO

Only two major surface water supply reservoirs currently exist in the San Jacinto River basin: Lake Houston and Lake Conroe. Lake Houston is located downstream of the planning area and its entire water supply yield is owned by and committed to the City of Houston. The San Jacinto River Authority diverts "run of the river" water from Lake Houston (based on a prior water right) which is the primary source of water for the Authority's Highlands

Canal System. The Authority has a water right permit to divert 49.1 MGD (55,000 acre-feet/year) of normal flow and flood waters from the San Jacinto River at Lake Houston. The 1955 contract between the Authority and the City governs the respective rights of the parties and affirms the right of the Authority to divert 50.0 MGD from Lake Houston. The canal system includes the 100 MGD pump station located east of the Lake Houston dam, approximately 38 miles of raw water canals which convey water east to Cedar Bayou and south to the Baytown Industrial complex, and the 1,400 acre Highlands Reservoir which serves as a regulating reservoir for the system.

Lake Conroe was completed in 1973 and is owned by the San Jacinto River Authority, the City of Houston, and the Texas Water Development Board. The total permitted water rights in Lake Conroe amount to 89.3 MGD (100,000 acre-feet/year), of which the Authority owns one-third, 29.8 MGD (33,333 acre-feet/year), and the City of Houston owns two-thirds, 59.5 MGD (66,666 acre-feet/year). A portion of the Authority's one-third share is contingent on loan repayments to the Texas Water Development Board. Lake Conroe impounds a total of 430,260 acre-feet at normal water level and has a firm yield of 89.3 MGD (100,600 acre-feet/year). The current price of raw water in Lake Conroe is about $0.23 per 1,000 gallons.

SJRA's total water rights in the San Jacinto River basin equal 79.8 MGD (88,333 acre-feet/year). Of this total, 70.95 MGD is committed in "take or pay" water supply contracts, leaving approximately 8.85 MGD currently available for use in the planning area. Table No. 9 presents a summary of the Authority's water supply contracts by user, contract quantity, and the average amount actually taken over the past five years. All of the Authority customers, except Gulf States Utilities, are served by the Highlands Canal system in southeast Harris County. Of the 66.5 MGD presently committed to customers on Highlands Canal system, approximately 17.4 MGD is supplied from Lake Conroe. On average, approximately 20 MGD of the total is not currently taken by the customers, although only about 14 MGD would be available based on the sum of each individual customer's maximum annual take during the last six years. A potential source of surface water for the planning area is to "free up" water in Lake Conroe presently committed through renegotiation of the supply contracts when they expire and are renewed in 1993.

The Bureau of Reclamation identified 13 potential reservoir sites in the basin in the recently prepared the Planning Report/Draft Environmental Statement for the San Jacinto Project, for which the San Jacinto River Authority was the local planning sponsor. Based on a preliminary analysis, the Bureau eliminated 10 of those 13 sites because of cost per unit of water, geologic conditions, and land availability. The Bureau studied the three remaining sites, Upper Lake Creek, Lower Lake Creek, and Lake Cleveland, in detail and prepared cost estimates for each lake.

The Bureau of Reclamation has selected Lower Lake Creek site as the preferred plan on the basis of the benefit/cost ratio. The Lake Creek sites are preferrable to the Lake Cleveland site due to their proximity to the future customers. In addition, there is strong local opposition to Lake Cleveland from the landowners and Commissioner's Court in San Jacinto County. Between the Upper and Lower Lake Creek sites, the lower is preferable due to its higher yield, fewer relocations required, and lower cost. The Bureau's proposed Lower Lake Creek project divides the available storage capacity between flood control and water supply with a firm yield of 58 MGD. The raw water cost for this project as estimated by the Bureau of Reclamation is $1.13 per 1,000 gallons excluding the costs of recreation and flood control. The San Jacinto River Authority has concurred in the Reclamation's selection of Lower Lake Creek (hereinafter referred to simply as Lake Creek) as the preferred alternative.

In this study, a single purpose Lake Creek project is considered in which all storage capacity is dedicated to water supply, as is the case with Lake Conroe, resulting in a higher firm yield of 65.2 MGD. The construction cost of Lake Creek was estimated based on a locally managed non-Federal single purpose project as discussed in Appendix C. Assuming financing through the Texas Water Development Board, the raw water cost is estimated to be $0.77 per 1,000 gallons, as shown in Table No. 8.

A system of small reservoirs capable of delivering the necessary yield would be geographically spread out. Since it is proposed to provide surface water primarily to the concentrated demands in the urban corridor, such a system would likely be inefficient relative to a large centrally located reservoir. In certain locations, a small reservoir may serve additional functions. Spring Creek Lake could provide raw water storage to an adjacent surface water treatment plant serving the urbanized area in southern Montgomery County. The proposed Spring Creek Lake has an estimated yield of 6.7 MGD with an estimated raw water cost of $0.44 per 1,000 gallons and would be located approximately five miles upstream of Interstate 45 as shown on Exhibit No. 16. The Woodlands Corporation, which owns much of the land impacted by construction of the lake, has indicated a willingness to assist in its development.

In conclusion, the existing uncommitted surface water in Lake Conroe is inexpensive and should be incorporated in the Base Scenario at the earliest date. Additional surface water in Lake Conroe should be obtained through contract negotiation for use in Montgomery County. Lake Creek is the best potential new reservoir in terms of cost and location, and should be included in the Base Scenario. Lastly, small reservoirs which offer special opportunities, such as the proposed Spring Creek Lake, should be considered in plan formulation and implementation.

IMPORT SCENARIO

The U.S. Army Corps of Engineers has proposed construction of Millican Reservoir on the Navasota River with the Brazos River Authority as the local sponsor. It was originally authorized by Congress in 1968, however, because of extensive lignite deposits in the area, an alternative site located upstream is currently being studied. Based on preliminary information from the Corps of Engineers, the yield of Millican would be approximately 222 MGD (249,049 acre-feet/year) and the raw water cost would be in the range of $1.00 per 1,000 gallons. Surplus yield is projected to be available for transfer to the San Jacinto Basin. The conveyance system necessary to convey 60 to 70 MGD of yield to the San Jacinto River Basin is estimated to be in the range of $0.20 per 1,000 gallons, bringing the total estimated cost of this source to $1.20 per 1,000 gallons. The Brazos River Authority indicates that it does not have plans to construct Lake Millican in the near future.

The Bureau of Reclamation has proposed construction of Bedias Reservoir with the Trinity River Authority as local sponsor. This reservoir would be located on Bedias Creek northwest of Montgomery County as shown on Exhibit No. 16. Based on estimates by the Bureau, the yield would be 81 MGD (91,000 acre-feet/year) and the raw water cost in the reservoir in the range of $0.71 per 1,000 gallons. Surplus yield is projected to be available for transfer to the San Jacinto Basin. The cost of conveyance of this yield to Lake Conroe is estimated to increase by $0.26 the cost per 1,000 gallons of water in the lake bringing the total cost of this source to $0.97 per 1,000 gallons. The Trinity River Authority indicates it does not currently plan to pursue construction of Bedias Reservoir.

Lake Livingston is an existing reservoir on the Trinity River completed in 1969 by the City of Houston, which owns 70% of the water rights, and the Trinity River Authority which owns the remaining 30% of the rights. The total permitted water rights in Lake Livingston amount to 1374 MGD (1,538,000 acre-feet/year), however, only 680 MGD is currently available to the City of Houston and 260 MGD is available to the Trinity River Authority due to prior downstream water rights (254 MGD), including those of canal companies now owned by CWA, and flushing requirements (180 MGD) to control saltwater intrusion in the lower reaches of the river. It is anticipated that the City of Houston, which already has the capability to pump Trinity River water through the CWA system and proposes to construct the Luce Bayou Diversion from the Trinity River to Lake Houston, will require and obtain all remaining uncommitted yield in Lake Livingston for its needs in Harris and Galveston Counties. For this reason, no yield was considered available to the SJRA service area.

The Sam Rayburn Reservoir was constructed on the Angelina River by the Corp of Engineers and the Lower Neches Valley Authority (LNVA) and has a firm yield of 1,006 MGD (1,127,200 acre-feet/year) with associated water permits totaling 732 MGD. In the 1980 "Report of Water Requirements and Supply" to the Lower Neches Valley Authority, Freese & Nichols projected that the demands of the LNVA would exceed the available yield by about 2010. Thus, Sam Rayburn Reservoir is currently committed to serve the future in-basin needs of the Lower Neches Basin.

The Corps of Engineers has proposed construction of Rockland Reservoir with the Lower Neches Valley Authority as local sponsor. Estimates of yield in Rockland range from 540 MGD (605,000 acre-feet/year) reported by the Corps of Engineers to 634 MGD reported by the Bureau of Reclamation. Much of the yield of Rockland is expected to be available for transfer to the San Jacinto Basin as indicated in the Texas Water Plan by the Texas Department of Water Resources. The cost of raw water in Rockland is estimated by the Corps of Engineers to be $1.25 per 1,000 gallons. There are no firm plans to construct Rockland at this time.

The Toledo Bend Reservoir on the boundary between Texas and Louisiana is the largest reservoir in the State of Texas. Its yield of 2,592 MGD (2,904,100 acre-feet/year) is owned equally by the Sabine River Authority of Texas and the Sabine River Authority of Louisiana. The SRA of Texas holds water rights to 926 MGD, of which only 2 MGD is presently committed to local users, and the majority of the remainder is projected to be available for export from the Sabine Basin. The raw water price, estimated to be $0.08 per 1,000 gallons, will be a function of volume and subject to negotiation. The San Jacinto River Authority has recognized the potential for Toledo Bend water to serve the future needs of customers in the basin. SJRA has entered into an option agreement for the purchase of up to 600 MGD of water from the Sabine River Authority and has commissioned an engineering feasibility study to evaluate transporting this water to the Houston area. The preliminary results of the feasibility investigation indicate that depending on the route selected and the amount of water transported, the cost of this conveyance system will add from $0.35 to $0.55 per 1,000 gallons to the price of the water in the reservoir. There is sufficient water for this source to meet SJRA in-basin needs.

Potential sources for inclusion in an Import Scenario must have an estimated delivered raw water cost less than or equal to the Lake Creek raw water cost of $0.77 per 1,000 gallons. Only Lake Livingston, Sam Rayburn Reservoir, and Toledo Bend reservoir satisfy this requirement. However, in the cases of Lake Livingston and Sam Rayburn Reservoir, little or no yield is anticipated to be available for import to Montgomery County. Thus, Toledo Bend is the only potential surface water sources which appears to be competitive with the Base Scenario.

SECTION V

PLAN DEVELOPMENT

GENERAL

The conceptual framework for comparing in-basin versus out-of-basin surface water supply sources was developed in Section I. The amount of water needed to sustain existing population and commercial activities and to allow continued economic expansion in the San Jacinto River Authority planning area was established in Section II. The inability of the natural groundwater system to provide a reliable long term supply and the consequent need for the development of additional surface water supplies was described in Section III. Based on the screening of surface water supplies described in Section IV, the Base Scenario should rely on some combination of Lake Conroe, Lake Creek and Spring Creek Lake, while the only competitive out-of-basin source identified for the Import Scenario was Toledo Bend.

In this section, the physical and financial components of a water supply plan to meet the conditions of the Base Scenario will be developed. A corresponding water supply plan will be defined based on importing surface water from Toledo Bend. A large number of possible variations of these scenarios can be formulated based on the specific mix of water supply sources, facilities, and timing. It is necessary to develop a set of decision criteria to assess each variation on an objective basis. This is accomplished with the development of a financial model which analyzes the impact on theoretical water rates required to amortize the revenue bonds needed to finance each alternative. Other important criteria include the predictability of implementation and public policy risks associated with each alternative.

METHODOLOGY

The principal criteria to be used to assess the feasibility of the alternative water supply plans are listed below and described more fully in the following paragraphs.

- Total Construction Cost
- Impact on the Ratepayer
- Public Policy Planning Risk
- Probability of Implementation

Total Construction Cost

Total construction costs are based on the conceptual engineering designs and cost estimates for each of the major components to the plan. The design assumptions, unit costs and tabulated cost estimates for the following components is provided in Appendix C:

- Remote Groundwater Wells
- Remote Groundwater Pump Stations
- Remote Groundwater Transmission Lines
- Lake Creek
- Spring Creek Lake
- Toledo Bend Raw Water Conveyance Facilities
- Surface Water Treatment Plants

Impact on the Ratepayer

In the evaluation of cost of large public works projects constructed in phases and funded by user fees, comparison of total capital costs or even of total financed costs is not sufficient to identify the most feasible alternative. The San Jacinto River Authority does not have the authority to levy a tax, and therefore, must pay for projects with revenue bonds. Project feasibility is dependent on the size of the ratepayer base and the reasonableness of the rate. Since the size of the ratepayer base is usually much smaller than the capacity of a large surface water project following construction, the required water rates might be too high in this initial period. Therefore, a financial model was developed in which the construction costs of each project component are converted to annual costs based on assumed financing and project phasing. Operation and maintenance costs, as well as the contract costs for raw surface water, are estimated for facilities and input for each year. The annual costs for all individual projects are then summed to give the total revenue required to support the water supply system for each year. This total revenue is then divided by the projected demand in that year to yield a theoretical required water rate. Thus, the financial models provide a year by year comparison of the impact on the ratepayer of competing alternatives.

It should be noted that the required water rate calculated by this financial model is theoretical and derived solely for the purpose of comparing alternatives. It does not include all costs required to deliver water to the residential meter and so should not be considered a residential water rate. Actual rates will be determined by each individual political subdivision. This analysis assumes that all identified costs of the regional water supply system are paid by the water consumer in the form of water rates. It is possible for taxing entities such as municipal utility districts and cities which purchase surface water from the regional supplier to pass the costs to their customers in a combination of ad valorum taxes and water rates.

The rate of inflation is assumed to be zero and all estimated costs are input to the model in constant 1987 dollars. The interest rate assumed for revenue bond financing has been assumed to be constant through the planning period. Realistically, it is expected that inflation will be greater than zero and that it will vary throughout the planning period. Since economic conditions which create a varying inflation rate would also cause a varying bond financing rate, the assumption of zero inflation simplifies the analysis and avoids the potential distortions which might be caused by projecting a varied financing rate.

Bond issue costs were based on the required project construction costs plus twelve percent non-construction costs for all projects except Lake Creek and Toledo Bend Conveyance, for which only ten percent non-construction costs were added due to the very large scale of the required bond issue. These nonconstruction costs include legal and fiscal agent fees associated with bond issuance as well as one year of capitalized interest. Annual debt service payments were assumed to be equal across the bond term which was assumed to be 25 years for all projects except Lake Creek and Toledo Bend, for which a bond term of 30 years was assumed.

It was assumed that the SJRA's revenue bonds would be sold to the Texas Water Development Board at an interest rate of seven percent, which approximates the current interest rate for similar projects. It is acknowledged that this interest may not be the rate in effect when bonds are sold in the future. Bond issues were sold, and interest payments begun, three years prior to project completion for construction of surface water reservoirs and conveyance facilities, and one year prior to project completion of surface water treatment plants. There is no separate "interest during construction" since the bonds are sold at the beginning of project construction.

It was also assumed that the Texas Water Development Board would participate in the construction of Lake Creek and the Toledo Bend conveyance project by purchasing a 50 percent share at the time of construction to be repurchased by the SJRA as service area demands grow. At the time of repurchase, SJRA would repay the original cost to the TWDB plus carry assumed to be seven percent compounded interest. In some cases, the repurchase was phased over a period from 10 to 20 years after project construction. Regional capacity acquisition funds are not currently available but have been in the past (e.g., Lake Conroe), and it is reasonable to assume they may be available in the future.

Public Policy Planning Risk

The concept of public policy risk when applied to the depletion of a finite groundwater resource yields another important criterion for plan evaluation.

As previously concluded, a major new source of surface water should be provided for the study area during the planning period. The later in time that this new source is provided, the greater the rate of groundwater depletion becomes and the lower the remaining readily available groundwater supply becomes. One way this can be quantified is by calculating the years of available groundwater supply (as defined in Section III) remaining for any given year, assuming a constant rate of withdrawal equal to the groundwater supplied for that given year. As the number of years of remaining groundwater supply decreases, the risk to the public becomes greater since the remaining time to plan and construct a surface water source will be shorter and may not be sufficient. The result would be a water shortage and a serious disincentive for economic growth. Given two alternatives which have roughly equivalent costs to the ratepayer, selection of the plan in which surface water is provided earlier should be favored.

Predictability of Implementation

Selection of the best water supply plan must also carefully consider the predictability of implementation. Projects which the SJRA can construct and finance are, relatively speaking, more predictable than projects in which the SJRA will need only a partial share of the project yield and must, therefore, participate with another regional entity. Participation in significantly larger projects usually results in economy of scale cost savings for both parties, however, the progress of the project is dependent on the concurrent timing of need and financial capability of each participant. It is reasonable and prudent, given two alternatives which have roughly equivalent impacts to the ratepayer, that selection of the plan with the higher predictability of implementation should be favored.

BASE SCENARIO

The Base Scenario is a water supply plan that meets the water needs of the SJRA service area (primarily Montgomery County) in the most cost-effective way from in-basin sources of supply. Water demand in the service area is projected to be 147 MGD by the year 2030, with approximately 60 percent of this demand (90 MGD) concentrated in areas of urban development in south Montgomery County and along the I-45 corridor north to and including the City of Conroe. These urbanized areas will be located in planning sectors 6, 10, 11, 12 and 13, as shown on Exhibit No. 14.

In-basin sources of supply include groundwater, which is ultimately limited, available surface water supplies in Lake Conroe, and new in-basin reservoirs. The available supply in Lake Conroe is currently 8 MGD based on existing contracts, but as much as an additional 14 MGD, judging from actual usage, could be made available depending on commitments for future sales to industrial users. The yield of Lake Creek, the most cost effective large reservoir which could be developed within the basin, is estimated to be 65.2 MGD. Lake Creek is, therefore, an essential element of the Base Scenario. However, the size and cost of Lake Creek will make implementation difficult before the year 2000 because of the difficulties of implementing large reservoirs and because the project will require a much larger ratepayer base to finance the project than currently exists. Several more years of growth and expansion of the economic base of Montgomery County must occur before financial commitments necessary for commencing the project could be secured. These factors suggest that a more reasonable timing for Lake Creek would be about the year 2010.

This study finds that groundwater is ultimately limited, and that shortages of local or in-sector groundwater will occur in the areas of concentrated urban development in Sectors 10, 11 and 13 around the year 2000, before Lake Creek could be completed under the most optimistic assumption. These projected shortfalls must be supplied from out-of-sector groundwater (remote well fields) or from available surface supplies, or a combination of both. In addition, small reservoirs such as Spring Creek Lake, which can be implemented quickly, are as cost effective for a short term supply as remote well fields and would speed conversion to surface water.

The Base Scenario, therefore, assumes the use of available Lake Conroe supply (8.0 MGD), the reallocation of currently committed Lake Conroe supply (12 MGD) and the construction of Spring Creek Lake (6.7 MGD) in addition to available in-sector groundwater to meet projected short term water supply needs through the year 2000. These "starter" projects would speed the conversion to surface water, defer expensive remote well fields, conserve groundwater, and buy time to implement the larger surface water project ultimately required.

A key objective of the Base Scenario is to insure the availability of water supplies required to sustain the projected urban growth and economic expansion of Montgomery County. Therefore, a key element of the Base Scenario is the use of remote well fields to insure water supplies in areas where in-sector groundwater depletion may occur before sufficient surface water can be developed and supplied. Sectors 6, 7 and 12 will also experience shortages of available in-sector groundwater around the year 2020.

The required number and capacity of remote well fields depends on the timing and delivery of surface supplies. In addition, both in-sector and remote well fields can be used conjunctively with surface water which is to say surface water would be used more heavily during the wet to moderate periods of the year preserving the limited groundwater resource and groundwater would be relied on more heavily during the dry portions of the year to meet peak demands thus minimizing the required capacity of surface water treatment facilities. Conjunctive use thus reduces total costs and make the most effective use of each resource.

In summary, the selected Base Scenario consists of utilization in-sector groundwater as availability permits; "starter" surface water projects using the remaining Lake Conroe yield (8.0 MGD), reallocation of presently committed Lake Conroe water (12.0 MGD), and a small Spring Creek Lake (6.7 MGD); remote well fields to insure water supply during conversion to surface water and provide for conjunctive use with surface water (40 MGD); and the construction of the Lake Creek reservoir to insure a renewable long term water supply (65.2 MGD). Exhibit No. 17 shows the phasing of the various sources of water in the Base Scenario proposed to meet the total service area demand.

The entire service area would remain on in-sector groundwater until 1995, after which the combined local well pumpage would remain constant. Remote groundwater use varies to serve growth occurring between the five year periods, thus conserving groundwater for conjunctive use applications and extending the useful life of the well field. Lake Creek is constructed in the year 2010, however, the Base Scenario assumes a realistic stepwise absorption of the 65.2 MGD yield. At the time of Lake Creek delivery, approximately 44 years of groundwater supply would remain in the aquifer based on the rate of groundwater pumpage in 2010. At the end of the planning period, the aquifer would have approximately 23 years of groundwater supply at the 2030 rate of groundwater pumpage providing a reasonable horizon to plan for and implement replacement supplies.

The components of the Base Scenario are shown schematically on Exhibit No. 18. Along with Lake Conroe, Lake Creek and Spring Creek Lake, three surface water treatment plants are envisioned at this plan development stage. One is located near the City of Conroe southeast of Lake Conroe. This plant would be supplied by Lake Conroe and serve the Conroe area with treated surface water. A second surface water treatment plant is shown adjacent to Spring Creek Lake and is anticipated to serve the urban development immediately adjacent to the lake with treated surface water from Spring Creek Lake. A third plant is shown centrally located in the urban corridor between Conroe and the County line. This plant, largest of the three, would receive releases from both Lake Conroe and Lake Creek to serve south Montgomery County both east and west of IH-45.

In addition to these surface water facilities, Exhibit No. 18 also shows remote groundwater production and transmission facilities. Each dot represents a well field composed of eight wells. These remote well fields are located in northern sectors with surplus in-sector groundwater to serve sectors to the south. The configuration of well fields and transmission lines is schematic and will be subject to refinement through the implementation and design process. The transmission lanes are intended to show the general area of distribution of these remote supplies.

A schedule of implementation for the Base Scenario showing the capacity, estimated construction costs, and estimated financed costs of each project component for five year periods is shown on Table No. 10. The conceptual design and cost estimating assumptions for the components are described in detail in Appendix C. The total estimated construction cost through the year 2030 is $593.2 million, and the total financed cost is $889.2 million. This implementation timing and cost was input into the financial model previously described to determine the theoretical impact on the ratepayer. Exhibit No. 19 illustrates the cost per month to a typical single family residence which provides a means of comparison between alternatives. The graph generally shows an initial rapid jump in rates around 1995 due to the introduction of surface water and then gradually increasing rates from 1995 to the peak rate in 2010, when Lake Creek is constructed, which corresponds to the period of surface water conversion. Rates remain fairly constant through the remainder of the planning period due to the continued buy down of Lake Creek capacity. After 2030, rates begin to decline.

In addition to the selected Base Scenario described above, two significant variations were evaluated which constitute boundary conditions between maximum use or depletion of groundwater on the one hand and a minimum use or conservation on the other. The "groundwater depletion" variation assumes that no new surface water facilities are constructed during the planning period. As a result, all of the available groundwater in the service area is depleted by the year 2030. This variation was not felt to represent a viable plan and was not carried forward because large sums of public capital would be invested in extensive remote groundwater facilities which would ultimately become obsolete and because the depletion of available groundwater supply by 2030 with no backup supply could create a serious crisis. The "groundwater conservation" variation assumes that construction of Lake Creek is expedited to the year 2000, which would reduce the required remote groundwater supply. As previously discussed, the size of the ratepayer base would make securing financing of Lake Creek at this early date difficult, and so this variation would have a low predictability of implementation.

IMPORT SCENARIO

The Import Scenario is a water supply plan that meets a major portion of the water supply needs of the SJRA service area from an out-of-basin source of supply. Although several alternative sources were analyzed in the development of this plan, the Toledo Bend Reservoir located on the Sabine River was the only import source of supply considered since the screening performed in Section IV indicated that Toledo Bend provided the only cost effective out-of-basin alternative to Lake Creek.

The source and phasing of supply proposed in the Import Scenario to meet the total service area demands through 2030 are shown graphically in Exhibit No. 20. As in the Base Scenario, the Import Scenario also assumes the use of available Lake Conroe supply (8.0 MGD), the reallocation of presently committed Lake Conroe water (12.0 MGD), and the construction of Spring Creek Lake (6.7 MGD) to meet projected short term water supply needs. Between 2000 and 2020, the Import Scenario relies on remote well fields to meet all increases in demand as illustrated on Exhibit No. 20. Surface water from Toledo Bend is introduced in the year 2020 and replaces some supply previously provided by remote groundwater. At the time of Toledo Bend delivery in the Import Scenario, approximately 19 years of groundwater supply would remain at the rate of groundwater pumpage in 2020. The components of the Import Scenario are shown schematically on Exhibit No. 21. The facilities in the Import Scenario differs from the Base Scenario in the absence of Lake Creek and the increased number of remote well fields.

This plan recognizes that in order to be cost effective, the construction of a surface water conveyance system from Toledo Bend to the service area will require the involvement of the City of Houston as a major participant. An analysis by the Bureau of Reclamation of such a conveyance system for delivery of a supply sufficient only to replace the potential yield of Lake Creek was indicated to be more costly than Lake Creek. Thus, the timing of a much larger more cost effective project is dependent on that of the only other potential importer of surface water to the area, the City of Houston. Based on the projected demands and available supplies defined in the Houston

Water Master Plan, the City of Houston's most probable timing of need for Toledo Bend supply is the year 2020 as assumed in the Import Scenario.

Two alternative Toledo Bend conveyance system alignments were evaluated in the Import Scenario as shown on Exhibit No. 22. The southerly alignment takes water from the Sabine River downstream of the Toledo Bend dam and transports it through a combined gravity and pumped to Lake Houston via Luce Bayou. The northerly alignment takes water directly from the reservoir and transports it to Lake Conroe in a combined gravity and pumped system. The northerly alignment, although crossing more varied topography than the southern alignment, is better positioned to transport surplus East Texas water westward beyond the San Jacinto Basin. This aspect makes a northern alignment more compatible with the Texas Water Development Board's statewide objectives. The construction costs are, given the conceptual level of the design and cost estimating, found to be approximately the same. The northern alignment costs were used for the purpose of scenario comparison.

A schedule of implementation with the capacity, estimated construction cost, and estimated financed cost of each component of the Import Scenario is shown on Table No. 11. The engineering design and cost estimating assumptions of each component are included in Appendix C. The total estimated construction cost of the Import Scenario is estimated to be $739.8 million and the total estimated financed cost is $983.1 million. This implementation schedule and cost was input into the financial model to project the theoretical impact of the project on the ratepayers presented in Exhibit No. 23. The theoretical rate as in the case of the Base Scenario has an initial rapid rise around 1995 due to the introduction of surface water and then steadily increases from 1995 to 2005, remains constant until 2020 when it increases sharply due to the first phase buy down of Toledo Bend conveyance. The rate then decreases until 2030 when it increases sharply again due to the final buy down of Toledo Bend. The peak rate occurs in 2030 and the rate remains high in the following years.

Also shown in Exhibit No. 23 is the ratepayer impact of a variation of the Import Scenario in which the delivery and phasing of Toledo Bend water matches that proposed in the Base Scenario and illustrated on Exhibit No. 24. Although this schedule is considered very unlikely based on the current planning of the City of Houston, it does provide a direct comparison with the Base Scenario which proposes construction of Lake Creek in 2010. A schedule of implementation is presented in Table No. 12. The total estimated construction cost of $584.9 million and the total estimated financed cost is $870.2 million. The impact on the ratepayer shown on Exhibit No. 23 is somewhat higher that the 2020 project and experiences the peak rate in 2010 instead of 2030, and is very similar to the Base Scenario rate pattern.

EXPORT SCENARIO

The Export Scenario is a water supply plan which, by scaling up the Base Scenario or Import Scenario, provides water to users adjacent to the SJRA service area at a lower cost to the ratepayer in the SJRA service area. At the beginning of the study, it was expected that construction of a large reservoir such as Lake Creek would result in surplus supply since it was believed that a substantial long-term groundwater supply was available. However, limited groundwater availability has made large surface water supplies essential for the needs of in-basin users.

Additionally, surface water supply plans have been recently adopted for north Harris County in which the import of water from the north was evaluated and rejected in lieu of service from Lake Houston. Implementation in north Harris County is proceeding with the recent creation of Harris County Regional District No. 2. For this reason, no viable Export Scenario has been identified for either the Base Scenario or the Import Scenario.

SECTION VI

RECOMMENDED PLAN AND IMPLEMENTATION

GENERAL

In the development of a long term water supply plan for Montgomery County, two scenarios were developed, a Base Scenario and an Import Scenario. No viable Export Scenario was identified. The Base Scenario meets water supply needs of the SJRA service area through existing and proposed in-basin sources, whereas the Import Scenario meets these needs through a combination of in-basin sources and the import of water from Toledo Bend in cooperation with the City of Houston.

In the selection of a recommended water supply plan, consideration must be given to a number of factors as outlined previously including cost to the ratepayers, public policy planning risk and predictability of implementation. From an evaluation of these factors for both scenarios, the recommended plan has been defined as the Base Scenario which provides future supplies from totally in-basin sources. This scenario provides the least public policy planning risk, is more predictable for the SJRA and is projected to have a ratepayer cost comparable to or less than the Import Scenario.

Public policy planning risk may be evaluated in terms of the depletion of available groundwater. This may be measured as the years of remaining groundwater supply in any year based on the groundwater demand of that year, as illustrated in Exhibit No. 25. The Base Scenario has 44 years of groundwater supply remaining at the time of Lake Creek delivery in 2010, whereas the Import Scenario has 19 years of groundwater supply remaining at the time of Toledo Bend delivery in 2020. The groundwater depletion scenario, shown on Exhibit No. 25 for purposes of comparison, has no groundwater remaining in the year 2030. Thus, the Base Scenario has the lower public policy planning risk.

All of the component projects in the Base Scenario can be implemented by the San Jacinto River Authority, in association with local entities, independent of other regional authorities. The sizing and phasing of the plan components are such that financing can be supported by the existing and projected in-basin ratepayer base. On the other hand, the Import Scenario depends on the need and availability of financing of the City of Houston in order to be implemented in a timely fashion. Additionally, the later delivery of surface water in the Import Scenario increases the risk that its lower predictability could result in a failure of the water supply plan to provide adequate supplies when needed. Thus, the Base Scenario has the higher predictability of implementation.

A comparison of project cost also favors the Base Scenario over the Import Scenario. The total estimated construction costs for the Base Scenario are less than those of the Import Scenario ($593.2 M versus $739.8 M) and the same is true for the total financed costs ($889.0 M versus $983.1 M). A comparison of the theoretical water rates as calculated by the financial model for the Base Scenario and Import Scenario is illustrated in Exhibit No. 26. The peaks in the water rates occur somewhat later and higher for the Import Scenario. Although somewhat lower in the early years of implementation, the average monthly water rate for the period 1990 through 2040 for the Base Scenario is about $13.50 per month and the average for the Import Scenario is $14.50 per month.

The SJRA water supply plan should provide a conservative, reliable strategy, and any increased risk of one alternative over another must be justified by a significant reduction in impact on the ratepayer. The Import Scenario does not have a signficiant ratepayer impact advantage over the Base Scenario and has increased public policy planning risks as well as lower predictability. Therefore, the Base Scenario is the recommended alternative for the San Jacinto River Authority Water Supply Development Plan for Montgomery County.

RECOMMENDED PLAN

The recommended water supply development plan for supplying the long term needs of the SJRA service area includes maximum utilization of available groundwater in combination with existing and proposed in-basin surface water supplies to provide a predictable cost effective supply through the year 2030 and beyond. Plan components include the continued use of groundwater both local (or in-sector) and remote combined with about 92 MGD of surface water supplied by Lake Conroe, and two proposed reservoirs, Spring Creek Lake and Lake Creek. The plan moves Montgomey County from the present reliance on groundwater to one supplied approximately 60 percent by surface water and 40 percent by groundwater by 2030.

As shown in Exhibit No. 27, the plan anticipates three surface water treatment plants to serve the projected areas of concentrated urban development highlighted in yellow. The northern site would treat Lake Conroe water for distribution to the Conroe area. The central site near the West Fork would treat both Lake Conroe and Lake Creek water for distribution to the southern portion of the County and the southern site would treat Spring Creek Lake water for distribution in the area immediately adjacent to the lake. Both the number and location of these surface water treatment facilities should remain flexible to meet the needs of the area as it grows to insure the development of the most responsive and cost effective system. The proposed three plant systems appear at this time to meet these criteria.
The total estimated construction cost of the recommended water supply plan through the year 2030 is $593.2 million, of which $157.6 million is for groundwater facilities and $435.6 million is for surface water facilities. The total financed cost is $889.2 million. Although much of this cost provides facilities for increases in population, the cost of water to the ratepayer will be 2.0 to 2.5 times today's cost since both remote groundwater and surface water supplies will cost more on a unit basis than local groundwater. This increase in cost is typical of all systems which convert or partially convert to surface water due to the increased capital cost of surface water facilities including lakes as well as conveyance and treatment facilities and the higher cost of water treatment.

The plan anticipates that the proposed remote groundwater supplies and surface water supplies will be constructed by the SJRA and treated water provided on a wholesale basis to the cities, municipal utility districts, and institutions for retail distribution to their customers. The project sizes and financial requirements of these facilities, both surface water and remote groundwater, are larger than most local jurisdictors need or can afford. A regional entity such as the SJRA with experience in the financing, construction, and operation of these facilities is required to coordinate the resources of the local entities to meet their collective needs. Local jurisdictions would continue to regulate, operate, and maintain their own distribution systems and, as groundwater availability allows, their local wells.

IMPLEMENTATION

The recommended water supply development plan provides the overall direction necessary to define and evaluate the smaller incremental water supply projects to be completed during the next ten years. The purpose of this section is to define a methodology for implementation of the recommended plan. Implementation of the master plan must be flexible to the needs of local jurisdictions in Montgomery County and responsive to changes in the assumptions and projections on which the foregoing comparative analysis is based. Cost effective opportunities to convert to a long term source of surface water earlier than anticipated in the recommended plan thus reducing groundwater depletion should be encouraged. The evaluation of any project component should find it either consistent with the plan's key planning factors or justified by demonstrated changes in these factors.

The key planning factors on which selection of this water supply plan is based are:

- o Substantial increase in water needs due to urban growth along the Interstate 45 corridor and throughout southern Montgomery County.

- Significant limitation in the dependable, long term supply of groundwater, particularly in urban areas, requires conversion to surface water.

- Current status of alternative sources of surface water, including project costs and implementation plans of other regional authorities.

- Present availability of land at proposed Lake Creek reservoir site.

The principal problem which this master plan has been designed to solve, i.e., insufficient local groundwater supply to meet the urban growth demands, has not yet developed into a recognized problem with a political mandate for its solution. Lake Creek is too big to implement immediately because the need, and public willingness to pay the cost, have not yet matured. A component in the implementation plan is the monitoring of these key planning factors in order to recognize any changes from today's conditions and projections which would necessitate an adjustment or revision to the master plan.

The growth in urban population and water use should be monitored and compared to the projections in the water supply plan on an annual basis. In addition, the behavior of the groundwater supply system in Montgomery County should be monitored annually to determine the trend in water levels in the Chicot, Evangeline and Upper Jasper aquifers and to identify the occurrence and nature of well production problems in Montgomery County. The evaluation of this information may adjust the implementation schedules of large and small project elements.

Additionally, starter projects should be defined which will allow program implementation to begin prior to 1995. The master plan calls for the introduction of surface water no later than 1995, but acknowledges that earlier introduction of surface water in the urban areas will both conserve groundwater and allow a more gradual increase in rates. Moderating cost increases to the ratepayer, second in importance only to assuring an adequate supply of water, can be achieved early in the planning period by the conjunctive use of surface water with existing urban groundwater supply systems. The existing capacity in these systems will allow the initial phase of the surface water treatment plant to be sized to handle average daily flow as opposed to maximum daily flow, resulting in a savings in the range of 35 percent. Early investment in surface water supply facilities would also avoid the expenditures of capital on additional groundwater facilities which would have a limited useful life. This savings, together with a blending of water rates of local groundwater and surface water, will result in smaller initial rate increases. Later in the planning period, as groundwater availability in an area decreases, more surface water will be required and surface water treatment plants will be expanded to provide maximum day capacity when the size of the ratepayer base will reduce the impact on rates.

The Conroe area represents an ideal opportunity to introduce uncommitted Lake Conroe yield due to the size of the City's regional groundwater supply and distribution system. The Conroe area has experienced significant economic growth through the past several years including the location of several new manufacturing companies. It is expected that additional water supply facilities will be a necessary part of the City's next Capital Improvement Program to continue to provide for this growth. The proximity to Lake Conroe and the West Fork provides flexibility in siting of a surface water treatment plant and the prospects for continued growth provides the opportunity for discussions between the SJRA and the City concerning an initial surface water project.

In south Montgomery County, the proposed Spring Creek Lake offers another opportunity to begin surface water conversion in the highly urbanized south I-45 corridor and within the scale of demand and financial capability of the existing ratepayer base. The Woodlands is already served by a regional groundwater supply and distribution system operated by the SJRA and composed of nine municipal utility districts. The projected growth of The Woodlands as well as other developing areas in southern Montgomery County will require the expansion of existing water production facilities before 1995. The construction of Spring Creek Lake and associated treatment facilities by the SJRA can meet these needs very likely as cost effectively as remote groundwater facilities. The rapidly declining local groundwater levels will make the development of local groundwater facilities difficult as well as ineffective long term.

SECTION VII

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Montgomery County has experienced extremely rapid growth through the 70's and 80's transforming its character from primarily rural to much more urban. This growth is concentrated along the I-45 corridor from the south Montgomery County line to just north of and including the City of Conroe and was facilitied by a readily available groundwater supply.

Continued and significant growth is projected to occur through the planning period (year 2030) for Montgomery County but is dependent on the availability of adequate public water supplies. The results of this study indicate that groundwater which has provided for this historical growth is limited and must be supplemented with surface water to predictably meet the projected short term and long term water needs of the County.

An evaluation of the potential sources of surface water to meet those needs indicates that the most cost effective method is through in-basin sources. These include the utilization of uncommitted or surplus supplies in Lake Conroe and the construction of two new surface water reservoirs, Spring Creek Lake (6.7 MGD) and Lake Creek (65.2 MGD). Spring Creek Lake located on Spring Creek and encompassing a surface area of approximately 1,000 acres is a relatively small reservoir which would supplement rapidly declining groundwater levels in south Montgomery County very early in the program as would Lake Conroe which already exists. Lake Creek, much larger and more costly, is not proposed by the plan until 2010 when the ratepayer base is sufficient to support such a project.

The transition from a predominantly groundwater system to a groundwater/ surface water system will result in significant increases in water rates in the service area but will be required to insure a dependable water supply for continued economic growth in the area. Careful analysis of the impact on the ratepayers of project timing and phasing can minimize the rate of increase and ultimately the maximum rate required. Early implementation of the plan tends to spread the project cost over a longer period and also reduces somewhat the maximum rate encountered.

The size and cost of the plan components are larger than the need and financial capacity of most of the individual local entities, and thus requires a regional entity experienced in the construction, financing, and operation of such projects to coordinate and manage the implementation of the recommended water supply development plan. The San Jacinto River Authority is the only regional agency in Montgomery County meeting these qualifications and should lead in program planning and implementation.

RECOMMENDATIONS

The following recommendations are made to the Board of Directors of the San Jacinto River Authority:

1. Adopt the Plan and assume the lead role in program implementation.

2. Expand Groundwater Monitoring Program.

3. Initiate a program of public education concerning water supply for Montgomery County.

4. Establish a program to periodically update population and water demand projections for Montgomery County to continually reassess the required schedule of plan implementation.

5. Initiate more detailed engineering evaluations of potential initial projects such as Spring Creek Lake including treatment and distribution facilities in south Montgomery County and Lake Conroe treatment facilities to serve the City of Conroe in order to provide data necessary to begin discussions concerning implementation of initial projects.

These recommendations recognize that the plan developed is a necessary initial step to begin implementation of such a major water supply program. However, as conditions change, the plan must be modified to reflect those changes whether that includes simply revising the schedule of implementation or changing major plan components.

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TABLE NO. 1

HISTORICAL POPULATION AND WATER USE
FOR MONTGOMERY COUNTY

GROUNDWATER USE	1966		1985	
Municipal and Rural Domestic	4.87	79%	20.6	78%
Industrial	1.13	18%	2.27	9%
Irrigation & Livestock	0.19	3%	0.19	1%
SUBTOTAL	6.19 MGD	100%	23.06 MGD	88%
SURFACE WATER USE				
Industrial (GSU)	0	0%	3.48	12%
SUBTOTAL	0	0%	3.48 MGD	12%
TOTAL WATER USE	6.19 MGD	100%	26.54 MGD	100%
POPULATION	41,000		171,000 (est.)	
AVERAGE PER CAPITA WATER USE	150 GPCD		155 GPCD	

TABLE NO. 2
PROJECTED POPULATION BY CENSUS TRACT
WITHIN PLANNING AREA

CENSUS TRACT	% OF CENSUS TRACT IN SERVICE AREA	1985 RESIDENTIAL POPULATION	1990 RESIDENTIAL POPULATION	2000 RESIDENTIAL POPULATION	2010 RESIDENTIAL POPULATION	2020 RESIDENTIAL POPULATION	2030 RESIDENTIAL POPULATION
MONTGOMERY CO.							
90101	100%	5869	6271	7876	12519	18236	23771
90102	100%	8245	8728	9410	13445	18359	22744
90103	100%	5267	5963	8183	13719	20593	27487
90201	100%	4821	7164	10563	14618	19523	23652
90202	100%	3899	5318	6781	8785	11196	13011
90203	100%	10133	15364	24272	33542	41347	46255
90204	100%	6091	7613	10155	11621	12918	12990
90205	100%	4205	5339	5748	8001	9582	10034
90206	100%	5156	7617	13911	21050	29133	36567
90207	100%	11812	20978	47284	76127	109249	141156
90301	100%	7792	8357	10124	15719	22594	29165
90302	100%	9153	10208	14476	24627	37186	49788
90400	100%	2231	2533	2727	3893	5317	6591
90500	100%	5339	7132	7977	11758	16397	20689
90601	100%	7854	8864	14459	25283	39518	53721
90602	100%	5334	6214	6601	8400	9672	9918
90603	100%	7510	9926	14666	24534	37630	50685
90701	100%	5729	7557	9060	13379	19245	24807
90702	100%	4227	4705	4805	6566	8690	10474
90703	100%	5966	6660	6622	8253	10484	12055
90801	100%	4092	4601	4659	6319	8325	9995
90802	100%	2551	2756	2928	4137	5607	6903
90803	100%	8225	9239	9360	12681	16681	19987
90900	100%	4240	4733	5114	7317	9995	12382
91000	100%	9575	11738	13348	18808	26184	32771
91101	100%	4444	5641	6893	10789	15589	20213
91102	100%	6553	8153	9337	13930	19535	24718
91201	100%	1279	2112	2167	2973	3947	4766
91202	100%	3564	7515	10694	18206	27471	36705
LIBERTY CO.							
100100	100%	3942	4120	5150	8157	11850	15411
100201	100%	3024	3477	3951	5858	8178	10300
100202	61%	4641	5163	6999	11611	17295	22909
100300	4%	202	237	310	504	743	977
100400	6%	146	231	276	425	607	779
SAN JACINTO CO.							
200100	4%	0	0	0	0	0	0
HARRIS CO.							
24920	17%	3193	4304	7017	11489	16991	19723
25000	31%	388	502	481	618	784	909

TABLE NO. 3
PROJECTED WATER DEMANDS BY CENSUS TRACT
WITHIN PLANNING AREA

CENSUS TRACT	% OF CENSUS TRACT IN SERVICE AREA	1985 TOTAL EST. AVE. DAY DEMAND (MGD)	1990 TOTAL EST. AVE. DAY DEMAND (MGD)	2000 TOTAL EST. AVE. DAY DEMAND (MGD)	2010 TOTAL EST. AVE. DAY DEMAND (MGD)	2020 TOTAL EST. AVE. DAY DEMAND (MGD)	2030 TOTAL EST. AVE. DAY DEMAND (MGD)
MONTGOMERY CO.							
90101	100%	0.910	1.003	1.339	2.128	3.100	4.041
90102	100%	1.278	1.396	1.600	2.286	3.121	3.867
90103	100%	0.816	0.954	1.391	2.332	3.501	4.673
90201	100%	0.747	1.146	1.796	2.485	3.319	4.021
90202	100%	0.604	0.851	1.153	1.494	1.903	2.212
90203	100%	1.571	2.458	4.126	5.702	7.029	7.863
90204	100%	0.944	1.218	1.726	1.976	2.196	2.208
90205	100%	0.652	0.854	0.977	1.360	1.629	1.706
90206	100%	0.799	1.219	2.365	3.579	4.953	6.216
90207	100%	1.831	3.356	8.038	12.942	18.572	23.996
90301	100%	1.208	1.337	1.721	2.672	3.841	4.958
90302	100%	1.419	1.633	2.461	4.187	6.322	8.464
90400	100%	0.346	0.405	0.464	0.662	0.904	1.120
90500	100%	0.828	1.141	1.356	1.999	2.787	3.517
90601	100%	1.217	1.418	2.458	4.298	6.718	9.133
90602	100%	0.827	0.994	1.122	1.428	1.644	1.686
90603	100%	1.164	1.588	2.493	4.171	6.397	8.617
90701	100%	0.888	1.209	1.540	2.274	3.272	4.217
90702	100%	0.655	0.753	0.817	1.116	1.477	1.781
90703	100%	0.925	1.066	1.126	1.403	1.782	2.049
90801	100%	0.634	0.736	0.792	1.074	1.415	1.699
90802	100%	0.395	0.441	0.498	0.703	0.953	1.173
90803	100%	1.275	1.478	1.591	2.156	2.836	3.398
90900	100%	0.657	0.757	0.869	1.244	1.699	2.105
91000	100%	1.484	1.878	2.269	3.197	4.451	5.571
91101	100%	0.689	0.903	1.172	1.834	2.650	3.436
91102	100%	1.016	1.305	1.587	2.368	3.321	4.202
91201	100%	0.198	0.338	0.368	0.505	0.671	0.810
91202	100%	0.552	1.202	1.818	3.095	4.670	6.240
LIBERTY CO.							
100100	100%	0.611	0.659	0.875	1.387	2.014	2.620
100201	100%	0.469	0.556	0.672	0.996	1.390	1.751
100202	61%	0.719	0.826	1.190	1.974	2.940	3.895
100300	4%	0.031	0.038	0.053	0.086	0.126	0.166
100400	6%	0.023	0.037	0.047	0.072	0.103	0.132
SAN JACINTO CO.							
200100	4%	0.000	0.000	0.000	0.000	0.000	0.000
HARRIS CO.							
24920	17%	0.495	0.689	1.193	1.953	2.888	3.353
25000	31%	0.060	0.080	0.082	0.105	0.133	0.154

TABLE NO. 4

HISTORICAL WATER LEVELS IN WELLS
IN THE CHICOT RECHARGE AREA

Well No.	Depth	Elevation of Land Surface	Date of Measurement	Depth of Water
60-62-402	106	133	9-16-44	2.0
			2-14-49	27.08
			2-17-54	32.48
			9-26-55	34.72
60-61-705	137	118	1-28-44	4.38
			2-14-49	30.76
60-61-706	242	118	12-20-62	67.3
			2-23-66	75.35
60-61-807	358	116	8-26-43	22.32
			2-17-48	36.30
			2-4-53	50.86
			2-24-58	65.07
			2-20-59	67.45
65-02-811	137	160	3-24-31	35.82
			3-12-40	49.77
			3-17-45	53.52
			3-14-50	61.25
			3-14-55	74.31
			3-9-60	82.02
			3-12-65	93.95
65-02-909	134	156	3-18-42	44.3
			3-26-47	48.14
			3-17-52	66.05
			12-3-58	85.03
65-03-106	158	156	4-3-31	5.87
			2-25-36	6.08
			5-27-41	9.64
			1-17-46	9.13
			2-26-51	22.78
			2-17-56	3.38
65-03-204	72	150	4-3-31	6.49
			2-25-36	6.43
			1-28-41	15.18
			1-17-46	7.05
			2-26-51	15.09
			2-17-56	32.73
			2-13-61	32.47
			2-17-66	44.91
			2-20-70	49.78
			12-10-74	54.03
			9-5-79	58.1

TABLE NO. 4 (CONTINUED)

Well No.	Depth	Elevation of Land Surface	Date of Measurement	Depth of Water
65-03-707	95	145	3-12-31	23.10
			3-17-33	25.64
			1-3-39	29.05
			10-11-44	34.35
			1-20-49	37.43
			12-2-54	38.37
			3-9-56	40.30
65-03-806	239	142	1-21-42	27.03
			3-26-47	26.50
			3-12-52	43.28
			3-18-57	61.49
			3-20-62	63.71
			3-11-66	72.60
			3-3-70	86.27
65-04-506	110	120	12-21-54	53.0
			2-17-59	57.03
			3-6-64	59.08
			2-23-66	62.0
65-04-507	103	122	1-30-47	29.87
			2-9-53	55.43
			2-21-58	64.34
			2-15-65	74.33
			2-23-66	76.19
			2-20-70	83.42
			2-26-75	84.57
			11-16-79	86.68
65-04-603	208	118	11-9-38	34.62
			1-22-42	33.60
			1-31-47	41.40
			2-11-52	65.01
			9-30-53	84.26
65-04-714	100	128	12-13-48	37.88
			2-6-52	47.0
			2-15-57	59.19
			2-13-61	53.67
65-05-104	238	118	12-23-52	52.32
			2-26-57	69.05
			2-21-62	66.55
			2-23-66	78.86
			2-18-70	83.37
			2-19-75	90.00
			5-31-78	100.30
65-05-106	96	118	7-22-44	28.75
			2-14-49	36.70
			9-16-52	44.29

TABLE NO. 4 (CONTINUED)

Well No.	Depth	Elevation of Land Surface	Date of Measurement	Depth of Water
65-05-207	152	105	4-8-60	73.21
			2-12-65	84.50
			2-23-66	87.60
			2-18-70	96.52
			2-19-75	105.24
65-05-505	189	96	11-9-31	27.86
			2-27-36	27.20
			12-5-40	38.26
65-07-401	200	56	9-21-43	29.64
			3-24-48	35.34
			2-3-53	50.63
			2-10-58	67.50
			2-26-63	61.93
			2-8-66	69.06
			2-17-70	74.69
			2-18-75	77.6
			1-26-78	79.86
65-07-902	196	55	2-13-54	75.85
			1-1-59	83.57
			1-1-64	91.61
			3-9-66	94.94
			1-1-70	103.0
			2-19-75	108.79
			1-25-79	110.01
Very Shallow Wells				
65-03-604	40	136	4-3-31	2.13
			2-25-36	2.04
			3-1-41	1.76
			1-17-46	0.80
			2-26-51	13.01
			6-14-56	15.09
			2-13-61	6.85
65-05-506	41	96	3-27-31	9.66
			11-10-37	18.20
			1-22-42	7.26
			1-29-47	5.32
			2-8-52	20.38
			2-14-57	28.15
			6-12-62	16.21
			2-23-66	18.60
65-05-904	50	83	11-9-38	12.44
			1-20-43	6.87
			2-17-48	9.87
			2-7-52	19.78
			2-18-58	16.15

TABLE NO. 5

ESTIMATED AVAILABLE GROUNDWATER SUPPLY
(MILLION GALLONS)

Sector	Chicot/ Evangeline MG	Upper Jasper MG	Lower Jasper MG	Total MG
1	0	39,866	237,779	277,645
2	42,847	0	0	42,847
3	17,264	66,861	101,704	185,829
4	29,821	20,716	70,471	121,008
5	36,255	44,888	101,704	182,847
6	8,475	35,471	63,251	107,197
7	14,440	14,753	0	29,193
8	55,717	0	0	55,717
9	26,368	0	0	26,368
10	8,161	52,108	0	60,269
11	12,713	628	0	13,341
12	71,412	50,224	0	121,636
13	33,901	0	0	33,901
TOTALS	357,374	325,515	574,909	1,257,798
PERCENT OF AVAILABLE SUPPLY	28%	26%	46%	100%

TABLE NO. 6
PROJECTED WATER DEMANDS BY GROUNDWATER ANALYSIS SECTOR
(MILLION GALLONS)

	1985 (MG)	1990 (MG)	2000 (MG)	2010 (MG)	2020 (MG)	2030 (MG)
SECTOR 1	43.42	74.46	80.66	110.69	146.94	177.44
SECTOR 2	184.60	246.48	286.80	416.87	576.06	721.17
SECTOR 3	408.19	701.24	1037.10	1734.90	2604.90	3465.35
SECTOR 4	271.40	347.92	438.35	662.01	942.08	1204.78
SECTOR 5	288.62	370.48	456.61	686.24	966.90	1228.28
SECTOR 6	1467.69	1848.23	2554.18	3950.52	5734.88	7409.84
SECTOR 7	487.44	600.28	709.57	1002.22	1382.39	1721.38
SECTOR 8	517.25	595.30	768.20	1191.82	1710.41	2204.18
SECTOR 9	254.91	327.64	392.13	580.91	812.47	1027.27
SECTOR 10	2853.63	4189.95	7019.54	10161.77	13600.67	16516.60
SECTOR 11	931.92	1102.88	1386.16	2041.51	2843.20	3579.76
SECTOR 12	1696.40	1974.20	2493.81	3752.26	5292.17	6564.56
SECTOR 13	1156.16	1478.28	2522.29	4108.82	6011.77	7872.93
TOTALS	10561.64	13857.34	20145.39	30400.55	42624.84	53693.53

TABLE NO. 7

COMPARISON OF PROJECTED GROUNDWATER SUPPLY AND DEMAND
(1987 - 2030)

Groundwater Analysis Sector	Groundwater Supply Volume (MG)	Demand Volume thru 2030 (MG)	Surplus (Deficit) (MG)	Approximate Year of Depletion
1	277,645	5,000	272,645	
2	42,847	18,800	24,047	
3	185,829	78,400	107,429	
4	121,008	29,900	91,108	
5	182,847	30,900	151,947	
6	107,197	178,400	(71,203)	2019
7	29,193	45,400	(16,207)	2020
8	55,717	53,800	1,917	2030
9	26,368	26,200	168	2030
10	60,269	432,700	(372,431)	1999
11	13,341	91,600	(78,259)	1998
12	121,636	167,900	(46,264)	2023
13	33,901	181,900	(147,999)	2003
TOTALS FOR PLANNING AREA	1,257,798 MG	1,340,900 MG	(83,102) MG	

TABLE NO. 8

SUMMARY OF POTENTIAL SURFACE WATER SOURCES

Reservoir	Owner	Construction Status	Reservoir Yield (MGD)	Yield Available to SJRA (MGD)	Estimated Raw Water Price (Per 1000 Gal)	Estimated Conveyance Cost to Basin (Per 1000 Gal)	Estimated Total Cost (Per 1000 Gal)
Base Scenario							
Lake Conroe	SJRA/Houston	Existing	89.3	7.90(1)	$0.23	0	$0.23
(Lower) Lake Creek(2)	SJRA	Future	65.2	65.2	$0.77	0	$0.77
Spring Creek Lake	SJRA	Future	6.7	6.7	$0.44	0	$0.44
Import Scenario							
Millican Reservoir	BRA	Future	222	135	$1.00	$0.20	$1.20
Bedias Reservoir	TRA	Future	81	60	$0.71	$0.26	$0.97
Lake Livingston	TRA/Houston	Existing	1374	0	$0.015	N/A	N/A
Rockland Reservoir	LNVA	Future	634	634	$1.25		
Sam Rayburn Reservoir	LNVA	Existing	1006	0	N/A	N/A	N/A
Toledo Bend Reservoir	SRA	Existing	1296	1296	$0.08	$0.35-$0.55	$0.43-$0.63

Notes:

(1) Additional yield might be made available through renegotiation of contracts in 1993
(2) Single Purpose Water Supply Reservoir, Non-Federal Project
(3) Based on 90 MGD
(4) Based on 600 MGD

TABLE NO. 9

SUMMARY OF SJRA SURFACE WATER SUPPLY CONTRACTS

Customer	Contractual Commitments (MGD)	For Period 1982 - 1987 Annual Average (MGD)	For Period 1982 - 1987 Annual Maximum (MGD)	Year Contract Expires
Amoco (3)	1.50	0.7	0.8	2000
Chevron	15.00	6.9	7.3	1993
Advanced Aromatics (CXI)	0.03	0	0	(1)
Exxon Chemical Americas	9.00	4.2	5.4	1993
Exxon Company U.S.A.	40.00	34.4	38.7	1993
Gulf States Utilities	4.46	3.6	4.4	1993
J. M. Huber	0.41	0.1	0.1	1993
N.G.O. (Helmerich & Payne)	0.05	0	0	1993
Stauffer Chemical	0.50	0.4	0.5	1993
SUBTOTAL	70.95	50.3	57.2	
Irrigation	0.0	2.1	3.0	(2)
TOTALS	70.95 MGD	52.4	60.2	

TOTAL SURFACE WATER RIGHTS 79.8 MGD

REMAINING UNCOMMITED SUPPLY 8.85 MGD

Notes:

(1) Contract automatically renews annually.
(2) Irrigation contracts are negotiated year to year subject to availability of water.
(3) For period 1985 - 1987

TABLE NO. 10

BASE SCENARIO SCHEDULE OF IMPLEMENTATION
(COSTS IN MILLIONS)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	TOTALS
IN-SECTOR WELLS (6-13)										
Capacity	9.1 MGD	2.1 MGD	3.5 MGD							14.7 MGD
Construction Cost	$12.4	$ 2.9	$ 4.8							$20.1
Financed Cost	$14.1	$ 3.3	$ 5.5							$22.9
REMOTE WELLS										
Capacity			10.0 MGD	20.0 MGD		5.0 MGD	5.0 MGD			40.0 MGD
Construction Cost			$37.7	$86.4		$ 6.8	$ 6.6			$137.5
Financed Cost			$42.8	$98.2		$ 7.7	$ 7.5			$156.2
SPRING CREEK LAKE										
Capacity		6.7 MGD								6.7 MGD
Construction Cost		$10.5								$10.5
Financed Cost		$11.9								$11.9
LAKE CREEK										
Capacity					32.6 MGD	2.5 MGD	9.9 MGD	13.2 MGD	7.0 MGD	65.2 MGD
Construction Cost					$98.2	$ 7.5	$29.8	$39.8	$21.1	$196.4
Financed Cost					$109.1	$13.3	$74.1	$138.6	$103.1	$438.2
SURFACE WATER TREATMENT PLANT										
Capacity		23.0 MGD	3.7 MGD		21.7 MGD	13.4 MGD	9.9 MGD	13.2 MGD	7.0 MGD	91.9 MGD
Construction Cost		$57.3	$ 9.1		$54.1	$34.0	$24.7	$34.0	$15.5	$228.7
Financed Cost		$65.1	$10.3		$61.5	$38.6	$28.1	$38.6	$17.6	$259.8
TOTALS										
Construction Cost	$12.4 M	$70.7 M	$51.6 M	$86.4 M	$152.3 M	$48.3 M	$61.1 M	$73.8 M	$36.6 M	$593.2 M
Financed Cost	$14.1 M	$80.3 M	$58.6 M	$98.2 M	$170.6 M	$59.6 M	$109.7 M	$177.2 M	$120.7 M	$889.0 M

TABLE NO. 11

IMPORT SCENARIO SCHEDULE OF IMPLEMENTATION
(COSTS IN MILLIONS)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	TOTALS
IN-SECTOR WELLS (6-13)										
Capacity	9.1 MGD	2.1 MGD	3.5 MGD							14.7 MGD
Construction Cost	$12.4	$ 2.9	$ 4.8							$20.1
Financed Cost	$14.1	$ 3.3	$ 5.5							$22.9
REMOTE WELLS										
Capacity			10.0 MGD	20.0 MGD	20.0 MGD	10.0 MGD	5.0 MGD			65.0 MGD
Construction Cost			$37.8	$82.6	$67.3	$17.7	$12.8			$218.2
Financed Cost			$43.0	$93.9	$76.5	$20.1	$14.5			$248.0
SPRING CREEK LAKE										
Capacity		6.7 MGD								6.7 MGD
Construction Cost		$10.5								$10.5
Financed Cost		$11.9								$11.9
TOLEDO BEND RESERVOIR										
Capacity							43.1 MGD		43.1 MGD	86.2 MGD
Construction Cost							$105.5		$105.5	$211.0
Financed Cost							$119.9		$262.1	$382.0
SURFACE WATER TREATMENT PLANT										
Capacity		23.0 MGD	3.7 MGD				43.1 MGD		43.1 MGD	112.9 MGD
Construction Cost		$57.4	$ 9.2				$106.7		$106.7	$280.0
Financed Cost		$65.2	$10.5				$121.3		$121.3	$318.3
TOTALS										
Construction Cost	$12.4 M	$70.8 M	$51.8 M	$82.6 M	$67.3 M	$17.7 M	$225.0 M		$212.2 M	$739.8 M
Financed Cost	$14.1 M	$80.4 M	$59.0 M	$93.9 M	$76.5 M	$20.1 M	$255.7 M		$383.4 M	$983.1 M

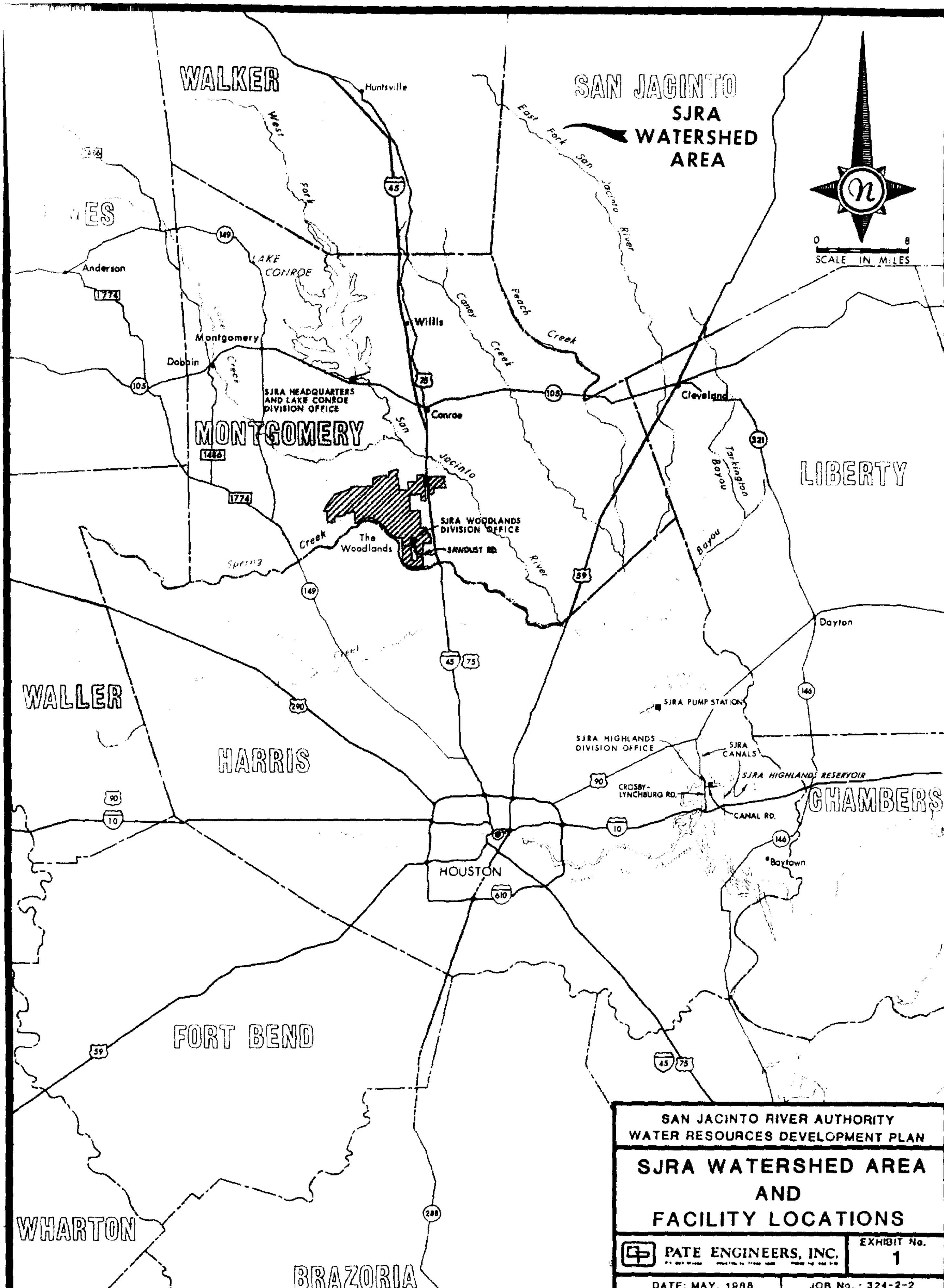
TABLE NO. 12

IMPORT VARIATION SCHEDULE OF IMPLEMENTATION
(COSTS IN MILLIONS)

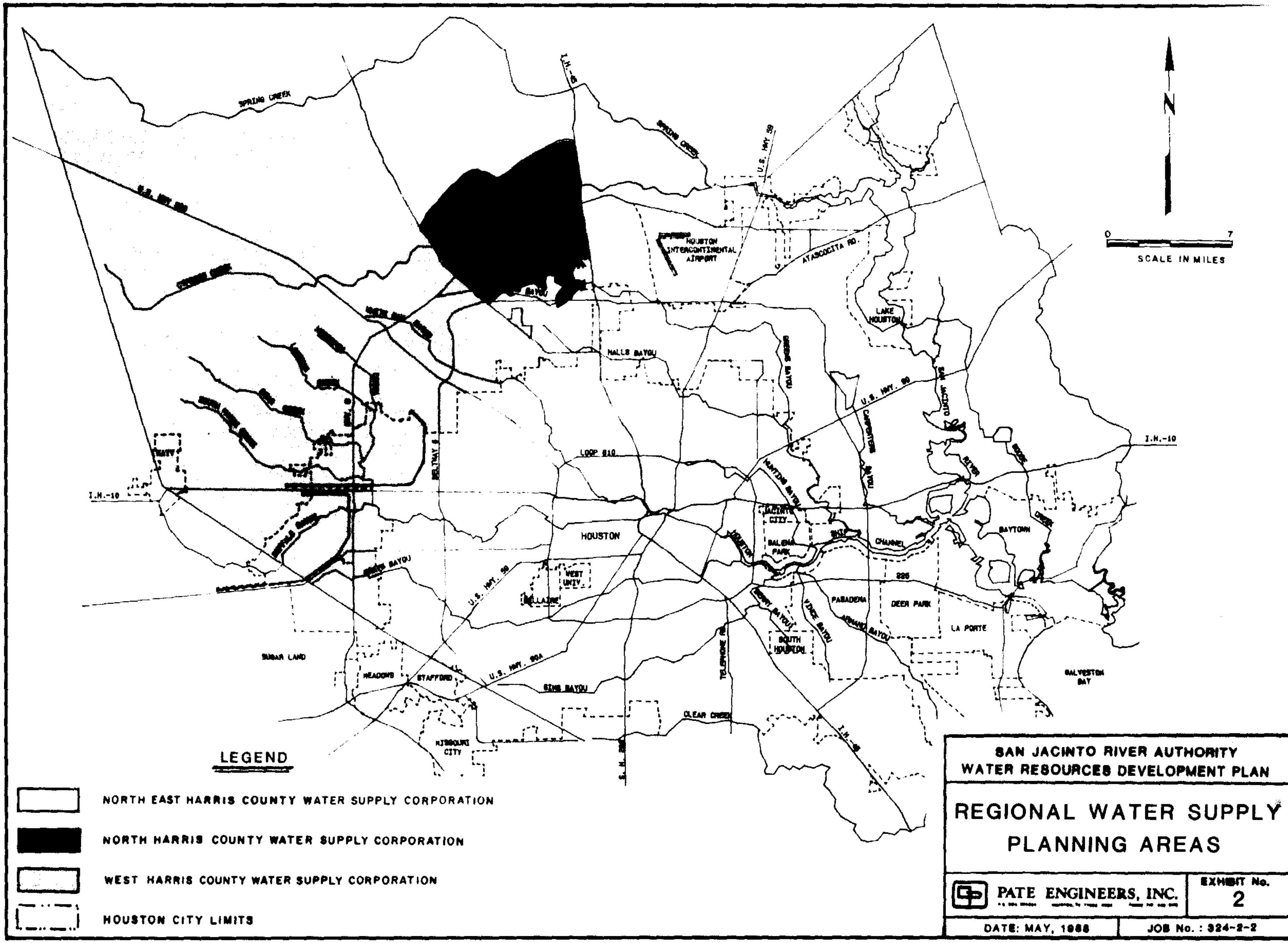
	1990	1995	2000	2005	2010	2015	2020	2025	2030	TOTALS
IN-SECTOR WELLS (6-13)										
Capacity	9.1 MGD	2.1 MGD	3.5 MGD							14.7 MGD
Construction Cost	$12.4	$ 2.9	$ 4.8							$20.1
Financed Cost	$14.1	$ 3.3	$ 5.5							$22.9
REMOTE WELLS										
Capacity			10.0 MGD	20.0 MGD		5.0 MGD	5.0 MGD			40.0 MGD
Construction Cost			$37.7	$86.4		$ 6.8	$ 6.6			$137.5
Financed Cost			$42.8	$98.2		$ 7.7	$ 7.5			$156.2
SPRING CREEK LAKE										
Capacity		6.7 MGD								6.7 MGD
Construction Cost		$10.5								$10.5
Financed Cost		$11.9								$11.9
LAKE CREEK										
Capacity					32.6 MGD	2.5 MGD	9.9 MGD	13.2 MGD	7.0 MGD	65.2 MGD
Construction Cost					$94.1	$ 7.2	$28.5	$38.1	$20.2	$188.1
Financed Cost					$104.5	$12.8	$70.8	$132.6	$98.7	$419.4
SURFACE WATER TREATMENT PLANT										
Capacity		23.0 MGD	3.7 MGD		21.7 MGD	13.4 MGD	9.9 MGD	13.2 MGD	7.0 MGD	91.9 MGD
Construction Cost		$57.3	$ 9.1		$54.1	$34.0	$24.7	$34.0	$15.5	$228.7
Financed Cost		$65.1	$10.3		$61.5	$38.6	$28.1	$38.6	$17.6	$259.8
TOTALS										
Construction Cost	$12.4 M	$70.7 M	$51.6 M	$86.4 M	$148.2 M	$48.0 M	$59.8 M	$72.1 M	$35.7 M	$584.9 M
Financed Cost	$14.1 M	$80.3 M	$58.6 M	$98.2 M	$166.0 M	$59.1 M	$106.4 M	$171.2 M	$116.3 M	$870.2 M

LIST OF EXHIBITS

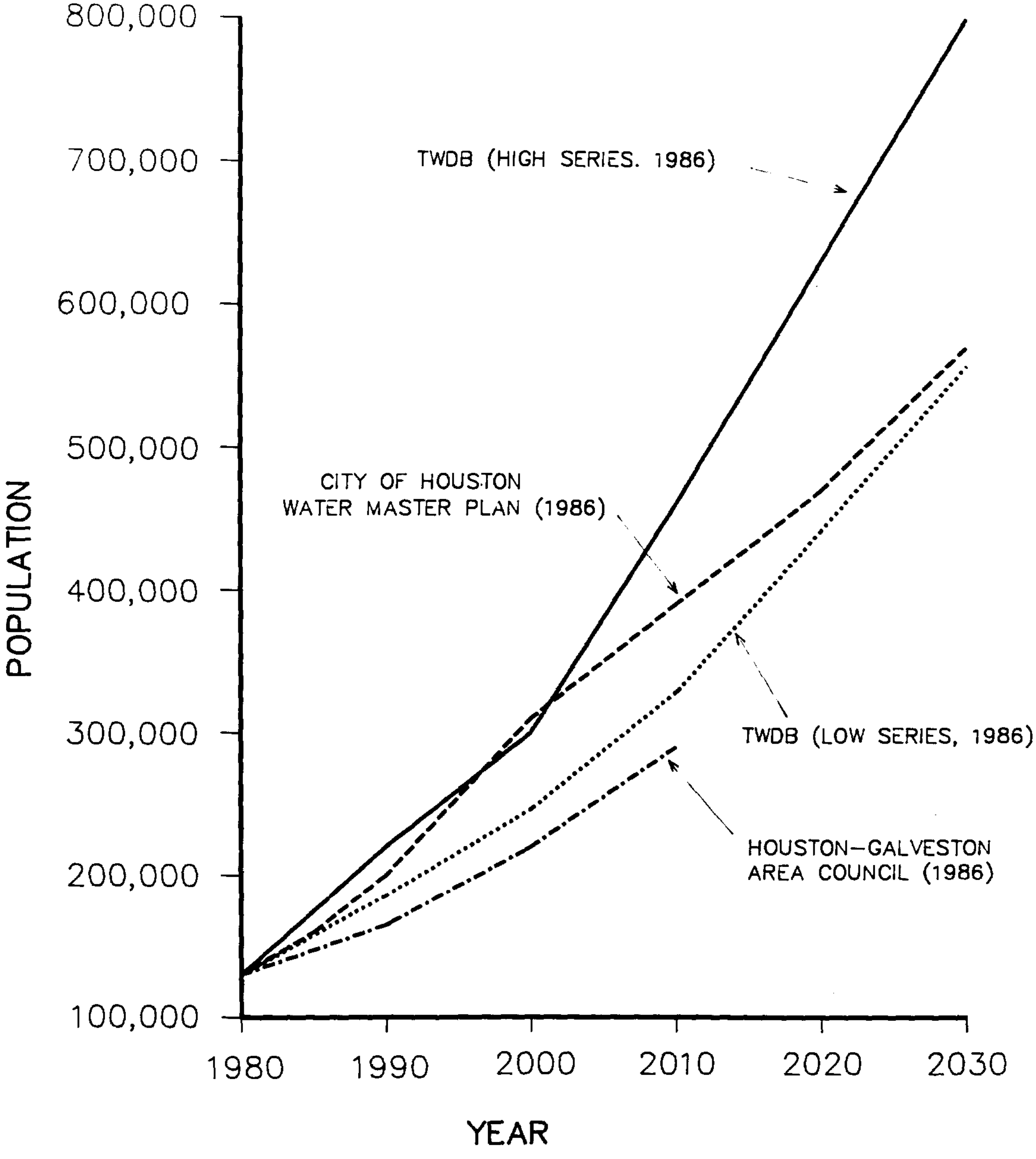
NO.	TITLE
1	SJRA Watershed Area and Facility Locations
2	Regional Water Supply Planning Areas
3	Population Projections for Montgomery County
4	Census Tracts in Planning Area
5	Gulf Coast Aquifer Hydrologic Section
6	Aquifer Recharge Zones
7	Evangeline Well Level Declines in North Harris County
8	Evangeline Well Level Declines in South Montgomery County
9	Surface Soils in Montgomery County
10	Representative Soil Borings in Harris and Montgomery Counties
11	Generalized Aquifer Stratigraphy
12	Well Level Declines in Chicot Recharge Zone in North Harris County
13	Jasper Well Level Declines in Conroe Area
14	Sector Layout for Hydrologic Model
15	Projected Groundwater Shortfall by Sector
16	Potential Surface Water Supply Sources
17	Base Scenario - Lake Creek 2010
18	Base Scenario Supply Facilities
19	Base Scenario Impact on Ratepayer
20	Import Scenario - Toledo Bend (2020)
21	Import Scenario Water Supply Facilities
22	Alternate Toledo Bend Alignments
23	Import Scenario Impact on Ratepayer
24	Toledo Bend (2010) Import Alternative
25	Groundwater Depletion of Alternative Scenarios
26	Comparison of Base Scenario and Import Scenario - Impact on Ratepayer
27	Recommended Water Supply Plan



WALKER
Huntsville
West Fork
SAN JACINTO
SJRA
WATERSHED
AREA
East Fork San Jacinto River
n
0
8
SCALE IN MILES
45
149
Anderson
LAKE CONROE
1774
Willis
Caney Creek
Peach Creek
Montgomery
Dobbin
Creek
105
SJRA HEADQUARTERS
AND LAKE CONROE
DIVISION OFFICE
Conroe
105
Cleveland
321
MONTGOMERY
1486
San Jacinto River
Tarkington Bayou
LIBERTY
1774
SJRA WOODLANDS
DIVISION OFFICE
SAWDUST RD.
The Woodlands
Spring Creek
59
Bayou
149
Dayton
45
75
WALLER
290
SJRA PUMP STATION
146
SJRA HIGHLANDS
DIVISION OFFICE
SJRA
CANALS
HARRIS
SJRA HIGHLANDS RESERVOIR
90
CROSBY-
LYNCHBURG RD.
CHAMBERS
90
10
CANAL RD.
10
146
Baytown
HOUSTON
610
FORT BEND
59
45
75
288
WHARTON
BRAZORIA
SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN
SJRA WATERSHED AREA
AND
FACILITY LOCATIONS
PATE ENGINEERS, INC.
EXHIBIT No.
1
DATE: MAY, 1988
JOB No.: 324-2-2



SPRING CREEK
I.H.-45
U.S. HWY. 59
U.S. HWY. 290
HOUSTON INTERCONTINENTAL AIRPORT
ATASCOCITA RD.
LAKE HOUSTON
SCALE IN MILES
0
7
N
HALLS BAYOU
GREENS BAYOU
U.S. HWY. 90
SAN JACINTO
LOOP 610
I.H.-10
BELTWAY 8
HOUSTON
HUNTING BAYOU
JACINTO CITY
GALENA PARK
SHIP CHANNEL
BAYTOWN
WEST UNIV.
BELLAIRE
PASADENA
DEER PARK
LA PORTE
225
SOUTH HOUSTON
SUGAR LAND
STAFFORD
U.S. HWY. 90A
SIMS BAYOU
CLEAR CREEK
MISSOURI CITY
GALVESTON BAY
TELEPHONE RD.
LEGEND
NORTH EAST HARRIS COUNTY WATER SUPPLY CORPORATION
NORTH HARRIS COUNTY WATER SUPPLY CORPORATION
WEST HARRIS COUNTY WATER SUPPLY CORPORATION
HOUSTON CITY LIMITS
SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN
REGIONAL WATER SUPPLY
PLANNING AREAS
PATE ENGINEERS, INC.
EXHIBIT No.
2
DATE: MAY, 1988
JOB No.: 324-2-2



SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

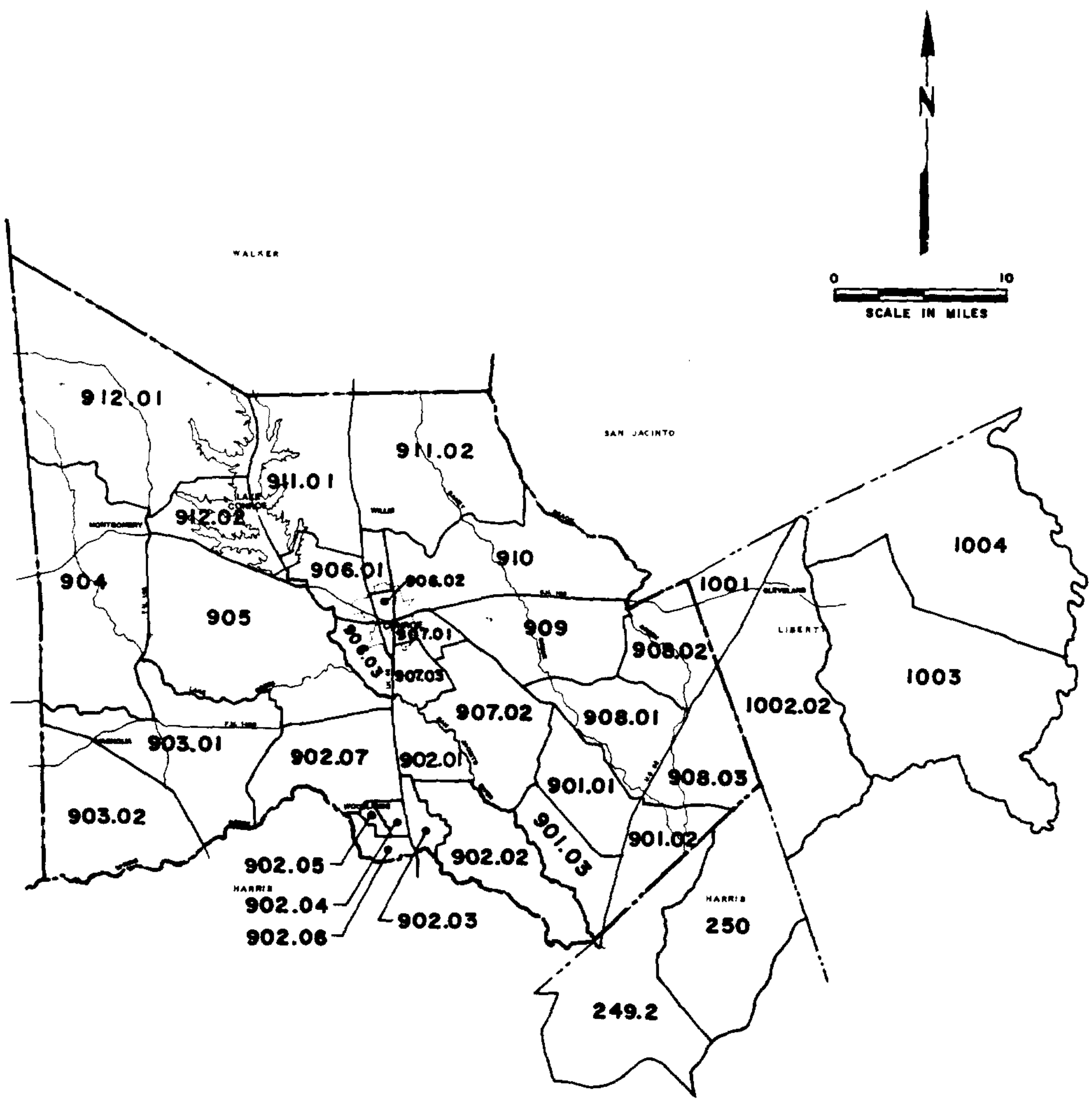
POPULATION PROJECTIONS FOR MONTGOMERY COUNTY

PATE ENGINEERS, INC.
P.O. BOX 934034 HOUSTON, TX 77282 – 4034
PHONE 713 – 462 – 3178

EXHIBIT NO. 3

DATE: MAY, 1988

JOB NO. : 324–2–2



SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

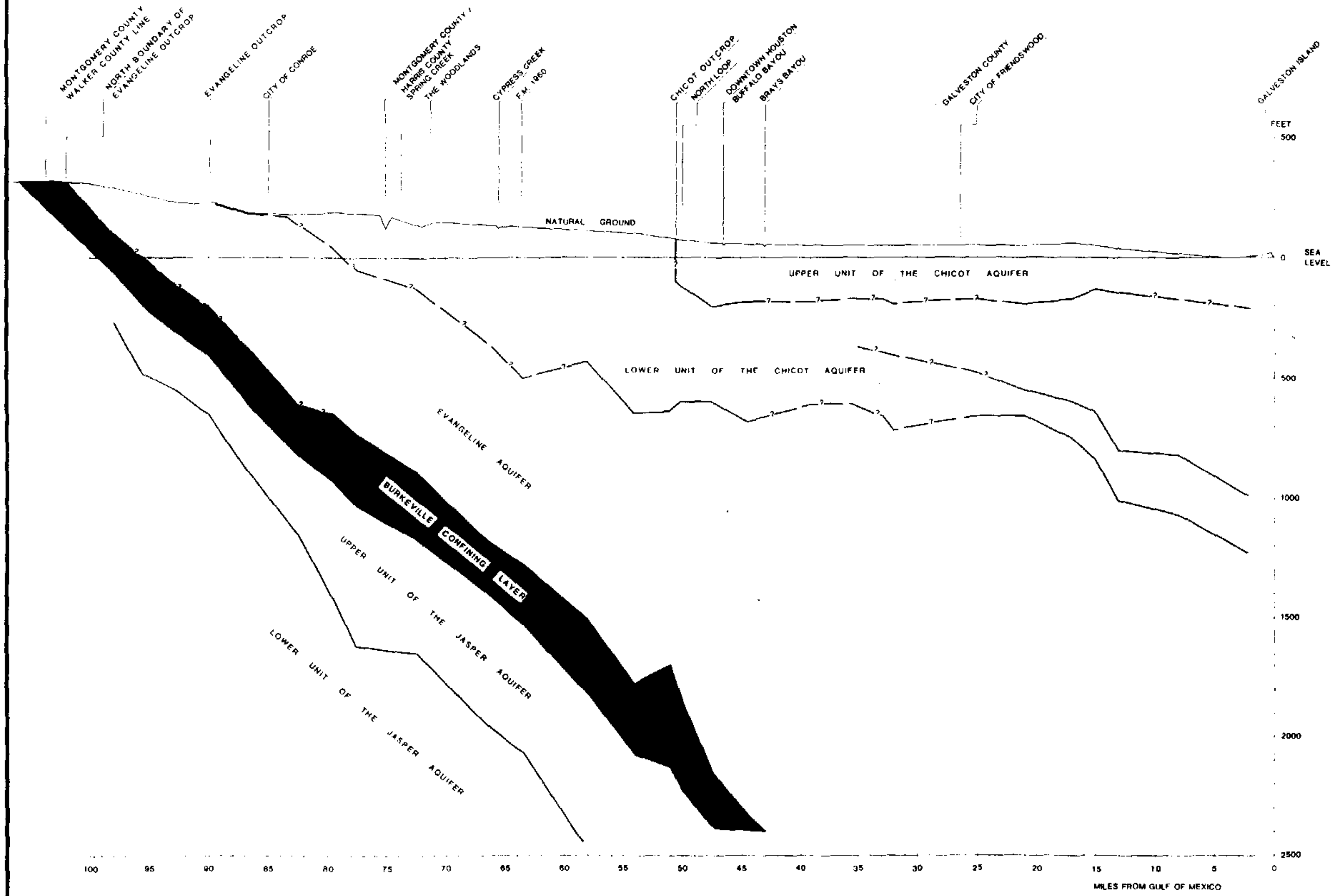
CENSUS TRACTS IN PLANNING AREA

PATE ENGINEERS, INC.

EXHIBIT No. 4

DATE: MAY, 1988

JOB No.: 324-2-2



ALIGNMENT OF HYDROGEOLOGIC SECTION

SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

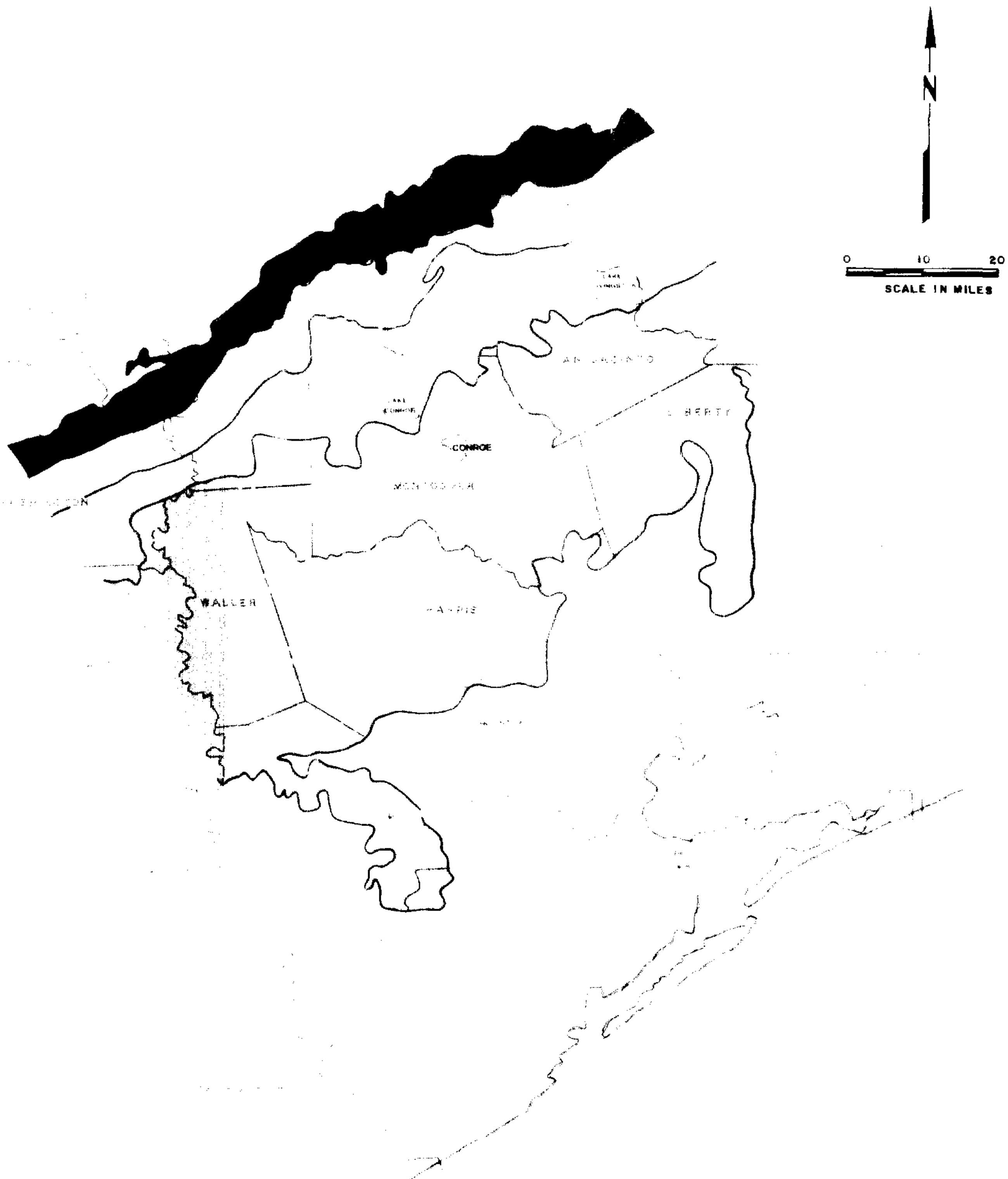
GULF COAST AQUIFER
HYDROGEOLOGIC SECTION

PATE ENGINEERS, INC.

EXHIBIT No. 5

DATE: MAY, 1986

JOB No.: 324-2-?



LEGEND

JASPER AQUIFER RECHARGE ZONE

EVANGELINE AQUIFER RECHARGE ZONE

CHICOT AQUIFER RECHARGE ZONE

SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

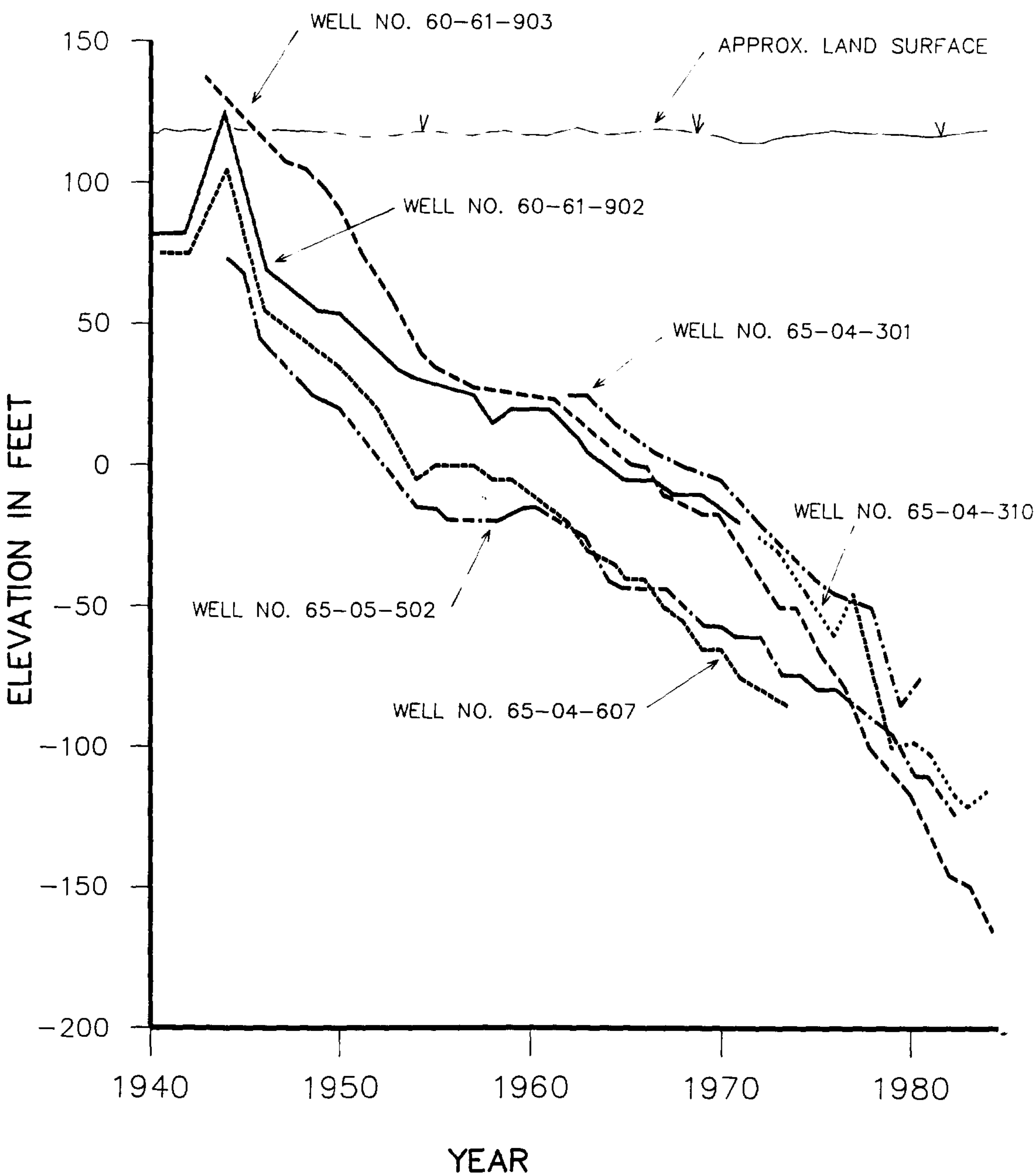
AQUIFER RECHARGE ZONES

PATE ENGINEERS, INC.

EXHIBIT No. 6

DATE: MAY, 1988

JOB No. : 324-2-2



SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

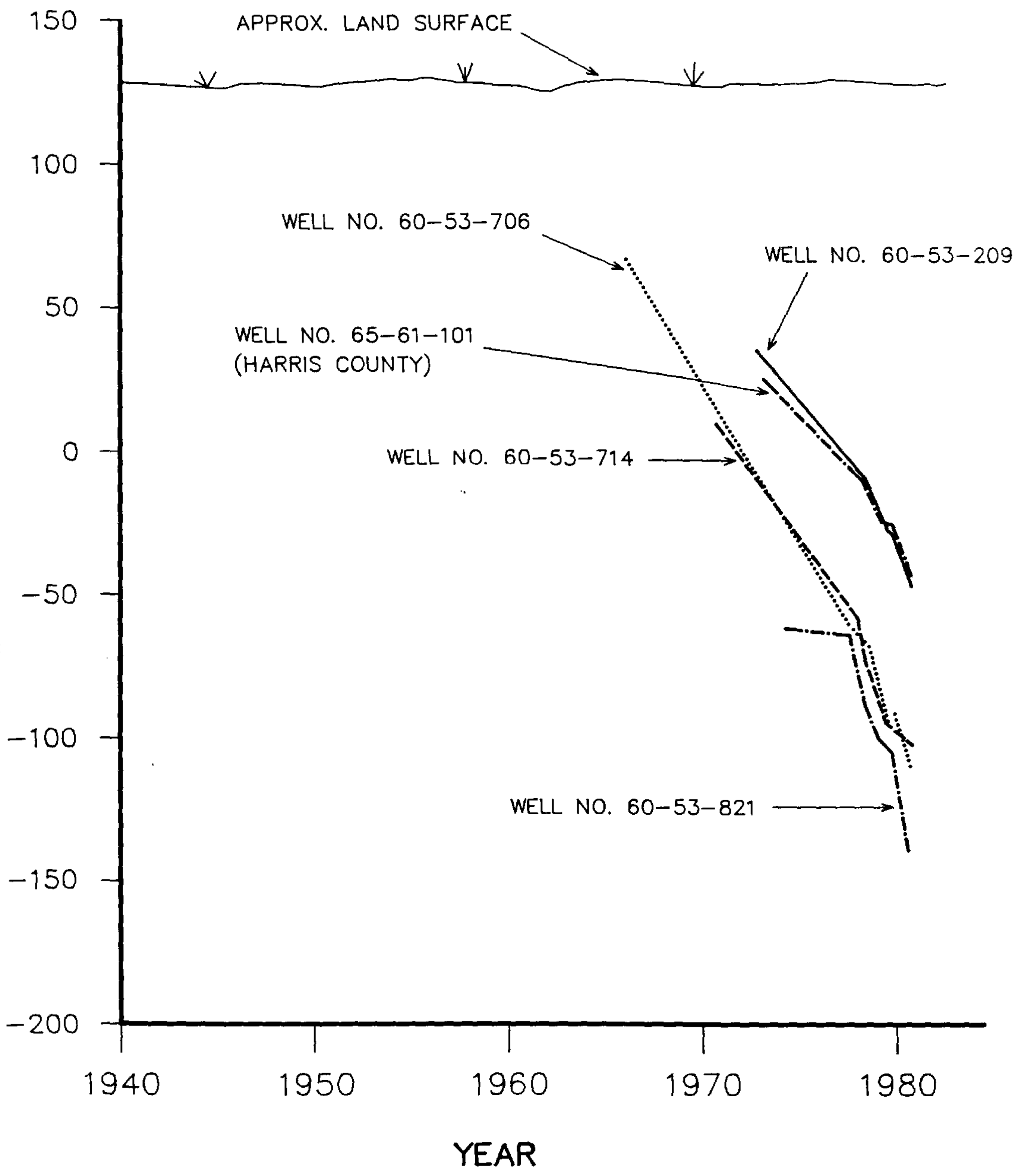
EVANGELINE WELL LEVEL DECLINES IN NORTH HARRIS COUNTY

PATE ENGINEERS, INC.
P.O. BOX 924024 HOUSTON, TX 77292 - 4024
PHONE 713 - 462 - 3178

EXHIBIT NO. 7

DATE: MAY, 1988

JOB NO.: 324-2-2



SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

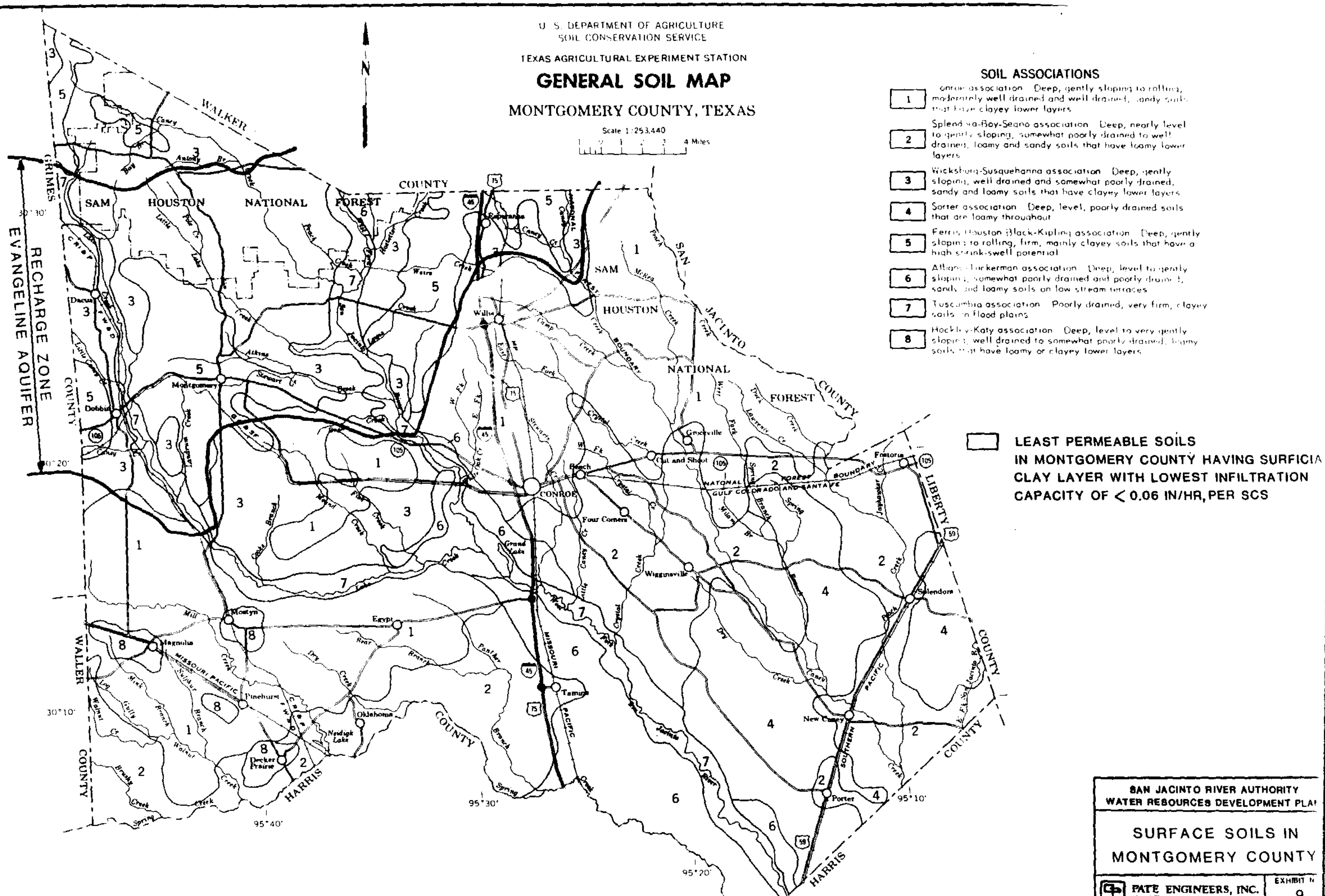
EVANGELINE WELL LEVEL DECLINES IN SOUTH MONTGOMERY COUNTY

PATE ENGINEERS, INC.
P.O. BOX 824024 HOUSTON, TX 77282 - 4024
PHONE 713 - 482 - 3178

EXHIBIT NO. 8

DATE: MAY, 1988

JOB NO.: 324-2-2



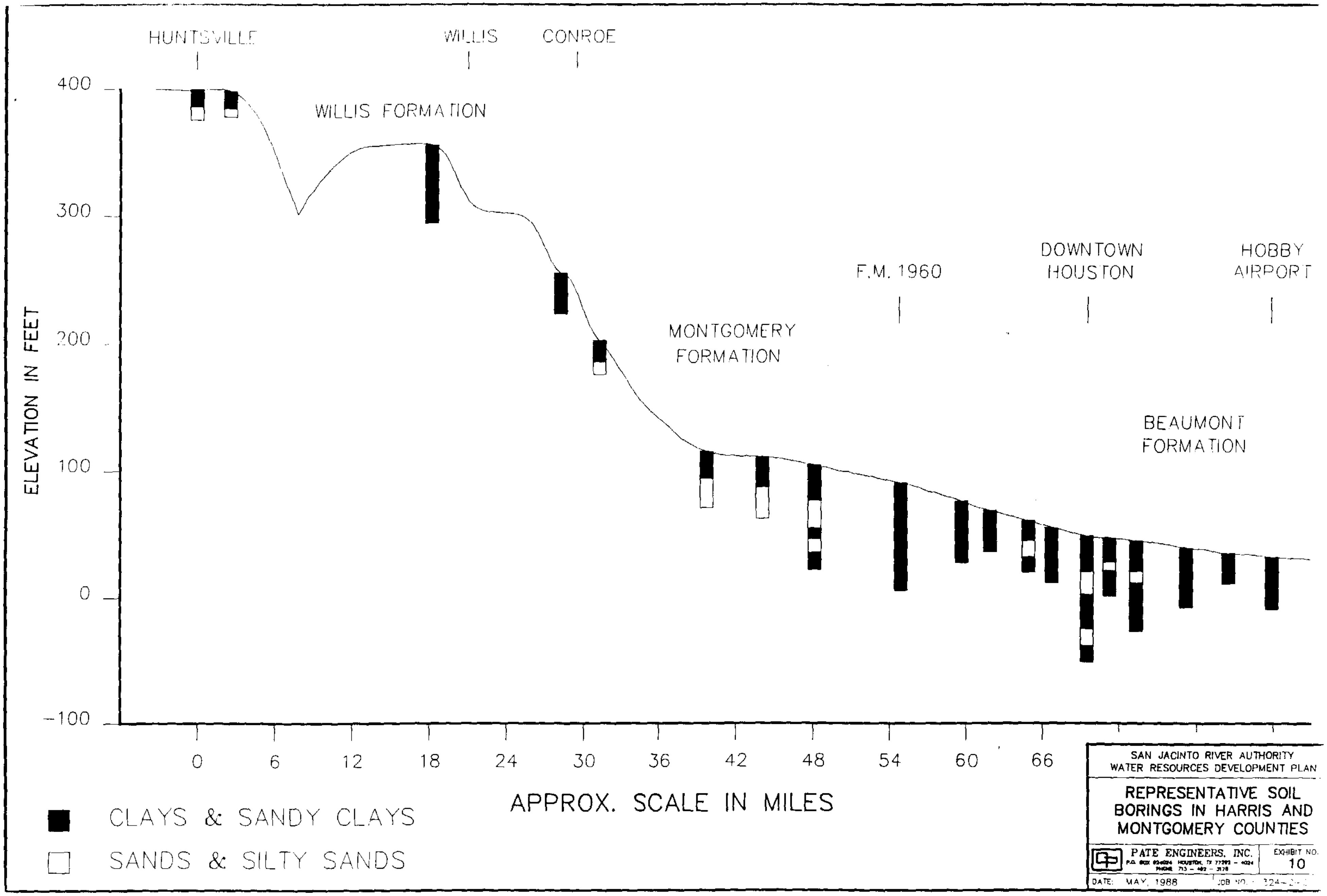
SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLA

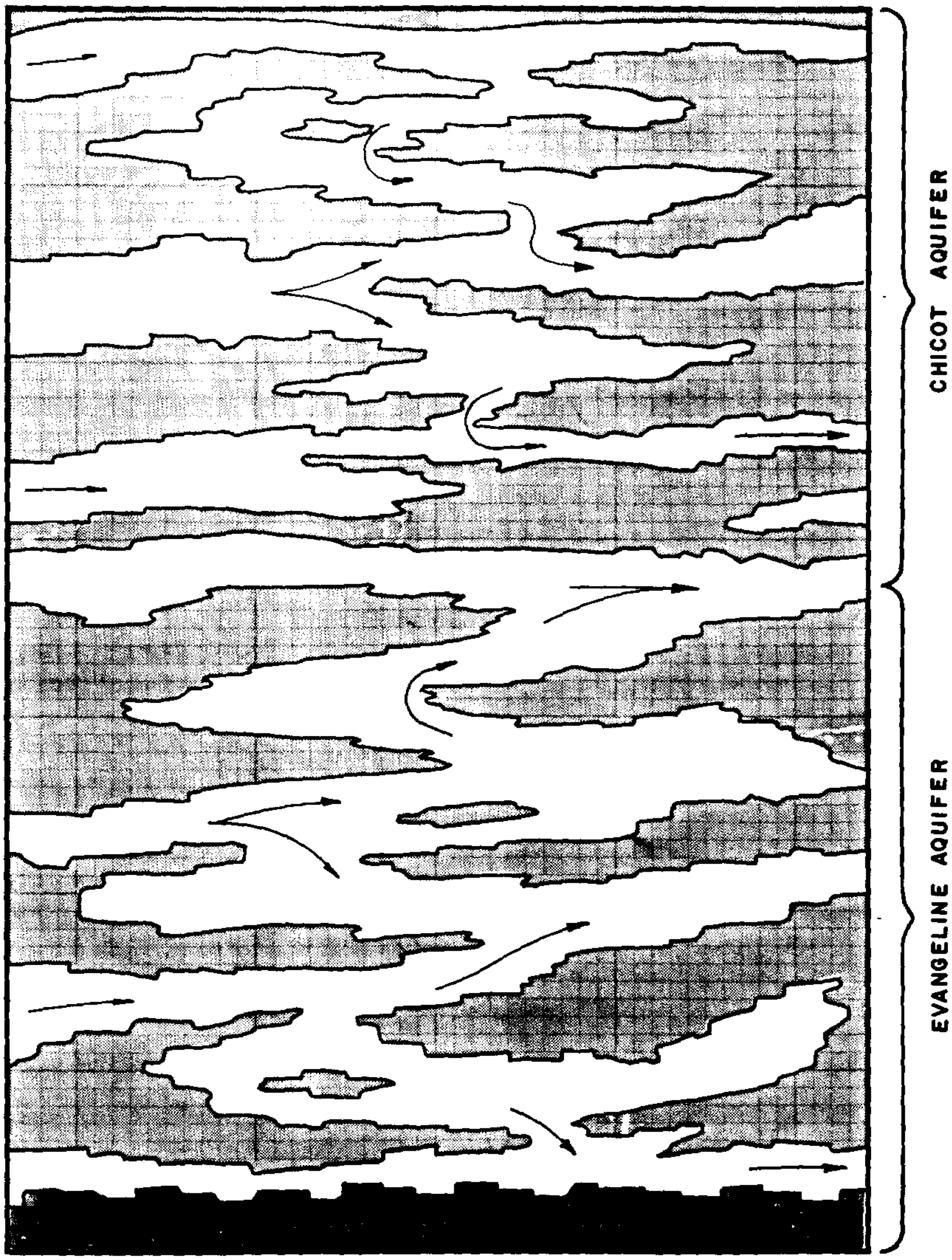
SURFACE SOILS IN
MONTGOMERY COUNTY

PATE ENGINEERS, INC.

EXHIBIT N
9

DATE: MAY, 1988 | JOB No.: 324-2


HUNTSVILLE
WILLIS
CONROE
WILLIS FORMATION
F.M. 1960
DOWNTOWN HOUSTON
HOBBY AIRPORT
MONTGOMERY FORMATION
BEAUMONT FORMATION
ELEVATION IN FEET
400
300
200
100
0
-100
0
6
12
18
24
30
36
42
48
54
60
66
APPROX. SCALE IN MILES
CLAYS & SANDY CLAYS
SANDS & SILTY SANDS
SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN
REPRESENTATIVE SOIL BORINGS IN HARRIS AND MONTGOMERY COUNTIES
PATE ENGINEERS, INC.
EXHIBIT NO. 10
DATE: MAY, 1988



LEGEND

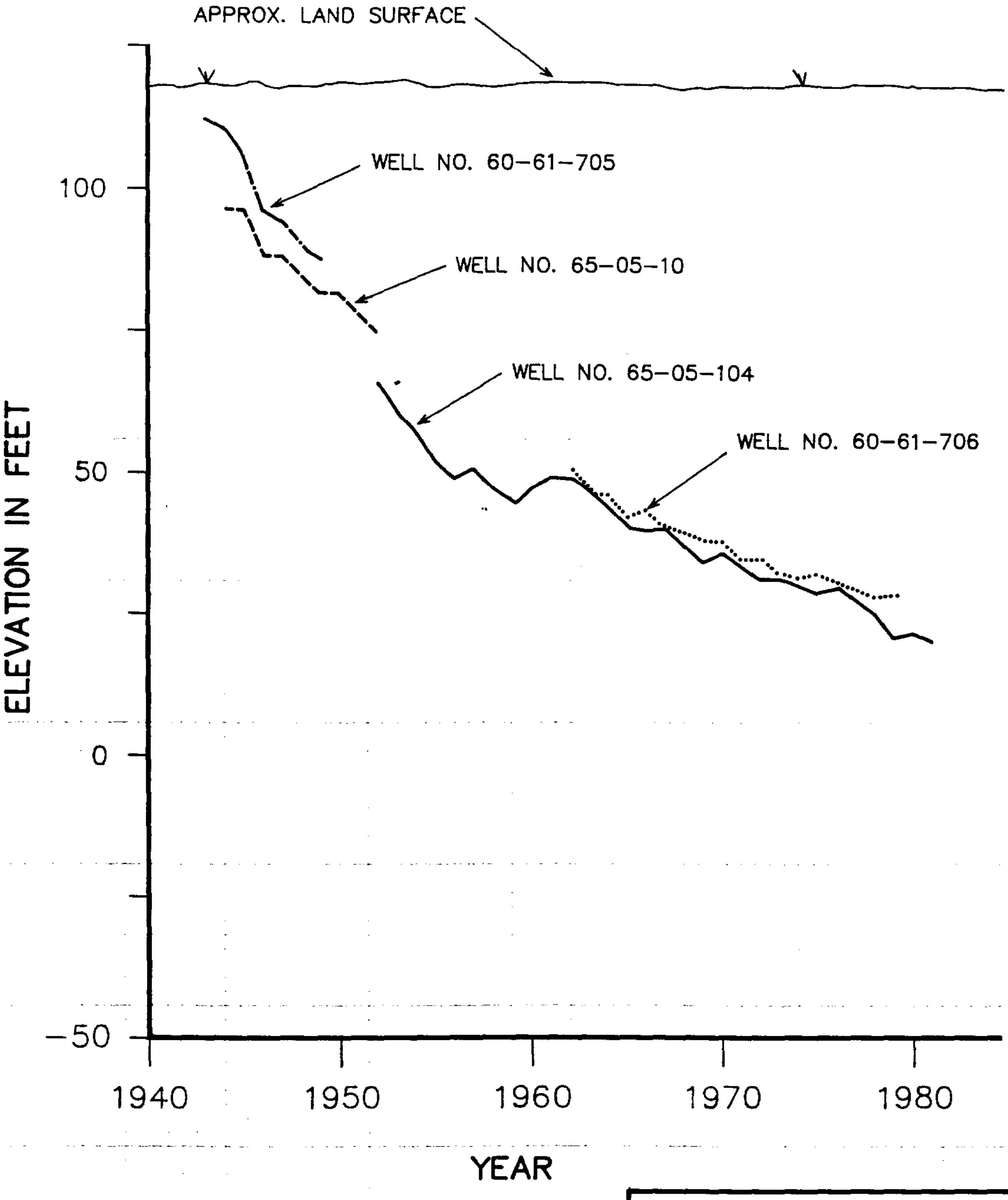
SANDS

CLAYS

GROUNDWATER FLOW DOWNDIP

ADAPTED FROM "A DIGITAL MODEL FOR SIMULATION OF GROUNDWATER HYDROLOGY IN THE HOUSTON AREA, TEXAS" TEXAS DEPT. OF WATER RESOURCES, 1979.

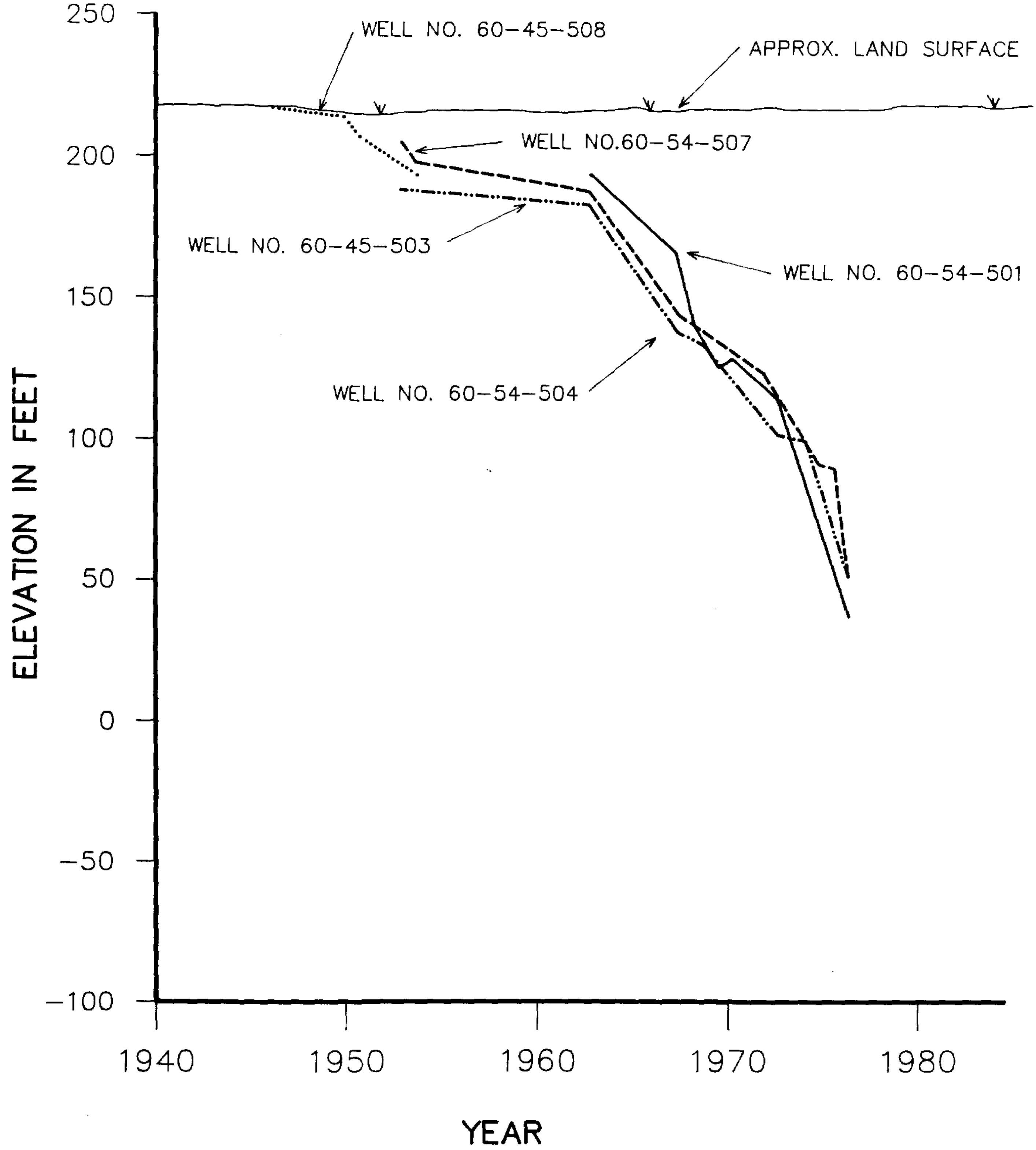
SAN JACINTO RIVER AUTHORITY WATER RESOURCES DEVELOPMENT PLAN	
GENERALIZED AQUIFER STRATIGRAPHY	
PATE ENGINEERS, INC.	EXHIBIT No. 11
DATE: MAY, 1986	JOB No.: 324-2-2



SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

WELL LEVEL DECLINES IN CHICOT RECHARGE ZONE IN NORTH HARRIS COUNTY

PATE ENGINEERS, INC. P.O. BOX 924084 HOUSTON, TX 77292 - 4084 PHONE 713 - 462 - 3178	EXHIBIT NO. 12
DATE: MAY, 1988	JOB NO. : 324-2-2



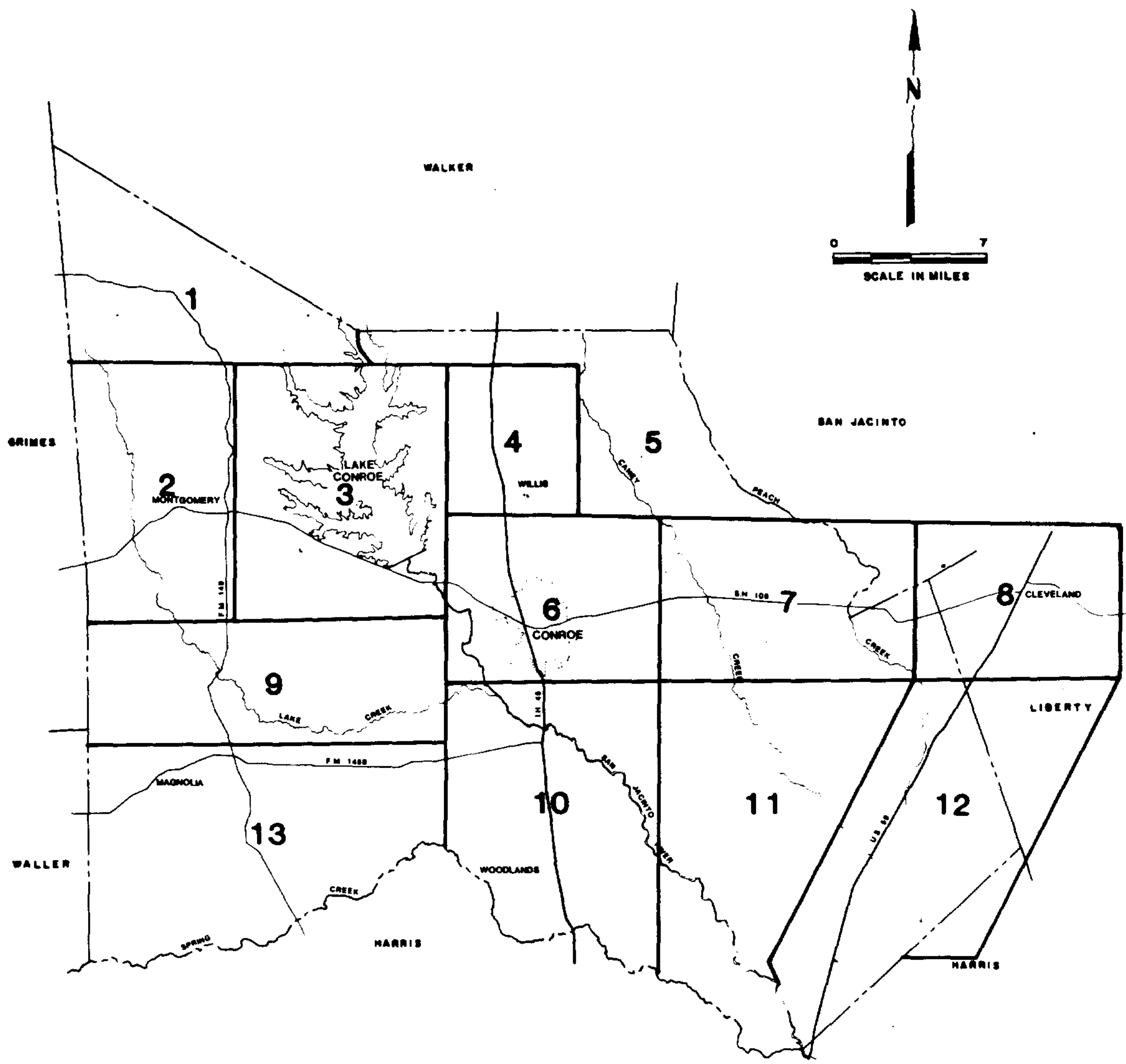
SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

JASPER WELL LEVEL DECLINES IN CONROE AREA

PATE ENGINEERS, INC.
P.O. BOX 924024 HOUSTON, TX 77292 - 4024
PHONE 713 - 462 - 3178

EXHIBIT NO. 13

DATE: MAY, 1988 | JOB NO. : 324-2-2



SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

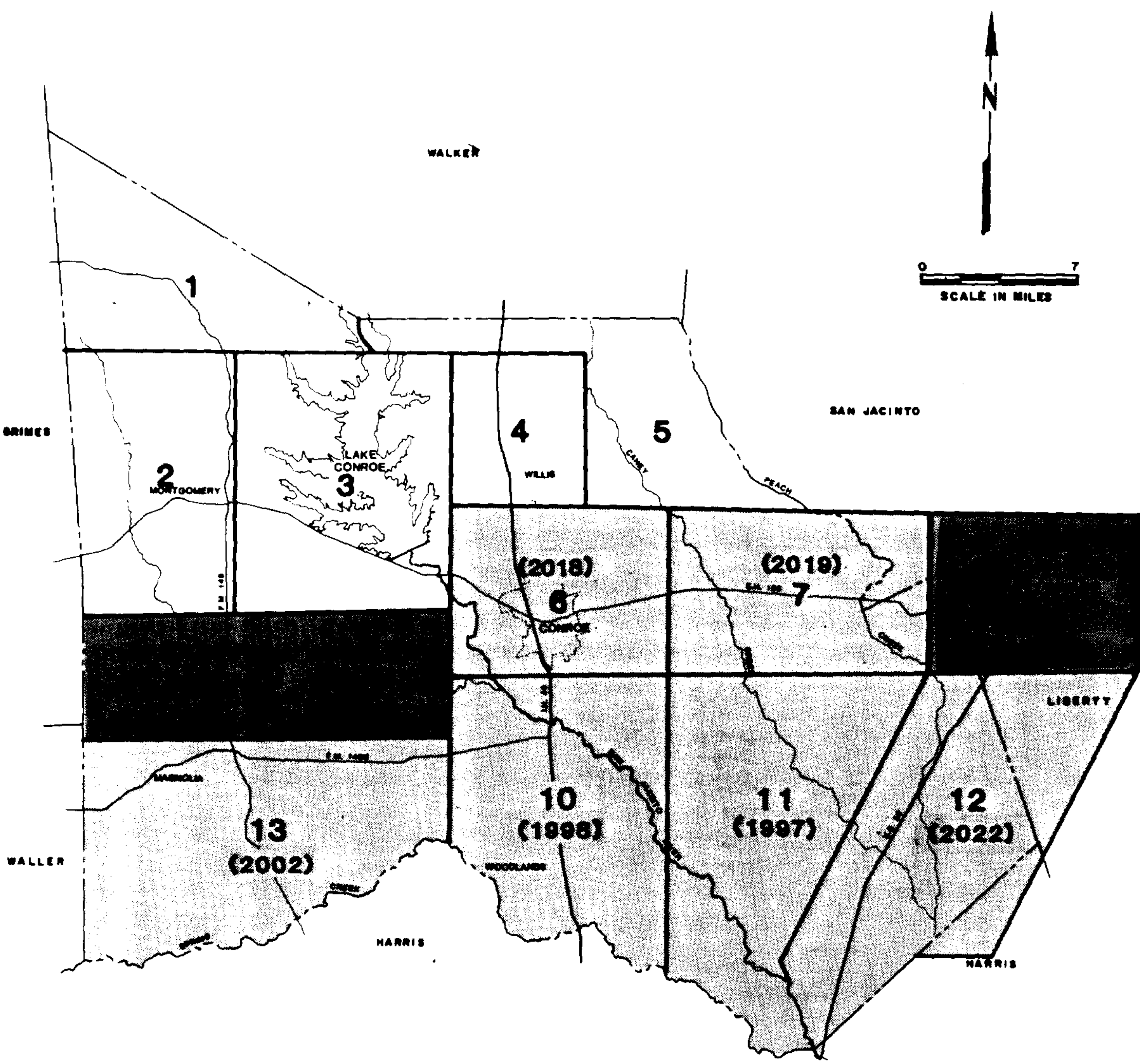
SECTOR LAYOUT FOR HYDROLOGIC MODEL

PATE ENGINEERS, INC.

EXHIBIT No. 14

DATE: MAY, 1988

JOB No.: 324-2-2



LEGEND

GROUNDWATER BREAKEVEN AT 2030

GROUNDWATER SHORTFALL PRIOR TO 2030

SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

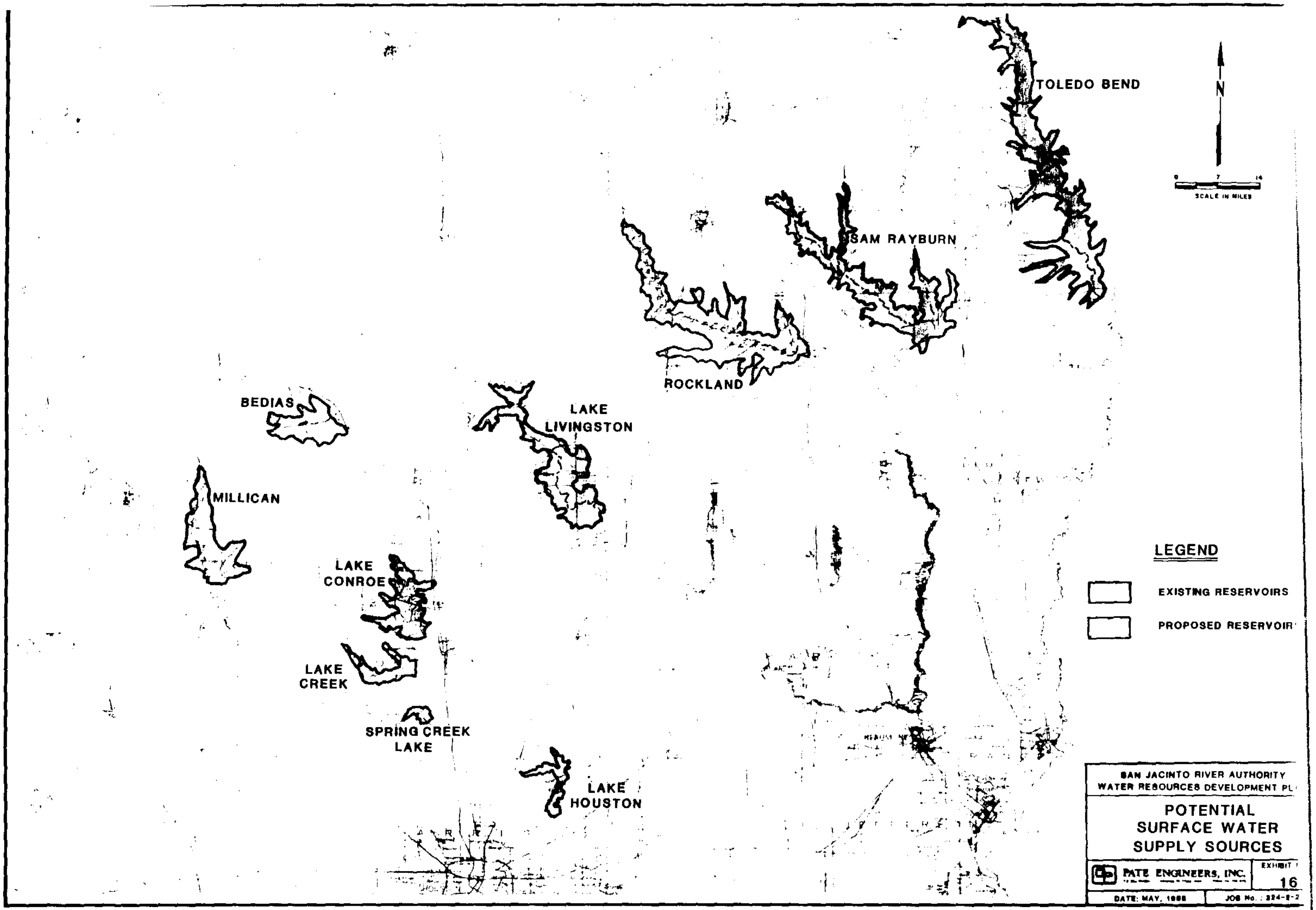
PROJECTED GROUNDWATER SHORTFALL BY SECTOR

PATE ENGINEERS, INC.

EXHIBIT No. 15

DATE: MAY, 1988

JOB No.: 324-2-2.


TOLEDO BEND
N
SCALE IN MILES
SAM RAYBURN
ROCKLAND
BEDIAS
LAKE LIVINGSTON
MILLICAN
LAKE CONROE
LAKE CREEK
SPRING CREEK LAKE
LAKE HOUSTON
LEGEND
EXISTING RESERVOIRS
PROPOSED RESERVOIR
SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PL
POTENTIAL SURFACE WATER SUPPLY SOURCES
PATE ENGINEERS, INC.
EXHIBIT
16
DATE: MAY,
JOB No.:

SJRA WATER SUPPLY DEVELOPMENT PLAN - BASE SCENARIO
65.2 MGD LAKE CREEK IN 2010
6.7 MGD SPRING CREEK LAKE, 20 MGD LAKE CONROE

2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)
1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21																
0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28											
0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47						
3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68						
8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	
								0.12	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
													0.12	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96									
1.16	8.79	8.79	8.79	8.79	8.79	8.79	8.79	8.79	8.79	8.79	8.79	8.79	8.79	8.79	8.79	8.79	8.79	8.79	8.79	8.79	8.79	8.79	8.79
								1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
													5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97
																		11.17	11.17	11.17	11.17	11.17	11.17
																							8.31
5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59												
0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89							
		0.97	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27
							0.61	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32
												0.44	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41
																	0.61	3.32	3.32	3.32	3.32	3.32	3.32
																						0.28	1.51
22.65	30.29	31.26	35.56	35.56	35.56	35.56	36.17	38.87	39.41	39.41	39.41	34.27	42.04	42.56	41.60	41.60	41.32	51.05	51.05	51.05	51.05	51.33	52.45
1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68
3.67	3.67	3.67	6.82	6.82	6.82	6.82	6.82	8.54	8.54	8.54	8.54	8.54	9.85	9.85	9.85	9.85	9.85	11.54	11.54	11.54	11.54	11.54	12.43
66.00	68.50	71.00	73.40	76.30	79.20	82.10	85.00	87.90	90.80	93.70	96.60	99.50	102.40	105.00	107.60	110.20	112.80	115.50	118.10	120.70	123.30	125.90	128.50
1.16	1.43	1.41	1.64	1.58	1.52	1.47	1.44	1.53	1.50	1.45	1.41	1.22	1.43	1.41	1.35	1.32	1.28	1.52	1.49	1.46	1.43	1.40	1.42
14.64	17.96	17.80	20.72	19.93	19.20	18.53	18.14	19.28	18.87	18.28	17.74	15.43	18.06	17.78	17.05	16.64	16.17	19.21	18.79	18.38	17.99	17.70	17.88
			44					44					36					29					23

SJRA WATER SUPPLY DEVELOPMENT PLAN - BASE SCENARIO
65.2 MGD LAKE CREEK IN 2010
6.7 MGD SPRING CREEK LAKE, 20 MGD LAKE CONROE

2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054
($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)
0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66															
0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64										
8.79	8.79	8.79	8.79	8.79	8.79																		
1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08										
5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97					
11.17	11.17	11.17	11.17	11.17	11.17	11.17	11.17	11.17	11.17	11.17	11.17	11.17	11.17	11.17	11.17	11.17	11.17	11.17	11.17	11.17	11.17	11.17	11.17
8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31
5.27	5.27	5.27																					
3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32																
2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41											
3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32						
1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	
52.45	52.45	52.45	47.17	47.17	47.17	38.38	38.38	35.06	34.40	34.40	34.40	34.40	31.99	30.27	30.27	30.27	30.27	26.96	20.99	20.99	20.99	20.99	19.47
1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68
12.43	12.43	12.43	12.43	12.43	12.43	12.43	12.43	12.43	12.43	12.43	12.43	12.43	12.43	12.43	12.43	12.43	12.43	12.43	12.43	12.43	12.43	12.43	12.43
128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50
1.42	1.42	1.42	1.31	1.31	1.31	1.12	1.12	1.05	1.03	1.03	1.03	1.03	0.98	0.95	0.95	0.95	0.95	0.88	0.75	0.75	0.75	0.75	0.72
17.88	17.88	17.88	16.46	16.46	16.46	14.10	14.10	13.21	13.03	13.03	13.03	13.03	12.38	11.92	11.92	11.92	11.92	11.03	9.43	9.43	9.43	9.43	9.02
				21					16					11					6				

SJRA WATER SUPPLY DEVELOPMENT PLAN - IMPORT SCENARIO
86.2 MGD TOLEDO BEND IN 2020 - NORTHERN ALIGNMENT
6.7 MGD SPRING CREEK LAKE, 20 MGD LAKE CONROE

* 10% NON-CC
** TOLEDO BEND CONVEYANCE FINANCING ASSUMES PARTIAL CARRY BY TWDB FROM 2010-2020
WITH 7% INTEREST AND 3% NON-CC ON DEFERRED AMOUNTS

324-2-2 DLA/LCL UPDATED 12-May-88

AMORTIZED COSTS (7% for 25 years // Reservoirs at 7% for 30 years)
(less one year capitalized interest in first year)

CAPITAL ITEMS	1987 $s ($M)	YEAR OF CONSTR	YEAR OF CONSTR $s (@ 0%)	YEAR OF CONSTR BOND AMOUNT (12% NON-CC)	1990 ($M)	1991 ($M)	1992 ($M)	1993 ($M)	1994 ($M)	1995 ($M)	1996 ($M)	1997 ($M)	1998 ($M)	1999 ($M)	2000 ($M)	2001 ($M)	2002 ($M)	2003 ($M)	2004 ($M)	2005 ($M)	2006 ($M)
IN-SECTOR WELLS																					
PHASE 1	12.4	1990	12.4	14.1	0.22	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21
PHASE 2	2.9	1995	2.9	3.3						0.05	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
PHASE 3	4.8	2000	4.8	5.5											0.09	0.47	0.47	0.47	0.47	0.47	0.47
REMOTE WELLS																					
PHASE 1	37.8	2000	37.8	43.0											0.68	3.69	3.69	3.69	3.69	3.69	3.69
PHASE 2	82.6	2005	82.6	93.9																1.48	8.05
PHASE 3	67.3	2010	67.3	76.5																	
PHASE 4	17.7	2015	17.7	20.1																	
PHASE 5	12.8	2020	12.8	14.5																	
RESERVOIRS																					
SPRING CREEK	10.5	1992	10.5	11.9			0.13	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
TOLEDO BEND	211.0	2017	105.5	119.9 *																	
		2030	105.5	262.1 **																	
SURFACE WATER PLANT (peak flow)																					
PHASE 1 (37.1)	57.4	1994	57.4	65.2					1.03	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60
PHASE 2 (5.9)	9.2	1999	9.2	10.5										0.17	0.90	0.90	0.90	0.90	0.90	0.90	0.90
PHASE 3 (69.0)	106.7	2019	106.7	121.3																	
PHASE 4 (69.0)	106.7	2029	106.7	121.3																	
CAPITAL COST	739.8		739.8	982.9	0.22	1.21	1.34	2.17	3.20	7.82	8.05	8.05	8.05	8.22	9.71	13.10	13.10	13.10	13.10	14.58	21.15
RAW WATER COST																					
CONROE ($0.23/1000 GALLONS)										1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68
TOLEDO BEND ($0.08/1000 GALLONS)																					
O & M					0.00	0.00	0.00	0.00	0.00	2.58	2.58	2.58	2.58	2.58	3.46	3.46	3.46	3.46	3.46	3.67	3.67
TOTAL DEMANDS SECTORS 6-13 (MGD)					33.20	34.80	36.30	37.90	39.50	41.00	42.60	44.20	45.80	47.30	48.90	51.30	53.80	56.20	58.70	61.10	63.60
COST/1000 Gallons ($s)					0.02	0.10	0.10	0.16	0.22	0.81	0.79	0.76	0.74	0.72	0.83	0.97	0.93	0.89	0.85	0.89	1.14
MONTHLY COST/ESFC (12,600 gal/mo)					0.23	1.20	1.27	1.98	2.80	10.17	9.97	9.61	9.28	9.10	10.49	12.28	11.71	11.21	10.73	11.26	14.38
YEARS OF GROUNDWATER PUMPAGE REMAINING AT CONSTANT DEMAND					86					65					102					64	

SJRA WATER SUPPLY DEVELOPMENT PLAN - IMPORT SCENARIO
86.2 MGD TOLEDO BEND IN 2020 - NORTHERN ALIGNMENT
6.7 MGD SPRING CREEK LAKE, 20 MGD LAKE CONROE

2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)
1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21																
0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28											
0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47						
3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69						
8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	
			1.21	6.56	6.56	6.56	6.56	6.56	6.56	6.56	6.56	6.56	6.56	6.56	6.56	6.56	6.56	6.56	6.56	6.56	6.56	6.56	6.56
								0.32	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73
													0.23	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96									
										1.27	9.66	9.66	9.66	9.66	9.66	9.66	9.66	9.66	9.66	9.66	9.66	9.66	9.66
																							21.13
5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60												
0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90							
												1.92	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40
																						1.92	10.40
21.15	21.15	21.15	22.36	27.72	27.72	27.72	27.72	26.82	28.23	29.50	37.90	34.21	42.65	43.67	42.71	42.71	41.81	37.66	37.66	37.66	37.66	39.57	61.13
1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68
													1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	2.52
3.67	3.67	3.67	3.83	3.83	3.83	3.83	3.83	3.99	3.99	3.99	3.99	3.99	14.28	14.28	14.28	14.28	14.28	14.43	14.43	14.43	14.43	14.43	24.58
66.00	68.50	71.00	73.40	76.30	79.20	82.10	85.00	87.90	90.80	93.70	96.60	99.50	102.40	105.00	107.60	110.20	112.80	115.50	118.10	120.70	123.30	125.90	128.50
1.10	1.06	1.02	1.04	1.19	1.15	1.11	1.07	1.01	1.02	1.03	1.24	1.10	1.60	1.59	1.53	1.49	1.43	1.31	1.28	1.25	1.22	1.24	1.92
13.86	13.36	12.89	13.11	15.03	14.48	13.97	13.49	12.76	12.89	12.96	15.57	13.84	20.18	20.02	19.23	18.77	18.06	16.44	16.08	15.74	15.40	15.61	24.15
			44					29					19					23					14

SJRA WATER SUPPLY DEVELOPMENT PLAN - IMPORT SCENARIO
86.2 MGD TOLEDO BEND IN 2020 - NORTHERN ALIGNMENT
6.7 MGD SPRING CREEK LAKE, 20 MGD LAKE CONROE

2031 ($M)	2032 ($M)	2033 ($M)	2034 ($M)	2035 ($M)	2036 ($M)	2037 ($M)	2038 ($M)	2039 ($M)	2040 ($M)	2041 ($M)	2042 ($M)
6.56	6.56	6.56	6.56								
1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73			
1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
9.66	9.66	9.66	9.66	9.66	9.66	9.66	9.66	9.66	9.66	9.66	1.27
21.13	21.13	21.13	21.13	21.13	21.13	21.13	21.13	21.13	21.13	21.13	21.13
10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40
10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40
61.13	61.13	61.13	61.13	54.57	54.57	54.57	54.57	54.57	52.84	52.84	44.45
1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68
2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52
24.58	24.58	24.58	24.58	24.58	24.58	24.58	24.58	24.58	24.58	24.58	24.58
128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50
1.92	1.92	1.92	1.92	1.78	1.78	1.78	1.78	1.78	1.74	1.74	1.56
24.15	24.15	24.15	24.15	22.39	22.39	22.39	22.39	22.39	21.93	21.93	19.67
				27					22		

2043 ($M)	2044 ($M)	2045 ($M)	2046 ($M)	2047 ($M)	2048 ($M)	2049 ($M)	2050 ($M)	2051 ($M)	2052 ($M)	2053 ($M)	2054 ($M)
1.25	1.25										
9.66	9.66	9.66	9.66								
21.13	21.13	21.13	21.13	21.13	21.13	21.13	21.13	21.13	21.13	21.13	21.13
10.40											
10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	
52.84	42.44	41.19	41.19	31.53	31.53	31.53	31.53	31.53	31.53	31.53	21.13
1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68
2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52
24.58	24.58	24.58	24.58	24.58	24.58	24.58	24.58	24.58	24.58	24.58	24.58
128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50
1.74	1.52	1.49	1.49	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.06
21.93	19.13	18.80	18.80	16.20	16.20	16.20	16.20	16.20	16.20	16.20	13.41
		17					12				

SJRA WATER SUPPLY DEVELOPMENT PLAN - IMPORT VARIATION
65.2 MGD TOLEDO BEND IN 2010 - NORTHERN ALIGNMENT
6.7 MGD SPRING CREEK LAKE, 20 MGD LAKE CONROE

* 10% NON-CC
** TOLEDO BEND CONVEYANCE ASSUMES PARTIAL CARRY BY TWDB FROM 2007-2020
WITH 7% INTEREST AND 3% NON-CC ON DEFERRED AMOUNTS

324-2-2 DLA/LCL UPDATED 12-May-88

AMORTIZED COSTS (7% for 25 years // Reservoirs at 7% for 30 years)
(less one year capitalized interest in first year)

CAPITAL ITEMS	1987 $s	YEAR OF CONSTR	YEAR OF CONSTR $s	YEAR OF CONSTR BOND AMOUNT	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
	($M)		(@ 0%)	(12% NON-CC)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)
IN-SECTOR WELLS																					
PHASE 1	12.4	1990	12.4	14.1	0.22	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21
PHASE 2	2.9	1995	2.9	3.3						0.05	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
PHASE 3	4.8	2000	4.8	5.5											0.09	0.47	0.47	0.47	0.47	0.47	0.47
REMOTE WELLS																					
PHASE 1	37.7	2000	37.7	42.8											0.68	3.68	3.68	3.68	3.68	3.68	3.68
PHASE 2	86.4	2005	86.4	98.2																1.55	8.42
PHASE 3	6.8	2015	6.8	7.7																	
PHASE 4	6.6	2020	6.6	7.5																	
RESERVOIRS																					
SPRING CREEK	10.5	1992	10.5	11.9			0.13	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
TOLEDO BEND	188.1	2007	94.1	104.5 *																	
		2015	7.2	12.8 **																	
		2020	28.5	70.8 **																	
		2025	38.1	132.6 **																	
		2030	20.2	98.7 **																	
SURFACE WATER PLANT (peak flow)																					
PHASE 1 (37.1)	57.3	1994	57.3	65.1					1.03	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59
PHASE 2 (5.9)	9.1	1999	9.1	10.3										0.16	0.89	0.89	0.89	0.89	0.89	0.89	0.89
PHASE 3 (35.0)	54.1	2009	54.1	61.5																	
PHASE 4 (22.0)	34.0	2014	34.0	38.6																	
PHASE 5 (16.0)	24.7	2019	24.7	28.1																	
PHASE 6 (22.0)	34.0	2024	34.0	38.6																	
PHASE 7 (10.0)	15.5	2029	15.5	17.6																	
CAPITAL COST	584.9		584.8	870.3	0.22	1.21	1.34	2.17	3.20	7.81	8.04	8.04	8.04	8.20	9.69	13.07	13.07	13.07	13.07	14.62	21.50
RAW WATER COST																					
CONROE ($0.23/1000 GALLONS)										1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68
TOLEDO BEND ($0.08/1000 GALLONS)																					
O & M					0	0	0	0	0	2.6	2.6	2.6	2.6	2.6	3.5	3.5	3.5	3.5	3.5	3.7	3.7
TOTAL DEMANDS SECTORS 6-13 (MGD)					33.20	34.80	36.30	37.90	39.50	41.00	42.60	44.20	45.80	47.30	48.90	51.30	53.80	56.20	58.70	61.10	63.60
COST/1000 Gallons ($s)					0.02	0.10	0.10	0.16	0.22	0.81	0.79	0.76	0.74	0.72	0.83	0.97	0.93	0.89	0.85	0.90	1.16
MONTHLY COST/ESFC (12,600 gal/mo)					0.23	1.20	1.27	1.98	2.80	10.16	9.97	9.61	9.27	9.10	10.47	12.26	11.69	11.19	10.71	11.28	14.57
YEARS OF GROUNDWATER PUMPAGE REMAINING AT CONSTANT DEMAND					86					65					102					64	

SJRA WATER SUPPLY DEVELOPMENT PLAN - IMPORT VARIATION
65.2 MGD TOLEDO BEND IN 2010 - NORTHERN ALIGNMENT
6.7 MGD SPRING CREEK LAKE, 20 MGD LAKE CONROE

2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)
1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21																
0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28											
0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47						
3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68						
8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	
								0.12	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
													0.12	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96									
1.11	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42
								1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
													5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71
																		10.69	10.69	10.69	10.69	10.69	10.69
																							7.96
5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59												
0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89							
		0.97	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27
							0.61	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32
												0.44	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41
																	0.61	3.32	3.32	3.32	3.32	3.32	3.32
																						0.28	1.51
22.60	29.92	30.89	35.19	35.19	35.19	35.19	35.80	38.45	38.99	38.99	38.99	33.85	41.35	41.88	40.92	40.92	40.64	49.89	49.89	49.89	49.89	50.17	50.93
1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68
			0.63	0.63	0.63	0.63	0.63	1.02	1.02	1.02	1.02	1.02	1.31	1.31	1.31	1.31	1.31	1.70	1.70	1.70	1.70	1.70	1.90
3.7	3.7	3.7	9.9	9.9	9.9	9.9	9.9	14.2	14.2	14.2	14.2	14.2	16.3	16.3	16.3	16.3	16.3	19.2	19.2	19.2	19.2	19.2	20.8
66.00	68.50	71.00	73.40	76.30	79.20	82.10	85.00	87.90	90.80	93.70	96.60	99.50	102.40	105.00	107.60	110.20	112.80	115.50	118.10	120.70	123.30	125.90	128.50
1.16	1.41	1.40	1.77	1.70	1.64	1.58	1.55	1.73	1.69	1.63	1.59	1.40	1.62	1.60	1.53	1.50	1.46	1.72	1.68	1.64	1.61	1.58	1.61
14.62	17.77	17.62	22.28	21.43	20.65	19.92	19.49	21.74	21.25	20.59	19.97	17.61	20.45	20.11	19.32	18.86	18.34	21.65	21.18	20.72	20.28	19.94	20.23
			44					44					36					29					23

SJRA WATER SUPPLY DEVELOPMENT PLAN - IMPORT VARIATION
65.2 MGD TOLEDO BEND IN 2010 - NORTHERN ALIGNMENT
6.7 MGD SPRING CREEK LAKE, 20 MGD LAKE CONROE

2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)
0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66			
0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
8.42	8.42	8.42	8.42	8.42	8.42						
1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71
10.69	10.69	10.69	10.69	10.69	10.69	10.69	10.69	10.69	10.69	10.69	10.69
7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
5.27	5.27	5.27									
3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32				
2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41
3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32
1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51
50.93	50.93	50.93	45.66	45.66	45.66	37.24	37.24	33.92	33.26	33.26	33.26
1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68
1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8
128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50
1.61	1.61	1.61	1.49	1.49	1.49	1.31	1.31	1.24	1.23	1.23	1.23
20.23	20.23	20.23	18.81	18.81	18.81	16.55	16.55	15.66	15.48	15.48	15.48
				21					16		

2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054
($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)
0.64	0.64										
1.03	1.03										
5.71	5.71	5.71	5.71	5.71	5.71	5.71					
10.69	10.69	10.69	10.69	10.69	10.69	10.69	10.69	10.69	10.69	10.69	10.69
7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2.41											
3.32	3.32	3.32	3.32	3.32	3.32						
1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	
33.26	30.85	29.18	29.18	29.18	29.18	25.86	20.16	20.16	20.16	20.16	18.64
1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68
1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8
128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50	128.50
1.23	1.18	1.14	1.14	1.14	1.14	1.07	0.95	0.95	0.95	0.95	0.92
15.48	14.83	14.38	14.38	14.38	14.38	13.49	11.96	11.96	11.96	11.96	11.55
		11					6				

SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN
FLOOD CONTROL PLAN

PREPARED BY:

PATE ENGINEERS, INC.
WITH MATCHING FUNDS PROVIDED BY
THE TEXAS WATER DEVELOPMENT BOARD

JUNE 1988

SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN
FLOOD CONTROL PLAN

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LIST OF EXHIBITS

NO.	TITLE
1	SJRA Watershed Area and Facility Locations
2	Major Streams in Montgomery County
3	100-Year Floodplains in Montgomery County
4	Stewarts Creek Watershed
5	100-Year Floodplain for Full Development of Stewarts Creek Watershed
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SECTION I

INTRODUCTION

PURPOSE

The effective use of water resources is a growing concern of Texas citizens. In addition to a reliable water supply, protection from damaging flood waters is an essential prerequisite for economic growth and is a prime determinant of the type and quality of urban development. State policy has been re-shaped in recent years to place more emphasis on total water resource management. The Texas Water Plan adopted by the voters in 1985 not only revitalized State water financial assistance programs, but also broadened those programs to cover regional water, wastewater and flood control projects for growing urban areas. State policy was also changed to promote conservation of water resources through reuse and reduction of consumption.

The existing institutional framework within the State reserves authority for planning and implementing specific water resource projects to local units of government, including river authorities. In many instances, an existing river authority may be the only local entity capable of long-term planning and implementation to meet changing needs as urban growth occurs in previously rural areas. These changing local circumstances as well as policy changes at the State level represent a challenge to local government, particularly entities with regional scope such as river authorities, to provide for effective water resource management programs that meet the needs of local areas and that reflect current State water policy.

Responding to that challenge, the San Jacinto River Authority authorized this study to define a comprehensive water resources development plan. The purpose of the study is to define a plan that 1) addresses the water supply, water quality, and flood control needs of the rapidly urbanizing service area of the Authority; 2) provides guidance for implementing specific water resource projects within the service area; 3) examines the relationship of the Authority to the larger metropolitan region of which it is part and evaluates broader regional projects in which the Authority may play a productive role; and 4) is consistent with State policy.

AUTHORIZATION

This study was authorized by the San Jacinto River Authority by contract dated December 1, 1986. Matching funds were provided by the Texas Water Development Board.

SCOPE

The Water Resources Development Plan is presented in three volumes. Volume I presents the Water Supply Plan, Volume II presents the Flood Control Plan and Volume III presents the Water Quality Plan.

The scope of work of the Flood Control Plan addressed in this volume has been defined as follows:

- Identification of entities currently performing flood plain management within Montgomery County.

- Analysis of alternative flood plain management strategies for a typical major lateral channel system (Stewarts Creek).

- Review of Lake Conroe operation for determination of potential for flood control benefits.

- Development of a general flood plain management strategy for lateral channels in Montgomery County, using results of the analysis outlined in above items.

- Evaluation of the role of the San Jacinto River Authority in flood management in Montgomery County.

SAN JACINTO RIVER AUTHORITY: THE FIRST FIFTY YEARS

The San Jacinto River Authority was created by the Texas Legislature in 1937 and is one of 15 major river authorities in the State of Texas. Over the past fifty years, the Authority has implemented soil conservation, water supply, wastewater treatment, flood control, and recreation programs. The SJRA's watershed area includes all of Montgomery County and portions of Waller, Grimes, San Jacinto, and Liberty Counties and contains approximately 1,200 square miles. It is empowered to and does operate facilities both within and outside of these boundaries as shown on Exhibit No. 1. The SJRA first implemented its soil conservation and reclamation program in 1946 in cooperation with agencies of the U.S. Department of Agriculture. The Authority purchased heavy equipment and provided interim financing for the construction of improvements to prevent erosion, reduce flooding, and restore soil fertility. More than $1.5 million was invested in individual projects which included over 400 small lakes and stock tanks, 150 miles of field terracing, 75 miles of water diversion channels, and the leveling of hundreds of acres of gullied land in preparation for reforestation or pasture use.

The Authority's first water supply project was the purchase in 1945 of the Highlands Canal System serving industrial and agricultural customers in southeast Harris County with water supply contracts currently totaling 66.5 million gallons per day (MGD). The canal system facilities presently include a 100 MGD pump station at Lake Houston Dam, 38 miles of canal, and the 1,400 acre Highlands Reservoir. In 1970, the San Jacinto River Authority constructed Lake Conroe in conjunction with the City of Houston and the Texas Water Development Board. Located in northwest Montgomery County, the 22,000 acre Lake Conroe has a firm yield of 89.3 MGD. Although its primary purpose is water supply, it also provides recreation benefits.
In 1975, the Authority entered into contractual agreements with The Woodlands Corporation and the associated municipal utility districts (MUDs) whereby the Authority owns and operates the regional water supply and wastewater treatment facilities serving The Woodlands. The Authority acts as a wholesaler of water and wastewater services to the nine existing MUDs

encompassing 9,000 acres and an existing resident population of approximately 23,000. Currently, the regional water supply facilities include seven wells and two storage and pumping plants capable of producing 20 MGD at peak demand. The regional wastewater collection and treatment system has a total treatment capacity of 6.1 MGD in two plants. These water and wastewater facilities will be expanded to serve a projected population of approximately 140,000 people at ultimate development of The Woodlands.

In recent years, SJRA has continued to pursue regional planning to address the long-term needs of the basin. In 1982, the SJRA sponsored the Bureau of Reclamation's San Jacinto Project investigation which has resulted in the Bureau's preliminary recommendation for construction of the Lake Creek reservoir. The Bureau's study is on-going. In cooperation with the Texas Department of Water Resources, SJRA prepared a Water Quality Management Plan for the San Jacinto River Basin in 1982 and a San Jacinto Upper Watershed Drainage Improvement and Flood Control Planning Study in 1985. In 1986, the Authority commissioned a feasibility study of the purchase of water from Toledo Bend Reservoir and its conveyance to Lake Houston.

PLANNING EMPHASIS

Beginning in the early 1970's, population growth in Montgomery County accelerated to make it one of the fastest growing counties in the nation. The frequency and extent of flooding damages has increased with this growth. Much of the flooding has affected unrestricted development that was constructed within the existing floodplains of major streams. Therefore, mitigation of increased runoff due to new development to maintain the existing floodplain will not reduce these flooding damages. Reduction of the existing floodplain is necessary to decrease damages to the structures that were built within the existing floodplain. The magnitude of the flood flows in the major streams, particularly the West Fork, drive the construction cost of flood control improvements beyond the financial capability of individual developers or municipalities. Recent planning studies by the San Jacinto River Authority and the Army Corps of Engineers found structural solutions to the flooding along these major channels had extremely low benefit to cost ratios and thus no projects to date have been identified for implementation.

The majority of the urbanizing areas in Montgomery County drain to lateral channels located beyond the floodplains of the major streams. Development in these smaller watersheds produces a larger relative increase in flooding, and represents a major source of existing and potential future flood damages. The continued and significant urban growth projected for Montgomery County insures that these flooding problems will compound unless a plan is defined of how and what flood control improvements are to be implemented on the lateral systems in conjunction with development. The impact of a specific lateral on a major stream is of consideration though the contribution to the major stream peak discharge can be minimal.

The planning emphasis of this study is to develop an appropriate flood control strategy for the lateral channels in Montgomery County. A detailed analysis of engineering alternatives will be performed on a typical lateral watershed, selected to be Stewart's Creek. Implementation and management considerations of each alternative will be evaluated, including the potential role of the San Jacinto River Authority in the recommended plan.

SECTION II

BACKGROUND CONSIDERATIONS

GENERAL

With the rapid increase in urban development in Montgomery County in the 70's and 80's has come increased instances of flooding and increased public pressure to address this growing problem. The 68th Texas Legislature in 1983 authorized the creation of the Montgomery County Flood Control District over all of Montgomery County to be funded with a sales tax in response to this pressure, but the required confirmation election held in 1985 failed indicating a lack of countywide consensus concerning the problem.

This section of the report provides background information on the physical characteristics, current flooding conditions, previous studies, and current floodplain management in Montgomery County.

PHYSICAL CHARACTERISTICS

The San Jacinto River drains all of Montgomery County as illustrated in Exhibit No. 1, which outlines the upper watershed that also corresponds to the SJRA service area boundary. Portions of six major streams are located in Montgomery County: Spring Creek, Lake Creek, the West Fork of the San Jacinto River, Caney Creek, Peach Creek, and the East Fork of the San Jacinto River. The delineation of the major watersheds of these streams is shown on Exhibit No. 2.

These streams generally flow from the northwest to the southeast from the hilly terrain in north Montgomery County toward the flatter areas in the south and southeast. Natural ground elevations vary from approximately 400 feet above sea level in north and northwest Montgomery County to 80 feet above sea level in the southeast adjacent to the West Fork. Throughout the County, the natural ground elevation rises rather sharply from the various stream channels so that the channel side slopes are steep. As a result, increases in water surface elevations will in most instances result in small increases in the areal extent of the floodplain.

Most of the urban population in Montgomery County is concentrated along the Interstate 45 corridor from the south County line to the northern extent of the City of Conroe. Additional areas of concentration are west of Interstate 45 along the south County line, areas along the US Highway 59 corridor, and the development surrounding Lake Conroe. Ongoing and proposed transportation improvements including the Hardy Toll Road, US 59 Widening, and the FM 149 widening as well as east-west major thoroughfare projects will continue to attract significant population growth.

CURRENT FLOODING CONDITIONS

A review of available reports as well as discussions with public officials focuses attention primarily on south and southeast Montgomery County when identifying existing flooding problems. The vast majority of the structural flooding, i.e., flood levels affecting buildings, is a result of unrestricted development within the floodplain of the major drainage channels. Unless specific protective measures are taken (levees, floor elevations above floodplain elevations, etc.), the unrestricted development within a floodplain will be subject to damages regardless of the development's efforts to mitigate increases in run-off for its specific impact. The most notable example of construction within the floodplain was the Whispering Oaks development along the West Fork of the San Jacinto River just east of IH-45. Whispering Oaks was relocated by the Federal Emergency Management Agency (FEMA) because of constantly recurring flood damage claims and payouts. Though a number of other examples of recurring flooding are available which are not as severe as Whispering Oaks, funding for buy-out programs no longer exists.

The other type of flooding, which is currently less prevalent, occurs when development increases flood flows and improvements to the existing drainage systems do not sufficiently provide for the increased flows occurring as a result of the development. These developments when initiated were beyond the limits of the floodplain of any major drainage channel, but as development occurred without adequate outfall drainage facility improvements, flooding developed.

PREVIOUS STUDIES

Although a number of studies have been conducted concerning flooding in Montgomery County only two are discussed herein: the Flood Insurance Study, Montgomery County, Texas dated February 1, 1984 and published by the Federal Emergency Management Agency (FEMA) and the San Jacinto Upper Watershed Drainage Improvement and Flood Control Planning Study dated July, 1985 and published by the San Jacinto River Authority and the Texas Department of Water Resources (TDWR). Both were countywide studies rather than site specific evaluations.

FEMA Flood Insurance Study

Montgomery County and the incorporated cities in Montgomery County entered the Emergency Phase of the National Flood Insurance Program beginning in 1973. This early phase of the program was referred to as the emergency phase since no detailed studies were available to define flooding conditions in the area. In lieu of the detailed studies, approximate delineations were made to allow insurance to be provided to Montgomery County residents.

The detailed studies were funded by FEMA and resulted in the publication in February of 1984 of the Flood Insurance Study, Montgomery County, Texas. The study provided the first comprehensive evaluation of flooding in Montgomery County based on a detailed hydrologic and hydraulic evaluation of the numerous primary and lateral channels within the county. Detailed Flood Boundary and Floodway Maps followed and are now available delineating the 100-year floodplain, the 500-year floodplain and the 100-year floodway along all significant drainage channels. Exhibit No. 3 provides an approximate composite representation of the existing 100-year floodplain in Montgomery County based on the FEMA maps.

The detailed study was performed for FEMA by the Soil Conservation Service using SCS methodologies. Although these methodologies are accepted and reliable methods for the definition of floodplains, they have and will continue to present problems for on-going floodplain management since the currently accepted and widely used standards for hydrologic and hydraulic evaluations are the U.S. Corps of Engineers HEC-1 and HEC-2 computer programs. Most floodplain updates in Montgomery County first require a conversion of the SCS data, when available, to the U.S. Corps of Engineers HEC-1 and HEC-2 format and a resolution of model variations due to methodology differences. This conversion will also standardize the methodologies used within the area so that stream hydraulic modeling does not differ in the incorporated and unincorporated portions of the County.

<u>San Jacinto Upper Watershed Drainage Improvement and Flood Control Planning Study</u>

This study prepared in 1985 by the San Jacinto River Authority and the Texas Department of Water Resources addressed flood control improvements on the primary stream channels in the Upper San Jacinto River basin. These channels included the East and West Fork of the San Jacinto River, Spring Creek, Lake Creek, Caney Creek and Peach Creek. The purpose of the study was to evaluate alternative improvements to address existing flooding problems along the primary streams in the study area and recommend a plan of drainage improvements for each watershed to address the existing flooding problems. Various improvement options were analyzed for the primary channels and benefit/cost ratios were computed based on reducing damages to existing structures in the floodplain. The options were total channelization, selective channelization, channel desnagging, bridge modifications, property buyout, and flood control reservoir construction.

The results of this study indicate that although significant flood damages occur along these primary channels, the scattered nature of the areas of flood damage results in no cost effective solutions to totally eliminate existing flooding of structures along these channels. Table No. 1 presents a summary indicating how few of the total defined options produced a benefit cost ratio greater than 1.0. Cost effective solutions were identified when applied selectively such as floodplain structure buyout in specific areas or reservoir storage acquisition which would provide damage reduction but not elimination in selected areas.

CURRENT FLOODPLAIN MANAGEMENT

Current floodplain management in Montgomery County is provided by multiple entities. The County Engineer administers the Flood Insurance Program in the unincorporated areas of the County and each city within the County administers the Program within its corporate limits. The current participants in the National Flood Insurance Program are listed in Table No. 2. Capital improvements for drainage and flood control are handled similarly. Almost all capital improvements for drainage and flood control in Montgomery County are provided by municipal utility districts or cities for resolution of drainage and flood problems within the jurisdictional boundaries of that particular entity. Limited coordination occurs between these entities concerning floodplain management or capital improvements.

The recent entry of Montgomery County as well as the incorporated cities into the regular phase of the FIP requires the adoption of specific rules for floodplain management. Enforcement of these rules coupled with the detailed information provided by FEMA delineating existing floodplains will minimize the damage potential to new development projects occurring within the existing 100-year floodplain in Montgomery County. Additionally, Montgomery County has made significant revisions to its Subdivision Regulations to better address drainage and flooding issues with regard to new development.

Montgomery County has no defined capital improvement plan for flood control. The Montgomery County Water Supply Flood Control Corporation was created through the Commissioners Court of Montgomery County in 1987 to pursue the potential for Texas Water Development Board loan funds for flood control projects. Voter approval of the Texas Water Plan in November 1985 makes available loan funds previously not available at relatively low interest for flood control. At this time, the Montgomery County Water Supply Flood Control Corporation has not defined any projects for local or state funding.

The floodplain management functions in Montgomery County are provided in an independent manner. The County and the incorporated municipalities have accepted the regulatory responsibility through their participation in the Flood Insurance Program. Individual implementation projects are planned and constructed by separate entities including cities, utility districts, and the County. However, a comprehensive planning effort that establishes the guidelines and coordination of the individual regulatory and implementation functions has not been undertaken in Montgomery County. The San Jacinto River Authority has conducted regional analyses of the major streams in the County and their future role in the provision of these management functions will be discussed in this report.

SUMMARY

Flooding is a growing concern in Montgomery County, especially in the rapidly urbanizing central and south portions of the County. A significant portion of this flooding occurs along the primary drainage channels where subdivisions were constructed within the floodplain. The extensive floodplains and scattered nature of the existing flooding along these primary channels make solutions very costly. The recent study of alternative methods of solving this flooding sponsored by the SJRA and the TDWR indicate few cost effective solutions other than floodplain management.

The detailed data recently available through the National Flood Insurance Program as well as modifications in the County subdivision regulations provides the tools to prevent to a large degree future development within existing flood prone areas. However, as development continues, the increased runoff associated with development will result in changes to this existing floodplain delineation ultimately affecting areas outside this boundary. This effect will be more significant along the smaller lateral

channels than along the primary channels. No countywide flood control planning exists in Montgomery County to provide guidance to new development.

Establishment of planning, regulatory, and implementation guidelines in Montgomery County will be a long-term asset in the economic development and growth of the County. The development and adoption of a master drainage plan and coordinated regulation and implementation of projects will allow the County to address the floodplain issues in a pro-active manner by anticipating and systematically resolving floodplain problems. This coordinated planning/regulatory/implementation effort will enable the County to ultimately resolve its floodplain issues at a lower cost than the contrasting method of applying flood management solutions in highly developed areas after flood damages have occurred and public opinion is demanding immediate and extensive relief.

SECTION III

RESERVOIR OPERATIONS

Flood control along major river channels can be accomplished by providing flood control storage capacity, in addition to water supply storage capacity, in major reservoirs. Such flood control storage would function in the same manner as the regional stormwater detention ponds proposed in the lateral drainage system analysis discussed in Section IV. In both cases, the flood storage must remain empty or dry until needed during a storm event. The storage and subsequent controlled release of stormwaters reduces the downstream peak flow.

Reservoir flood control in Texas has generally been viewed as a federal responsibility. Practically all the existing flood control storage capacity in the state was constructed and is owned and operated by federal agencies. Reservoirs constructed by state and local agencies have not included storage capacity for flood control due to a lack of funding for flood control. The flood storage capacity proposed by the Bureau of Reclamation for the Lake Creek reservoir would be paid for solely by federal funds.

Most urban development in Montgomery County, and consequently most flooding damage to existing buildings and property, occurs along the West Fork in the I-45 corridor. Due to its upstream location on the West Fork, the issue of using Lake Conroe for flood control purposes is frequently raised. A review of the design basis for Lake Conroe indicates that the reservoir was designed and financed solely as a water supply and conservation reservoir with no flood control features. Debt incurred for construction of the Lake is being retired with revenue from water sales. Two-thirds of the storage capacity is owned by the City of Houston and one-third is owned by the San Jacinto River Authority. Existing water sales contracts prohibit the reallocation of conservation storage capacity (below the normal pool level of 201.0 feet) to flood control. Therefore, the remainder of this analysis focused on the use of storage above the conservation level for downstream flood control.

The design of Lake Conroe dam and outflow structure is based on passing a maximum probable flood inflow of 203,700 cubic feet per second (cfs) resulting from a 34.6 inch rainfall over the upstream watershed in a 48 hour period. Reservoir outflow is controlled by three tainter gates each with a maximum opening of 22 feet. The peak outflow from the dam for the maximum probable flood is 145,000 cfs with all gates fully open and a lake level rise of 4.5 feet from its normal level of 201.0 feet to maximum design water surface of 205.5 feet. The maximum design water surface of 205.5 feet is the critical condition for which the dam and appurtenant structures were designed. The structural integrity of the dam is threatened if flood waters rise above this level.

Previous studies have demonstrated that for storms of lesser magnitude than the maximum probable storm, an optimum release rule can be defined which provides flood peak attenuation to minimize downstream flooding. Different optimum release procedures would be defined for storms of different magnitudes. Utilization of storage above the conservation level of 201.1 feet for storms of lesser magnitude than the maximum probable amounts to borrowing from the emergency reserve with the assumption that it can be paid back prior to really needing it. However, in practice, this requires the ability to reliably predict future rainfall across the watershed, and failure to do so could threaten the integrity of the dam structure. Trying to minimize the effects of a smaller storm by using up a portion of the flood surcharge runs the risk of continued rainfall of even higher intensity producing a lake level above the maximum design water surface.

Consequently, the Authority's operating release policies are and should continue to be based on maintaining or attempting to maintain the conservation pool level of the Lake for all storm events. This procedure results in minimal flood peak attenuation for frequent storm events but maximizes the flood surcharge storage available for the maximum probable storm to protect the integrity of the structure and thus minimizes the potential for catastrophic loss of life and property consistent with the original design philosophy and Texas Water Commission permit.

SECTION IV

LATERAL DRAINAGE SYSTEM ANALYSIS

GENERAL

A primary result of land development is construction of drainage systems to direct rainwater away from buildings, houses, and streets to a point of outfall, shortening the time water ponds on the developed property as compared to pre-development conditions. Development also increases somewhat the volume of rainfall runoff since infiltration is reduced by the impervious cover of pavement and buildings. These effects combine to increase the peak rate of runoff. The internal drainage systems are designed to accommodate this increased rate of runoff. Increased runoff from these developments will also increase the peak flows and the flood elevations in the lateral drainage systems, and the resulting downstream impacts must be addressed by the regulatory authorities.

This section presents an analysis of alternatives to control the flood impacts of land development on a selected lateral drainage system in Montgomery County. Lateral or tributary streams collect runoff flowing overland, in open roadside ditches, and within an underground storm sewer system and convey those flows to a major stream. Although the lateral stream watersheds in the County are relatively undeveloped at this time, the potential for increased floodplain areas is significant as urban development continues. The increased potential for flooding on the laterals due to future development is a distinct problem from flooding on the main streams. Though the lateral channels do contribute to the main stream flows, improvements of conditions on the main stream will not provide for flood mitigation of the lateral channels to accommodate full development. Conversely, mitigation of flooding on any specific lateral will not significantly alter the discharges occurring on the main stream. This study presents an opportunity to institute a management plan which will address flood impacts on the lateral channels in affordable increments. Managing the flood impacts can prevent the accumulation of flooding problems with insurmountable remediation costs which would inhibit continued economic development. Therefore, this study addresses future development of a watershed and is not limited solely to mitigating existing flood damage problems.

Stewarts Creek was selected as a representative lateral stream for Montgomery County because of its average size, shape, and slope; mixed urban and rural land use; and potential for further development due to its proximity to the City of Conroe. Four alternative floodplain management strategies were developed for Stewarts Creek using detailed hydrologic and hydraulic analyses and assuming full development conditions in the watershed. The goal of these strategies is to address existing flood damage issues as a component of overall planning in the watershed for its ultimate development condition. As the damage mitigation goal for all alternatives is consistent, it is valid to compare these alternatives directly on cost and implementation aspects.

STEWARTS CREEK WATERSHED

The Stewarts Creek watershed encompasses approximately 19 square miles (12,160 acres) and stretches 14.5 miles in a north-south alignment from its headwaters north of Panorama Village to its confluence with the West Fork of the San Jacinto River near the River Plantation subdivision, as shown on Exhibit No. 4. The watershed is generally undeveloped, though concentrated areas of urban development currently exist in the City of Conroe and River Plantation. Approximately 1,155 acres, or 9 percent of the watershed, is in the existing 100-year floodplain. The watershed topography is generally steeper in the northern portion and flatter as it enters the West Fork floodplain.

Development potential is great in this watershed due to the proximity to the City of Conroe. Unless offsetting drainage improvements are constructed, new development will increase flood flows in Stewarts Creek causing the defined area of the 100-year floodplain for the lateral to expand. The impact of

Stewarts Creek on the peak discharges of the West Fork of the San Jacinto River are minimal. The Stewarts Creek peak discharge at its mouth occurs nearly one day before the West Fork peak flow at this section. Flooding at the mouth of Stewarts Creek generally occurs due to backwater conditions from the West Fork peak flow period.

Alternative structural drainage improvements on the lateral could consist of either channel modifications, onsite detention facilities, regional detention facilities, or a combination. As a nonstructural alternative, future development could be managed to not be impacted by the expanded ultimate floodplain. Limited structural improvements could be defined where necessary to mitigate impacts on existing development in both the existing and proposed ultimate floodplain.

STREAM MODELING METHODS

Hydrologic and hydraulic conditions along Stewarts Creek were first modeled as part of the Flood Insurance Study conducted by the Federal Emergency Management Agency in 1984. The hydrology was developed using the Soil Conservation Service (SCS) TR-20 computer model throughout the watershed while the stream hydraulics were modeled using two different computer programs. The SCS WSP2 computer model was used for the unincorporated areas both upstream and downstream of the City of Conroe and the U.S. Army Corps of Engineers HEC-2 computer model was used within Conroe's city limits. A single hydraulic model of Stewarts Creek is necessary in order to efficiently analyze the impacts of development and develop alternative flood control plans.

A revised hydraulic model was developed for this study using the HEC-2 program since it has become the recognized standard for floodplain analysis. Although the same hydrologic model was used throughout the watershed, it does not have the capabilities to model flood routing and floodplain storage which are necessary to evaluate regional detention projects. Thus, the TR-20 model for Stewarts Creek was converted to the Army Corps of Engineers HEC-1 hydrologic model, which is also the recognized standard in the field. The same statistical storm event, a 12-inch 48-hour rainfall, used in the Flood Insurance Program study is used in this analysis. The models were calibrated to produce flood flows and a water surface profile closely matching the Flood Insurance Program Study results and represent the existing condition floodplain.

IMPACTS OF DEVELOPMENT

The effect of full development in the Stewarts Creek watershed assuming no future channel improvements or stormwater detention was analyzed with the hydrologic and hydraulic models developed in this study. The existing and full development 100-year peak flows and water surface elevations at specific locations along Stewarts Creek are shown in Table No. 3. With full development in the Stewarts Creek watershed and no channel improvements, peak flows will increase by approximately 40 percent from existing conditions and water surface elevations will increase an average of 2.5 feet. Exhibit No. 5 shows the 100-year floodplain delineations for the existing base condition. Lateral channels in Montgomery County have relatively steep side slopes, so the increase in width of the floodplain is not as great as would be observed in a flatter terrain where the increase in elevation spreads out over a larger area. Exhibit No. 8 shows a typical cross-section of Stewarts Creek with existing floodplain boundary and the projected boundary with full development and no channel improvements. In addition, in areas where the natural ground slopes are so flat, storm sewers and drainage ditches dramatically increase the available hydraulic gradient and thus markedly improve the conveyance of flows to the lateral stream channels. In contrast, the steeper natural ground slopes of Montgomery County already provide a faster accumulation of flows to the lateral streams so that the improved conveyance of a storm sewer system does not increase this rate of accumulation as much as in flatter terrains.

DEVELOPMENT OF ALTERNATIVES

Four alternative strategies for floodplain management of lateral drainage systems were identified and evaluated. These strategies address the accommodation of full development in the watershed and consider the mitigation of impacts on existing structures as a component of the long-term plan. The alternatives can be briefly described as full channelization, regional detention, on-site detention, and floodplain buyout, and are representative of the full range of possible drainage solutions. The objective of the three structural alternatives is to allow full development of the watershed while maintaining the existing 100-year water surface elevations. The nonstructural alternative of floodplain buyout would allow the 100-year water surface elevations to increase but would compensate the landowners within the expanded 100-year floodplain who would be impacted by the increased flooding.

Full Channelization

The stormwater flows discharged from a developed site's internal drainage system are higher than those occurring prior to development. The traditional approach to prevent increased flooding in the stream to which the internal drainage systems outfall is to increase the conveyance capacity of the outfall channel by clearing, desnagging, excavating, concrete lining and/or straightening. The extent downstream to which these various improvements are carried is usually based on an evaluation of relative impact. Channelization is reasonably successful and cost effective in rural areas where sparse development downstream limits flooding impacts and allows right-of-way expansion.

Channelization becomes more expensive as development densities increase because of the distance downstream which flood flow increases must be mitigated. In addition, channelization in and of itself increases the peak rate of runoff, and so the solution adds to the magnitude of the problem to be solved. Utility crossings of streams must also be modified or replaced which can add significantly to the cost of channelization.

The required channel improvement for Stewarts Creek was defined which would contain the full development of the watershed within the existing floodplain. The ultimate channel required for the Stewarts Creek would have a bottom width of approximately 100 feet and a depth of approximately 15 feet. To limit the erosive effect of high velocity flows in the ultimate channel, a flat channel slope was utilized requiring eighteen drop structures to maintain channel depth. This plan is illustrated in Exhibit No. 6. The preliminary construction cost estimate of this alternative including right-of-way, contingencies, and engineering is $63,302,000, as shown in Table No. 4.

On-Site Detention

In contrast to the channelization approach, the application of on-site stormwater detention does not increase flood flows in the lateral stream and thus no downstream drainage improvements are required. On-site detention requires each new development to limit the maximum rate of stormwater runoff from its boundaries to the level occurring in the undeveloped state. Detention may be provided by shallow ponding in parking lots, landscape areas or drainage swales for smaller tracts and by detention pond facilities for larger developments. In either case, a minimum volume of detention storage must be provided, depending on the characteristics of the watershed, in order to control the maximum outflow.

For on-site detention in Stewarts Creek watershed, an average storage factor of 0.36 acre-feet/acre was derived based on a detailed analysis of storage requirements for three representative tracts of 10 acres, 100 acres, and 1,000 acres. Runoff hydrographs were developed for each of these typical tracts for undeveloped and fully developed conditions, and the difference between these hydrographs was computed as the required storage. Based on this storage requirement, a preliminary construction cost estimate of this alternative is $33,708,000 including land acquisition for pond sites, engineering, and contingencies as shown in Table No. 5.

Regional Detention

In a regional detention alternative, increased flows due to development are controlled with larger regional detention ponds located at selected points along the lateral stream channel. Limited channel improvements may be required at certain locations between the regional ponds. The advantages of regional ponds over on-site ponds are a potential reduction in the required amount of detention storage, greater efficiency in long-term maintenance, potential for varied operation by modifying release rate of stored stormwater, and potential for joint public uses such as recreational parks. The Addicks and Barker Reservoirs constructed by the Army Corps of Engineers in the late 1940's are regional detention systems which protect City of Houston's central business district. More recently, regional detention plans have been adopted in five major watersheds in Harris County.

In the analysis of Stewarts Creek, it was found that the regional detention pond in the upper portion of the watershed did not control peak flows efficiently and substantial channel improvements would still be required. A more efficient plan was developed which included a combination of on-site detention and regional detention. On-site detention would be utilized only in the uppermost portion of the watershed to limit the increase of flows in the upper channel, and no channel improvements would be required in this reach. Regional detention facilities would be located upstream of the existing City of Conroe urban areas to control flood flows at these locations, and channelization would be utilized in the reaches upstream of these regional ponds to accommodate the higher flows of development in these areas. Regional facilities can decrease flows downstream allowing downstream areas to develop without negative impacts. This plan is illustrated in Exhibit No. 7. The preliminary cost estimate of this plan including land and right-of-way acquisition for pond sites, right-of-way, contingencies and engineering is $27,193,000 as shown in Table No. 6.

Floodplain Buyout

In contrast to the three structural alternatives discussed above, the floodplain buyout approach would allow development to proceed without requiring the construction of either channel improvements or detention facilities. Certain bridges currently posing significant restrictions to flood flow are proposed to be modified. The increased flood flows produced by full development add approximately 430 acres to the 1155 acres currently in the 100-year Stewart's Creek floodplain, a 40 percent increase. This plan would damage the 430 acres now located outside the 100-year floodplain by reducing its market value. It would also potentially damage any structure not currently in the floodplain but located in the ultimate 100-year floodplain.

Conditions in Montgomery County provide the opportunity for a nonstructural plan to work. Presently, many of the lateral watersheds in the county have relatively low concentrations of urban development, and so future development can be directed away from the 100-year floodplain or be constructed to minimum slab elevations based on the ultimate 100-year flood levels at full development. In addition, the County's steep topography limits the extent of future floodplain expansion. Exhibit No. 8 illustrates the impact of increased flood elevations on a typical channel cross-section and the extent of floodplain width which is limited by the steep channel side slopes. Both of these conditions are quite different in the flatter more urbanized areas in Harris County.

The cost of this alternative is the purchase of the 1,590 acres within the limits of the existing and ultimate 100-year floodplain and the purchase or modification of any existing structures within the floodplain. The number of existing structures to be purchased used in this study is a rough estimate based on the limited available data, however, it should be sufficient for the purposes of this comparative analysis. The preliminary capital cost estimate for this plan is $17,125,000 as shown in Table No. 7.

SUMMARY

The least absolute cost of the four alternative flood control strategies evaluated was the floodplain buyout alternative which is also the least traditional approach to the problem. Its relatively low costs are due to a small increase in the 100-year floodplain coupled with low land prices and minimal numbers of existing structures requiring buyout along Stewarts Creek. On the other hand, full channelization is the most traditional and most costly solution. Selection of a recommended plan cannot be based on capital cost alone, but must be evaluated along with institutional, management and implementation issues to determine the best approach for Stewarts Creek in Montgomery County. The ability to implement a plan in phases will reduce its immediate funding requirements. Evaluation of the costs of each alternative with consideration to project phasing will be included in the next section.

SECTION V

RECOMMENDED PLAN

GENERAL

Continued urban development in Montgomery County will place increasing demands on existing drainage systems, and without compensating flood control improvements the impacts on the lateral stream systems will become all too evident. The technical feasibility and capital costs of the four alternative strategies were established in the previous section. Each strategy addressed full development of the watershed and the mitigation necessary to accommodate the peak flows. The addressing of existing flood damages was considered to be a component of the full development alternative plans. In this section, implementation and institutional issues will be considered in the selection of the recommended plan or strategy.

COMPARISON OF ALTERNATIVES

The selection of the lateral system plan must take into account the institutional structure required for plan implementation including funding, coordination, and management. Any plan selected will be implemented in phases due to the magnitude of the total cost of improvements, and each phase must be compatible with the guidelines of the Federal Flood Insurance Program since Montgomery County and each of the incorporated cities within the County are in the program. The following paragraphs briefly discuss the relative advantages and disadvantages inherent in the implementation of each alternative.

Full Channelization

The implementation of the full channelization alternative would likely require public funding in any initial phase due to the magnitude of cost for this alternative. Channel improvements must be carried the entire distance downstream from the location of development or system improvements to the mouth of the system (in this case Stewarts Creek) in order to address the impacts of increased peak flows. This is in part due to the fact that channel improvements alone -- apart from any land development activity-- increase downstream flood flows and thus must be offset. With channel improvements must also come right-of-way acquisition and the necessity for eminent domain powers to ensure acquisition.

The phasing of the full channelization alternative is complex. Any proposed development has the potential to require extensive downstream improvements to offset the impacts of increased peak discharges. In addition, channel sections could require numerous modifications over time for independent development projects. Alternatively, the ultimate channel could be constructed for individual reaches but could negatively impact downstream areas and the cost may not be commensurate with the demands of the proposed development. No single development project, therefore, could predictably move forward with necessary outfall drainage improvements without public entity participation through assistance in construction funding, and right-of-way acquisition. Implementation would be dependent on both public and private sector funding and a compatible timing of need or desire for the project. The required compatibility in timing of the project will likely serve to inhibit urban growth.

Although a number of vehicles are available to provide such public sector funding including existing municipal utility districts, drainage districts, cities and the county, all would likely have difficulty meeting the funding required for this alternative without limiting development. Additionally, watershed planning and management must be on-going in order to monitor the changes in hydrologic and hydraulic conditions throughout the watershed caused by each phase of channel improvements as required by the National Flood Insurance Program. This will require a regional entity with the authority to plan and coordinate across existing jurisdictional boundaries within a watershed.

Regulation of floodplains and drainage improvements in the full channelization alternative can continue to be administered by existing municipalities and the County based on the adopted watershed plan, as updated from time to time by the regional planning agency. Regulatory mechanisms include platting requirements, subdivision design criteria, and building permits. Construction and maintenance of the channel system can also continue to be performed by local jurisdictions, including municipal utility districts, drainage districts, municipalities, and the county.

On-Site Detention

The most flexible alternative with respect to phasing is on-site detention. Each developer is responsible for providing detention on his own property based on a uniform set of criteria and thus no downstream impacts are created in the lateral channel. The size and cost of facilities are directly proportional to the amount of acreage to be developed. Thus funding is "pay as you go" and joint funding of projects is not required. The timing of a developer's project is not contingent on any other public or private entity's project or financing.

On-site detention requires the development of the watershed plan which would consist of determining the appropriate stormwater detention storage requirement and design criteria. A regional planning entity is needed for these tasks but the on-going planning effort will not be as large as in the full channelization alternative. Floodplain regulation and approval of drainage plans can continue to be administered by existing jurisdictions within their own boundaries.

On-site detention systems will be constructed by the user, including both public and private entities. Maintenance will also be the responsibility of the individual detention facility owner, and this represents a potential disadvantage of the on-site detention alternative because long-term reliability will be difficult to assure given the large number of facilities, many of which will be privately operated and maintained.

Regional Detention

The regional detention alternative provides the implementation flexibility of the on-site detention alternative coupled with the enhanced cost effectiveness of regional detention. The most effective regional detention plan for Stewarts Creek required the use of on-site detention in the upper portion of the watershed, and for this area the flexibility of phasing is as high as discussed above. Each developer in this area is responsible only for paying for detention of his own site, and his timing is independent of other private and public activities.

The lower portion will rely on regional detention pond with limited channel improvements. Flexibility of phasing will vary depending on which element of the plan must be constructed next. Certain elements will have initial construction costs sufficiently high so as to require joint funding, two or more private developers or with the assistance of municipal financing through a governmental entity. Until sufficient development momentum builds in these regional areas to support joint funding, initial developments could be allowed to move forward with onsite detention. Once regional pond sites have been purchased and the basic outfall structure built, additional detention storage can then be easily provided for individual projects on a "dig as you go" basis.

Regional detention requires the initial development of a watershed plan. On-going monitoring and coordination of successive phases of construction will be required to assure conformance with the watershed plan as updated from time to time and with the National Flood Insurance Program. A regional entity is required with authority to plan throughout the watershed.

As with the previous two alternatives, regulation of floodplains and drainage improvements can continue to be carried out by existing municipalities and the County based on the adopted watershed plan as amended from time to time by the regional planning agency. The regional detention alternative will require on-going maintenance of the regional ponds and limited channel improvements. These could be performed by separate public agencies as long as a single regional authority has the responsibility to monitor maintenance performance to assure the reliability of the flood control system to the public.

Floodplain Buyout

As with the full channelization alternative, the floodplain buyout alternative would likely require public funding in any initial phase project. The increased flood flows from a single development project requires the initiation of downstream floodplain buyout to avoid aggravation of existing flooding conditions as required by the Flood Insurance Program. Such a buyout would require the purchase of many parcels of land along the channel, the direct and administrative cost of which would be impractical. A joint funding mechanism is, therefore, required to implement the floodplain buyout plan. In addition, a governmental entity with the power of eminent domain is needed for land acquisition. Adversarial condemnation of private property, as well as the minimum upfront cost of purchasing of the existing floodplain could potentially make this alternative politically unacceptable.

The floodplain buyout would require the initial development of a watershed plan in which the ultimate 100-year floodplain and water surface elevations are determined by a regional planning agency using National Flood Insurance Program procedures. Once this is accomplished, the very large task of land acquisition would be administered with funding for the land acquisition required at the initiation of the program. Regulation of floodplain management can continue to be administered by existing agencies. No construction or maintenance of drainage facilities is required in the floodplain buyout plan.

PLAN SELECTION AND IMPLEMENTATION

After a review of both the cost and implementation considerations of each of the alternatives, the regional detention alternative is recommended for implementation in the Stewarts Creek watershed. This strategy of flood control management should also be considered for other similar lateral watersheds in Montgomery County. Although a plan to purchase the ultimate floodplain appears to provide a solution which has a lower absolute cost, the inability to phase project funding will make this alternative impractical to implement. Channelization alone is the most costly alternative considered and is both difficult to phase and complex to manage. Table No. 8 presents an evaluation of the four alternative flood control strategies for Stewarts Creek.

The potential for phasing any given alternative in its implementation can affect the front end funding requirements. The floodplain buyout alternative is not readily phased so the entire funding requirement occurs at the inception of the project. The three structural alternatives, however, do allow for some project phasing (though phasing the channelization alternative varies complex management and equity issues). Implementing an alternative over a longer period in multiple phases will reduce the present worth value of the project cost. For instance, phasing Alternative III, the regional detention plan over a 15 year period with four funding equivalent implementation steps and a discount rate of eight percent yields a present worth of $16,700,000. The present worth of this phased plan is, therefore, less than the cost of the floodplain buyout and provides the advantages of phased construction and implementation. Extending the construction period or number of phases will further reduce the present worth funding requirement.

Implementation of the recommended plan for Stewarts Creek as well as other lateral watersheds within Montgomery County will require regulatory control, on-going watershed planning and funding. No entity currently has the power to implement and regulate a drainage plan across the entire county. Therefore, implementation must be based on the mutual agreement between the affected municipalities and the County to adopt the selected plan and regulate floodplains, land development, and drainage improvements within their respective jurisdictional boundaries in accordance with the recommended plan guidelines. This is not unlike the system used in Harris County which is often referenced as a model program. In Harris County, the Harris County Flood Control District provides guidance through watershed planning and criteria development but lacks the regulatory control to require compliance. Compliance is dictated through the regulatory controls available to the individual municipalities and Harris County and by the approval authority voluntarily granted to the Harris County Flood Control District by these entities.

Implementation of the recommended plan could begin without public sector funding by requiring on-site stormwater detention facilities for all new development in the Stewarts Creek watershed. This will allow development to proceed in all areas of the watershed without any delay due to funding a regional project and without any aggravation of existing flooding conditions. Each regulatory entity would be responsible for adopting detention requirements and enforcing compliance within their respective jurisdictions. In the later phases of plan implementation, the upstream portion of the watershed as shown on Exhibit No. 7 will continue to employ on-site detention to prevent increases in downstream flood flows. As the density and rate of land development begins to increase in the lower portion of the watershed, adequate funding can then be generated to construct elements of the proposed regional detention ponds and channel improvements.

A number of joint funding mechanisms exist for the regional detention facilities but require sufficient development momentum to be successful. One mechanism is mutual agreement of several private developers with enough land and capital to fund an initial phase of the regional facilities. Another involves participation by municipal utility districts and drainage districts which can finance construction costs through the sale of municipal bonds repaid over time by ad valorem taxes levied within the boundaries of these special districts. A third vehicle for regional project funding is utilization of the recently created Montgomery County Water Supply Flood Control Corporation to obtain loans from the Texas Water Development Board to be repaid by impact fees paid by new development and/or a tax pledge by Montgomery County.

The successful implementation of any flood control program will require on-going planning to update the hydrologic and hydraulic models to confirm that each successive phase of construction prevents increased flooding throughout the watershed. This regional flood control planning must also be performed by an entity with the authority to plan and coordinate across existing jurisdictional boundaries within the County. No entity currently provides such watershed planning in Montgomery County on an on-going basis and without this planning function the flood control problem will continue to worsen.

The San Jacinto River Authority and the recently created Montgomery County Water Supply Flood Control Corporation both have clear authority to perform flood control planning on a regional or countywide basis. However, neither has taxing authority to provide funding to defray the cost of this on-going flood control planning, but must rely on grants or other revenue sources to provide funding. Montgomery County, with taxing powers, has clear authority to plan and construct drainage improvements in conjunction with county roadways and to administer the National Flood Insurance Programs in Montgomery County, but has no specific authority to plan, design or construct flood control improvements.

ROLE OF SAN JACINTO RIVER AUTHORITY

The efforts of the San Jacinto River Authority and the Texas Water Development Board through this study as well as the previous study of the major drainage channels in Montgomery County have served to focus on the flood control problems and potential solutions for Montgomery County. Funding of the recommended program of capital improvements can occur through existing mechanisms, and therefore, is not a function which should be considered by the San Jacinto River Authority. However, consideration should be given to a continuation of the leadership role provided by the San Jacinto River Authority in flood control planning but on an on-going basis. To be effective, a flood control plan will depend on the voluntary agreement of the cities and the county to require conformance with the plan. This will require coordination with and possibly funding support of the existing entities in Montgomery County involved with providing drainage and flood control facilities. Discussions with these entities concerning on-going planning, coordination, regulation and funding will be required to evaluate community support and should be pursued as an initial step if a role in on-going flood control planning is pursued by the San Jacinto River Authority. Subsequent planning efforts by the Authority should be contingent on receiving cooperation from local government entities.

Comprehensive regional flood control planning will require participation by and coordination with all local governmental entities in the County. Examples of planning tasks which would be centrally administered and coordinated include the following:

- Obtain and maintain copies of the computer models developed for the Montgomery County Flood Insurance Study.

- Convert all computer models to HEC-1 (Hydrology) and HEC-2 (Hydraulics) to provide uniform modeling.

- Prepare Drainage Criteria Manual for use countywide which would define uniform analytic methodologies, minimum design criteria, and minimum construction specifications for drainage and flood control facilities.

- Prepare flood control plans for each watershed in Montgomery County. Such planning should be phased with the initial efforts focused on watersheds with existing problems and on-going development.

SECTION VI

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Over the past twenty years, flooding problems in Montgomery County have significantly increased in the areas of concentrated urban development. Many of these problems were associated with "red flag" residential subdivisions developed without obtaining regulatory approvals, and constructed within low lying floodplain areas adjacent to the major drainage channels, particularly the West Fork of the San Jacinto River. A review of design and operating parameters for Lake Conroe indicates that no flood peak attenuation can be provided by the water supply reservoir.

Local regulation of the existing floodplains through the National Flood Insurance Program as well as the more stringent subdivision regulations adopted by the County in response to this problem will prevent such new development within the existing floodplain. However, no plan exists for addressing the effects of future development outside of the existing floodplain. The increased runoff associated with future development will cause existing flood elevations and flood plains to increase, thereby inducing flooding on approved development outside the existing floodplain but within the projected floodplain. This effect will be more significant along the smaller lateral channels than along the primary or major streams.

As a part of this study, a detailed analysis of alternative floodplain management strategies was performed for Stewarts Creek. A combination of on-site stormwater detention and regional stormwater detention was found to be the most effective method for floodplain management based on an analysis of both cost and implementation considerations. Plan implementation can occur utilizing existing regulatory controls and funding mechanisms without inhibiting future development, but will require that regional plans be adopted and enforced by intergovernmental agreement and cooperation.

Based on the analysis of alternative flood control strategies for Stewarts Creek, it is concluded that the full channelization is generally not cost effective for lateral channels in Montgomery County. The regional plan for Stewarts Creek, which is a hybrid of several strategies, is expected to be representative of the most cost-effective solution for other small lateral watersheds. Since each watershed varies to some degree, the alternative strategies should be tested prior to final adoption for any specific watershed plan. In lieu of a detailed watershed plan, on-site detention should be imposed as a general rule throughout a lateral watershed until study and selection of a specific watershed plan can be accomplished.

As indicated previously, specific plan implementation can occur utilizing existing regulatory controls and funding mechanisms. However, no county-wide flood control planning currently occurs. Planning is largely fragmented along the jurisdictional boundaries of incorporated cities, municipal utility districts and the County. There is a need for a regional planning entity to assist in the coordination and preparation of comprehensive drainage and flood control plans for each watershed in the County utilizing criteria which are consistent and acceptable to the Federal Emergency Management Agency.

RECOMMENDATIONS

The San Jacinto River Authority has performed flood control planning for Montgomery County through this study effort as well as the previously referenced study of the primary channel systems. As an entity with countywide jurisdiction and authority to perform such planning, it is recommended that the San Jacinto River Authority consider a continued role in flood control planning in Montgomery County. This should begin through discussions with existing entities involved with providing drainage and flood control facilities to determine community support for the San Jacinto River Authority providing this on-going planning function and potential sources of funding.

Although recently recognized as one of the fastest growing counties in the country, much of Montgomery County remains to be developed. Development of plans for flood control early in the development process will ensure that cost-effective solutions are implemented as development occurs thus providing for continued and quality urban development in Montgomery County.

TABLE NO. 1

SUMMARY OF BENEFIT/COSTS ANALYSIS
FOR ALTERNATIVE PROJECTS DEFINED IN SJRA
UPPER WATERSHED DRAINAGE IMPROVEMENT AND
FLOOD CONTROL PLANNING STUDY (1985)

Flood Control Alternative	West Fork	Lake Creek	Spring Creek	Peach Creek	Caney Creek	East Fork	Summary by Alternative
Structural							
Desnagging	2 of 4	0 of 1	0 of 1	0 of 1	0 of 1	0 of 1	2 of 9
Bridge Modification	0 of 1	*	0 of 3	0 of 1	0 of 1	0 of 2	0 of 8
Select Channelization	0 of 4	*	*	*	*	*	0 of 4
Full Channelization	0 of 1	0 of 1	0 of 1	0 of 1	0 of 1	0 of 1	0 of 5
Reservoir Storage	2 of 2	0 of 2	0 of 2	0 of 2	0 of 1	0 of 1	2 of 10
Summary	4 of 12	0 of 4	0 of 7	0 of 5	0 of 4	0 of 4	4 of 30
Nonstructural							
Floodplain Structure Buyout	2 of 10	0 of 2	1 of 10	7 of 11	9 of 12	4 of 10	23 of 50

* No projects identified as having potential feasibility.

Note: This table shows, for a given number of areas on a stream that a flood control alternative is applied, the number of areas where that alternative had a benefit to cost ratio greater than 1.0. For example, desnagging was applied to four areas on the West Fork of which two had a benefit to cost ratio greater than 1.0. Overall, only four areas were identified that could be effectively addressed by structural modifications in the referenced study.

TABLE NO. 2

PARTICIPANTS IN NATIONAL FLOOD INSURANCE PROGRAM
IN MONTGOMERY COUNTY

Participant	Streams
Montgomery County	All
Chateau Woods	While Oak Creek
Conroe	Alligator Creek, Grand Lake, Little Caney Creek, Silverdale Creek, and Stewarts Creek
Cut-N-Shoot	Caney Creek and Crystal Creek
Magnolia	Mill Creek and Sulphur Branch
Montgomery	Stewarts Creek and Town Creek
Oak Ridge North	Sam Bell Gully
Panorama Village	Stewarts Creek, West Fork, and White Oak Creek
Patton Village	Lateral of Peach Creek
Roman Forest	Peach Creek
Shennandoah	Panther Branch
Splendora	Peach Creek
Stagecoach	Sulphur Branch and Walnut Creek
Willis	Crystal Creek
Woodbranch	Peach Creek
Woodloch	West Fork

TABLE NO. 3

100-YEAR FLOWS AND WATER SURFACE ELEVATIONS
IN STEWARTS CREEK

		100-Year Peak Flows (CFS)		100-Year Water Surface Elevations (Feet)		
Station	Description	Existing	Ultimate	Existing	Ultimate	Increase
4122	River Planation Drive	4870	7780	123.7	123.8	0.1
8593	Creighton Road	4840	7760	132.4	133.9	1.5
18571		4760	7700	147.9	149.6	1.7
24437	Foster Road	4580	7560	158.8	161.3	2.5
31480	Avenue F	4350	7640	173.1	174.9	1.8
33285	S.H. 105	4290	7660	175.8	179.3	3.5
35846	Airport Road	4200	7690	179.5	182.6	3.1
37108	Dallas Street	4170	7710	182.4	184.0	1.6
43440	S.H. 336	3970	7780	196.7	200.0	3.3
49437	D/S Trib 1	3350	6550	208.1	209.3	1.2
49760	U/S Trib 1	2510	4630	209.0	210.1	1.1
53630	M.P.R.R.	2430	4750	219.2	222.6	3.4
66209	US 75	2340	4060	257.7	260.1	2.4
69376	IH 45	2190	3780	269.8	275.6	5.8
72619	FM 830	2040	3500	279.5	282.7	3.2

TABLE NO. 4

PRELIMINARY COST ESTIMATE FOR FULL CHANNELIZATION
OF STEWARTS CREEK

Item	Quantity	Unit	Unit Price	Amount
Channel Excavation (Includes Clearing, Seeding, Backslope, Drains, and Disposal)	15,744,000	CY	$ 2.75	$43,296,000
Drop Structures	18	EA	170,000	3,060,000
Bridge Replacements				
Creighton Road	11,400	SF	45.00	513,000
Avenue F	5,600	SF	45.00	252,000
SH 105	11,500	SF	45.00	518,000
Airport Road	7,000	SF	45.00	315,000
Dallas Road	6,100	SF	45.00	275,000
Railroad Bridge Replacement				
AT & SF	250	LF	1,500	375,000
MPRR	175	LF	1,500	278,000
Right-Of-Way	500	AC	5,000	2,500,000
SUBTOTAL				$51,382,000
Contingencies (10%)				5,138,000
Engineering (12%)				6,782,000
TOTAL ESTIMATED COST				$63,302,000

TABLE NO. 5

PRELIMINARY COST ESTIMATE OF ON-SITE DETENTION
OF STEWARTS CREEK

Item	Quantity	Unit	Unit Price	Amount
Detention Pond Excavation* (Includes Clearing, Seeding, Backslope, Drains, Outflow Control Structure, and Disposal)	5,345,000	CY	$ 4.00	$21,380,000
Land	598	AC	10,000	5,980,000
SUBTOTAL				$27,360,000
Contingencies (10%)				2,736,000
Engineering (12%)				3,612,000
TOTAL ESTIMATED COST				$33,708,000

*Based on 9,200 remaining developable acres in Stewarts Creek Watershed.

TABLE NO. 6

PRELIMINARY COST ESTIMATE FOR REGION DETENTION
OF STEWARTS CREEK

Item	Quantity	Unit	Unit Price	Amount
Regional Pond "A"				
Excavation	1,924,900	CY	$ 2.75	$ 5,293,000
Control Structure (Inline)	1	EA	1,000,000	1,000,000
Land - Regular	175	AC	10,000	1,750,000
- Floodplain	66	AC	5,000	330,000
Regional Pond "B"				
Excavation	33,880	CY	3.00	102,000
Control Structure (Side Weir)	1	EA	75,000	75,000
Land	4	AC	5,000	20,000
On-Site Detention*				
Excavation	2,568,300	CY	4.00	10,632,000
Land	287	AC	10,000	2,870,000
Channel Improvements				
Excavation	94,800	CY	3.00	284,000
SUBTOTAL				$22,072,000
Contingencies (10%)				2,207,000
Engineering and Surveying (12%)				2,914,000
TOTAL ESTIMATED COST				$27,193,000

*Based on 4,422 acres in Upper Stewarts Creek Watershed requiring on-site detention.

TABLE NO. 7

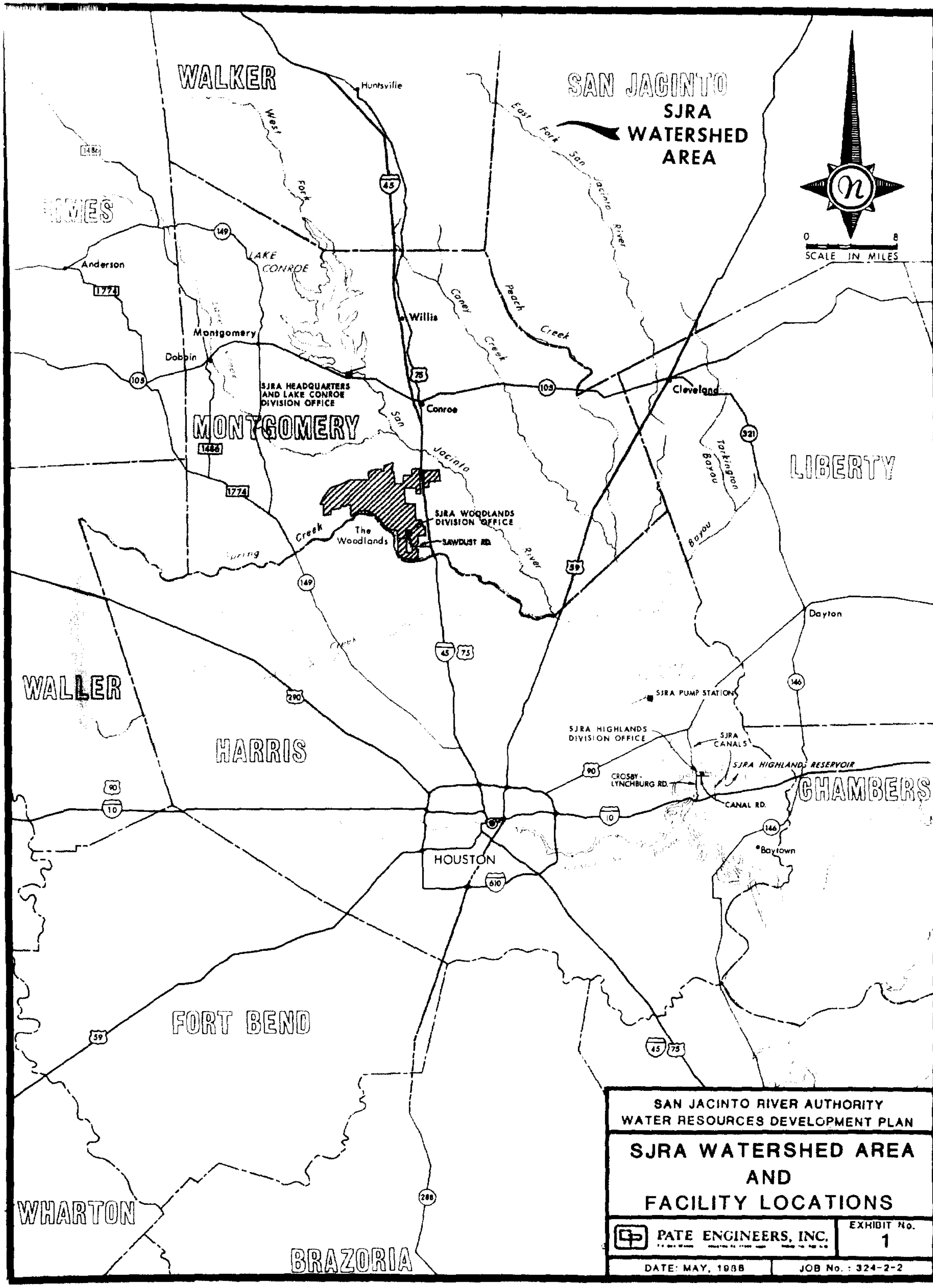
PRELIMINARY COST ESTIMATE FOR FLOODPLAIN BUYOUT
OF STEWARTS CREEK

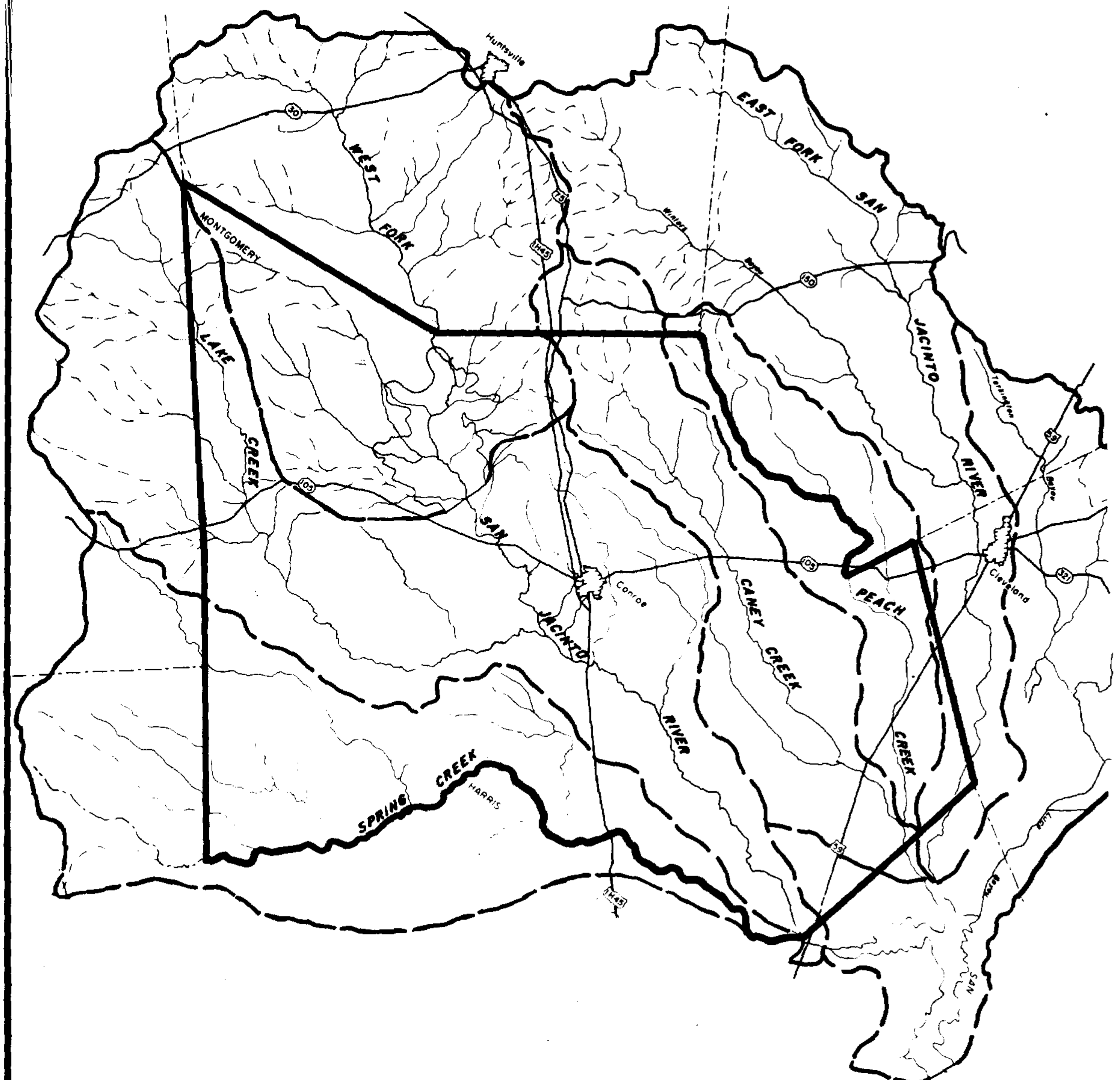
Item	Quantity	Unit	Unit Price	Amount
Channel Excavation	90,900	CY	$ 3.00	$ 273,000
Drop Structures	1	EA	170,000	170,000
Bridge Replacements				
US Highway 75	4,800	SY	45.00	216,000
Railroad Bridge Replacement				
MPRR	450	LF	1,500	675,000
Floodplain Buyout				
Land - Regular	430	AC	10,000	4,300,000
- Floodplain	1,155	AC	5,000	5,775,000
Structures	50	EA	50,000	2,500,000
SUBTOTAL				$13,900,000
Contingencies (10%)				1,390,000
Administration, Engineering and Surveying (12%)				1,835,000
TOTAL ESTIMATED COST				$17,125,000

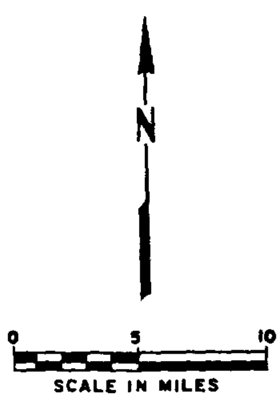
TABLE NO. 8

COMPARISON OF ALTERNATIVE FLOOD CONTROL STRATEGIES
FOR STEWARTS CREEK

Alternative	Estimated Cost	Flexibility of Phasing	Joint Funding Required	On-Going Planning Required	Regulation Required	Maintenance Required
Full Channelization	$63,302,000	Low	Yes	Regional Agency (More Intensive)	Local Agency	Local Agency
On-Site Detention	33,708,000	High	No	Regional Agency	Local Agency	Local Agency/ Private
Regional Detention	27,193,000	Moderate	Yes	Regional Agency (More Intensive)	Local Agency	Local Agency/ Private
Floodplain Buyout	17,125,000	Low	Yes	Regional Agency	Local Agency	Local Agency


WALKER
SAN JACINTO
SJRA
WATERSHED
AREA
0
8
SCALE IN MILES
Huntsville
West Fork
East Fork San Jacinto River
Anderson
LAKE CONROE
Willis
Caney Creek
Peach Creek
Montgomery
Dobbin
SJRA HEADQUARTERS
AND LAKE CONROE
DIVISION OFFICE
Conroe
Cleveland
MONTGOMERY
San Jacinto River
Tarkington Bayou
LIBERTY
SJRA WOODLANDS
DIVISION OFFICE
The Woodlands
SAWDUST RD.
Spring Creek
Dayton
WALLER
HARRIS
SJRA PUMP STATION
SJRA HIGHLANDS
DIVISION OFFICE
SJRA
CANALS
SJRA HIGHLANDS RESERVOIR
CROSBY-
LYNCHBURG RD.
CANAL RD.
CHAMBERS
HOUSTON
Baytown
FORT BEND
WHARTON
BRAZORIA
SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN
SJRA WATERSHED AREA
AND
FACILITY LOCATIONS
PATE ENGINEERS, INC.
EXHIBIT No.
1
DATE: MAY, 1988
JOB No.: 324-2-2

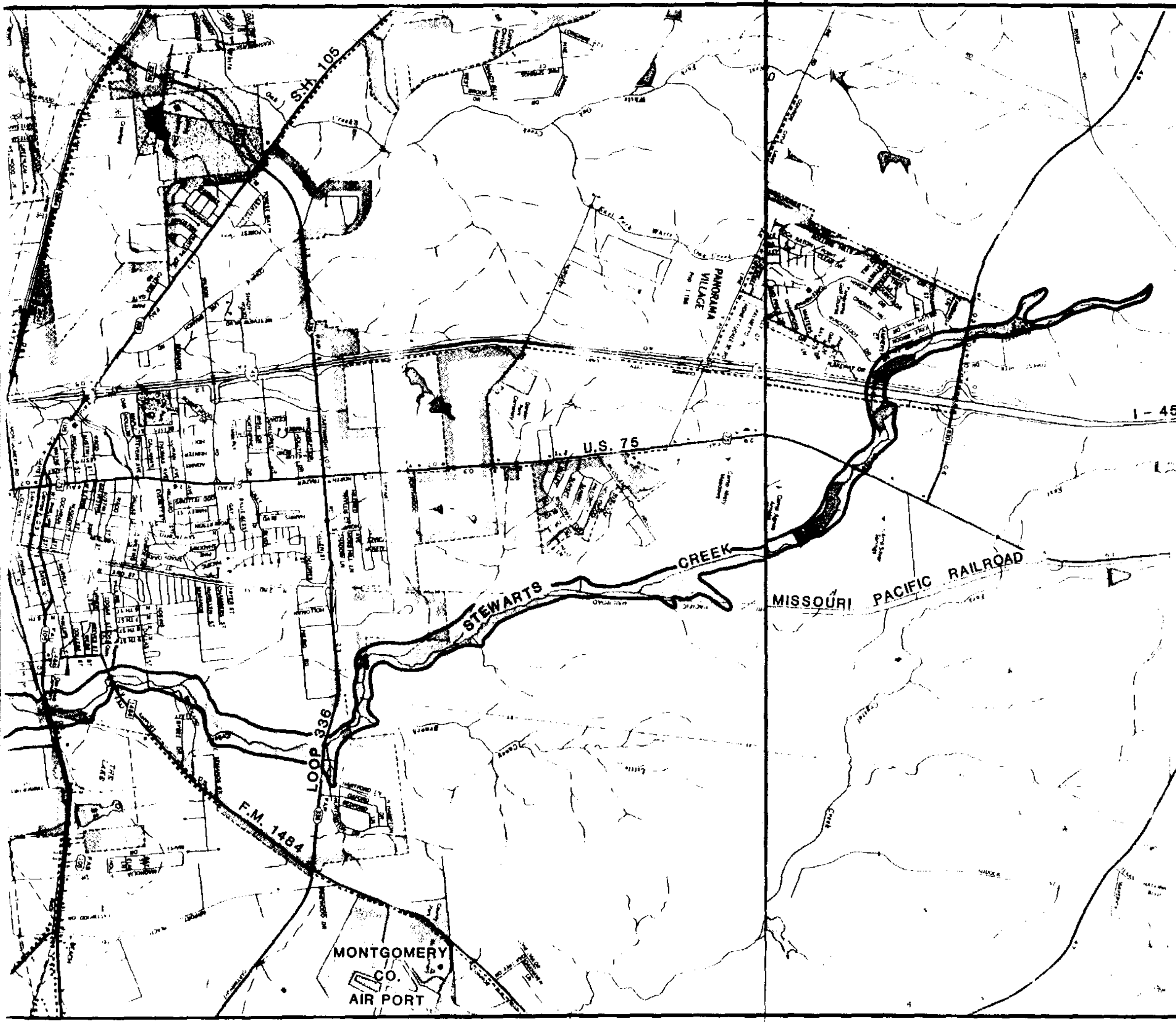




SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

MAJOR STREAMS IN MONTGOMERY COUNTY

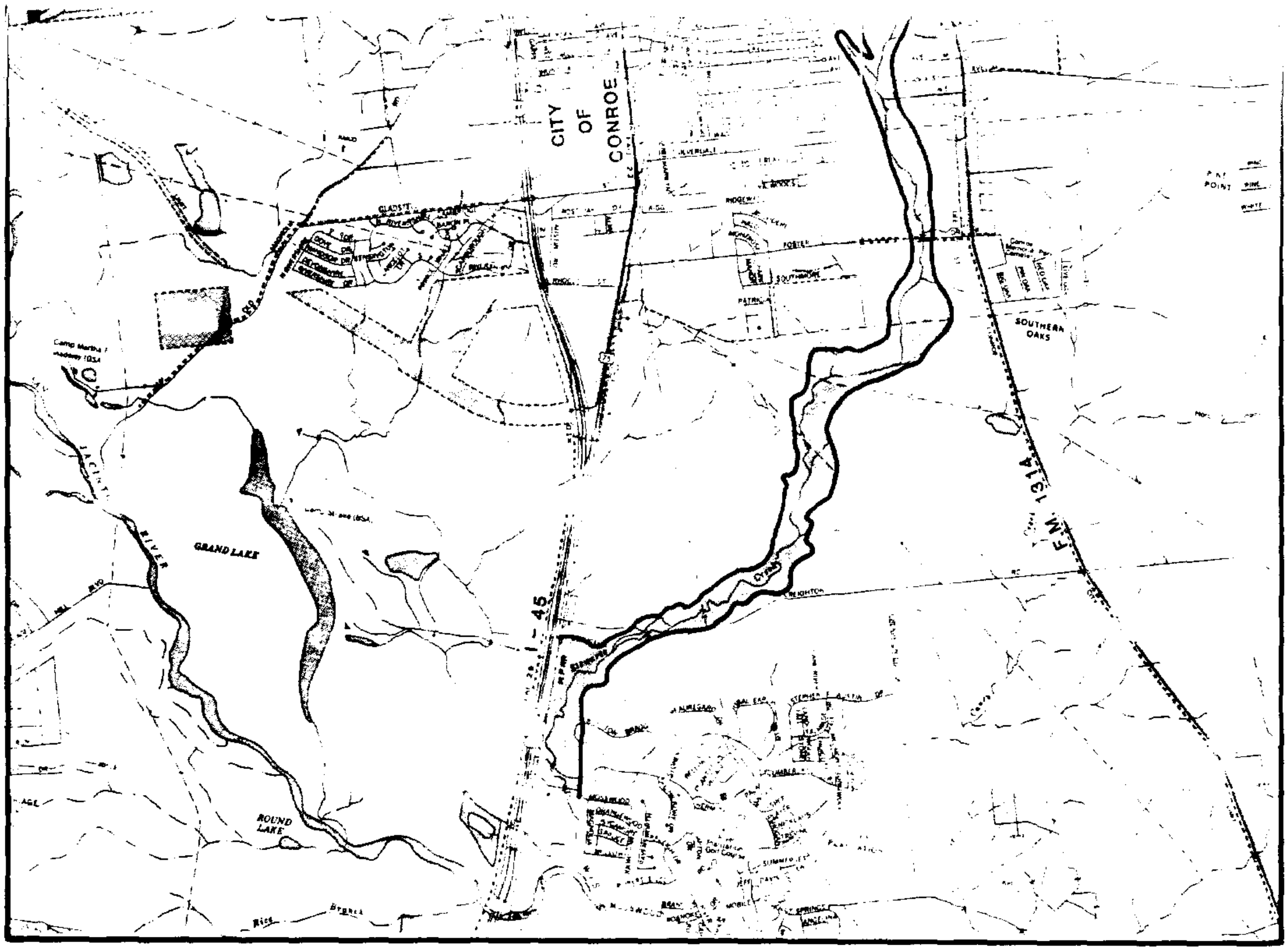
PATE ENGINEERS, INC.	EXHIBIT NO. 2
DATE: AUGUST, 1988	JOB NO.: 324-2-4



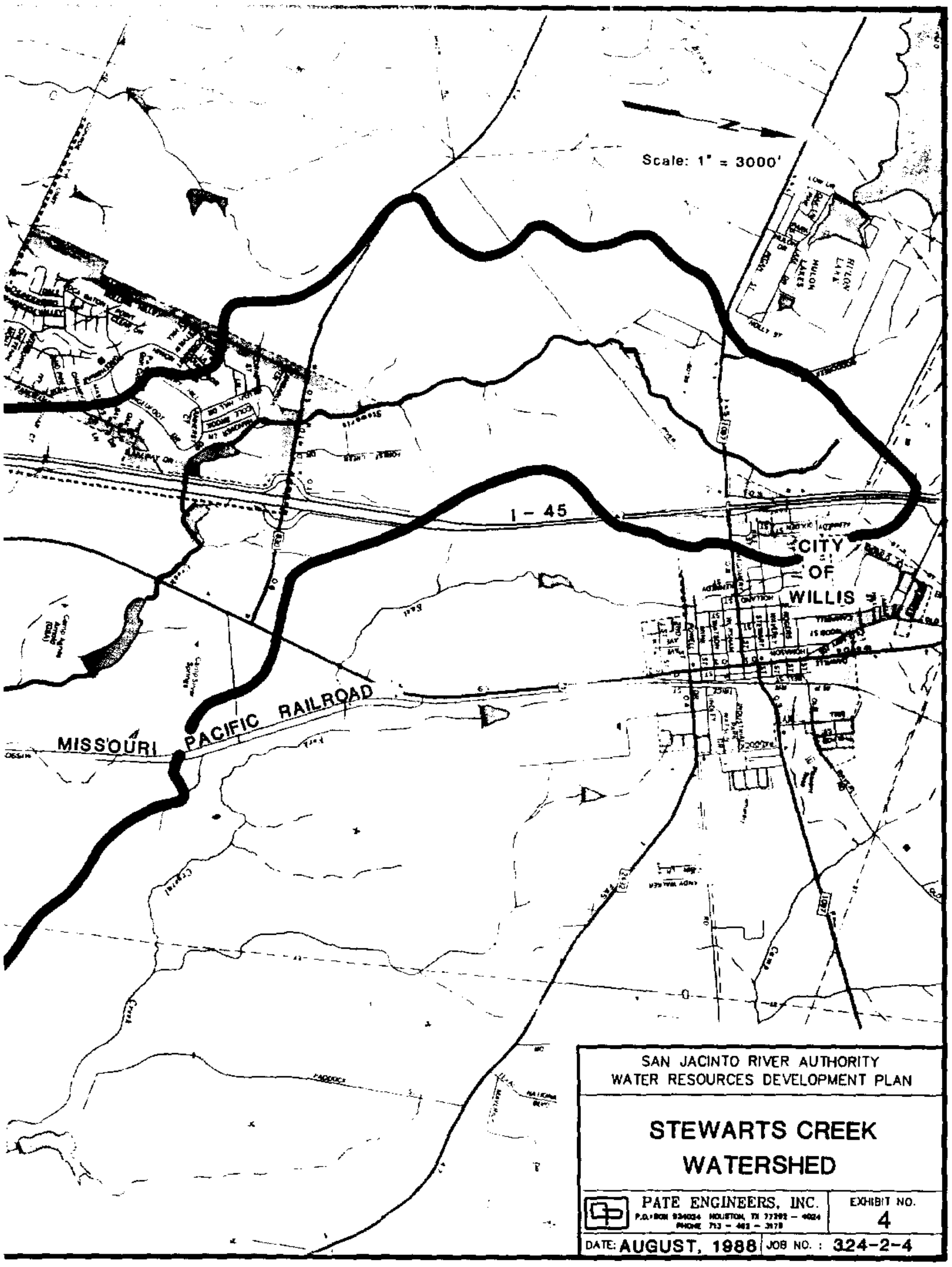
SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

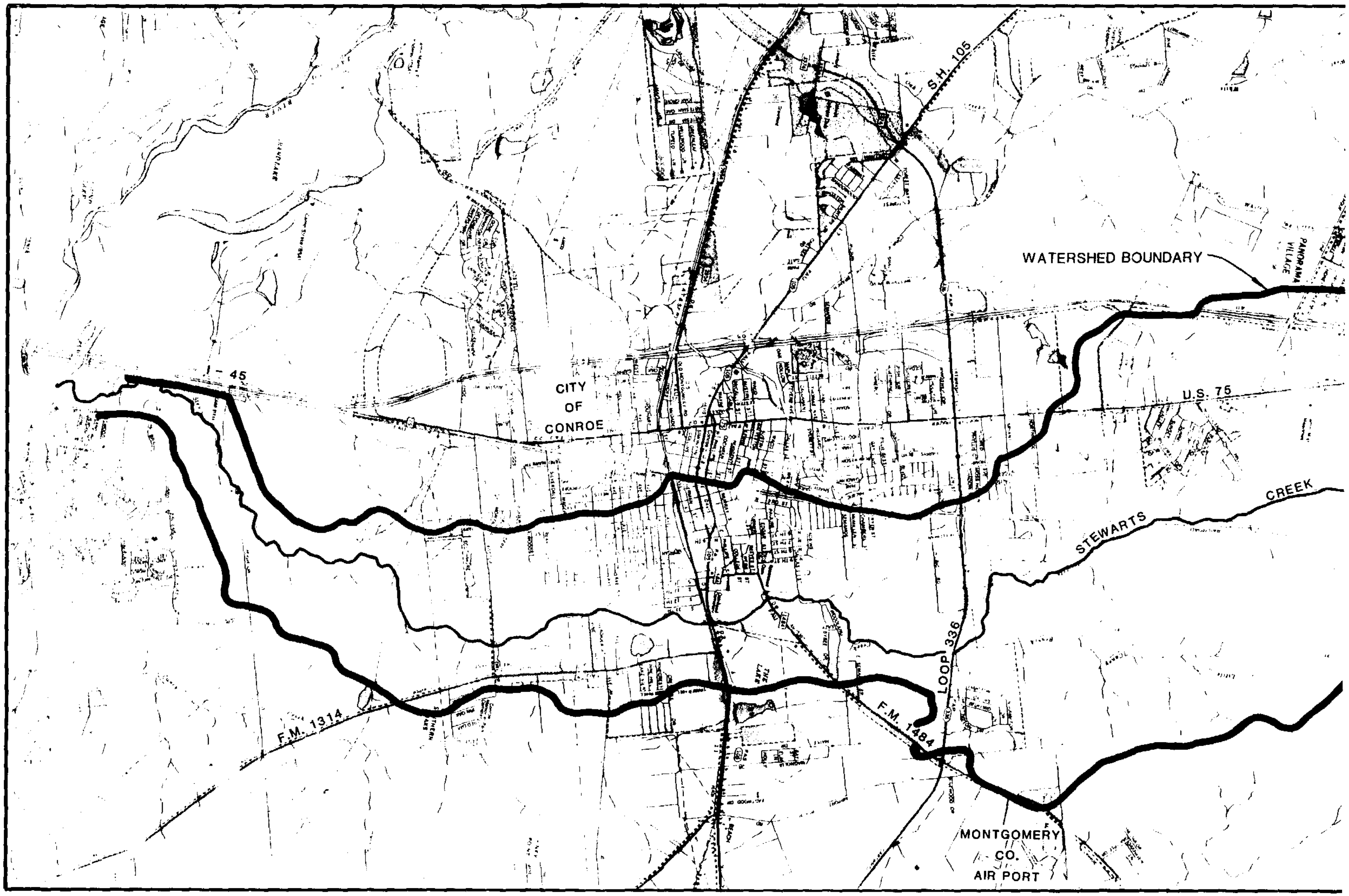
EXISTING 100-YEAR FLOOD PLAIN

PATE ENGINEERS, INC.
EXHIBIT NO. 3
DATE: AUGUST, 1988 JOB NO.: 324-2-4

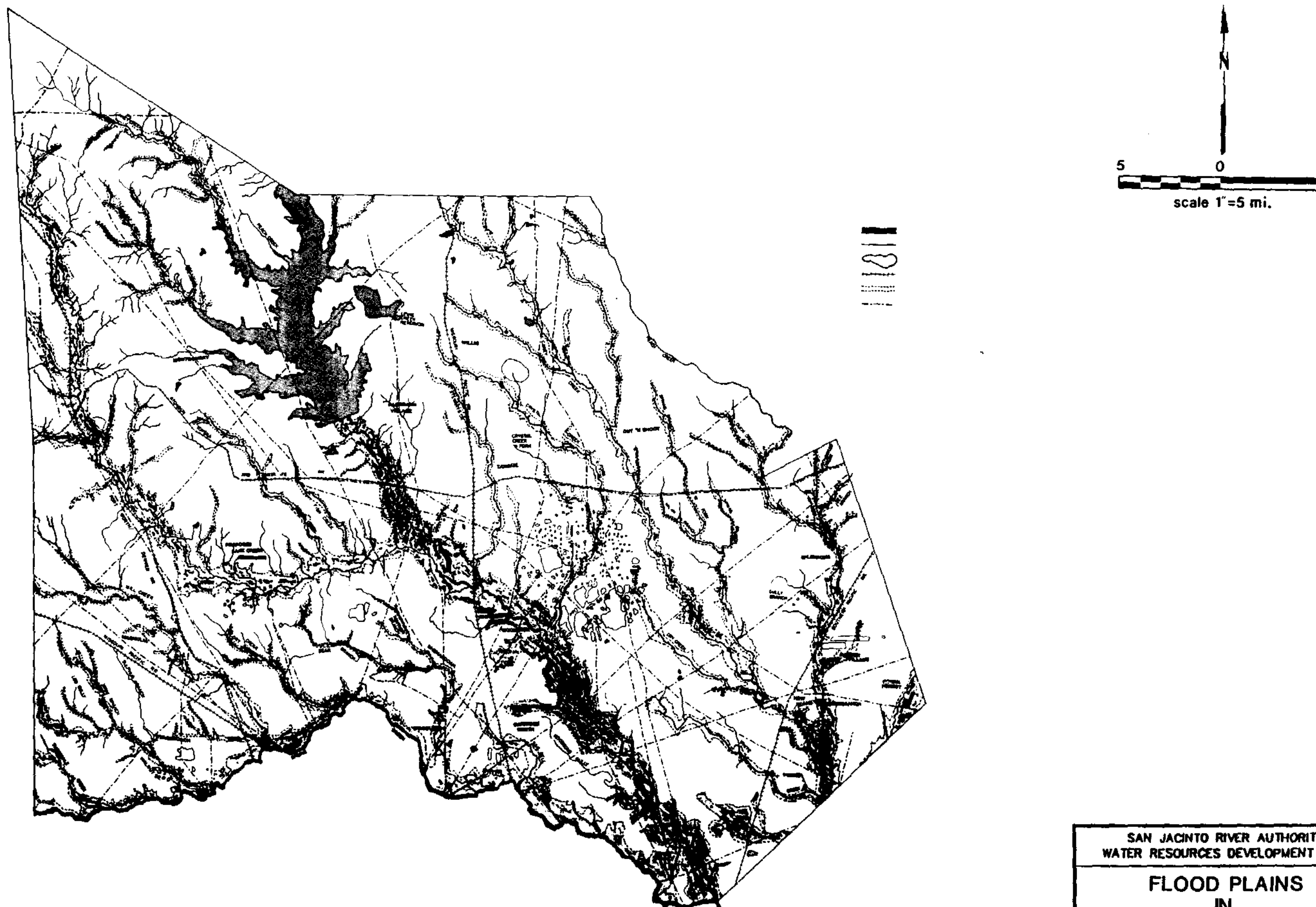


CITY OF CONROE
I - 45
F.M. 131A
GRAND LAKE
ROUND LAKE
RIVER
SOUTHERN OAKS


Scale: 1" = 3000'
N
I - 45
CITY
OF
WILLIS
MISSOURI PACIFIC RAILROAD
SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN
STEWARTS CREEK
WATERSHED
PATE ENGINEERS, INC.
EXHIBIT NO.
4
DATE: AUGUST, 1988
JOB NO.: 324-2-4



S.H. 105
WATERSHED BOUNDARY
PANORAMA VILLAGE
I - 45
CITY OF CONROE
U.S. 75
STEWARTS CREEK
LOOP 336
F.M. 1314
F.M. 1484
MONTGOMERY CO. AIR PORT

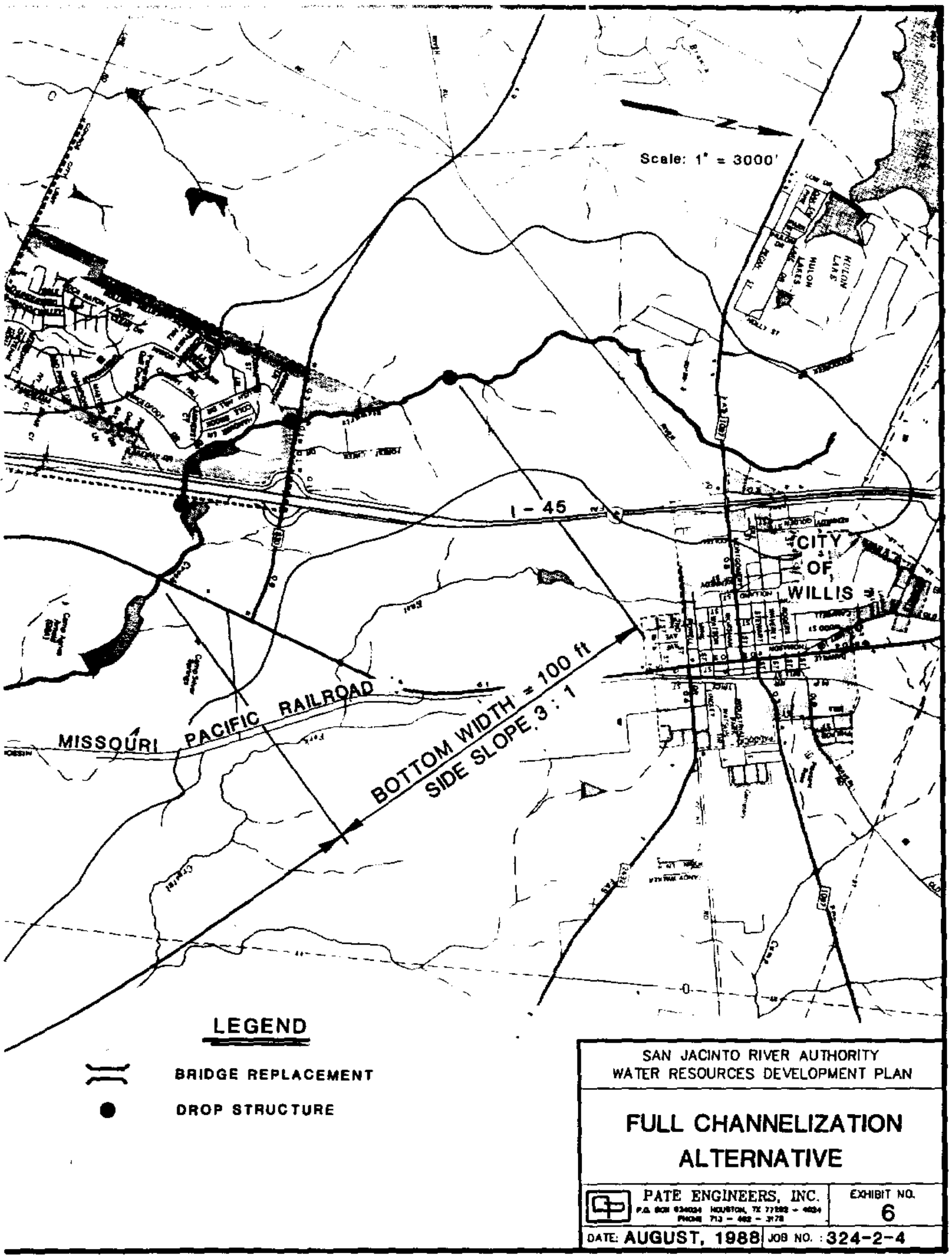


SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

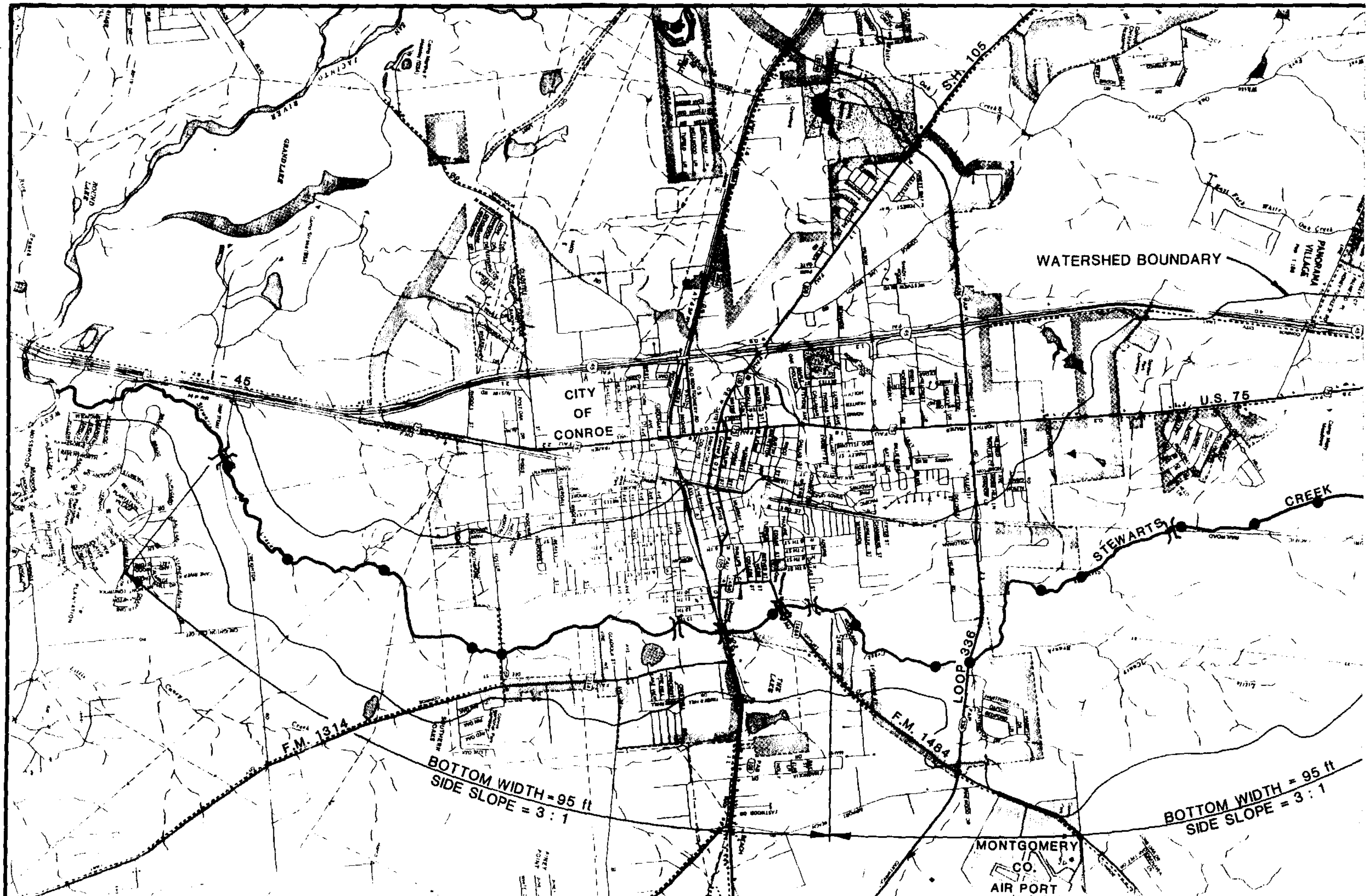
FLOOD PLAINS
IN
MONTGOMERY COUNTY

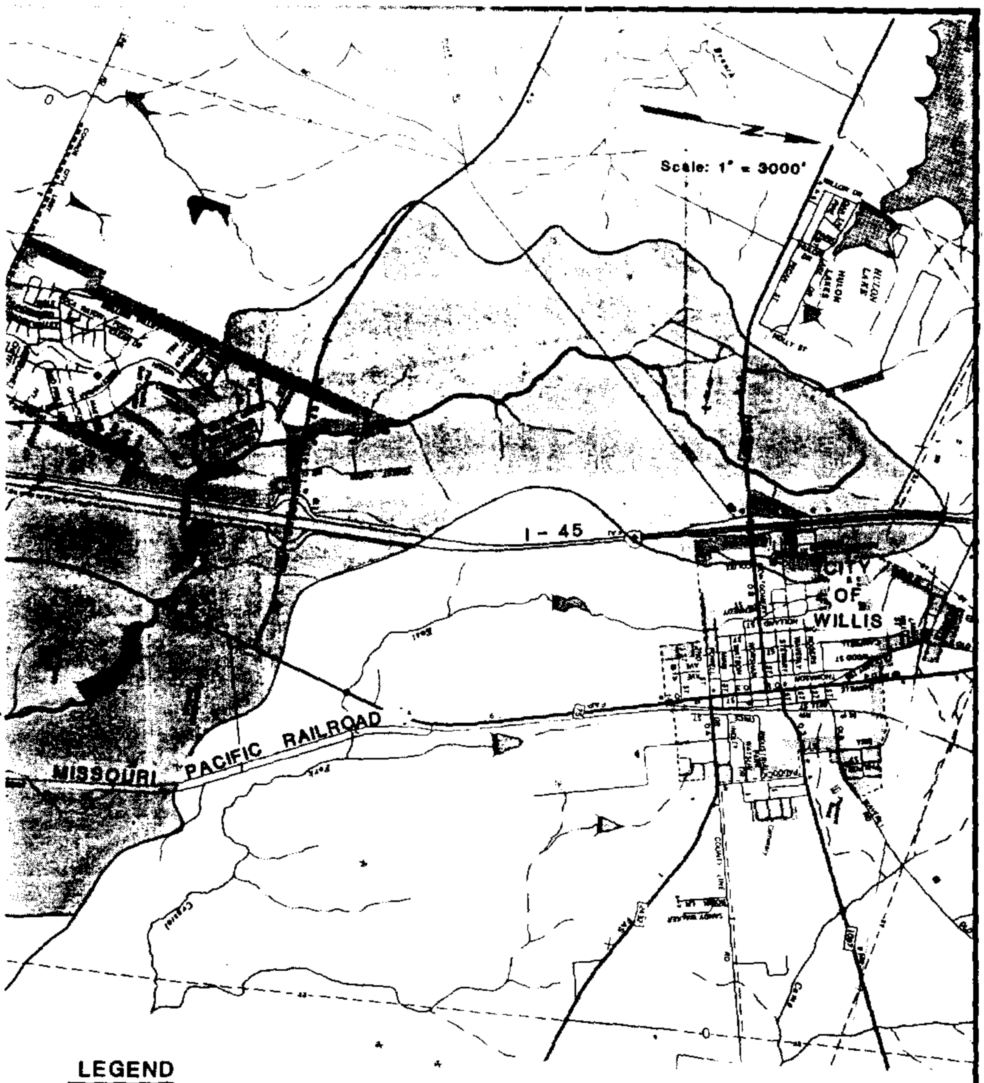
PATE ENGINEERS, INC.

EXHIBIT NO.
5



Scale: 1" = 3000'
N
I - 45
CITY OF WILLIS
MISSOURI PACIFIC RAILROAD
BOTTOM WIDTH = 100 ft
SIDE SLOPE 3 : 1
LEGEND
BRIDGE REPLACEMENT
DROP STRUCTURE
SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN
FULL CHANNELIZATION ALTERNATIVE
PATE ENGINEERS, INC.
EXHIBIT NO. 6
DATE: AUGUST, 1988
JOB NO. : 324-2-4


WATERSHED BOUNDARY
S.H. 105
I - 45
CITY OF CONROE
U.S. 75
STEWARTS CREEK
LOOP 336
F.M. 1314
F.M. 1484
BOTTOM WIDTH = 95 ft
SIDE SLOPE = 3 : 1
BOTTOM WIDTH = 95 ft
SIDE SLOPE = 3 : 1
MONTGOMERY CO. AIR PORT
PANORAMA VILLAGE



LEGEND

REGIONAL DETENTION POND

EARTHEN TRAPEZOIDAL CHANNEL

AREA REGULATED USING ONSITE DETENTION

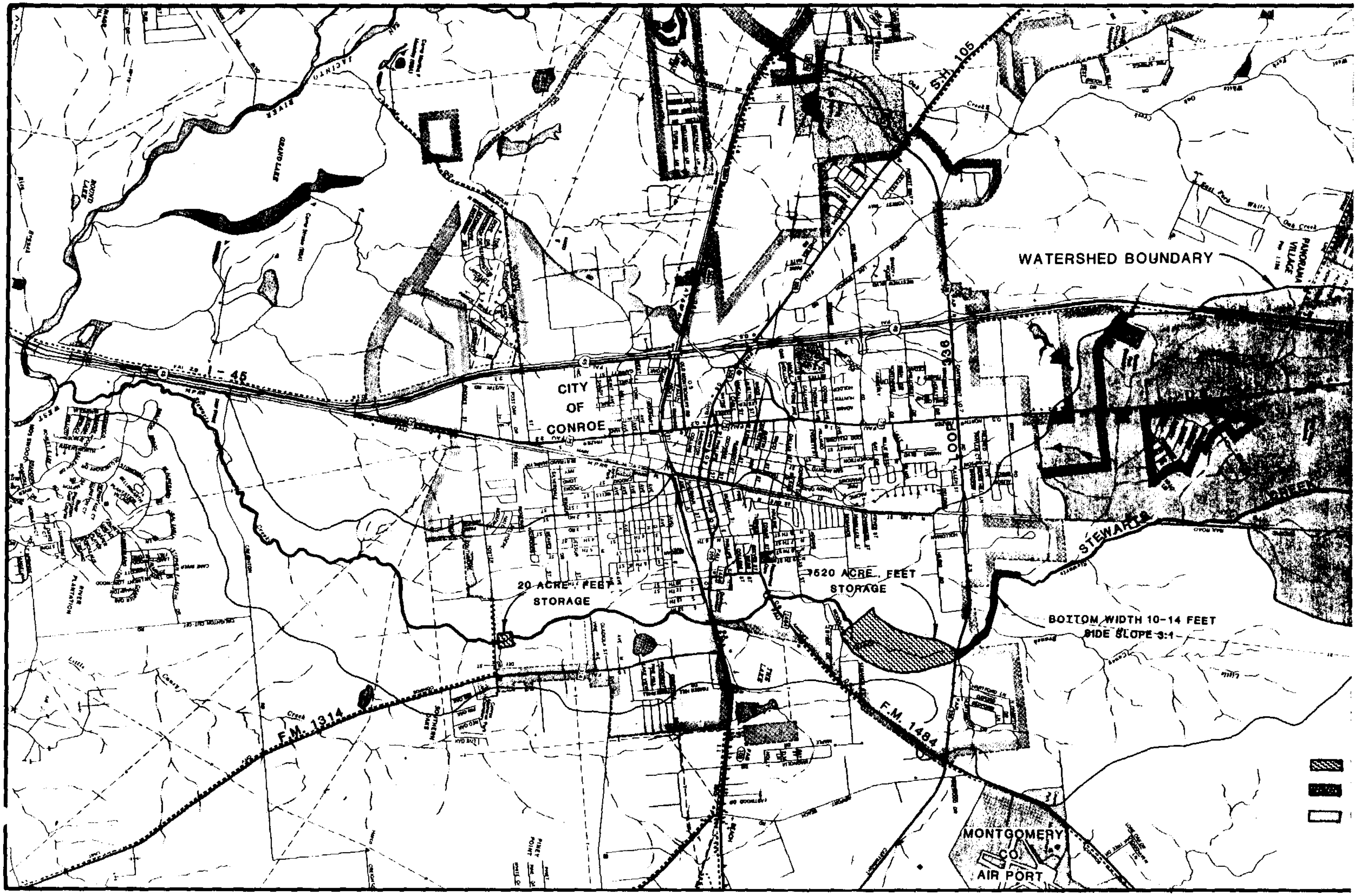
SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

REGIONAL DETENTION ALTERNATIVE

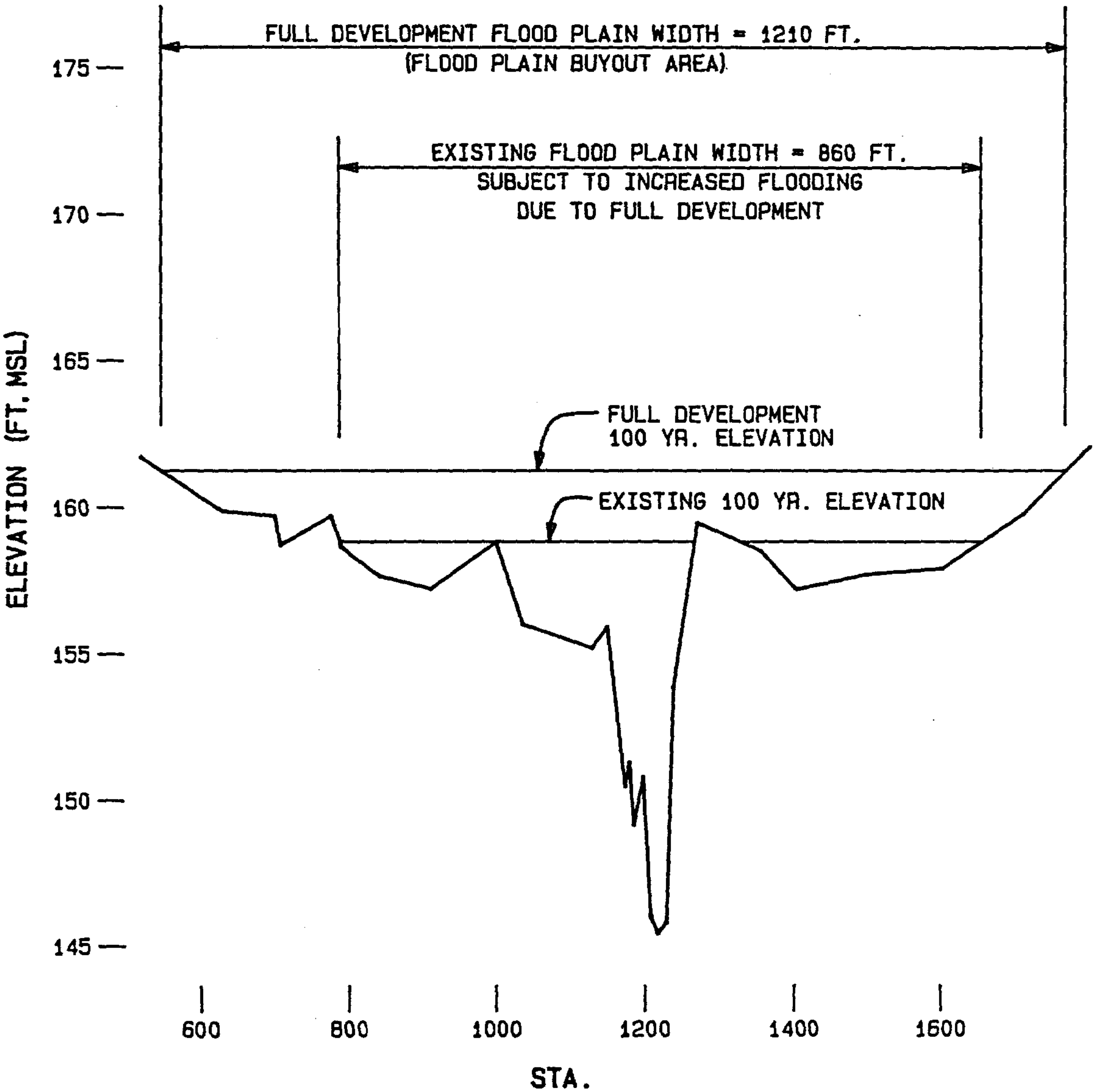
PATE ENGINEERS, INC.

EXHIBIT NO. 7

DATE: AUGUST, 1988 JOB NO.: 324-2-4



S.H. 105
WATERSHED BOUNDARY
PANORAMA VILLAGE
I - 45
CITY OF CONROE
LOOP 336
STEWARTS CREEK
20 ACRE - FEET STORAGE
520 ACRE - FEET STORAGE
BOTTOM WIDTH 10-14 FEET
SIDE SLOPE 3:1
F.M. 1314
F.M. 1484
MONTGOMERY CO. AIR PORT
RIVER PLANTATION



SCALE: 1"= 200' H.
SCALE: 1"= 5' H.

SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

TYPICAL CROSS-SECTION
ON STEWARTS CREEK
FLOODPLAIN BUYOUT

PATE ENGINEERS, INC.
P.O. BOX 924034 HOUSTON, TX 77292 - 4034
PHONE 713 - 462 - 3178

EXHIBIT NO. 8

DATE: FEB., 1989

JOB NO.: 324-2-4

SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN
WATER QUALITY PLAN

PREPARED BY:

PATE ENGINEERS, INC.
WITH MATCHING FUNDS PROVIDED BY
THE TEXAS WATER DEVELOPMENT BOARD

JUNE 1988

SAN JACINTO RIVER AUTHORITY
WATER RESOURCE DEVELOPMENT PLAN
WATER QUALITY PLAN

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SECTION I

INTRODUCTION

PURPOSE

The effective use of water resources is a growing concern of Texas citizens. Clean water is essential for fish and wildlife, recreation, and most importantly the protection of public health and water supplies. The enjoyment of lakes and streams is a prime ingredient in the quality of life an area can offer to attract economic investment in the community. In addition, State policy has been re-shaped in recent years to place more emphasis on total water resource management. The Texas Water Plan adopted by the voters in 1985 not only revitalized State water financial assistance programs, but also broadened those programs to cover regional water and wastewater projects and flood control projects for growing urban areas. State policy was also changed to promote conservation of water resources through reuse and reduction of consumption.

The existing institutional framework within the State reserves authority for planning and implementing specific water resource projects to local units of government, including river authorities. In many instances, an existing river authority may be the only local entity capable of long-term planning and implementation to meet changing needs as urban growth occurs in previously rural areas. These changing local circumstances as well as policy changes at the State level represent a challenge to local government, particularly entities with regional scope such as river authorities, to provide for effective water resource management programs that meet the needs of local areas and that reflect current State water policy.

Responding to that challenge, the San Jacinto River Authority (SJRA) authorized this study to define a comprehensive water resources development plan. The purpose of the study is to define a plan that 1) addresses the water supply, water quality, and flood control needs of the rapidly urbanizing service area of the Authority; 2) provides guidance for implementing specific water resource projects within the service area; 3) examines the relationship of the Authority to the larger metropolitan region of which it is part and evaluates broader regional projects in which the Authority may play a productive role; and 4) is consistent with State policy.

AUTHORIZATION

This study was authorized by the San Jacinto River Authority by contract dated December 1, 1986. Matching funds were provided by the Texas Water Development Board.

SCOPE

The Water Resources Development Plan is presented in three volumes. Volume I presents the Water Supply Plan, Volume II presents the Flood Control Plan and Volume III presents the Water Quality Plan.

The scope of work of the Water Quality Plan addressed in this volume has been defined as follows:

- Collect and review data on stream quality within the defined planning area.
- Collect and review data on all existing wastewater treatment facilities.
- Identify level of compliance with stream standards and point source effluent quality standards.
- Estimate current and future stream waste loadings and compare to available waste load allocations.
- Define water quality concerns.

- Develop strategies to resolve operating and waste loading concerns in coordination with the Texas Water Commission.
- Evaluate the SJRA role in implementing the water quality protection plan.

SAN JACINTO RIVER AUTHORITY: THE FIRST FIFTY YEARS

The San Jacinto River Authority was created by the Texas Legislature in 1937 and is one of 15 major river authorities in the State of Texas. Over the past fifty years, the Authority has implemented soil conservation, water supply, wastewater treatment, flood control, and recreation programs. The SJRA's watershed area includes all of Montgomery County and portions of Waller, Grimes, San Jacinto, and Liberty Counties and contains approximately 1,200 square miles. It is empowered to and does operate facilities both within and outside of these boundaries as shown on Exhibit No. 1. The SJRA first implemented its soil conservation and reclamation program in 1946 in cooperation with agencies of the U.S. Department of Agriculture. The Authority purchased heavy equipment and provided interim financing for the construction of improvements to prevent erosion, reduce flooding, and restore soil fertility. More than $1.5 million was invested in individual projects which included over 400 small lakes and stock tanks, 150 miles of field terracing, 75 miles of water diversion channels, and the leveling of hundreds of acres of gullied land in preparation for reforestation or pasture use.

The Authority's first water supply project was the purchase in 1945 of the Highlands Canal System serving industrial and agricultural customers in southeast Harris County with water supply contracts currently totaling 66.5 million gallons per day (MGD). The canal system facilities presently include a 100 MGD pump station at Lake Houston Dam, 38 miles of canal, and the 1,400 acre Highlands Reservoir. In 1970, the San Jacinto River Authority constructed Lake Conroe in conjunction with the City of Houston and the Texas Water Development Board. Located in northwest Montgomery County, the 22,000 acre Lake Conroe has a firm yield of 89.3 MGD. In 1976,

the Authority began its septic tank licensing and inspection program for all areas within 2,000 feet of the Lake Conroe shoreline. Although its primary purpose is water supply, it also provides recreation benefits.
In 1975, the Authority entered into contractual agreements with The Woodlands Corporation and the associated municipal utility districts (MUDs) whereby the Authority owns and operates the regional water supply and wastewater treatment facilities serving The Woodlands. The Authority acts as a wholesaler of water and wastewater services to the nine existing MUDs encompassing 9,000 acres and an existing resident population of approximately 23,000. Currently, the regional water supply facilities include seven wells and two storage and pumping plants capable of producing 20 MGD at peak demand. The regional wastewater collection and treatment system has a total treatment capacity of 6.1 MGD in two plants. These water and wastewater facilities will be expanded to serve a projected population of approximately 140,000 people at ultimate development of The Woodlands.

In recent years, SJRA has continued to pursue regional planning to address the long-term needs of the basin. In cooperation with the Texas Department of Water Resources, SJRA prepared a Water Quality Management Plan for the San Jacinto River Basin in 1978. The San Jacinto Upper Watershed Drainage Improvement and Flood Control Planning Study was prepared in 1985. In 1982, the SJRA sponsored the Bureau of Reclamation's San Jacinto Project investigation which has resulted in the Bureau's preliminary recommendation for construction of the Lake Creek reservoir. The Bureau's study is on-going. In 1986, the Authority commissioned a feasibility study of the purchase of water from Toledo Bend Reservoir and its conveyance to Lake Houston.

PLANNING EMPHASIS

The San Jacinto River Authority's principal water resource activity has historically been the provision of public water supply, and based on the analysis developed in the Water Supply Plan, there will be a critical need in Montgomery County for a regional agency to implement surface large water supply projects. The Authority's water quality management activities have been developed around the objective of protecting surface water supply sources with a recognition of the strong role that the Texas Water Commission plays in water quality standards, permitting, and enforcement. This study examines the existing and future water quality concerns due to the continued urban development in Montgomery County with a focus on the SJRA's role in protecting future surface water supplies in the basin.

SECTION II

BACKGROUND AND EXISTING CONDITIONS

GENERAL

The existing water quality in Montgomery County's streams is very good overall due to the continuing management efforts of both State and local agencies. Since 1978, when the 208 Water Quality Management Plan found water quality in Montgomery County to be generally good, a number of water quality concerns have been identified and subsequently addressed with appropriate planning, regulatory, and/or capital improvement responses. All stream segments in the County are presently designated by the Texas Water Commission for public water supply, contact recreation, and high quality aquatic habitat with appropriately high water quality standards established for each. All streams are in substantial compliance with standards with the exception of fecal coliform concentrations.

Some dissolved oxygen standard violations have occurred, notably in the West Fork of the San Jacinto River and Spring Creek. In response, the Texas Water Commission prepared Spring Creek and West Fork waste load evaluations which require advanced wastewater treatment for all facilities in these segments. The City of Conroe has made extensive capital improvements to its regional wastewater collection and treatment system, including expanding the overloaded Southwest treatment plant and abandoning the obsolete Southeast treatment plant.

The degree of fecal coliform noncompliance is the result both of a large number of natural and manmade sources, including septic tanks and wastewater treatment plants, and a strict contact recreation water quality standard. The generally poor performance of septic tanks in many areas of Montgomery County, as well as other areas in Texas, has been recognized for years. In response, Montgomery County, the San Jacinto River Authority, and the State Department of Health have recently revised regulations and minimum construction standards for on-site sewage facilities imposing much stricter requirements on new installations. In addition, a number of septic tank areas have been provided with central sewage collection and treatment systems, including New Caney Municipal Utility District, Porter Municipal Utility District, and the Artesian Lakes/McDade Estates subdivisions within the City of Conroe.

Growing concerns over water quality in Lake Houston led to the TWC imposing the Lake Houston Watershed Rule, which requires advanced wastewater treatment for all permitted dischargers in Montgomery County, except those located in the Lake Conroe watershed which must also provide advanced wastewater treatment in accordance with TWC's public water supply rule. Advanced treatment combined with improved solids management required by the Rule will improve overall compliance with the streams' dissolved oxygen and fecal coliform standards.

There are presently 118 wastewater discharge permits issued by the Texas Water Commission in Montgomery County, 88 of which are actively discharging. About 40 percent of these active wastewater plants are relatively small having treatment capacities less than or equal to 50,000 gallons per day, whereas 11 percent have treatment capacities of over 500,000 gallons per day. Approximately 88 percent of these treatment plants are generally compliant with their respective effluent water quality standards. Permit noncompliance appears in most cases to be due to underloaded conditions or operational/maintenance problems as opposed to overloaded conditions, which are apparently responsible in only three cases.

This section will briefly describe previous studies, current water quality management, current stream water quality standards compliance, current wastewater treatment plant compliance, and the impact and regulation of septic tanks.

208 WATER QUALITY MANAGEMENT PLAN

Section 208 of the Federal Clean Water Act requires the states to perform areawide wastewater treatment management planning. Montgomery County, except for the portion which lies within the Spring Creek watershed, is located within the San Jacinto Basin Nondesignated Planning Area. In 1978, the San Jacinto River Authority prepared portions of the 208 Water Quality Management Plan for this area under contract to the Texas Department of Water Resources (TDWR). Subsequent update tasks have also been performed by SJRA for the TDWR, including an assessment of nonpoint source pollution problems in the West Fork of the San Jacinto River completed in 1984.

The 208 planning process identified water quality problem areas based on a review of in-stream water quality data, assessed the need for higher treatment levels in each stream based on a projection of future waste loads, defined wastewater treatment facilities expansion required in specific service areas, and selected the management agency(ies) best capable of implementing the areawide plan. The San Jacinto Basin Water Quality Management Plan recommended that the State continue to have responsibility for a majority of the required management functions including permitting, standard setting, design criteria, monitoring, enforcement, planning, and coordination. The design, construction, operation, maintenance and financing of wastewater treatment facilities are local activities and thus were recommended to remain the responsibility of local and regional entities.

STREAM WATER QUALITY COMPLIANCE

In 1985, the Texas Department of Water Resources was reorganized into two State agencies: the Texas Water Commission (TWC) and the Texas Water Development Board (TWDB). The Texas Water Commission is the principal State water pollution control agency with the responsibilities for planning, permitting, design criteria, monitoring, enforcement, and coordination with the Federal Environmental Protection Agency (EPA). Most Federal water pollution control programs are implemented through the TWC with guidance and financial assistance provided by EPA. The Texas Water Development Board administers the State's financial assistance to local and regional entities for facilities planning and construction. The Texas Department of Health (TDH) administers the on-site treatment system (septic tank) management programs including defining minimum design criteria, although the TWC must authorize the septic tank regulations of water district, river authorities, and counties.

The Texas Water Commission's regulatory process is based on the geographic subdivision of the State into watershed or subwatershed units called stream segments. Stream segments are delineated based on similarity of characteristics including hydrology, habitat, and desired surface water uses. The delineation of the stream segments located in Montgomery County are shown on Exhibit No. 2. The stream segments partially located within Montgomery County are Spring Creek, West Fork of the San Jacinto River, Lake Conroe, Caney Creek, Peach Creek, East Fork of the San Jacinto River, Lake Creek, and Lake Houston. Only a very small portion of the Lake Houston and East Fork stream segments are located within Montgomery County, and are therefore not included in the geographic scope of this study. Lake Houston is wholly within Harris County. A large portion of Lake Houston stream segment is in the Greater Houston Designated Planning Area and under the 208 planning jurisdiction of the Harris-Galveston Area Council. All streams in the County are designated for the same three uses: public water supply, contact recreation, and high quality aquatic habitat.

The TWC establishes surface water quality standards for each segment to insure that water quality will be sufficient to maintain the designated uses. The seven principal water quality parameters for which numerical criteria are set for each stream segment are: (1) dissolved oxygen, (2) temperature, (3) pH (acidity), (4) chloride, (5) sulfate, (6) total dissolved solids, and (7) fecal coliform. The current water quality standards for the stream segments in Montgomery County are shown in Table No. 1.

Based on a review of stream sampling data compiled by the Statewide Monitoring Network and reported in the TWC's State of Texas Water Quality

Inventory, 8th Edition (1986) and 9th Edition (1988 Draft), compliance with the applicable surface water quality standards in Montgomery County is generally very good with the exception of the fecal coliform standard. The Water Quality Inventory reports present cumulative sampling results over four year periods which overlap: 1981-1985 and 1983-1987. A summary of the percent of noncompliant samples for each water quality standard for the two reporting periods is presented in Table No. 2.

All streams were predominantly compliant with the dissolved oxygen, temperature, pH, chloride, and sulfate water quality standards, for the recent period of 1983 through 1987. No stream had a significant percentage of noncompliant dissolved oxygen samples, Spring Creek had the highest with three percent. Spring Creek was the only stream to have a significant percentage (19%) violation of the total dissolved solids (TDS) standard. There appears to be a slight improvement in the degree of compliance betweeen the two reporting periods (from 1981-1985 to 1983-1987) in these six water quality standards.

In contrast to the other surface water quality standards, the percentage of noncompliant fecal coliform samples is significantly higher in all stream segments except Lake Conroe, ranging from 16 percent to 45 percent for the recent four year period. Fecal coliforms are a type of nonpathogenic bacteria found in the intestines of all warm blooded animals which are used as an indicator of fecal contamination of streams, and thus the potential presence of disease causing microorganisms. Sources of fecal coliform bacteria include inadequately treated sewage, septic tank overflow, domestic pets, livestock, and wild birds and mammals. The large number of possible sources makes identification of the specific cause of the stream standard violations difficult.

Septic tank areas have been demonstrated to be one of the sources of fecal coliforms in Montgomery County streams. Many subdivisions in the County utilize individual septic tank systems to treat domestic wastewater. Septic tanks do not function well in certain areas because of low percolation rates and climatic conditions, and numerous complaints concerning poor operation have been received by the State and County health departments.

As a result, the Texas Department of Water Resources conducted an investigation in 1982 to determine if septic tank subdivisions were causing bacterial contamination in Montgomery County surface waters. Water quality samples were collected downstream of eleven different drainage basins which were either undeveloped basins, developed basins served by organized wastewater collection and treatment systems, or developed basins served by individual septic tank systems. Sampling was performed on four different days during or following a significant rainfall event and analyzed for several bacteriological and chemical parameters.

The results demonstrated that occasionally high fecal coliform levels exist during wet weather conditions in all three types of basins, however, the average fecal coliform concentration downstream of the septic tank communities was four times that found downstream of undeveloped or sewered areas. In addition, the ratios of fecal coliform to fecal streptocci indicated that the bacterial levels were more frequently caused from human waste contamination, as opposed to animal waste contamination, in the septic tank areas than in the other two types of areas.

As part of the 208 Water Quality Management Plan Update, the San Jacinto River Authority completed a Nonpoint Source Impact Study of the West Fork of the San Jacinto River (Segment 1004) in March 1984. In addition to the TDWR study discussed above, water quality data from two other field investigations were analyzed. In one study under summer low-flow conditions, the West Fork experienced low dissolved oxygen, elevated nutrient and fecal coliform concentrations in the upper and middle reaches. The primary causes of these conditions were identified by the TDWR as the overloaded conditions at the City of Conroe's Southwest and Southeast wastewater treatment plants. Since that time, Conroe has abandoned the Southeast Plant and diverted flow to an expanded and upgraded Southwest Plant.

During a wet-weather sampling program conducted by SJRA in 1982, fecal coliform counts substantially above 200/100 ml were found in the West Fork and three tributaries, Stewarts Creek, Crystal Creek, and Lake Creek. The undeveloped Lake Creek had significantly lower values than the other two tributaries. The data showed that fecal coliform concentrations dropped back to low levels after the storm events. The SJRA concluded that both point and nonpoint sources, including poorly functioning treatment plants, septic tank overflows, and urban and rural stormwater runoff, have probably contributed to high fecal coliform levels. It was further concluded that the fecal coliform criteria will probably continue to be exceeded during wet weather flows, even after improvements to wastewater treatment plants and septic tank systems are made, because high fecal coliform levels are found to occur in undeveloped watersheds.

WASTEWATER TREATMENT PLANT COMPLIANCE

The Texas Water Commission establishes the effluent quality standards required for discharges from wastewater treatment plants in order to maintain each stream segment's designated water quality standards. Wasteload evaluation studies determine the required level of wastewater treatment by comparing the allowable wasteload a stream can assimilate to the projected waste load. The principal concern in Texas streams has been maintaining adequate dissolved oxygen, and so waste load evaluations have focused on concentrations of biochemical oxygen demand, ammonia nitrogen, and dissolved oxygen in the effluent discharged from treatment plants. The segment classification, date of the last waste load evaluation, and required effluent quality standards for domestic wastewater treatment plants for the stream segments in Montgomery County are presented in Table No. 3.

At a minimum, all wastewater treatment plants in the State are required to provide secondary treatment as defined by the TWC (monthly average BOD5 20 mg/l). However, all dischargers in Montgomery County are required to provide an advanced level of treatment (monthly average BOD5 10 mg/l). In addition, most dischargers are required to provide an ammonia nitrogen removal so that the monthly average is 3 mg/l or less. This significantly higher level of treatment is in response to dissolved oxygen violations and continued urban growth.

Waste load evaluations were recently prepared for Spring Creek (1984) and the West Fork (1986). On the basis of these evaluations and concerns over the deterioration of water quality in Lake Houston, the Texas Water Commission adopted the Lake Houston Watershed Rule in June, 1985 requiring advanced wastewater treatment for all dischargers in the entire drainage area of Lake Houston, with the exception of Lake Conroe. These treatment levels shall be achieved for all new and existing permitees by July 1, 1988, although extensions up to January 1, 1990 may be granted by the Texas Water Commission on a case-by-case basis. A copy of the Lake Houston Watershed Rule is included for reference in Appendix C. Advanced wastewater treatment is also required for most dischargers in Lake Conroe due to the TWC "lake rule", which requires an advanced level of treatment for any discharge made within five (5) miles upstream of a reservoir which may be used as a public drinking water supply or is subject to certain septic tank regulations.

There are presently 118 wastewater dischargers in Montgomery County permitted by the TWC with a total treatment capacity of 33.7 MGD. Of these permitted facilities, 88 are constructed and in operation with a capacity of 30.3 MGD. About 40 percent of the treatment plants are relatively small having a design capacity of 50,000 gallons per day or less, whereas 11 percent are facilities with a design capacity of over 500,000 gallons per day. Table No. 4 presents the distributions of permitted discharges by stream segment and treatment capacity. Most of the dischargers (82 percent) and the capacity (88 percent) of the active permits are located within just three of the County's watersheds: West Fork, Spring Creek, and Lake Conroe. The location of these discharges is shown on Exhibit No. 3.

Based on an analysis of effluent quality data over the twenty month period from January, 1986 to August, 1987 from the TWC Self Reporting System, most of the wastewater treatment plants in Montgomery County (76 of 88, or 86 percent) are generally compliant with permitted effluent quality standards.

This corroborates the finding of good compliance with surface water quality standards.

For the purposes of this study, a discharger's effluent quality is considered generally compliant if it satisfies both of the following conditions: (1) the twenty month averages of flow, BOD, and TSS are lower than the permitted monthly average values; and (2) the combined number of monthly violations over the twenty month period of flow, BOD, and TSS is less than seven. The first condition represents a long-term indicator of plant performance and the second condition identifies dischargers with a notable number of monthly violations which otherwise "average out" over the twenty month period. These data are summarized by discharger and by stream segment in Table No. 5. On the basis of this definition, 76 of the 88 wastewater dischargers in Montgomery County are generally compliant with their respective permits over the period of January, 1986 through August, 1987.

Probable causes of non-compliance are difficult to judge even for the owner and operator of a treatment facility. The most obvious cause of non-compliance is a facility operating at a flow above design capacity. Significant underloading can also be a problem due to the difficulty in maintaining a healthy biological process. Based on a review of reported average monthly flows, the probable cause of non-compliance is judged to be overloading for three dischargers and underloading for four other dischargers. For the remaining five dischargers, the probable cause of non-compliance is likely due to operational problems including inadequate solids management.

In addition, the proportion of non-compliant facilities with treatment capacities less than 50,000 GPD is higher than the proportion of all permitted facilities less than 50,000 GPD capacity (75% versus 41%). This indicates that the smaller facilities are more prone to non-compliance due to various factors including irregular loadings, susceptibility to shock loads, and lack of adequate operation attention. The small size of these facilities means that the individual impact of non-compliant discharges is often also small to overall water quality.

SEPTIC TANK REGULATION

The Texas Department of Health has the primary responsibility in the State for the regulation of private on-site sewage facilities (including septic tanks) from which there is no open discharge to the ground. TDH establishes and publishes the Construction Standards for Private Sewage Facilities which determine the minimum criteria which must be applied by any political subdivision within the State regulating septic tank facilities, including river authorities, counties, and cities. The TWC must authorize counties and river authorities to regulate on-site facilities by issuance of a waste control order.

Montgomery County began regulating septic tanks in 1974, coinciding with the rapid subdivision development which began in the early 1970's. Prior to that time, septic tank installation in the County was essentially unregulated. After 1974, design and construction of septic tank systems was required to meet the minimum standards established by the Texas Department of Health. In response to a TWC waste control order, the San Jacinto River Authority began regulating the installation of septic tanks in areas within 2,000 feet of the shoreline of Lake Conroe in 1976. The Authority updates its rules to generally match those established by Montgomery County and coordinates with the Montgomery County Health Department so that there is no overlap in septic tank licensing and inspection.

In spite of these regulatory efforts, a combination of factors resulted in a large number of subdivisions with septic systems which were not functioning properly. These factors included generally poor soil suitability, high rainfall, construction in the floodplain, lot densities similar to subdivisions with central sewage collection systems, and poor compliance with septic tank regulations.

In response to these problems, Montgomery County began in the early 1980's to place requirements stricter than the TDH minimum standards on private sewage facilities and to strengthen enforcement against "red flag" subdivision development. In 1983, the County prohibited construction of septic tanks in the 100-year floodplain. Since septic tank problems and the resulting exposure to public health risks directly relate to lot size, the County adopted revised rules in 1986 for private sewage facilities significantly increasing the minimum platted lot sizes allowed for septic tank installation from 15,000 square feet to 43,560 square feet (one acre). The larger minimum lot sizes increase the available area for the drain field, and provides additional land for an alternate drain field should the initial system fail. The SJRA supported these rule revisions and requested the TWC to approve similar revisions to its septic tank regulations.

The County minimum lot sizes are larger than the minimums required by the 1977 TDH standards and even the revised 1988 TDH standards, as the comparison in Table No. 6 shows. These rules reflect the Authority's and the County's recognition of the need for more stringent standards in Montgomery County than the statewide minimums due to local conditions and their resolve to address the septic tank problem.

SECTION III

ASSESSMENT OF WATER QUALITY CONCERNS

In the previous section, the current status of compliance with surface water quality standards and waste discharge permit standards was examined. In both areas compliance with the Texas Water Commission's standards was very good, with the exception that fecal coliform concentrations in most streams exceeded the established standard. Of the few wastewater treatment plants with significant or chronic compliance problems, overloading is judged to be the probable cause in only three plants. In fact, many facilities have available capacity for additional population growth. This demonstrates that local entities in Montgomery County are performing well in the construction and operation of wastewater treatment facilities.

Regulatory agencies have addressed water quality problems as they have arisen. Rapid population growth and occurrence of low dissolved oxygen levels in the Spring Creek and West Fork watersheds prompted the TWC to perform updated Waste Load Evaluations resulting in the requirement of higher levels of wastewater treatment. Increasing concerns for water quality in Lake Houston led to promulgation of the Lake Houston Watershed Rule which requires higher levels of wastewater treatment, solids management programs, and specific triggers for plant expansions in the Lake Houston, Caney Creek, Peach Creek, and East Fork stream segments. The stepped up enforcement program of the Texas Water Commission since 1985 has improved compliance with point source standards.

High fecal coliform concentrations have been addressed through more stringent septic tank regulations by the San Jacinto River Authority, the higher level of wastewater treatment and solids management required by the Lake Houston Watershed Rule, and the enforcement activities of the State. Capital improvement projects by local entities including facilities expansions (e.g., Conroe) and septic tank area conversions (e.g., New Caney MUD, Porter MUD, Conroe) will also improve compliance with fecal coliform stream standards. The Texas Water Commission is currently assessing the nature, magnitude, and best management practices for non-point sources from which additional control programs may emerge.

Previous non-point studies in Montgomery County have found fecal coliform levels exceeding the standard during wet weather even in undeveloped watersheds, presumably from livestock, wild animals and birds. It is reasonable to expect that some degree of non-compliance with the fecal coliform standard will continue to occur due to natural background sources.

PROJECTED WASTE LOADS

The continued urbanization of Montgomery County will produce additional waste loads to the streams which could potentially impact surface water quality. In order to evaluate the potential for future water quality problems, a projection of waste loads in terms of lbs. BOD5 per day was made and compared to existing waste loads, permitted waste loads, and the projected waste loads estimated in either the 208 San Jacinto Basin Water Quality Management Plan prepared by the San Jacinto River Authority in 1978, or more recent waste load evaluations prepared by the Texas Water Commission if available. The projected waste loads in these studies were determined to be assimilated in the respective streams without causing a violation of minimum dissolved oxygen standards.

The 208 Plan projected waste loads for the year 2000, as did the West Fork Waste Load Evaluation. This target year is still an appropriate water quality planning horizon for individual stream segments since it provides adequate time for local entities to respond to any capital or operational improvements which may be determined necessary to protect water quality through the planning period. An evaluation of total waste load in Montgomery County for the projected year 2010 population has been conducted to provide a longer term focus for water quality activities.

Domestic waste loads for the year 2000 were estimated in this study based on the 1986 TWDB (High Series) population projections selected for use in the

Water Supply Plan. The TWDB High Series population projection for Montgomery County (291,000 persons) is higher than the County projection used in the previous 208 Plan (197,000 persons). Projected populations in this study were apportioned to stream segment watersheds on an area basis. The portion of the existing (1985) population not served by central wastewater collection and treatment systems is assumed to remain on septic tanks in the future. All increases in population beyond 1985 are assumed to be served by central facilities as opposed to septic tanks. Effluent quality is based on application of the advanced wastewater treatment requirements now in effect, which is half of that assumed in the 1978 208 Plan due to changes in standards (10 mg/l BOD_5 versus 20 mg/l BOD5 in the 1978 plan).

The existing and projected waste loads for five stream segments in Montgomery County are shown in Table No. 7. The Stream Segment 1002 was not included in the waste load evaluation because it is being included in the Lake Houston evaluation currently being conducted. In every stream, the existing waste loads, based on actual reported wastewater treatment plant performance in 1986, are significantly less than the total permitted waste loads found by summing the allowable monthly average discharges for each existing permit. This is a result of existing surplus capacity, good treatment plant performance, and permitted but unconstructed facilities.

In all of the streams, the currently permitted waste loads are greater than the allowable waste loads determined from recent waste load evaluations or the 208 Plan. In the case of the West Fork, the total permitted load reflects a majority of permits which have not yet been revised to reflect the more stringent BOD5 effluent quality standard (10 mg/l). Once this standard is taken into account, the total permitted waste load will be approximately the same as the allowable waste load. In the other streams, the difference appears to be due to higher total permitted capacities than will be required by projected population growth through the year 2000.

The waste loads projected in this study for the year 2000 are less than the respective previously projected 208 Plan allowable waste loads for the West

Fork, Peach Creek and Lake Conroe, as shown on Table No. 7. The projected Spring Creek waste load is approximately equal to the allowable load. These projected waste loads reflect that the higher population projections used in this study of the projected waste loads will be offset by the higher levels of wastewater treatment now required by the Lake Houston Watershed Rule. In the case of Caney Creek, the projected load is somewhat higher than the 208 Plan projected waste load (117 lbs BOD5/day versus 85 lbs BOD5/day). Since the existing waste loading is so low (11 lbs BOD5/day), it will be a number of years before actual loading actually approaches the 208 Plan loading.

To project BOD_5 waste loading on a countywide basis through the year 2010, which provides a 20 year planning horizon, the projected waste load for the year 2000 was pro-rated using population projections for these two years. The population is projected to increase by 50 percent in this ten year period as indicated in the Montgomery County population projections (Table 2 of Volume I of this report). The countywide waste load may also be expected to also increase by 50 percent assuming the higher quality effluent quality permit limits. The projected year 2010 waste load using this method is 3,325 lbs/day (2,213 lbs/day for year 2000 x 1.5 - see Table No. 7) which is less than the current cumulative permitted loading of 4334 lbs/day.

Overall, the projected domestic waste loads in this study indicate that current effluent quality standards in Montgomery County defined by the Lake Houston Watershed Rule and, in the case of Lake Conroe, the TWC "lake rule", should be adequate for the next 5 to 10 years. On the basis of these observations, it is concluded that the current water quality management program encompassing the activities of State and local agencies is functioning well in protecting water quality and in identifying and responding to water quality concerns. The primary goal for the San Jacinto River Authority in water quality management is to protect surface water quality for existing and future water supply purposes. The Authority's current water quality management activities program, including planning, septic tank regulation, and operations and maintenance of wastewater collection and treatment facilities, have been successful in this regard and should be continued.

FUTURE SERVICE NEEDS

The evaluation of historical treatment operations presented in this report shows that water quality standards are met or exceeded by a predominant number of facilities and that waste loads will not exceed that currently allowed levels through this study's planning horizon. Therefore, no cost evaluations of proposed service alternatives are presented in this report. However, certain issues relating to long term water quality planning bear discussion. Previously, noted in this report is the assumption that the existing level of septic system service will not increase and that future growth will be accommodated by permitted treatment facilities. This assumed limit on septic system utilization will serve to control the fecal coliform levels currently being experienced.

A review Table No. 5 shows six plants in the study area that exceeded 75 percent of design capacity. Under current guidelines of the Texas Water Commission, the four plants that exceed 90 percent of design capacity should undergo expansion, and the other two facilities should commence with expansion design activity. Prior to requiring design or construction activity, the permittee should be allowed to prepare an analysis of their onground facilities, historical operating records, and potential for increased demands in their service areas to ascertain the specific requirement for plant expansion or, alternatively, adustment of the permitted treatment capacities.

Regional wastewater treatment facilities currently serve two of the major urban areas in Montgomery County: The Woodlands and the City of Conroe. This trend towards regionalization should continue as development densities increase and analysis of participation in regional facilities required in the Texas Water Commission permit application process demonstrates the feasibility. The regionalization process can be further enhanced by an entity such as the San Jacinto River Authority willing and capable of assisting individual developments in the organization, operations and management of regional wastewater collection and treatment systems.

The development density in Montgomery County is still very low except in the areas of concentrated urban development already referenced. Development of a facility plan for regionalization is, therefore, premature. For regionalization to be successful, the location of facilities must accommodate to actual development patterns rather than attempting to force development patterns to mold to a predefined regionalization plan.

The details of development patterns, including major street alignments, land use densities, topography, discharge location and the type of private and public entities requiring service all affect water quality benefits and the economic feasibility of a regional plan. Furthermore, planning at the facility plan level should be accomplished with the direct involvements of the proposed local participants in order to develop an acceptable implementation program.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The existing water quality in Montgomery County streams is very good. Overall compliance with the established surface water quality standards occurs over 95 percent of the time, excepting fecal coliform. All stream segments except Lake Conroe have experienced significant non-compliance with the fecal coliform standard. Sources of this fecal coliform contamination in Montgomery County have been shown to be both manmade and natural. Local and State agency management responses addressing the fecal coliform problem include much stricter septic tank regulations, requirements for advanced wastewater treatment with improved solid management, and stricter permit enforcement.

Most of the wastewater treatment facilities in Montgomery County (76 of 88) are generally compliant with the permitted effluent quality standards. Of the twelve non-compliant facilities, the probable causes of non-compliance are judged to be overloading in three cases, underloading in four cases, and operation problems including inadequate solids management in the remaining five cases. Overloading is not presently a problem and many existing facilities have capacity available for growth.

In response to occasional dissolved oxygen violations and concern over continued urban growth, wastewater treatment facilities in Montgomery County are required to provide advanced wastewater treatment either by the Spring Creek and West Fork waste load evaluations, the Lake Houston Watershed Rule, or, in the case of Lake Conroe, the TWC's lake rule regarding water supply sources. While development in some portions of Montgomery County have not yet reached a density to make regionalization feasible, two of the County's most concentrated urban areas, the City of Conroe and The Woodlands, are currently organized into regional wastewater collection and treatment systems representing 49 percent of the County's treated wastewater flow.

It is concluded that the current water quality management in Montgomery County is effective in maintaining surface water quality and responsive to water quality problems. State, regional and local agencies, including the Authority, have all fulfilled their respective cooperative roles as recommended in the 208 Water Quality Management Plan.

RECOMMENDATIONS

It is recommended that the San Jacinto River Authority continue to perform its current water quality management functions. No additional roles are presently considered necessary to protect future water quality. This is not to say that existing functions such as treatment plant operations should not be expanded to respond to service area growth. In particular, the Authority should continue its role as the local planning agency for the San Jacinto Basin Nondesignated 208 Water Quality Management Plan. SJRA should review stream water quality data in Montgomery County on an annual basis to determine if the currently high levels of compliance continue to be maintained and notify the appropriate State or local management agency as water quality concerns are identified.

It is recommended that the Authority continue its septic tank licensing and inspection program around Lake Conroe and institute a similar septic regulation programs around the proposed Lake Creek and Spring Creek Lake reservoirs in the future in order to have direct sanitary control within 2000 feet of these water supply reservoirs.

It is recommended that the Authority continue to respond to requests for assistance in the organization, operations and management of wastewater collection and treatment systems. This may take the form of an advisory role in which the Authority assists local entities in developing an implementation plan including application for State financial assistance for planning and construction. Or the Authority may be invited to own, operate and manage a regional system in a manner similar to The Woodlands.

It is recommended that the Authority monitor future demands and permit applications so they may recognize potential areas for promoting regionalization of treatment services as development density increases and facilities are being expanded.

LIST OF EXHIBITS

EXHIBIT NO. 1 SJRA Watershed Area and Facility Locations

EXHIBIT NO. 2 Stream Segments in Montgomery County

EXHIBIT NO. 3 Location of Permitted Wastewater Treatment Facilities

LIST OF TABLES

TABLE NO. 1 Surface Water Quality Standards for Stream Segments in Montgomery County

TABLE NO. 2 Stream Water Quality Compliance in Montgomery County

TABLE NO. 3 Effluent Quality Standards for Stream Segments in Montgomery County

TABLE NO. 4 Wastewater Treatment Facilities in Montgomery County

TABLE NO. 5 Wastewater Treatment Plant Compliance in Montgomery County

TABLE NO. 6 Comparison of Construction Standards for Private Sewage Facilities

TABLE NO. 7 Existing and Projected Domestic Waste Loading for Montgomery County Streams

TABLE NO. 1

SURFACE WATER QUALITY STANDARDS FOR STREAM SEGMENTS IN MONTGOMERY COUNTY

			Surface Water Quality Standards						
Stream Segment No.	Name	Designated Water Uses	Dissolved Oxygen (mg/l)	Temperature (oF)	pH	Chloride (mg/l)	Sulfate (mg/l)	TDS (mg/l)	Fecal Coliforms (#/100 ml)
1004	West Fork of San Jacinto River	Public Water Supply Contact Recreation High Quality Aquatic Habitat	5.0	95	6.5-9.0	80	40	300	200
1008	Spring Creek	Public Water Supply Contact Recreation High Quality Aquatic Habitat	5.0	90	6.5-9.0	80	40	300	200
1010	Caney Creek	Public Water Supply Contact Recreation High Quality Aquatic Habitat	5.0	90	6.0-8.5	50	40	300	200
1011	Peach Creek	Public Water Supply Contact Recreation High Quality Aquatic Habitat	5.0	90	6.0-8.5	50	40	200	200
1012	Lake Conroe	Public Water Supply Contact Recreation High Quality Aquatic Habitat	5.0	90	6.5-9.0	50	40	200	200
1015	Lake Creek	Public Water Supply Contact Recreation High Quality Aquatic Habitat	5.0	90	6.5-8.5	80	20	300	200

* Portions of these segments are not presently considered safe for contact recreation due to levels of fecal coliform.

TABLE NO. 2

STATUS OF STREAM WATER QUALITY IN MONTGOMERY COUNTY

Stream Segment No.	Name	Dissolved Oxygen 1985	Dissolved Oxygen 1987	Temperature 1985	Temperature 1987	pH 1985	pH 1987	Chloride 1985	Chloride 1987	Sulfate 1985	Sulfate 1987	TDS 1985	TDS 1987	Fecal Coliforms 1985	Fecal Coliforms 1987
		Percent of Samples Noncompliant with Surface Water Quality Standards													
1004	West Fork of San Jacinto River	7	2	0	0	28	0	5	1	0	1	2	5	53	45
1008	Spring Creek	1	3	0	0	5	5	23	9	2	1	18	19	18	16
1010	Caney Creek	0	1	0	0	22	11	5	1	1	0	0	0	37	40
1011	Peach Creek	1	0	1	1	11	11	6	0	0	0	3	0	40	41
1012	Lake Conroe	8	0	0	0	4	0	11	0	0	0	17	0	7	0

NOTE: Data for the newly classified Lake Creek stream segment not available.

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TABLE NO. 3

EFFLUENT QUALITY STANDARDS FOR STREAM SEGMENTS IN MONTGOMERY COUNTY

Stream Segment No.	Name	Classification	Date of Waste Load Evaluation	Effluent Quality Standards BOD5 (mg/l)	TSS (mg/l)	NH3-N (mg/l)	P (mg/l)	O2 (mg/l)	Cl2(min) (mg/l)	Cl2(max) (mg/l)
1004	West Fork of San Jacinto River	Water Quality Limited	March, 1986*	10	15	3	-	6	1	4
1008	Spring Creek	Water Quality Limited	*	10	15	3	-	4	1	4
1010	Caney Creek	Water Quality Limited	*	10	15	3	-	4	1	4
1011	Peach Creek	Water Quality Limited	*	10	15	3	-	4	1	4
1012	Lake Conroe	Water Quality Limited	**	10**	15**	-	-	4**	1**	-
1015	Lake Creek	Water Quality Limited	*	10	15	3	-	4	1	4

* Subject to the provisions of the Lake Houston Watershed Rule, TAC 333.41-333.47, adopted June 20, 1985.

** Any discharge made with five miles of the normal pool elevation of Lake Conroe must meet this advanced level of treatment in accordance with TAC 309.3(d).

TABLE NO. 4

WASTEWATER TREATMENT FACILITIES IN MONTGOMERY COUNTY

		Permitted Discharges			Wastewater Treatment Facility Size Distribution (MGD)				
Segment No.	Name	Flow (MGD)	Total	Active	0.005	.006-.050	.051-.150	.151-.500	0.500
1002	Lake Houston	0.867	3	3	2	0	0	0	1
1004	West Fork of San Jacinto River	13.703	44	33	2	15	10	10	7
1008	Spring Creek	10.929	25	16	1	9	6	7	2
1010	Caney Creek	1.648	13	10	0	6	5	1	1
1011	Peach Creek	1.528	5	4	0	1	1	2	1
1012	Lake Conroe	5.163	28	22	0	12	7	6	3
TOTALS		33.839	118	88	5	43	29	26	15
					(4%)	(37%)	(25%)	(22%)	(11%)

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TABLE NO. 5
WASTEWATER TREATMENT PLANT COMPLIANCE
IN MONTGOMERY COUNTY

AVERAGES FROM 1-86 TO 8-87

PERMITTEE	PERMIT NO.	ACTUAL FLOW MGD	PERMIT FLOW MGD	% LOAD	ACTUAL BOD5 mg/l	PERMIT BOD5 mg/l	ACTUAL BOD5 lb/day	PERMIT BOD5 lb/day	ACTUAL TSS mg/l	PERMIT TSS mg/l	ACTUAL TSS lb/day	PERMIT TSS lb/day
SEGMENT 1002 ACTIVE PLANTS												
PORTER MUD	12242.001	0.5103	0.8600	59%	3.9	12.0	16.5	86.2	10.2	16.0	40.7	114.8
ROWLAND SCHOOL OF BALLE	12727.001	0.0018	0.0024	76%	5.9	10.0	0.1	0.2	10.0	15.0	0.1	0.3
NORTHPARK BUSINESS CENT	12943.001	0.0008	0.0048	17%	5.5	10.0	0.1	0.4	7.8	15.0	0.1	0.6
TOTAL (ACTIVE PLANTS)		0.5129	0.8672	59%			16.7	86.8			40.9	115.7
SEGMENT 1004 ACTIVE PLANTS												
TEXACO CHEMICAL CO.	584.001	0.2859	0.6170	46%			61.9	102.0	18.3	29.9	40.9	154.0
WHITTAKER CORP.	2365.001	0.0067	0.1108	6%								
WHITTAKER CORP.	2365.101	0.0015	0.0060	25%	4.1	20.0	0.1	1.0	7.8	20.0	0.1	1.0
ALAMO MFG CO.	2475.001	0.0028	0.0160	18%								
CREEKWOOD CORP.	2811.001	0.0011	0.0165	7%	0.1		0.1	2.6				
CONROE, CITY	10008.002	4.0368	6.0000	67%	5.2	20.0	185.1	1000.0	5.9	20.0	198.3	1000.8
CONROE, CITY	10008.004	0.0243	0.0500	49%	4.3	20.0	1.3	8.3	6.9	20.0	1.4	8.3
WILLIS, CITY	10315.001	0.2319	0.4000	58%	9.8	20.0	20.1	66.8	20.5	20.0	37.9	66.7
RIVER PLANTATION MUD	10978.001	0.3524	0.6000	59%	3.4	20.0	10.2	100.0	5.8	20.0	17.1	100.1
PANORAMA VILLAGE, CITY	11097.001	0.2447	0.4000	61%	3.0	20.0	6.1	67.0	6.9	20.0	14.2	66.7
CONSUMERS WATER	11293.001	0.0207	0.0600	34%	9.3	20.0	1.7	10.0	13.8	20.0	2.5	10.0
MONT CO MUD 15	11395.001	0.1567	0.1860	84%	3.3	20.0	4.4	16.0	5.8	15.0	7.7	23.3
WOODLOCH, TOWN	11580.001	0.0280	0.0250	112%	13.9	20.0	2.1	4.2	28.4	20.0	6.0	4.2
MONT CO MUD 39	11658.001	0.1121	0.2500	45%	2.1	20.0	1.6	41.7	5.6	20.0	4.8	41.7
MARTIN, JR. MITCHELL	11710.001	0.0145	0.0150	97%	7.3		0.9	2.5	12.0	20.0	1.5	2.5
LAZY RIVER ID	11820.001	0.0421	0.1250	34%	7.1	20.0	2.6	21.0	16.4	20.0	6.0	20.9
EVANGELISTIC TEMPLE	11878.001	0.0033	0.0080	42%	8.0	10.0	0.4	0.7	11.2	15.0	0.3	1.0
LORANCE, TOM	11937.001	0.0028	0.0050	56%	7.1	20.0	3.8	0.8	16.3	20.0	0.3	0.8
MONT CO MUD 42	11963.001	0.0077	0.1500	5%	2.6	20.0	0.3	25.0	8.4	20.0	0.5	25.0
MONT CO MUD 44	12203.001	0.1422	0.2200	65%	8.1	10.0	9.5	18.4	10.9	15.0	12.9	27.5
SHENANDOAH, CITY	12212.002	0.1988	0.6688	30%	2.9	10.0	3.3	56.7	4.4	15.0	7.1	83.7
WOODGATE UTILITY	12245.001	0.0048	0.0250	19%	3.3	20.0	0.1	4.2	6.4	20.0	0.3	4.2
MONT CO MUD 48	12434.001	0.0360	0.5000	7%	3.7	10.0	1.1	42.0	5.7	15.0	1.8	62.6
CLIF MOCK CO	12456.001	0.0005	0.0050	10%	6.9	10.0	0.0	0.4	8.0	15.0	0.0	0.6
MONTGOMERY CO COMM	12463.001	0.0010	0.1000	1%	7.4	20.0	0.1	17.0	69.0	20.0	0.6	16.7
MONT CO MUD 56	12503.001	0.0206	0.1000	21%	3.8	10.0	0.7	8.3	3.4	15.0	0.5	12.5
INTER FIRST BANK	12508.001	0.0010	0.0050	20%	1.5	10.0	0.0	0.4	8.0	15.0	0.1	0.6
MONT CO MUD 58	12530.001	0.0440	0.6000	7%	2.7	10.0	0.9	50.0	4.0	15.0	1.5	75.1
CHATEAU WOODS, CITY	12532.001	0.0549	0.2000	27%	5.8	10.0	2.5	17.0	11.3	15.0	5.3	25.0
CONROE FORGE & MFG	12538.001	0.0003	0.0030	11%	10.7	20.0	0.0	0.5	28.6	20.0	0.0	0.5
WILLOW RIDGE ESTATES	12622.001	0.0095	0.0250	38%	2.2	10.0	0.1	2.1	6.4	15.0	0.5	3.1
WESLEY CONSTRUCTION	12761.001	0.0051	0.0500	10%	4.0	10.0	0.1	4.2	5.7	15.0	0.2	6.3
MONT CO MUD 53	12794.001	0.0039	0.2000	2%	3.2	10.0	0.2	17.0	7.1	15.0	0.2	25.0
TOTAL (ACTIVE PLANTS)		6.0986	11.7421	52%			321.2	1707.8			370.6	1870.4

TABLE NO. 5 (CON'T)
WASTEWATER TREATMENT PLANT COMPLIANCE

AVERAGES FROM 1-86 TO 8-87

PERMITTEE	PERMIT NO.	ACTUAL FLOW MGD	PERMIT FLOW MGD	% LOAD	ACTUAL BOD5 mg/l	PERMIT BOD5 mg/l	ACTUAL BOD5 lb/day	PERMIT BOD5 lb/day	ACTUAL TSS mg/l	PERMIT TSS mg/l	ACTUAL TSS lb/day	PERMIT TSS lb/day
SEGMENT 1004 INACTIVE PLANTS												
PIONEER CONCRETE	2502.001		0.3500	0%						25.0		73.0
CONROE, CITY	10008.005		1.0000	0%		10.0		83.0		15.0		
OWENS CORNING FIBERGLAS	11289.001					20.0		20.0				
HIGHLAND HOLLOW MUD	11793.001		0.0500	0%		20.0		8.3		20.0		8.3
DELL DEVELOPMENT CORP	12586.001		0.1020	0%		10.0		8.5		15.0		
FERGUSON & COMPANY	12746.001		0.2000	0%		10.0		17.0		15.0		
WEST, CHARLES	12884.001		0.0150	0%		20.0		2.5		20.0		
HOLIGAN, HAROLD	12940.001		0.0350	0%		20.0		5.8		20.0		
MCCOMB DEVELOPMENT	13058.001		0.1020	0%		10.0		8.5		15.0		
LEAGUE LINE UTILITY	13118.001		0.0871	0%		10.0		7.3		15.0		10.9
HFD, INC	13265.001		0.0200	0%		10.0		1.7		15.0		
TOTAL (INACTIVE PLANTS)		0.0000	1.9611	0%			0.0	162.6			0.0	92.2
SEGMENT 1008 ACTIVE PLANTS												
MONT CO WCID 01	10857.001	0.2399	0.4500	53%	3.2	10.0	8.3	38.0	5.8	15.0		
SOUTHERN MONT CO MUD	11001.001	0.7880	2.0000	39%	3.7	10.0	25.4	167.0	5.9	15.0	39.3	250.2
SAN JAC RIVER AUTHOR	11401.001	2.2650	6.0000	38%	3.3	10.0	62.4	500.0	5.8	15.0	108.2	750.6
SPRING CREEK UD	11574.001	0.1188	0.3825	31%	4.5	10.0	5.8	31.7	9.0	15.0	9.1	47.9
MAGNOLIA, TOWN	11871.001	0.0922	0.1770	52%	5.1	10.0	4.9	14.8	8.4	15.0	6.9	22.1
L & C ENTERPRISES	11968.001	0.0032	0.0520	6%	6.5	10.0	0.2	4.3	12.3	15.0	0.4	6.5
MONT CO MUD 19	11970.001	0.1832	0.3500	52%	3.6	10.0	3.8	29.2	5.4	15.0	8.2	43.8
RAYFORD ROAD MUD	12030.001	0.0769	0.2800	27%	2.7	10.0	2.5	23.0	3.9	15.0	2.5	35.0
SPRING BRANCH SAVING &	12544.001	0.0011	0.0030	35%	8.3	10.0	0.1	0.3	16.9	15.0	0.1	0.4
GREAT WESTERN UTILITY	12587.001	0.0374	0.2700	14%	3.2	10.0	1.1	22.5	9.0	15.0	2.7	33.8
SAN JAC RIVER AUTHORITY	12597.001	0.0177	0.1000	18%	1.3	10.0	0.2	8.3	13.8	15.0	2.0	12.5
COE UTILITIES	12687.001	0.0155	0.0255	61%	4.0	10.0	0.5	2.1	9.4	15.0	1.1	3.2
MAGNOLIA ISD	12703.001	0.0037	0.0120	31%	3.5	10.0	0.2	1.0	8.2	15.0	0.3	1.5
EAGEN, JC	12788.001	0.0043	0.0500	9%	2.5	10.0	0.1	4.2	6.5	15.0	0.2	6.3
CLARK, RICHARD	12851.001	0.0127	0.0600	21%	3.3	10.0	0.2	5.0	4.2	15.0	0.4	7.5
BRUSHY CREEK VENTURE	12898.001	0.0013	0.0750	2%	3.7	10.0	0.1	6.3	7.8	15.0	0.1	9.4
TOTAL (ACTIVE PLANTS)		3.8607	10.2870	38%			115.7	857.7			181.5	1230.6

TABLE NO. 5 (CON'T)
WASTEWATER TREATMENT PLANT COMPLIANCE

AVERAGES FROM 1-86 TO 8-87

PERMITTEE	PERMIT NO.	ACTUAL FLOW MGD	PERMIT FLOW MGD	% LOAD	ACTUAL BOD5 mg/l	PERMIT BOD5 mg/l	ACTUAL BOD5 lb/day	PERMIT BOD5 lb/day	ACTUAL TSS mg/l	PERMIT TSS mg/l	ACTUAL TSS lb/day	PERMIT TSS lb/day
SEGMENT 1008 INACTIVE PLANTS												
FEDERAL SAVINGS/LOAN	12838.001		0.0250	0%		10.0		2.1		15.0		
GAY, JAMES	12862.001		0.0500	0%		5.0		2.1		5.0		
LANCO PROPERTIES	12890.001		0.0600	0%		10.0		5.0		15.0		7.5
JACK FREY PROPERTIES	12953.001		0.0400	0%		10.0		3.3		15.0		
ANCHOR FINANCIAL	12956.001		0.0400	0%		10.0		3.4		15.0		
GRIFFIN, NORMAN	12994.001		0.0270	0%		10.0		2.3		15.0		
PLAUTX	13028.001		0.2500	0%		10.0		21.0		15.0		
CLOVER CREEK MUD	13115.001		0.1000	0%		10.0		8.3		15.0		12.5
SAWDUST ROAD	13119.001		0.0500	0%		10.0		4.1		15.0		
TOTAL (INACTIVE PLANTS)		0.0000	0.6420	0%			0.0	51.6			0.0	20.0
SEGMENT 1010 ACTIVE PLANTS												
O & O ENTERPRISES	2662.001	0.0016	0.0300	5%			0.3	3.8				
TX NATIONAL MUD	11715.001	0.0164	0.0755	22%	3.6	10.0	0.5	6.3	8.9	15.0	1.3	9.5
MONT CO MUD 24	11789.001	0.0285	0.1000	28%	5.9	10.0	0.5	8.3	10.7	15.0	2.4	12.5
CONROE ISD	12204.001	0.0029	0.0072	41%	7.3	30.0	0.2	1.8	6.8	90.0	0.2	5.4
CONROE ISD	12205.001	0.0025	0.0072	34%	14.8	30.0	0.3	1.8	18.7	90.0	0.5	5.4
NEW CANEY MUD	12274.001	0.1592	1.0600	15%	6.1	10.0	6.8	88.0	13.8	15.0	18.3	132.6
CONROE ISD	12281.001	0.0029	0.0120	24%	20.7	30.0	0.4	3.0	17.0	90.0	0.4	9.0
CONROE ISD	12607.001	0.0107	0.0200	53%	4.9	20.0	0.4	3.3	12.6	20.0	1.1	3.3
MARTIN REALTY & LAND	12621.001	0.0575	0.1000	57%	3.0	10.0	0.6	8.3	6.1	15.0	2.6	12.5
CREIGHTON, FRANK	12670.001	0.0018	0.1584	1%	4.9	20.0	0.1	26.3	10.3	20.0	0.1	26.4
TOTAL (ACTIVE PLANTS)		0.2839	1.5703	18%			10.0	150.9			26.8	216.6
SEGMENT 1010 INACTIVE PLANTS												
TOTAL HOUSING	12627.001		0.0300	0%		10.0		2.5		15.0		
BEDFORD R&T	12820.001		0.0080	0%		20.0		1.3		20.0		
MARTIN & SHEFFIELD	13223.001		0.0400	0%		10.0		3.3		15.0		
TOTAL (INACTIVE PLANTS)		0.0000	0.0780	0%			0.0	7.1			0.0	0.0

TABLE NO. 5 (CON'T)
WASTEWATER TREATMENT PLANT COMPLIANCE

AVERAGES FROM 1-86 TO 8-87

PERMITTEE	PERMIT NO.	ACTUAL FLOW MGD	PERMIT FLOW MGD	% LOAD	ACTUAL BOD5 mg/l	PERMIT BOD5 mg/l	ACTUAL BOD5 lb/day	PERMIT BOD5 lb/day	ACTUAL TSS mg/l	PERMIT TSS mg/l	ACTUAL TSS lb/day	PERMIT TSS lb/day
SEGMENT 1011 ACTIVE PLANTS												
SPLENDORA ISD	11143.001	0.0215	0.0200	108%	5.9	20.0	0.9	3.3	13.2	20.0	2.7	3.3
ROMAN FOREST CONSOL	11185.001	0.1158	0.6000	19%	3.2	20.0	3.1	100.0	5.5	20.0	5.2	100.1
MONT CO MUD 16	11386.001	0.0379	0.3830	10%	2.2	20.0	0.9	64.0	6.9	20.0	2.5	63.9
WOODBRANCH VILLAGE,	11993.001	0.0629	0.1250	50%	16.2	20.0	12.7	21.0	32.1	20.0	17.6	20.9
TOTAL (ACTIVE PLANTS)		0.2381	1.1280	21%			17.6	188.3			27.9	188.2
SEGMENT 1011 INACTIVE PLANTS												
NORTH AMERICAN PROPERTY	12821.001		0.4000	0%		10.0		18.8		15.0		
TOTAL (INACTIVE PLANTS)		0.0000	0.4000	0%			0.0	18.8			0.0	0.0
SEGMENT 1012 ACTIVE PLANTS												
GULF STATES UTILITIES	1966.001	0.7018										7.5
MONT CO UD 03	11203.001	0.1223	0.3500	35%	3.3	10.0	2.0	29.0	7.8	15.0	7.0	43.8
POINT AQUARIUS MUD	11219.001	0.0833	0.3900	21%	3.3	10.0	0.6	33.0	7.2	15.0	4.3	48.8
MONT CO UD 02	11271.001	0.1013	0.2500	41%	2.9	10.0	1.8	21.0	7.6	15.0	6.6	31.3
CORINTHIAN PT MUD 2	11285.001	0.0382	0.2500	15%	2.6	10.0	0.8	21.0	5.0	15.0	1.6	31.3
STANLEY LAKE MUD	11367.001	0.0267	0.9720	3%	5.5	10.0	0.8	81.0	10.2	15.0	3.2	121.6
MONT CO MUD 08	11371.001	0.3678	1.4500	25%	3.0	10.0	8.4	120.8	10.6	15.0	29.5	181.4
B&B SEWER CO	11419.001	0.0183	0.1200	15%	3.3	10.0	0.4	10.0	5.7	15.0	1.1	15.0
DIAMONDHEAD WATER & SEW	11478.001	0.0156	0.0400	39%	3.2	10.0	3.1	3.5	4.9	15.0	0.6	5.0
MONTGOMERY, CITY	11521.001	0.0563	0.2500	23%	4.0	10.0	2.3	21.0	3.4	15.0	1.8	31.3
LAKE CONROE HILLS MUD	11569.001	0.0967	0.1500	64%	5.8	10.0	4.1	12.5	7.3	15.0	5.7	18.8
ANDREWS, HAROLD	11693.001	0.0122	0.0180	68%	2.1	10.0	0.2	1.5	4.3	15.0	0.4	2.3
FOREST WATER & SEWER	11708.001	0.0245	0.0500	49%	5.9	10.0	1.1	4.2	14.6	15.0	3.2	6.3
GULF COAST TRADES CT	11829.001	0.0014	0.0055	26%	3.6	10.0	0.0	0.5	6.5	15.0	0.1	0.7
HUNTERS POINT	12023.001	0.0014	0.0200	7%	5.7	10.0	0.1	1.7	8.0	15.0	0.1	2.5
THOUSAND TRAILS	12349.001	0.0055	0.0300	18%	2.3	10.0	0.1	2.5	6.0	15.0	0.3	3.8
ASSOCIATED PROPERTY	12416.001	0.0122	0.0200	61%	11.8	10.0	0.9	1.7	12.2	15.0	1.3	2.5
WESTLAND OIL DEVELOP	12440.001	0.0049	0.0100	49%	4.9	10.0	0.1	0.8	9.2	15.0	0.4	1.3
D L INDUSTRIES	12493.001	0.0245	0.2500	10%	7.3	10.0	2.6	21.0	12.8	15.0	2.3	31.3
WAYWARD WIND PROPERTY	12582.001	0.0201	0.0170	119%	2.9	10.0	0.2	1.4	9.1	15.0	1.4	2.1
LAKE MEADOWS	12634.001	0.0182	0.0250	73%	2.7	10.0	0.2	2.1	4.3	15.0	0.7	3.1
STOECKER, MIKE	13064.001	0.0040	0.0800	5%	4.9	10.0	0.1	6.6	9.8	15.0	0.3	10.0
TOTAL (ACTIVE PLANTS)		1.7573	4.7475	37%			30.0	396.8			71.9	601.4

TABLE NO. 5 (CON'T)
WASTEWATER TREATMENT PLANT COMPLIANCE

AVERAGES FROM 1-86 TO 8-87

PERMITTEE	PERMIT NO.	ACTUAL FLOW MGD	PERMIT FLOW MGD	% LOAD	ACTUAL BOD5 mg/l	PERMIT BOD5 mg/l	ACTUAL BOD5 lb/day	PERMIT BOD5 lb/day	ACTUAL TSS mg/l	PERMIT TSS mg/l	ACTUAL TSS lb/day	PERMIT TSS lb/day
SEGMENT 1012 INACTIVE PLANTS												
BRIDGECOVE MARINA	11918.001		0.0075	0%		10.0		0.6		15.0		0.9
DONALD B. CLARK DEV	12439.001		0.1500	0%		10.0		12.5		15.0		18.8
THOMPSON, PEYTON	13010.001		0.1000	0%		10.0		8.3		15.0		
CAFLAN, MEL	13127.001		0.0500	0%		10.0		4.2		15.0		
SAN JACINTO FINANCIAL	13273.001		0.1000	0%		10.0		8.3		15.0		
SAN JAC GIRL SCOUTS	13277.001		0.0080	0%		10.0		0.7		15.0		
TOTAL (INACTIVE PLANTS)		0.0000	0.4155	0%			0.0	34.6			0.0	19.7

TABLE NO. 6

COMPARISON OF CONSTRUCTION STANDARDS FOR PRIVATE SEWAGE FACILITIES

	Texas Department of Health Construction Standards for Private Sewage Facilities		Montgomery County Rules for Private Sewage Facilities
	1977	1988	1986
Single Family Residence			
Minimum Lot Size in Square Feet			
With Public Water Supply	15,000	21,780	43,560
With Individual Wells	20,000	43,560	65,340

TABLE NO. 7

EXISTING AND PROJECTED DOMESTIC WASTE LOADS
FOR MONTGOMERY COUNTY STREAM SEGMENTS

Stream Segment	Name	Existing Waste Loading (1986 Average) lbs BOD5/Day	Cumulative Waste Discharge Permit Loading lbs BOD5/Day	Actual to Permit Waste Loading	Allowable Waste Loading in 2000 208 Plan (1978) lbs BOD5/Day	Projected Waste Loading in 2000 lbs BOD5/Day
1004	West Fork	322	1,872*	17%	1,083 (1,198)**	629
1008	Spring Creek	220	1,354	16%	Not Included (1,007)***	1,136
1010	Caney Creek	11	190*	6%	85	117
1011	Peach Creek	18	207	9%	112	45
1012	Lake Conroe	85	711	12%	361	286
TOTALS		656	4,334	12%	2,718	2,213

* Many permits did not yet reflect reduced BOD5 effluent limitation from 20 mg/l to 10 mg/l.
** Projected waste load in 2000 on which Waste Load Evaluation dated March 1986 was based.
*** Projected waste load in 1990 on which Waste Load Evaluation dated September 1984 was based.

NOTES: Loads are for entire stream segment.

Lake Houston Watershed
§§333.41-333.47

The following sections are adopted under ther authority of the §§5.131, 5.132 and 26.011, Texas Water Code.

§333.41. Definitions. The following words and terms, when used in this chapter, shall have the following meanings, unless the context clearly indicates otherwise:

"Lake Houston Watershed" - The entire drainage area of Lake Houston, with the exception of that portion of the drainage basin of the West Fork of the San Jacinto River which lies upstream of the Lake Conroe Dam.

§333.42. Effluent Requirements (Domestic). All domestic sewage treatment permit applicants, all permittees who construct authorized treatment facility expansions, and all permittees who apply for increases in their permitted effluent flows, who propose to dispose of treated sewage effluent by discharge into the waters of the State in the Lake Houston Watershed shall, at a minimum, achieve the effluent treatment level specified in Effluent Set 2-N and A in §327.4 of this title (relating to Table I - Effluent Standards for Domestic Wastewater Treatment Plants), except as otherwise provided in this section. All permittees within the Lake Houston Watershed that are not covered by the preceding sentence shall achieve the treatment levels specified in Effluent Sets 2-N and A in §327.4 of this title (relating to Table I - Effluent Standards for Domestic Wastewater Treatment Plants) on or before July 1, 1988. Time extensions may be specified by the Texas Water Commission in wastewater discharge permits on a case-by-case basis where circumstances so dictate, but in no case will extend beyond January 1, 1990. The Texas Water Commission may require more stringent effluent limitations where advisable to protect water quality. The Texas Water Commission may authorize variances to allow less stringent effluent limitations as are necessary based on considerations consistent with the provisions of the Texas Water Code.

§333.43. Effluent Requirements (Industrial). All industrial wastewater treatment permit applicants, all permittees who construct authorized treatment facility expansions, and all permittees who apply for increases in pollutant loadings, who propose to dispose of treated industrial wastewater effluent by discharge into the waters of the state in the Lake Houston Watershed shall achieve effluent treatment levels commensurate with the goals of this rule. All permittees within the Lake Houston Watershed that are not covered by the preceding sentence shall achieve the effluent requirements of this section on or before July 1, 1988. Time extensions may be specified by the Texas Water Commission in wastewater discharge permits on a case-by-case basis where circumstances so dictate, but in no case will extend beyond January 1, 1990. The Texas Water Commission may require more stringent effluent limitations where advisable to protect water quality. The Texas Water Commission may authorize a variance to allow less stringent effluent limitations based on considerations consistent with the provisions of the Texas Water Code.

§333.44. Land Disposal. All sewage treatment facilities which dispose of wastewater effluent by land disposal methods in the Lake Houston Watershed shall provide secondary treatment as specified in §§327.1-327.4 of this title (relating to Domestic Wastewater Treatment Plants) prior to discharge into storage ponds for land disposal. Storage ponds and land disposal facilities shall be designed, constructed, and operated in accordance with §325.30(c) of this title (relating to Appendix B - Land Disposal of Sewage Effluent - Irrigation).

§333.45. Domestic Solids Treatment. The permittee of a domestic sewage treatment facility discharging into the Lake Houston Watershed which requests renewal or amendment of an existing permit, or any person who submits an application for a new wastewater discharge permit within the Lake Houston Watershed shall be required to submit with the application for renewal, amendment, or new permit, a solids management plan. The report describing such plan shall contain, at a minimum, the following information:

(1) The type of wastewater treatment process used;
(2) The dimensions and capacities of all solids handling and treatment units and processes;
(3) Calculations showing the amount of solids generated at design flow and at 75 percent, 50 percent, and 25 percent of design flow;
(4) Operating range for mixed liquor suspended solids in the treatment process based on the projected actual and design flow expected at the facility;
(5) A description of the procedure and method of solids removal from the treatment process;
(6) Quantity of solids to be removed from the process and schedule for removal of solids that is designed to maintain an appropriate solids inventory; and
(7) Identification of the ultimate disposal site and a system of documenting the amount of solids removed in dry weight form.

§333.46. Hydraulic Overloads.

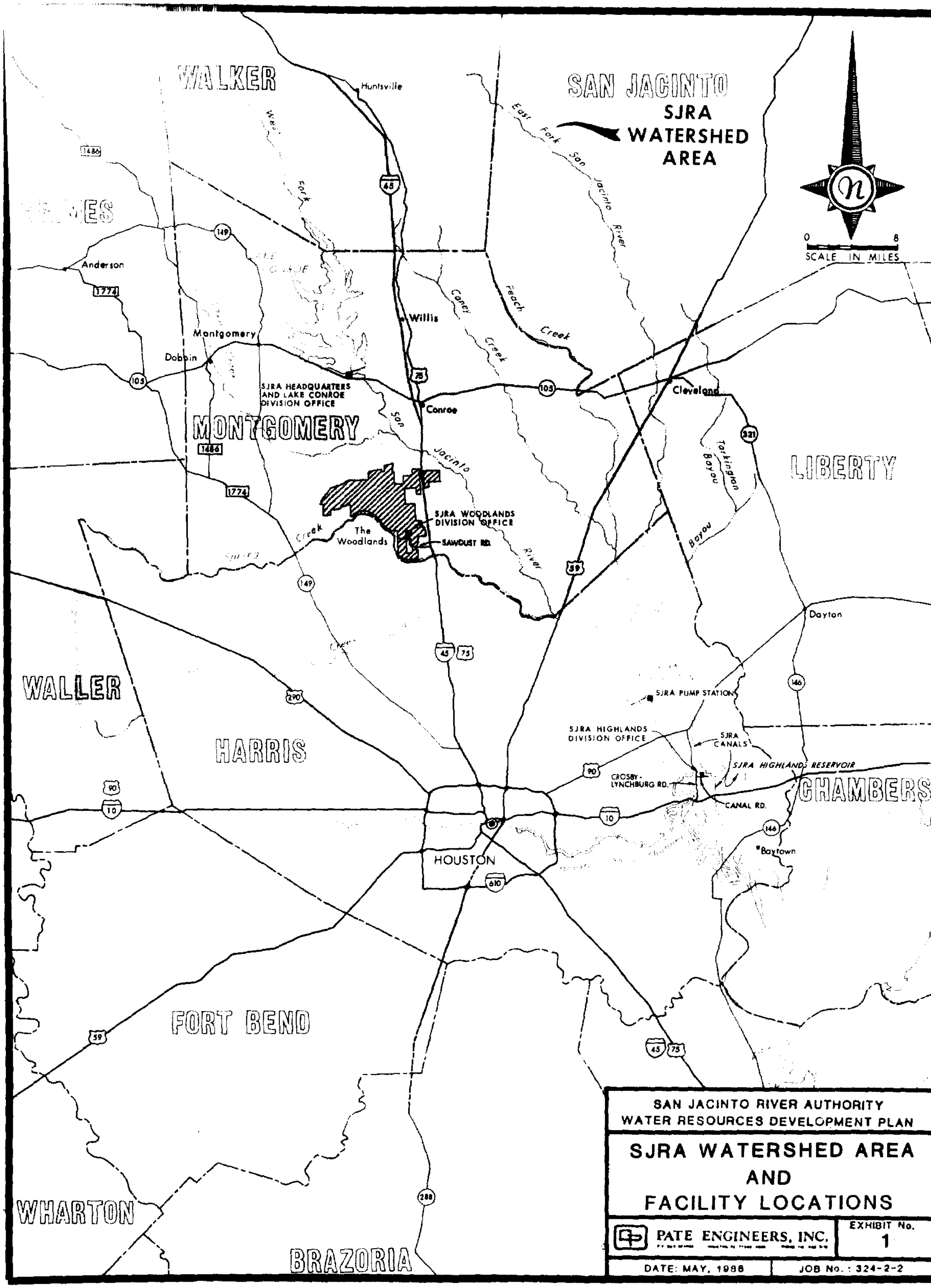
(a) Whenever flow measurements for any domestic sewage treatment facility discharging into the Lake Houston Watershed exceed the allowable daily maximum flow by 40 percent during any 30-day period, the permittee must initiate engineering and financial planning for expansion and/or upgrading of the domestic wastewater treatment facilities. However, this provision sentence shall not be interpreted as condoning or excusing any violation of any permit parameter. Prior to commencing construction of additional treatment facilities, the permittee shall obtain necessary authorization from the Texas Water Commission.

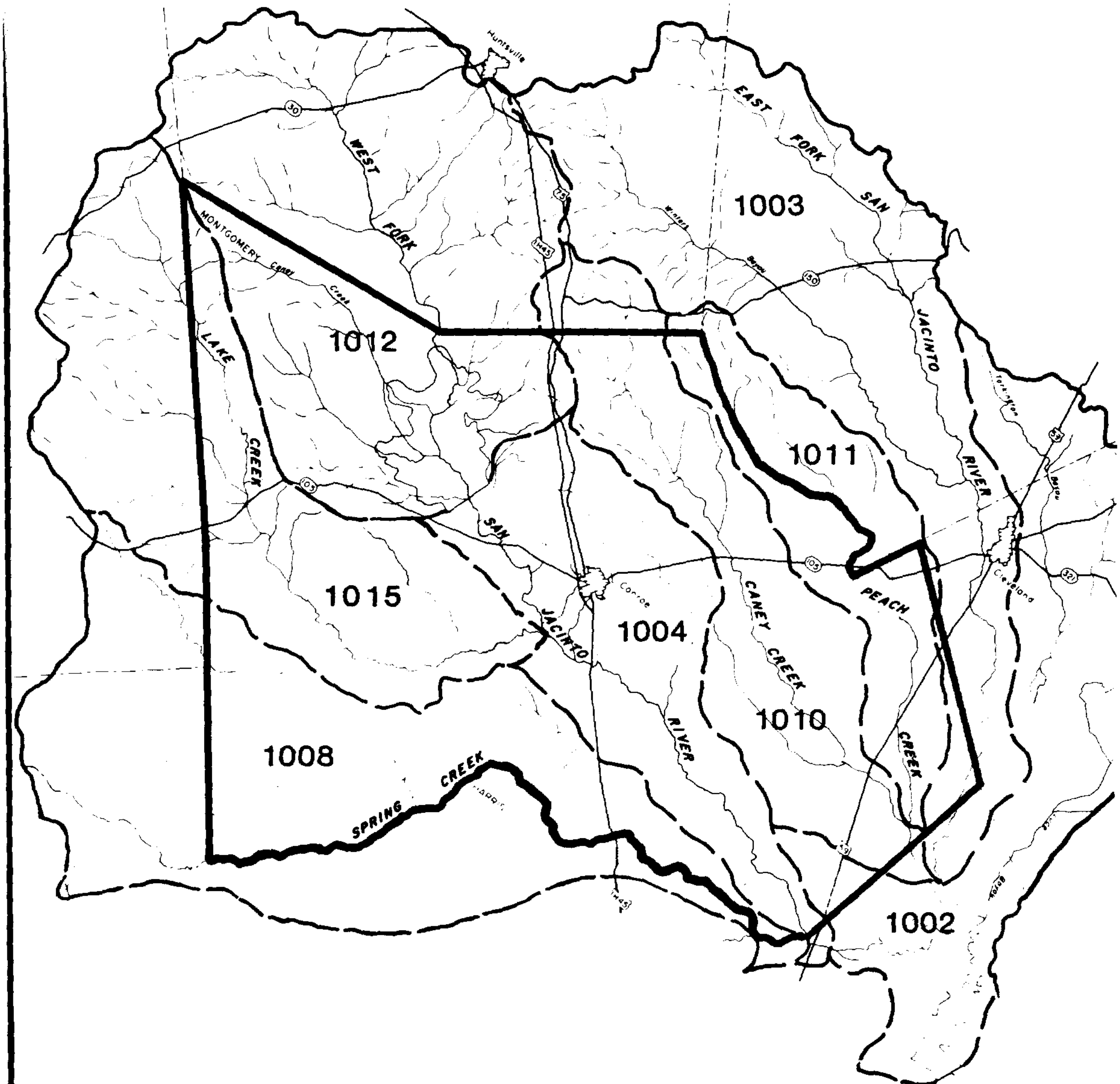
(b) Whenever flow measurements for any domestic sewage treatment facility discharging into the Lake Houston Watershed reach 75 percent of the permitted average daily flow for three consecutive months, the permittee must initiate engineering and financial planning for expansion and/or upgrading of the domestic wastewater treatment and/or collection facilities. Whenever, the average daily flow reaches 90 percent of the permitted average daily flow for three consecutive months, the permittee shall obtain necessary authorization from the Texas Water Commission to commence construction of the necessary additional treatment facilities. In the case of a domestic wastewater treatment facility which reaches 75 percent of the permitted average flow for three consecutive months, and the planned population to be served is not expected to exceed the design limitations of the treatment facility, the permittee will submit an engineering report supporting this claim to the executive director. If in the judgment of the executive director the population to be served will not cause permit noncompliance, then the requirements of this section may be waived. To be effective, any waiver must be in writing and signed by the executive director of the Texas Department of Water Resources, and such waiver of these requirements will be reviewed upon expiration of the existing permit. However, any such waiver shall not be interpreted as condoning or excusing any violation of any permit parameter.

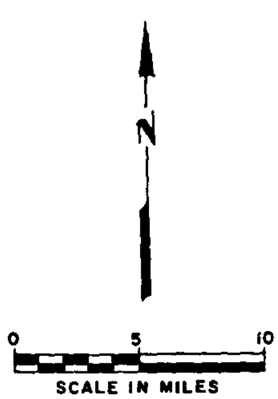
§333.47. Disinfection.

(a) By May 1, 1986, the permittees of all domestic sewage and industrial wastewater treatment facilities discharging into the Lake Houston Watershed which utilize gaseous chlorination disinfection systems shall install dual-feed chlorination systems which are capable of automatically changing from one cylinder to another.

(b) Chlorination disinfection systems shall be operated so that a maximum chlorine residual of 4.0 mg/l measured on an instantaneous grab sample is not exceeded for discharges into the Lake Houston Watershed.


SAN JACINTO
SJRA
WATERSHED
AREA
0 8
SCALE IN MILES
WALKER
Huntsville
East Fork San Jacinto River
West Fork
Anderson
Montgomery
Dobbin
Willis
Caney Creek
Peach Creek
SJRA HEADQUARTERS AND LAKE CONROE DIVISION OFFICE
Conroe
San Jacinto River
Cleveland
MONTGOMERY
Tarkington Bayou
LIBERTY
SJRA WOODLANDS DIVISION OFFICE
SAWDUST RD.
The Woodlands
Spring Creek
Dayton
WALLER
HARRIS
SJRA PUMP STATION
SJRA HIGHLANDS DIVISION OFFICE
SJRA CANALS
SJRA HIGHLANDS RESERVOIR
CROSBY-LYNCHBURG RD.
CANAL RD.
CHAMBERS
Baytown
HOUSTON
FORT BEND
WHARTON
BRAZORIA
SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN
SJRA WATERSHED AREA
AND
FACILITY LOCATIONS
PATE ENGINEERS, INC.
EXHIBIT No.
1
DATE: MAY, 1988
JOB No.: 324-2-2





SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

STREAM SEGMENTS
IN
MONTGOMERY COUNTY

PATE ENGINEERS, INC.
P.O. BOX 924034 HOUSTON, TX 77292 - 4034
PHONE 713 - 462 - 3178

EXHIBIT NO.
2

DATE: MAY, 1988
JOB NO.: 324-2-3

SJRA WATER SUPPLY DEVELOPMENT PLAN - BASE SCENARIO
65.2 MGD LAKE CREEK IN 2010
6.7 MGD SPRING CREEK LAKE, 20 MGD LAKE CONROE

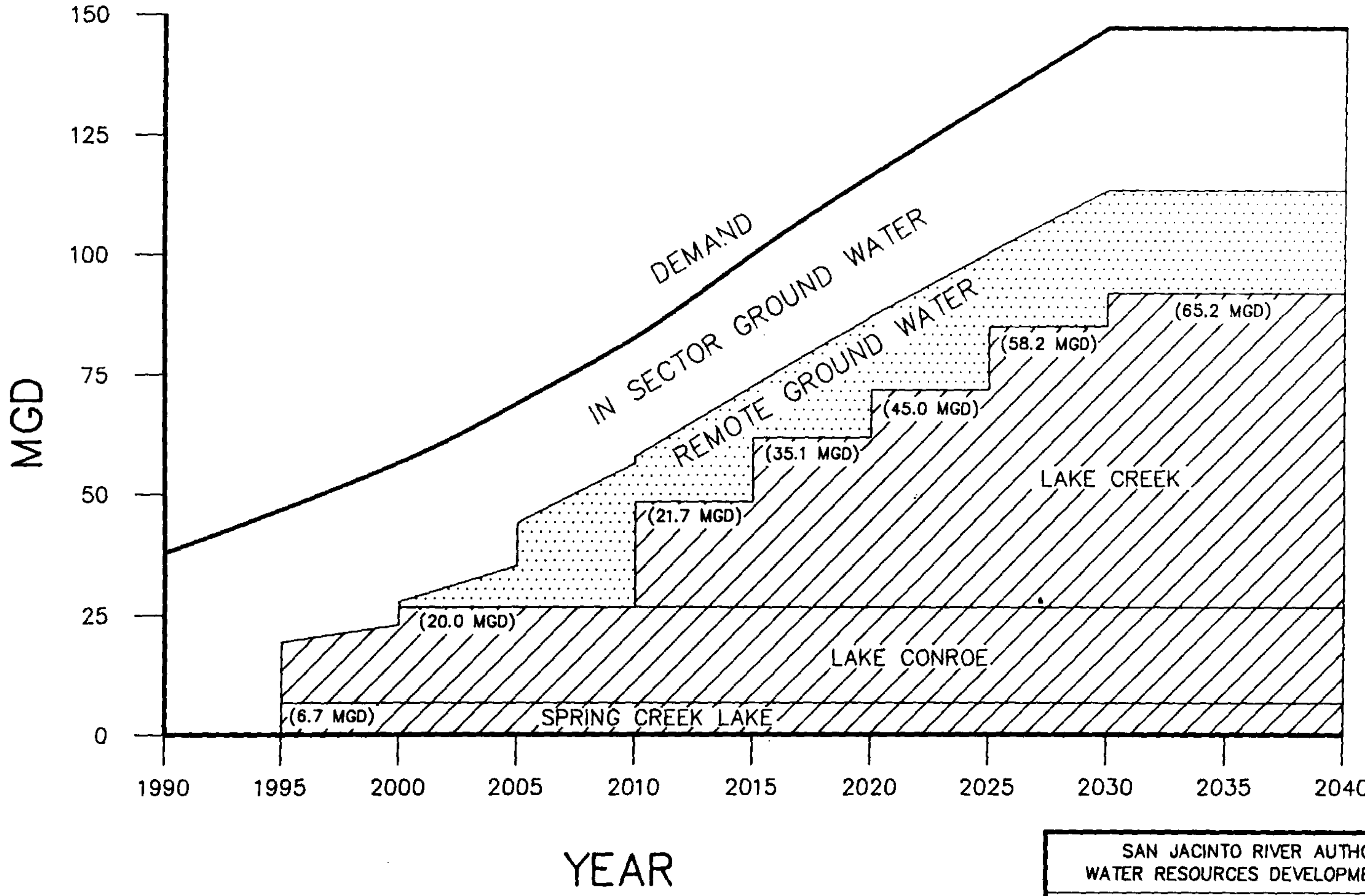
* 10% NON-CC
** LAKE CREEK FINANCING ASSUMES PARTIAL CARRY BY TWDB FROM 2007-2020
WITH 7% INTEREST AND 3% NON-CC ON DEFERRED AMOUNTS

324-2-2 DLA/LCL UPDATED 12-May-88

CAPITAL ITEMS	1987 $s	YEAR OF CONSTR	YEAR OF CONSTR $s	YEAR OF CONSTR BOND AMOUNT
	($M)		(@ 0%)	(12% NON-CC)
IN-SECTOR WELLS				
PHASE 1	12.4	1990	12.4	14.1
PHASE 2	2.9	1995	2.9	3.3
PHASE 3	4.8	2000	4.8	5.5
REMOTE WELLS				
PHASE 1	37.7	2000	37.7	42.8
PHASE 2	86.4	2005	86.4	98.2
PHASE 3	6.8	2015	6.8	7.7
PHASE 4	6.6	2020	6.6	7.5
RESERVOIRS				
SPRING CREEK	10.5	1992	10.5	11.9
LAKE CREEK	196.4	2007	98.2	109.1 *
		2015	7.5	13.3 **
		2020	29.8	74.1 **
		2025	39.8	138.6 **
		2030	21.1	103.1 **
SURFACE WATER PLANT (peak flow)				
PHASE 1 (37.1)	57.3	1994	57.3	65.1
PHASE 2 (5.9)	9.1	1999	9.1	10.3
PHASE 3 (35.0)	54.1	2009	54.1	61.5
PHASE 4 (22.0)	34.0	2014	34.0	38.6
PHASE 5 (16.0)	24.7	2019	24.7	28.1
PHASE 6 (22.0)	34.0	2024	34.0	38.6
PHASE 7 (10.0)	15.5	2029	15.5	17.6
CAPITAL COST	593.2		593.2	889.1

AMORTIZED COSTS (7% for 25 years // Reservoirs at 7% for 30 years)
(less one year capitalized interest in first year)

CAPITAL ITEMS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)	($M)
IN-SECTOR WELLS																	
PHASE 1	0.22	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21
PHASE 2						0.05	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
PHASE 3											0.09	0.47	0.47	0.47	0.47	0.47	0.47
REMOTE WELLS																	
PHASE 1											0.68	3.68	3.68	3.68	3.68	3.68	3.68
PHASE 2																1.55	8.42
RESERVOIRS																	
SPRING CREEK			0.13	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
SURFACE WATER PLANT (peak flow)																	
PHASE 1 (37.1)					1.03	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59
PHASE 2 (5.9)										0.16	0.89	0.89	0.89	0.89	0.89	0.89	0.89
CAPITAL COST	0.22	1.21	1.34	2.17	3.20	7.81	8.04	8.04	8.04	8.20	9.69	13.07	13.07	13.07	13.07	14.62	21.50
RAW WATER COST																	
CONROE ($0.23/1000 GALLONS)						1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68
O & M	0.00	0.00	0.00	0.00	0.00	2.58	2.58	2.58	2.58	2.58	3.46	3.46	3.46	3.46	3.46	3.67	3.67
TOTAL DEMANDS SECTORS 6-13 (MGD)	33.20	34.80	36.30	37.90	39.50	41.00	42.60	44.20	45.80	47.30	48.90	51.30	53.80	56.20	58.70	61.10	63.60
COST/1000 Gallons ($s)	0.02	0.10	0.10	0.16	0.22	0.81	0.79	0.76	0.74	0.72	0.83	0.97	0.93	0.89	0.85	0.90	1.16
MONTHLY COST/ESFC (12,600 gal/mo)	0.23	1.20	1.27	1.98	2.80	10.16	9.97	9.61	9.27	9.10	10.47	12.26	11.69	11.19	10.71	11.28	14.57
YEARS OF GROUNDWATER PUMPAGE REMAINING AT CONSTANT DEMAND	86					65					102					64	



SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

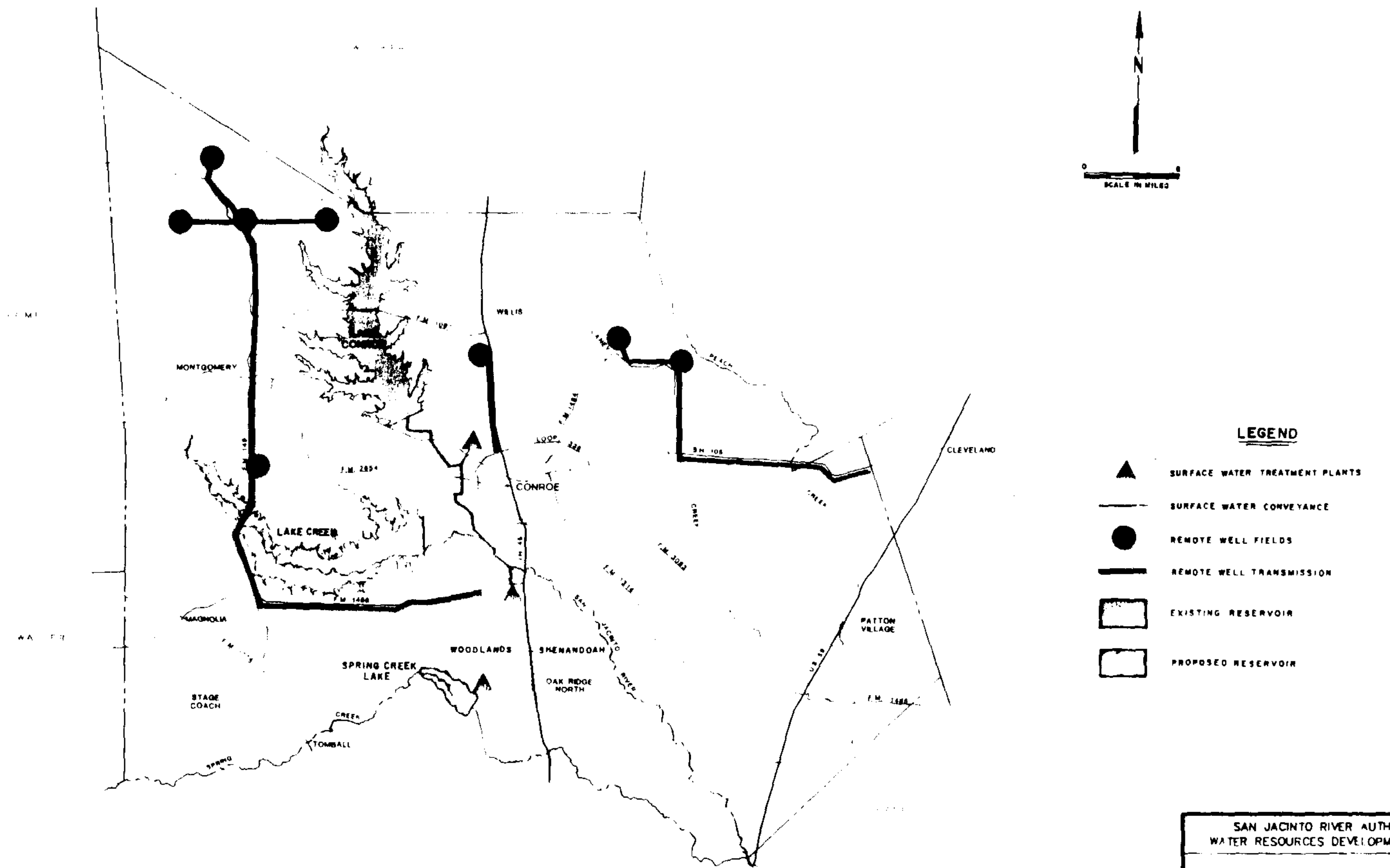
BASE SCENARIO
LAKE CREEK (2010)

PATE ENGINEERS, INC.
P.O. BOX 924024 HOUSTON, TX 77292 – 4024
PHONE 713 – 462 – 3178

EXHIBIT NO. 17

DATE: MAY, 1988

JOB NO. : 324–2–2



SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

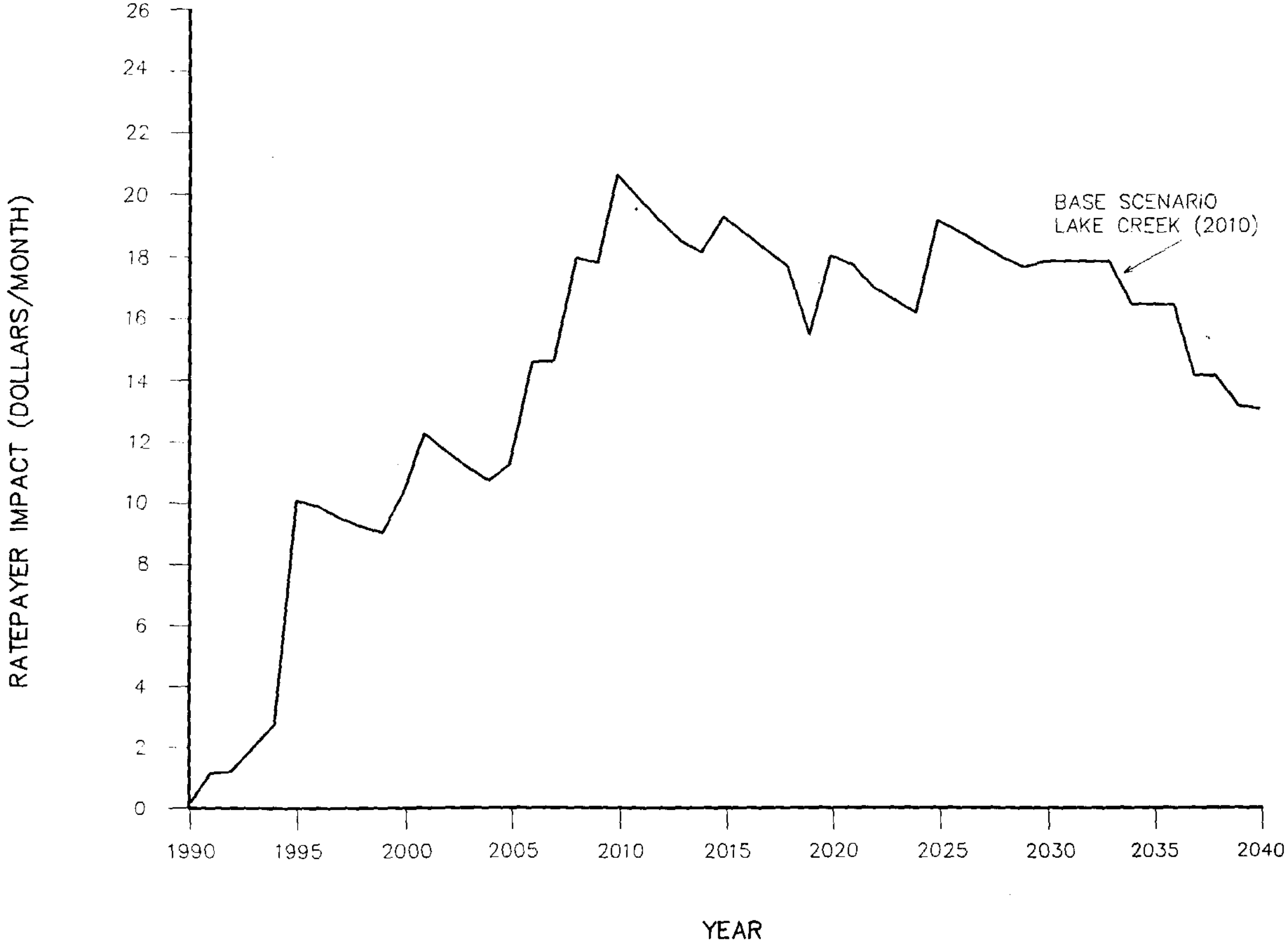
BASE SCENARIO
SUPPLY FACILITIES

PATE ENGINEERS, INC.

EXHIBIT NO 18

DATE: MAY, 1988

JOB NO: 324-2-2



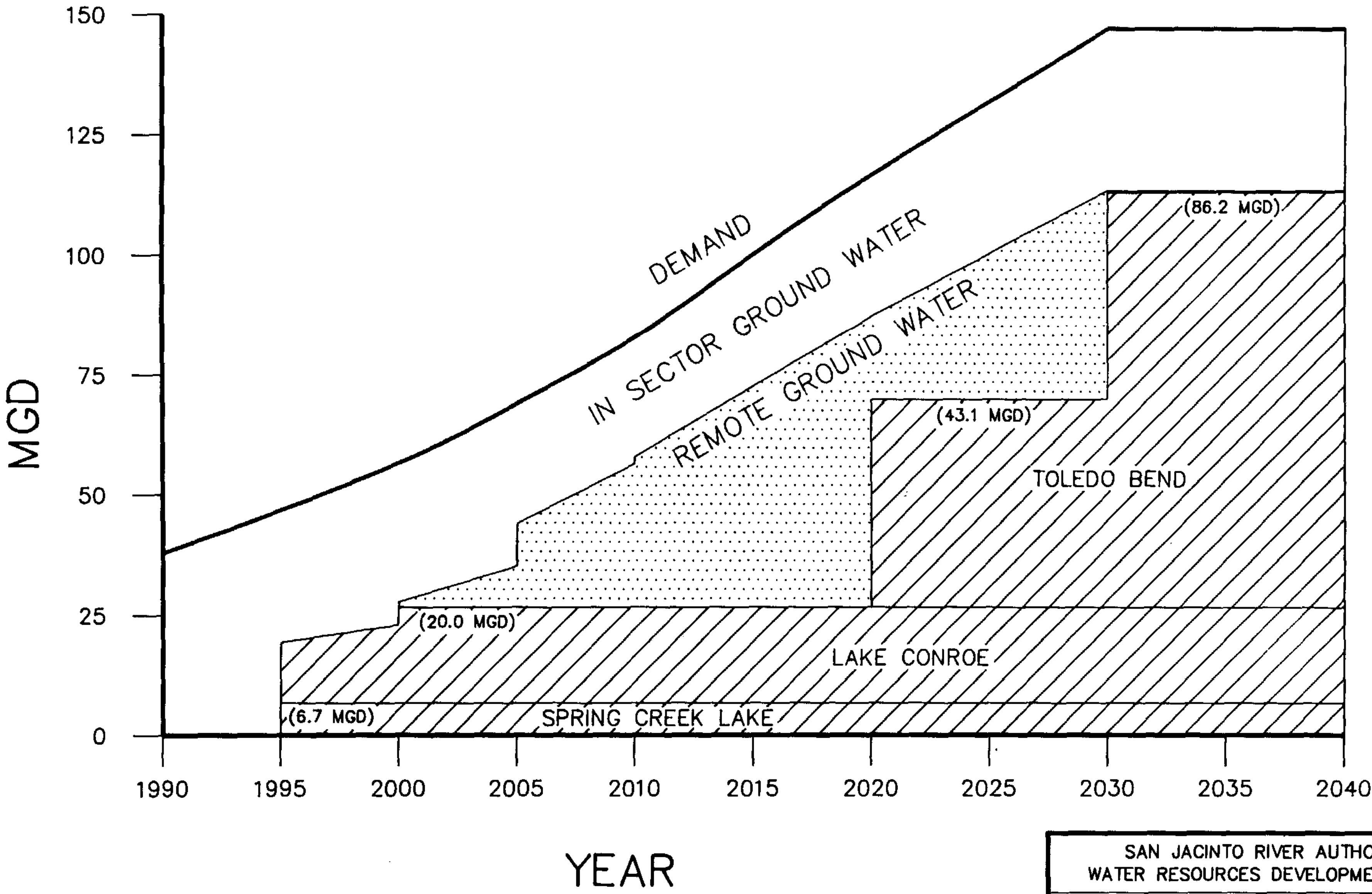
SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

BASE SCENARIO
IMPACT ON RATEPAYER

PATE ENGINEERS, INC.
P.O. BOX 924024 HOUSTON, TX 77292 - 4024
PHONE 713 - 462 - 3178

EXHIBIT NO.
19

DATE: MAY, 1988
JOB NO.: [illegible]



SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

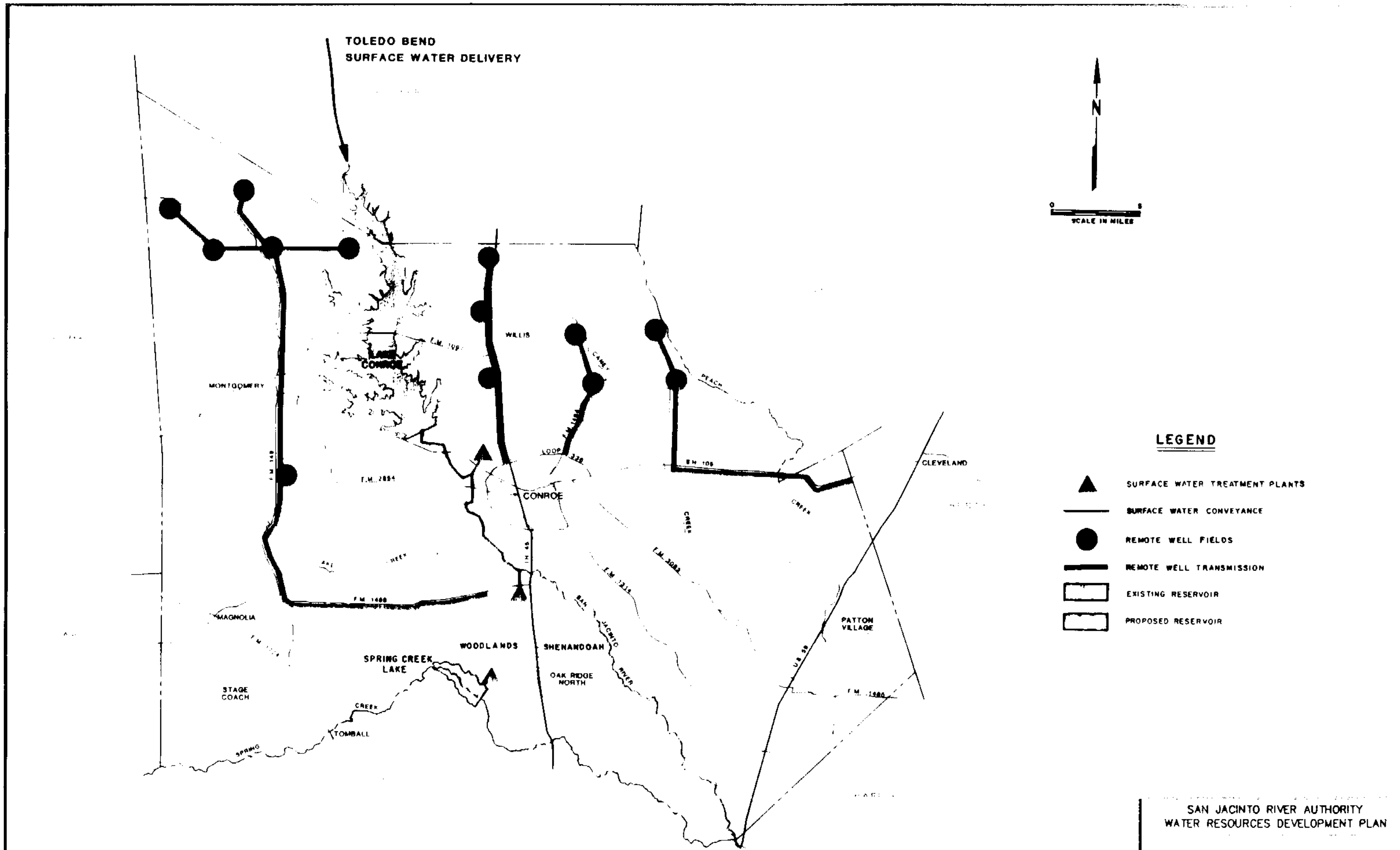
IMPORT SCENARIO
TOLEDO BEND (2020)

PATE ENGINEERS, INC.
P.O. BOX 924024 HOUSTON, TX 77292 - 4024
PHONE 713 - 462 - 3178

EXHIBIT NO. 20

DATE: MAY, 1988

JOB NO. : 324-2-2



SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

IMPORT SCENARIO

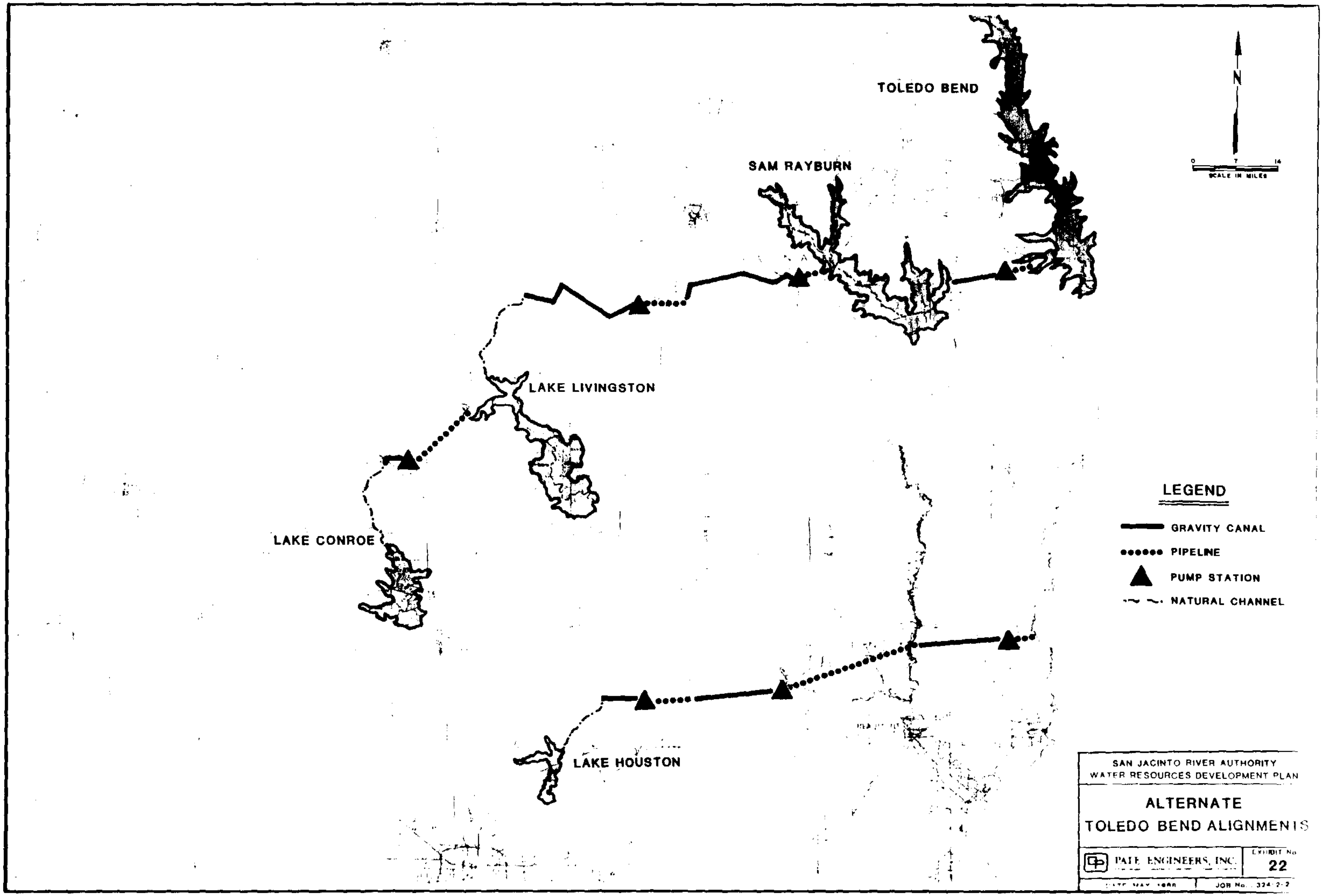
WATER SUPPLY FACILITIES

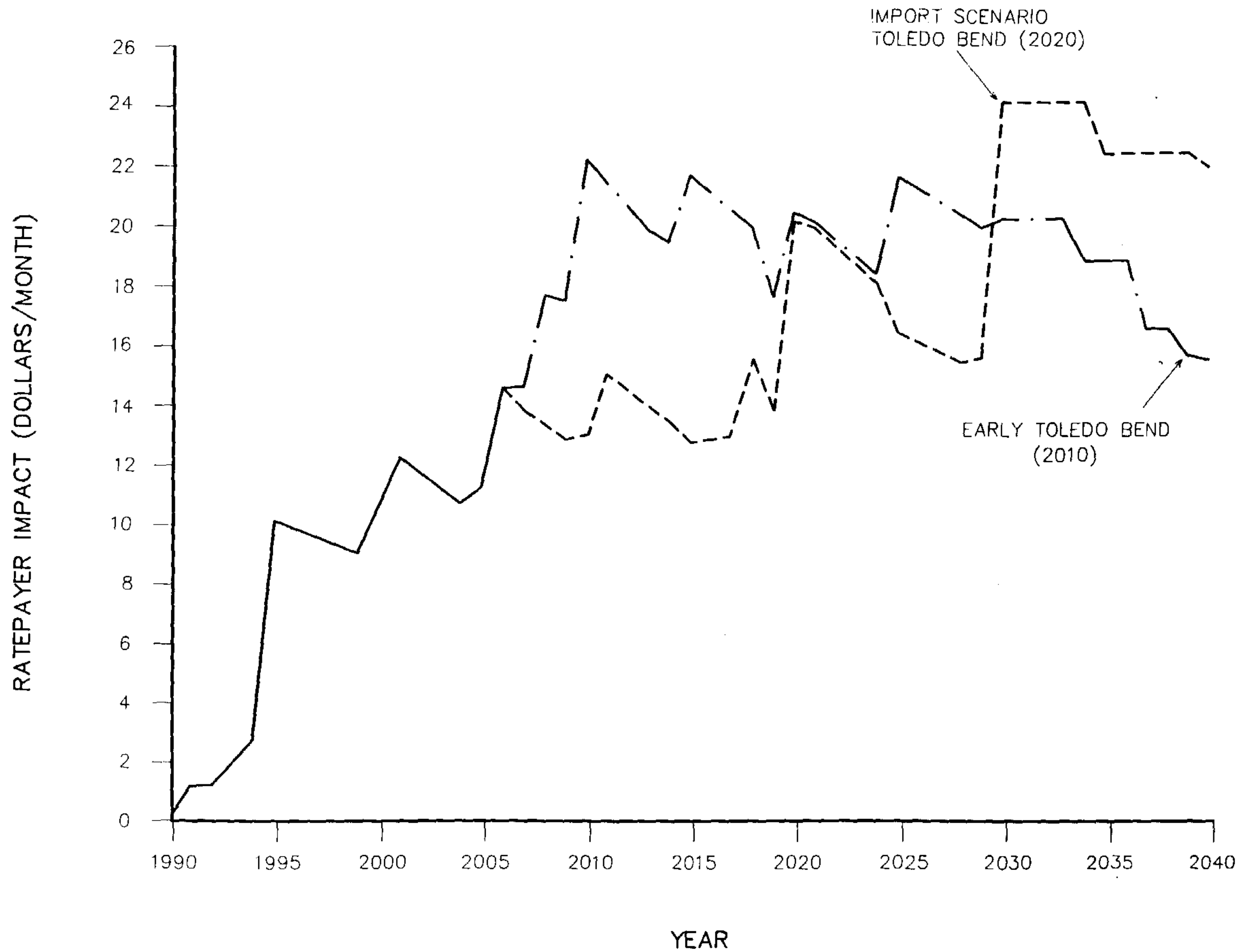
PATE ENGINEERS, INC.

EXHIBIT NO. 21

DATE: MAY, 1988

JOB NO.: 324-2-2

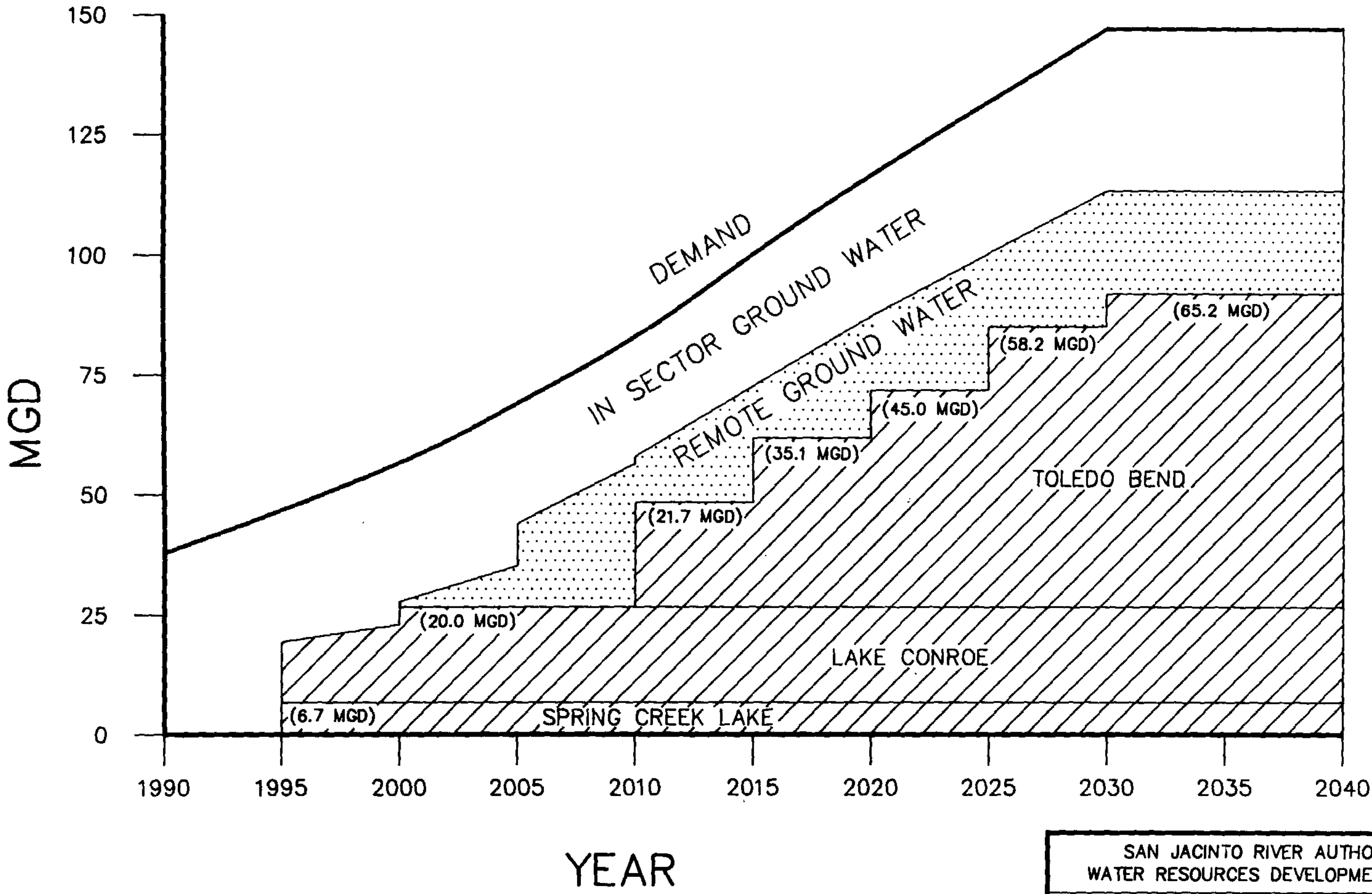

TOLEDO BEND
N
SCALE IN MILES
0
7
14
SAM RAYBURN
LAKE LIVINGSTON
LAKE CONROE
LAKE HOUSTON
LEGEND
GRAVITY CANAL
PIPELINE
PUMP STATION
NATURAL CHANNEL
SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN
ALTERNATE
TOLEDO BEND ALIGNMENTS
PATE ENGINEERS, INC.
EXHIBIT No
22
JOB No. 324-2-2



SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

IMPORT SCENARIO
IMPACT ON RATEPAYER

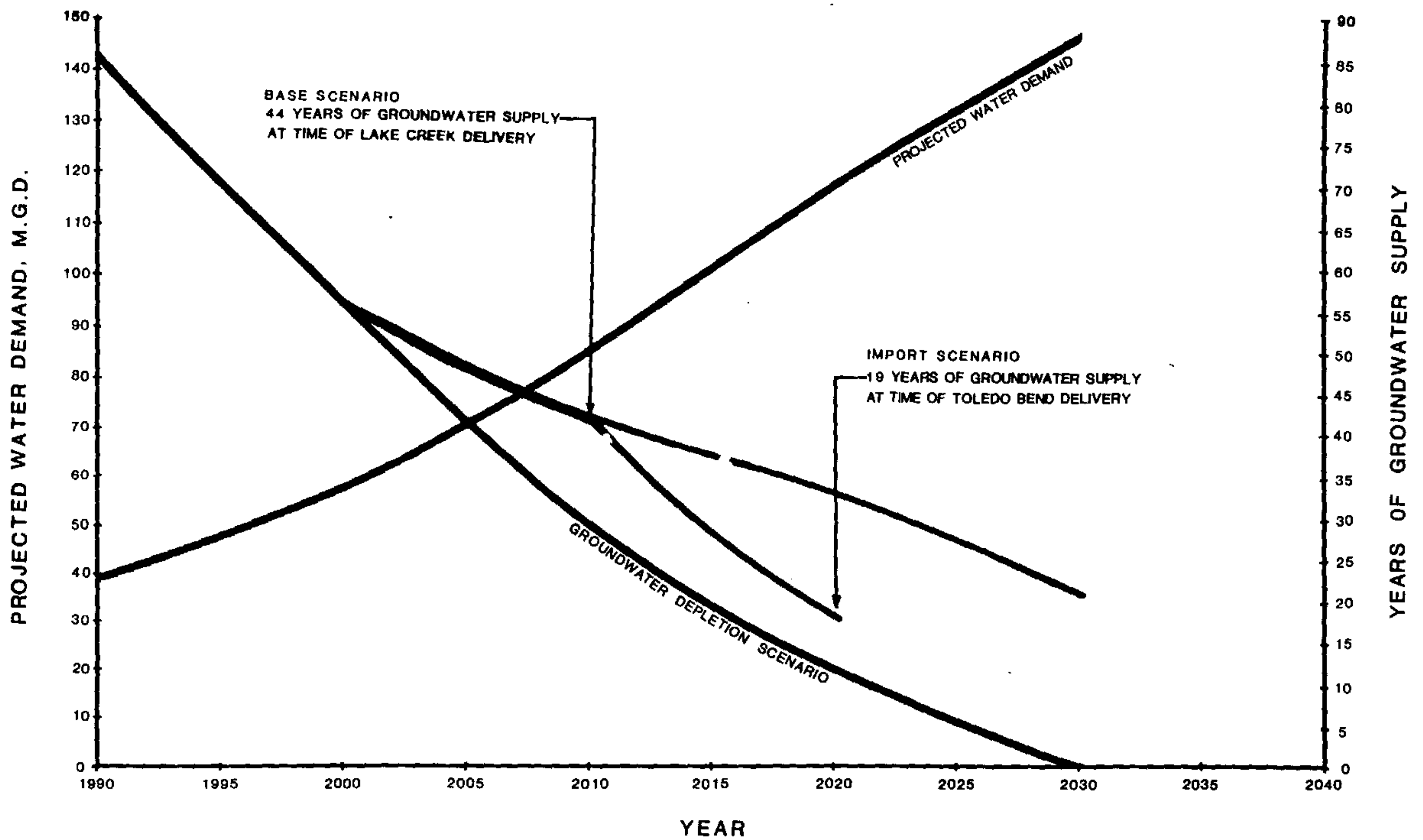
PATE ENGINEERS, INC.	EXHIBIT NO. 23
DATE: MAY, 1988	JOB NO. : 324-2-2



SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

TOLEDO BEND (2010) IMPORT ALTERNATIVE

PATE ENGINEERS, INC. P.O. BOX 924884 HOUSTON, TX 77292 – 4024 PHONE 713 – 462 – 3178	EXHIBIT NO. 24
DATE: MAY, 1988	JOB NO.: 324–2–2



SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

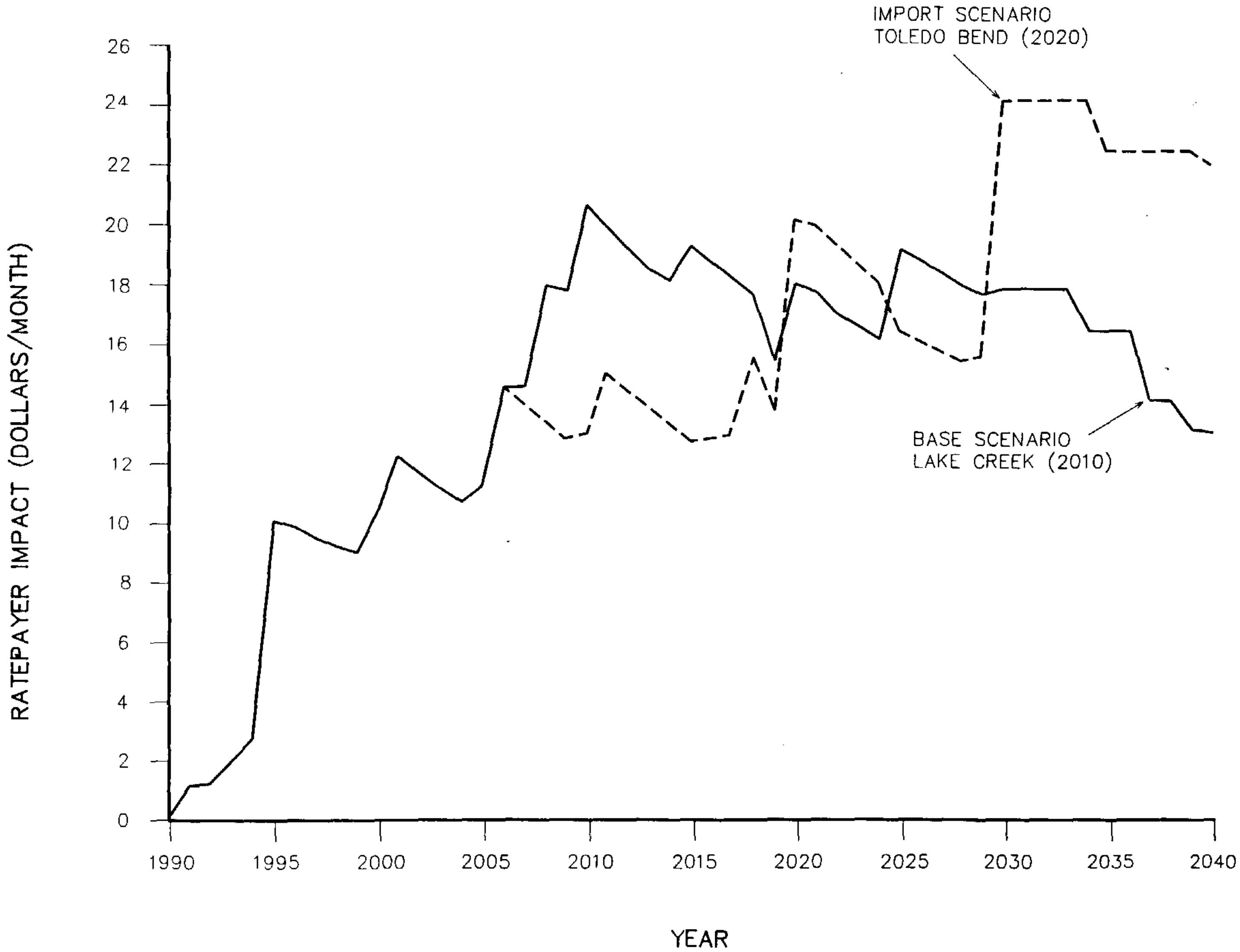
GROUNDWATER DEPLETION OF ALTERNATIVE SCENARIOS

PATE ENGINEERS, INC.

EXHIBIT No. 25

DATE: MAY, 1988

JOB No.: 324-2-2



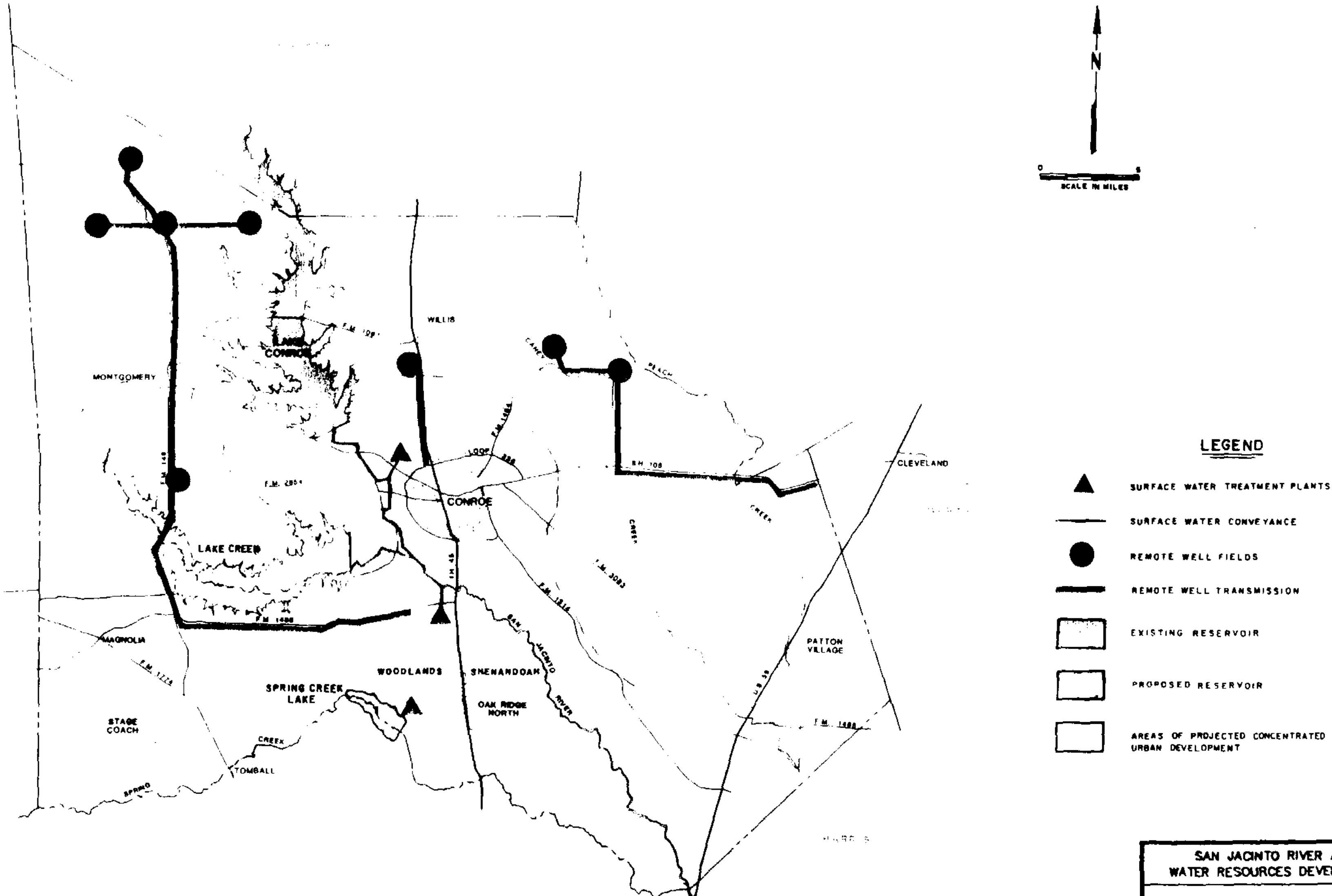
SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

COMPARISON OF BASE SCENARIO & IMPORT SCENARIO IMPACT ON RATEPAYER

PATE ENGINEERS, INC.

EXHIBIT NO. 26

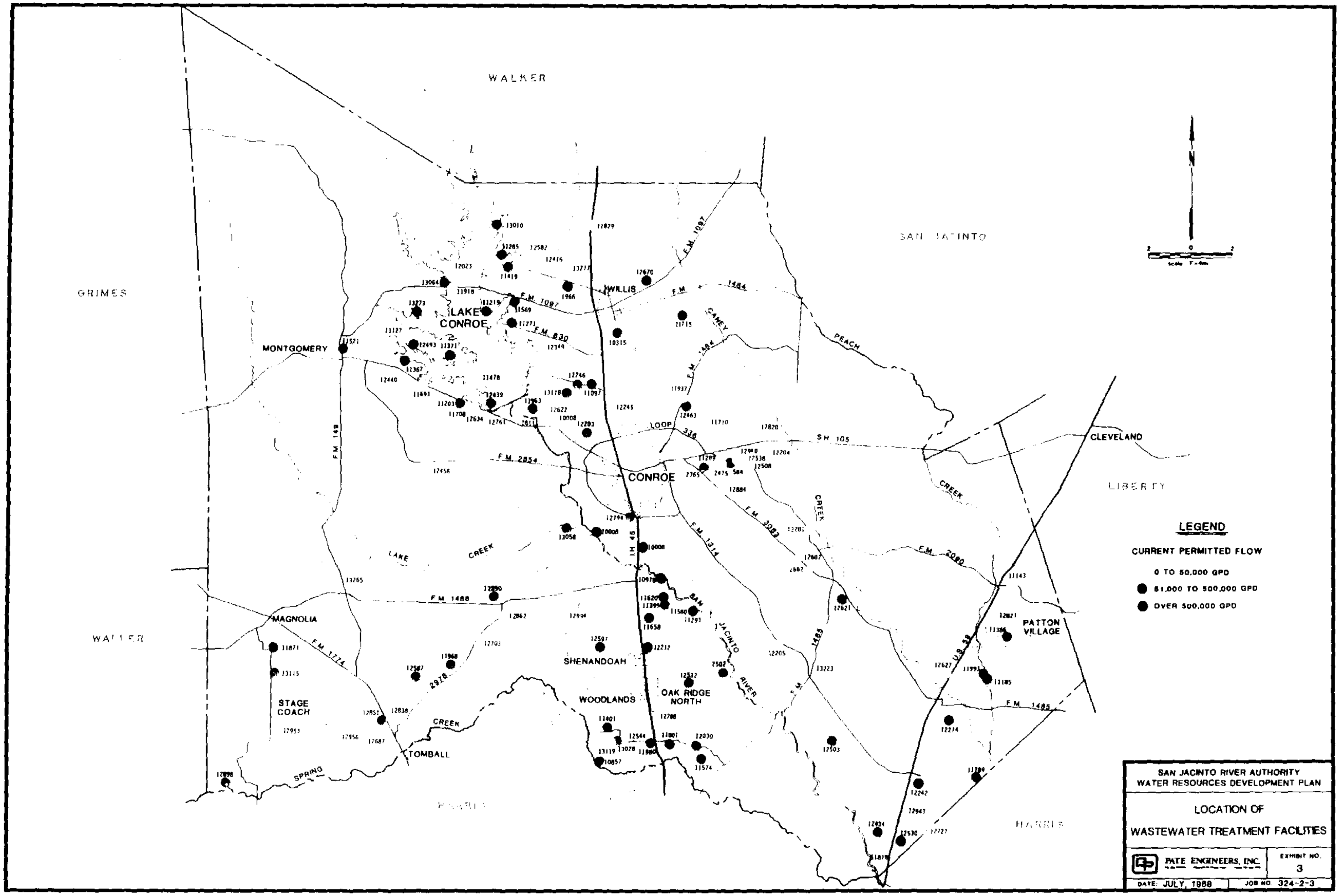
DATE: MAY, 1988 | JOB NO.: 324-2-2



SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN

RECOMMENDED WATER SUPPLY PLAN

PATE ENGINEERS, INC.	EXHIBIT NO. 27
DATE: MAY, 1988	JOB NO.: 324-2-2


WALKER
SAN JACINTO
GRIMES
WALLER
LIBERTY
HARRIS
HARRIS
LAKE CONROE
MONTGOMERY
WILLIS
CONROE
CLEVELAND
MAGNOLIA
STAGE COACH
TOMBALL
SHENANDOAH
WOODLANDS
OAK RIDGE NORTH
PATTON VILLAGE
LOOP 336
SH 105
IH 45
U.S. 59
F.M. 1097
F.M. 1484
F.M. 830
F.M. 149
F.M. 2854
F.M. 1488
F.M. 1774
F.M. 2978
F.M. 1314
F.M. 3083
F.M. 2090
F.M. 1485
PEACH
CANEY
CREEK
LAKE CREEK
SPRING CREEK
SAN JACINTO RIVER
N
LEGEND
CURRENT PERMITTED FLOW
0 TO 50,000 GPD
51,000 TO 500,000 GPD
OVER 500,000 GPD
SAN JACINTO RIVER AUTHORITY
WATER RESOURCES DEVELOPMENT PLAN
LOCATION OF
WASTEWATER TREATMENT FACILITIES
PATE ENGINEERS, INC.
EXHIBIT NO.
3
DATE: JULY, 1988
JOB NO. 324-2-3

APPENDIX C

ENGINEERING COST ESTIMATES FOR COMPONENT PROJECT IN WATER SUPPLY PLAN ALTERNATIVES

The conceptual design and cost estimating assumptions used in the preparation of preliminary construction cost estimates used in the analysis of alternative water supply plans are summarized in this Appendix.

The alternatives do not include costs for distribution of remote groundwater and treated surface water to individual entities such as cities and municipal utility districts since these costs will be very similar from one alternative to the next. For the purposes of comparison, remote groundwater is assumed to be pumped to one of three distribution points in the planning area as shown on Exhibit No. 18.

In-Sector Groundwater Wells

Additional groundwater supply plants complete with well, ground storage, booster pumps, hydropneumatic tank, and emergency power facilities were provided in those sectors where growth in demand could be supplied by available groundwater in that sector. Wells were assumed to be capable of delivering 1,000 GPM under peak demands but operate at 500 GPM continuously for average day demands. Although this probably represents above average utilization of well capacity, the in-sector groundwater supply, and thus the number and cost of wells, is the same for all scenarios. Water supply plants were estimated to cost $735,000 each with engineering and contingencies added at 15% and 12%, respectively.

Remote Groundwater Wells, Pump Station and Pipelines

Remote groundwater wells were located in Sectors 1 through 5 which have a surplus of available groundwater to the year 2030. Remote wells were assumed to be organized in well field of eight 1,000 gpm wells spaced approximately

2,500 feet apart. Seven of the eight wells are assumed to be normally operating so that each well field would produce 3,500 gpm (5.0 MGD) average daily flow and be capable of 7,000 gpm at peak production conditions. Each well field is estimated to cost $3,414,000, which includes eight wells at $300,000 apiece, well collection lines to a pump station, clearwell storage (two hours based on average daily flow), and land.

Remote well field pump stations were costed on the basis of $36.00 per gpm. Pump stations and transmission lines were sized based on maximum day flows equal to 1.6 times average day flows. Pumping heads were used in estimating operations and maintenance costs. Transmission lines were sized based on maximum velocity of 8 feet per second a maximum day flows. Construction costs per linear foot were based on a review of local and statewide bid tabulations and preliminary engineering studies. Costs for fittings, valves, bores, steel sections, wet sand construction, utility relocations, and right-of-way acquisition and preparation were assumed to equal to 50% of the transmission line costs. Engineering and contingencies costs were estimated to be 15% and 12%, respectively, of the remote well system costs.

Surface Water Treatment Plants

The capital cost of surface water treatment plants was estimated to be $1.20 per gallon per day. Maximum day treatment capacity was provided in all alternatives by assuming maximum day demands are 1.6 times average day demands. Engineering and contingencies added to surface water treatment plant costs were assumed to be 15% and 12%, respectively.

Spring Creek Lake

Spring Creek Lake will have a safe yield of 6.7 MGD and a surface area of approximately 1,000 acres. The estimated construction cost of Spring Creek Lake is $10,500,000 including clearing, dam and spillway construction, land acquisition, engineering and contingencies.

Lake Creek

The Lower Lake Creek project proposed by the Bureau of Reclamation is a multi-purpose project which provides 55.5 MGD of water supply, flood control benefits, and public recreation facilities. In order to increase the yield, reduce the unit cost, and make the Base Scenario comparable to Import Scenario (which does not provide flood control benefits), Lake Creek has been redefined as a non-federal single purpose water supply reservoir for the SJRA. Of course, public recreational facilities could still be constructed, operated and funded by another agency such as the Texas Department of Parks and Wildlife. When capacity reserved for flood storage is added to the water supply storage, the reservoir yield is increased to 62.5 MGD (70,000 Ac. Ft/Yr) as calculated by the Bureau of Reclamation. The detailed cost estimates prepared by the Bureau of Reclamation were reviewed in light of a local sponsored single purpose project, and some minor adjustments were made as shown on Table C-1. For the purposes of this analysis, the total estimated capital cost including contingencies and engineering for Lake Creek is $196,372,000.

Toledo Bend, Canals, Pump Station, and Pipelines

Raw water conveyance costs from Toledo Bend were estimated for two alternative alignments as shown in Exhibit No. 22: a northern route and a southern route. The definition of alignments utilized previous studies including TWDB's "Preliminary Basin Import Study - Sabine River to lake Livingston" (1977), TWDB's "Transportation of Water in Southeast Texas - A Preliminary Engineering Study of Alternative Conveyance Systems" (1967), and SJRA's "Preliminary Feasibility Report of Sabine River Surface Water to Lake Houston" (1986).

In the northern alignment, water from Toledo Bend is lifted to a 13 mile gravity canal from a pump station and intake structure located on the Reservoir about 10 miles upstream of the dam. The canal system delivers water to the east side of Sam Rayburn Reservoir, and is then again lifted by pump station from the west side of Sam Rayburn into a 24 mile gravity canal.

Near the town of Diboll, water must be pumped across the Neches River valley to where it enters a third gravity canal section approximately 29 miles long which empties into Little White Rock Creek, a tributary of Lake Livingston. Water is then lifted out of Lake Livingston and transported by pipeline along State Highway 19 to and around the north side of Huntsville where it then flows into McGary Creek, then the West Fork of the San Jacinto River, and finally Lake Conroe.

In the south alignment, water is lifted by pump station from the Sabine River to an 18 mile long gravity canal located north of Deweyville. Southeast of Silsbee, a pipeline will be required to pump across the Neches River Valley. It was assumed that this underground pipeline would be extended across the Big Thicket to the west side of the Little Pine Island Bayou instead of a gravity canal in order to minimize potential environment impacts. On the west side of Little Pine Island Bayou, water enters a gravity canal about 16 miles long ending at Hardin and being pumped across the Trinity River Valley. On the west side of the Trinity River, the pipeline enters an 8 mile long canal section which delivers water to Luce Bayou and thence Lake Houston.

Both the north and south alignments were assumed to be large projects in which the SJRA would purchase a minority ownership. This is consistent with the Houston Water Master Plan which proposes using 450 MGD of Toledo Bend water by year 2030. Since the quantity of Toledo Bend supply needed for the SJRA planning area based on peak day factor of 1.6 is in the range of 130 MGD, the total conveyance capacity of both alignments was assumed to be 600 MGD. This would result in a cost savings due to economy of scale for the SJRA ratepayers.

The pipeline and canal alignments were laid out on USGS 7-1/2 minute quadrangle maps. Pump stations and pipelines were sized and costed in the same fashion as those for remote well systems. Canals were designed based on an average gradient of 0.01% and an average velocity of 4 feet per second. Concrete lining of the canal, fencing, and a paved access road (one side) was assumed for the entire length. A quantity take off was prepared for canal reaches which accounted for cut and fill, concrete lining, gates, cross drainage structures, siphons, highway bridges, railroad crossings, pipeline crossing, access roads, fencing, and right-of-way acquisition and preparation.

The northern alignment was divided into two reaches, one from Toledo Bend to Lake Livingston sized at 600 MGD, and the other from Lake Livingston to Lake Conroe sized for 138 MGD capacity. The preliminary unit cost estimate for these two reaches are $409,933,222 (Table C-2) and $116,759,730 (Table C-3), respectively, for a total Toledo Bend conveyance cost for the northern alignment of $526,693,000.

TABLE NO. C-1

PRELIMINARY ESTIMATE OF COSTS FOR LAKE CREEK
AS A NON-FEDERAL PROJECT
SINGLE PURPOSE LAKE (65.2 MGD YIELD)

Item	Burec Project (x1000)	Adjustment	SJRA Project (x1000)
Row & Esmts.	$ 90,880		$ 90,880
Relocations	15,940		15,940
Clearing	3,940		3,940
Dam Structure	44,388	Engineering & Administration 5% reduction (25% to 20%)	42,612
Spillway	25,975	Engineering & Administration 5% reduction (25% to 20%)	24,936
Outlet Works	3,087	Engineering & Administration 5% reduction (25% to 20%)	2,964
Bldgs. & Equip.	1,100		1,100
Archeology	1,380	Reduced to $1,000	1,000
Recreation	13,160	Eliminate	-0-
Mitigation ROW	15,200	Revised estimate $13,000	13,000
Construction Cost	$215,050		$196,372

TABLE NO. C-2
PRELIMINARY ESTIMATE OF COSTS
FOR SURFACE WATER CONVEYANCE FROM
TOLEDO BEND TO LAKE LIVINGSTON
(600 MGD CAPACITY)

Item	Quantity		Unit Cost	Total
Excavation	15,634,700	C.Y.	$ 3	$ 46,904,100
Fill	1,957,150	C.Y.	3	5,871,450
Clearing	2,704	Acre	1,000	2,704,029
Fencing (8' high)	915,000	L.F.	10	9,150,000
Access road (14' wide)	814,333	S.Y.	15	12,215,000
Channel lining	2,513,708	S.Y.	25	62,842,708
Pressure piping (102")	132,000	L.F.	600	79,200,000
Pump station	3	Ea.	15,000,000	45,000,000
Intake structure	2	Ea.	3,500,000	7,000,000
Emergency spillway	4	Ea.	150,000	600,000
Channel gates	9	Ea.	100,000	900,000
Drop structure	2	Ea.	150,000	300,000
Small stream crossing	82	Ea.	50,000	4,100,000
Large stream crossing	4	Ea.	450,000	1,800,000
Highway Bridges				
2 Lane	26	Ea.	160,000	4,160,000
1 Lane	29	Ea.	70,000	2,030,000
Railroad bridge	1	Ea.	200,000	200,000
Pipeline crossing	12	Ea.	100,000	1,200,000
Channel cleanout	571,900	C.Y.	3	1,715,700
Maintenance facilities	3	Ea.	200,000	600,000
Automation and control	1	Ea.	1,000,000	1,000,000
Right of way (225')	2,704	Acre	2,500	6,760,072
Pipeline bridge	800	L.F.	1,000	800,000
Contingency (20%)				59,410,612
Engineering (15%)				53,469,551
TOTAL COST				$ 409,933,222

TABLE NO. C-3
PRELIMINARY ESTIMATE OF COSTS
FOR SURFACE WATER CONVEYANCE FROM
LAKE LIVINGSTON TO LAKE CONROE
(138 MGD CAPACITY)

Item	Quantity	Unit Cost	Total
Excavation	7,564,000 C.Y.	$ 3	$ 22,692,000
Fill	17,850 C.Y.	3	53,550
Clearing	590 Acre	1,000	589,618
Fencing (8' high)	123,500 L.F.	10	1,235,000
Access road (14' wide)	177,567 S.Y.	15	2,663,500
Channel lining	177,223 S.Y.	25	4,430,563
Pressure piping (66")	104,800 L.F.	360	37,728,000
Pump station	1 Ea.	3,448,000	3,448,000
Intake structure	1 Ea.	3,500,000	3,500,000
Emergency spillway	1 Ea.	150,000	150,000
Channel gates	2 Ea.	100,000	200,000
Small stream crossing	32 Ea.	50,000	1,600,000
Highway Bridges			
4 Lane	2 Ea.	500,000	1,000,000
2 Lane	8 Ea.	160,000	1,280,000
1 Lane	5 Ea.	70,000	350,000
Pipeline crossing	6 Ea.	100,000	600,000
Channel cleanout	138,075 C.Y.	3	414,225
Maintenance facilities	1 Ea.	200,000	200,000
Automation and control	1 Ea.	1,000,000	1,000,000
Right of way (225')	590 Acre	2,500	1,474,044
Contingency (20%)			16,921,700
Engineering (15%)			15,229,530
TOTAL COST			$ 116,759,730