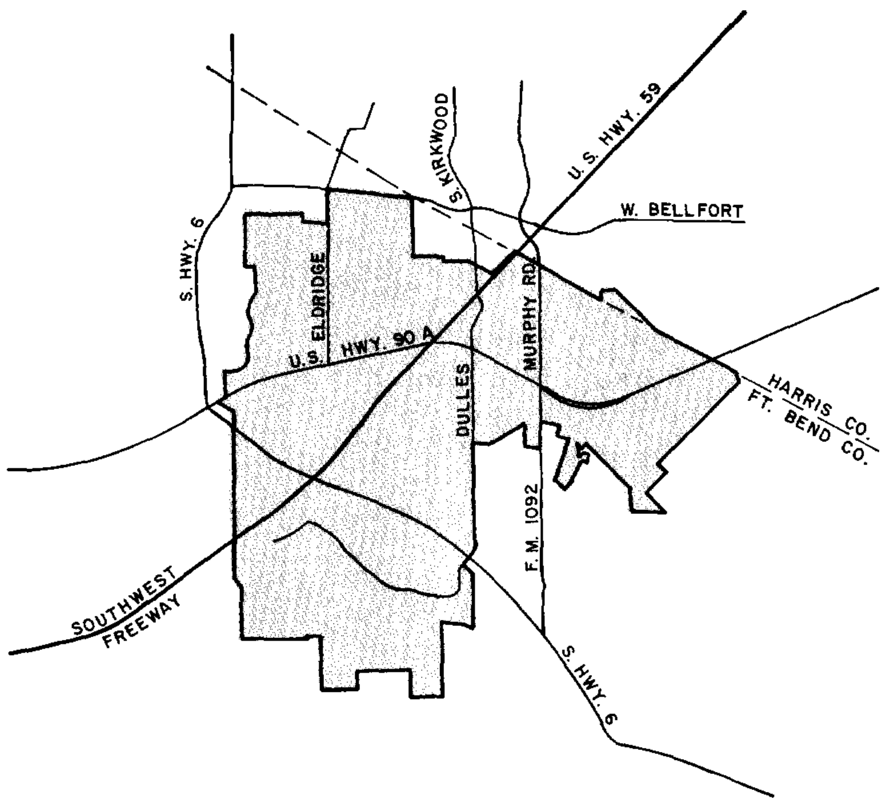
REGIONAL WATER SUPPLY AND PLANNING STUDY



FORT BEND COUNTY

WATER CONTROL & IMPROVEMENT DISTRICT 2

AND

CITY OF SUGAR LAND

PREPARED BY

JONES & CARTER/PATE ENGINEERS
A Joint Venture

JONES & CARTER / PATE ENGINEERS
A JOINT VENTURE

OCT 20 1988

August 30, 1988

Board of Directors
Fort Bend County
Water Control & Improvement
District No. 2
2331 South Main Street
Stafford, Texas 77477

The Honorable Mayor and
City Council
City of Sugar Land
200 Matlage Way
Post Office Box 110
Sugar Land, Texas 77487-0110

Dear Directors and Council:

We are pleased to submit the enclosed Regional Water Supply and Planning Study for Fort Bend County Water Control & Improvement District No. 2 and the City of Sugar Land.

This report includes an analysis of existing groundwater conditions, projections for future water demand, an evaluation of the need for a long-term surface water supply, and recommendations for a surface water conversion program. Potential surface water resources are listed and analyzed. The report includes recommendations on the source of surface water as well as proposed surface water facilities. These facilities include a surface water treatment plant and conveyance lines. The cost of these surface water facilities and an economic analysis of the project are also provided.

It is our opinion that you should adopt this report as your plan for implementing an orderly conversion from total dependence on groundwater to a surface water supply system which is supplemented with groundwater. This report provides a practical and economical solution to the long-term water needs of the area.

Sincerely,

JONES & CARTER, INC.

J. R. (Bob) Jones, P.E.

STATE OF TEXAS
JAMES ROBERT JONES
36949
REGISTERED
PROFESSIONAL ENGINEER

PATE ENGINEERS, INC.

Gerry E. Pate, P.E.

STATE OF TEXAS
GERRY E. PATE
28304
REGISTERED
PROFESSIONAL ENGINEER

JONES & CARTER, INC. - 6335 Gulfton, Suite 200, Houston, Texas 77081 (713) 777-5337

PATE ENGINEERS, INC. - 13403 Northwest Freeway, Suite 160, Houston, Texas 77040-6071 (713) 462-3178

REGIONAL WATER SUPPLY

AND

PLANNING STUDY

Prepared for

Fort Bend County Water Control & Improvement District No. 2

and

City of Sugar Land

August 1988

JONES & CARTER/PATE ENGINEERS

ACKNOWLEDGMENTS

This report was sponsored by Fort Bend County Water Control & Improvement District No. 2 and the City of Sugar Land with matching funds provided by the Texas Water Development Board. We would like to commend the sponsors of this project for their foresight in realizing the need for prudent planning for the future. We would also like to acknowledge the efforts of the Texas Water Development Board and their active participation in regional planning studies which examine the future water needs of the State of Texas.

We would like to express our gratitude to the Brazos River Authority, Galveston County Water Authority, United States Geological Survey, Fort Bend County Appraisal District, and the City of Houston for providing useful service and information. We especially appreciate the invaluable help from the staff of Fort Bend County Water & Control Improvement District No. 2 and the City of Sugar Land Public Works Department. We are also grateful for the cooperation from the various well drillers and utility district consultants within the study area.

AUTHORIZATION

On June 2, 1987, the Texas Water Development Board approved a matching funds grant for a regional surface water supply study within the boundaries of Fort Bend County Water Control & Improvement District No. 2 (WC&ID No. 2) and the City of Sugar Land (Sugar Land). The joint venture of Jones & Carter, Inc. and Pate Engineers, Inc. was authorized on August 5, 1987, to represent WC&ID No. 2 and Sugar Land in this study.

REGIONAL WATER SUPPLY AND PLANNING STUDY
FOR
FORT BEND COUNTY
WATER CONTROL & IMPROVEMENT DISTRICT NO. 2
AND
THE CITY OF SUGAR LAND

CONTENTS

TABLES

EXECUTIVE SUMMARY

Fort Bend County Water Control & Improvement District No. 2 (WC&ID No. 2) and the City of Sugar Land, including the portion of its extraterritorial jurisdiction known as First Colony, jointly cover approximately 21,000 acres in the northeast corner of Fort Bend County which make up the regional planning area (RPA) for this study. In August 1987, this study was authorized to investigate the area groundwater supply and to develop a surface water conversion and implementation plan to bring surface water to the area if the groundwater situation indicated a need for a surface water supply. WC&ID No. 2 and Sugar Land have a current combined water demand of approximately six million gallons per day (MGD). By 2030, that demand is forecasted to reach approximately 20 MGD. First Colony will add an additional 10 MGD to the demand, to bring the total water needs of the RPA to 30 MGD by 2030.

Background

The Regional Planning Area (RPA) is one of the areas currently experiencing a rapidly declining water table because of heavy demand on the groundwater supply. Groundwater sources currently supply all of the water utilized in the entire RPA.

Heavy groundwater pumpage causes declines in groundwater levels which leads to land surface subsidence. Because groundwater pumpage over a regional area creates these problems, their solutions should be addressed on a regional basis. This study develops a plan to address the problems occurring within the RPA.

This study includes an evaluation by McBride-Ratcliff and Associates of the projected effects on the yield of the groundwater aquifers and estimates the projected land surface subsidence between 1987 and 2030. That portion of the study shows land surface subsidence can be reduced substantially over the next 40 years if regional conversion to 80 percent surface water use occurs by the year 2000.

Regional Water Supply Planning

The most economical means of reducing groundwater pumpage within the RPA would be obtained through the conjunctive use of surface water and groundwater which optimizes the use of both sources of water. Providing surface water at average daily flow to existing groundwater storage tanks and meeting peak demands using well water would maximize use of existing facilities and eliminate the need to oversize conveyance lines to carry peak flows. Conversion to 80 percent surface water will optimize the economic benefits associated with conjunctive use systems while substantially reducing groundwater dependence.

The plan presented provides an initial 16-MGD surface water plant by the year 2000, plus ultimate conveyance waterlines adequate to serve 80 percent of the water demand of WC&ID No. 2, Sugar Land, and the portion of First Colony within the Sugar Land extraterritorial jurisdiction. A plant expansion to 24 MGD in 2020 provides adequate surface water capacity through 2030.

A review of surface water sources indicates there is currently an adequate supply of raw water available from the Tri-County canal system to meet the future needs of the RPA. Although there is currently an adequate supply of water from this source, it is a limited quantity which will be fully committed in the future. Therefore, the RPA entities should take steps to secure this source of water for their future needs. The estimated cost of raw water from the Tri-County canal system is $0.115 per thousand gallons. As a comparison, Brazos River water from the Brazos River Authority is currently available for about $0.37 per thousand gallons.

Raw Water Treatment

The Texas Department of Health has established regulations limiting the amount of chlorides allowable in drinking water. It is anticipated that the United States Environmental Protection Agency (EPA) will soon further limit chloride concentrations. The Brazos River is known to exceed these allowable concentrations about five percent of the time, or about 18 days per year.

Purification plants treating Brazos River water typically adjust for these periods by drawing upon water that was impounded during periods of lower chloride concentrations. Providing for an impoundment for this purpose requires substantial land area and increases the cost of treatment facilities. By utilizing the existing lake system on the Tri-County canal system within the City of Sugar Land for raw water impoundment, this cost can be avoided. With no changes to current canal system operations, the lake system could provide 18 days of impoundment for a plant up to 115 MGD capacity, well above the 24 MGD needed by the RPA.

Regional Facilities

A site capable of supporting a 24-MGD plant and utilizing the Tri-County lake system for raw water impoundment has been identified. The site lies south of Avenue E, just east of Brand Lane along the Tri-County canal near Dulles Avenue. To provide flexibility in phasing, the plant should consist of three parallel 8-MGD trains.

The proposed conveyance system will deliver treated water to existing and future ground storage tanks. Surface water will be mixed at this point with groundwater and pressurized for distribution to retail customers.

Financial Impact

It is estimated that the proposed treatment plant can be constructed for a cost of $28,700,000 (1988 dollars). Conveyance facilities are estimated at $5,007,000 bringing total project costs to $33,707,000 (1988 dollars).

Two funding concepts were considered. These are (1) a water rate-based option and (2) a combination tax rate and water rate option. Following is a description of these options:

Rate-Based Option - Under this option, all costs associated with the surface water project would be met through water rates. These costs include retirement of debt, interest, raw water, operations, and maintenance costs.

Tax/Rate-Based Option - Under this option, debt retirement and interest would be covered by collections from an ad valorem tax. Other costs, including raw water, operations, and maintenance costs would be met with water rates.

The rate-based financing will require water rate increases of between $0.62 and $0.93 per 1,000 gallons of water. The tax/water rate-based financing creates a need for a tax between $0.04 and $0.06/$100 in assessed valuation and a water rate increase of $0.28 to $0.46 per 1,000 gallons of water.

Conclusions and Recommendations

WC&ID No. 2, Sugar Land, and the First Colony area should take steps to convert their primary source of water from groundwater to surface water by the year 2000. This conversion can be accomplished most economically by acquiring adequate water rights in the Tri-County canal system, purchasing an acceptable plant site on Avenue E, constructing a 24-MGD surface water treatment plant in phases, and building the planned surface water conveyance lines.

WC&ID No. 2, Sugar Land, and the First Colony area should begin steps to protect possible corridors for future surface water conveyance lines and begin discussions with other possible participants in the proposed surface water plan.

This plan is consistent with the surface water conversion plans of the surrounding municipalities and is a feasible way to meet the surface water needs of the area.

I. INTRODUCTION

The increased groundwater pumping accompanying the rapid development and population growth in northeast Fort Bend and southwest Harris Counties has made land surface subsidence and water table (potentiometric) declines regional issues of concern. Unlike other developed areas of the southeast Texas Gulf Coast which have experienced land subsidence, the region is not at risk from tidal flooding. Subsidence can, however, impact inland area storm drainage and levee protection systems. Additionally, significant water table declines will cause loss of well capacity and will increase maintenance costs.

The impact of land subsidence is realized as the result of regional groundwater withdrawal, although the intensity of subsidence is related to local pumping. Recognizing this phenomenon, Harris and Galveston Counties have embarked on a regional program to reduce groundwater pumping by significantly converting to surface water use. As a result of this program, which has resulted in dramatic reductions in groundwater pumpage in east Harris County, the "cone," or area of most rapid and greatest rate of land surface subsidence, shifted westward from the industrial area along the Houston Ship Channel to the primarily residential area in southwest Houston and adjacent communities in Fort Bend County where groundwater pumpage has continued to increase.

Fort Bend County Water Control & Improvement District No. 2 (WC&ID No. 2) and the City of Sugar Land (Sugar Land), both lie on the edge of this cone. Analysis presented in this report shows that if groundwater pumping remains unabated in the region of the cone, these two entities can expect to experience substantial declines in water table (potentiometric level) and up to six feet of subsidence in the next 40 years. On the other hand, conversion to surface water on a regional basis, in accordance with targets and timetables similar to those planned for Harris and Galveston Counties, will reduce water table (potentiometric) declines in these two entities by as much as 175 feet and reduce projected land subsidence by as much as two feet over the same period.

Purpose

The purpose of this study is to define a surface water conversion plan for WC&ID No. 2 and Sugar Land, to develop an implementation plan to evaluate the financial impacts on these two entities, and to describe the activities to be accomplished to convert to surface water. There is no existing institutional vehicle leading surface water conversion planning in Fort Bend County at this time. A number of cities and districts in Fort Bend County, however, are studying conversion. The plan presented herein does not depend on other Fort Bend County municipalities and districts participating. The plan has been developed, however, so that such entities are not precluded from doing so.

Scope

The study analyzed the various water sources and water availability based on projected demands. Also included is an analysis of groundwater availability including projections of subsidence and future water table (potentiometric) levels. Because there is an adequate supply of groundwater available for the near future, the conversion to surface water could be incorporated to control subsidence within the service area.

Included in this report is information on existing groundwater supplies, historic subsidence, wells, distribution systems, (including capacities, operating pressures, interconnects, and water storage facilities), population, and water use. Growth projections of population have been analyzed to project water use. Sources of raw water are identified with capacities and costs listed. Facilities are defined to convert to surface water and costs are presented. An implementation plan is provided including financial impacts for two alternative plans.

Regional Planning Area (RPA)

For the purposes of this report, we have defined a regional planning area (RPA) that includes Fort Bend County Water Control & Improvement District No. 2 (WC&ID No. 2), the City of Sugar Land (Sugar Land), and the First Colony Utility Districts (First Colony), which is a group of 10 water districts located within the extraterritorial jurisdiction (ETJ) of Sugar Land. (See Figure 1, Vicinity Map, for the location of the RPA.) The corporate boundary of Sugar Land includes 7,148 acres of land and WC&ID No. 2 includes 6,879 acres of land. The ETJ of Sugar Land and future service area of WC&ID No. 2 used for the RPA includes approximately 7,000 additional acres, making the grand total of the RPA approximately 21,000 acres. Figure 2, Regional Planning Area, outlines the area encompassed within the RPA. The RPA of this study was specifically analyzed in order to establish a regional water supply plan for Sugar Land and WC&ID No. 2.

Coordination with Other Regional Water Supply Entities

A number of other planning efforts are currently on-going with which coordination is required to avoid duplication of efforts. These plans are primarily focused in northeast Fort Bend County and west and southwest Harris County. Entities studying surface water conversion include the Brazos Bend Water Authority, the West Harris County Water Supply Corporation, the City of Houston, and the City of Rosenberg, all except the City of Houston partially funded by planning grants from the Texas Water Development Board. The geographic relationship of each of these entities is illustrated in Figure 3. The general scope, available data, and relevant planning conclusions for each of these plans follow.

Brazos Bend Water Authority

The Brazos Bend Water Authority (BBWA) was created on behalf of the Cities of Missouri City, Pearland, Manvel, and Brookside Village. The BBWA has obtained financial assistance from the Texas Water Development Board. The service area contains 100,670 acres, which is divided into two large areas. The western area includes Missouri City and the eastern area includes the other three municipalities. The City of Alvin is not a participant. The study is evaluating the use of Brazos River Authority Canal "A" water and the City of Houston Southeast Water Purification Plant as sources of raw or treated water, respectively.

The BBWA study has only recently started. Preliminary growth projections for the BBWA area show water demand to be 14 MGD in the year 2000 and 22 MGD in 2020. The planning conclusions and recommendations will be released after this report.

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 Harris-Galveston Coastal Subsidence District (HGCSD) Plan and the City of Houston Water Master Plan in order to provide a reliable supply of surface water and minimize land subsidence. The WHCWSC 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 recommended 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.

City of Rosenberg

The City of Rosenberg recently started a surface water conversion study with partial funding by the Texas Water Development Board. Preliminary discussions with the City's consultant disclosed that they are evaluating the use of water from Allen's Creek reservoir as proposed by the West Harris County Water Supply Corporation. The Rosenberg study will also be available after this report.

City of Houston Water Master Plan

The City of Houston 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 additional water supply alternatives yielded three candidates: (1) Toldeo Bend Alternative, (2) Western Water Alternative (including the Bedias Reservoir), 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 eight-county area master plan also includes a Southwest Water Purification Plant near Sugar Land of approximately 100 MGD capacity. This plant is consistent with this report.

Report Organization

This study has been prepared in two volumes. Volume I addresses the needs of the regional planning area, benefits of surface water conversion, supplies and facilities, financial impacts, and an implementation plan. Volume II includes a supplementary study of groundwater conditions prepared by McBride-Ratcliff and Associates on a subcontract basis. This volume also contains a written conservation plan prepared in accordance with the terms of the research and planning grant funding contract with the Texas Water Development Board.

II. EXISTING CONDITIONS

Growth in eastern Fort Bend County began as early as 1843 with the founding of the Imperial Sugar Company. With continued growth of the Sugar Company, the area around it grew proportionally. In the 1950's and 1960's several other companies opened plants in eastern Fort Bend County. These early companies and their industries encouraged continual growth in the area. Between 1970 and 1982 eastern Fort Bend County had a 732 percent population growth. This growth rate helped to rank Fort Bend County as the third fastest growing county in Texas. Between 1980 and 1987 population in Fort Bend Conty continued this rapid growth showing nearly a 50 percent increase in population, thus helping Fort Bend County to remain one of the fastest growing counties in Texas.

Description of RPA

The regional planning area (RPA) is located in northeast Fort Bend County approximately 20 miles southwest of downtown Houston. Three individual entities consitute the RPA. They are Fort Bend County Water Control & Improvement District No. 2 (WC&ID No. 2), the City of Sugar Land (Sugar Land), and a group of 10 water districts which serve the First Colony Subdivision (First Colony). The City of Stafford lies within WC&ID No. 2. The major highways crossing the RPA are U.S. Highway 59, State Highway 6, FM 1092, and U.S. Highway 90 Alternate. The Brazos River flows as close as one-half mile from the southwest corner of the RPA. The Brazos River Authority (BRA) operates a canal system known as Canal "A" which passes through the center of the RPA. The Canal "A" system contains a number of lakes located in the western half of the RPA. See Figure 4, Tri-County Canal.

The RPA contains a wide variety of land with a multitude of uses, ranging from agricultural acreage to highly developed residential subdivisions and specialized industrial complexes. The RPA includes approximately 21,000 acres of land with an estimated population of nearly 50,000 people. The average water use within the RPA is between eight and nine million gallons of water each day.

Data on current groundwater pumpage and assessed land values was obtained as a part of the evaluation of current conditions within the RPA. Monthly groundwater pumpage records from 1984 to 1987 were compiled for the three major water suppliers within the RPA. These records are illustrated graphically in Figure 5. The monthly pumpage is shown both as a total for the RPA and with the breakdown of usage by WC&ID No. 2, Sugar Land, and First Colony. Assessed land values for various entities located in northeast Fort Bend County were obtained from the Fort Bend County Appraisal District. Table 1, Assessed Land Values, lists the assessed values of entities located in and around the RPA. The total assessed value for the RPA in 1987 was estimated at $2.8 billion.

WC&ID No. 2

WC&ID No. 2 contains approximately 6,880 acres consisting of predominantly commercial and industrial development with several areas of residential development. WC&ID No. 2 is currently at 15 to 20 percent of full development. WC&ID No. 2 has an estimated population of 9,000 people. Wells within WC&ID No. 2 pumped an average of 2.58 million gallons of groundwater each day for 1987. Groundwater is currently the only source of water used by WC&ID No. 2. Because WC&ID No. 2 has a large number of

TABLE NO. 1

ASSESSED LAND VALUES

Water Districts	Assessed Values 1980	1985	1986	1987
Eldrige Rd. MUD	$ N/A	$ 40,562,419	$ 50,992,267	$ 50,063,027
FBCMUD No. 2	52,118,200	104,764,911	105,746,180	95,639,920
FBCMUD No. 12	69,869,170	230,487,594	244,112,631	243,854,910
FBCMUD No. 13	N/A	N/A	N/A	37,704,470
FBCMDU No. 16	38,115,640	150,225,085	148,000,292	147,910,192
FBCMUD No. 21	46,882,770	146,582,984	165,422,570	157,621,940
FBCMUD No. 25	9,626,305	32,240,235	32,895,620	30,235,160
FBCMUD No. 27	N/A	53,372,235	54,450,760	54,444,130
FBCMUD No. 28	9,275,840	66,980,365	72,730,310	75,036,250
FBCMUD No. 67	N/A	N/A	9,392,620	11,016,420
FBCWC&ID No. 2	**188,938,840**	**912,183,784**	**901,422,684**	**835,625,267**
FC MUD No. 1	3,187,490	83,428,070	96,502,070	93,315,020
FC MUD No. 2	N/A	26,351,292	27,318,000	30,624,030
FC MUD No. 3	N/A	N/A	1,308,605	3,010,550
FC MUD No. 4	N/A	77,392,740	86,684,900	90,637,740
FC MUD No. 5	N/A	N/A	24,693,880	23,522,690
FC MUD No. 6	N/A	61,888,055	64,194,690	60,043,780
FC MUD No. 8	N/A	N/A	25,263,930	25,750,880
City of Cities MUD	128,655,391	Annexed by Sugar Land in 1984		
Subtotal	$ 546,669,646	$1,986,459,769	$2,111,132,054	$2,028,351,906
Cities				
The Meadows	$ N/A	$ 138,799,905	$ 144,236,992	$ 139,825,560
Missouri City	N/A	1,158,619,331	1,185,236,139	1,147,788,228
Stafford	183,178,640	733,506,169	723,271,594	675,084,889
Sugar Land	**353,644,382**	**1,197,671,119**	**1,272,455,002**	**1,212,859,291**
Subtotal	$ 536,823,022	$3,228,569,524	$3,325,199,727	$3,175,557,968
TOTAL	$1,083,492,668	$5,215,056,293	$5,436,331,781	$5,203,909,874

N/A - not available

commercial and industrial water users, the per capita water demand is relatively high [about 286 gallons per capita per day (gpcd)].

Sugar Land

Sugar Land contains approximately 7,150 acres comprised of predominantly residential development with a mixture of industrial and commercial development. Sugar Land is approximately 30 percent developed. Approximately 16,000 people live within the corporate boundaries of Sugar Land, accounting for an average of 3.52 million gallons of groundwater each day for 1987. Groundwater is currently the only source of water used by Sugar Land. Sugar Land has a per capita water demand averaging 220 gpcd. The per capita water usage for Sugar Land also reflects a substantial amount of non-residential water usage.

First Colony

First Colony refers to a master planned community, which consists of approximately 6,600 acres of land within the extra territorial jurisdiction (ETJ) of Sugar Land. First Colony is a typical residential subdivision with a few scattered commercial developments. The estimated population of First Colony is approximately 24,000 people. Average groundwater pumpage for 1987 in First Colony was 3.34 million gallons per day. Per capita water demand for First Colony averages 140 gpcpd. First Colony has a relatively low per capita water consumption primarily because it is a large residential area with little or no non-residential water usage.

Water Demands

On a composite basis, RPA water demands average about 190 gpcd. This figure is higher than is typically used for water supply planning, reflecting a relatively high proportion of non-residential use. As the RPA continues to develop, the proportion of non-residential use will likely increase. Continuing the trend of high non-residential water use will likely cause per capita water consumption to increase over today's levels.

Potentially offsetting this growth in per capita consumption is the impact of water conservation. In general, public understanding of the need to conserve groundwater supplies is growing throughout the Gulf Coast region. Additionally, it has been observed that increased water conservation accompanies higher water rates. If surface water conversion programs are implemented and the costs of these programs are met with increased water rates, conservation at the retail level can be anticipated.

Water Supply Sources

Despite the proximity of the Brazos River, the regional planning area entities have utilized groundwater to meet municipal demands. In this area, groundwater wells have provided abundant supplies of easily treatable water at a low cost. The availability of this low cost water has significantly contributed to the rapid growth of the RPA.

The entire Gulf Coast region, including the RPA, is underlain by a system of two water bearing aquifers: the Chicot and Evangeline aquifers. Both are typical aquifers in that they are not single, thick water bearing sands confined by impermeable clay layers, but dozens of interspersed sand and clay layers. The upper portion of the Chicot aquifer is only partially saturated and offers a limited availability of quality groundwater in this area. However, the Evangeline aquifer is a thick acquifer which yields abundant supplies of good quality groundwater throughout most of the Texas

Coastal Plain. When groundwater pumpage exceeds the recharge rate of an aquifer, the potentiometric head or "static water level" within the aquifer is reduced and compaction occurs within the clay layers. It is this compaction within the clay layers that results in land surface subsidence. The majority of the water used within the RPA comes from the Evangeline Aquifer.

Water well data was obtained from the United States Geologic Survey (USGS) for Fort Bend and Harris Counties. The data obtained from the USGS indicates a total of 60 wells have been completed within the RPA since 1921. The majority of the 60 wells within the RPA have been completed in either the Chicot aquifer or the Evangeline aquifer. Over 80 percent of the completed wells are six inches in diameter and larger. Less than 20 percent are small, low capacity wells less than six inches in diameter. Thirty-six wells have been completed in the Chicot aquifer and 14 wells have been completed in the Evangeline aquifer. The remaining 10 wells fall into one of two categories--they are either completed in both aquifers or they have no determination in which aquifer they are completed. Table 2 lists the breakdown of wells in each aquifer along with the water usage for wells in both aquifers. Seven wells have been completed in sections of both the Chicot and Evangeline aquifers. Three wells are listed as undetermined; information from these three wells indicates that they have been completed within the past year and complete data is not available. Preliminary data indicates that two of the three wells are probably completed in the Evangeline aquifer for use in a public water system. The third well is most likely completed in the Chicot aquifer and used for individual or private domestic purposes.

TABLE NO. 2

WELLS STATISTICS FOR WELLS IN REGIONAL PLANNING AREA

USGS Wells on Record
(1921-1985)

Chicot	36
Evangeline	14
Both	7
Undetermined	3
Total	60

Typical Well	Chicot Average	Chicot Range	Evangeline Average	Evangeline Range
Average Depth* (ft)	353	(40-750)	1411	(900-1775)
Average Yield (gpm)	605	(50-1321)	1494	(457-3544)
Average Drawdown (ft)	30	(17-57)	80	(38-315)
Screen Length (ft)	64	(10-255)	189	(60-315)
Screen Setting* (depth)	310-393	(27-733)	940-1346	(610-1760)

Well Usage	Chicot	Evangeline
Industrial	7	3
Public	3	11
Domestic	2	--
Irrigation	7	--
Livestock	2	--
Not Designated	15	--
Total	36	14

*Depth measured from natural ground approximately 75 feet above mean sea level (MSL)

The average yield of wells categorized by well usage and aquifer is also shown in Table 2. This data on average yield clearly shows the largest capacity wells in the RPA serve public supply systems with water from the Evangeline aquifer.

This data implies that water used for public supply within the RPA generally comes from the Evangeline aquifer. The high yield of wells completed in the Evangeline aquifer indicates that it is a better water source for public water systems than the Chicot.

In order to further investigate the differences between the two aquifers, the information obtained from the USGS was tablulated for a larger area. A total of 178 wells were inventoried in and around the RPA. (See Table 3.) See Figure 6, Well Location Map, for the approximate location of these wells. Appendix A, USGS Well Data, corresponds to the Well Location Map and provides basic information on each well. A summary of well data shows that the average yield of water wells completed in the Evangeline aquifer has over twice the average yield of water wells completed in the Chicot aquifer. Even in the expanded well study area, the Evangeline aquifer remains the major water source of supply for public water systems.

Water System

The regional planning study for WC&ID No. 2 and Sugar Land included an inventory of existing water supply facilities within the RPA. There are currently three independent water supply systems providing potable water for the RPA. WC&ID No. 2, Sugar Land and MUD No. 13 each have their own water supply systems providing water to designated areas of the RPA. A listing of plant facilities is shown in Table 4.

TABLE NO. 3

WELL STATISTICS FOR WELLS IN EXPANDED AREA

USGS Wells on Record
(1921-1985)

Chicot	114
Evangeline	36
Both	19
Undetermined	9
Total	178

Typical Well	Chicot Average	Chicot Range	Evangeline Average	Evangeline Range
Average Depth* (ft)	322	(40-809)	1266	(900-1775)
Average Yield (gpm)	580	(50-1321)	1371	(457-3544)
Average Drawdown (ft)	35	(14-61)	82	(32-315)
Screen Length (ft)	48	(8-300)	220	(60-442)
Screen Setting* (depth)	284-342	(17-799)	840-1230	(610-1760)

Well Usage	Chicot	Evangeline
Industrial	16	4
Public	11	32
Domestic	18	--
Irrigation	31	--
Livestock	5	--
Not Designated	33	--
Total	114	36

*Depth measured from natural ground approximately 75 feet above mean sea level (MSL)

TABLE NO. 4

EXISTING WATER PLANT FACILITIES

	WC&ID No. 2	Sugar Land	First Colony*	Total
Number of Water Plants	4	3	2	9
Number of Water Wells	5	7	3	15
Total Well Yield (Gallons Per Minute)	5,300	7,975	7,200	20,475
Ground Storage (Million Gallons)	3.30	4.74	3.84	11.88
Elevated Storage (Million Gallons)	1.075	2.25	2.00	5.325
Booster Pump Capacity (Gallons Per Minute)	9,000	11,260	9,500	29,760

* First Colony is the area which includes 10 utility districts in the First Colony subdivision located within the ETJ of Sugar Land.

WC&ID No. 2 is a relatively old water district with a branched water distribution system. The District expanded the system as needed in order to meet the growth of the area.

Sugar Land has also expanded its water supply system to meet growth of the area. Sugar Land incorporates a looped water distribution system that is sized to reflect future development.

First Colony is a fairly new master planned development with a looped distribution system sized to meet the planned development of the community.

In addition to plant facilities each water supply system has its own distribution network. The major distribution system (10-inch lines and larger) is shown in Figure 7. Water plants, elevated storage tanks, and interconnects are also shown in Figure 7. There are two 12-inch interconnects between Sugar Land and MUD No. 13, and one 12-inch interconnect between WC&ID No. 2 and Sugar Land.

Financial Data

Property taxes and water rates provide the funds which pay for the capital and operating expenses of water supply systems. Tax rates for the entities in and around the RPA are shown in Table 5. The ad valorem tax rate for Sugar Land is $0.48 per $100 of assessed valuation which supports full city services. The tax rate for WC&ID No. 2 is $0.14 per $100 valuation for water and sewer service only. Other city services are provided in most of WC&ID No. 2 by the City of Stafford which has a tax rate of $0.17/$100 valuation, for a combined rate of $0.31 per $100.

TABLE NO. 5

TAX RATES

Water Districts	Tax Rate 1980	1983	1984	1985	1986
Eldridge Rd. MUD	N/L	$1.25	$1.25	$1.35	$1.35
FBCMUD No. 2	$1.10	$1.00	$0.95	$0.87	$0.87
FBCMUD No. 12	$0.75	$0.65	$0.40	$0.29	$0.29
FBCMUD No. 16	$0.90	$0.80	$0.75	$0.70	$0.74
FBCMUD No. 21	$0.20	$0.34	$0.32	$0.32	$0.35
FBCMUD No. 25	$1.25	$1.45	$1.45	$1.60	$1.60
FBCMUD No. 27	$0.75	$0.85	$0.85	$0.80	$0.80
FBCMUD No. 28	$0.68	$1.20	$1.14	$1.05	$1.05
FBCMUD No. 67	N/L	N/L	N/L	N/L	$1.25
FBCWC&ID No. 2	**$0.25**	**$0.18**	**$0.18**	**$0.14**	**$0.14**
FC MUD No. 1	$0.90	$1.10	$1.20	$1.00	$1.00
FC MUD No. 2	N/L	N/L	$0.85	$0.85	$1.00
FC MUD No. 3	N/L	N/L	N/L	N/L	N/L
FC MUD No. 4	N/L	$0.70	$0.70	$0.70	$0.70
FC MUD No. 5	N/L	N/L	N/L	N/L	$1.00
FC MUD No. 6	N/L	$1.10	$1.10	$0.95	$0.95
FC MUD No. 8	N/L	N/L	N/L	N/L	$0.90
City of Cities MUD	$0.66	$0.51	Annexed by Sugar Land in 1984		

Cities	1980	1983	1984	1985	1986
The Meadows	N/L	N/L	N/L	$0.38	$0.39
Missouri City	$0.43	$0.39	$0.41	$0.41	$0.43
Stafford	$0.27	$0.19	$0.21	$0.17	$0.17
Sugar Land	**$0.53**	**$0.50**	**$0.50**	**$0.49**	**$0.48**

N/L - Taxes not levied

Water rates for WC&ID No. 2 are as follows:

0 - 3,000 gals	$3.00 flat
over 3,000 gals	$1.12/thousand gallons

These rates reflect combined water and sewer rates for residential and multi-family users.

Water rates for Sugar Land are as follows:

0 - 1,000 gals	$6.00 flat
over 1,000 gals	$1.05/thousand gallons

These rates reflect the water rates for commercial and residential users.

Water rates for First Colony vary for each water district within the area; however, rates follow reasonably close to those of Sugar Land. (See Table 6, Residential Water Rates.)

TABLE NO. 6

RESIDENTIAL WATER RATES

	Base Rate	Base Flow	Additional Charge Per 1000 Gallons
First Colony MUD No. 1	$ 6.00	1,000	$1.05
First Colony MUD No. 2	$ 6.00	1,000	$1.05
First Colony MUD No. 3	$ 5.00	1,000	$1.05
First Colony MUD No. 4	$ 6.00	1,000	$1.05
First Colony MUD No. 5	$ 6.00	1,000	$1.05
First Colony MUD No. 6	$11.16	7,000	$0.88
First Colony MUD No. 8	$ 6.00	1,000	$1.05
Fort Bend County MUD No. 12	$ 6.00	1,000	$1.05
Fort Bend County MUD No. 13	$ 5.00	1,000	$0.88
Fort Bend County MUD No. 16	$ 5.00	1,000	$0.88
Fort Bend County WC&ID No. 2*	$ 3.00	3,000	$3.00
City of Sugar Land	$ 6.00	1,000	$1.05

* Rates for Fort Bend County WC&ID No. 2 reflect combined water and sewer rates.

III. WATER DEMAND PROJECTIONS

Projections of local water demands were used to define the proposed surface water supply facilities required to serve the entities within the RPA. Multiple sources of information were utilized to develop these demand projections including an evaluation of current development, historical groundwater pumpage records, prior studies, available population, and water demand projections.

The future water demand in an area is a function of population that can be estimated from employment projections and water demand factors which reflect variance between residential and commercial/industrial water usage. Population estimates and projections for an eight-county area, including Fort Bend County, were recently developed as part of the City of Houston Water Master Plan. Population estimates were developed for each census tract in the eight-county area as described in the 1980 census of population and housing. Population projections were based on an econometric growth model developed by the Rice Center, a non-profit corporation, which provides research and disseminates information for communities in the area.

Rice Center Projections

During the 1970s and early 1980s, the rate of growth in employment in the greater Houston area was more than three times the national average. However, in the next several decades this growth is expected to more nearly equal the national rate of growth which is reflected in the Rice Center model. Population and water demand projections for Fort Bend County were estimated using the Rice Center model. Census data shows the population of

Fort Bend County as 130,846 in 1980. This population is projected to increase to 655,068 by the year 2030. The estimated actual population for 1987 is 195,742 which correlates well with the estimates projected in the Rice Center model.

RPA Population and Demand Projections

Future water demands for the entities within the RPA were determined based on the Rice Center population projections for the census tracts within the RPA. Other available data on water demands and population was used as a cross reference. The following procedure was utilized for determination of the water demand projections used in the facility plan development:

1. Information available on each entity, including existing and proposed development, current groundwater usage, and previous population and demand projections, was reviewed.

2. The 1985, 2000, and 2030 projected populations for each entity were determined based on the population estimates by census tract developed by the Rice Center for the eight-county area included in the City of Houston Water Master Plan. Each entity's share of the 1985 population for a census tract was based on current development of the entity within that census tract by inspection of aerial photographs. Similarly, each entity's share of the 2000 or 2030 projected population for a census tract was based on projected development of the entity, at that time, within the census tract. Figure 8 illustrates the census tracts within the RPA, along with the boundaries of the entities to be served by the plan.

3. A composite demand factor, accounting for total water consumption including residential, industrial and commercial use was developed and applied to population forecasts. This composite factor was adjusted over the planning period to reflect the relatively large proportion of industrial and commercial growth in the RPA and the impact of expected water conservation.

The total demand for each entity was assumed to increase in a linear manner from the 1985 demand level to the projected 2000 demand level, and linearly from 2000 to the projected 2030 demand level. The 1985 water demands projected by this methodology compare favorably to actual pumpage in that year. The water demands projected with this approach also compare favorably with the magnitude of previous water use projections determined in previous studies for each entity, though the demand growth rates in each entity are more gradual than the previous projections. This more gradual rate of water demand growth is more reasonable for the long-term even though the RPA may see periods of both high and low growth rates in the future. The water demand projection methology was coordinated with the individual entities in the RPA, and the projections are presented herein. These water demand projections were used in this study to define the required water supply facilities for each system alternative analyzed.

Fort Bend County Water Control & Improvement District No. 2 (WC&ID No. 2) contains approximately 6,880 acres of land and forms the eastern portion of the RPA. Existing and proposed land uses in WC&ID No. 2 consist primarily of single and multi-family residential housing, along with commercial and light industrial developments. The District lies within the corporate limits of Missouri City, Stafford, and the City of Houston and within the extraterritorial jurisdictions (ETJs) of Stafford and Sugar Land. The Southwest Freeway (US 59), Alternate 90 (US 90A), and Murphy Road (FM 1092) currently provide the major routes for traffic flow through the area. Completion of Beltway 8, currently under construction in the vicinity of WC&ID No. 2, is expected to increase the growth potential in the area.

Currently, WC&ID No. 2 is approximately 17 percent developed and has an average annual water demand of approximately 2.58 million gallons per day (MGD). Based on the method of calculation previously described, water demand in the District is projected to reach 10.84 MGD by the year 2030. The projected water demands for WC&ID No. 2 are graphically presented in Figure 9.

The **City of Sugar Land** (Sugar Land) contains approximately 7,150 acres of land within its current corporate limits and forms the northwestern portion of the Southwest Water Supply system study area. Land use within the City consists primarily of residential housing and commercial developments with some scattered industrial uses. Certain industries, such as Imperial Sugar, do not use the City's water system for process of potable supply. Major traffic flow through the area is provided by the Southwest Freeway, Alternate 90, and State Highway 6.

Currently, Sugar Land is approximately 30 percent developed and has an average annual water demand of approximately 3.52 MGD. As illustrated in Figure 10, water demand within Sugar Land is projected to reach 9.57 MGD by the year 2030.

First Colony is a subdivision located entirely within the ETJ of Sugar Land. As used in this report, First Colony refers to the combined service areas and demands of several utility districts which have a contractual water supply and wastewater treatment service agreement with Fort Bend Country Municipal Utility District No. 13. First Colony includes the following water districts: First Colony MUD No. 1

First Colony MUD No. 2
First Colony MUD No. 3
First Colony MUD No. 4
First Colony MUD No. 5
First Colony MUD No. 6
First Colony MUD No. 8
Fort Bend County MUD No. 12
Fort Bend County MUD No. 13
Fort Bend County MUD No. 16

For purposes of this report, "First Colony" will refer to the entire area included in the water districts listed above.

First Colony, as defined previously, contains approximately 6,610 acres of land and forms the southwest portion of the regional planning area (RPA). Land use within First Colony consists primarily of single family residential housing, with some commercial developments along the major roadways through the area. Major traffic access through First Colony is provided by the Southwest Freeway and State Highway 6.

Currently, First Colony is approximately 20 percent developed and has an average annual water demand of approximately 3.34 MGD. As illustrated in

Figure 11, water demand within First Colony is projected to reach 10.08 MGD by the year 2030.

The combined projections for the regional planning area show that the water demands will double by the year 2000 and grow to a level that is almost four times the current demand by the year 2030. The combined water demand projections are shown in the table below.

Projected Water Demands

Entity	1985	1987*	2000	2020	2030
WC&ID No. 2	2.26	2.58	5.80	9.16	10.84
Sugar Land	3.44	3.52	5.58	8.24	9.57
First Colony	2.16	3.34	4.34	8.17	10.08
RPA Total	7.86	9.44	15.72	25.57	30.49

*Actual groundwater pumpage for 1987

IV. GROUNDWATER RESOURCES

Historically, water demands along the Gulf Coast region of Texas have been met primarily with groundwater resources. Economic growth in the region, however, has increased demands on area groundwater supplies, resulting in regional water table (potentiometric) declines and land surface subsidence. Subsidence and its contribution to tidal flooding has long been recognized as a major problem facing the Gulf Coast region of Texas and, in particular, the greater Houston area. This problem has been mitigated in the coastal area through substantial conversion to surface water use in eastern Harris County, as mandated by the Harris-Galveston Coastal Subsidence District (HGCSD). The HGCSD was created by the 64th Texas Legislature to abate subsidence in Harris and Galveston Counties with preliminary focus on the coastal areas.

Recently the increase in population and associated groundwater pumpage in the southwestern portion of the greater Houston area has made subsidence an issue for this inland area. Although inland areas are not at risk from tidal flooding, a recent study completed by the HGCSD showed that land surface subsidence does impact local storm sewer, riverine, and levee drainage systems. In addition, groundwater withdrawals in inland areas affects subsidence not only in those areas, but in the coastal areas as well.

The HGCSD has established a specific timetable and target date for substantial conversion to surface water use in the two-county area to reduce regional subsidence in Harris and Galveston Counties. This timetable was based on the HGCSD Board's judgment as to when surface water conversion projects in the area could reasonably be implemented with the surface water supplies currently available. These projects are large surface water treatment and conveyance systems designed to move treated surface water from east Harris County to western areas. As such, they require large investments and significant lead time.

The RPA is not within the jurisdictional boundaries of the HGCSD Plan, but it is significantly affected by groundwater and surface water use in the HGCSD area. This section presents forecasts of water table declines and land subsidence within the RPA based on analysis of the hydrogeology of the Gulf Coast region and two scenarios of surface water conversion in the area.

Hydrogeology

Understanding the hydrogeology of the Texas Gulf Coast is important for providing the best possible development of groundwater resources. The various characteristics of the aquifers along the Texas Gulf Coast help to determine location, availability, and quality of groundwater.

An aquifer is a geologic formation, group of formations, or part of a formation that contains and transmits water. The two aquifers which provide freshwater to Fort Bend County are the Evangeline and Chicot aquifers. It should be noted that a third aquifer, the Jasper aquifer, also underlies Fort Bend County. Within Fort Bend County, the Jasper aquifer contains saline water ranging from slightly saline to highly saline. Therefore, the Jasper aquifer is not used as a water source within Fort Bend County.

The two aquifers used as a freshwater source in Fort Bend County are the Evangeline aquifer and the Chicot aquifer. The Evangeline aquifer overlies the Burkeville aquiclude and underlies the Chicot aquifer. Within the RPA, the base of the Evangeline aquifer lies at a depth of 2,200 to 2,500 feet below mean sea level. The Evangeline aquifer ranges from 1,200 to 2,000 feet thick with approximately 400 to 700 feet of the total thickness accounting for the water bearing sands. The Chicot aquifer overlies the Evangeline aquifer. Within the RPA, the base of the Chicot aquifer lies at a depth of 500 to 700 feet below mean sea level. The Chicot aquifer ranges from 600 to 800 feet thick with somewhere between 200 and 300 feet of the total thickness comprising the water bearing sands.

The distinguishable characteristics between the aquifers include differences in stratigraphic position, lithology, and permeability. The Chicot aquifer has more porous sands which often contain undesirable chemicals. The Evangeline aquifer is mainly utilized as a municipal source of water in the RPA. The water quality is excellent, requiring only chlorine disinfection. The wells in the Evangeline aquifer are able to have longer screens than Chicot wells, allowing higher productivity.

Saline water at various concentrations is present in the Evangeline and Chicot aquifers at several different locations throughout Fort Bend County. The presence of saline water is related, at least in part, to the presence of salt domes. Eight salt domes have been located in Fort Bend County. Two of those eight salt domes are located in the vicinity of the RPA. (See Figure 12.) In locations where the aquifers have been pierced by salt domes, the water in the aquifer will typically have a high saline content.

Water wells can act as a catalyst to draw saline rich water away from salt dome locations. As wells continue to pump and lower the hydraulic pressure within the aquifer, the saline rich water will begin to migrate to these areas of lower pressure.

The geologic formations along the Texas Gulf Coast generally dip toward the Gulf at an angle greater than the slope of the land surface with the dip increasing as the formations reach the coastline. These formations also tend to thicken as this depth increases. (See Figure 13, Hydrogeologic Cross Section.)

Regional Water Demands

Regional groundwater pumpage will influence water table (potentiometric) levels within the RPA. Therefore, water demands in adjacent areas are considered in forecasting water table (potentiometric) declines and land subsidence for the study area. However, this influence diminishes with distance from the study area, so only the projected water demands in northeast Fort Bend County and southwest Harris County are considered as regional demands influencing the RPA. These projected regional demands were determined using data from the City of Houston Water Master Plan and are as follows:

	1985	2000	2020	2030
Regional Water Demand (MGD)	429	533	649	706

Two scenarios of projected groundwater withdrawals were developed to assess available groundwater supplies and to forecast land surface subsidence within the RPA. Both scenarios are based on these regional water demands, the fact that some areas have previously converted to surface water use and reflect the HGCSD timetable for conversion within the remainder of Harris County.

Scenario 1

Scenario 1 assumes groundwater will be used on an uncontrolled basis to meet all future water demands, aside from those being met by existing surface water facilities. Existing surface water facilities include the City of Houston's East Water Purification Plant as expanded to 310 MGD capacity, and the City of Houston's Southeast Water Purification Plant at 80 MGD capacity.

Scenario 2

Scenario 2 assumes conjunctive use of groundwater and surface water by the year 2000. Surface water would be developed to meet the average daily needs of the RPA by the year 2000 and the peak needs would be met from groundwater sources. This scenario is consistent with the HGCSD Plan within its jurisdictional boundaries. The HGCSD timetable for adjacent areas of Harris County calls for conversion to 80 percent surface water use in 2000. Then, through 2019, additional demands can be met with groundwater as long as total surface water use is not reduced. In 2020, additional conversion occurs so that 80 percent of the total water use in that year is again met by surface water. From then on, additional demand can be met with groundwater as long as total surface water use is not reduced.

Summary of Groundwater Study

An evaluation of the impact of groundwater withdrawal to serve the RPA was completed by McBride-Ratcliff and Associates as part of the Regional Planning Study. The groundwater study included evaluation of the quantity of groundwater available for water supply, the distribution of groundwater withdrawal, expected water table (potentiometric) declines, and land surface subsidence associated with the withdrawal of groundwater. Additionally, possible contamination of the groundwater supply by salt water migration from area salt domes was evaluated.

The groundwater study was based on evaluation of existing United States Geological Survey (USGS) and Texas Water Development Board reports, review of geologic literature concentrating on Gulf Coast geology, analysis of regional topographic and geologic maps of the area, and geophysical logs of water and petroleum wells in the area.

Because of the thickness and width of the acquifer and the associated available storage, groundwater availability was not found to be of immediate concern. Sufficient supplies of groundwater are available from the Evangeline aquifer to meet RPA demands well past 2030. Thus, the anaysis focused on the projections of water level (potentiometric) declines and projected subsidences

Water level (potentiometric) declines for the study area were forecast using MODFLOW, the USGS three dimensional groundwater flow model, and subsidence analysis was performed using the PRESS model developed by McBride-Ratcliff. Both models were calibrated from historic data, and then used to predict water level (potentiometric) declines and subsidence for two groundwater withdrawal scenarios.

Scenario 1 assumes groundwater withdrawals will be used to meet all future water demands, aside from those being met by existing surface water facilities. Existing surface water facilities include the City of Houston's East Water Purification Plant as expanded to 310 MGD capacity, and the City of Houston's Southeast Water Purification Plant at 80 MGD capacity.

Between the years 1987 and 2030, the projected Scenario 1 groundwater withdrawal produces a decline in the Evangeline aquifer water table (potentiometric level) of 160 to 280 feet within the RPA. Predicted water table declines between 1987 and 2030 range from 160 feet in the southern portion of the RPA to 280 feet in the northern portion. See Figure 14, Scenario 1, Water Level Declines 1987 - 2030.

Predicted land surface subsidence for Scenario 1 follows the pattern of water table (potentiometric level) decline, with the greatest land surface subsidence occurring in the northeast portion of the RPA. For analysis and presentation of data, all land surface subsidence is predicted relative to 1987 elevations. By the year 2030, land surface subsidence within the RPA is predicted to range from 4.3 feet in the southwest portion to 7.0 feet in the northeast portion. This differential land surface subsidence across the RPA produces a flattening of the available grade for drainage to the Brazos River. This elevation loss may ultimately require levee improvements to maintain an acceptable freeboard along the levee around First Colony. Figure 15 illustrates the predicted land surface subsidence in the vicinity of the RPA for the Scenario 1 projected groundwater withdrawals.

Scenario 2 assumes conjunctive use of groundwater and surface water with conversions to 80 percent of annual surface water use within the RPA in the years 2000 and 2020. It is also assumed that the HGCSD will implement its plan within its jurisdictional boundaries.

Between the years 1987 and 2030, the Scenario 2 projected groundwater withdrawals produce a decline in the Evangeline aquifer potentiometric level of 60 to 75 feet within the RPA. Projected water table (potentiometric level) declines between 1987 and 2030 range from 60 feet in the northeastern portion of the RPA to 75 feet in the western portion of the RPA. Figure 16, Scenario 2, Water Level Declines 1987 to 2030. This predicted decline is a significant improvement over Scenario 1, which predicted declines of 160 to 280 feet across the RPA.

Predicted land surface subsidence for Scenario 2 groundwater withdrawals also provide a significant improvement over Scenario 1 predictions. From 1987 to 2030, land surface subsidence across the RPA is predicted to range from 3.9 feet to 4.3 feet. By the year 2030, differential land surface subsidence across the RPA would only be 0.4 feet, with no differential land surface subsidence occurring between the Brazos River and the levee. The groundwater modeling results are summarized in Table 7. Figures 17 illustrates the predicted land surface subsidence for the Scenario 2 projected groundwater withdrawals.

Comparison of the predicted impacts of the two scenarios shows there are significant benefits to be gained by surface water conversion on a regional basis in accordance with the Scenario 2 time frame. This scenario, which reflects the published plans of the HGCSD, is realistically achievable.

TABLE NO. 7

SUMMARY OF GROUNDWATER MODELING

Location	1987 Existing Potentiometric Levels in the Evangeline Aquifer	Scenario 1(1) Projected Potentiometric Drop (ft) 1987-2030	Scenario 2(2) Projected Potentiometric Drop (ft) 1987-2030
Northeast RPA	145	280	75
Southwest RPA	90	160	60

Location	1987-2030 Land Surface Subsidence (ft)	
	Scenario 1(1)	Scenario(2)
Northeast RPA	7.0	4.3
Southwest RPA	4.5	3.9

NOTES:

(1) Assumes no regional surface water conversion.

(2) Assumes 80% regional surface water conversion in 2000.

V. SURFACE WATER RESOURCES

Surface Water Requirements

Development of a surface water conversion plan requires definition of an adequate and economical surface water supply source. This amount is related to both conversion objectives and to system operation and design philosophy.

The surface water plan must provide for minimal disruption in current system operations, minimize the capital cost of facilities, and maximize the use of available groundwater while at the same time meeting conversion objectives. This can be accomplished through a conjunctive use system which delivers treated surface water to existing ground storage tanks, which during peak periods, is supplemented by groundwater.

This approach allows the three entities to operate water distribution systems to remain essentially unchanged. Each entity can continue to operate its own system independently. A conjunctive use system will allow the facilities to operate at full capacity at all times. The treatment facilities and conveyance lines are substantially smaller than those sized to meet peak demands. The conjunctive use system proposed is designed to provide surface water at a steady rate sufficient to meet conversion objectives with peak demands satisfied by groundwater.

Within the RPA, seasonal water demands are quite large. Primarily due to irrigation, summer water demands may range as high as twice winter demands. Figure 5, Monthly Groundwater Pumpage, shows this relationship for WC&ID No. 2, Sugar Land, First Colony, and the RPA as a whole.

Analysis of this data, as well as an analysis of water demands of other areas in the greater Houston area similar in character to the RPA entities, shows that the average daily flow (ADF) is the appropriate rate to most economically supply surface water to achieve the proposed conversion levels as compared to supplying surface water as a fixed percentage of demand at all times. Supplying surface water at the ADF in the summer will offset periods when total demand drops below the 80 percent level in the winter; when demand rises above this level, groundwater will be used as a supplement.

A system designed to obtain the benefits of surface water conversion associated with Scenario 2 will require a supply source capable of meeting year 2020 ADF. Projected total ADF for the RPA year 2020 is estimated at 25.6 MGD.

Surface Water Sources

A number of sources were considered for surface water, including diversions from other river basins. These potential sources were narrowed to three sources. Because of the proximity of the RPA to the Brazos River and the Brazos River canal system, these two sources are logical surface water supplies. The City of Houston has historically cooperated with other cities and districts to provide treated surface water. Each of these three sources were evaluated for suitability as a surface water supply to the RPA.

Tri-County Canal System

The Tri-County canal system, also known as the Brazos River Authority Canals "A" and "B," has been utilized to supply irrigation water to farmers in and around the RPA for many years. Canal "A," which is closest to the

RPA, transports water to the Imperial Sugar Refinery in Sugar Land and to municipal and industrial customers south and southeast of the RPA.

Canal "A" begins at a pump station, known as the River Pump Station, south of Fulshear, Texas. (See Figure 4.) Originally constructed in 1908, the pump station has undergone a number of modifications and improvements to bring it to its current capacity of 242,000 gallons per minute (gpm). The pump station discharges into Jones Creek, which drains into Oyster Creek. Approximately 20 miles east of the pump station, Oyster Creek forms a series of lakes. The level of water in these lakes is controlled by a series of three dams. Just east of Dam No. 3, the most downstream dam near River Bend Country Club and Dulles Avenue, a second pump station lifts water from Oyster Creek into a channelized section flowing from that point south to the Galveston County Water Authority (GCWA) 12-MGD treatment plant near Texas City and beyond.

The Tri-County canal system is currently owned by the Brazos River Authority (BRA). The sale of the canal system to the GCWA has been announced with a closing anticipated in the summer of 1988. For convenience, this canal system will be hereinafter referred to in this report as the "Tri-County" canal system.

According to a press release published by the GCWA, approximately 77 MGD is available for sale from Tri-County canal. A review of the current commitments shows that 63.9 MGD is currently available. Both figures exceed the 25.6 MGD required to meet RPA demands, indicating supplies adequate to meet RPA requirements.

The GCWA intends to enter into yearly and "take or pay" contracts to sell the canal system water on a first come first serve basis. According to the press release and confirmed by the discussions with GCWA staff, the cost of this water will be determined by the yearly operating cost budget, including items such as bond payments, lease payments, maintenance, operations, and administrative costs and the contract quantity. Based on preliminary estimates of the factors, the cost of water from the canal system is estimated at $0.095 to $0.115 per thousand gallons.

Brazos River

The BRA operates a basin-wide water supply system, committing water to supply customers in the immediate vicinity of impoundments as well as to downstream customers. The BRA will not quote terms and conditions of proposed sales without a formal request. Recently the BRA made a water supply offer to the West Harris County Water Supply Corporation (WHCWSC), a non-profit water supply corporation planning for western Harris County. According to this proposal, the BRA can make approximately 67 MGD available from existing sources. The price of this water would be $0.37 per thousand gallons.

The quantity of water available from the Brazos River is well above the RPA requirements. Although no written specific proposal has been made to the BRA regarding water supply, it is anticipated that a similar offer would be made to the RPA entities.

City of Houston

The City of Houston (COH) has historically cooperated with other municipalities and districts to provide treated surface water.

Conversations with COH Public Works Department personnel indicate the COH may transport treated water from the new Southeast Water Purification Plant and from the East Water Purfication Plant to serve areas within the City near the RPA to meet the requirements of the HGCSD.

City of Houston ordinances define formulas for setting prices to out-of-city customers. The price structure consists of a base price plus a premium for peak flows. According to the formula, the price of treated water to the RPA entities would be a minimum of $1.00 per thousand gallons, increasing with peak demand. The minimum price of water from the City of Houston was used for comparison costs of other options discussed in this report.

Evaluation of Surface Water Alternates

After reviewing all of the potential surface water sources available, the following three alternates were evaluated in detail: (1) the Brazos River Authority; (2) The GCWA; and (3) the City of Houston.

The first two of the alternates evaluated are raw water sources while the City of Houston is for treated surface water. To evaluate the alternates on a equal basis, estimated treatment costs were developed for the raw water alternates.

The Galveston County Water Authority (GCWA) currently treats Brazos River water at its Texas City treatment plant. Analysis of plant records shows that treatment costs average $0.55 per thousand gallons. For evaluation of alternates, this figure was added to the raw water costs of Brazos River and Lake Bedias alternates.

Adjusting for treatment the total cost of each of the alternative sources of water is as follows:

Source	Raw Water	Treatment	Total Cost
Brazos River	$0.37	$0.55	$0.92
Tri-County	$0.12	$0.55	$0.67
City of Houston	N/A	N/A	$1.00

Based on this analysis, the Tri-County canal system is the least expensive source of treated surface water for the RPA.

Another factor to be considered regarding surface water sources is conveyance from the supply source to the RPA. Conveyance from the canal system and from the Brazos River to an RPA plant would be relatively short due to the proximity of the RPA to these sources. Surface water conveyance within the City of Houston (COH) system to a point near the RPA does not exist and has not been defined at this time. Thus, the cost of conveyance from the COH system to the RPA has not been estimated.

The water cost for the COH option is higher than both the Tri-County canal system option and the Brazos River option without regard to conveyance. Since the added cost of conveyance increases the cost of the COH option relative to the other two, the Tri-County canal system remains the least expensive alternative.

Conveyance costs will be required regardless of the source of water used. The cost of conveyance will depend on the distance from the source of water to the RPA. The cost to deliver treated water to the RPA from any treatment plant location will require an additional cost of approximately $1.6 million per mile of conveyance.

Based on the proximity of the Tri-County canal system to the RPA, the adequacy of supply from that source, and the relatively low cost, the Tri-County canal system is the recommended surface water supply source for the RPA.

VI. FACILITY PLAN

The recommended facility plan to deliver 24 MGD of surface water to the regional planning area was defined based on the GCWA canals as a supply source. To define the appropriate facilities, issues related to treating Brazos River water, treatment plant site selection, conveyance system layout, and capital cost estimating were addressed.

The conjunctive use system proposed should be sized to deliver surface water approximately equal to the year 2020 ADF of 25.6 MGD. In defining treatment plant capacity, consideration was given to the practical aspects of plant component sizes and configurations. This anaylsis indicated that a 24-MGD plant consisting of three parallel 8-MGD treatment unit trains would provide flexibility and capture the economies associated with utilization of standard components, while providing adequate capacity to meet conversion objectives. Therefore, a 24-MGD capacity was selected to define a facility plan.

Surface Water Treatment

Brazos River water is variable in turbidity and has a distinctive red color, high organic content, high iron content, and seasonally high algae content. Though sometimes troublesome, these characteristics are treatable with proper plant operation.

A conventional physical-chemical treatment process as shown in Figure 18 is proposed to treat the Brazos River water to acceptable quality and to meet the U.S. Public Health Service Standards for drinking water. The system selected consists of raw water storage, softening, clarification, filtration, stabilization, and chlorination. Details of the treatment unit processes are provided below.

Raw Water Reservoir - High chloride levels in Brazos River water are of serious concern. According to minimum Texas Department of Health (TDH) regulations, water supplied to customers should not exceed chloride content of 300 mg/l. It is anticipated that in the near future, this maximum level will be reduced by the U.S. Environmental Protection Agency to 250 mg/l. Brazos River water has exceeded these concentrations occasionally in the past. To provide a margin of safety, a limit of 240 mg/l should be considered as a maximum allowable for raw water.

To manage raw water supplies during periods of excursion above allowable chloride concentrations, raw water impoundments are typically provided at water purification plants processing Brazos River water. These impoundments are sized so that when chloride concentrations exceed allowable limits, raw water withdrawal from the river is curtailed and the plant processes impounded water in the interim. When river chloride concentrations drop below limits, withdrawals resume and the impoundment is refilled.

The raw water quality of the Brazos River has been monitored over the past 20 years at a gauging station near Richmond, Texas. Water quality summaries of that location are published annually in the USGS Water Resources Data Texas, Volume 2. The Brazos River Authority (BRA) monitors chloride levels in the Brazos River and at the two lift stations located along Canal "A." The BRA recommends 18 days of raw water storage to supply water when chloride levels in the Brazos River are above 250 mg/l.

Low Lift Pump Station - Raw water is lifted from a raw water reservoir through primary metering equipment and into the rapid mix facilities of the treatment plant.

Rapid Mix Chamber - This unit process provides violent agitation of the raw water for dispersing chemicals that are added to control taste and odor and remove turbidity and hardness. Chemicals added to raw water at this stage include chlorine dioxide for disinfection and floc forming reagents, such as iron coagulant, lime, and polymer. Rapid mixing is important in the treatment process since failure to uniformly mix the treatment chemicals into the raw water flow is a major cause of poor performance.

Flocculation Basins - The flocculation process provides for the agglomeration of cooloidal and finely divided suspended matter by gently stirring the treated water and additive chemicals through either mechanical or hydraulic means. The flocculation process typically involves several stages of decreasing agitation intensity to enhance floc formation.

Sedimentation Basins - The objective of the sedimentation (clarification) process is to separate a clear supernatant water from the suspended floc. The clear water goes to the filters, and the sludge settles to the bottom of the sedimentation basins and is collected for disposal.

Sludge Pumps - Sludge pumps provide a mechanical means to remove sludge from the sedimentation basins. Part of the sludge is recycled to the influent line of the rapid mix process to enhance overall flocculation. The remaining part of the sludge produced is pumped to the sludge thickener unit.

Sludge Handling - Underflow sludge from the sedimentation basins has a low solids content and, subsequently, this sludge needs to be concentrated before it can be further processed and disposed of economically. It is typical to pump sludge from the sedimentation basins to a thickener which is a small sludge clarifier where polymer may be added to thicken the sludge as much as possible, potentially up to 35 to 30 percent solids content by weight. Should the utilization of gravity thickening not produce such a concentrated sludge, then supplemental forms of sludge dewatering such as centrifugation must be employed. This plan utilizes sludge lagoons for ultimate disposal.

Filtration - Water filtration is the most important single unit operation of all of the involved processes. The objective of the filtration process is to remove the particulate suspended matter in the supernatant of the clarified water. Particulate suspended matter penetrates into the pores of the filter bed and adhere to the grains of the filter media. Different types of filter media are in use today with multimedia types predominating. To control the growth of algae and bacteria in the filters, a small dosage of chlorine is added to the water as it enters the filters. Other chemicals such as polymer and pH stabilizing carbon dioxide are also added at this point to achieve a low turbidity filter effluent and to prevent the deposition of scale on the filter medial and the treated water distribution system.

Filter Backwash Tank - When the head losses across the filter beds becomes excessive and/or when the turbidity of the filter effluent increases to an unacceptable level, the filters need to be backwashed. The filter backwash tank provides a supply of backwash water to the filters at sufficiently high pressure and flow rate to assure that the filters are adequately cleansed of particulate matter.

Waste Filter Backwash Surge Tank - Filter backwashing operations usually last between 6 to 10 minutes at high rates of flow. The waste filter backwash surge tank provides storage for this waste backwash water to dampen out the surge of flow. The wastewater collected in the surge tank is pumped back to the head of the treatment unit for recycle at a constant rate. This procedure minimizes rapid rates of change in the treatment flow rate, thereby minimizing process upsets.

Clearwell, Ground Storage, and Distribution Pumps - Filtered water is collected at the clearwell. Before the water enters the clearwell, more chemicals are added to the finished water to provide a safe and palatable municipal water supply. Chemicals added at this final stage include ammonia to provide residual chlorine in the distribution system. Sodium fluoride is added to reduce tooth decay in both children and adults. Zinc orthophosphate is added to prevent corrosion in the distribution system. From the clearwell, treated water is pumped to the ground storage tanks. The high service pumps introduce treated water from the ground storage tanks to the distribution system.

Treatment Plant Site

Selection of a treatment plant site requires consideration of the area needed to provide for raw water impoundment, treatment units, and sludge handling and disposal. For a 24-MGD plant, 1,332 acre-feet of raw water impoundment is needed to provide the required 18-day storage. This can be accomplished with a 12-foot deep reservoir, 122 acres on the surface, including access roads.

In examining potential sites, the possibility of utilizing the existing Tri-County canal lake system in Sugar Land was considered. As previously discussed, Oyster Creek forms a series of lakes as it flows through the Sugar Land area. Although the lakes have a primarily aesthetic purpose, they also are part of the GCWA canal system and provide some storm water control. The BRA (in the future the GCWA) manages water surface elevations by manually controlling spillway elevations at three dams.

The surface area of these lakes cover about 1,600 acres, and they range in depth from two feet to four feet. Conversations with BRA/GCWA personnel along with our analysis show that approximately 6,393 acre-feet of storage are available in the lake system including storage in Oyster Creek upstream of the lakes as currently operated. (See Table 8.) This storage includes honoring all existing customer commitments, including maintaining minimum levels above raw water intakes in the lakes. Utilizing this storage would provide 86 days of impoundment for a 24-MGD plant. Conversely, using 18 days of impoundment, the existing lake storage would support a 115-MGD plant. Figure 19 shows the Tri-County Canal Lake System.

Conversations with BRA and GCWA personnel showed that by managing spillway elevations and acquiring a small amount of additional land, storage could readily be increased to over 9,400 acre-feet. This volume would support a water purification plant of 170 MGD capacity.

TABLE NO. 8

EXISTING RAW WATER STORAGE

OYSTER CREEK

	Existing Storage (Acre-Ft)
DAM NO. 3	
Channel Storage	2219
Lake Storage	
Horseshoe	724
Alkire	796
Eldridge	1458
DAM NO. 2	
Channel Storage	699
Lake Storage	
Cleveland	211
Brooks	286
Hall	
DAM NO. 1	
Channel Storage	-0-
Lake Storage	
Gannoway	-0-
JONES CREEK	-0-
TOTAL	6393

The treatment plant site selected would take full advantage of the savings afforded by utilizing the lake system to store raw water. This site lies north of the channelized section of the Tri-County canal near Dulles Avenue. The triangular shaped site is situated on the south side of Avenue E just east of Brand Lane.

This site is centrally located in the RPA, minimizing conveyance lines required. Road access is nearby on FM 1092 (Murphy Road), US 90A, and US 59 (the Southwest Freeway). The Southern Pacific Railroad line paralleling US 90A provides heavy rail access for the ROA.

The canal section downstream of the second pump station will not support the 24 MGD required for the plant. The plan includes expansion of the pump station currently utilized to lift water into the canal from the lake system at Dam No. 3, supplying the plant by a pressurized raw waterline. Figure 20 shows the proposed treatment plant layout.

Several options for treatment unit configurations were considered. To provide flexibility, three parallel 8-MGD trains are proposed. Five acres will be required for these and other associated treatment facilities. Sludge handling and disposal will require about 15 acres.

Conveyance System

The design philosophy behind this plan is the delivery of surface water to ground storage tanks for mixing with groundwater as required and for distribution to customers. A conveyance system layout was developed to accomplish this, delivering surface water to WC&ID No. 2, Sugar Land, and First Colony.

The preliminary design for the facilities proposed is in accordance with applicable standards and design criteria. The following is a summary of relevant specific design factors:

Initial Pressure - To maintain pressure across the system, a maximum pressure of 90 psi at the surface water purification plant was assumed. The operating pressure will be typically lower.

Velocities - A maximum design velocity of six feet per second (fps) and a minimum design velocity of two fps were maintained.

Right-of-Way - All waterlines should be adjacent to public rights-of-way. In cases where rights-of-way cannot be obtained, an exclusive waterline easement will be required.

Delivery Pressure - A minimum delivery pressure of 20 psi was maintained. This pressure will permit filling of existing ground storage facilities.

Pipe Friction Loss Factors ("C" Values) - The following C values were used:

Diameter	C Value
12"	150
16" and Larger	130

Sugar Land would receive surface water at the City's two centrally located water distribution plants by way of a 20-inch conveyance line along Brand Lane and Alternate 90. This line will also serve the most westerly water distribution plant in WC&ID No. 2. WC&ID No. 2 will also receive surface water at the District's two eastern existing water distribution plants, by way of a 20-inch conveyance line along Avenue E, and 16-inch and 12-inch lines along Alternate 90. The 20-inch line along Avenue E will also convey surface water to a proposed district water distribution plant at Murphy Road and Alternate 90.

Surface water will be provided to both of the water distribution plants in First Colony by way of an independent 20-inch conveyance line constructed along Dulles Road, Oyster Creek, and State Highway 6. This proposed alignment for the First Colony conveyance line was selected to utilize available public right-of-way along Oyster Creek to minimize the required length of line to be constructed. Approval of this alignment by the Fort Bend County Engineer's Office will be required. Alternatively, the conveyance line would be constructed along Lexington Boulevard. However, extensive development along Lexington Boulevard would require the use of costly construction techniques and would result in a construction cost similar to that shown for the proposed alignment.

Due to the central location of the Canal A plant site, the lines serving each entity generally function as independent surface water supply systems. However, the most westerly water plant in WC&ID No. 2 is served by the 20-inch trunkline along Brand Lane which also proves service to Sugar Land. This segment is the only shared conveyance line in the proposed system. The proposed supply system was defined as a branched system of independent trunklines to minimize construction costs. The entire network could be looped in the future to provide service reliability benefits. Figure 21, Facility Plan, illustrates the proposed water plant site and conveyance lines.

Cost Estimates

Construction cost estimates were prepared for a phased 24-MGD surface water purification plant and conveyance system, based on the conveyance network and alternate supply scenarios previously described. Surface water purification plant capital costs are based on recent bids for the City of Houston's Southeast Water Purification Plant. Conveyance system cost estimates are based on current construction costs of similar facilities in the area, and include allowances for right-of-way acquisition and special crossings under major thoroughfares and drainageways.

Based on this methodology, the treatment plant projected cost will total $28,700,000, including modification of the second pump station. The conveyance system estimated cost is $5,007,000. Detailed cost estimates of the plant and the conveyance system are presented in Tables 9 and 10, respectively.

As a comparison, an alternate treatment plant near the Brazos River was considered to test if conveyance system economies might lower the total project cost. To utilize this plant site, construction of raw water impoundment would be required. The estimated cost of a plant at this site is $35,240,000, or $6,540,000 more than the cost of the plant at the proposed site. Since this difference exceeds the total cost of the proposed conveyance system by over $1.5 million, no net economies could be gained and the site was not considered further. A generalized plant layout for the alternate site and a detailed cost estimate are presented in Figure 21 and Table 11, respectively.

TABLE NO. 9

WATER PLANT COSTS

PROPOSED SITE

Item	24 MGD
Raw Water Intake	$ 1,320,000
Land Acquisition[(1)]	800,000
Raw Water Reservoir	-0-
Plant Construction Costs[(2)]	19,200,000
Plant Pumping Costs	2,400,000
Contingencies (10%)	2,370,000
Engineering (10%)	2,610,000
Total Estimated Plant Cost	$28,700,000[(3)]
Cost Per Gal Per Day	$1.20

NOTES:

(1) Assumes land costs $40,000 per acre

(2) Includes sludge lagoon

(3) 24 MGD Participation

Sugar Land Share	(32.21%)	= $ 9,244,000
FBCWC&ID No. 2 Share	(35.83%)	= $10,283,000
First Colony Share	(31.96%)	= $ 9,173,000

TABLE NO. 10

PRELIMINARY COST ESTIMATE

SURFACE WATER CONVEYANCE LINES

ITEM	QUANTITY	UNIT	UNIT COST	AMOUNT
12-Inch Waterline	26,025	L.F.	$20.00	$ 520,500
16-Inch Waterline	12,600	L.F.	25.00	315,000
20-Inch Waterline	41,225	L.F.	35.00	1,442,875
24-Inch Waterline	9,600	L.F.	50.00	480,000
Appurtenances	50%			1,379,625
Contingency	10%			413,800
Engineering	10%			455,180
Total				$5,007,000

SUGAR LAND Share = $1,690,400
FBCWC&ID NO. 2 Share = $1,462,900
FIRST COLONY Share = $1,853,700

TABLE NO. 11

WATER PLANT COSTS

ALTERNATE SITE

Item	24 MGD
Raw Water Intake	$ 1,440,000
Land Acquisition(1)	1,420,000
Raw Water Reservoir	4,320,000
Plant Construction Costs(2)	19,200,000
Plant Pumping Cost	2,400,000
Contingencies (10%)	2,600,000
Engineering (10%)	2,860,000
Army Permit for Intake	1,000,000
Total Plant Cost	$35,240,000(3)
Cost Per Gal Per Day	$1.47

NOTES:

(1) Assumes floodplain land costs $10,000 per acre

(2) Includes sludge lagoon

(3) 24 MGD Participation

Sugar Land Share (32.21%) = $11,351,000
FBCWC&ID No. 2 Share (35.83%) = $12,626,000
First Colony Share (31.96%) = $11,263,000

VII. IMPLEMENTATION

The proposed surface water facilities described will supply the RPA with sufficient surface water to meet conversion to 80 percent surface water by the year 2000. Timely conversion is necessary to make maximum use of both the groundwater and the surface water supplies and to gain maximum benefit from the reduction in projected land subsidence levels.

This proposed plan is consistent with the conversion plan developed for Harris and Galveston Counties by the Harris-Galveston Coastal Subsidence District (HGCSD). According to the HGCSD plan, areas of Harris County adjacent to the RPA will convert to the 80 percent surface water use level in 2000. In accordance with the plan, increases in water demand may be met with groundwater through the year 2019, so long as total surface water use is not reduced. Then in 2020, additional expansion to the 80 percent level is required.

Regional phased conversion according to this same timetable is also consistent with the recommendations developed in this study which are supported by Scenario 2 of the groundwater modeling analysis. To achieve the optimum benefits of this proposed plan, the RPA surface water conversion plan should be implemented to maximize the flexibility afforded by a phased project. An implementation plan addressing project phasing was developed to facilitate accomplishment of the proposed program. The financial impact and a timetable of activities leading to implementation were also addressed in this plan.

Surface Water Plan Phasing

Since the regional conversion plan calls for two conversion dates, the facilities will be constructed in two phases. Due to economies of scale, the conveyance system does not lend itself to segmenting into phases. Thus, it is proposed to construct the ultimate conveyance system in the year 2000.

Treatment Plant capacity can be phased by construction of the plant in a modular fashion, consistent with the underlying design philosophy of supplying treated surface water at average daily flow rates. Phase I of the plant should be constructed as two parallel trains totaling 16 MGD in the year 2000 and an 8-MGD expansion should be completed prior to 2020, bringing total plant capacity to 24 MGD. Table 12 shows the allocation of capacity in these plant increments among WC&ID No. 2, Sugar Land, and First Colony.

Although conversion objectives will be achieved, phasing in accordance with this schedule will not meet all water needs for the RPA. Because of the cost advantage of groundwater compared to surface water, additional groundwater facilities are recommended to meet shortfalls. As phases of this plan are implemented, there will likely be surplus groundwater capacity in the period immediately following surface water plant conversion construction. The surplus capacity will be needed, however, as water demand grows.

Based on current projected demands, Sugar Land will require one additional well prior to construction of the Phase I surface water plant. No further wells will be required for Sugar Land through 2030 if the surface water conversion program is implemented as outlined. WC&ID No. 2 will need three additional groundwater wells by 2000 and a fourth additional well

TABLE NO. 12

SURFACE WATER PLANT SHARE, MGD

	Phase I 16 MGD	Phase II 24 MGD
WC&ID No. 2	5.9	8.6
Sugar Land	5.7	7.7
First Colony	4.4	7.7
	16.0	24.0

between 2020 and 2030. First Colony has adequate well capacity through the Phase I surface water plant construction. Between the years 2000 and 2020, First Colony will need two additional wells to meet interim demand. Thereafter, until 2030, no further wells will be required.

Figures 23 through 25 illustrate peak day water demands, surface water phasing, and well phasing for the three entities.

Plan Financial Impacts

Using the cost estimates previously discussed, the projected financial impact on each entity was developed. For this analysis, estimated costs were first segmented to match the two phases of facility construction. Phase I, construction of the entire conveyance system, and a 16-MGD plant in 2000 is estimated to cost $24,207,000 in 1988 dollars. Phase II, construction of an additional 8-MGD plant in the year 2020, is estimated at $9,500,000, in 1988 dollars.

The ground storage, elevated storage, and service pump requirements for each water system are unchanged by the conversion to surface water proposed in this plan. All of these facilities must be enlarged to meet water demand whether surface water or groundwater is used. Therefore, no costs associated with the expansion of these facilities are presented in this study.

The conveyance lines proposed in this report are planned to operate at a lower pressure than distribution lines and are not intended to be service lines. The conveyance lines are to carry treated surface water only to ground storage tanks from which service pumps will draw mixed well and surface water for the distribution system in the drier periods.

As discussed previously, the cost of water produced by the surface water plant is $0.67 per thousand gallons including raw water costs. Historically, the groundwater produced in the RPA costs approximately $0.21 per thousand to produce.

Project Funding

Two funding concepts were considered. These are (1) a water rate-based option and (2) a combination tax rate and water rate option. Following is a description of these options:

Rate-Based Option - Under this option, all costs associated with the surface water project would be met through water rates. These costs include retirement of debt, interest, raw water, operations, and maintenance costs.

Tax/Rate-Based Option - Under this option, debt retirement and interest would be covered by collections from an ad valorem tax. Other costs, including raw water, operations, and maintenance costs would be met with water rates.

A financial model was developed to project the water rates and/or tax rates required to defray the cost of implementing a surface water conversion project for both of these funding options. The model predicts increases in water rates for the rate-based option and increases in tax and water rates for the tax/rate-based option over current rate and tax levels for WC&ID No. 2, Sugar Land, and First Colony. The analysis of both alternatives reflects the decrease in groundwater withdrawal and the cost savings associated with this decrease for both models.

The primary assumptions on which the model is based are the following:

- Raw water is secured from the GCWA canals at a cost of $0.115/thousand gallons.
- Raw water is treated at a cost of $0.55/thousand gallons.
- Groundwater production costs are $0.21 /thousand gallons produced.
- Capital cost of groundwater and surface water facilities match the schedule previously defined.
- Capital costs are amortized at 8 percent interest for a period of 25 years, and payment of annual capital costs start at the time of construction. Financial fees total 5 percent of bonds cost.
- A two-year lead time for construction of surface water treatment plant capacity is required, and a one-year lead time is required for construction of groundwater facilities and the conveyance network.

The financial model projects are made for each year through the year 2030.

Rate-Based Financing

Addressing rate-based financing first, a similar pattern of rate adjustment is projected for each entity, although the magnitude varies among the three. Due to the higher cost of surface water relative to groundwater, and the financial obligations associated with the Phase I capital cost, water rates will need to increase substantially upon Phase I implementation in the year 2000. From this point, water rates tend to decrease for two reasons. First, as water demand grows, the fixed cost of amortization of capital expenditures is borne by a greater number of customers. This expansion of the rate base causes the cost per gallon required to defray capital amortization to drop. Secondly, increases in demand will be met with groundwater after each phase. The lower cost of groundwater relative to surface water causes the average cost per gallon to decrease as the proportion of groundwater increases.

Because of these two factors, the required water rate increases generally decline steadily from the year 2000 through the year 2017, with occasional small adjustments for additional groundwater facilities. An increase occurs in 2018 when capital expenditures begin for Phase II, with a larger increase due to higher treatment costs when surface water is processed in the Phase II plant. After that year, required rate increases begin to generally decline through the year 2030 due to expansion of the rate base, increased groundwater use, and reduced debt obligations as bonds are retired.

Figures 27, 29, and 31 graphically present these trends for each of the three entities. To summarize, however, presented below are projected increases in water rates representative years:

	Standard Rate $/Thousand Gallons	Projected Required Rate Increases ($/Thousand Gallons)			
		2000	2017	2020	2030
WC&ID No. 2	1.12	0.91	0.59	0.77	0.45
Sugar Land	1.05	0.89	0.63	0.78	0.43
First Colony	1.05	0.90	0.55	0.82	0.47

Note: Existing water rates are shown on pages 20 and 21.

Tax Rate-Based Financing

In the case of tax rate-based financing, capital debt retirement is covered by ad valorem taxes. As a result, rate increases do not vary as a result of the rate base increase. They do vary with the mix of surface water and groundwater utilized since the average water cost decreases as growing demand is met by groundwater.

A similar pattern of rate increases holds for all three entities. Rates increase sharply upon Phase I implementation in the year 2000, declining with lower average water cost until 2019, increasing again in 2020 with Phase II implementation. From that point, rates generally decline as more groundwater is utilized.

Following are projected rate increases required for each of the entities in critical years:

	Standard Rate $/Thousand Gallons	Projected Required Rate Increases ($/Thousand Gallons)			
		2000	2019	2020	2030
WC&ID No. 2	1.12	0.45	0.30	0.42	0.36
Sugar Land	1.05	0.45	0.32	0.42	0.36
First Colony	1.05	0.45	0.25	0.42	0.34

Note: Existing water rates are shown on pages 20 and 21.

Tax rate-based financing also requires imposition of an ad valorem tax to defray the cost of capital facilities. All three entities are projected to require an increase as financing for Phase I is secured in 1998. This rate is projected to hold fairly steady over the project life, declining in the mid-2020s as Phase I debt is retired. Following are projected tax rate increases in representative years:

Projected Required Tax Rate Increases
($/$100 Valuation)

	1998	2017	2018	2025
WC&ID No. 2	0.05	0.04	0.05	0.01
Sugar Land	0.05	0.04	0.05	0.01
First Colony	0.05	0.04	0.05	0.02

Figures 26, 28, and 30 graphically depict this financial option for each entity.

TABLE NO. 13
IMPLEMENTATION SCHEDULE

Step	Remarks	Time Required	Date(1) Complete
1.	Discuss and Reserve Raw Water Capacity	N/A	Oct. 1988
2.	Protect Corridors for Conveyance Lines	N/A	Oct. 1988-Jan. 2000
3.	Implement Surface Water Conservation Plan	2 Mo.	Dec. 1988
4.	Sell Bonds for Land Purchase	2 Mo.	Feb. 1989
5.	Purchase 20-Acre Site for 24-MGD Water Treatment Plant	2 Mo.	Apr. 1989
6.	Monitor Other Surface Water Studies to Determine Additional Participants	Ongoing	Oct. 1988-Nov. 1995
7.	Design Phase I Plant and Ultimate Conveyance Lines	1 Yr.	Nov. 1996
8.	Sell Bonds for Phase I Plant and Ultimate Conveyance Lines	2 Mo.	Jan. 1997
9.	Advertise and Bid Phase I Project	2 Mo.	Nov. 1996
10.	Construct Phase I Project	30 Mo.	Jun. 1999
11.	Start-Up Phase I Plant	6 Mo.	Jan. 2000
12.	Determine Participants in Phase II Plant	Ongoing	Nov. 1995-Nov. 2015
13.	Design Phase II Plant	1 Yr.	Nov. 2016
14.	Advertise And Bid Phase II Project	2 Mo.	Jan. 2017
15.	Construct Phase II Project	30 Mo.	Jun. 2019
16.	Start-Up Phase II Project	6 Mo.	Jan. 2020

NOTE:

(1) Assumes final surface water study is adopted by October 1, 1988.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. Heavy groundwater pumpage in Fort Bend County has resulted in significant water level (potentiometric) declines in the Evangeline aquifer.

2. The WC&ID No. 2/Sugar Land regional planning area (RPA) has experienced approximately two feet of subsidence over the last 90 years. If groundwater use is not decreased in the regional area, seven additional feet of subsidence may occur in the northeast area of the RPA by the year 2030.

3. Land surface subsidence is a regional problem. To control land subsidence, regional reductions in groundwater use are required.

4. The magnitude of land surface subsidence will be reduced by approximately 2.4 feet between now and 2030 if the WC&ID No. 2 and Sugar Land RPA, along with adjacent areas regulated by the Harris-Galveston Coastal Subsidence District convert to 80 percent surface water by the year 2000.

5. Water demand in the RPA is currently 9.44 MGD. This demand is projected to increase to 25.57 MGD in the year 2020.

6. Sufficient surface water to meet the needs of the RPA is currently available in the Tri-County canal system. Other entities in Harris, Galveston, Fort Bend, and Brazoria Counties may look to this system to meet their future needs also.

7. The Tri-County canal system water cost is estimated at $0.115 per thousand gallons.

8. Brazos River water can be treated to acceptable levels for a cost of approximately $0.55 thousand gallons.

9. To control chlorides, it will be necessary to provide a raw water storage reservoir sized to hold a minimum 18-day supply of water.

10. The Tri-County canal system "A" River Pump Station, Jones Creek, Oyster Creek, and lakes in Sugar Land can provide 18-day storage for up to 115 MGD of water purification with no change in canal system operation procedures.

11. The estimated cost for surface water treatment and conveyance facilities within the RPA is $33,707,000.

12. Use of surface water creates a need for a tax of $0.04 to $0.06/$100 assessed value and a $0.28 to $0.46 per thousand gallons cost increase if combined ad valorem tax and water rate financing is used. If only water rate financing is used, the plan results in water cost increases of between $0.62 to $0.93 per thousand gallons.

13. The proposed surface water facilities will cost the owner of a $100,000 house using 10,000 gallons of water each month between $6.13 and $9.60 per month using tax/rate-based financing. The same house would cost the owner between $6.20 and $9.30 per month using rate-based financing only.

14. Inclusion or exclusion of the First Colony area in the proposed plan does not impact the cost of the plan to WC&ID No. 2 or Sugar Land.

15. A water conservation plan is needed and could result in a five percent or more reduction in water use.

Recommendations

1. Based on the plan included in this report, begin to address issues critical to plan implementation.

2. Initiate discussions with the owner of the Tri-County canal system to obtain water supply commitments for phased growth to 24 MGD in 2020.

3. Take the necessary steps through City Council action by Sugar Land and the City of Stafford (for WC&ID No. 2) to protect corridors for the necessary water conveyance lines as soon as possible.

4. Explore the póssibility of other participants, such as the Brazos Bend Water Authority, City of Houston, or the West Harris County Water Supply Corporation joining together to afford some savings through economy of scale.

5. Begin negotiations for the purchase of a water plant site which utilizes the existing storage capacity within the Tri-County canal system.

6. Implement a water conservation plan which will help reduce the per capita water consumption.

7. Initiate conversion to 80 percent surface water by the year 2000.

BIBLIOGRAPHY

Anglin, Debra L. and Jeff E. Ross, "Analysis of Surface Water Conveyance Capacity Requirements for Conjunctive Use Systems," Houston, Pate Engineers, Inc., 1987.

Baker, E.T., Jr., Stratigraphic and Hydrogeologic Framework of Part of the Coastal Plain of Texas, Report 236, Texas Department of Water Resources, 1979.

Carr, J.E., Meyer, W.R., Sandeen, W.M., and McLane, I.R., Digital Models for Simulation of Ground-Water Hydrology of the Chicot and Evangeline Aquifers along the Gulf Coast of Texas, Report 289, Texas Department of Water Resources, 1985.

District Boundaries, City of Sugar Land, May 1986.

Gabrysch, R.K., Approximate Areas of Recharge to the Chicot and Evangeline Aquifer Systems in the Houston-Galveston Area, Texas, Open File Report 77-754, U.S. Geological Survey, 1977.

Gabrysch, R.K., Development of Ground Water in the Houston District, Texas, 1970-74, Report 241, Texas Department of Water Resources, 1980.

Gabrysch, R.K., Ground-Water Withdrawals and Land-Surface Subsidence in the Houston-Galveston Region, Texas, 1906-80, Report 287, Texas Department of Water Resources, 1984.

Gabrysch, R.K., Naftel, W.L., McAdoo, Gene D., and Bonnet, C.W., Ground-Water Data For Harris County, Texas, Volume II, Records of Wells, 1892-1972, Report 178, Texas Water Development Board, 1974.

Greater Fort Bend County Economic Development Council, Economic and Demographic Analysis, Sugar Land, Greater Fort Bend Economic Development Council, 1987.

Harris-Galveston Coastal Subsidence District, Groundwater Report Year Ending December 31, 1986, Friendswood, Harris-Galveston Coastal Subsidence District, 1987.

Harris-Galveston Coastal Subsidence District, District Plan, Friendswood, Harris-Galveston Coastal Subsidence District, 1985.

Harris-Galveston Coastal Subsidence District, Subsidence '88, Friendswood, Harris-Galveston Coastal Subsidence District, 1987.

Houston Southwest Quadrant Data Book, February 1984, City of Houston, Department of Planning and Development.

Master Facilities Plan, Fort Bend County Water Control and Improvement District No. 2, October, 1985, by Jones & Carter, Inc.

Naftel, W.L., Vaught, Kenneth, and Flemming, Bobbie, Records of Wells, Drillers' Logs Water-Level Measurements and Chemical Analysis of Ground Water in Harris and Galveston Counties, Texas, 1970-74, Report 203, Texas Water Development Board, 1976.

Popkin, B.P., Groundwater Resources of Montgomery County, Texas, Report 136, Texas Water Development Board, 1971.

Rice Center, East Fort Bend County Area - Research Brief 16, Houston Rice Center, December 1982.

Second Phasing Plan Update for Water and Sewerage Syste, Fort Bend County Municipal Utility District No. 13 Service Area, Revised April 1986, by Espey Huston & Associates, Inc.

Texas Department of Water Resources, Water For Texas: Volume 2, Technical Appendix, Austin, Texas Department of Water Resources, 1984.

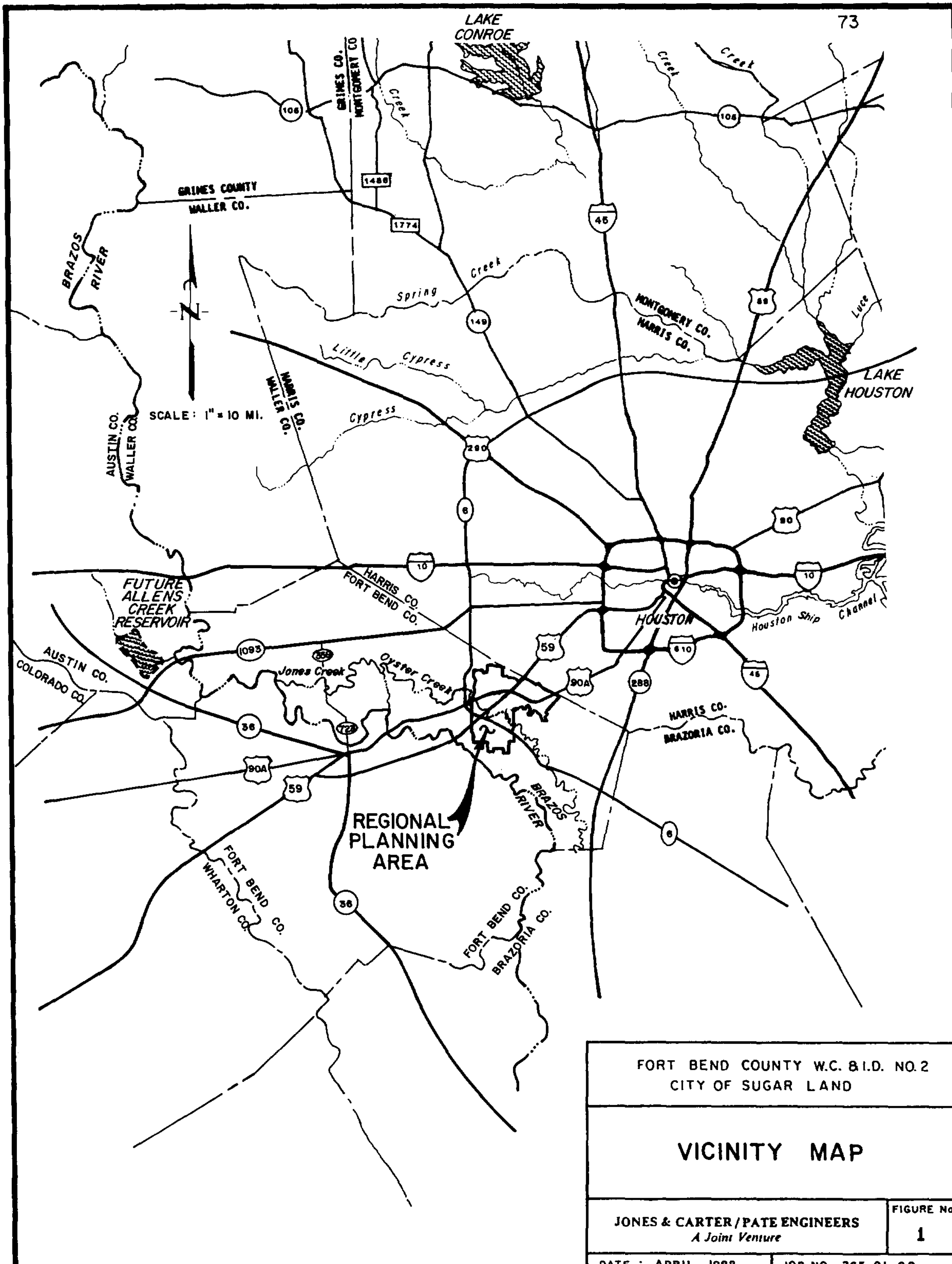
Texas Department of Water Resources, Water For Texas: Volume 1, A Comprehensive Plan for the Future, Austin, Texas Department of Water Resources, 1984.

Wastewater Capacity Inventory, City of Sugar Land, October 1985, by J.B. Hostetler Engineering Co., Inc.

Water Conservation and Drought Contingency Plan, Master District of Fort Bend County Municipal Utility District No. 13, 1987, by Eco-Resources, Inc.

Wesselman, J.B., Ground-Water Resources of Fort Bend County, Texas, Report 155, Texas Water Development Board, 1972.

FIGURES



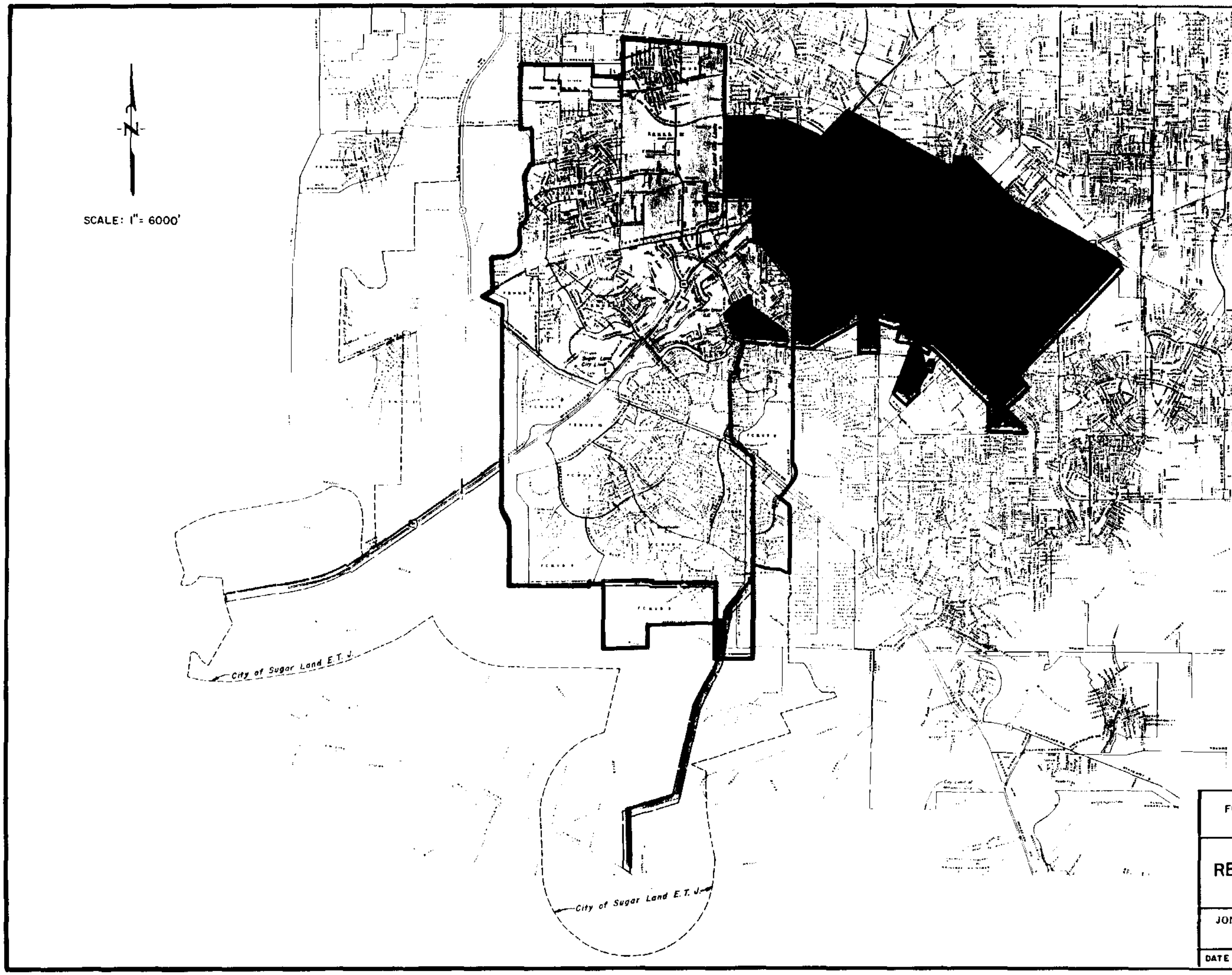
FORT BEND COUNTY W.C. & I.D. NO. 2
CITY OF SUGAR LAND

VICINITY MAP

JONES & CARTER / PATE ENGINEERS
A Joint Venture

FIGURE No. 1

DATE : APRIL, 1988 | JOB NO. 265-01-00



F.B.C.W.C. & I.D. NO. 2

CITY OF SUGAR LAND

FIRST COLONY

REGIONAL PLANNING AREA

FORT BEND COUNTY W.C. & I.D. NO. 2
CITY OF SUGAR LAND

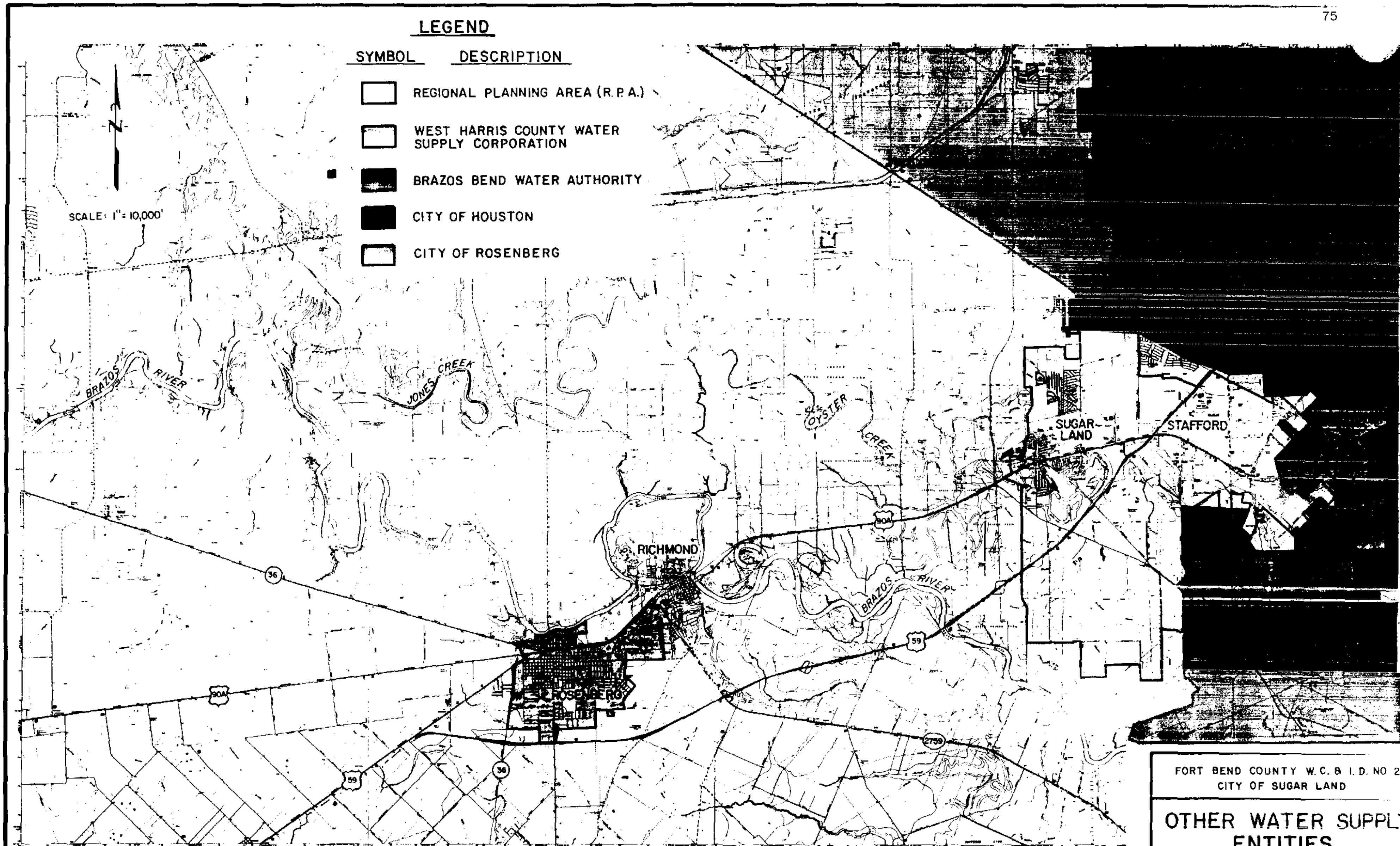
REGIONAL PLANNING AREA

JONES & CARTER/PATE ENGINEERS
A Joint Venture

FIGURE No 2

DATE: MAY, 1986

JOB NO.



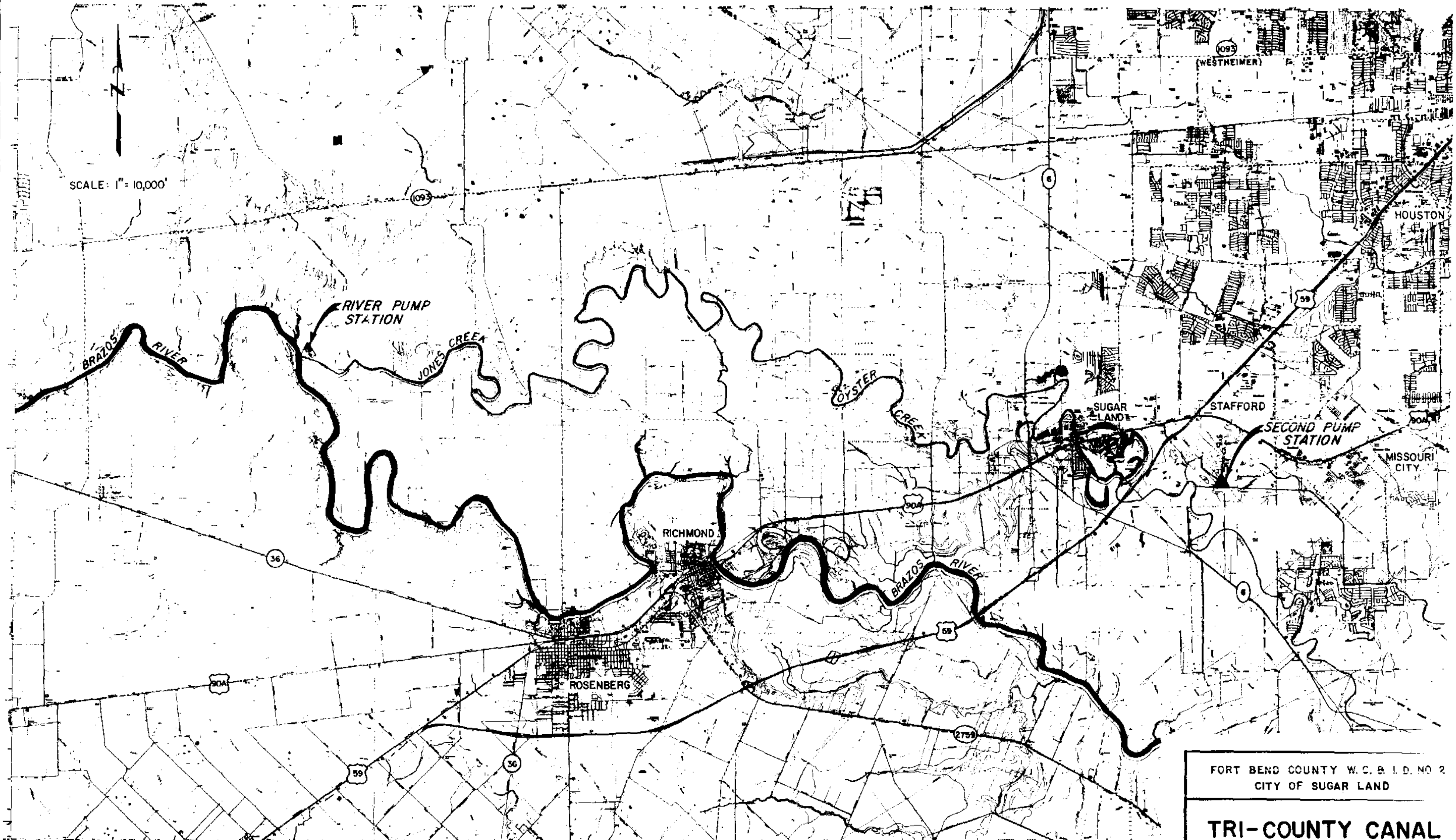
FORT BEND COUNTY W.C. & I.D. NO 2
CITY OF SUGAR LAND

OTHER WATER SUPPLY ENTITIES

JONES & CARTER / PATE ENGINEERS
A Joint Venture

FIGURE 3

DATE: MAY, 1988 | JOB NO.



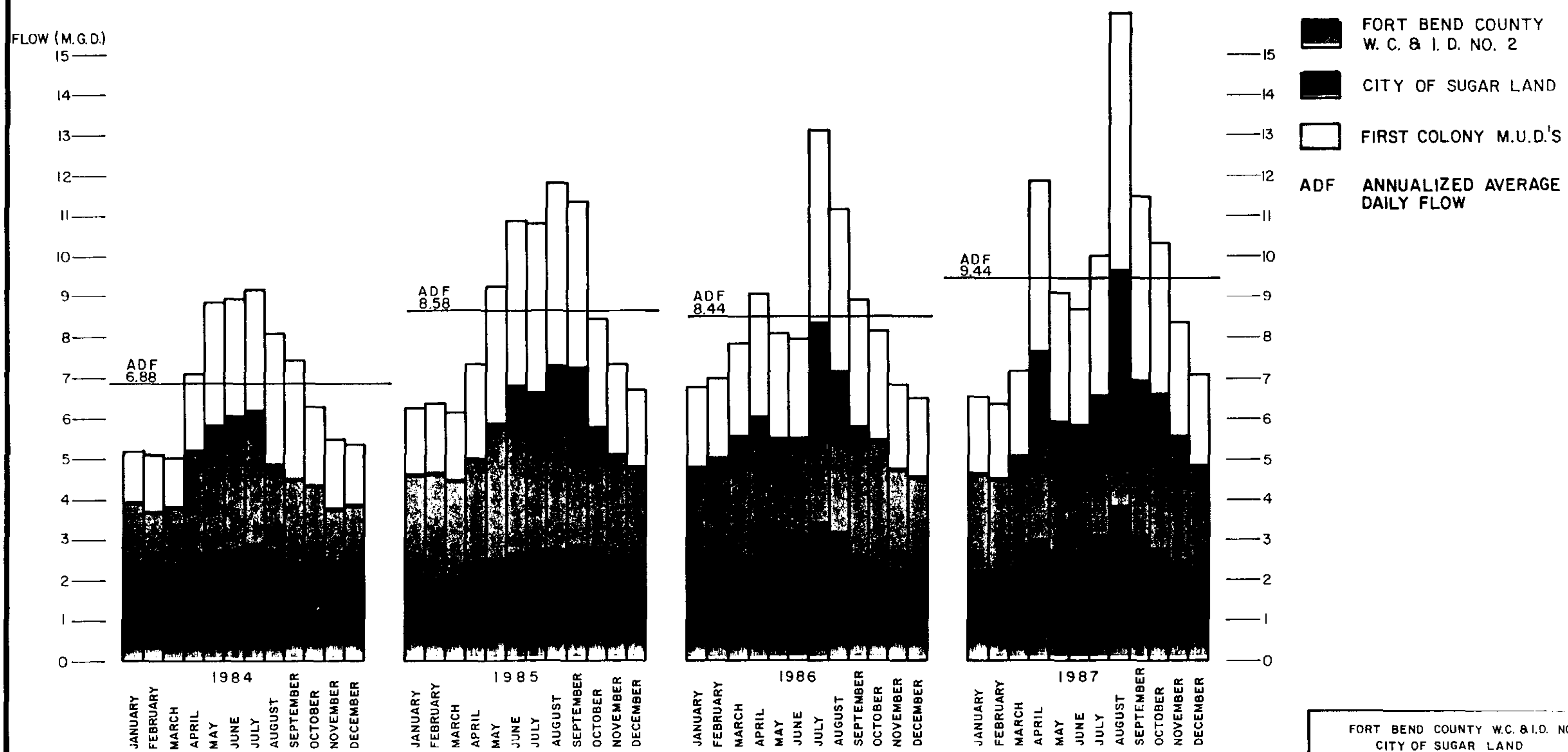
FORT BEND COUNTY W. C. & I. D. NO. 2
CITY OF SUGAR LAND

TRI-COUNTY CANAL

JONES & CARTER / PATE ENGINEERS
A Joint Venture

FIGURE 4

DATE: MAY, 1988 | JOB NO.



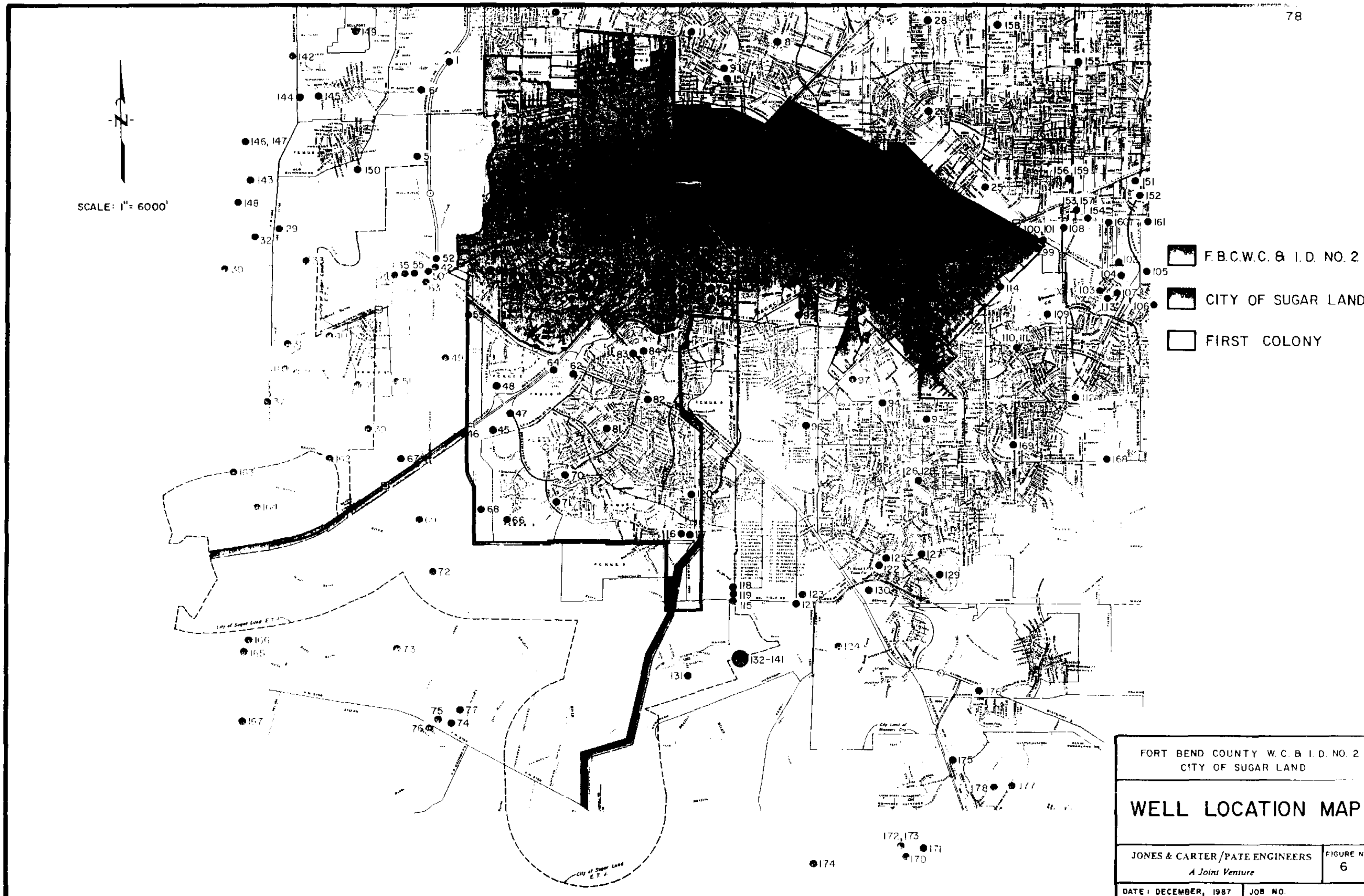
FORT BEND COUNTY W.C. & I.D. NO. 2
CITY OF SUGAR LAND

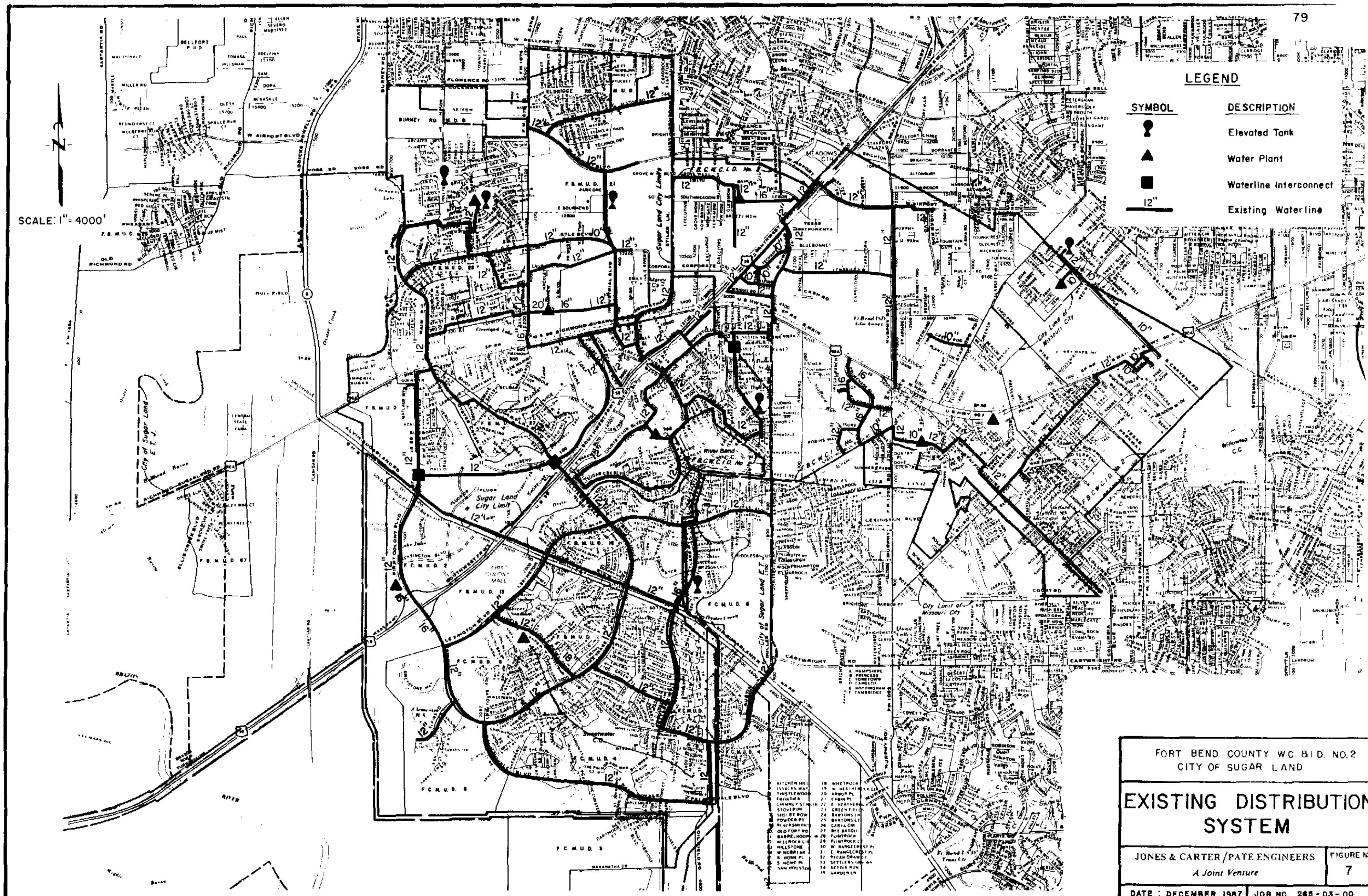
MONTHLY
GROUND WATER PUMPAGE
1984 - 1987

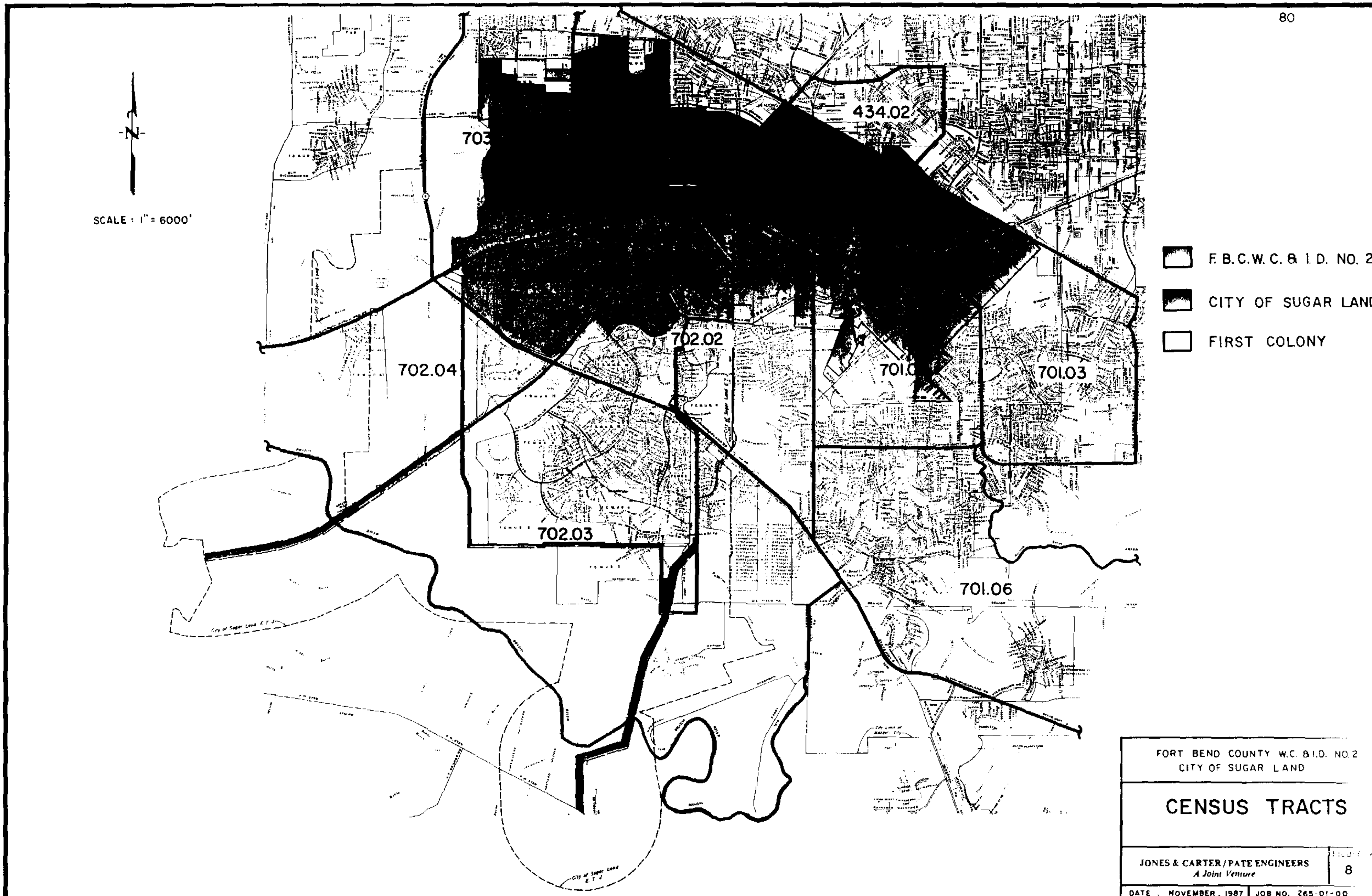
JONES & CARTER/PATE ENGINEERS
A Joint Venture

FIGURE NO. 5

DATE: MAY, 1988 | JOB NO. 265-01-00

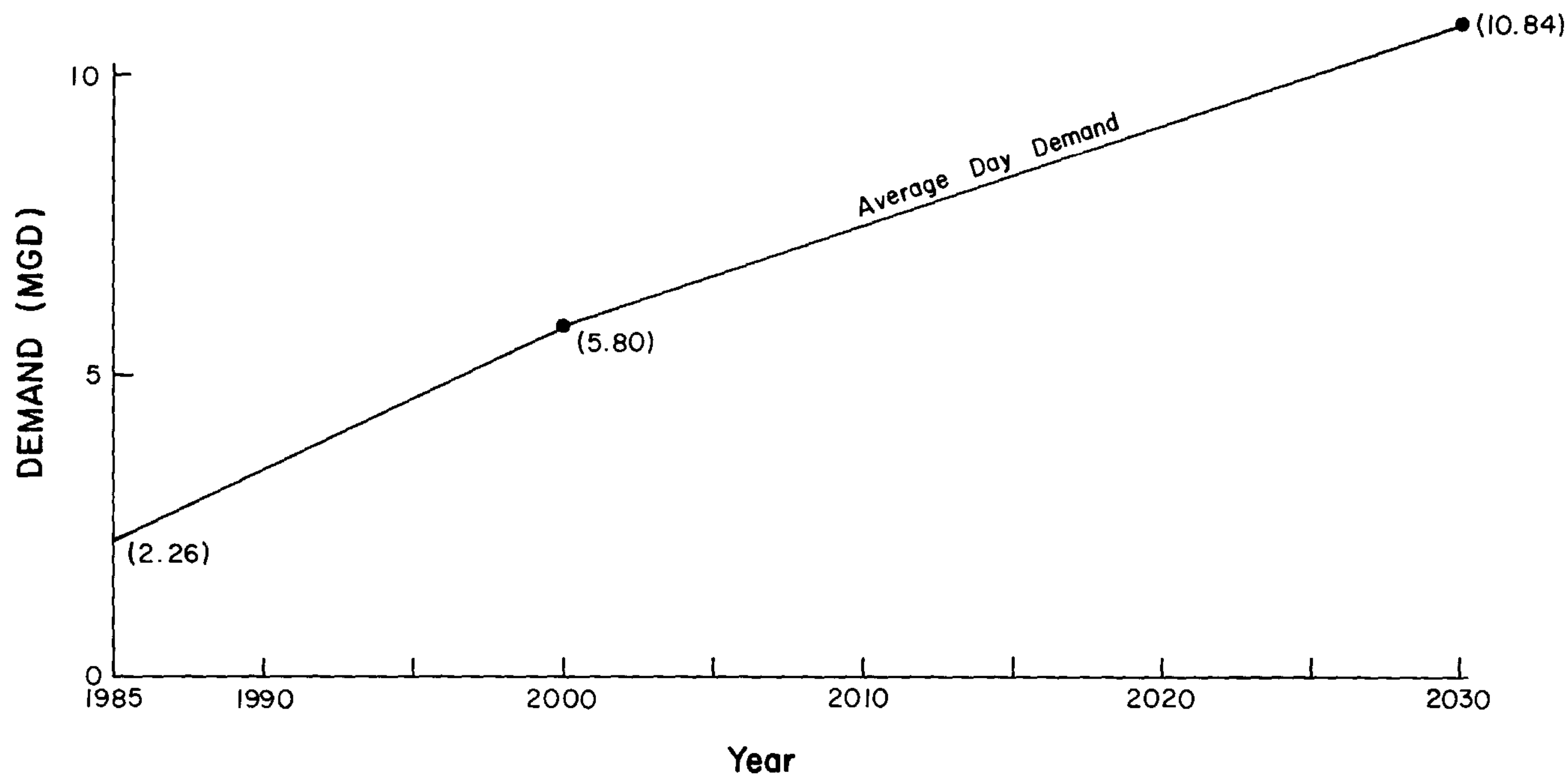

N
SCALE: 1" = 6000'
F.B.C.W.C. & I.D. NO. 2
CITY OF SUGAR LAND
FIRST COLONY
City of Sugar Land E.T.J.
FORT BEND COUNTY W.C. & I.D. NO. 2
CITY OF SUGAR LAND
WELL LOCATION MAP
JONES & CARTER / PATE ENGINEERS
A Joint Venture
FIGURE No. 6
DATE: DECEMBER, 1987
JOB NO.


LEGEND
SYMBOL
DESCRIPTION
Elevated Tank
Water Plant
Waterline Interconnect
12"
Existing Waterline
SCALE: 1" = 4000'
N
FORT BEND COUNTY W.C. & I.D. NO. 2
CITY OF SUGAR LAND
EXISTING DISTRIBUTION SYSTEM
JONES & CARTER / PATE ENGINEERS
A Joint Venture
FIGURE No. 7
DATE : DECEMBER, 1987
JOB NO. 265-03-00

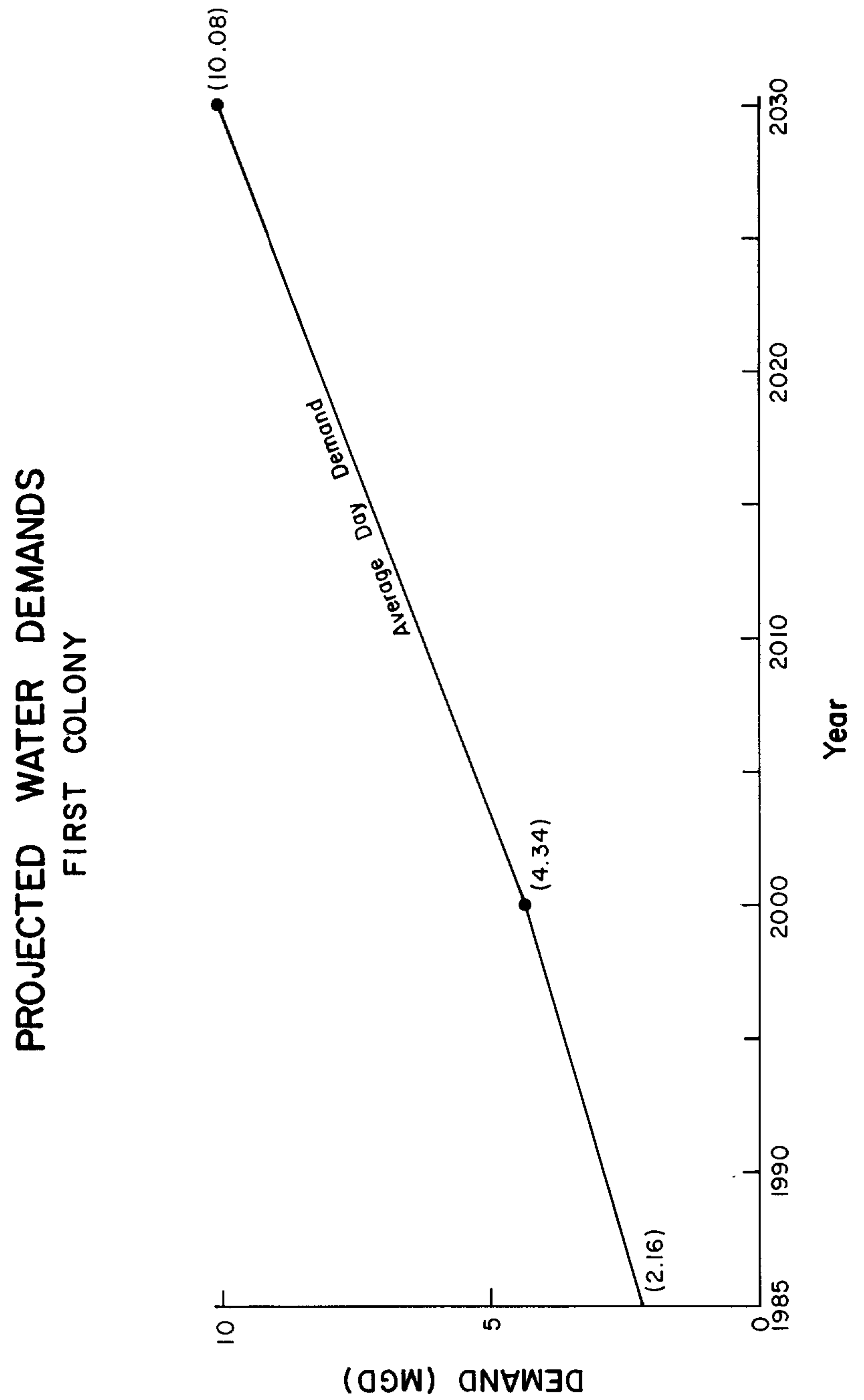

N
SCALE : 1" = 6000'
434.02
702.02
702.04
701.03
702.03
701.06
F. B.C.W.C. & I.D. NO. 2
CITY OF SUGAR LAND
FIRST COLONY
FORT BEND COUNTY W.C. & I.D. NO. 2
CITY OF SUGAR LAND
CENSUS TRACTS
JONES & CARTER / PATE ENGINEERS
A Joint Venture
8
DATE . NOVEMBER , 1987
JOB NO. 265-01-00

PROJECTED WATER DEMANDS

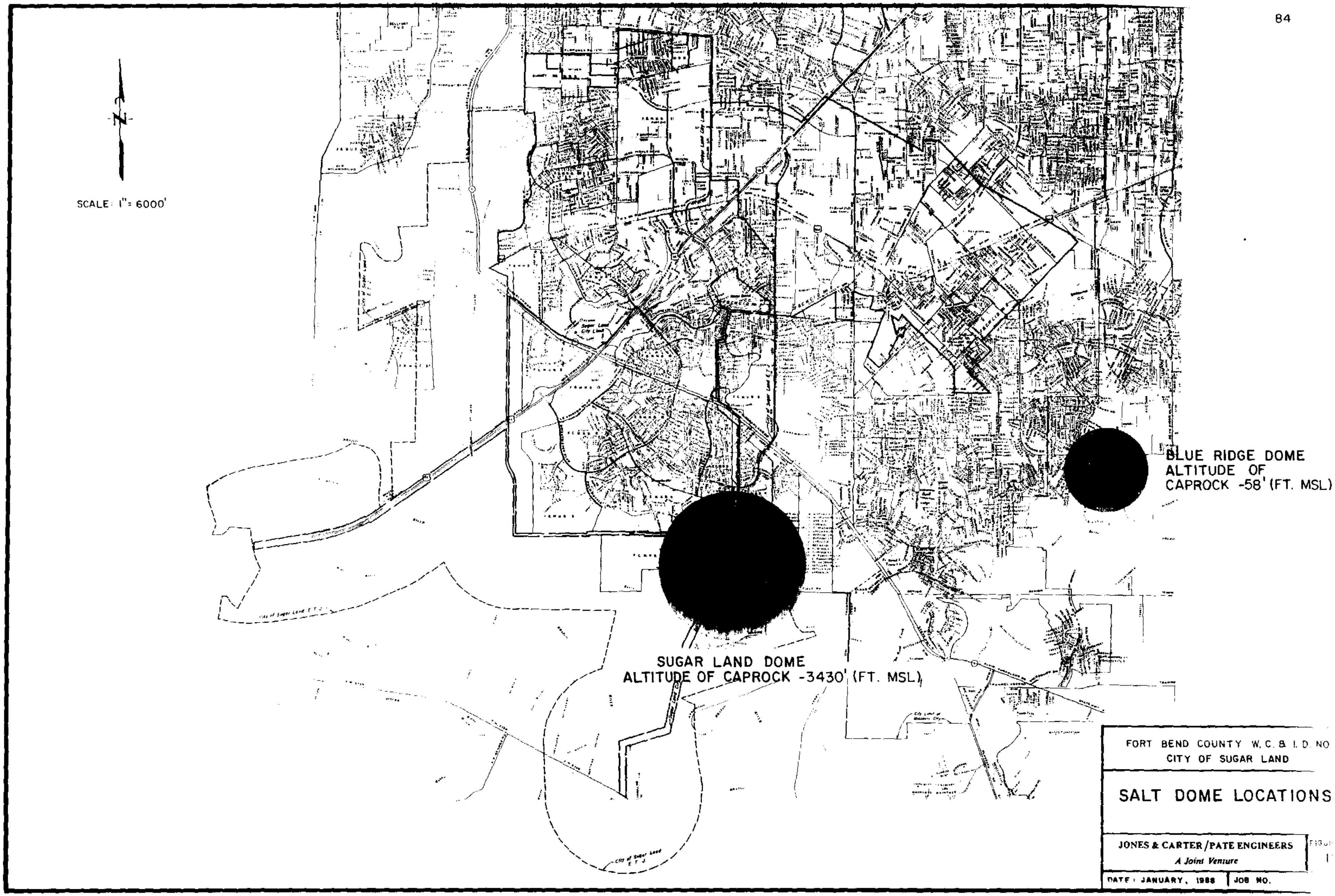
FBCWCID #2



FORT BEND COUNTY W.C.&I.D. NO. 2 CITY OF SUGAR LAND	
FBCWCID #2 WTR. DEMAND	
DATE: MAY, 1988	FIGURE NO. 9



FORT BEND COUNTY W.C.&I.D. NO. 2 CITY OF SUGAR LAND	
FIRST COLONY WATER DEMAND	
DATE: MAY, 1988	FIGURE NO. 11


N
SCALE: 1" = 6000'
BLUE RIDGE DOME
ALTITUDE OF
CAPROCK -58' (FT. MSL)
SUGAR LAND DOME
ALTITUDE OF CAPROCK -3430' (FT. MSL)
City of Sugar Land E.T.J.
FORT BEND COUNTY W. C. & I. D. NO
CITY OF SUGAR LAND
SALT DOME LOCATIONS
JONES & CARTER / PATE ENGINEERS
A Joint Venture
DATE: JANUARY, 1988
JOB NO.

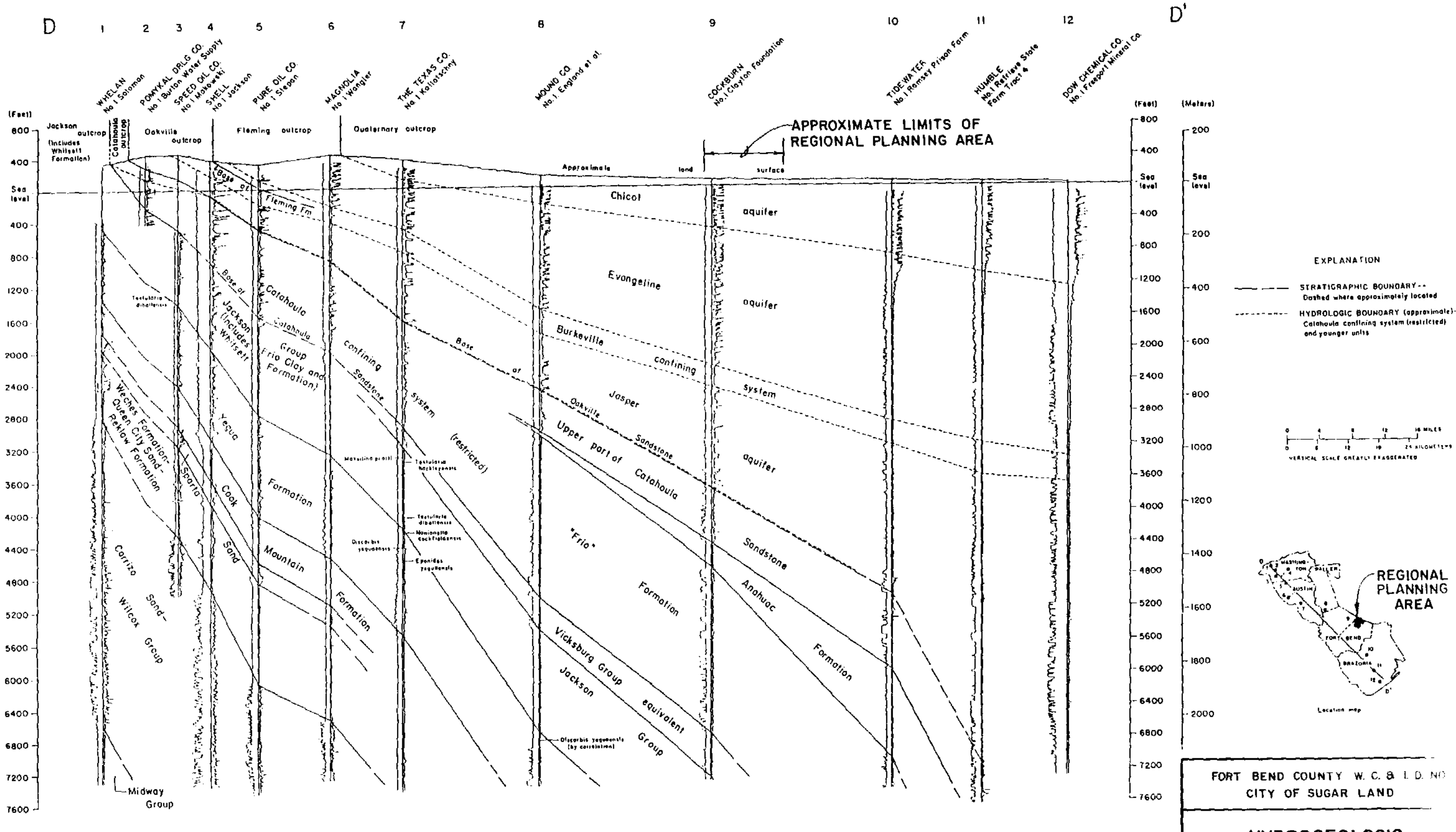


Figure 5
Stratigraphic and Hydrogeologic Section D-D'

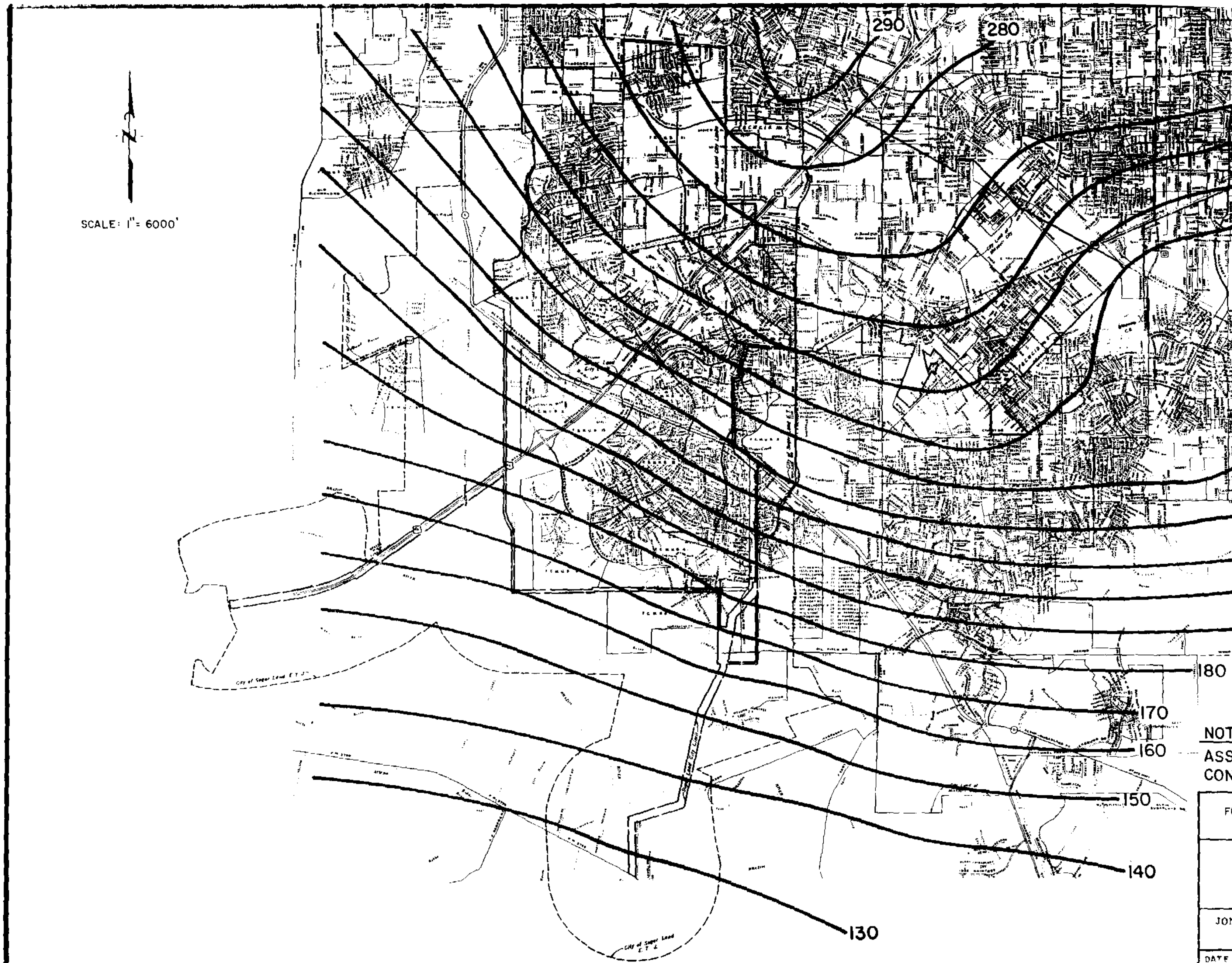
Courtesy of Texas Department of Water Resources
Report 236 July, 1979

FORT BEND COUNTY W. C. & I. D. NO.
CITY OF SUGAR LAND

HYDROGEOLOGIC CROSS SECTION

JONES & CARTER / PATE ENGINEERS
A Joint Venture

DATE: MAY 1988 | JOB NO. 265-01



NOTE:
ASSUMES NO SURFACE WATER CONVERSION.

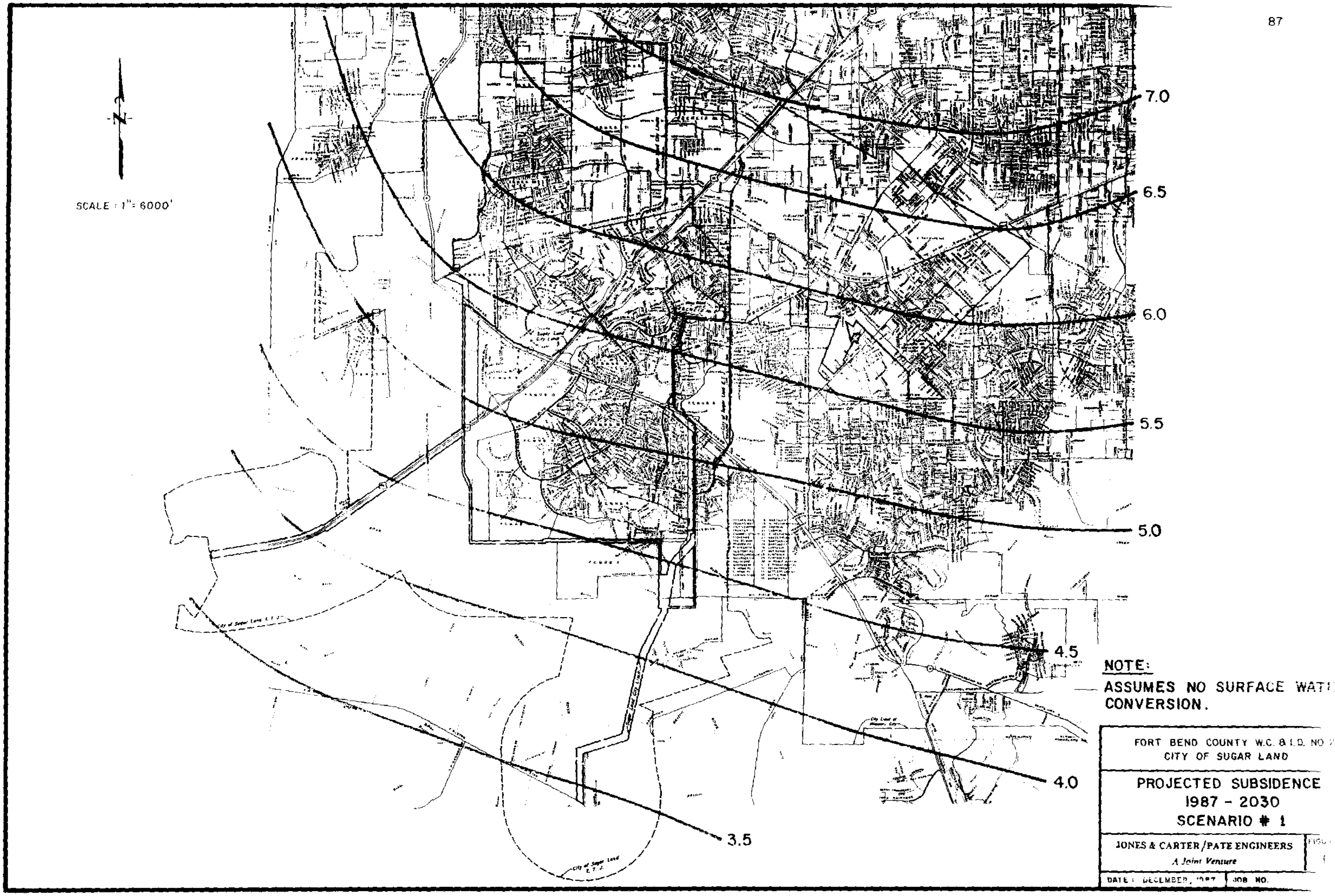
FORT BEND COUNTY W. C. & I. D. NO. 2
CITY OF SUGAR LAND

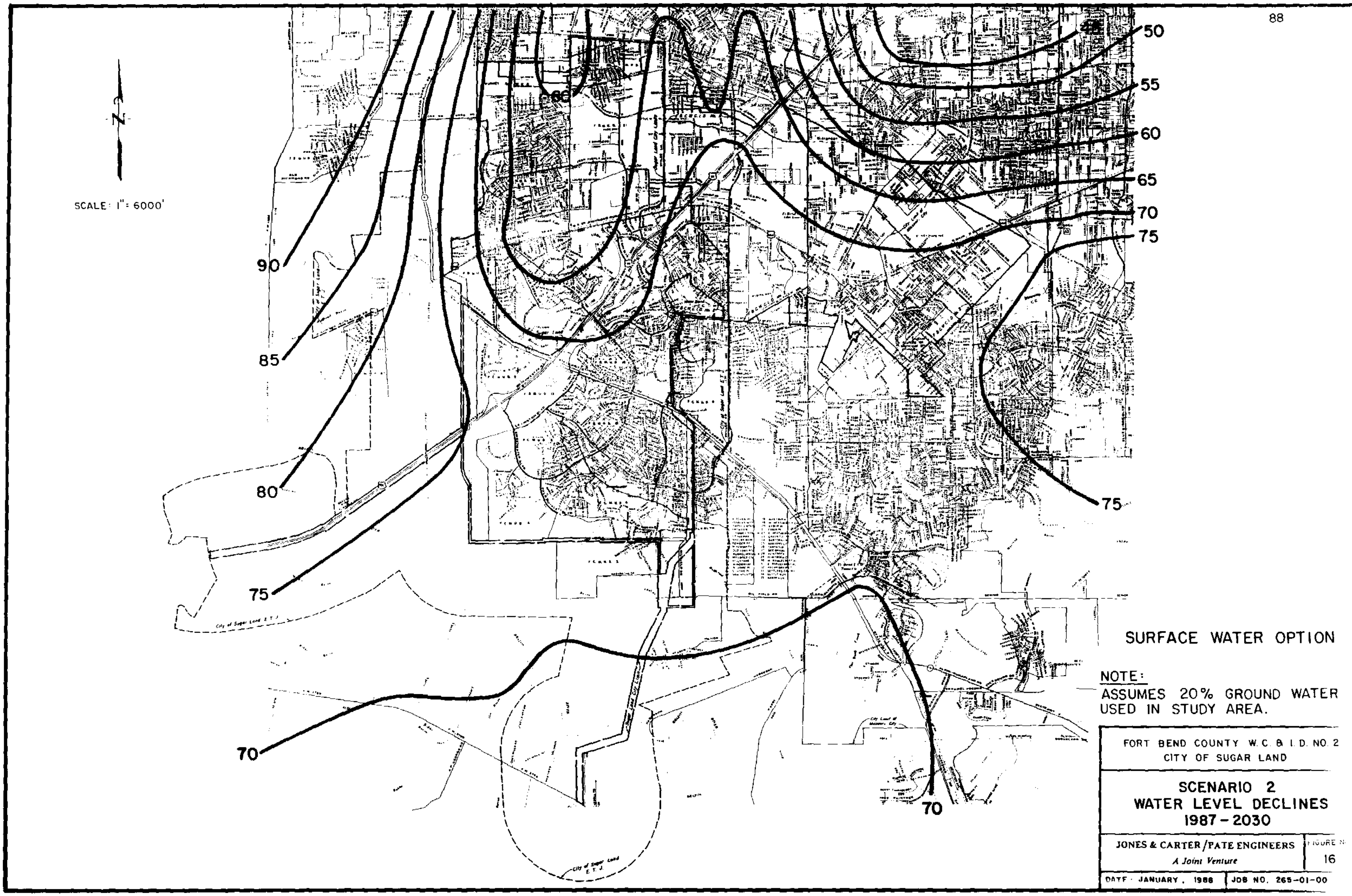
SCENARIO 1
WATER LEVEL DECLINES
1987 - 2030

JONES & CARTER / PATE ENGINEERS
A Joint Venture

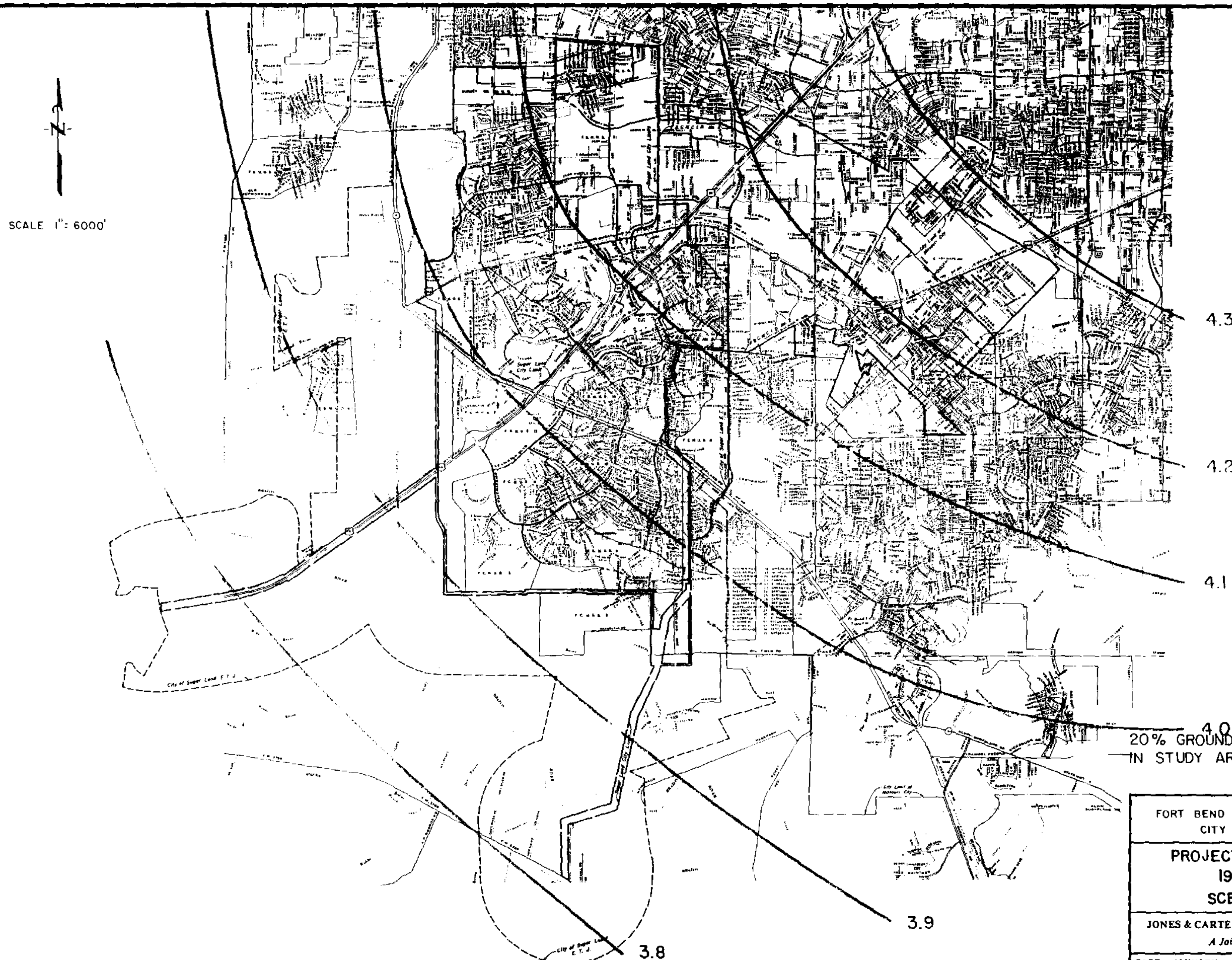
FIGURE No. 14

DATE: JANUARY, 1988 | JOB NO. 265-01-00


N
SCALE : 1" = 6000'
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
NOTE:
ASSUMES NO SURFACE WAT
CONVERSION.
FORT BEND COUNTY W.C. & I.D. NO 2
CITY OF SUGAR LAND
PROJECTED SUBSIDENCE
1987 - 2030
SCENARIO # 1
JONES & CARTER/PATE ENGINEERS
A Joint Venture
DATE : DECEMBER, 1987
JOB NO.



SCALE: 1" = 6000'
90
85
80
75
70
50
55
60
65
70
75
75
70
SURFACE WATER OPTION
NOTE:
ASSUMES 20% GROUND WATER USED IN STUDY AREA.
FORT BEND COUNTY W.C. & I.D. NO. 2
CITY OF SUGAR LAND
SCENARIO 2
WATER LEVEL DECLINES
1987 - 2030
JONES & CARTER / PATE ENGINEERS
A Joint Venture
FIGURE NO.
16
DATE: JANUARY, 1988
JOB NO. 265-01-00



20% GROUND WATER USED IN STUDY AREA.

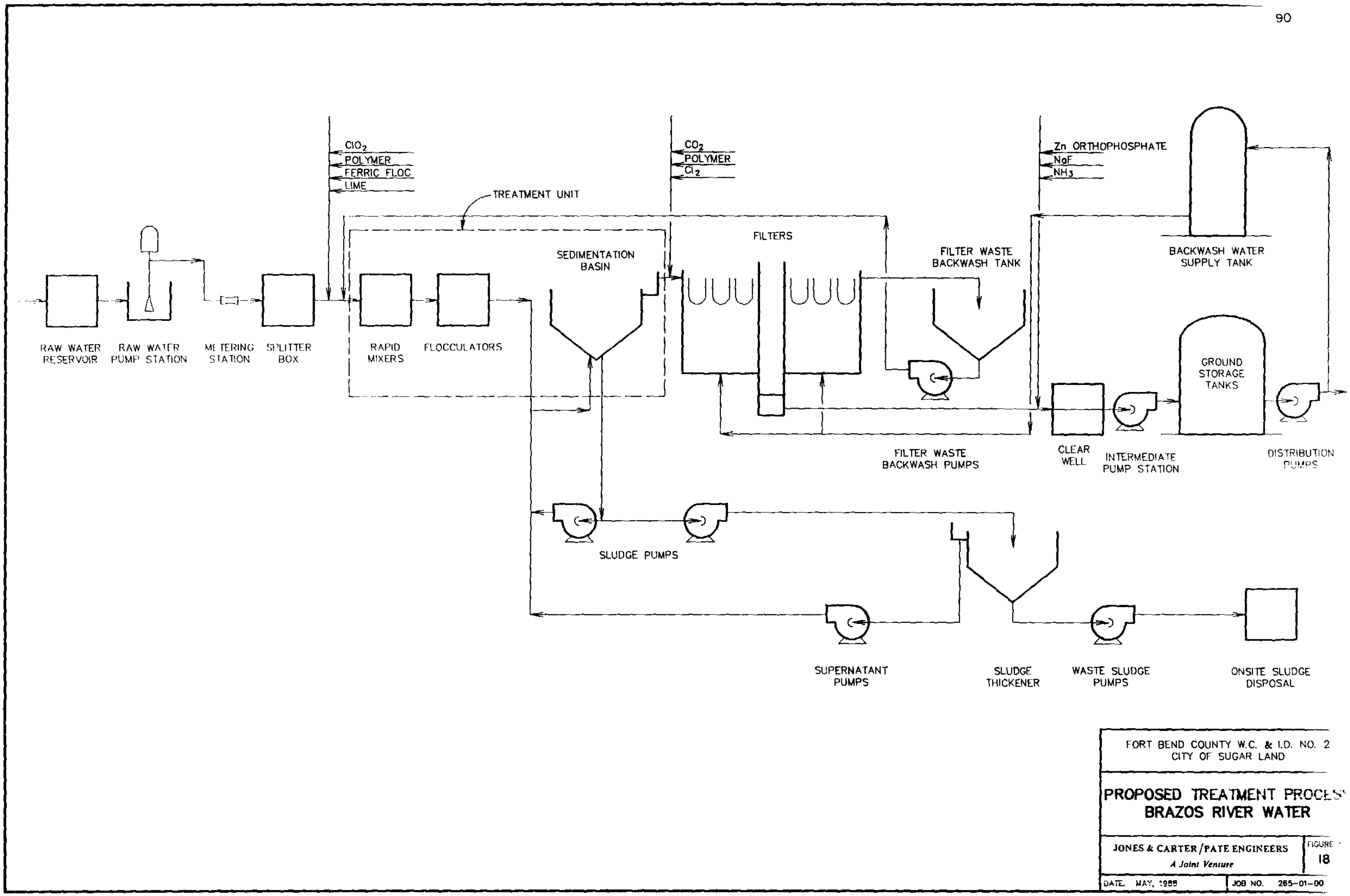
FORT BEND COUNTY W.C. & I.D. NO. 2
CITY OF SUGAR LAND

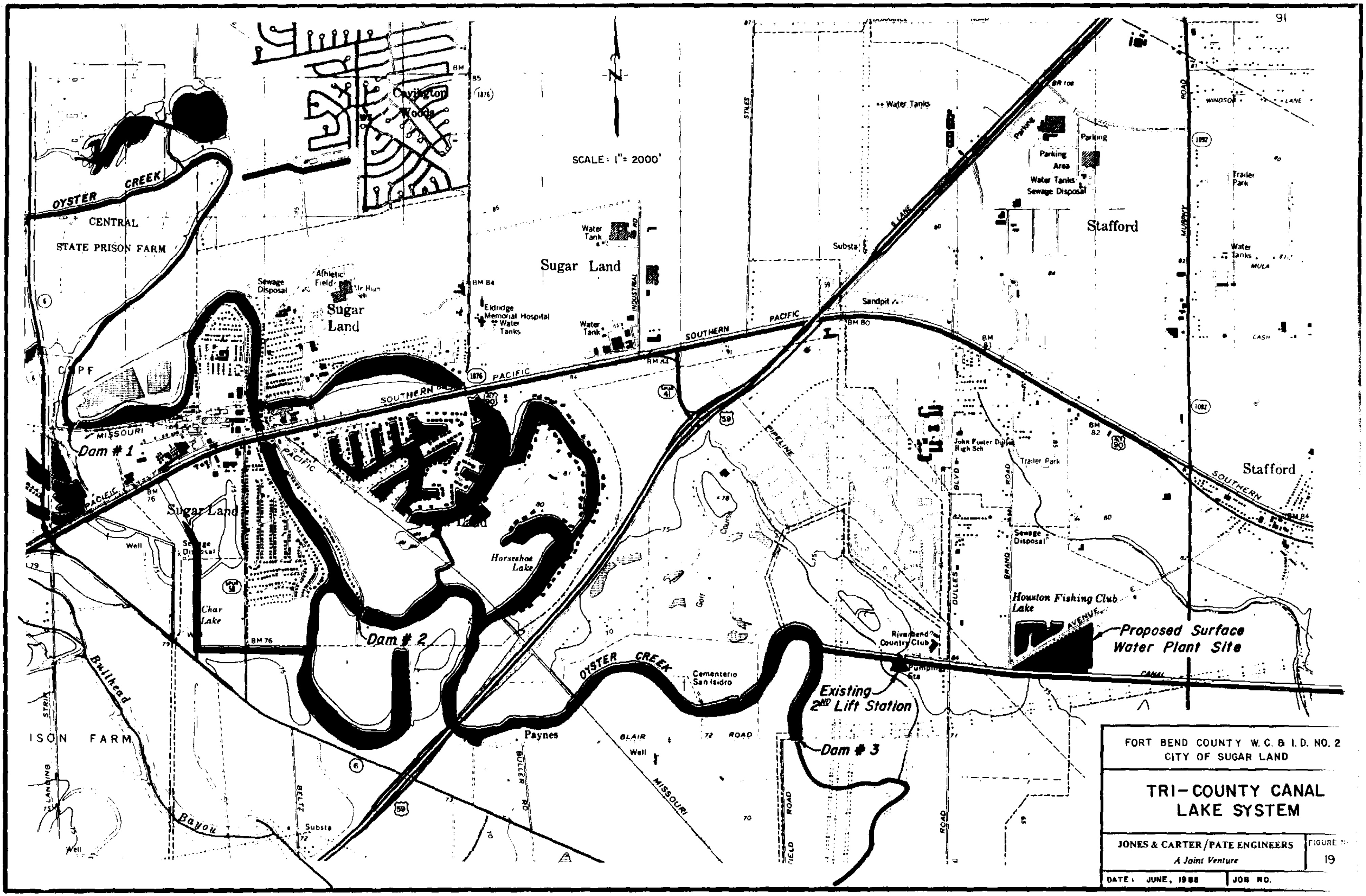
PROJECTED SUBSIDENCE
1987 - 2030
SCENARIO # 2

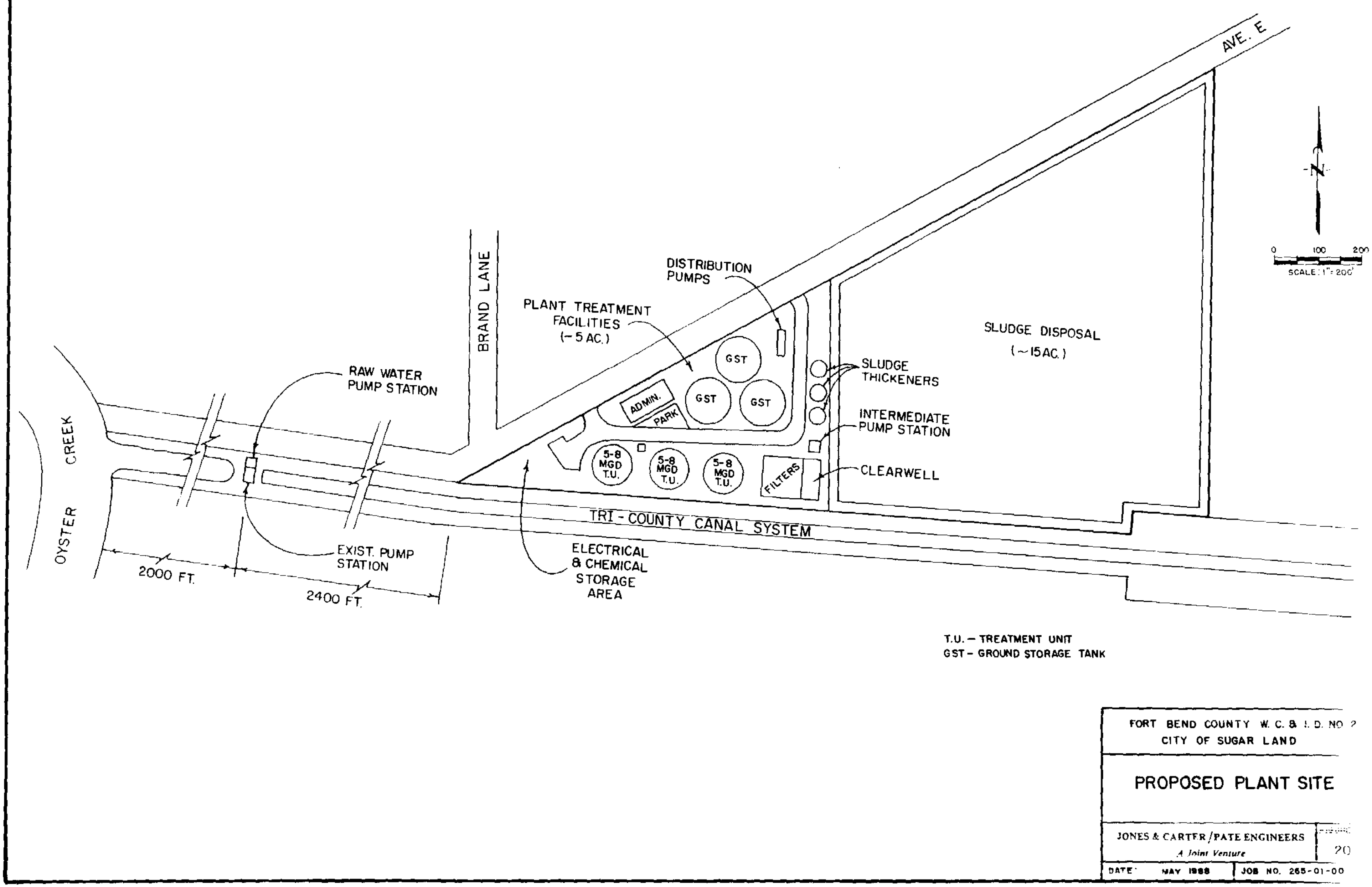
JONES & CARTER/PATE ENGINEERS
A Joint Venture

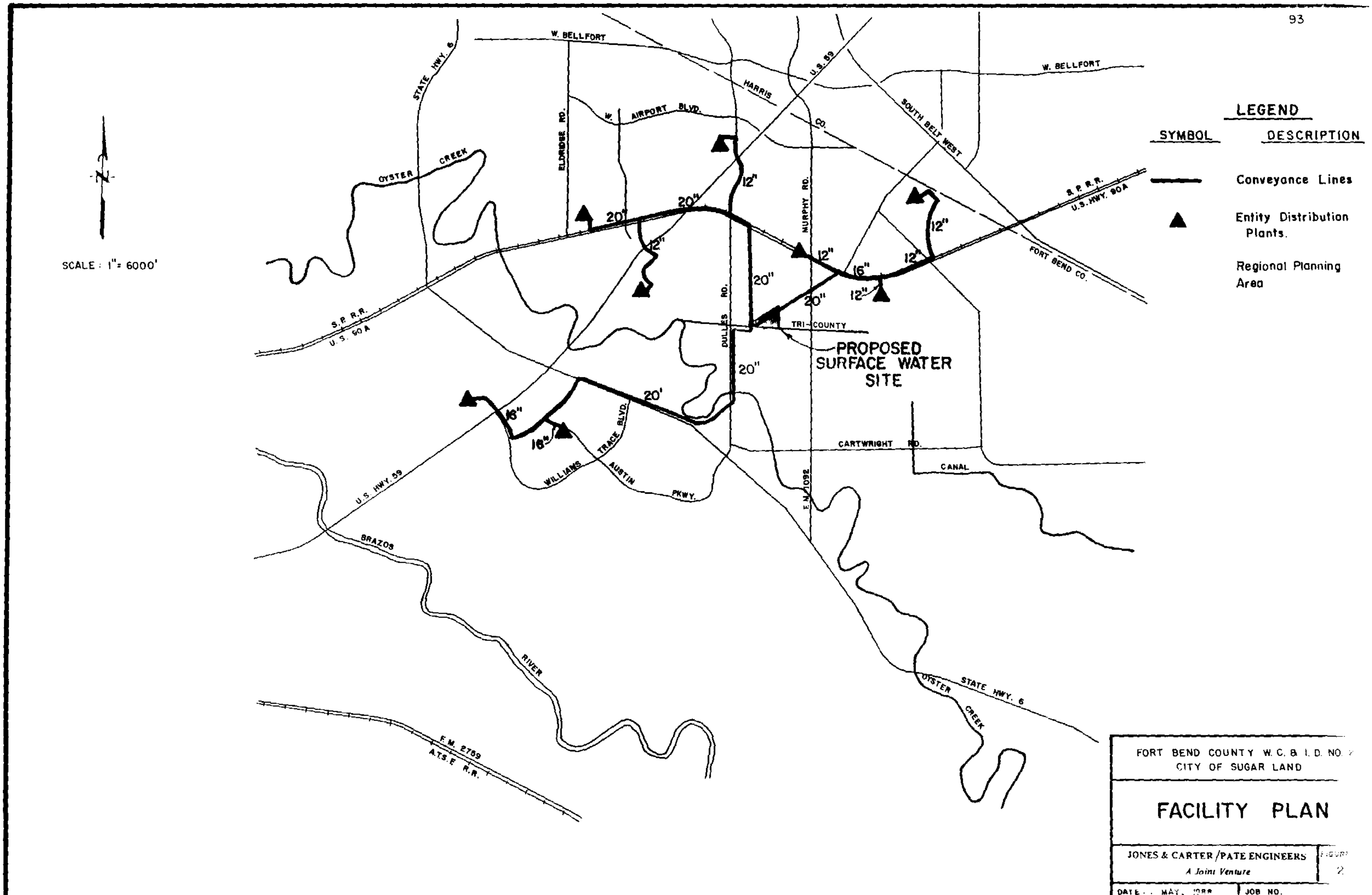
FIGURE 17

DATE: JANUARY, 1988 | JOB NO.


ClO_2
POLYMER
FERRIC FLOC
LIME
TREATMENT UNIT
CO_2
POLYMER
Cl_2
Zn ORTHOPHOSPHATE
NaF
NH_3
FILTERS
SEDIMENTATION BASIN
FILTER WASTE BACKWASH TANK
BACKWASH WATER SUPPLY TANK
RAW WATER RESERVOIR
RAW WATER PUMP STATION
METERING STATION
SPLITTER BOX
RAPID MIXERS
FLOCCULATORS
GROUND STORAGE TANKS
FILTER WASTE BACKWASH PUMPS
CLEAR WELL
INTERMEDIATE PUMP STATION
DISTRIBUTION PUMPS
SLUDGE PUMPS
SUPERNATANT PUMPS
SLUDGE THICKENER
WASTE SLUDGE PUMPS
ONSITE SLUDGE DISPOSAL
FORT BEND COUNTY W.C. & I.D. NO. 2
CITY OF SUGAR LAND
PROPOSED TREATMENT PROCESS
BRAZOS RIVER WATER
JONES & CARTER/PATE ENGINEERS
A Joint Venture
FIGURE
18
DATE MAY, 1985
JOB NO. 265-01-00


SCALE: 1" = 2000'
OYSTER CREEK
CENTRAL
STATE PRISON FARM
Covington Woods
Sugar Land
Stafford
Water Tanks
Parking
Parking Area
Water Tanks
Sewage Disposal
Trailer Park
Substa
Sandpit
Sewage Disposal
Athletic Field
Sugar Land
Eldridge Memorial Hospital
Water Tanks
Water Tank
SOUTHERN PACIFIC
MISSOURI PACIFIC
Dam # 1
Sugar Land
Well
Sewage Disposal
Char Lake
Horseshoe Lake
Dam # 2
PIPELINE
John Foster Dulles High Sch
Trailer Park
Sewage Disposal
Houston Fishing Club Lake
Proposed Surface Water Plant Site
River Bend Country Club
Pumping Sta
CANAL
OYSTER CREEK
Cementerio San Isidro
Existing 2ND Lift Station
Dam # 3
Paynes
BLAIR ROAD
Well
ISON FARM
Bullhead Bayou
Substa
Well
FORT BEND COUNTY W.C. & I.D. NO. 2
CITY OF SUGAR LAND
TRI-COUNTY CANAL LAKE SYSTEM
JONES & CARTER/PATE ENGINEERS
A Joint Venture
FIGURE 19
DATE: JUNE, 1988
JOB NO.


AVE. E
BRAND LANE
OYSTER CREEK
DISTRIBUTION PUMPS
PLANT TREATMENT FACILITIES (~5 AC.)
RAW WATER PUMP STATION
GST
GST
GST
ADMIN.
PARK
SLUDGE THICKENERS
INTERMEDIATE PUMP STATION
5-8 MGD T.U.
5-8 MGD T.U.
5-8 MGD T.U.
FILTERS
CLEARWELL
SLUDGE DISPOSAL (~15AC.)
TRI-COUNTY CANAL SYSTEM
EXIST. PUMP STATION
ELECTRICAL & CHEMICAL STORAGE AREA
2000 FT.
2400 FT.
N
0 100 200
SCALE: 1" = 200'
T.U. – TREATMENT UNIT
GST – GROUND STORAGE TANK
FORT BEND COUNTY W.C. & I.D. NO. 2
CITY OF SUGAR LAND
PROPOSED PLANT SITE
JONES & CARTER / PATE ENGINEERS
A Joint Venture
20
DATE: MAY 1988
JOB NO. 265-01-00



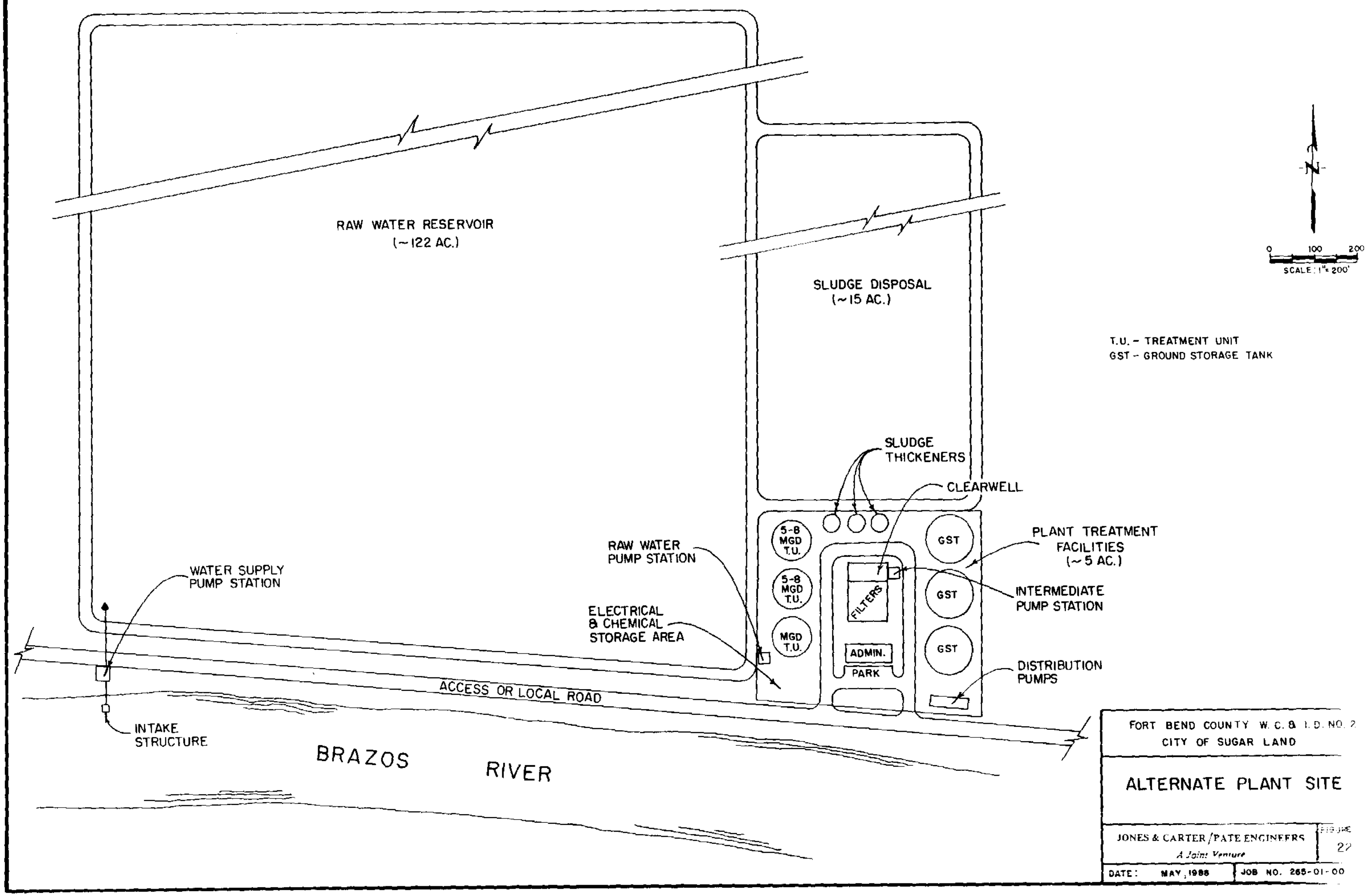
FORT BEND COUNTY W.C. & I.D. NO. 2
CITY OF SUGAR LAND

FACILITY PLAN

JONES & CARTER / PATE ENGINEERS
A Joint Venture

FIGURE 2

DATE: MAY, 1988 | JOB NO.



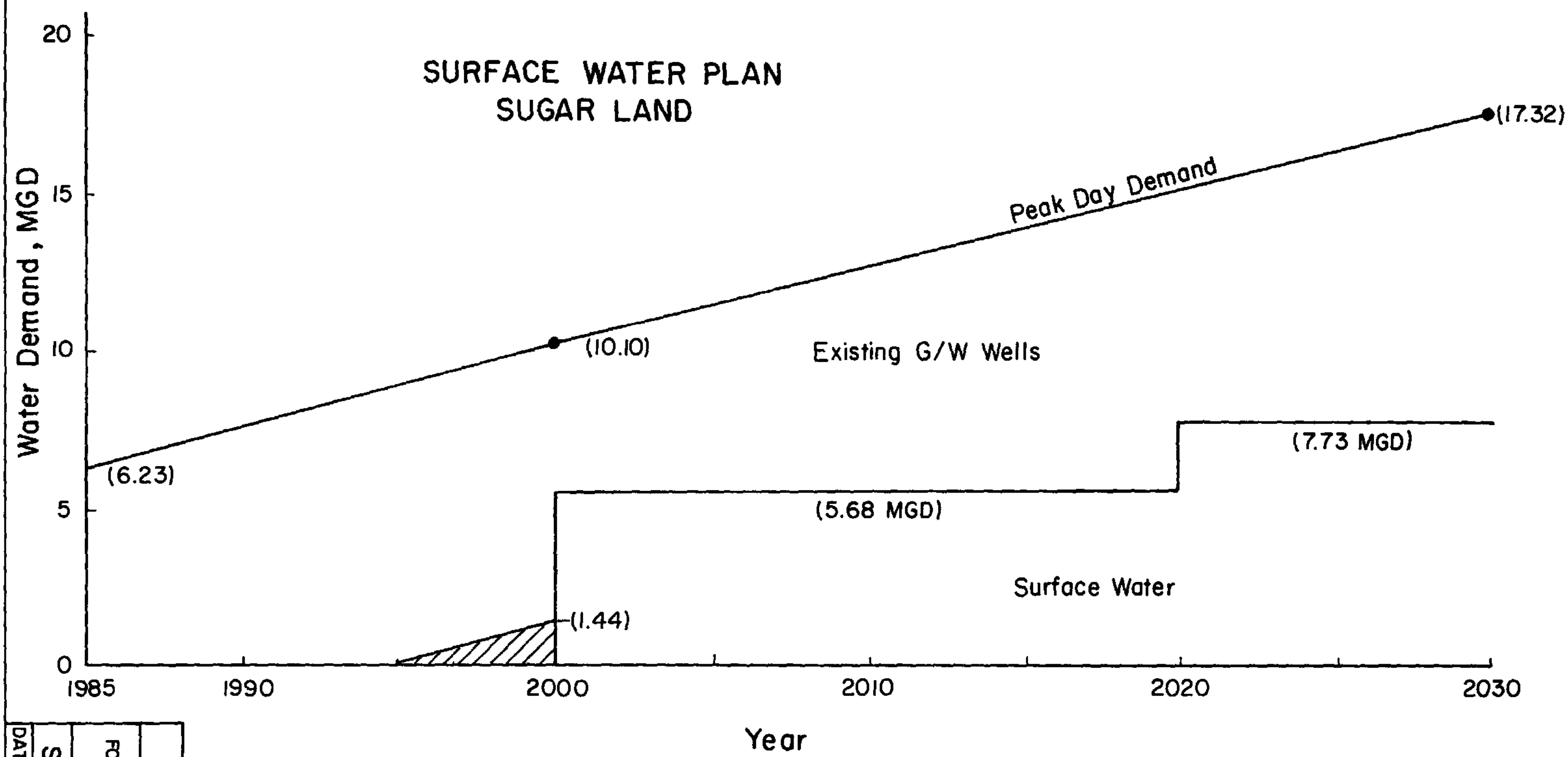
FORT BEND COUNTY W.C. & I.D. NO. 2
CITY OF SUGAR LAND

ALTERNATE PLANT SITE

JONES & CARTER / PATE ENGINEERS
A Joint Venture

FIGURE 22

DATE: MAY, 1988 | JOB NO. 265-01-00



First Additional Well Required

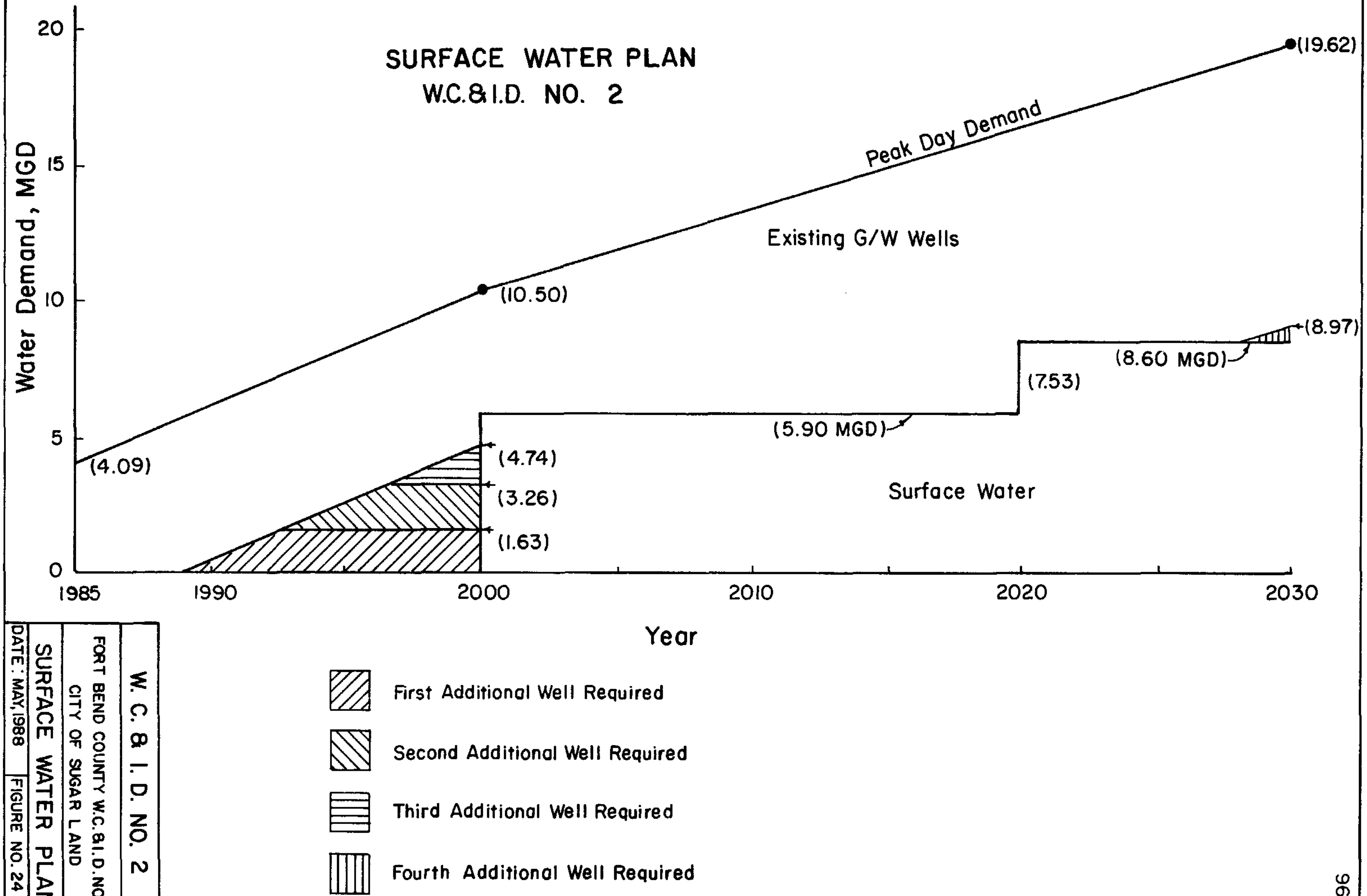
SUGAR LAND

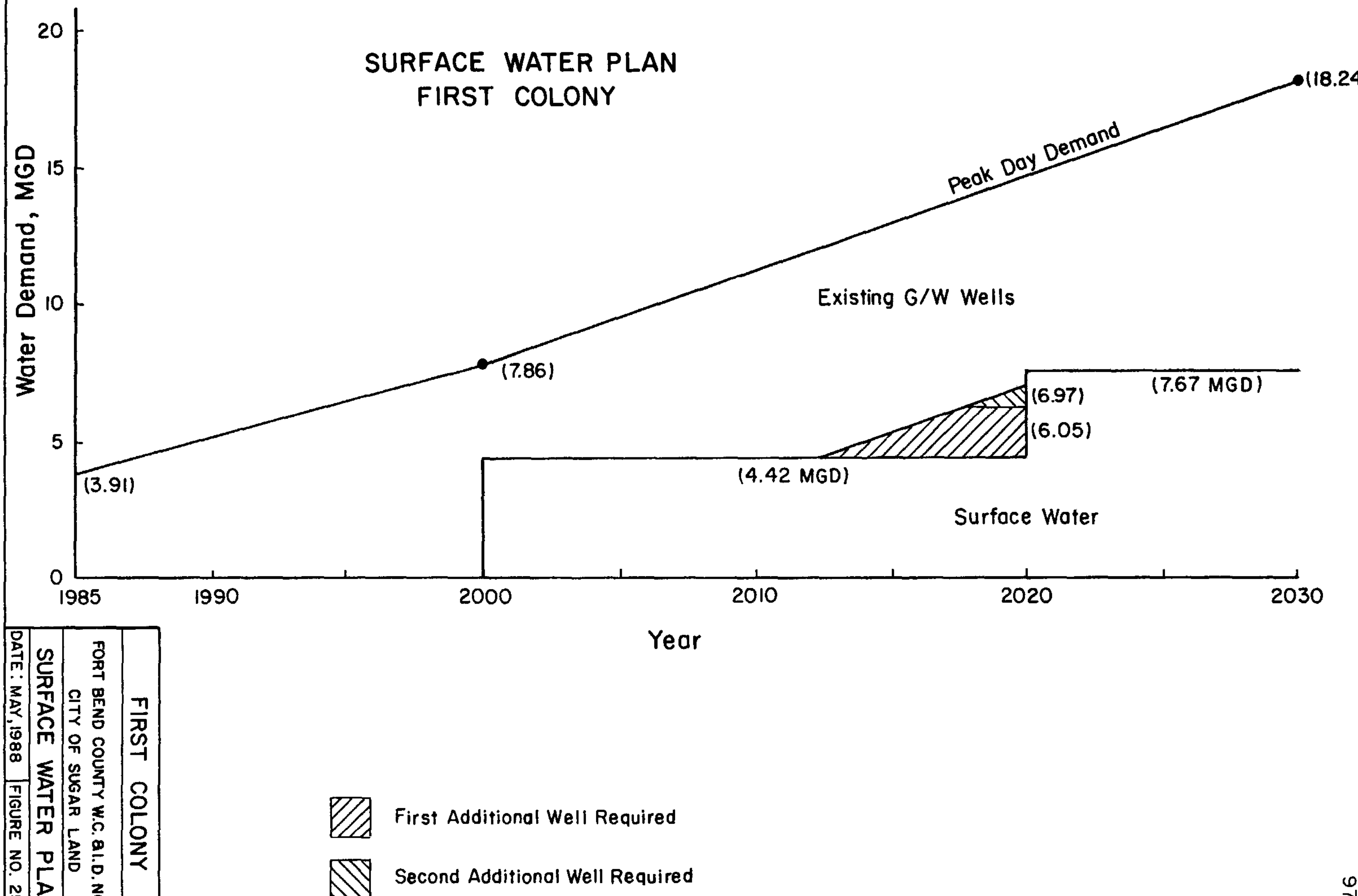
FORT BEND COUNTY W.C.& I.D. NO.2
CITY OF SUGAR LAND

SURFACE WATER PLAN

DATE: MAY, 1988

FIGURE NO. 23


SURFACE WATER PLAN
W.C.& I.D. NO. 2
Water Demand, MGD
0
5
10
15
20
1985
1990
2000
2010
2020
2030
Year
Peak Day Demand
Existing G/W Wells
Surface Water
(4.09)
(10.50)
(19.62)
(8.97)
(8.60 MGD)
(7.53)
(5.90 MGD)
(4.74)
(3.26)
(1.63)
First Additional Well Required
Second Additional Well Required
Third Additional Well Required
Fourth Additional Well Required
W. C. & I. D. NO. 2
FORT BEND COUNTY W.C.& I.D. NO. 2
CITY OF SUGAR LAND
SURFACE WATER PLAN
DATE : MAY, 1988
FIGURE NO. 24



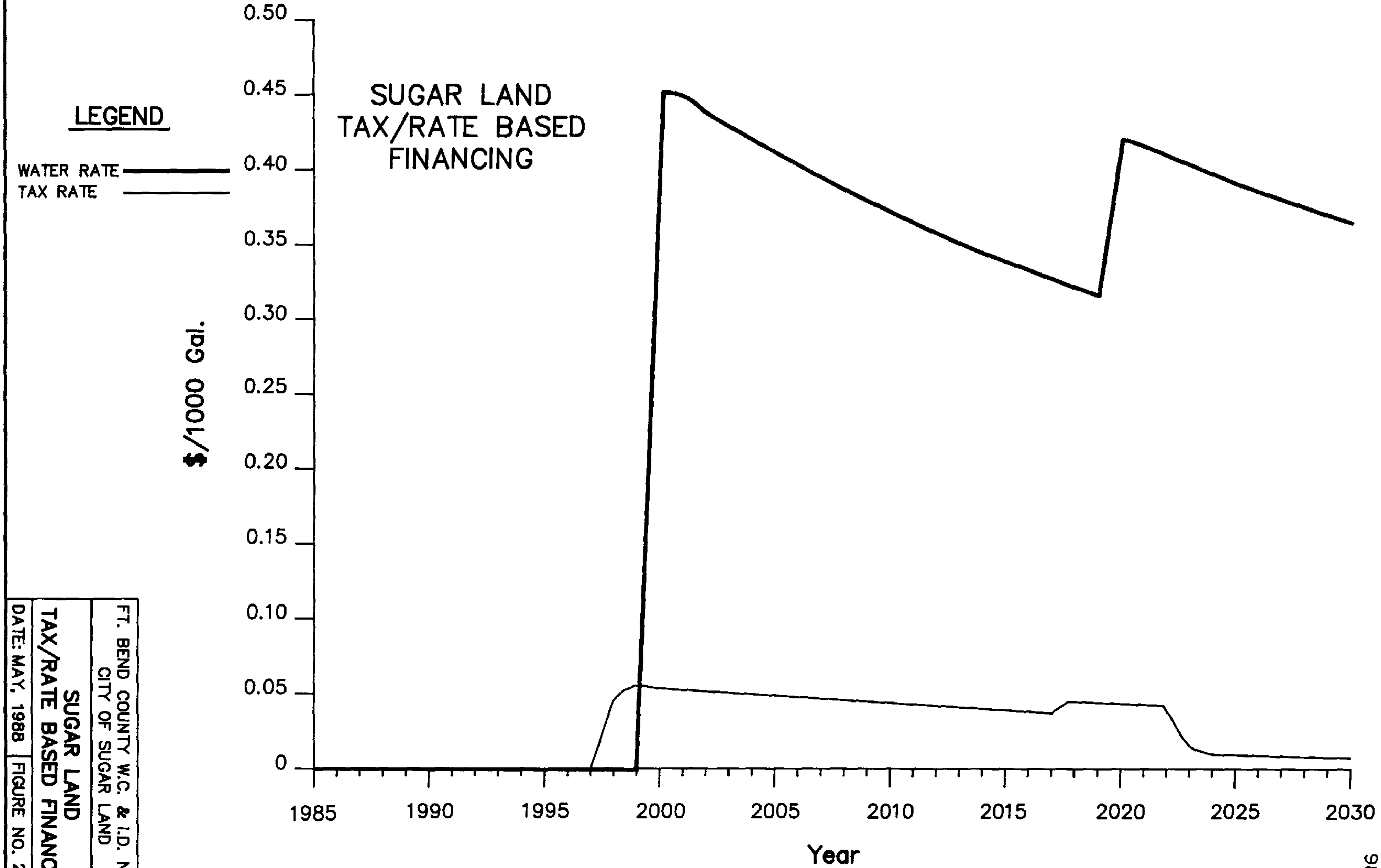
FIRST COLONY

FORT BEND COUNTY W.C.&I.D. NO. 2
CITY OF SUGAR LAND

SURFACE WATER PLAN

DATE: MAY, 1988

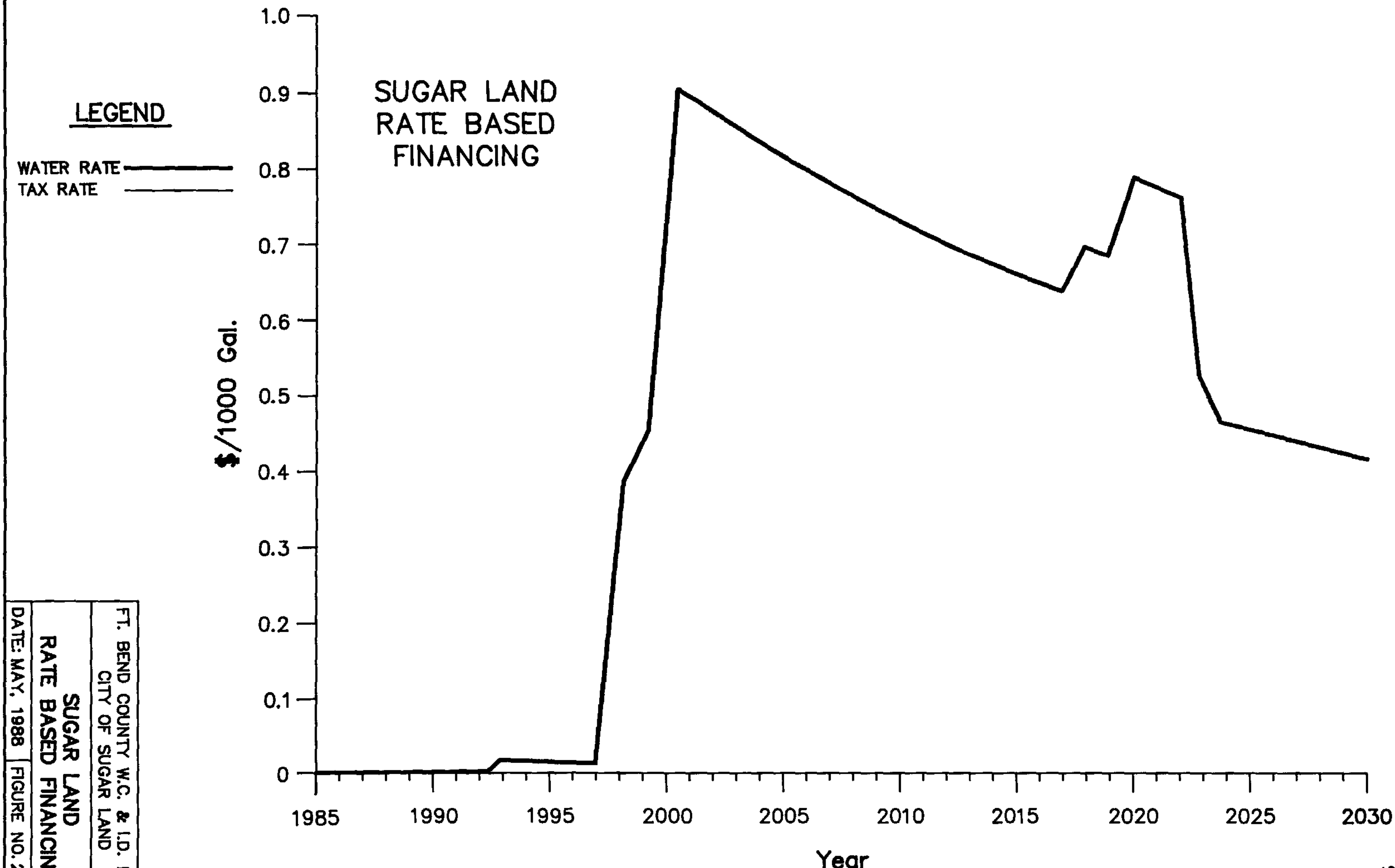
FIGURE NO. 25



FT. BEND COUNTY W.C. & I.D. NO. 2
CITY OF SUGAR LAND

SUGAR LAND
TAX/RATE BASED FINANCING

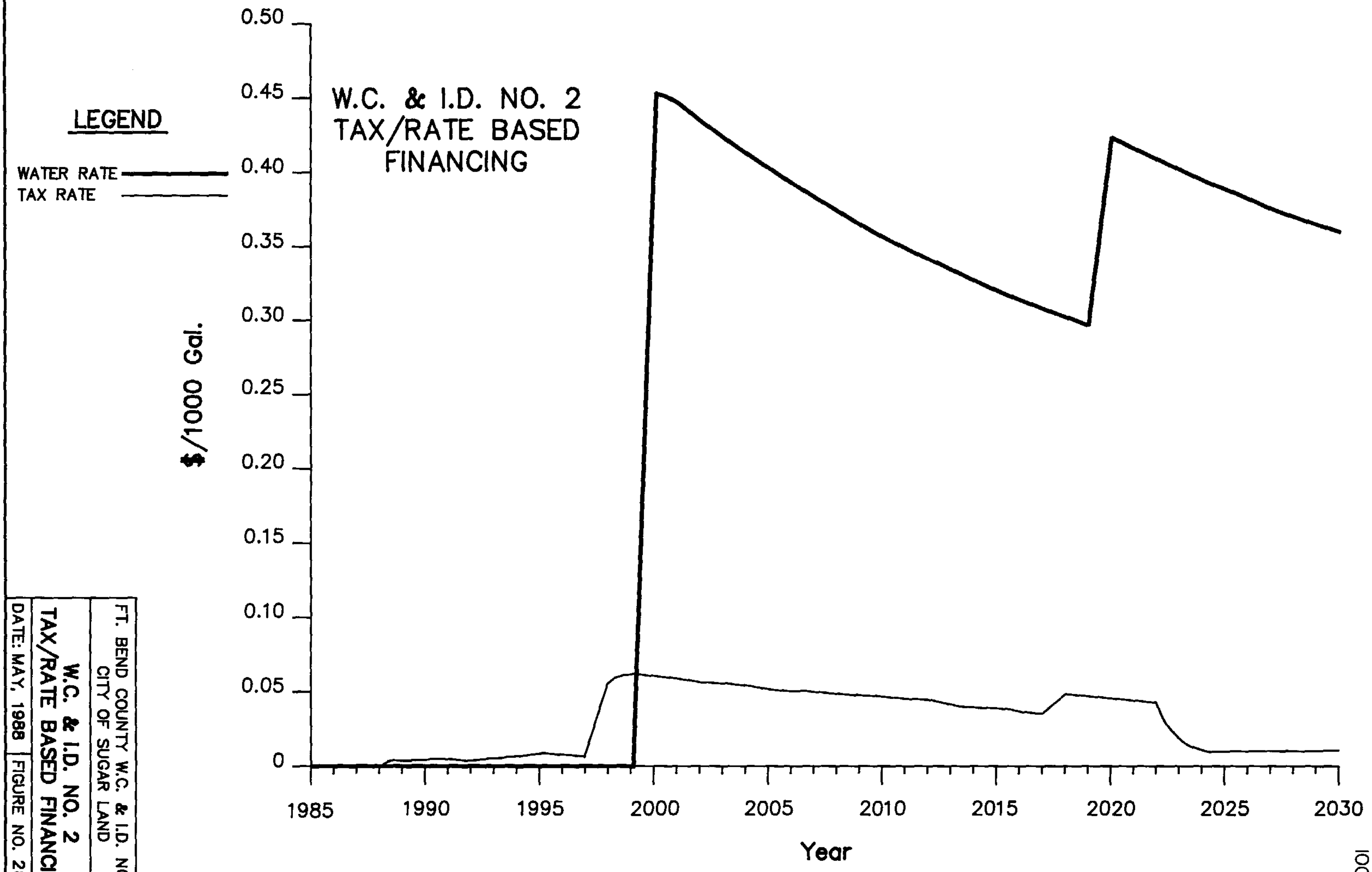
DATE: MAY, 1988 | FIGURE NO. 26



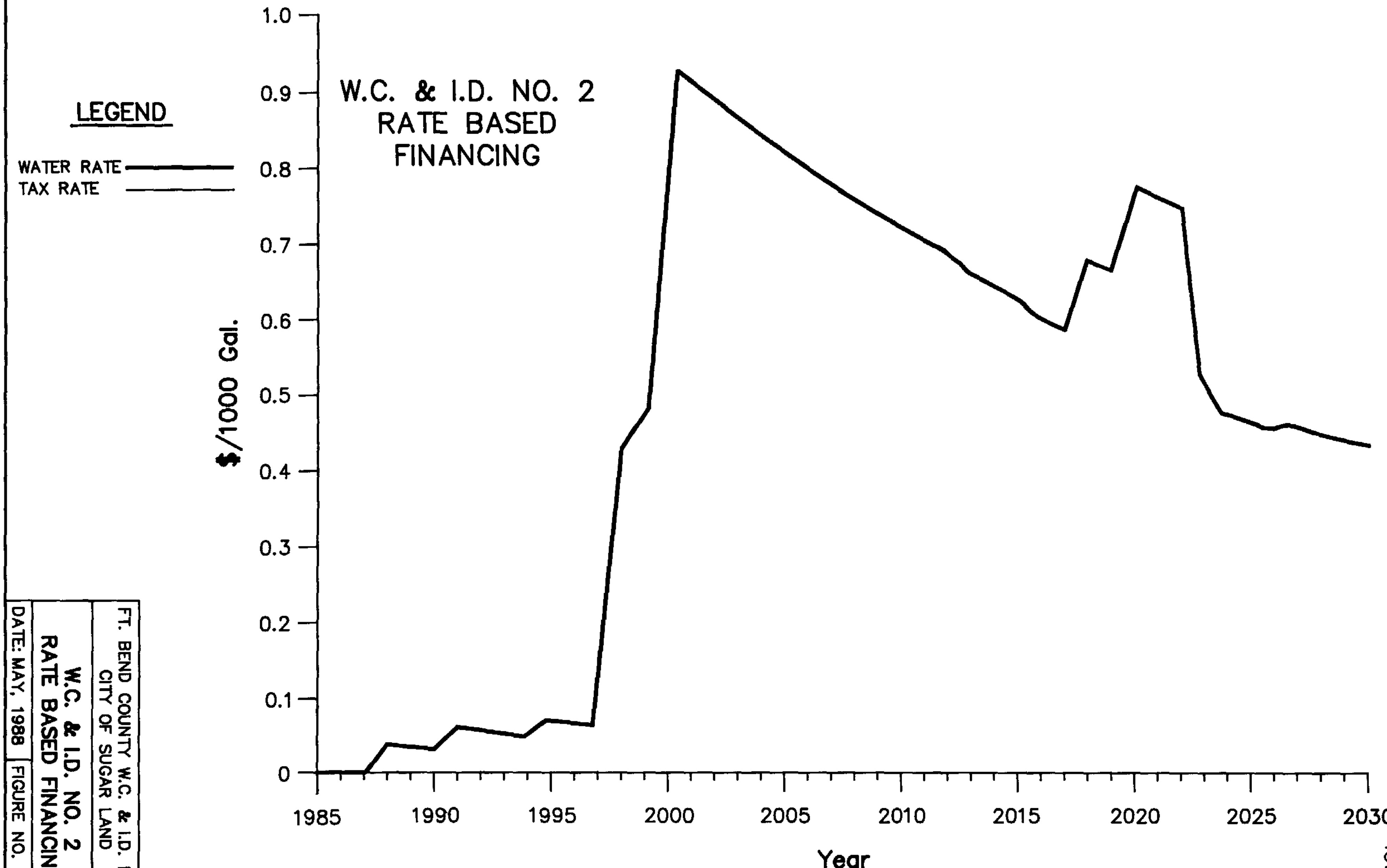
FT. BEND COUNTY W.C. & I.D. NO. 2
CITY OF SUGAR LAND

SUGAR LAND
RATE BASED FINANCING

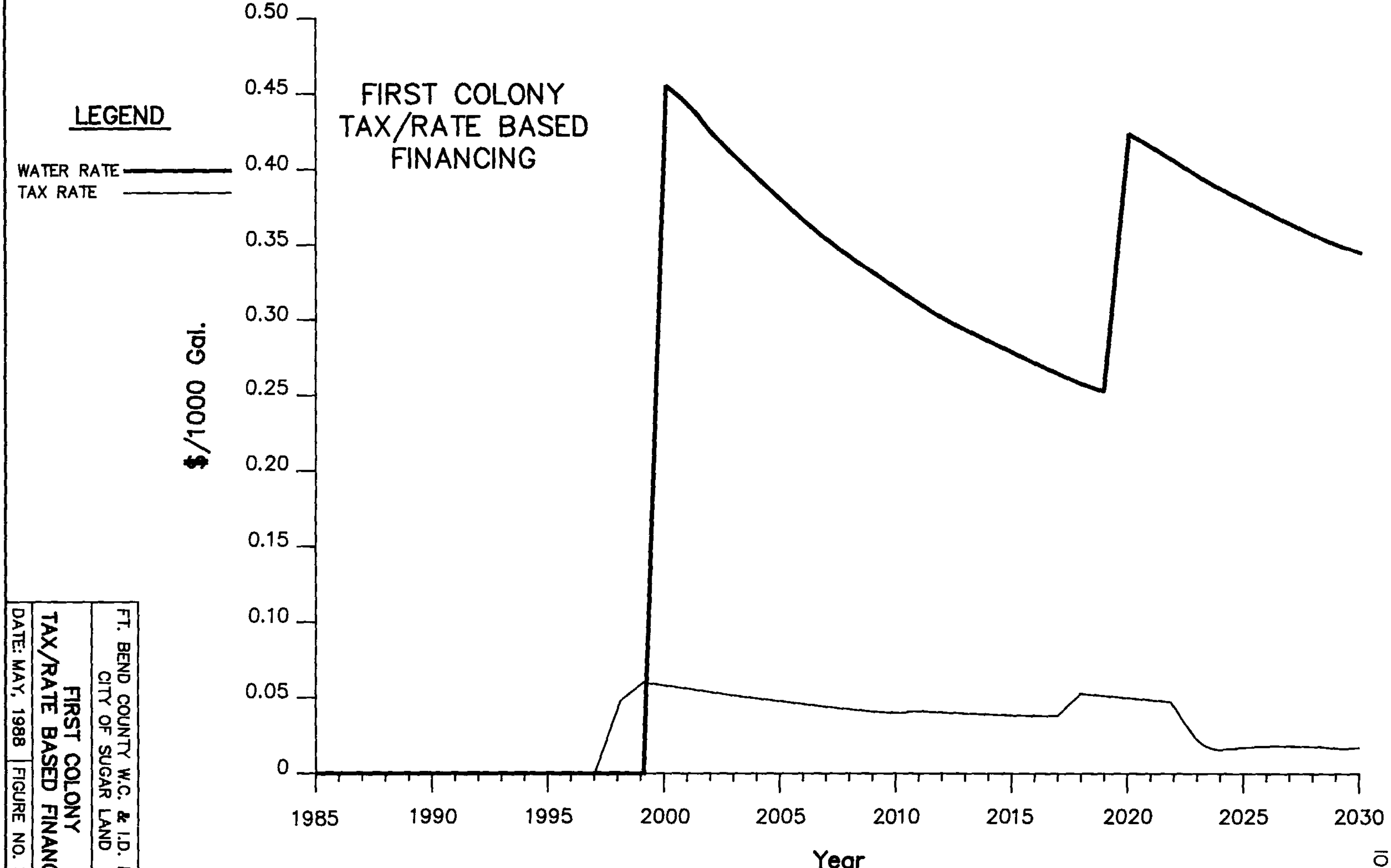
DATE: MAY, 1988 | FIGURE NO. 27



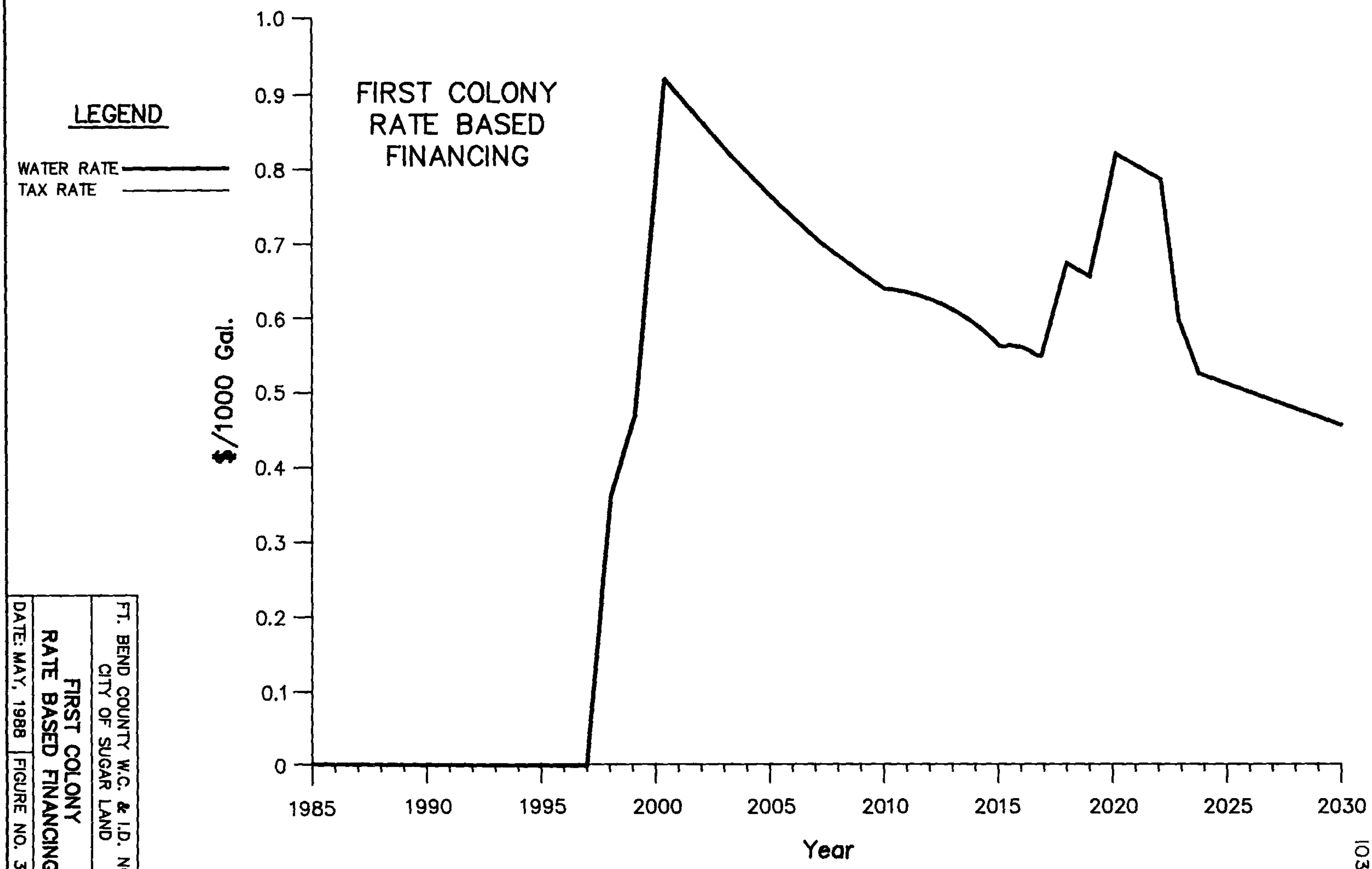
FT. BEND COUNTY W.C. & I.D. NO. 2 CITY OF SUGAR LAND	
W.C. & I.D. NO. 2 TAX/RATE BASED FINANCING	
DATE: MAY, 1988	FIGURE NO. 28



FT. BEND COUNTY W.C. & I.D. NO. 2 CITY OF SUGAR LAND	
W.C. & I.D. NO. 2 RATE BASED FINANCING	
DATE: MAY, 1988	FIGURE NO. 29



FT. BEND COUNTY W.C. & I.D. NO. 2 CITY OF SUGAR LAND	
FIRST COLONY TAX/RATE BASED FINANCING	
DATE: MAY, 1988	FIGURE NO. 30



FT. BEND COUNTY W.C. & I.D. NO. 2
CITY OF SUGAR LAND

FIRST COLONY
RATE BASED FINANCING

DATE: MAY, 1988 | FIGURE NO. 31

APPENDIX - VOLUME I

FILE: WELLS
DISC: WELL DATA - STATISTICAL WELL INFORMATION FOR FBCWCID NO. 2 / SUGAR LAND (CROSS REFERENCED WITH WELL LOCATION FIGURE)
UPDATED ON: 27-Jun-88 7-31-87

	WELL NUMBER	WELL OWNER	DATE DRILLED	TOTAL DEPTH (FT)	WATER LEVELS FIRST DEPTH (FT)	FIRST DATE	MOST RECENT DEPTH (FT)	MOST RECENT DATE	WATER USAGE	YIELD (GPM)	PUMP DRAWDOWN (FT)	AQUIFER	CHANGE IN DEPTH (FT)	YEARS BETWEEN CHANGE	WATER TABLE DECLINE (FT/YR) (-RISE)
1	JY 65-19-901	Unknown	?	40	20	1969	?	?	UN.	?	?	Cu			
2	JY 65-19-902	State Prison	1963	70	17	1969	?	?	STOCK	?	?	Cu			
3	JY 65-19-903	State Prison	1963	70	17	1969	?	?	STOCK	?	?	Cu			
4	JY 65-19-904	FBCWCID 4	1969	1,775	192	1969	?	?	PUB.	457	56	E			
5	JY 65-19-905	FBCMUD 25	1980	924	168	1980	?	?	PUB.	1,000	33	C/E			
6	JY 65-19-906	FBCMUD 41	1984	1,565	281	1984	263	1987	PUB.	1,022	42	E	-18	3	-6.000
7	JY 65-19-907	FBMUD 2 Town West	?	?	?	?	?	?	?	?	?	?			
**															
8	LJ 65-20-706	Parkglen West MUD	1970	1102	191	1970	?	?	PUB.	1012	81	E			
**															
9	JY 65-20-701	Dorrance & Wing	1950	761	?	?	?	?	IRR.	?	?	Cl			
10	JY 65-20-702	Austin Co.	1957	1,017	110	1959	?	?	IND.	1,227	69	E			
11	JY 65-20-703	Thommy Hefner	1965	199	107	1965	?	?	DOM.	?	?	Cu			
12	JY 65-20-704	Parker Bros.	1968	298	90	1968	?	?	IND.	80	18	Cl			
13	JY 65-20-705	Unknown	?	40	35	1969	?	?	UN.	?	?	Cu			
14	JY 65-20-708	FBWCID 2, well 3	1970	1,625	185	1970	?	?	PUB.	1,277	44	E			
15	JY 65-20-709	Meadows MUD	1972	1,035	205	1972	?	?	PUB.	1,235	57	E			
16	JY 65-20-710	Baylor Co.	1968	452	128	1968	?	?	IND.	?	?	C			
17	JY 65-20-711	Sugar Land	1975	1,665	239	1975	?	?	PUB.	1,800	81	E			
18	JY 65-20-712	Sugarland (new)	?	?	?	?	300	1987	?	?	?	?			
19	JY 65-20-801	Texas Instruments	1967	1,030	158	1967	?	?	IND.	760	41	E			
20	JY 65-20-802	Weatherford	1957	387	111	1968	?	?	IRR.	50	?	Cl			
21	JY 65-20-804	Weatherford	1971	377	125	1971	?	?	DOM.	?	?	C			
22	JY 65-20-805	Texas Instruments	1969	1,020	164	1971	?	?	IND.	765	64	E/C			
23	JY 65-20-806	The Meadows MUD	1970	1,040	178	1970	285	1987	PUB.	1,023	39	E	107	17	6.294
24	JY 65-20-809	Texas Instruments	1980	934	242	1980	?	?	PUB.	1,000	38	E/C			
25	JY 65-20-901	FBWCID 2, well 4	1977	1,690	282	1978	?	?	PUB.	1,266	69	E			
**															
26	LJ 65-20-803	Glenshire MUD	1970	880	200	1970	?	?	PUB.	1,000	50	E/Cl			
27	LJ 65-20-804	Glenshire MUD	1972	888	208	1972	?	?	PUB.	1,345	66	E/Cl			
28	LJ 65-20-807	HCMUD 139	1976	1030	260	1977	?	?	PUB.	1022	62	E/Cl			
**							?	?							
29	JY 65-27-201	State Prison	1956	721	84	1956	?	?	PUB.	402	38	Cl/E			
30	JY 65-27-202	State Prison	1956	90	18	1964	?	?	IRR.	593	48	Cu			
31	JY 65-27-203	Smith Ranches	1956	73	25	1964	?	?	IRR.	692	43	Cu			
32	JY 65-27-204	State Prison	1956	91	14	1964	?	?	IRR.	519	61	Cu			
33	JY 65-27-205	State Prison	1956	86	14	1964	?	?	IRR.	540	59	Cu			
34	JY 65-27-206	State Prison	1956	62	9	1964	?	?	IRR.	419	43	Cu			
35	JY 65-27-207	State Prison	1956	62	10	1964	?	?	IRR.	593	44	Cu			
36	JY 65-27-208	H. Helmcamp	1957	138	33	1964	?	?	IRR.	600	?	Cu			
37	JY 65-27-209	H. Helmcamp	1957	100	29	1964	?	?	IRR.	600	?	Cu			
38	JY 65-27-210	H. Helmcamp	1957	100	25	1964	?	?	IRR.	600	?	Cu			
39	JY 65-27-211	Clayton Foundation	1951	8,748	?	?	?	?	?	?	?	?			
40	JY 65-27-212	Robert Schumann	1971	329	84	1971	?	?	DOM.	?	?	C			
41	JY 65-27-213	FBCMUD 69	1984	1,058	169	1984	161	1987	PUB.	1,500	40	E	-8	3	-2.667

JONES & CARTER/PATE ENGINEERS

APPENDIX A

42	JY 65-27-301	State Prison	1948	702	57	1948	75	1953	(disc.)	PUB.	524	45	Cl	18	5	3.600
43	JY 65-27-302	Ft. Bend Utilities	1944	1,565	57	1945	282	1986		PUB.	847	55	E	225	41	5.488
44	JY 65-27-303	Ft. Bend Utilities	1958	876	108	1958	203	1986		IND.	1,599	63	Cl/E	95	28	3.393
45	JY 65-27-304	State Prison	1956	103	26	1969	?	?		IRR.	1,027	35	Cu			
46	JY 65-27-305	State Prison	1956	72	27	1964	25	1969		IRR.	450	17	Cu	-1.8	5	-0.360
47	JY 65-27-306	State Prison	1956	100	20	1969	?	?		IRR.	1,027	19	Cu			
48	JY 65-27-307	State Prison	1958	83	20	1964	?	?		IRR.	1,180	23	Cu			
49	JY 65-27-308	State Prison	1958	104	19	1964	?	?		IRR.	1,321	37	Cu			
50	JY 65-27-309	State Prison	1931	700	32	1945	55	1951	(dest.)	UN.	200	?	Cl	23	6	3.833
51	JY 65-27-310	H. Helmcamp	1957	100	21	1964	?	?		IRR.	600	?	Cu			
52	JY 65-27-311	State Prison	1961	406	70	1961	?	?		PUB.	300	37	Cl			
53	JY 65-27-312	Ft. Bend Utilities	1920	1,606	1	1920	169	1966		PUB.	?	?	E	168	46	3.652
54	JY 65-27-313	Ft. Bend Utilities	1941	726	49	1941	204	1986		IND.	?	?	Cl	155	45	3.444
55	JY 65-27-314	State Prison	1930	257	19	1930	41	1950	(dest.)	UN.	?	?	Cl	22	20	1.100
56	JY 65-27-315	Ft. Bend Utilities	1934	733	30	1938	94	1959	(dest.)	UN.	1,262	57	Cl	64	21	3.048
57	JY 65-27-316	Ft. Bend Utilities	1921	1,049	37	1940	40	1941	(dest.)	UN.	?	?	Cl/E	3	1	3.000
58	JY 65-27-317	Ft. Bend Utilities	1922	604	10	1940	?	?		UN.	?	?	Cl			
59	JY 65-27-318	State Prison	1932	750	?	?	?	?		UN.	150	?	Cl			
60	JY 65-27-319	Venetian Estates	1968	190	9	1968	?	?		IRR.	1,067	28	C			
61	JY 65-27-320	Signal Oil Co.	1968	219	84	1968	?	?		IND.	?	?	C			
62	JY 65-27-321	B.R.A.	1974	302	81	1974	105	1987		IND.	?	?	C	24	13	1.846
63	JY 65-27-322	T.D.C.	1975	407	89	1975	107	1987		DOM.	448	23	C	18	12	1.500
64	JY 65-27-323	FBCMUD No. 13	1982	1,070	198	1982	189	1987		PUB.	2,464	81	E	-9	5	-1.800
65	JY 65-27-324	Ft. Bend Utilities	1985	1,025	231	1985	240	1986		IND.	1,507	73	E	9	1	9.000
66	JY 65-27-601	State Prison	1956	86	32	1964	?	?		IRR.	1,027	35	Cu			
67	JY 65-27-602	State Prison	1958	83	33	1964	?	?		IRR.	1,283	35	Cu			
68	JY 65-27-603	State Prison	1956	78	30	1964	?	?		IRR.	1,027	18	Cu			
69	JY 65-27-604	State Prison	1958	79	38	1964	?	?		IRR.	927	41	Cu			
70	JY 65-27-605	Sugar Land Ind.	1931	160	16	1931	?	?		UN.	?	?	Cu			
71	JY 65-27-606	Sugar Land Ind.	1931	353	14	1931	?	?		UN.	?	?	Cl			
72	JY 65-27-607	Agnes Booth	old	200	49	1964	?	?		STOCK	?	?	Cu/Cl			
73	JY 65-27-608	Agnes Booth	1949	200	49	1964	?	?		STOCK	?	?	Cu/Cl			
74	JY 65-27-901	A.E.Meyers	1944	720	30	1964	120	1976		DOM.	100	?	Cl	90	12	7.500
75	JY 65-27-902	A.E.Meyers	1936	300	28	1947	49	1956	(disc.)	UN.	?	?	Cl	21	9	2.333
76	JY 65-27-903	A.E.Meyers	1964	674	91	1964	148	1987		PUB.	?	?	Cl	57	23	2.478
77	JY 65-27-904	A.E.Meyers	1935	179	17	1936	?	?		UN.	?	?	Cu			
78	JY 65-28-101	J. D. Nickleson	1966	465	111	1966	?	?		DOM.	?	?	Cl			
79	JY 65-28-102	Sugar Creek	1970	900	148	1970	216	1987		PUB.	1,100	62	E	68	17	4.000
80	JY 65-28-103	City of Cities	1973	995	168	1974	?	?		PUB.	1,218	64	C/E			
81	JY 65-28-104	FBCMUD 12	1976	1,658	185	1976	217	1987		PUB.	3,000	107	C/E	32	11	2.909
82	JY 65-28-105	FBCMUD 13	1982	1,105	203	1982	201	1987		PUB.	2,464	92	C/E		5	0.000
83	JY 65-28-106	Land & Water Amm.	1982	501	170	1982	?	?		PUB.	?	?	C			
84	JY 65-28-107	Greystone	1983	536	?	?	?	?		IND.	?	?	C			
85	JY 65-28-108	Kaneb Services	1982	550	184	1984	196	1987		PUB.	426	35	C	12	3	4.000
86	JY 65-28-109	Sugarland-Sugar Cr	?	1,700	?	?	230	1987		?	?	?	?			
87	JY 65-28-201	FBWCID 2, well 1	1954	690	161	1968	252	1987		PUB.	503	30	Cl	91	19	4.789
88	JY 65-28-202	FBWCID 2, well 2	1956	1,690	194	1968	284	1987		PUB.	1,016	38	E	90	19	4.737
89	JY 65-28-203	Haydite Co.	1957	440	103	1968	?	?		UN.	96	?	Cu/Cl			
90	JY 65-28-204	So. Pacific R.R.	OLD	41	20	1968	?	?		UN.	?	?	Cu			
91	JY 65-28-205	So. Pacific R.R.	1946	275	?	?	?	?		UN.	175	?	Cl			
92	JY 65-28-206	Riverbend CC	1957	643	143	1969	?	?		IND.	254	35	Cl			
93	JY 65-28-207	Meadow Creek MUD	1974	1,130	200	1974	?	?		PUB.	818	49	Cl/E			
94	JY 65-28-208	Quail Valley U.D.	1978	1,325	217	1978	246	1987		PUB.	2,411	110	E	29	9	3.222
95	JY 65-28-209	FBWCID 2, well 5	1980	1,433	282	1980	?	?		PUB.	2,151	54	E			
96	JY 65-28-210	FBCMUD 9	1984	1,205	233	1984	226	1987		PUB.	2,023	68	E	-7	3	-2.333
97	JY 65-28-211	FBCMUD 42	1984	1,092	256	1984	?	?		PUB.	1,500	48	E/C			

98	JY 65-28-301	J. E. Roane	1925	[illegible]	51	1945	?	?		UN.	?	?	Cl			
99	JY 65-28-302	Roland Mason	1931	320	48	1947	?	?		UN.	?	?	Cl			
100	JY 65-28-303	Roland Mason	1944	300	?	?	?	?		UN.	?	?	Cl			
101	JY 65-28-304	Roland Mason	1946	300	?	?	?	?		UN.	?	?	Cl			
102	JY 65-28-305	John Congolosi	1963	54	42	1968	?	?		IND.	1,000	?	Cu			
103	JY 65-28-306	Willow Wisp C.C.	?	420	158	1968	?	?		IRR.	180	?	Cl			
104	JY 65-28-307	Willow Wisp C.C.	?	280	?	?	?	?		IND.	?	?	Cl			
105	JY 65-28-308	United Gas Co.	1951	300	109	1968	137	1987		IRR.	?	18	Cl	28	19	1.474
106	JY 65-28-309	Chasewood	1969	1,032	189	1969	245	1986		PUB.	1,100	94	E	56	17	3.294
107	JY 65-28-310	Willow Wisp C.C.	1971	504	125	1971	?	?		IRR.	?	?	Cl			
108	JY 65-28-311	C.O.H. Sims Bayou	1974	1,200	218	1974	324	1986		PUB.	?	?	E	106	12	8.833
109	JY 65-28-312	Hunters Glen	1975	1,256	213	1975	274	1987		PUB.	1,461	73	E	61	12	5.083
110	JY 65-28-313	FBCMUD 26	1980	1,190	274	1980	272	1987		PUB.	1,230	38	E	-2	7	-0.286
111	JY 65-28-314	FBCMUD 26	1979	403	34	1979	?	?		PUB.	308	31	C			
112	JY 65-28-315	Blue Ridge W. MUD	1980	1,155	260	1980	?	?		PUB.	1,248	298	E			
113	JY 65-28-317	Willow Wisp C.C.	1981	509	150	1981	142	1987		PUB.	190	47	C	-8	6	-1.333
114	JY 65-28-318	(small church)	?	?	?	?	?	?		?	?	?	?			
115	JY 65-28-401	Humble Oil & Ref.	1955	711	81	1955	182	1987		IND.	80	?	Cl	101	32	3.156
116	JY 65-28-402	Humble Oil & Ref.	1946	484	34	1947	85	1964	(disc.)	UN.	?	?	Cl	51	17	3.000
117	JY 65-28-403	Humble Oil & Ref.	1947	671	38	1947	89	1965	(disc.)	UN.	?	?	Cl	51	18	2.833
118	JY 65-28-404	Humble Oil & Ref.	1928	716	40	1947	139	1976		UN.	?	?	Cl	99	29	3.414
119	JY 65-28-405	Humble Oil & Ref.	1929	710	?	?	?	?		UN.	200	?	Cl			
120	JY 65-28-406	FBCMUD 12	1976	1,664	179	1976	?	?		PUB.	3,544	315	E			
121	JY 65-28-501	Humble Oil & Ref.	1945	448	41	1947	178	1987		UN.	?	?	Cl	137	40	3.425
122	JY 65-28-502	C. Renshaw	1968	599	129	1968	?	?		PUB.	?	?	Cl			
123	JY 65-28-503	Roy H. Schmidt	old	47	12	1969	?	?		UN.	?	?	Cu			
124	JY 65-28-504	R.T. Herrin	1971	104	10	1971	?	?		IRR.	?	?	C			
125	JY 65-28-505	Quail Valley	1972	1,074	343	1972	?	?		PUB.	1,266	?	E/Cl			
126	JY 65-28-506	Quail Valley MUD	1969	1,200	155	1969	?	?		PUB.	524	85	E			
127	JY 65-28-507	Thunderbird UD	1976	1,167	205	1977	?	?		PUB.	863	84	E			
128	JY 65-28-508	Quail Valley UD	1977	1,320	214	1978	236	1987		PUB.	1,500	273	E	22	9	2.444
129	JY 65-28-509	Plantation MUD	1983	1,225	220	1983	224	1987		PUB.	1,313	56	E	4	4	1.000
130	JY 65-28-510	FBCMUD 46	1985	1,065	238	1985	?	?		PUB.	1,005	50	E			
131	JY 65-28-701	Humble Oil & Ref.	1947	523	36	1947	?	?		UN.	?	?	Cl			
132	JY 65-28-702	Glen R. Shultz	1974	247	68	1975	?	?		DOM.	?	?	Cl			
133	JY 65-28-703	Lee Brawner	1973	300	?	?	?	?		DOM.	?	?	Cl			
134	JY 65-28-704	John Hasty	1976	233	62	1976	?	?		DOM.	?	?	Cl			
135	JY 65-28-705	Robert Newton	1976	237	61	1976	?	?		DOM.	?	?	Cl			
136	JY 65-28-706	Mr. Newberne	1976	250	64	1976	?	?		DOM.	?	?	Cl			
137	JY 65-28-707	Charles J. Shuman	1976	303	66	1976	?	?		DOM.	?	?	Cl			
138	JY 65-28-708	Bill Cayan	1974	239	65	1974	?	?		DOM.	?	?	Cl			
139	JY 65-28-709	Drake Williams	1976	303	64	1976	?	?		DOM.	?	?	Cl			
140	JY 65-28-710	Peter Meilan	1976	242	64	1976	?	?		DOM.	?	?	Cl			
141	JY 65-28-711	Arthur Kennedy	1976	243	61	1976	?	?		DOM.	?	?	Cl			
142	JY 65-19-801	State Prison	1958	256	74	1964	?	?		IRR.	1,300	36	C			
143	JY 65-19-802	State Prison	1957	91	14	1964	?	?		IRR.	889	46	Cu			
144	JY 65-19-803	State Prison	1956	233	64	1964	?	?		IRR.	1,110	?	C			
145	JY 65-19-804	State Prison	1956	231	53	1964	?	?		IRR.	1,300	?	C			
146	JY 65-19-805	Texas Prison	1946	320	34	1946	?	?		UN.	?	?	Cl			
147	JY 65-19-806	Texas Prison	1942	?	?	?	?	?		UN.	?	?	?			
148	JY 65-19-807	Texas Dpt. of Corr	1978	1,040	156	1978	172	1987		D/IND.	521	32	E	16	9	1.778
149	JY 65-19-808	(nursery)	?	?	?	?	?	?		?	?	?	?			
150	JY 65-19-809	FBCMUD 25	1979	850	167	1979	?	?		PUB.	?	?	?			
**																
151	LJ 65-20-901	S & R Oil Co.	1966	328	?	?	?	?		IND.	?	?	Cl			
152	LJ 65-20-902	Sam Navarro	1928	334	20	1928	34	1941	(dest.)	NONE	?	?	Cl	14	13	1.077

JONES & CARTER/PATE ENGINEERS

153	LJ 65-20-903	Builders Supply Co	1969	328	110	1969	?	?		IND.	?	?	CI			
154	LJ 65-20-904	Diamond "L" Ranch	1928	315	29	1938	50	1947	(dest.)	NONE	?	?	CI	21	9	2.333
155	LJ 65-20-905	W.W.Fondren Estate	1952	899	?	?	?	?		IRR.	?	?	CI/E			
156	LJ 65-20-906	Fondren Park	1964	933	150	1964	?	?		PUB.	708	76	E/CI			
157	LJ 65-20-907	Builders Supply Co	1969	328	110	1969	?	?		IND.	?	?	CI			
158	LJ 65-20-908	Braeburn West UD	1969	955	225	1969	298	1986		PUB.	1,200	61	E/CI	73	17	4.294
159	LJ 65-20-909	Fondren Park	1970	1,167	215	1970	?	?		PUB.	1,235	63	E			
160	LJ 65-20-910	COH Sims Bayou	1974	1,200	230	1974	305	1986		PUB.	2,118	56	E	75	12	6.250
161	LJ 65-20-911	COH Sims Bayou	1974	1,200	234	1975	313	1986		PUB.	?	?	E	79	11	7.182
**************************************																
162	JY 65-27-501	Vallet Bros.	1967	81	39	1967	?	?		STOCK	?	?	Cu			
163	JY 65-27-502	Bertrand	1939	6,503	?	?	?	?		?	?	?	?			
164	JY 65-27-503	R.J. Ranson	old	95	?	?	?	?		UN.	?	?	Cu			
165	JY 65-27-504	Plantation MUD	1978	809	114	1978	136	1987		PUB.	1,000	45	C	22	9	2.444
166	JY 65-27-505	Plantation MUD	1980	840	150	1980	?	?		PUB.	1,000	67	C/E			
167	JY 65-27-803	TX Ea. Trans. Corp	1955	614	62	1955	?	?		IND.	75	14	CI			
168	JY 65-28-601	Phillips Petr. Co	1929	297	31	1938	41	1947	(disc.)	UN.	?	?	CI	10	9	1.111
169	JY 65-28-603	Quail Valley MUD	1972	1,077	180	1972	?	?		PUB.	1,500	41	E			
170	JY 65-28-803	Christianson & Matthews	1946	420	21	1947	90	1987		IND.	75	?	CI	69.1	40	1.728
171	JY 65-28-804	Scanlon Estate	?	418	19	1947	?	?		UN.	?	?	CI			
172	JY 65-28-805	So. Tex.Water Co.	1944	505	14	1947	?	?		IND.	?	?	CI			
173	JY 65-28-806	So. Tex.Water Co.	1935	498	14	1947	?	?		UN.	?	?	CI			
174	JY 65-28-807	William A. Smith	1958	291	64	1958	?	?		DOM.	200	28	CI			
175	JY 65-28-808	Hurricane Steel	1970	560	110	1970	?	?		DOM.	?	?	C			
176	JY 65-28-901	Fred Johnson	1956	225	58	1969	?	?		UN.	?	?	C			
177	JY 65-28-902	Waterbrook	1979	72	4	1979	?	?		PUB.	200	?	C			
178	JY 65-28-903	Senior, Bill	1980	80	8	1980	?	?		IRR.	250	?	C			

APPENDIX B

ACQUISITION OF BRAZOS RIVER AUTHORITY CANAL DIVISION
BY
GALVESTON COUNTY WATER AUTHORITY

The Galveston County Water Authority welcomes the opportunity to discuss with you its acquisition of the Brazos River Authority Canal Division. We view this as an opportunity to develop the water resources for the benefit of Brazoria, Ft. Bend, and Galveston Counties for the economic growth of each one.

Before discussing this matter further, I will introduce the members of our board of directors. These are the gentlemen who are responsible for the growth of the Authority and have the vision to help the tri-county area develop its full potential.

[Introduce those board members present.]

Mr. Carson Hoge has given you the prospectives of the transaction from the view of the Seller. The Authority has had a long and harmonious relationship with the B.R.A. Without their concern for beneficial use of water within the Brazos River basin, the tri-county area would not have grown as it has. Many dollars have been saved by flood control measures. The monitoring of the water entering the river assures a high quality water readily available for our use. Their operation of the canal division has assured each of their customers an adequate water supply when it is needed. We thank them for a job well done and look forward to our mutual cooperation in the future.

The B.R.A. has now decided to divest themselves of the Canal Division. The G.C.W.A. will acquire the assets of the Canal Division and maintain and operate them for the benefit of the tri-county area.

It is a concern of the tri-county area as to how the regional canal system will function under the G.C.W.A.

First and foremost, there will not be any change of personnel. The present employee staff headed by Gene Shannon, Canal Division General Manager, will remain in their present positions. All of these employees are well acquainted with these canals and will continue to operate them in the same manner.

Second, all existing water supply contracts will be honored.

Third, the G.C.W.A. is interested in serving the entire tri-county area on a fair and equitable basis and will sell additional water.

There are water right permits associated with the canal system which total about 212 million gallons per day. Some of that water, about 135 million, is presently under contract, leaving about 77 million gallons per day available for new customers. The G.C.W.A. is interested in selling this water.

The G.C.W.A. is presently negotiating contract amendments with its existing customers to reflect the acquisition of the canal division.

The G.C.W.A. operates its system based upon take or pay contracts. All customers receiving like service have the same contract and pay their pro rata costs based upon these contracts. The G.C.W.A. will operate the canal system in a like manner. The G.C.W.A., as stated previously, will honor the existing water supply contracts and their terms but will contact these customers to see if they would desire to convert to the G.C.W.A. Contracts.

The cost of water is determined by the yearly budget and the contract quantity. The budget is prepared to reflect the cost of operating the canal system including items such as bond payments, lease payment, water cost, maintenance, operation and administrative costs. This total is divided by the total contract water quantity to determine the unit cost of water. Each customer then pays based upon their contract water. The more water sold, the less the unit cost.

The G.C.W.A. will also sell water on year to year contracts. The cost of this water will not be less than what is charged water contract customers. Policy, yet to be determined, will probably be drawn such that it will be more than the water contract price. We anticipate this to be water for irrigation and spot sales.

Based upon preliminary maintenance and operating costs and water contract quantities, the cost of water is estimated to cost between 9.5 and 11.5 cents per thousand gallons. The G.C.W.A. is negotiating for water contracts with existing customers and working to develop 1989 budgets. Once the quantities are known, the cost of water can be determined.

There is considerable amount of work to be done before this transaction is completed. We are working daily on the matter and we have scheduled the closing date to be July 20, 1988.

I have with me the General Manger and consultants of the G.C.W.A.

[Introduce: J. A. Willhelm, Guy Furgiuele,
J. Marvin Moreland, Jr.,
Chas. B. Smith, Bill Walsh,
and Clifford W. Youngblood]

These gentlemen will assist me in answering any questions you may have regarding the purchase of the Brazos River Authority Canal Division by the G.C.W.A. to form the Tri-county Regional Canal System and/or the G.C.W.A. in general. A brief history of the G.C.W.A. is also available to you for more information. The G.C.W.A. looks forward to a long and fruitful relationship all along the canal system and we ask your support and cooperation to make this venture a great success.

Thank you and are there any questions?

Surface Water Conversion Plan
Financial Impact on Sugar Land

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
TOTAL WATER DEMAND (MGD)	4.30	4.44	4.58	4.72	4.87	5.01	5.15	5.29	5.44	5.58
SURFACE WATER AVAILABLE (MGD)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.68
ANNUAL WATER COSTS										
RAW WATER COST	$0	$0	$0	$0	$0	$0	$0	$0	$0	$238,418
TREATMENT COST	0	0	0	0	0	0	0	0	0	1,120,185
SYSTEM MAINTENANCE COST	0	0	0	0	0	0	0	0	0	2,981
G/W PUMPING COST REDUCTION	0	0	0	0	0	0	0	0	0	(407,340)
G/W MAINTENANCE COST REDUCTION	0	0	0	0	0	0	0	0	0	(30,551)
TOTAL ANNUAL WATER COST	$0	$0	$0	$0	$0	$0	$0	$0	$0	$923,694
ANNUAL CAPITAL COSTS										
WELLS	$0	$0	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568
SURFACE WATER PLANT	0	0	0	0	0	0	0	672,121	672,121	672,121
DISTRIBUTION SYSTEM	0	0	0	0	0	0	0	0	166,689	166,689
TOTAL ANNUAL CAPITAL COST	$0	$0	$40,568	$40,568	$40,568	$40,568	$40,568	$712,688	$879,377	$879,377
TOTAL ANNUAL COST	$0	$0	$40,568	$40,568	$40,568	$40,568	$40,568	$712,688	$879,377	$1,803,071
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.45
CAPITAL COST/KGAL	$0.00	$0.00	$0.02	$0.02	$0.02	$0.02	$0.02	$0.37	$0.44	$0.43
TOTAL COST/KGAL	$0.00	$0.00	$0.02	$0.02	$0.02	$0.02	$0.02	$0.37	$0.44	$0.89
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.05	$0.06	$0.05
WATER COST/KGAL	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.45

JONES & CARTER/PATE ENGINEERS

APPENDIX C

Surface Water Conversion Plan
Financial Impact on Sugar Land

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
TOTAL WATER DEMAND (MGD)	5.71	5.85	5.98	6.11	6.25	6.38	6.51	6.64	6.78	6.91
SURFACE WATER AVAILABLE (MGD)	5.68	5.68	5.68	5.68	5.68	5.68	5.68	5.68	5.68	5.68
ANNUAL WATER COSTS										
RAW WATER COST	$238,418	$238,418	$238,418	$238,418	$238,418	$238,418	$238,418	$238,418	$238,418	$238,418
TREATMENT COST	1,140,260	1,140,260	1,140,260	1,140,260	1,140,260	1,140,260	1,140,260	1,140,260	1,140,260	1,140,260
SYSTEM MAINTENANCE COST	2,981	2,981	2,981	2,981	2,981	2,981	2,981	2,981	2,981	2,981
G/W PUMPING COST REDUCTION	(414,640)	(414,640)	(414,640)	(414,640)	(414,640)	(414,640)	(414,640)	(414,640)	(414,640)	(414,640)
G/W MAINTENANCE COST REDUCTION	(31,098)	(31,098)	(31,098)	(31,098)	(31,098)	(31,098)	(31,098)	(31,098)	(31,098)	(31,098)
TOTAL ANNUAL WATER COST	$935,921	$935,921	$935,921	$935,921	$935,921	$935,921	$935,921	$935,921	$935,921	$935,921
ANNUAL CAPITAL COSTS										
WELLS	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568
SURFACE WATER PLANT	672,121	672,121	672,121	672,121	672,121	672,121	672,121	672,121	672,121	672,121
DISTRIBUTION SYSTEM	166,689	166,689	166,689	166,689	166,689	166,689	166,689	166,689	166,689	166,689
TOTAL ANNUAL CAPITAL COST	$879,377	$879,377	$879,377	$879,377	$879,377	$879,377	$879,377	$879,377	$879,377	$879,377
TOTAL ANNUAL COST	$1,815,299	$1,815,299	$1,815,299	$1,815,299	$1,815,299	$1,815,299	$1,815,299	$1,815,299	$1,815,299	$1,815,299
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.45	$0.44	$0.43	$0.42	$0.41	$0.40	$0.39	$0.39	$0.38	$0.37
CAPITAL COST/KGAL	$0.42	$0.41	$0.40	$0.39	$0.39	$0.38	$0.37	$0.36	$0.36	$0.35
TOTAL COST/KGAL	$0.87	$0.85	$0.83	$0.81	$0.80	$0.78	$0.76	$0.75	$0.73	$0.72
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05	$0.04	$0.04
WATER COST/KGAL	$0.45	$0.44	$0.43	$0.42	$0.41	$0.40	$0.39	$0.39	$0.38	$0.37

Surface Water Conversion Plan
Financial Impact on Sugar Land

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
TOTAL WATER DEMAND (MGD)	7.04	7.18	7.31	7.44	7.58	7.71	7.84	7.97	8.11	8.24
SURFACE WATER AVAILABLE (MGD)	5.68	5.68	5.68	5.68	5.68	5.68	5.68	5.68	5.68	7.73
ANNUAL WATER COSTS										
RAW WATER COST	$238,418	$238,418	$238,418	$238,418	$238,418	$238,418	$238,418	$238,418	$238,418	$324,467
TREATMENT COST	1,140,260	1,140,260	1,140,260	1,140,260	1,140,260	1,140,260	1,140,260	1,140,260	1,140,260	1,551,798
SYSTEM MAINTENANCE COST	2,981	2,981	2,981	2,981	2,981	2,981	2,981	2,981	2,981	2,981
G/W PUMPING COST REDUCTION	(414,640)	(414,640)	(414,640)	(414,640)	(414,640)	(414,640)	(414,640)	(414,640)	(414,640)	(564,290)
G/W MAINTENANCE COST REDUCTION	(31,098)	(31,098)	(31,098)	(31,098)	(31,098)	(31,098)	(31,098)	(31,098)	(31,098)	(42,322)
TOTAL ANNUAL WATER COST	$935,921	$935,921	$935,921	$935,921	$935,921	$935,921	$935,921	$935,921	$935,921	$1,272,634
ANNUAL CAPITAL COSTS										
WELLS	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568	$0	$0	$0
SURFACE WATER PLANT	672,121	672,121	672,121	672,121	672,121	672,121	672,121	914,699	914,699	914,699
DISTRIBUTION SYSTEM	166,689	166,689	166,689	166,689	166,689	166,689	166,689	166,689	166,689	166,689
TOTAL ANNUAL CAPITAL COST	$879,377	$879,377	$879,377	$879,377	$879,377	$879,377	$879,377	$1,081,388	$1,081,388	$1,081,388
TOTAL ANNUAL COST	$1,815,299	$1,815,299	$1,815,299	$1,815,299	$1,815,299	$1,815,299	$1,815,299	$2,017,310	$2,017,310	$2,354,022

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.36	$0.36	$0.35	$0.34	$0.34	$0.33	$0.33	$0.32	$0.32	$0.42
CAPITAL COST/KGAL	$0.34	$0.34	$0.33	$0.32	$0.32	$0.31	$0.31	$0.37	$0.37	$0.36
TOTAL COST/KGAL	$0.71	$0.69	$0.68	$0.67	$0.66	$0.65	$0.63	$0.69	$0.68	$0.78
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04	$0.05	$0.05	$0.04
WATER COST/KGAL	$0.36	$0.36	$0.35	$0.34	$0.34	$0.33	$0.33	$0.32	$0.32	$0.42

Surface Water Conversion Plan
Financial Impact on Sugar Land

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
TOTAL WATER DEMAND (MGD)	8.37	8.51	8.64	8.77	8.91	9.04	9.17	9.30	9.44	9.57
SURFACE WATER AVAILABLE (MGD)	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73
ANNUAL WATER COSTS										
RAW WATER COST	$324,467	$324,467	$324,467	$324,467	$324,467	$324,467	$324,467	$324,467	$324,467	$324,467
TREATMENT COST	1,551,798	1,551,798	1,551,798	1,551,798	1,551,798	1,551,798	1,551,798	1,551,798	1,551,798	1,551,798
SYSTEM MAINTENANCE COST	2,981	2,981	2,981	2,981	2,981	2,981	2,981	2,981	2,981	2,981
G/W PUMPING COST REDUCTION	(564,290)	(564,290)	(564,290)	(564,290)	(564,290)	(564,290)	(564,290)	(564,290)	(564,290)	(564,290)
G/W MAINTENANCE COST REDUCTION	(42,322)	(42,322)	(42,322)	(42,322)	(42,322)	(42,322)	(42,322)	(42,322)	(42,322)	(42,322)
TOTAL ANNUAL WATER COST	$1,272,634	$1,272,634	$1,272,634	$1,272,634	$1,272,634	$1,272,634	$1,272,634	$1,272,634	$1,272,634	$1,272,634
ANNUAL CAPITAL COSTS										
WELLS	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
SURFACE WATER PLANT	914,699	914,699	242,579	242,579	242,579	242,579	242,579	242,579	242,579	242,579
DISTRIBUTION SYSTEM	166,689	166,689	166,689	0	0	0	0	0	0	0
TOTAL ANNUAL CAPITAL COST	$1,081,388	$1,081,388	$409,268	$242,579	$242,579	$242,579	$242,579	$242,579	$242,579	$242,579
TOTAL ANNUAL COST	$2,354,022	$2,354,022	$1,681,901	$1,515,212	$1,515,212	$1,515,212	$1,515,212	$1,515,212	$1,515,212	$1,515,212
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.42	$0.41	$0.40	$0.40	$0.39	$0.39	$0.38	$0.37	$0.37	$0.36
CAPITAL COST/KGAL	$0.35	$0.35	$0.13	$0.08	$0.07	$0.07	$0.07	$0.07	$0.07	$0.07
TOTAL COST/KGAL	$0.77	$0.76	$0.53	$0.47	$0.47	$0.46	$0.45	$0.45	$0.44	$0.43
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.04	$0.04	$0.02	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
WATER COST/KGAL	$0.42	$0.41	$0.40	$0.40	$0.39	$0.39	$0.38	$0.37	$0.37	$0.36

Surface Water Conversion Plan
Financial Impact on WC&ID No. 2

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
TOTAL WATER DEMAND (MGD)	3.68	3.91	4.15	4.38	4.62	4.86	5.09	5.33	5.56	5.80
SURFACE WATER AVAILABLE (MGD)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.90
ANNUAL WATER COSTS										
RAW WATER COST	$0	$0	$0	$0	$0	$0	$0	$0	$0	$247,653
TREATMENT COST	0	0	0	0	0	0	0	0	0	1,164,350
SYSTEM MAINTENANCE COST	0	0	0	0	0	0	0	0	0	3,576
G/W PUMPING COST REDUCTION	0	0	0	0	0	0	0	0	0	(423,400)
G/W MAINTENANCE COST REDUCTION	0	0	0	0	0	0	0	0	0	(31,755)
TOTAL ANNUAL WATER COST	$0	$0	$0	$0	$0	$0	$0	$0	$0	$960,423
ANNUAL CAPITAL COSTS										
WELLS	$81,136	$81,136	$81,136	$81,136	$121,704	$121,704	$121,704	$121,704	$121,704	$121,704
SURFACE WATER PLANT	0	0	0	0	0	0	0	698,153	698,153	698,153
DISTRIBUTION SYSTEM	0	0	0	0	0	0	0	0	144,255	144,255
TOTAL ANNUAL CAPITAL COST	$81,136	$81,136	$81,136	$81,136	$121,704	$121,704	$121,704	$819,857	$964,112	$964,112
TOTAL ANNUAL COST	$81,136	$81,136	$81,136	$81,136	$121,704	$121,704	$121,704	$819,857	$964,112	$1,924,536
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.45
CAPITAL COST/KGAL	$0.06	$0.06	$0.05	$0.05	$0.07	$0.07	$0.07	$0.42	$0.47	$0.46
TOTAL COST/KGAL	$0.06	$0.06	$0.05	$0.05	$0.07	$0.07	$0.07	$0.42	$0.47	$0.91
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.06	$0.06	$0.06
WATER COST/KGAL	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.45

Surface Water Conversion Plan
Financial Impact on WC&ID No. 2

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
TOTAL WATER DEMAND (MGD)	5.97	6.14	6.30	6.47	6.64	6.81	6.98	7.14	7.31	7.48
SURFACE WATER AVAILABLE (MGD)	5.90	5.90	5.90	5.90	5.90	5.90	5.90	5.90	5.90	5.90
ANNUAL WATER COSTS										
RAW WATER COST	$247,653	$247,653	$247,653	$247,653	$247,653	$247,653	$247,653	$247,653	$247,653	$247,653
TREATMENT COST	1,184,425	1,184,425	1,184,425	1,184,425	1,184,425	1,184,425	1,184,425	1,184,425	1,184,425	1,184,425
SYSTEM MAINTENANCE COST	3,576	3,576	3,576	3,576	3,576	3,576	3,576	3,576	3,576	3,576
G/W PUMPING COST REDUCTION	(430,700)	(430,700)	(430,700)	(430,700)	(430,700)	(430,700)	(430,700)	(430,700)	(430,700)	(430,700)
G/W MAINTENANCE COST REDUCTION	(32,303)	(32,303)	(32,303)	(32,303)	(32,303)	(32,303)	(32,303)	(32,303)	(32,303)	(32,303)
TOTAL ANNUAL WATER COST	$972,651	$972,651	$972,651	$972,651	$972,651	$972,651	$972,651	$972,651	$972,651	$972,651
ANNUAL CAPITAL COSTS										
WELLS	$121,704	$121,704	$121,704	$121,704	$121,704	$121,704	$121,704	$121,704	$121,704	$121,704
SURFACE WATER PLANT	698,153	698,153	698,153	698,153	698,153	698,153	698,153	698,153	698,153	698,153
DISTRIBUTION SYSTEM	144,255	144,255	144,255	144,255	144,255	144,255	144,255	144,255	144,255	144,255
TOTAL ANNUAL CAPITAL COST	$964,112	$964,112	$964,112	$964,112	$964,112	$964,112	$964,112	$964,112	$964,112	$964,112
TOTAL ANNUAL COST	$1,936,763	$1,936,763	$1,936,763	$1,936,763	$1,936,763	$1,936,763	$1,936,763	$1,936,763	$1,936,763	$1,936,763
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.45	$0.43	$0.42	$0.41	$0.40	$0.39	$0.38	$0.37	$0.36	$0.36
CAPITAL COST/KGAL	$0.44	$0.43	$0.42	$0.41	$0.40	$0.39	$0.38	$0.37	$0.36	$0.35
TOTAL COST/KGAL	$0.89	$0.86	$0.84	$0.82	$0.80	$0.78	$0.76	$0.74	$0.73	$0.71
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.06	$0.06	$0.06	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05
WATER COST/KGAL	$0.45	$0.43	$0.42	$0.41	$0.40	$0.39	$0.38	$0.37	$0.36	$0.36

Surface Water Conversion Plan
Financial Impact on WC&ID No. 2

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
TOTAL WATER DEMAND (MGD)	7.65	7.82	7.98	8.15	8.32	8.49	8.66	8.82	8.99	9.16
SURFACE WATER AVAILABLE (MGD)	5.90	5.90	5.90	5.90	5.90	5.90	5.90	5.90	5.90	8.60
ANNUAL WATER COSTS										
RAW WATER COST	$247,653	$247,653	$247,653	$247,653	$247,653	$247,653	$247,653	$247,653	$247,653	$360,985
TREATMENT COST	1,184,425	1,184,425	1,184,425	1,184,425	1,184,425	1,184,425	1,184,425	1,184,425	1,184,425	1,726,450
SYSTEM MAINTENANCE COST	3,576	3,576	3,576	3,576	3,576	3,576	3,576	3,576	3,576	3,576
G/W PUMPING COST REDUCTION	(430,700)	(430,700)	(430,700)	(430,700)	(430,700)	(430,700)	(430,700)	(430,700)	(430,700)	(627,800)
G/W MAINTENANCE COST REDUCTION	(32,303)	(32,303)	(32,303)	(32,303)	(32,303)	(32,303)	(32,303)	(32,303)	(32,303)	(47,085)
TOTAL ANNUAL WATER COST	$972,651	$972,651	$972,651	$972,651	$972,651	$972,651	$972,651	$972,651	$972,651	$1,416,126
ANNUAL CAPITAL COSTS										
WELLS	$121,704	$121,704	$81,136	$81,136	$81,136	$40,568	$40,568	$40,568	$40,568	$0
SURFACE WATER PLANT	698,153	698,153	698,153	698,153	698,153	698,153	698,153	1,017,647	1,017,647	1,017,647
DISTRIBUTION SYSTEM	144,255	144,255	144,255	144,255	144,255	144,255	144,255	144,255	144,255	144,255
TOTAL ANNUAL CAPITAL COST	$964,112	$964,112	$923,545	$923,545	$923,545	$882,977	$882,977	$1,202,471	$1,202,471	$1,161,903
TOTAL ANNUAL COST	$1,936,763	$1,936,763	$1,896,195	$1,896,195	$1,896,195	$1,855,627	$1,855,627	$2,175,121	$2,175,121	$2,578,029
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.35	$0.34	$0.33	$0.33	$0.32	$0.31	$0.31	$0.30	$0.30	$0.42
CAPITAL COST/KGAL	$0.35	$0.34	$0.32	$0.31	$0.30	$0.29	$0.28	$0.37	$0.37	$0.35
TOTAL COST/KGAL	$0.69	$0.68	$0.65	$0.64	$0.62	$0.60	$0.59	$0.68	$0.66	$0.77
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.05	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04	$0.05	$0.05	$0.05
WATER COST/KGAL	$0.35	$0.34	$0.33	$0.33	$0.32	$0.31	$0.31	$0.30	$0.30	$0.42

JONES & CARTER/PATE ENGINEERS

Surface Water Conversion Plan
Financial Impact on WC&ID No. 2

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
TOTAL WATER DEMAND (MGD)	9.33	9.50	9.66	9.83	10.00	10.17	10.34	10.50	10.67	10.84
SURFACE WATER AVAILABLE (MGD)	8.60	8.60	8.60	8.60	8.60	8.60	8.60	8.60	8.60	8.60
ANNUAL WATER COSTS										
RAW WATER COST	$360,985	$360,985	$360,985	$360,985	$360,985	$360,985	$360,985	$360,985	$360,985	$360,985
TREATMENT COST	1,726,450	1,726,450	1,726,450	1,726,450	1,726,450	1,726,450	1,726,450	1,726,450	1,726,450	1,726,450
SYSTEM MAINTENANCE COST	3,576	3,576	3,576	3,576	3,576	3,576	3,576	3,576	3,576	3,576
G/W PUMPING COST REDUCTION	(627,800)	(627,800)	(627,800)	(627,800)	(627,800)	(627,800)	(627,800)	(627,800)	(627,800)	(627,800)
G/W MAINTENANCE COST REDUCTION	(47,085)	(47,085)	(47,085)	(47,085)	(47,085)	(47,085)	(47,085)	(47,085)	(47,085)	(47,085)
TOTAL ANNUAL WATER COST	$1,416,126	$1,416,126	$1,416,126	$1,416,126	$1,416,126	$1,416,126	$1,416,126	$1,416,126	$1,416,126	$1,416,126
ANNUAL CAPITAL COSTS										
WELLS	$0	$0	$0	$0	$0	$0	$40,568	$40,568	$40,568	$40,568
SURFACE WATER PLANT	1,017,647	1,017,647	319,494	319,494	319,494	319,494	319,494	319,494	319,494	319,494
DISTRIBUTION SYSTEM	144,255	144,255	144,255	0	0	0	0	0	0	0
TOTAL ANNUAL CAPITAL COST	$1,161,903	$1,161,903	$463,749	$319,494	$319,494	$319,494	$360,062	$360,062	$360,062	$360,062
TOTAL ANNUAL COST	$2,578,029	$2,578,029	$1,879,875	$1,735,620	$1,735,620	$1,735,620	$1,776,187	$1,776,187	$1,776,187	$1,776,187
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.42	$0.41	$0.40	$0.39	$0.39	$0.38	$0.38	$0.37	$0.36	$0.36
CAPITAL COST/KGAL	$0.34	$0.34	$0.13	$0.09	$0.09	$0.09	$0.10	$0.09	$0.09	$0.09
TOTAL COST/KGAL	$0.76	$0.74	$0.53	$0.48	$0.48	$0.47	$0.47	$0.46	$0.46	$0.45
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.05	$0.04	$0.02	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
WATER COST/KGAL	$0.42	$0.41	$0.40	$0.39	$0.39	$0.38	$0.38	$0.37	$0.36	$0.36

JONES & CARTER/PATE ENGINEERS

Surface Water Conversion Plan
Financial Impact on First Colony

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
TOTAL WATER DEMAND (MGD)	3.03	3.18	3.32	3.47	3.61	3.76	3.90	4.05	4.19	4.34
SURFACE WATER AVAILABLE (MGD)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.42
ANNUAL WATER COSTS										
RAW WATER COST	$0	$0	$0	$0	$0	$0	$0	$0	$0	$185,530
TREATMENT COST	0	0	0	0	0	0	0	0	0	871,255
SYSTEM MAINTENANCE COST	0	0	0	0	0	0	0	0	0	3,608
G/W PUMPING COST REDUCTION	0	0	0	0	0	0	0	0	0	(316,820)
G/W MAINTENANCE COST REDUCTION	0	0	0	0	0	0	0	0	0	(23,762)
TOTAL ANNUAL WATER COST	$0	$0	$0	$0	$0	$0	$0	$0	$0	$719,811
ANNUAL CAPITAL COSTS										
WELLS	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
SURFACE WATER PLANT	0	0	0	0	0	0	0	523,023	523,023	523,023
DISTRIBUTION SYSTEM	0	0	0	0	0	0	0	0	182,792	182,792
TOTAL ANNUAL CAPITAL COST	$0	$0	$0	$0	$0	$0	$0	$523,023	$705,815	$705,815
TOTAL ANNUAL COST	$0	$0	$0	$0	$0	$0	$0	$523,023	$705,815	$1,425,626
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.45
CAPITAL COST/KGAL	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.35	$0.46	$0.45
TOTAL COST/KGAL	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.35	$0.46	$0.90
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.05	$0.06	$0.06
WATER COST/KGAL	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.45

Surface Water Conversion Plan
Financial Impact on First Colony

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
TOTAL WATER DEMAND (MGD)	4.53	4.72	4.91	5.11	5.30	5.49	5.68	5.87	6.06	6.25
SURFACE WATER AVAILABLE (MGD)	4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42
ANNUAL WATER COSTS										
RAW WATER COST	$185,530	$185,530	$185,530	$185,530	$185,530	$185,530	$185,530	$185,530	$185,530	$185,530
TREATMENT COST	887,315	887,315	887,315	887,315	887,315	887,315	887,315	887,315	887,315	887,315
SYSTEM MAINTENANCE COST	3,608	3,608	3,608	3,608	3,608	3,608	3,608	3,608	3,608	3,608
G/W PUMPING COST REDUCTION	(322,660)	(322,660)	(322,660)	(322,660)	(322,660)	(322,660)	(322,660)	(322,660)	(322,660)	(322,660)
G/W MAINTENANCE COST REDUCTION	(24,200)	(24,200)	(24,200)	(24,200)	(24,200)	(24,200)	(24,200)	(24,200)	(24,200)	(24,200)
TOTAL ANNUAL WATER COST	$729,593	$729,593	$729,593	$729,593	$729,593	$729,593	$729,593	$729,593	$729,593	$729,593
ANNUAL CAPITAL COSTS										
WELLS	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
SURFACE WATER PLANT	523,023	523,023	523,023	523,023	523,023	523,023	523,023	523,023	523,023	523,023
DISTRIBUTION SYSTEM	182,792	182,792	182,792	182,792	182,792	182,792	182,792	182,792	182,792	182,792
TOTAL ANNUAL CAPITAL COST	$705,815	$705,815	$705,815	$705,815	$705,815	$705,815	$705,815	$705,815	$705,815	$705,815
TOTAL ANNUAL COST	$1,435,408	$1,435,408	$1,435,408	$1,435,408	$1,435,408	$1,435,408	$1,435,408	$1,435,408	$1,435,408	$1,435,408
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.44	$0.42	$0.41	$0.39	$0.38	$0.36	$0.35	$0.34	$0.33	$0.32
CAPITAL COST/KGAL	$0.43	$0.41	$0.39	$0.38	$0.37	$0.35	$0.34	$0.33	$0.32	$0.31
TOTAL COST/KGAL	$0.87	$0.83	$0.80	$0.77	$0.74	$0.72	$0.69	$0.67	$0.65	$0.63
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.06	$0.05	$0.05	$0.05	$0.05	$0.05	$0.04	$0.04	$0.04	$0.04
WATER COST/KGAL	$0.44	$0.42	$0.41	$0.39	$0.38	$0.36	$0.35	$0.34	$0.33	$0.32

Surface Water Conversion Plan
Financial Impact on First Colony

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
TOTAL WATER DEMAND (MGD)	6.44	6.64	6.83	7.02	7.21	7.40	7.59	7.78	7.98	8.17
SURFACE WATER AVAILABLE (MGD)	4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42	7.67
ANNUAL WATER COSTS										
RAW WATER COST	$185,530	$185,530	$185,530	$185,530	$185,530	$185,530	$185,530	$185,530	$185,530	$321,948
TREATMENT COST	887,315	887,315	887,315	887,315	887,315	887,315	887,315	887,315	887,315	1,539,753
SYSTEM MAINTENANCE COST	3,608	3,608	3,608	3,608	3,608	3,608	3,608	3,608	3,608	3,608
G/W PUMPING COST REDUCTION	(322,660)	(322,660)	(322,660)	(322,660)	(322,660)	(322,660)	(322,660)	(322,660)	(322,660)	(559,910)
G/W MAINTENANCE COST REDUCTION	(24,200)	(24,200)	(24,200)	(24,200)	(24,200)	(24,200)	(24,200)	(24,200)	(24,200)	(41,993)
TOTAL ANNUAL WATER COST	$729,593	$729,593	$729,593	$729,593	$729,593	$729,593	$729,593	$729,593	$729,593	$1,263,405
ANNUAL CAPITAL COSTS										
WELLS	$40,568	$40,568	$40,568	$40,568	$40,568	$81,136	$81,136	$81,136	$81,136	$81,136
SURFACE WATER PLANT	523,023	523,023	523,023	523,023	523,023	523,023	523,023	907,599	907,599	907,599
DISTRIBUTION SYSTEM	182,792	182,792	182,792	182,792	182,792	182,792	182,792	182,792	182,792	182,792
TOTAL ANNUAL CAPITAL COST	$746,383	$746,383	$746,383	$746,383	$746,383	$786,951	$786,951	$1,171,527	$1,171,527	$1,171,527
TOTAL ANNUAL COST	$1,475,976	$1,475,976	$1,475,976	$1,475,976	$1,475,976	$1,516,544	$1,516,544	$1,901,120	$1,901,120	$2,434,933
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.31	$0.30	$0.29	$0.28	$0.28	$0.27	$0.26	$0.26	$0.25	$0.42
CAPITAL COST/KGAL	$0.32	$0.31	$0.30	$0.29	$0.28	$0.29	$0.28	$0.41	$0.40	$0.39
TOTAL COST/KGAL	$0.63	$0.61	$0.59	$0.58	$0.56	$0.56	$0.55	$0.67	$0.65	$0.82
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04	$0.05	$0.05	$0.05
WATER COST/KGAL	$0.31	$0.30	$0.29	$0.28	$0.28	$0.27	$0.26	$0.26	$0.25	$0.42

Surface Water Conversion Plan
Financial Impact on First Colony

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
TOTAL WATER DEMAND (MGD)	8.36	8.55	8.74	8.93	9.12	9.31	9.51	9.70	9.89	10.08
SURFACE WATER AVAILABLE (MGD)	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67
ANNUAL WATER COSTS										
RAW WATER COST	$321,948	$321,948	$321,948	$321,948	$321,948	$321,948	$321,948	$321,948	$321,948	$321,948
TREATMENT COST	1,539,753	1,539,753	1,539,753	1,539,753	1,539,753	1,539,753	1,539,753	1,539,753	1,539,753	1,539,753
SYSTEM MAINTENANCE COST	3,608	3,608	3,608	3,608	3,608	3,608	3,608	3,608	3,608	3,608
G/W PUMPING COST REDUCTION	(559,910)	(559,910)	(559,910)	(559,910)	(559,910)	(559,910)	(559,910)	(559,910)	(559,910)	(559,910)
G/W MAINTENANCE COST REDUCTION	(41,993)	(41,993)	(41,993)	(41,993)	(41,993)	(41,993)	(41,993)	(41,993)	(41,993)	(41,993)
TOTAL ANNUAL WATER COST	$1,263,405	$1,263,405	$1,263,405	$1,263,405	$1,263,405	$1,263,405	$1,263,405	$1,263,405	$1,263,405	$1,263,405
ANNUAL CAPITAL COSTS										
WELLS	$81,136	$81,136	$81,136	$81,136	$81,136	$81,136	$81,136	$81,136	$81,136	$81,136
SURFACE WATER PLANT	907,599	907,599	384,576	384,576	384,576	384,576	384,576	384,576	384,576	384,576
DISTRIBUTION SYSTEM	182,792	182,792	182,792	0	0	0	0	0	0	0
TOTAL ANNUAL CAPITAL COST	$1,171,527	$1,171,527	$648,504	$465,712	$465,712	$465,712	$465,712	$465,712	$465,712	$465,712
TOTAL ANNUAL COST	$2,434,933	$2,434,933	$1,911,909	$1,729,117	$1,729,117	$1,729,117	$1,729,117	$1,729,117	$1,729,117	$1,729,117
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.41	$0.40	$0.40	$0.39	$0.38	$0.37	$0.36	$0.36	$0.35	$0.34
CAPITAL COST/KGAL	$0.38	$0.38	$0.20	$0.14	$0.14	$0.14	$0.13	$0.13	$0.13	$0.13
TOTAL COST/KGAL	$0.80	$0.78	$0.60	$0.53	$0.52	$0.51	$0.50	$0.49	$0.48	$0.47
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.05	$0.05	$0.03	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02
WATER COST/KGAL	$0.41	$0.40	$0.40	$0.39	$0.38	$0.37	$0.36	$0.36	$0.35	$0.34

Surface Water Conversion Plan - WC&ID No. 2 and Sugar Land Only
Financial Impact on Sugar Land

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
TOTAL WATER DEMAND (MGD)	4.30	4.44	4.58	4.72	4.87	5.01	5.15	5.29	5.44	5.58
SURFACE WATER AVAILABLE (MGD)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.88
ANNUAL WATER COSTS										
RAW WATER COST	$0	$0	$0	$0	$0	$0	$0	$0	$0	$246,813
TREATMENT COST	0	0	0	0	0	0	0	0	0	1,120,185
SYSTEM MAINTENANCE COST	0	0	0	0	0	0	0	0	0	2,981
G/W PUMPING COST REDUCTION	0	0	0	0	0	0	0	0	0	(407,340)
G/W MAINTENANCE COST REDUCTION	0	0	0	0	0	0	0	0	0	(30,551)
TOTAL ANNUAL WATER COST	$0	$0	$0	$0	$0	$0	$0	$0	$0	$932,089
ANNUAL CAPITAL COSTS										
WELLS	$0	$0	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568
SURFACE WATER PLANT	0	0	0	0	0	0	0	695,787	695,787	695,787
DISTRIBUTION SYSTEM	0	0	0	0	0	0	0	0	166,689	166,689
TOTAL ANNUAL CAPITAL COST	$0	$0	$40,568	$40,568	$40,568	$40,568	$40,568	$736,355	$903,044	$903,044
TOTAL ANNUAL COST	$0	$0	$40,568	$40,568	$40,568	$40,568	$40,568	$736,355	$903,044	$1,835,132
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.46
CAPITAL COST/KGAL	$0.00	$0.00	$0.02	$0.02	$0.02	$0.02	$0.02	$0.38	$0.46	$0.44
TOTAL COST/KGAL	$0.00	$0.00	$0.02	$0.02	$0.02	$0.02	$0.02	$0.38	$0.46	$0.90
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.05	$0.06	$0.06
WATER COST/KGAL	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.46

JONES & CARTER/PATE ENGINEERS

Surface Water Conversion Plan - WC&ID No. 2 and Sugar Land Only
Financial Impact on Sugar Land

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
TOTAL WATER DEMAND (MGD)	5.71	5.85	5.98	6.11	6.25	6.38	6.51	6.64	6.78	6.91
SURFACE WATER AVAILABLE (MGD)	5.88	5.88	5.88	5.88	5.88	5.88	5.88	5.88	5.88	5.88
ANNUAL WATER COSTS										
RAW WATER COST	$246,813	$246,813	$246,813	$246,813	$246,813	$246,813	$246,813	$246,813	$246,813	$246,813
TREATMENT COST	1,146,885	1,173,585	1,180,410	1,180,410	1,180,410	1,180,410	1,180,410	1,180,410	1,180,410	1,180,410
SYSTEM MAINTENANCE COST	2,981	2,981	2,981	2,981	2,981	2,981	2,981	2,981	2,981	2,981
G/W PUMPING COST REDUCTION	(417,049)	(426,758)	(429,240)	(429,240)	(429,240)	(429,240)	(429,240)	(429,240)	(429,240)	(429,240)
G/W MAINTENANCE COST REDUCTION	(31,279)	(32,007)	(32,193)	(32,193)	(32,193)	(32,193)	(32,193)	(32,193)	(32,193)	(32,193)
TOTAL ANNUAL WATER COST	$948,351	$964,614	$968,771	$968,771	$968,771	$968,771	$968,771	$968,771	$968,771	$968,771
ANNUAL CAPITAL COSTS										
WELLS	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568
SURFACE WATER PLANT	695,787	695,787	695,787	695,787	695,787	695,787	695,787	695,787	695,787	695,787
DISTRIBUTION SYSTEM	166,689	166,689	166,689	166,689	166,689	166,689	166,689	166,689	166,689	166,689
TOTAL ANNUAL CAPITAL COST	$903,044	$903,044	$903,044	$903,044	$903,044	$903,044	$903,044	$903,044	$903,044	$903,044
TOTAL ANNUAL COST	$1,851,395	$1,867,657	$1,871,815	$1,871,815	$1,871,815	$1,871,815	$1,871,815	$1,871,815	$1,871,815	$1,871,815
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.45	$0.45	$0.44	$0.43	$0.43	$0.42	$0.41	$0.40	$0.39	$0.38
CAPITAL COST/KGAL	$0.43	$0.42	$0.41	$0.40	$0.40	$0.39	$0.38	$0.37	$0.37	$0.36
TOTAL COST/KGAL	$0.89	$0.88	$0.86	$0.84	$0.82	$0.80	$0.79	$0.77	$0.76	$0.74
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05	$0.04
WATER COST/KGAL	$0.45	$0.45	$0.44	$0.43	$0.43	$0.42	$0.41	$0.40	$0.39	$0.38

Surface Water Conversion Plan - WC&ID No. 2 and Sugar Land Only
Financial Impact on Sugar Land

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
TOTAL WATER DEMAND (MGD)	7.04	7.18	7.31	7.44	7.58	7.71	7.84	7.97	8.11	8.24
SURFACE WATER AVAILABLE (MGD)	5.88	5.88	5.88	5.88	5.88	5.88	5.88	5.88	5.88	8.52
ANNUAL WATER COSTS										
RAW WATER COST	$246,813	$246,813	$246,813	$246,813	$246,813	$246,813	$246,813	$246,813	$246,813	$357,627
TREATMENT COST	1,180,410	1,180,410	1,180,410	1,180,410	1,180,410	1,180,410	1,180,410	1,180,410	1,180,410	1,654,180
SYSTEM MAINTENANCE COST	2,981	2,981	2,981	2,981	2,981	2,981	2,981	2,981	2,981	2,981
G/W PUMPING COST REDUCTION	(429,240)	(429,240)	(429,240)	(429,240)	(429,240)	(429,240)	(429,240)	(429,240)	(429,240)	(601,520)
G/W MAINTENANCE COST REDUCTION	(32,193)	(32,193)	(32,193)	(32,193)	(32,193)	(32,193)	(32,193)	(32,193)	(32,193)	(45,114)
TOTAL ANNUAL WATER COST	$968,771	$968,771	$968,771	$968,771	$968,771	$968,771	$968,771	$968,771	$968,771	$1,368,154
ANNUAL CAPITAL COSTS										
WELLS	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568	$40,568	$0	$0	$0
SURFACE WATER PLANT	695,787	695,787	695,787	695,787	695,787	695,787	695,787	1,008,181	1,008,181	1,008,181
DISTRIBUTION SYSTEM	166,689	166,689	166,689	166,689	166,689	166,689	166,689	166,689	166,689	166,689
TOTAL ANNUAL CAPITAL COST	$903,044	$903,044	$903,044	$903,044	$903,044	$903,044	$903,044	$1,174,870	$1,174,870	$1,174,870
TOTAL ANNUAL COST	$1,871,815	$1,871,815	$1,871,815	$1,871,815	$1,871,815	$1,871,815	$1,871,815	$2,143,641	$2,143,641	$2,543,024
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.38	$0.37	$0.36	$0.36	$0.35	$0.34	$0.34	$0.33	$0.33	$0.45
CAPITAL COST/KGAL	$0.35	$0.34	$0.34	$0.33	$0.33	$0.32	$0.32	$0.40	$0.40	$0.39
TOTAL COST/KGAL	$0.73	$0.71	$0.70	$0.69	$0.68	$0.67	$0.65	$0.74	$0.72	$0.85
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04	$0.05	$0.05	$0.05
WATER COST/KGAL	$0.38	$0.37	$0.36	$0.36	$0.35	$0.34	$0.34	$0.33	$0.33	$0.45

JONES & CARTER/PATE ENGINEERS

Surface Water Conversion Plan - WC&ID No. 2 and Sugar Land Only
Financial Impact on Sugar Land

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
TOTAL WATER DEMAND (MGD)	8.37	8.51	8.64	8.77	8.91	9.04	9.17	9.30	9.44	9.57
SURFACE WATER AVAILABLE (MGD)	8.52	8.52	8.52	8.52	8.52	8.52	8.52	8.52	8.52	8.52
ANNUAL WATER COSTS										
RAW WATER COST	$357,627	$357,627	$357,627	$357,627	$357,627	$357,627	$357,627	$357,627	$357,627	$357,627
TREATMENT COST	1,680,880	1,707,580	1,710,390	1,710,390	1,710,390	1,710,390	1,710,390	1,710,390	1,710,390	1,710,390
SYSTEM MAINTENANCE COST	2,981	2,981	2,981	2,981	2,981	2,981	2,981	2,981	2,981	2,981
G/W PUMPING COST REDUCTION	(611,229)	(620,938)	(621,960)	(621,960)	(621,960)	(621,960)	(621,960)	(621,960)	(621,960)	(621,960)
G/W MAINTENANCE COST REDUCTION	(45,842)	(46,570)	(46,647)	(46,647)	(46,647)	(46,647)	(46,647)	(46,647)	(46,647)	(46,647)
TOTAL ANNUAL WATER COST	$1,384,417	$1,400,679	$1,402,391	$1,402,391	$1,402,391	$1,402,391	$1,402,391	$1,402,391	$1,402,391	$1,402,391
ANNUAL CAPITAL COSTS										
WELLS	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
SURFACE WATER PLANT	1,008,181	1,008,181	312,394	312,394	312,394	312,394	312,394	312,394	312,394	312,394
DISTRIBUTION SYSTEM	166,689	166,689	166,689	0	0	0	0	0	0	0
TOTAL ANNUAL CAPITAL COST	$1,174,870	$1,174,870	$479,083	$312,394	$312,394	$312,394	$312,394	$312,394	$312,394	$312,394
TOTAL ANNUAL COST	$2,559,287	$2,575,549	$1,881,474	$1,714,785	$1,714,785	$1,714,785	$1,714,785	$1,714,785	$1,714,785	$1,714,785
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.45	$0.45	$0.44	$0.44	$0.43	$0.43	$0.42	$0.41	$0.41	$0.40
CAPITAL COST/KGAL	$0.38	$0.38	$0.15	$0.10	$0.10	$0.09	$0.09	$0.09	$0.09	$0.09
TOTAL COST/KGAL	$0.84	$0.83	$0.60	$0.54	$0.53	$0.52	$0.51	$0.50	$0.50	$0.49
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.05	$0.05	$0.02	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
WATER COST/KGAL	$0.45	$0.45	$0.44	$0.44	$0.43	$0.43	$0.42	$0.41	$0.41	$0.40

Surface Water Conversion Plan - WC&ID No. 2 and Sugar Land Only
Financial Impact on WC&ID No. 2

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
TOTAL WATER DEMAND (MGD)	3.68	3.91	4.15	4.38	4.62	4.86	5.09	5.33	5.56	5.80
SURFACE WATER AVAILABLE (MGD)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.12
ANNUAL WATER COSTS										
RAW WATER COST	$0	$0	$0	$0	$0	$0	$0	$0	$0	$256,887
TREATMENT COST	0	0	0	0	0	0	0	0	0	1,164,350
SYSTEM MAINTENANCE COST	0	0	0	0	0	0	0	0	0	3,576
G/W PUMPING COST REDUCTION	0	0	0	0	0	0	0	0	0	(423,400)
G/W MAINTENANCE COST REDUCTION	0	0	0	0	0	0	0	0	0	(31,755)
TOTAL ANNUAL WATER COST	$0	$0	$0	$0	$0	$0	$0	$0	$0	$969,658
ANNUAL CAPITAL COSTS										
WELLS	$81,136	$81,136	$81,136	$81,136	$121,704	$121,704	$121,704	$121,704	$121,704	$121,704
SURFACE WATER PLANT	0	0	0	0	0	0	0	724,186	724,186	724,186
DISTRIBUTION SYSTEM	0	0	0	0	0	0	0	0	144,255	144,255
TOTAL ANNUAL CAPITAL COST	$81,136	$81,136	$81,136	$81,136	$121,704	$121,704	$121,704	$845,890	$990,145	$990,145
TOTAL ANNUAL COST	$81,136	$81,136	$81,136	$81,136	$121,704	$121,704	$121,704	$845,890	$990,145	$1,959,803
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.46
CAPITAL COST/KGAL	$0.06	$0.06	$0.05	$0.05	$0.07	$0.07	$0.07	$0.43	$0.49	$0.47
TOTAL COST/KGAL	$0.06	$0.06	$0.05	$0.05	$0.07	$0.07	$0.07	$0.43	$0.49	$0.93
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.06	$0.06	$0.06
WATER COST/KGAL	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.46

Surface Water Conversion Plan - WC&ID No. 2 and Sugar Land Only
Financial Impact on WC&ID No. 2

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
TOTAL WATER DEMAND (MGD)	5.97	6.14	6.30	6.47	6.64	6.81	6.98	7.14	7.31	7.48
SURFACE WATER AVAILABLE (MGD)	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12
ANNUAL WATER COSTS										
RAW WATER COST	$256,887	$256,887	$256,887	$256,887	$256,887	$256,887	$256,887	$256,887	$256,887	$256,887
TREATMENT COST	1,198,076	1,228,590	1,228,590	1,228,590	1,228,590	1,228,590	1,228,590	1,228,590	1,228,590	1,228,590
SYSTEM MAINTENANCE COST	3,576	3,576	3,576	3,576	3,576	3,576	3,576	3,576	3,576	3,576
G/W PUMPING COST REDUCTION	(435,664)	(446,760)	(446,760)	(446,760)	(446,760)	(446,760)	(446,760)	(446,760)	(446,760)	(446,760)
G/W MAINTENANCE COST REDUCTION	(32,675)	(33,507)	(33,507)	(33,507)	(33,507)	(33,507)	(33,507)	(33,507)	(33,507)	(33,507)
TOTAL ANNUAL WATER COST	$990,200	$1,008,786	$1,008,786	$1,008,786	$1,008,786	$1,008,786	$1,008,786	$1,008,786	$1,008,786	$1,008,786
ANNUAL CAPITAL COSTS										
WELLS	$121,704	$121,704	$121,704	$121,704	$121,704	$121,704	$121,704	$121,704	$121,704	$121,704
SURFACE WATER PLANT	724,186	724,186	724,186	724,186	724,186	724,186	724,186	724,186	724,186	724,186
DISTRIBUTION SYSTEM	144,255	144,255	144,255	144,255	144,255	144,255	144,255	144,255	144,255	144,255
TOTAL ANNUAL CAPITAL COST	$990,145	$990,145	$990,145	$990,145	$990,145	$990,145	$990,145	$990,145	$990,145	$990,145
TOTAL ANNUAL COST	$1,980,345	$1,998,931	$1,998,931	$1,998,931	$1,998,931	$1,998,931	$1,998,931	$1,998,931	$1,998,931	$1,998,931
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.45	$0.45	$0.44	$0.43	$0.42	$0.41	$0.40	$0.39	$0.38	$0.37
CAPITAL COST/KGAL	$0.45	$0.44	$0.43	$0.42	$0.41	$0.40	$0.39	$0.38	$0.37	$0.36
TOTAL COST/KGAL	$0.91	$0.89	$0.87	$0.85	$0.82	$0.80	$0.79	$0.77	$0.75	$0.73
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.06	$0.06	$0.06	$0.06	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05
WATER COST/KGAL	$0.45	$0.45	$0.44	$0.43	$0.42	$0.41	$0.40	$0.39	$0.38	$0.37

JONES & CARTER/PATE ENGINEERS

Surface Water Conversion Plan - WC&ID No. 2 and Sugar Land Only
Financial Impact on WC&ID No. 2

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
TOTAL WATER DEMAND (MGD)	7.65	7.82	7.98	8.15	8.32	8.49	8.66	8.82	8.99	9.16
SURFACE WATER AVAILABLE (MGD)	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	9.48
ANNUAL WATER COSTS										
RAW WATER COST	$256,887	$256,887	$256,887	$256,887	$256,887	$256,887	$256,887	$256,887	$256,887	$397,923
TREATMENT COST	1,228,590	1,228,590	1,228,590	1,228,590	1,228,590	1,228,590	1,228,590	1,228,590	1,228,590	1,838,870
SYSTEM MAINTENANCE COST	3,576	3,576	3,576	3,576	3,576	3,576	3,576	3,576	3,576	3,576
G/W PUMPING COST REDUCTION	(446,760)	(446,760)	(446,760)	(446,760)	(446,760)	(446,760)	(446,760)	(446,760)	(446,760)	(668,680)
G/W MAINTENANCE COST REDUCTION	(33,507)	(33,507)	(33,507)	(33,507)	(33,507)	(33,507)	(33,507)	(33,507)	(33,507)	(50,151)
TOTAL ANNUAL WATER COST	$1,008,786	$1,008,786	$1,008,786	$1,008,786	$1,008,786	$1,008,786	$1,008,786	$1,008,786	$1,008,786	$1,521,538
ANNUAL CAPITAL COSTS										
WELLS	$121,704	$121,704	$81,136	$81,136	$81,136	$40,568	$40,568	$40,568	$40,568	$0
SURFACE WATER PLANT	724,186	724,186	724,186	724,186	724,186	724,186	724,186	1,121,779	1,121,779	1,121,779
DISTRIBUTION SYSTEM	144,255	144,255	144,255	144,255	144,255	144,255	144,255	144,255	144,255	144,255
TOTAL ANNUAL CAPITAL COST	$990,145	$990,145	$949,577	$949,577	$949,577	$909,010	$909,010	$1,306,602	$1,306,602	$1,266,034
TOTAL ANNUAL COST	$1,998,931	$1,998,931	$1,958,363	$1,958,363	$1,958,363	$1,917,795	$1,917,795	$2,315,388	$2,315,388	$2,787,572
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.36	$0.35	$0.35	$0.34	$0.33	$0.33	$0.32	$0.31	$0.31	$0.46
CAPITAL COST/KGAL	$0.35	$0.35	$0.33	$0.32	$0.31	$0.29	$0.29	$0.41	$0.40	$0.38
TOTAL COST/KGAL	$0.72	$0.70	$0.67	$0.66	$0.64	$0.62	$0.61	$0.72	$0.71	$0.83
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.05	$0.05	$0.04	$0.04	$0.04	$0.04	$0.04	$0.05	$0.05	$0.05
WATER COST/KGAL	$0.36	$0.35	$0.35	$0.34	$0.33	$0.33	$0.32	$0.31	$0.31	$0.46

Surface Water Conversion Plan - WC&ID No. 2 and Sugar Land Only
Financial Impact on WC&ID No. 2

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
TOTAL WATER DEMAND (MGD)	9.33	9.50	9.66	9.83	10.00	10.17	10.34	10.50	10.67	10.84
SURFACE WATER AVAILABLE (MGD)	9.48	9.48	9.48	9.48	9.48	9.48	9.48	9.48	9.48	9.48
ANNUAL WATER COSTS										
RAW WATER COST	$397,923	$397,923	$397,923	$397,923	$397,923	$397,923	$397,923	$397,923	$397,923	$397,923
TREATMENT COST	1,872,596	1,903,110	1,903,110	1,903,110	1,903,110	1,903,110	1,903,110	1,903,110	1,903,110	1,903,110
SYSTEM MAINTENANCE COST	3,576	3,576	3,576	3,576	3,576	3,576	3,576	3,576	3,576	3,576
G/W PUMPING COST REDUCTION	(680,944)	(692,040)	(692,040)	(692,040)	(692,040)	(692,040)	(692,040)	(692,040)	(692,040)	(692,040)
G/W MAINTENANCE COST REDUCTION	(51,071)	(51,903)	(51,903)	(51,903)	(51,903)	(51,903)	(51,903)	(51,903)	(51,903)	(51,903)
TOTAL ANNUAL WATER COST	$1,542,080	$1,560,666	$1,560,666	$1,560,666	$1,560,666	$1,560,666	$1,560,666	$1,560,666	$1,560,666	$1,560,666
ANNUAL CAPITAL COSTS										
WELLS	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
SURFACE WATER PLANT	1,121,779	1,121,779	397,592	397,592	397,592	397,592	397,592	397,592	397,592	397,592
DISTRIBUTION SYSTEM	144,255	144,255	144,255	0	0	0	0	0	0	0
TOTAL ANNUAL CAPITAL COST	$1,266,034	$1,266,034	$541,848	$397,592	$397,592	$397,592	$397,592	$397,592	$397,592	$397,592
TOTAL ANNUAL COST	$2,808,114	$2,826,700	$2,102,514	$1,958,258	$1,958,258	$1,958,258	$1,958,258	$1,958,258	$1,958,258	$1,958,258
WATER/RATE-BASED FINANCING										
WATER COST/KGAL	$0.45	$0.45	$0.44	$0.43	$0.43	$0.42	$0.41	$0.41	$0.40	$0.39
CAPITAL COST/KGAL	$0.37	$0.37	$0.15	$0.11	$0.11	$0.11	$0.11	$0.10	$0.10	$0.10
TOTAL COST/KGAL	$0.82	$0.82	$0.60	$0.55	$0.54	$0.53	$0.52	$0.51	$0.50	$0.49
TAX/RATE-BASED FINANCING										
TAX RATE/100	$0.05	$0.05	$0.02	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
WATER COST/KGAL	$0.45	$0.45	$0.44	$0.43	$0.43	$0.42	$0.41	$0.41	$0.40	$0.39

JONES & CARTER/PATE ENGINEERS

APPENDIX - VOLUME II

APPENDIX E

PROPOSED WATER CONSERVATION PLAN
WC&ID NO. 2/SUGAR LAND

INTRODUCTION

The objective of a conservation program is to reduce the quantity of water used for day-to-day activities through the implementation of efficient water use practices. In the residential and commercial sector, this includes water used for drinking, bathing, cooking, laundry, dish washing, car washing, sanitation, lawn watering, swimming pools, and fire protection. In addition to these permanent conservation practices, a drought contingency program is implemented during water shortages. It provides for voluntary and mandatory actions to be put into effect which will cause a significant, but temporary, reduction in water use for the duration of the shortage.

A Water Conservation Plan and a Drought Contingency Plan are required as part of an application submitted by a political subdivision to the Texas Water Development Board (TWDB) for financial assistance from the Development Fund or the Water Loan Assistance Fund.

<u>Background</u>

Fort Bend County Water Control and Improvement District No.2 and the City of Sugar Land (WCID #2/Sugar Land) currently meet all of their water supply needs via ground water wells. Due to increasing awareness of the effects of groundwater pumpage on the water table and land surface subsidence, they have recently contracted with the Water Development Board to investigate the feasibility of conversion to surface water use. The Harris-Galveston Coastal Subsidence District (HGCSD) has established specific requirements for substantial conversion to surface water use within Harris and Galveston Counties, but the WCID #2/Sugar Land area is adjacent to, and not within the jurisdictional boundaries of the HGCSD.

The WCID #2/Sugar Land Regional Planning Area (RPA) comprises approximately 20,600 acres in northeast Fort Bend

County as shown on Exhibit No. 1, and includes the service areas of WCID #2 and the City of Sugar Land as well as the service area of First Colony. The area consists primarily of single family and light commercial development, with some scattered industrial development. Currently, the area is partially developed, but substantial growth is anticipated within the planning period of the surface water conversion study.

First Colony, as referenced herein, refers to the combined service areas and demands of various utility districts which have entered into a contractual agreement for water service from Fort Bend County Municipal Utility District No. 13 (MUD #13). MUD #13 has previously prepared a Water Conservation Plan and Drought Contingency Plan for the First Colony service area, so to avoid duplication of this work, these Plans are included in their entirety in Appendix C.

<u>Purpose and Scope</u>

The purpose of this report is to present the Water Conservation and Drought Contingency Plans as developed for the WCID #2/Sugar Land service areas. Utility evaluation data as required by the Water Development Board is included, along with a summary of the alternative conservation and drought contingency methods considered, and the plan elements selected. Procedures and information for the implementation of these programs are also included. However, each entity within the study area has its own adminstrative structure, and each will be individually responsible for implementation of applicable portions of the Plans. This effort was authorized by the Fort Bend County Water Control and Improvement District No. 2 and the City of Sugar Land as part of the regional water supply planning study for the area.

SYSTEM AUDIT

This section provides a brief description of the WCID #2/ Sugar Land utility systems and demands. Detailed utility evaluation data as required by the Texas Water Development Board is included in Appendix A.

The WCID #2 and Sugar Land service areas generally exhibit typical residential/commercial mixed-use water consumption patterns, with higher average use in the summer months due to lawn watering and outdoor recreation. The ratio of peak day water use to annual average water use in 1986 was 2.00 for WCID #2, and 2.47 for Sugar Land. However, these were isolated peak demands. In both entities, the summer peak ratio in 1986 (defined by the TWDB as the ratio of the average daily summer use to the annual average use) was less than 1.25. This is a fairly typical summer peak ratio for water systems along the Texas Gulf Coast, and poses no significant problems in the design or operation of a supply system.

According to their water system records, both water supply systems have high operating efficiencies with losses less than 10 percent of total water pumped in 1986. The remaining unaccounted for water can typically be attributed to distribution system flushing, fire fighting, unauthorized water use, inaccurate metering of wells or customer use, and distribution system leaks. Aggressive inspection and repair programs by the operators of both systems minimize the losses due to meter inaccuracies and system leaks. In addition, the City of Sugar Land has been monitoring the water used in their system flushing program since October of 1986. This has reduced their unaccounted for water to less than 6 percent.

The existing production, treatment, storage, and distribution systems in the WCID #2/Sugar Land service areas have been constructed in phases in anticipation of projected demands.

Water supply needs in the area are currently met through ground water wells, and the only treatment is chlorination. System components were sized in accordance with Texas Department of Health requirements, and the water is tested on a regular basis in accordance with EPA and Texas Water Commission regulations.

The study area has not experienced any serious water supply problems, but it is recognized that expansion of the production, storage, and distribution systems will be required as development continues. Currently, the City of Sugar Land has significant ground storage capacity which minimizes peak demands placed on the City water wells. However, Sugar Land is planning additional elevated storage capacity for maintenance of system pressures. WCID #2 is currently planning construction of an additional ground water well, along with related water plant improvements, to increase the District system capacity. In addition, the two entities (WCID #2/Sugar Land) are investigating the feasibility of conversion to substantial surface water use. Available surface water from the Brazos River could be used in conjunction with existing ground water supplies to meet projected demands.

Wastewater treatment for WCID #2 is provided by a District wastewater treatment plant with a current capacity of 4.5 MGD. Future expansions of the plant are anticipated as development in the area continues, along with construction of an additional treatment plant on the eastern side of the District. Wastewater treatment capacity will be phased in anticipation of projected demands.

Wastewater treatment for Sugar Land is provided by the Sugar Land Regional Brazos River Authority Wastewater Treatment Plant and the Eldridge Road MUD Interim Wastewater Treatment Plant. Currently, the combined capacity at these two facilities available to serve the City of Sugar Land is 2.95 MGD.

WATER CONSERVATION PLAN

The objective of the conservation plan for the WCID #2/Sugar Land service areas is to reduce the quantity of water required for each water using activity, insofar as is practical, through the implementation of efficient water use practices. The area is not currently threatened by a water supply shortage, but implementation of moderate conservation methods will effectively increase the capacity of the system, and minimize expenditures for expansion and repairs. The goal of this conservation plan is to reduce overall water consumption by 5 percent.

The principal water conservation methods considered in developing the conservation plan for the WCID #2/Sugar Land service areas are as follows:

1. Education and information
2. Plumbing codes for new construction
3. Retrofit programs for existing buildings
4. Conservation-oriented water rate structures
5. Water conserving landscaping
6. Universal metering and meter repair and replacement
7. Leak detection and repair
8. Recycling and reuse

The first five of these methods are typically considered to be Demand Management Conservation Methods. They address water consumption on the user side of a customer meter, and provide for education or incentives to reduce demands on the system. These methods generally result in a decrease in water revenues because less water is purchased by current customers. However, more water is available to serve area growth without costly expansion of the system. The last three methods listed are typically considered to be Supply Management Conservation Methods. The goal of supply management is to improve efficiency and reduce waste within the production, treatment, and distribution system.

This usually results in decreased water costs as losses in the system are reduced. A combination of these two management methods will provide a practical Water Conservation Plan for the WCID #2/Sugar Land service areas as described below:

1. **Education and information:** The most readily available and lowest cost method of promoting water conservation is to inform water users about ways to save water inside homes and other buildings, in landscaping and lawn uses, and in recreational uses.

   In the WCID #2/Sugar Land service area, the City of Sugar Land currently makes available conservation pamphlets and coloring books for area schools and other interested groups. In addition, conservation articles are published in the City of Sugar Land Newsletter, "The Sweet Sheet".

   These programs will be expanded by Sugar Land, and WCID #2 will begin an education and information program of its own. The programs in both entities will include the following:

   a. Distribution of initial information to all water system customers explaining the conservation plan and water conservation methods.

   b. One additional distribution within the first year of the program presenting water conserving tips such as those listed in Appendix B.

   c. Semi-annual distributions of similar information in subsequent years to coincide with peak summer and winter demand periods.

   d. Articles in local newspapers and newsletters. The major newspapers distributed in the area are the Fort Bend County Mirror, the Fort Bend Herald Coaster, and the Southwest Star.

2. **Plumbing codes:** The TWDB recommends water saving plumbing codes for new construction and for replacement of plumbing in existing structures, which include standards for residential and commercial fixtures as follows:

Tank-type toilets	-No more than 3.5 gal/flush
Flush valve toilets	-No more than 3.0 gal/flush
Tank-type urinals	-No more than 3.0 gal/flush
Flush valve urinals	-No more than 1.0 gal/flush
Shower heads	-No more than 3.0 gpm
Faucets	-No more than 2.75 gpm
Hot water lines	-Insulated
Swimming pools	-Recirculating filtration

According to the TWDB, these standards represent readily available products and technology, and do not involve additional costs when compared to "standard" fixtures.

Currently, the 1982 Southern Standard Building Code is the only plumbing regulation applied in the WCID #2/Sugar Land service areas. Within the first year of the Conservation Program, water saving plumbing codes will be adopted by both entities.

3. **Retrofit programs:** Information regarding retrofit devices can be made available for plumbers and customers to use when purchasing and installing plumbing fixtures, lawn watering equipment, or water using appliances. Retrofit devices, such as low-flow shower heads or toilet dams, reduce water use by replacing or modifying existing fixtures or appliances.

In the WCID #2/Sugar Land service areas, information will be included in the education and information program regarding retrofit devices.

4. **Water rate structures:** A conservation-oriented water rate structure usually takes the form of an increasing block rate. In this structure, the price per unit of water increases in steps or blocks as customer use levels are reached. The price increases at the higher use levels discourage the use of large quantities of water.

   WCID #2 currently has an established residential rate order that includes an increasing block water rate structure, which will remain in effect. Sugar Land currently has a decreasing block water rate structure, but will implement a conservation oriented rate structure within the first year of the conservation program.

5. **Water conserving landscaping:** According to the TWDB, exterior water use, such as lawn watering and car washing, accounts for approximately 35 percent of total residential water use. However, during the summer months, as much as 50 percent of the water used in urban areas is applied to lawns and gardens, which significantly adds to the peak demands placed on the water system. Water conserving landscaping by residential customers and commercial establishments engaged in the sale or installation of landscape plants or watering equipment can reduce this impact.

   In the WCID #2/Sugar Land service area, information will be included in the education and information program concerning water conserving landscaping. Guidelines for selection of locally adaptive grasses and plants, recommended soil improvements, appropriate maintenance, and required watering frequency and amounts will be provided.

6. **Universal metering:** Metering of all water users, along with a master meter at each supply source, provides the means for an accurate accounting of water uses throughout the system. The TWDB recommends a regularly scheduled meter testing

program as follows:

a. Production (master) meters - test once each year
b. Meters larger than 1" - test once each year
c. Meters 1" or smaller - test every 10 years

Currently, all water users within the WCID #2/Sugar Land service areas are metered, and all production wells have master meters. If a surface water supply system is implemented to serve the area, metering at all points of supply will be included in the project, as will a master meter at the surface water treatment plant.

WCID #2 and Sugar Land have been testing all water meters based on in-service age, or when unusually high or low meter readings were reported. However, each entity is currently developing a formal program for meter testing which will follow the above guidelines.

7. **Leak detection and repair:** A continuous leak detection and repair program can be an important part of a water conservation plan. In addition, an annual water audit can help to identify sources of unaccounted for water, and corrective repairs or actions can be undertaken.

   In the WCID #2/Sugar Land service area, the operators of both water systems currently maintain aggressive inspection and repair programs which will be continued. These include routine inspections for leaks or illegal water use, and monthly water audits. Customers are notified if water use is abnormally high, and encouraged to check their home for possible leaks.

8. **Recycling and reuse:** Use of wastewater treatment plant effluent, or reuse of industrial process water, can reduce the amount of fresh water required within a service area.

Since the WCID #2/Sugar Land service areas consist primarily of single family and light commercial development, there is minimal potential for reuse. The Imperial Sugar Company, a major industrial user in the Sugar Land service area, does not currently obtain water from the Sugar Land system. The Sugar Company does, however, use and recycle cooling water from area lakes. Within the WCID #2 service area, Texas Instruments and WKM, Inc. both operate recycling water systems. Texas Instruments maintains its own water supply wells and is not tied into the District system, but WKM Inc. does obtain its water supply from the WCID #2 system. These practices reduce the demand on the area-wide ground water supply and treatment systems.

IMPLEMENTATION AND ENFORCEMENT

Fort Bend County Water Control and Improvement District No. 2 and the City of Sugar Land will be individually responsible for implementation and enforcement of applicable portions of the Water Conservation Plan. Acting as administrators of the Plan will be the General Manager of WCID #2, and the City Manager of Sugar Land. These administrators will oversee implementation of all elements of the program, and be responsible for keeping adequate records for program verification.

In addition, the administrators will be responsible for submission of annual reports to the TWDB concerning the Water Conservation Plan in the individual service areas. These reports will include:

1. Progress made in the implementation of the program.
2. Response to the program by the public.
3. Quantitative effectiveness of the program.

The conservation programs will be formally adopted by the Board of Directors in WCID #2 and the City Council in Sugar Land, and will be enforced through existing mechanisms of control for similar regulatory items. Each entity will provide copies of all regulatory documents as necessary for administration of the plan.

DROUGHT CONTINGENCY PLAN

A number of uncontrollable circumstances can disrupt a community's water supply. A drought could severely reduce the amount of water available, or the water supply could become contaminated or destroyed by disaster. Alternatively, a failure in the water treatment, storage, or distribution system could result in a water emergency. The onset of emergency conditions is often rapid, so it is important that a community be prepared in advance by establishment of a Drought Contingency Plan.

Drought contingency planning is significantly different from water conservation planning. While water conservation involves implementing permanent water use efficiency practices, drought contingency plans include measures to cause a significant, but temporary, reduction in water use during a water emergency. Drought contingency measures may include conservation, but may also include voluntary use reductions, the restriction or elimination of certain types of water use, water rationing, or the temporary use of water from sources other than established supplies.

WCID #2 and Sugar Land have previously established general policies for regulation of water use during water emergency periods. These policies were considered in the drought contingency planning presented in this section. The following elements were also considered in developing the WCID #2/Sugar Land Drought Contingency Plan:

1. Trigger conditions signaling the start of an emergency period
2. Drought contingency measures
3. Information and education
4. Initiation procedures
5. Termination notification actions
6. Means of implementation

Currently, WCID #2 and Sugar Land meet their water supply needs through deep ground water wells, drawing primarily from the Evangeline Aquifer. In a recent study of aquifer yield by McBride Ratcliff and Associates, it was determined that adequate water would be available to serve the projected demands of the area at least through the year 2030. However, continued dependence on ground water would have an impact on future land surface subsidence. Therefore, the two entities are investigating the feasibility of conversion to substantial surface water use with potential raw water supply from the Brazos River.

WCID #2 currently maintains 5,300 gpm of ground water well capacity and 9,000 gpm of distribution pumping capacity. In addition, approximately 4.38 million gallons of storage is available in the system, of which 1.08 million gallons is in elevated storage. These facilities are adequate to meet current demands on the system, but additional facilities are planned in the near future to allow continued system reliability. In addition, future improvements to the system are planned, but will be constructed in phases to meet projected demands.

Sugar Land currently has 7,975 gpm of ground water well capacity and 11,260 gpm of distribution pumping capacity. Total storage capacity of 6.99 million gallons is available in the Sugar Land system, of which 2.25 million gallons is in elevated storage. As in WCID #2, additional facilities are planned to meet future demands on the system, but current demands can be met with the existing facilities.

Trigger Conditions

For both the WCID #2 and Sugar Land water systems, ground storage capacity is well in excess of currently required amounts. In addition to providing for peak hour demands, this excess storage helps to mitigate the impact of peak day demands on the production capacities of the two systems. Storage depleted during daily peak demand periods can be replenished during off-peak hours. However, during peak use periods, distribution pumping capacities may be the limiting constraint on system capacity. Therefore, peak use volumes are likely to be the primary indicator of when drought contingency measures should be put into effect for the WCID #2/Sugar Land service areas. In consideration of this constraint, the following trigger conditions based on peak use volumes have been established for the WCID #2/Sugar Land Drought Contingency Plan:

1. Mild Conditions
   Peak use demands approaching 80 percent of distribution pumping capacity.

2. Moderate Conditions
   Peak use demands approaching 90 percent of distribution pumping capacity.

3. Severe Conditions
   Peak use demands approaching 100 percent of distribution pumping capacity.

As each of these trigger conditions is reached, emergency measures applicable to that level of severity will be implemented.

<u>Drought Contingency Measures</u>

The following actions will be taken when a trigger condition is reached:

1. Mild Conditions

   a. Inform the public through the news media that a mild drought exists and that the public should voluntarily reduce water use.

   b. Publicize a voluntary lawn watering schedule, as well as proper methods and times to water lawns.

Customers with odd-numbered street addresses would water on odd-numbered days and customers with even-numbered street addresses would water on even-numbered days. Watering would be permitted only between the hours of 11 p.m. and 5 a.m.

c. Request water users to insulate exposed water pipes rather than running water to prevent freezing during winter months.

d. Notify all major commercial water users of the situation and request voluntary reduction of water use.

2. Moderate Conditions

a. Continue implementing all actions under Mild Conditions unless otherwise modified in this section.

b. Publicize information announcing a mandatory lawn watering schedule, as described above.

c. Publicize information announcing prohibition of all car washing, window washing, and pavement washing except when a bucket is used.

d. Publicize prohibition of all public water uses not essential for public health and safety, such as:

1) Driveway and street washing
2) Fire hydrant flushing
3) Filling of swimming pools
4) Athletic field watering

3. Severe Conditions

   a. Continue implementing all actions under Moderate Conditions unless other wise modified in this section.

   b. Prohibit all outdoor use of water such as lawn watering, car washing, and pavement washing.

   c. Implement a water bill surcharge based on meter size for excessive water users as follows:

5/8" meter	- over 6,000 gal/month	200%
meter > 5/8" but < 2"	- over 10,000 gal/month	200%
meters 2" and larger	- over 20,000 gal/month	300%

   d. In selected portions of the service area, ration or terminate water service according to the following order:

      1) Institutional users
      2) Commercial users
      3) Residential users

<u>Information and Education</u>

Initial information explaining the Drought Contingency Plan will be distributed to all water system customers in the WCID #2/Sugar Land service areas, and this information will be supplemented with articles published in local newspapers and newsletters, such as the Fort Bend County Mirror and the Fort Bend Herald Coaster. Notification of approaching trigger conditions in either service area will be made by announcements in local newspapers within that service area, and information concerning water conserving methods will be included with these announcements. In addition, water conservation articles will appear regularly in local newspapers while each trigger condition is in effect.

<u>Initiation Procedures</u>

In WCID #2, the General Manager for the District will monitor system water demands and notify the President of the District Board of Directors (the Board) of an approaching trigger condition. When the trigger condition is reached, the Board President will declare the existence of a water emergency by filing a written declaration to that effect with the Board Secretary, and the defined drought contingency measures for that trigger condition will be put into effect within the WCID #2 service area.

In the City of Sugar Land, the City Manager will monitor system water demands and notify the mayor of an approaching trigger condition. When a trigger condition is reached, the mayor will declare the existence of a water emergency by filing a written declaration to that effect with the city secretary, and the defined drought contingency measures for that trigger condition will be put into effect within the City of Sugar Land service area.

<u>Termination Actions</u>

In WCID #2, the General Manager for the District will monitor the emergency until it is determined that a trigger condition no longer exists. The General Manager will then notify the Board President that drought contingency measures can be downgraded or completely eliminated, and the Board President will file a declaration to that effect with the Board Secretary. Notifications to the public will be published in local newspapers and newsletters.

In Sugar Land, the City Manager will monitor the emergency until it is determined that a trigger condition no longer exists. The City Manager will then notify the mayor that drought contingency measures can be downgraded or completely eliminated, and the mayor will file a declaration to that effect with the city secretary. Notifications to the public will be published in local newspapers and newsletters.

Implementation

Fort Bend County Water Control and Improvement District No. 2 and the City of Sugar Land will be individually responsible for implementation of the Drought Contingency Plan. The program will be adopted by the Board of Directors in WCID #2 and the City Council in Sugar Land.

In addition, the operator for each water system will review water production capacities and requirements, annually. Should the operator of either system determine that the defined trigger conditions or drought contingency measures need to be revised, the Drought Contingency Plan will be amended as required by the individual entity. It is recognized that these revisions may result in different trigger conditions or measures for each entity. Any required amendments to the plan will be accomplished through the WCID #2 Board of Directors or the City Council of the City of Sugar Land, whichever is applicable.

APPENDIX A
UTILITY EVALUATION DATA

The WCID #2/Sugar Land Regional Planning Area includes the service area of First Colony as well as the service areas for WCID #2 and Sugar Land. Presented herein is utility evaluation data as required by the TWDB for the WCID #2 and Sugar Land service areas. Utility evaluation data for the First Colony service area is presented in the MUD #13 Water Conservation Plan included in Appendix C.

A. Estimated population of service area including commercial and industrial demands as population equivalents (1987):

(1)	WCID #2	17,075
(2)	Sugar Land	23,275

B. Estimated area of service area:

(1)	WCID #2	10.7 sq.mi.
(2)	Sugar Land	11.2 sq.mi.

C. Number/type of Connections:

		Res.	Comm.	Ind.
(1)	WCID #2	2937	677	*
(2)	Sugar Land	5416	366	2

* Included in commercial connections

D. Net new connections per year:

		Res.	Comm.	Ind.
(1)	WCID #2	130	10	*
(2)	Sugar Land	111	25	0

* Included in commercial connections

E. Water use information:

1. Water production for the last year (1986):

(1)	WCID #2	880,905,400 gallons
(2)	Sugar Land	1,187,016,000 gallons

2. Average water production for the last two years (1985 and 1986):

(1)	WCID #2	856,967,850 gallons
(2)	Sugar Land	1,205,050,500 gallons

3. Average monthly water production for the last two years (1985 and 1986):

(1)	WCID #2	71,413,988 gal/mo
(2)	Sugar Land	100,420,875 gal/mo

4. Estimated monthly water sales by user category in 1,000 gallons:

(1) WCID #2

	Res.	Comm.	Ind.	Total
January	*	*	*	48,004
February	*	*	*	55,702
March	*	*	*	46,628
April	*	*	*	66,411
May	*	*	*	77,529
June	*	*	*	58,600
July	*	*	*	68,684
August	*	*	*	103,593
September	*	*	*	81,306
October	*	*	*	57,733
November	*	*	*	56,535
December	*	*	*	63,230

* Data not currently available

(2) Sugar Land

	Res.	Comm.	Ind.	Total
January	41,993	27,655	*	69,648
February	40,385	24,826	*	65,211
March	40,629	24,314	*	64,943
April	56,526	24,697	*	81,223
May	80,355	42,973	*	123,328
June	54,085	36,419	*	90,504
July	52,887	30,598	*	83,485
August	86,889	42,298	*	129,187
September	101,140	53,516	*	154,656
October	63,705	43,600	*	107,305
November	45,920	33,418	*	79,338
December	42,392	23,282	*	65,674

* Included in commercial sales

5. Average daily water use (1986):

(1)	WCID #2	2.41 MGD
(2)	Sugar Land	3.25 MGD

6. Peak daily use (1986):

(1) WCID #2 4.83 MGD
(2) Sugar Land 8.04 MGD

7. Peak to average use ratio - average daily summer use to annual average (1986):

(1) WCID #2 1.22
(2) Sugar Land 1.25

8. Unaccounted for water (1986):

(1) WCID #2 8.71 %
(2) Sugar Land 9.18 %

F. Wastewater Information:

1. Percent of water customers served by area wastewater treatment system:

(1) WCID #2 97 %
(2) Sugar Land 86 %

2. Percent of water customers served by septic tanks:

(1) WCID #2 1 %
(2) Sugar Land 3 %

3. Percent of water customers served by another wastewater treatment system:

(1) WCID #2 negligible
(2) Sugar Land 11 %

4. Percent of total water sales to:

a. Customers served by area wastewater treatment system:

(1) WCID #2 *
(2) Sugar Land 78 %

* Data not currently available

b. Customers on septic tanks:

(1) WCID #2 *
(2) Sugar Land 17 %

* Data not currently available

c. Customers served by another wastewater treatment system:

(1) WCID #2 *
(2) Sugar Land 5 %

* Data not currently available

5. Average daily volume of wastewater treated (1986):

(1) WCID #2 1.95 MGD
(2) Sugar Land 2.28 MGD

6. Peak daily wastewater volume (1986):

(1) WCID #2 9.69 MGD
(2) Sugar Land 4.54 MGD

7. Estimated percent of wastewater flows to area treatment plant that originate from the following categories:

(1) WCID #2

Residential	*
Industrial	*
Commercial	*
Stormwater	*
Other	*

(2) Sugar Land

Residential	*
Industrial	*
Commercial	*
Stormwater	*
Other	*

* Data not currently available

G. Safe annual yield of water supply (1988):

(1) WCID #2 1,160 MGD
(2) Sugar Land 1,746 MGD

H. Peak daily design capacity of water system (1988):

(1) WCID #2 5.76 MGD
(2) Sugar Land 8.66 MGD

I. Major high-volume customers:

(1) WCID #2

WKM (Flow Control Division)
Tri Gas Inc. (Liquid Air)
Windfield Townhomes
Gulf Coast Concrete

(Texas Instruments has separate supply facilities)

(2) Sugar Land

Nalco Chemical #1
Continental Can
Nalco Chemical #2

(Imperial Sugar Company has separate supply facilities)

J. Population and water demand projections:

(1) WCID #2	Pop.	Demand (MGD)
2000	36,250	5.80
2020	57,250	9.16

(2) Sugar Land	Pop.	Demand (MGD)
2000	34,875	5.58
2020	51,500	8.24

K. Percent of metered water connections:

	Res.	Comm.	Ind.
(1) WCID #2	100%	100%	
(2) Sugar Land	100%	100%	

L. Residential Water Rate Structure:

(1) WCID #2: Increasing block

0 - 3,000 gals	$ 3.00
over 3,000 gals	$ 1.12/thou gal

(2) Sugar Land: Block

0 - 1,000 gals	$ 6.00
over 1,000 gals	$ 1.05/thou gal

M. Average annual revenue from water and sewer rates (1986):

(1) WCID #2	$ 1,243,693
(2) Sugar Land	$ 2,871,660

N. Average annual revenue from non-rate sources (1986):

(1)	WCID #2	$ 160,482
(2)	Sugar Land	$ 225,005

O. Average annual fixed costs of water and sewer operation (1986):

(1)	WCID #2	$ 663,621
(2)	Sugar Land	$ 1,497,668

P. Average annual variable costs of water and sewer operation (1986):

(1)	WCID #2	$ 647,715
(2)	Sugar Land	$ 266,089

Q. Average annual water revenues for other purposes:

(1)	WCID #2	-0-
(2)	Sugar Land	$ 125,000

R. Copies of applicable local regulations:

The only applicable regulation in the WCID #2/Sugar Land service areas concerning water supply and distribution is the 1982 Southern Building Code.

S. Copies of applicable State, Federal, or other regulations:

As public suppliers of water, WCID #2 and Sugar Land must abide by the rules of the following agencies:

(1) Texas Water Commission
(2) Texas Department of Health
(3) Environmental Protection Agency

PUBLIC PARTICIPATION

(1) WCID #2
The Board of Directors for the District conducts regularly scheduled meetings on the third Wednesday of each month. The meetings are open to the public, and citizens are free to express their opinions.

(2) Sugar Land
The City Council conducts regularly scheduled meetings on the first and third Tuesdays of each month. The meetings are open to the public, and citizens are free to express their opinions.

In addition to the above-mentioned public meetings, the general public may attend the following meetings and express their opinions:

a. Fort Bend County Chamber of Commerce
b. Various homeowner associations
c. Various civic organizations

APPENDIX B
Water Conservation Methods for the Individual User

According to the TWDB, in-home water use accounts for an average of 65 percent of total residential use, while the remaining 35 percent is used for exterior residential purposes such as lawn watering and car washing. Average residential in-home water use data indicates that about 40 percent is used for toilet flushing, 35 percent for bathing, 11 percent for kitchen uses, and 14 percent for clothes washing. The TWDB distributes the following list of water saving methods that can be practiced by the individual water user.

In the bathroom:

1. Take a shower instead of filling the tub and taking a bath. Showers usually use less water than tub baths.

2. Install a low-flow shower head which restricts the quantity of flow at 60 psi to no more than 3.0 gallons per minute.

3. Take short showers and install a cutoff valve or turn the water off while soaping and back on again to rinse.

4. Do not use hot water when cold will do. Water and energy can be saved by washing hands with soap and cold water: hot water should only be added when hands are expecially dirty.

5. Reduce the level of the water being used in a bath tub by one or two inches if a shower is not available.

6. Turn water off when brushing teeth until it is time to rinse.

7. Do not let the water run when washing hands. Instead, hands should be wet, and water should be turned off while soaping and scrubbing and turned on again to rinse. A cutoff valve may also be installed on the faucet.

8. Shampoo hair in the shower. Shampooing in the shower takes only a little more water than is used for bathing and much less than shampooing and bathing separately.

9. Hold hot water in the basin when shaving instead of letting the faucet continue to run.

10. Test toilets for leaks. To test for a leak, a few drops of food coloring can be added to the water in the

tank. The toilet should not be flushed. If the coloring appears in the bowl within a few minutes, the fixture needs adjustment or repair.

11. Use a toilet tank displacement device. A one-gallon plastic milk bottle can be filled with stones or with water, recapped, and placed in the toilet tank. This will reduce the amount of water in the tank but still provide enough for flushing. (Bricks are not recommended for this purpose since they crumble eventually and could damage the working mechanism, necessitating a call to the plumber.) Displacement devices should never be used with new low-volume flush toilets.

12. Install faucet aerators to reduce water consumption.

13. Never use the toilet to dispose of cleansing tissues, cigarette butts, or other trash. This can waste a great deal of water and also places an unnecessary load on the sewage treatment plant or septic tank.

14. Install a new low-volume flush toilet that uses 3.5 gallons or less per flush when building a new home or remodeling a bathroom.

In the kitchen:

15. Use a pan of water (or place a stopper in the sink) for rinsing pots and pans and cooking implements when cooking rather than turning on the water faucet each time a rinse is needed.

16. Never run the dishwasher without a full load. In addition to saving water, expensive detergent will last longer and a significant energy saving will appear on the utility bill.

17. Use the sink disposal sparingly, and never use it for just a few scraps.

18. Keep a container of drinking water in the refrigerator. Running water from the tap until it is cool is wasteful. Better still, both water and energy can be saved by keeping cold water in a picnic jug on a kitchen counter to avoid opening the refrigerator door frequently.

19. Use a small pan of cold water when cleaning vegetables rather than letting the faucet run.

20. Use only a little water in the pot and put a lid on it for cooking most food. Not only does this method save water, but food is more nutritious since vitamins and

minerals are not poured down the drain with the extra cooking water.

21. Use a pan of water for rinsing when hand washing dishes rather than a running faucet.

22. Always keep water conservation in mind, and think of other ways to save in the kitchen. Small kitchen savings such as not making too much coffee or letting ice cubes melt in the sink can add up in a year's time.

In the laundry:

23. Wash only a full load when using an automatic washing machine (32 to 59 gallons are required per load).

24. Use the lowest water level setting on the washing machine for light loads whenever possible.

25. Use cold water as often as possible to save energy and to conserve the hot water for uses which cold water cannot serve. (This is also better for clothing made of today's synthetic fabrics.)

For appliances and plumbing:

26. Check water requirements of various models and brands when considering purchasing any new appliance that uses water. Some use less water than others.

27. Check all water line connections and faucets for leaks. If the cost of water is $ 1.00 per thousand gallons, one could be paying a large bill for water that simply goes down the drain because of leakage. A slow drip can waste as much as 170 gallons of water each day, or 5,000 gallons per month, and can add as much as $ 5.00 per month to the water bill.

28. Learn to replace faucet washers so that drips can be corrected promptly. It is easy to do, costs very little, and can represent a substantial amount saved in plumbing and water bills.

29. Check for "invisible" water leakage, such as a leak between the water meter and the house. To check, all indoor and outdoor faucets should be turned off, and the water meter should be checked. If it continues to run or turn, a leak probably exists and needs to be located.

30. Insulate all hot water pipes to avoid the delays (and wasted water) experienced while waiting for the water

to "run hot".

31. Be sure the hot water heater thermostat is not set too high. Extremely hot settings waste water and energy because the water often has to be cooled with cold water before it can be used.

32. Use a moisture meter to determine when house plants need water. More plants die from over-watering than from being on the dry side.

For out-of-door use:

33. Water lawns early in the morning during the hotter summer months. Much of the water used on the lawn can simply evaporate between the sprinkler and the grass.

34. Use a sprinkler that produces large drops of water, rather than a fine mist, to avoid evaporation.

35. Turn soaker hoses so the holes are on the bottom to avoid evaporation.

36. Water slowly for better absorption, and never water on windy days.

37. Forget about watering the streets or walks or driveways. They will never grow a thing.

38. Condition the soil with compost before planting grass or flower beds so that water will soak in rather than run off.

39. Fertilize lawns at least twice a year for root stimulation. Grass with a good root system makes better use of less water.

40. Learn to know when grass needs watering. If it has turned a dull grey-green or if footprints remain visible, it is time to water.

41. Do not water too frequently. Too much water can overload the soil so that air cannot get to the roots and can encourage plant diseases.

42. Do not over-water. Soil can absorb only so much moisture and the rest simply runs off. A timer will help, and either a kitchen timer or an alarm clock will do. An inch and one-half of water applied once a week will keep most Texas grasses alive and healthy.

43. Operate automatic sprinkler systems only when the demand on the local water supply system is lowest. Set

the system to operate between four and six a.m.

44. Do not scalp lawns when mowing during hot weather. Taller grass holds moisture better. Rather, grass should be cut fairly often, so that only 1/2 to 3/4 inch is trimmed off. A better looking lawn will result.

45. Use a watering can or hand water with the hose in small areas of the lawn that need more frequent watering (those near walks or driveways or in expecially hot, sunny spots).

46. Learn what types of grass, shrubbery, and plants do best in the area and in which parts of the lawn, and then plant accordingly. If one has a heavily shaded yard, no amount of water will make roses bloom. In especially dry sections of the state, attractive arrangements of plants that are adapted to arid or semi-arid climates should be chosen.

47. Consider decorating areas of the lawn with rocks, gravel, wood chips, or other materials now available that require no water at all.

48. Do not "sweep" walks and driveways with the hose. Use a broom or rake instead.

49. Use a bucket of soapy water for washing the car, and use the hose only for rinsing.

APPENDIX F

MASTER DISTRICT OF
FORT BEND COUNTY
MUNICIPAL UTILITY DISTRICT
NO. 13

WATER CONSERVATION
AND
DROUGHT CONTINGENCY
PLAN

PREPARED BY THE
OPERATOR FOR THE DISTRICT

EOO-RESOURCES, INC.
12550 Emily Court
SUGAR LAND, TEXAS 77478

INTRODUCTION

The goal of any Water Conservation Plan is to reduce required quantities of water for each specified use. The Plan should include a means for implementing of efficient water use practices.

The goal of a Drought Contingency Plan is to provide procedures for mandatory and voluntary action that, when put into effect, will temporarily reduce demand on the water supply system during a water shortage situation. The Drought Contingency Plan should include various conservation measures, as well as the mechanism for prohibiting certain other uses during the shortage emergency.

Currently, the Master District of Fort Bend County Municipal Utility District No. 13 has no shortage of water. However, the District recognizes the benefits of water conservation and has prepared plans case a drought occurs. The goal of Fort Bend County Municipal Utility District No. 13 is to reduce per capita water usage by five percent. The District is currently developing at a rate of five percent per year. The District's existing water supply is from deep wells located within its boundaries. Yearly pumpage from these wells is not limited like those in Harris and Galveston Counties. The District serves approximately 21,500 users within its boundaries, with the predominate users being single-family residences.

This report will present the data collected, along with available alternatives and various selected elements for the Water Conservation/ Drought Contingency Plan, and outline procedures and information for implementing the Plan.

UTILITY EVALUATION

To understand the following utility evaluation, one must first understand the Master District concept of Water Districts. Under the Master District concept, one District assumes responsibility for providing water and/or wastewater services to other Districts located within the Master District. These services are generally provided by contract agreement between the various Water Districts and the Master District. The following data presents a complete utility evaluation of the Master District:

1. Estimated Population of Service Area: (July 1987)

a.	First Colony M.U.D. No. 1	4,025
b.	First Colony M.U.D. No. 2	154
c.	First Colony M.U.D. No. 3	4
d.	First Colony M.U.D. No. 4	767
e.	First Colony M.U.D. No. 5	257
f.	First Colony M.U.D. No. 6	1,941
g.	First Colony M.U.D. No. 8	301
h.	Fort Bend County M.U.D. No. 12	8,201
i.	Fort Bend County M.U.D. No. 13 (Internal District)	Ø
j.	Fort Bend County M.U.D. No. 16	5,985
	TOTAL	21,635

2. Estimated Area of Service Area: (1987)

a.	First Colony M.U.D. No. 1	444 Ac
b.	First Colony M.U.D. No. 2	397 "
c.	First Colony M.U.D. No. 3	613 "
d.	First Colony M.U.D. No. 4	839 "
e.	First Colony M.U.D. No. 5	587 "
f.	First Colony M.U.D. No. 6	411 "
g.	First Colony M.U.D. No. 8	"
h.	Fort Bend County M.U.D. No. 12	1,064 "
i.	Fort Bend County M.U.D. No. 13 (Internal District)	226 "
j.	Fort Bend County M.U.D. No. 16	827 "
	TOTAL	6,614 Ac

3. Number/Type of Connection: (July 1987)

	(Res)	(Com)	(Ind)
a. First Colony M.U.D. No. 1	1,307	3	0
b. First Colony M.U.D. No. 2	13	4	0
c. First Colony M.U.D. No. 3	28	0	0
d. First Colony M.U.D. No. 4	333	2	0
e. First Colony M.U.D. No. 5	9	3	0
f. First Colony M.U.D. No. 6	457	0	0
g. First Colony M.U.D. No. 8	112	0	0
h. Fort Bend County M.U.D. No.12	2,202	61	0
i. Fort Bend County M.U.D. No.13 (Internal District)	3	6	0
j. Fort Bend County M.U.D. No.16	1,448	9	0
TOTAL	5,912	88	0

4. Net New Connections Per Year: (1985-1986)

	(Res)	(Com)	(Ind)
a. First Colony M.U.D. No. 1	51	0	0
b. First Colony M.U.D. No. 2	0	5	0
c. First Colony M.U.D. No. 3	0	0	0
d. First Colony M.U.D. No. 4	48	2	0
e. First Colony M.U.D. No. 5	0	1	0
f. First Colony M.U.D. No. 6	41	0	0
g. First Colony M.U.D. No. 8	15	2	0
h. Fort Bend County M.U.D. No.12	32	14	0
i. Fort Bend County M.U.D. No.13 (Internal District)	0	2	0
j. Fort Bend County M.U.D. No.16	50	2	0
TOTAL	237	28	0

5. Water Use Information:

a. Water Production for Last Year: (1986)

1) First Colony M.U.D. No. 1	111,931,000	gal/yr
2) First Colony M.U.D. No. 2	2,254,000	"
3) First Colony M.U.D. No. 3	0	"
4) First Colony M.U.D. No. 4	43,308,000	"
5) First Colony M.U.D. No. 5	11,769,000	"
6) First Colony M.U.D. No. 6	67,057,000	"
7) First Colony M.U.D. No. 8	8,150,000	"
8) Fort Bend County M.U.D. No. 12	323,593,000	"
9) Fort Bend County M.U.D. No. 13 (Internal District)	476,000	"
10) Fort Bend County M.U.D. No. 16	180,181,000	"
TOTAL	748,719,000	gal/yr

5. Water Use Information (con't):

b. Water Production for Last Two Years: (1985 and 1986)

1) First Colony M.U.D. No. 1	155,658,500	gal/yr
2) First Colony M.U.D. No. 2	1,449,500	"
3) First Colony M.U.D. No. 3	0	"
4) First Colony M.U.D. No. 4	27,864,000	"
5) First Colony M.U.D. No. 5	6,164,500	"
6) First Colony M.U.D. No. 6	81,027,500	"
7) First Colony M.U.D. No. 8	4,851,500	"
8) Fort Bend County M.U.D. No. 12	385,542,500	"
9) Fort Bend County M.U.D. No. 13 (Internal District)	1,524,000	"
10) Fort Bend County M.U.D. No. 16	246,252,500	"
TOTAL	1,820,669,000	gal/yr

c. Average Monthly Water Production for Last Two Years: (1985 and 1986)

1) First Colony M.U.D. No. 1	12,971,500	gal/mo
2) First Colony M.U.D. No. 2	120,800	"
3) First Colony M.U.D. No. 3	0	"
4) First Colony M.U.D. No. 4	2,738,800	"
5) First Colony M.U.D. No. 5	513,700	"
6) First Colony M.U.D. No. 6	6,752,300	"
7) First Colony M.U.D. No. 8	404,300	"
8) Fort Bend County M.U.D. No. 12	32,128,500	"
9) Fort Bend County M.U.D. No. 13 (Internal District)	127,000	"
10) Fort Bend County M.U.D. No. 16	20,521,000	"
TOTAL	76,277,900	gal/mo

d. Estimated Monthly Water Sales by User Category: (1986) (1,000 gallons)

1) First Colony M.U.D. No. 1

	Residential	Commercial	Industrial	Total
January	7,296	321	0	7,617
February	7,428	159	0	7,587
March	6,887	114	0	7,001
April	10,466	159	0	10,625
May	9,136	206	0	8,989
June	8,736	253	0	9,100
July	12,966	115	0	13,081
August	16,035	247	0	16,282
September	8,796	232	0	9,028
October	7,594	188	0	7,782
November	7,054	152	0	7,206
December	7,159	91	0	7,250
TOTAL	109,553	2,237	0	111,790

5. Water Use Information (con't):

2) First Colony M.U.D. No. 2

	Residential	Commercial	Industrial	Total
January	14	53	0	67
February	2	58	0	60
March	30	36	0	66
April	9	56	0	65
May	8	66	0	74
June	9	100	0	109
July	9	124	0	133
August	483	215	0	698
September	10	163	0	173
October	181	193	0	374
November	27	195	0	222
December	12	201	0	213
TOTAL	794	1,460	0	2,254

3) First Colony M.U.D. No. 3

	Residential	Commercial	Industrial	Total
January	0	0	0	0
February	0	0	0	0
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
October	0	0	0	0
November	0	0	0	0
December	0	0	0	0
TOTAL	0	0	0	0

4) First Colony M.U.D. No. 4

	Residential	Commercial	Industrial	Total
January	1,993	458	0	2,451
February	2,036	415	0	2,451
March	1,922	322	0	2,244
April	3,369	474	0	3,843
May	3,867	477	0	4,344
June	2,573	668	0	3,241
July	4,063	410	0	4,473
August	6,326	1,421	0	7,747
September	3,494	790	0	4,284
October	2,567	613	0	3,180
November	2,159	714	0	2,873
December	1,572	595	0	2,167
TOTAL	35,941	7,357	0	43,298

5. Water Use Information (con't):

5) First Colony M.U.D. NO. 5

	Residential	Commercial	Industrial	Total
January	6	470	0	476
February	13	854	0	867
March	118	358	0	476
April	45	974	0	1,019
May	26	1,236	0	1,262
June	16	832	0	848
July	34	1,387	0	1,421
August	57	1,664	0	1,721
September	39	1,314	0	1,353
October	10	943	0	953
November	12	772	0	784
December	7	582	0	589
TOTAL	383	11,386	0	11,769

6) First Colony M.U.D. No. 6

	Residential	Commercial	Industrial	Total
January	2,786	1,865	0	4,651
February	2,728	1,476	0	4,204
March	3,049	1,085	0	4,134
April	3,842	2,179	0	6,021
May	3,567	1,843	0	5,410
June	3,567	2,245	0	5,812
July	5,832	1,785	0	7,617
August	6,247	3,878	0	10,125
September	3,643	2,320	0	5,963
October	2,925	1,952	0	4,877
November	2,565	1,985	0	4,550
December	2,365	1,257	0	3,622
TOTAL	43,116	23,870	0	66,986

7) First Colony M.U.D. No. 8

	Residential	Commercial	Industrial	Total
January	473	0	0	473
February	473	0	0	473
March	450	0	0	450
April	824	0	0	824
May	668	0	0	668
June	691	0	0	691
July	914	0	0	914
August	1,205	0	0	1,205
September	725	0	0	725
October	700	0	0	700
November	500	0	0	500
December	527	0	0	527
TOTAL	8,150	0	0	8,150

5. Water Use Information (con't):

8) Fort Bend County M.U.D. No. 12

	Residential	Commercial	Industrial	Total
January	17,576	6,547	0	24,123
February	17,353	4,962	0	22,315
March	18,594	4,549	0	23,143
April	23,635	5,353	0	28,988
May	19,765	4,952	0	24,717
June	20,273	5,854	0	26,127
July	32,303	4,591	0	36,894
August	34,181	10,369	0	44,550
September	20,900	7,430	0	28,330
October	17,509	5,634	0	23,143
November	16,972	4,836	0	21,808
December	15,076	4,379	0	19,455
TOTAL	254,137	69,456	0	323,593

9) Fort Bend County M.U.D. No. 13 (Internal District)

	Residential	Commercial	Industrial	Total
January	0	53	0	53
February	0	26	0	26
March	0	18	0	18
April	0	31	0	31
May	0	33	0	33
June	0	28	0	28
July	0	17	0	17
August	0	29	0	29
September	0	27	0	27
October	0	67	0	67
November	0	65	0	65
December	0	82	0	82
TOTAL	0	476	0	476

10) Fort Bend County M.U.D. No. 16

	Residential	Commercial	Industrial	Total
January	9,341	3,213	0	12,554
February	10,555	2,423	0	12,978
March	10,950	2,304	0	13,254
April	12,925	2,968	0	15,893
May	12,167	2,823	0	14,990
June	10,587	3,202	0	13,789
July	16,098	3,021	0	19,119
August	19,466	4,565	0	24,031
September	11,627	3,896	0	15,523
October	10,158	2,892	0	13,050
November	10.093	3,061	0	13,154
December	9,808	2,038	0	11,846
TOTAL	143,775	36,406	0	180,181

5. Water Use Information (con't):

11) Total of All Districts

	Residential	Commercial	Industrial	Total
January	39,485	12,980	0	52,465
February	40,588	10,403	0	50,991
March	42,000	8,796	0	50,796
April	55,115	12,194	0	67,309
May	49,275	11,636	0	60,911
June	46,563	13,182	0	59,745
July	72,219	11,450	0	83,669
August	84,000	22,388	0	106,388
September	49,234	16,172	0	65,406
October	41,644	12,482	0	54,126
November	39,382	11,780	0	51,162
December	36,526	9,225	0	45,751
TOTAL	596,031	152,688	0	748,719

e. Average Daily Water Use: (1986)

1) First Colony M.U.D. No. 1	306,600	gal/day
2) First Colony M.U.D. No. 2	6,200	"
3) First Colony M.U.D. No. 3	0	"
4) First Colony M.U.D. No. 4	118,600	"
5) First Colony M.U.D. No. 5	32,200	"
6) First Colony M.U.D. No. 6	183,700	"
7) First Colony M.U.D. No. 8	22,300	"
8) Fort Bend County M.U.D. No. 12	886,600	"
9) Fort Bend County M.U.D. No. 13 (Internal District)	1,300	"
10) Fort Bend County M.U.D. No. 16	493,600	"
TOTAL	2,051,100	gal/day

f. Peak Daily Use: (1986)

1) First Colony M.U.D. No. 1	957,000	gal/day
2) First Colony M.U.D. No. 2	19,000	"
3) First Colony M.U.D. No. 3	0	"
4) First Colony M.U.D. No. 4	370,000	"
5) First Colony M.U.D. No. 5	100,000	"
6) First Colony M.U.D. No. 6	573,000	"
7) First Colony M.U.D. No. 8	70,000	"
8) Fort Bend County M.U.D. No. 12	2,766,000	"
9) Fort Bend County M.U.D. No. 13 (Internal District)	5,000	"
10) Fort Bend County M.U.D. No. 16	1,540,000	"
TOTAL	6,400,000	gal/day

g. Peak to Average Use Ratio: (1986)

1) First Colony M.U.D. No. 1	3.12
2) First Colony M.U.D. No. 2	3.06
3) First Colony M.U.D. No. 3	0
4) First Colony M.U.D. No. 4	3.12
5) First Colony M.U.D. No. 5	3.11
6) First Colony M.U.D. No. 6	3.13
7) First Colony M.U.D. No. 8	3.14
8) Fort Bend County M.U.D. No. 12	3.12
9) Fort Bend County M.U.D. No. 13 (Internal District)	3.85
10) Fort Bend County M.U.D. No. 16	3.12
AVERAGE	3.12

h. Unaccounted For Water: (% of water production) (1986)

1) First Colony M.U.D. No. 1	25
2) First Colony M.U.D. No. 2	25
3) First Colony M.U.D. No. 3	25
4) First Colony M.U.D. No. 4	25
5) First Colony M.U.D. No. 5	25
6) First Colony M.U.D. No. 6	25
7) First Colony M.U.D. No. 8	25
8) Fort Bend County M.U.D. No. 12	25
9) Fort Bend County M.U.D. No. 13 (Internal District)	25
10) Fort Bend County M.U.D. No. 16	25
TOTAL	25

6. Wastewater Information

a. Percent of Water Customers Served by Your Wastewater Treatment System: (1986)

1) First Colony M.U.D. No. 1	98.0
2) First Colony M.U.D. No. 2	0.0
3) First Colony M.U.D. No. 3	100.0
4) First Colony M.U.D. No. 4	43.0
5) First Colony M.U.D. No. 5	0.0
6) First Colony M.U.D. No. 6	0.0
7) First Colony M.U.D. No. 8	100.0
8) Fort Bend County M.U.D. No. 12	0.0
9) Fort Bend County M.U.D. No. 13 (Internal District)	0.0
10) Fort Bend County M.U.D. No 16	0.0
TOTAL	34.1

6. <u>Wastewater Information (con't)</u>

b. Percent of Water Customers Served by Septic Tank: (1986)

1) First Colony M.U.D. No. 1	0.0
2) First Colony M.U.D. No. 2	0.0
3) First Colony M.U.D. No. 3	0.0
4) First Colony M.U.D. No. 4	0.0
5) First Colony M.U.D. No. 5	0.0
6) First Colony M.U.D. No. 6	0.0
7) First Colony M.U.D. No. 8	0.0
8) Fort Bend County M.U.D. No. 12	0.0
9) Fort Bend County M.U.D. No. 13 (Internal District)	0.0
10) Fort Bend County M.U.D. No. 16	0.0
TOTAL	0.0

c. Percent of Water Customers Served by Another Wastewater Treatment System: (1986)

1) First Colony M.U.D. No. 1	2.0
2) First Colony M.U.D. No. 2	100.0
3) First Colony M.U.D. No. 3	0.0
4) First Colony M.U.D. No. 4	57.0
5) First Colony M.U.D. No. 5	100.0
6) First Colony M.U.D. No. 6	100.0
7) First Colony M.U.D. No. 8	100.0
8) Fort Bend County M.U.D. No. 12	100.0
9) Fort Bend County M.U.D. No. 13 (Internal District)	100.0
10) Fort Bend County M.U.D. No. 16	100.0
TOTAL	65.9

d. Percent of Total Potable Water Sales to the Three Categories Described in 6a, 6b, and 6c:

The percent of total potable water sales in this category will be the same as that described in 6a, 6b, and 6c.

e. Average Daily Volume of Wastewater Treated: (1986)

1) First Colony M.U.D. No. 1		gal/day
2) First Colony M.U.D. No. 2		"
3) First Colony M.U.D. No. 3		"
4) First Colony M.U.D. No. 4		"
5) First Colony M.U.D. No. 5		"
6) First Colony M.U.D. No. 6		"
7) First Colony M.U.D. No. 8		"
8) Fort Bend County M.U.D. No. 12		"
9) Fort Bend County M.U.D. No. 13 (Internal District)		"
10) Fort Bend County M.U.D. No. 16		"
Total		gal/day

6. Wastewater Information (con't)

f. Peak Daily Wastewater Volume: (1986)

1) First Colony M.U.D. No. 1	gal/day
2) First Colony M.U.D. No. 2	"
3) First Colony M.U.D. No. 3	"
4) First Colony M.U.D. No. 4	"
5) First Colony M.U.D. No. 5	"
6) First Colony M.U.D. No. 6	"
7) First Colony M.U.D. No. 8	"
8) Fort Bend County M.U.D. No. 12	"
9) Fort Bend County M.U.D. No. 13 (Internal District)	"
10) Fort Bend County M.U.D. No. 16	"
TOTAL	gal/day

g. Estimated Percent of Wastewater Flow to Treatment Plants (2) Originating From the Following Categories: (1986)

	RES	COMM	IND	STORMWATER
1) First Colony M.U.D. No. 1	89	1	0	10
2) First Colony M.U.D. No. 2	70	20	0	10
3) First Colony M.U.D. No. 3	90	0	0	10
4) First Colony M.U.D. No. 4	89	1	0	10
5) First Colony M.U.D. No. 5	60	30	0	10
6) First Colony M.U.D. No. 6	90	0	0	10
7) First Colony M.U.D. No. 8	90	0	0	10
8) Fort Bend County MUD NO.12	80	10	0	10
9) Fort Bend County MUD No.13 (Internal District)	0	90	0	10
10) Fort Bend County MUD No.16	85	5	0	10
TOTAL	74	16	0	10

7. Safe Annual Yield Of Water Supply

Since the Master District of Fort Bend County M.U.D. No. 13 supplies all water to other Districts, no breakdown will be made for each District.

Gal. per Year

8. Peak Daily Design Capacity

Since the Master District of Fort Bend County M.U.D. No. 13 supplies all water to other Districts, no breakdown will be made for each District.

16,256,000 Gal. per Day

9. Major High-Volume Customers: (1986)

a. First Colony M.U.D. No. 1	
Settlers Way Elementary School	2,266,000 gal/yr
b. First Colony M.U.D. No. 2	
O'Connell Building	912,000 gal/yr
Charter Hospital	467,000 gal/yr
c. First Colony M.U.D. No. 3	
	NONE
d. First Colony M.U.D. No. 4	
Sweetwater Country Club	6,039,000 gal/yr
First Colony Aquatic Center	1,347,000 gal/yr
e. First Colony M.U.D. No. 5	
William P. Clements Sr. High School	9,879,000 gal/yr
Villas of Sweetwater	1,066,000 gal/yr
f. First Colony M.U.D. No. 6	
Austin Colony Apartments	23,870,000 gal/yr
g. First Colony M.U.D. No. 8	
	NONE
h. Fort Bend County M.U.D. No. 12	
Towns of Grant's Lake Apts.	8,478,000 gal/yr
Colony Bend Jr. High School	7,354,000 gal/yr
i. Fort Bend County M.U.D. No. 13 (Internal District)	
Lexington Center Service	956,000 gal/yr
La Petite Academy	94,000 gal/yr
j. Fort Bend County M.U.D. No. 16	
Lions Head Apartments	14,545,000 gal/yr
Rivercrest Apartments	15,733,000 gal/yr

10. Population And Water Use Projections

	POPULATION	WATER USE (1000 gal/yr)
a. First Colony M.U.D. No. 1		
1986	4,025	111,931
1994	4,991	236,812
2003	4,991	236,812
b. First Colony M.U.D. No. 2		
1986	154	2,254
1994	1,260	59,787
2003	7,784	369,344

	POPULATION	WATER USE (1000 gal/yr)
c. First Colony M.U.D. No. 3		
1986	4	0
1994	4,758	224,074
2003	5,213	245,682
d. First Colony M.U.D. No. 4		
1986	767	43,308
1994	3,072	142,460
2003	3,229	142,460
e. First Colony M.U.D. No. 5		
1986	257	11,769
1994	3,115	160,637
2003	8,000	356,167
f. First Colony M.U.D. No. 6		
1986	1,941	67,057
1994	4,096	181,259
2003	8,119	355,985
g. First Colony M.U.D. No. 8		
1986	301	8,150
1994	4,067	192,976
2003	4,767	226,191
h. Fort Bend County M.U.D. No. 12		
1986	8,201	323,593
1994	12,713	580,533
2003	12,783	583,854
i. Fort Bend County M.U.D. No. 13 (Internal District)		
1986	~~0~~ 4	476
1994	3,696	175,383
2003	10,654	505,525
j. Fort Bend County M.U.D. No. 16		
1986	5,985	180,181
1994	7,231	317,331
2003	18,392	816,177
TOTAL		
1986	21,635	748,719
1994	48,999	2,271,252
2003	83,775	3,838,197

11. Percent Of Metered Water

	Residential	Commercial	Industrial
a. First Colony MUD No. 1	100	73	0
b. First Colony MUD No. 2	100	73	0
c. First Colony MUD No. 3	100	73	0
d. First Colony MUD No. 4	100	73	0
e. First Colony MUD No. 5	100	73	0
f. First Colony MUD No. 6	100	73	0
g. First Colony MUD No. 8	100	73	0
h. Fort Bend County MUD No. 12	100	73	0
i. Fort Bend County MUD No. 13 (Internal District)	100	73	0
j. Fort Bend County MUD No. 16	100	73	0
TOTAL	100	73	0

12. Water Rate Structures

a. First Colony M.U.D. No. 1

Residential
$6.00 Minimum
$1.00 per 1,000 Gal. over
Builder
$10.00 flat rate

b. First Colony M.U.D. No. 2

Residential
$6.00 for first 1,000 Gal.
$1.05 per 1,000 Gal. over
Sprinkler
$16.00 flat rate
Builder
Same as residential

c. First Colony M.U.D. No. 3

Residential
$5.00 for first 1,000 Gal.
$1.05 per 1,000 Gal over
Sprinkler and Non-Profit Org.
$16.00 flat rate
Builder
$20.00 flat rate
Commercial
Same as residential times no. of equivalent units

d. First Colony M.U.D. No. 4

Residential
$6.00 for first 1,000 Gal.
$1.05 per 1,000 Gal over
Builder and Sprinkler
$20.00 flat rate

e. First Colony M.U.D. No. 5

Residential
$6.00 for first 1,000 Gal.
$1.05 per 1,000 Gal over
Builder
$15.00 flat rate
Sprinkler
$16.00 flat rate

f. First Colony M.U.D. No. 6

Residential
$11.16 for first 7,000 Gal.
$0.88 per 1,000 Gal. over
Builder
$10.00 flat rate
Churches and Schools
$25.00 flat rate
Multi-Family
Same as residential times number of units

g. First Colony M.U.D. No. 8

Residential
$6.00 for first 1,000 Gal
$1.05 per 1,000 Gal. over
Builder
$16.00 flat rate
Sprinkler
$20.00 flat rate
Commercial
Same as residential

h. Fort Bend County M.U.D. No. 12

Residential
$6.00 for first 1,000 Gal.
$1.05 per 1,000 Gal. over
Builder
$15.00 flat rate
Sprinkler
$6.50 flat rate
Non-Profit Org.
$16.00 flat rate
Commercial
Same as residential
Multi-Family
Same as residential

i. Fort Bend County M.U.D. No. 13
(Internal District)

Residential
$5.00 Min.
$0.88 per 1,000 Gal.
Commercial
$5.00 times No. of SFEQ units
$0.88 per 1,000 Gal.
Multi-Family
$5.00 min. times No. of units
$0.88 per 1,000 Gal.

j. Fort Bend County M.U.D. No. 16

Residential
$5.00 Min.
$0.88 per 1,000 Gal.
Builder, Sprinkler, and Non-Profit Org.
Same as residential
Commercial
Same as residential times No. of SFRQ units
Multi-Family
Same as residential times No. of units

13. Average Annual Revenues From Water Sales: $578,000 (1986)

14. Average Annual Cost of Operation For Water: $527,000 (1986)

15. Applicable Local Regulations:

The only applicable regulations to the Districts in regards to water supply and distribution are the following:

a. 1982 Southern Standard Building Code with Appendix J

b. Water/Wastewater Contracts between the Master District (Ft. Bend M.U.D. No. 13) and the individual Water Districts

16. Applicable State, Federal and Other Regulations:

As a public supplier of water, Fort Bend County M.U.D. No. 13 must abide by rules under the following agencies:

a. Texas Water Commission
b. Texas Department of Health
c. Texas Water Development Board
d. Environmental Protection Agency

PUBLIC PARTICIPATION

As described in the Utility Evaluation Section of this Plan, the Master District assumes responsibility for providing water service to other Districts located within the Master District service area. This Section of the Plan describes Public Participation activities for the Master District as well as the other Water Districts within the service area.

1. First Colony M.U.D. No. 1:

   The Board of Directors for the Water District conducts regular meetings on the second Wednesday of each month. The meetings are open to the public, and citizens are free to express their opinions.

2. First Colony M.U.D. No. 2:

   The Board of Directors for the Water District does not have a regularly scheduled meeting day; however, a meeting notice is posted to inform the public of any scheduled meeting. All meetings are open to the public, and citizens are free to express their opinions.

3. First Colony M.U.D. No. 3:

   The Board of Directors for the Water District does not have a regularly scheduled meeting day; however, a meeting notice is posted to inform the public of any scheduled meeting. All meetings are open to the public, and citizens are free to express their opinions.

4. First Colony M.U.D. No. 4:

   The Board of Directors for the Water District conducts regular meetings on the third Friday of each month. The meetings are open to the public, and citizens are free to express their opinions.

5. First Colony M.U.D. No. 5:

   The Board of Directors for the Water District conducts regular meetings on the third Friday of each month. The meetings are open to the public, and citizens are free to express their opinions.

6. First Colony M.U.D. No. 6:

   The Board of Directors for the Water District conducts regular scheduled meetings on the first Tuesday of each momth. The meetings are open to the public, and citizens are free to express their opinions.

7. <u>First Colony M.U.D. No. 8</u>:

The Board of Directors for the Water District does not have a regularly scheduled meeting day; however, a meeting notice is posted to inform the public of any scheduled meeting. All meetings are open to the public, and citizens are free to express their opinions.

8. <u>Fort Bend County M.U.D. No. 12</u>:

The Board of Directors for the Water District conducts regular scheduled meetings on the second Tuesday of each month. The meetings are open to the public, and citizens are free to express their opinions.

9. <u>Fort Bend County M.U.D. No. 13</u>:
(Master District and Internal District)

The Board of Directors of the Water District conducts regular scheduled meetings on the second Thursday of each month. The meetings are open to the public, and citizens are free to express their opinions.

10. <u>Fort Bend County M.U.D. No. 16</u>:

The Board of Directors of the Water District conducts regular scheduled meetings on the third Tuesday of each month. The meetings are open to the public, and citizens are free to express their opinions.

11. In addition to the above-mentioned public meetings, the general public is invited to attend the following meetings and express their opinions:

a. Fort Bend County Chamber of Commerce
b. Various homeowner associations
c. Various civic and religious organizations

SYSTEM AUDIT AND PROBLEMS

As shown in Tables 5.d.11, 5.e., and 5.f., the monthly water use, average daily use, and peak daily use illustrate various use patterns for the calendar year 1986. These tables indicate that the service area is like most large residential areas, with higher average use in the summer months due to lawn irrigation. The ratio of peak water use to the average water use is 3.12, whict is higher than normal because of the relatively low amount of rainfall during 1986 and the high air temperatures.

Table 5h indicates that an average of 25 percent of all water produced by the Master District is unaccounted for. The difference between the amount of water produced by the Master District and the amount of water billed to the customers of each Water District can typically be attributed to all or some of the following:

1. Flushing of water mains
2. Unmetered irrigation systems
3. Unauthorized water use
4. Distribution system leaks
5. Inaccurate metering of wells and customer use
6. Fire fighting

The production, storage, and distribution systems curently serving the Master District are very adequate. All water is obtained from groundwater sources, and the only treatment is chlorination. The water is tested on a regular basis in accordance with EPA and Texas Department of Health regulations The Master District is well aware that expansion of the production, storage, an distribution systems will be required as more area within its boundary is developed. The District has no serious water supply problems at this time.

Currently, 34.1 percent of the present water customers are served by a wastewater treatment system owned by the Master District. The other 65.9 percer of the district's customers are served by a treatment system owned and operated by the Brazos River Authority. The Master District plans to construct a 5.0 million gallon per day treatment facility by 1990. The collection system will t altered to serve most of the customers within the Master District's service are

WATER CONSERVATION PLAN

There are two management methods of water conservation: the Customer or Demand Management method and the Production or Supply Management method.

The Customer or Demand Management Method relates to water use by the consumer. This management method has a goal reducing customer demand in the systems throu education or incentives.

The Production or Supply Management Method relates to the ability of the Distric to provide the customer with water. The goal of this management method is to operate the production, treatment, and distribution systems efficiently to reduc waste or losses, which results in decreased costs to the District.

Complete utilization of either these above management methods is not a practical solution to water conservation. A combination of the two methods is appropriate.

CUSTOMER OR DEMAND MANAGEMENT
ALTERNATIVES

There are several alternatives to promote water conservation by the consumer. These are education and information, plumbing codes, retrofit programs, rate orders, and landscaping. Each alternative is discussed in the following paragraphs.

1. <u>Education and Information</u>:

Education and information are the most readily available methods for promoting water conservation. Customers can be taught various means of conserving water inside homes and other buildings, in landscaping and lawn use, and in recreational uses. An effective education and information program can be administered by the Master District through its operator. Materials available from state and national organizations can be made available through mail-outs tc customers. Also, articles concerning water conservation can be printed in the local newspaper.

2. <u>Plumbing Codes</u>:

The Master District could require adoption of water-saving plumbing codes for new construction and replacement of plumbing in existing structures. Adoption of water-conserving plumbing codes could be specially tailored to the rate orders of each District within the Master District, or changes could be ma to the contracts between the Master District and each District within its servic area.

3. <u>Retrofit Programs</u>:

The Master District could make information available through an educational program for plumbers and customers to use when they purchase and install plumbing fixtures, lawn watering equipment, or other water-using appliances. Information regarding devices such as low-flow shower heads or toilet dams that reduce water use could be provided.

4. <u>Rate Orders</u>:

A water conservation-oriented rate order usually takes the form of an increasing block rate. Continuously increasing rate structures, peak or season load rates, excessive use fees, and other rate structures could be used. The increasing block rate is the most commonly used water conservation rate structure.

5. <u>Landscaping</u>:

The Master District could encourage water conserving methods, either through education or requirement, for all landscaping throughout the service area. The Master District could require that all landscaping water taps be metered, which would reduce unnecessary irrigation of green belt areas and provide better accounting of water used. The District could encourage the use of water conserving landscape plants and watering equipment.

PRODUCTION OR SUPPLY MANAGEMENT METHODS

The Master District has several alternatives for promoting water conservation. These methods include universal metering, leak detection and repair, and water reuse. The following paragraphs describe these alternatives.

1. Universal Metering:

The Master District could meter all its supply sources. In addition, all customers, including the District itself, should be metered. A regularly scheduled meter repair and replacement program could be established to ensure proper metering. Metering and meter repair and replacement could be used in conjunction with a leak detection program, which would save significant quantities of water.

2. Leak Detection and Repair:

A continuous leak detection, location, and repair program could be an important part of any water conservation program. The operator of the District should check for leaks while reading meters and driving through the service area to perform regular maintenance. Customers in the service area should report leaks as they become aware of them. Electronic, sonic leak detection devices should also be available and used by the operator.

3. Recycling and Reuse:

The potential of recycling and reuse of treated wastewater should be evaluated. In many cases, use of treated effluent water is proved to be economical. Recycling of in-plant process water can reduce the amount of fresh water required by industrial users.

WATER CONSERVATION PLAN

Based on an evaluation of all alternatives available to the Master District the following methods have been selected as best suited to meet the needs of water conservation:

1. Education and Information
2. Plumbing Codes
3. Retrofit Program
4. Rate Order
5. Universal Meeting
6. Meter Repair and Replacement
7. Leak Detection and Repair
8. Reuse and Recycling

It is the goal of the Water Conservation Plan to reduce water consumption by five percent per connection to the system.

1. Education and Information:

A program will be instituted to promote water conservation by the general public utilizing the following:

a. Educational and information materials distributed four times during the initial year of the program
b. Initial information to explain conservation plan - will coincide with published article in Fort Bend but Advocate.
c. Additional information to explain water conserving methods, including plumbing fixtures, landscaping, and conservative water uses
d. Additional material distributed semi-annually to coincide with peak summer and winter demand periods
e. Articles in Fort Bend Advocate on water conservation such as those listed in Appendix A

These materials can be obtained with assistance from the following organizations:

Texas Water Development Board
American Water Works Association
American Public Works Association

2. Plumbing Code:

The Water Districts within the Fort Bend County M.U.D. 13 Master District service area will adopt plumbing codes that are based on water conservation. T codes will apply to replacement of plumbing for existing structures as well as new construction.

3. Retrofit Program:

The Master District includes information in its educational program for customers and plumbers to use when they purchas and install various plumbing fixtures, irrigation equipment, and other water-saving devices. Information wi. also be provided concerning retrofit devices for conserving water.

4. Rate Orders:

Currently, each Water District within the Master District service area has an established rate order. In order to meet the requirements set out by the Texas Water Development Fund for conservation-oriented rate structures, each district will implement conservation-oriented rate structures as soon as possible. However, each district will be given one year from the date of this plan to convert to the new rate structure.

5. Universal Metering:

Currently, all Water Districts within the service area (except some green belt area) meter all water sales from their systems. Within one year from the date of this Plan, all water users will be metered. All water wells are currently metered at the well head. The program of universal metering will continue and is a part of this Plan.

6. <u>Meter Repair and Replacement</u>:

Currently, there is no formal meter repair and replacement program in any of the Water Districts within the service area. The operator for each district will establish the following meter repair and testing program:

a. Production meters - test once each year and repair as needed
b. Meters larger than 4 inches - test once each year and repair as needed
c. Meters between 1 inch and 4 inches - test once every five years and repair as needed
d. Meters smaller than 1 inch - test once every 10 years and replace as needed

The program will be adopted by all Water Districts.

7. <u>Leak Detection and Repair</u>:

The Districts that form the Master District's service area have a formal leak detection and repair program that will be maintained. This program include the following:

a. Monthly water use accounting by the operator which identifies high water use
b. Visual inspection by the operator of abnormal conditions indicating leaks
c. An adequate maintenance staff provided by the operator to repair any leaks
d. Leak detection equipment owned by the operator to determine non-visibl leaks and pinpoint hard-to-find meters.

8. <u>Reuse and Recycling</u>:

Currently, treated effluent from the existing wastewater treatment facility is being used to wash down the plant. Plans exist for the treated effluent to b used for washdown and irrigation purposes at the new treatment facility. Also, effluent could be used for chlorination water.

IMPLEMENTATION AND ENFORCEMENT

The operator of the Master District will act as Administrator of the Water Conservation Plan. The Administrator will oversee execution and implementation of all elements of the program. He will also be responsible for program verification and records keeping. Each Water District will be responsible for furnishing all information requested by the Master District.

In addition, the operator will be responsible for submitting an annual report to the Texas Water Development Board concerning the Water Conservation Plan. The report will include but not be limited to the following elements:

1. Progress made on implementing the program
2. Public response to the program
3. Program's effectiveness in achieving goal

The Water Conservation Plan will be enforced through the adoption of resolutions by each Water District and the Master District. Each District will provide certified copies of all resolutions concerning water rates, plumbing codes, and other regulatory documents necessary for administration of this Plan, as well as any revisions or updates.

DROUGHT CONTINGENCY PLAN

There are a number of uncontrollable circumstances that can disrupt currently normal availability of water supplies, including drought. A service area may presently have an adequate water supply system; however, the supply could become contaminated or destroyed by a disaster. Customer demands are ofte greater during drought periods than during normal periods. Older systems or systems serving rapidly developing areas may not have enough capacity to provide higher-than-normal demands during droughts. These high-demand periods result ir system failures. Failures of the treatment, storage, or distribution system often result in emergency demand management situations.

Water conservation planning and drought contingency planning are significantly different. Water conservation planning involves implementation oi permanent efficient water use, whereas drought contingency planning establishes temporary constraints designed for use onlu as long as an emergency exists. The following seven elements provide a sound base for an effective Drought Contingency Plan:

1. Trigger conditions that signal the beginning of a possible emergency situation
2. Drought contingency measures
3. Drought contingency procedures
4. Education and information
5. Implementation and enforcement
6. Abatement procedures
7. Plan revisions and updates

SYSTEM LIMITATIONS

The Fort Bend County M.U.D. No. 13 Master District comprises different Wate Districts. The Master District, through contracts, sells water to each Water District. The Master District currently has three wells with capacities of 2,4C gallons per minute each. The booster pump capacity is 9,500 gallons per minute or 1.3 times the production capacity. Additional production, storage, and pumping capacities are being planned.

TRIGGER CONDITIONS

To develop an effective Drought Contingency Plan, certain production conditionsthat indicate the beginning of emergency periods must be analyzed. Fo the purpose of this Plan, these production conditions, called trigger condition have been established and are based on a seven-day average daily demand.

1. Mild Condition:

   Demand approaching 80 per cent of the production capacity or 8.3 million gallons per day

2. Moderate Condition:

   Demand approaching 90 per cent of the production capacity or 9.3 million gallons per day

3. Severe Condition:

   Demand approaching 100 per cent of the production capacity or 10.3 million gallons per day

4. Critical Condition:

   Demand exceeding 100% of the production capacity or 10.3 million gallons per day

EMERGENCY MANAGEMENT PROGRAM

The following actions will be taken by the operator for the Master District when various trigger conditions are reached:

1. Mild Conditions:

   a. Inform the public through the news media that a mild drought exists and that the public should voluntarily reduce water use. The news media will be used to announce specific steps that should be taken.

   b. Notify all major commercial water users of the situation and request voluntary reduction of water use.

   c. Notify the news media and, distribute individual mail-outs to publicize a voluntary lawn watering schedule, as well as proper methods and times to water lawns.

   d. Initiate a publicity campaign requesting water users to insulate exposed water pipes rather than running water to prevent freezin during winter months.

2. Moderate Condition:

   a. Continue implementing all actions under Mild Condition.

   b. Publicize information announcing prohibition of all car washing, window washing, and pavement washing except when a bucket is use

   c. Publicize information announcing a mandatory lawn watering schedule

Customers with odd-numbered street addresses would water on odd-numbered days and customers with even-numbered street addresses would water on even-numbered days. Watering would be permitted only between the hours of 6 a.m. - 10 a.m. and 8 p.m. - 10 p.m.

d. Publicize policy that prohibits all public water uses not essential for public health and safety such as:

1. Driveway and street washing
2. Fire hydrant flushing
3. Filling of swimming pools
4. Athletic field watering

3. Severe Conditions:

a. Continue implementing all actions under Moderate Condition.

b. Prohibit all outdoor use of water, such as lawn watering, car washing, and pavement washing.

c. Implement a surcharge on the water bills for excessive water users, as follows:

5/8" meter - over 6,000 gal/month	200%
1" - 1-1/2" - over 10,000 gal/month	200%
2" and larger meter - over 20,000 gal/month	300%

4. Critical Condition:

a. Continue implementing all actions under Severe Condition.

b. In selected portions of the service area, ration or terminate water service according to the following order:

1. Institutional users
2. Commercial users
3. Residential users

EDUCATION AND INFORMATION

As with the Education and Information Section of the Water Conservation Plan, the purpose and conditions of the Drought Contingency Plan will be publicized in the Fort Bend County Advocate. These articles will be supplement by mail-outs with water bills. The public will be notified of approaching trigger conditions by announcements in the Advocate. The announcements will include information concerning water conserving methods.

While each trigger condition is in effect, articles will appear regularly the Advocate to educate and explain to the public the purpose, cause, and metho of conservation for that trigger condition. As trigger conditions pass, the Advocate will publish information that drought contingency measures are abated for that condition and will describe necessary measures for returning to a reduced condition.

IMPLEMENTATION AND ENFORCEMENT

The operator for the Master District will monitor the status of the water supply and distribution system. The operator will notify each Water Board President when a trigger condition is reached and actions that will be taken.

The operator will monitor the emergency until it is determined that the trigger condition no longer exists. The operator will then notify each Board President of such, and abatement procedures will be implemented.

UPDATE OF PLAN

Once each year, the operator will examine production capacities and requirements. Should the operator determine that trigger conditions need to be revised, the operator will amend the Drought Contingency Plan. Each Water District will be notified of any update of this Plan.

McBride-Ratcliff
and Associates, Inc.

Geotechnical Consultants
7220 Langtry
Houston, Texas 77040
713-460-3766

May 18, 1988

Pate/Jones & Carter A Joint Venture
c/o Pate Engineers
13403 Northwest Freeway, Suite 160
Houston, Texas 77040

ATTENTION: Mr. Alex Sutton, P.E.

SUBJECT: Transmittal of Final Report
Groundwater Evaluation, Regional Water Supply Planning Study
City of Sugarland and the Fort Bend County Water Control and Improvement District No. 2
MRA File No: 87-338

Gentlemen:

Transmitted herein are the results for the above referenced program. Two hydrologic scenarios have been modeled using a three dimensional finite difference program. The results of these scenarios were input to calculate subsidence using the PRESS model program. This report outlines the hydrogeologic setting, methodlogy of scenario development, the modelling processes, and results.

It has been a pleasure to be of service to you. Please call if you have any questions.

Sincerely,

McBRIDE-RATCLIFF AND ASSOCIATES, INC.

J. L. Ireland, C.P.G.
Vice President

JLI:ka:wp

FIGURES

SUMMARY

A groundwater study was performed for the Sugarland area of Fort Bend County in an effort to evaluate what factors would affect the withdrawal of groundwater by the year 2030. Factors considered for the study included the availability of groundwater to meet population demand, ground surface subsidence, and possible contamination of wells from a natural occurring salt water plume from the Blue Ridge Salt Dome.

The study area draws groundwater from the Chicot and Evangeline aquifers which lie in formations of the Quaternary period. Two salt domes are nearby the study area but only one, the Blue Ridge Salt Dome, is a piercement structure that penetrates the aquifers and can cause salt water contamination of the aquifers.

Groundwater elevation changes were modelled using MODFLOW, the USGS three dimensional finite-difference groundwater flow model, and calibrated using historical information.

Two pumpage scenarios were performed using MODFLOW; the first called for all demands to be met by groundwater except for an area in Harris County that received some amount of surface water, the second requires that the groundwater pumpage in the model area be reduced to twenty percent of total demand in the year 2000 with areas in Harris County meeting demands only partially with ground water.

The model calculated water level data indicating that at no time did the Evangeline lose its artesian condition and go to a gravity condition.

The resulting water level data was also used to model subsidence using the PRESS model. Subsidence ranged from about four feet to over seven feet by the year 2030 depending on the pumpage scenario used.

Water level changes and aquifer parameters were used to evaluate salt water contamination from the Blue Ridge Salt Dome. The results of the analyses (bracketed to the year 2030) were that the wells in the study area should not be impacted by the salt water plume from the salt dome.

INTRODUCTION

General

This project is directed at evaluating groundwater supply for the Regional Water Supply Planning Study, City of Sugar Land and the Fort Bend County Water Control and Improvement District No. 2. McBride-Ratcliff and Associates has been contracted by Pate/Jones and Carter, a Joint Venture, to provide geologic, hydrogeologic and geotechnical services for the program. The model area is shown on Figure 1.

Project Description

The project involves an evaluation of the quantity of groundwater that is available to the study area for water supply, its distribution, and expected drawdown and subsidence associated with the withdrawal of groundwater. The general time frame to be addressed by the study is from the present to the year 2030. Additionally, the evaluation included an analysis to identify if salt water migration from salt domes would propose a risk to water quality.

Scope of Work

The thrust of the study was to do the following:

a) Assemble available data on existing wells and plans for new wells;

b) Assemble oil and gas well logs for the area;

c) Review previous studies on groundwater withdrawal and subsidence for various municipalities, municipal utility districts, and special districts and agencies within the study area;

d) Develop a geologic model for the major aquifers, and delineate recharge zones and discharge zones;

e) Reorganize the studies and data bases from a regional geologic perspective;

f) Compartmentalize the study area on the basis of common geology, hydrogeology and groundwater usage;

g) Model two ground water extraction scenarios involving groundwater withdrawal at unique prescribed rates and with given well distributions; and

h) Use the computed drawdown and subsidence patterns from those studies to draw conclusions concerning the future water supply from well fields in the study area.

GEOLOGIC SETTING

General

This section presents the regional and site specific geologic setting of the model area (Figure 2), the stratigraphic units associated with the geologic setting, and the assessment of the impact of geologic faulting on the hydrogeologic regime. The geologic parameters presented herein are based upon an evaluation of existing United States Geological Survey (U.S.G.S.) and Texas Water Commission reports covering the study area.

Geography

The model area is situated within the Gulf Coastal Plain of Texas. The Gulf Coastal Plain includes the area located between the Balcones Fault Zone, near San Antonio, Texas, to the continental slope which is located off-shore within the Gulf of Mexico (Hunt, 1967). The surface area varies from rolling hills north of the greater Houston area to the rather flat featureless surface found adjacent to the coast line. Regional uplift, subsidence, and surface erosion formed the present day surfaces.

Surface drainage for the Gulf Coastal Plain is accomplished by numerous rivers and their tributaries. The Brazos River and the San Jacinto River are the largest river systems in the general vicinity of the model area.

Geology

General. The geologic interpretations have been developed by a review of geologic literature concentrating on Gulf Coast Quaternary and Tertiary geology, and analysis of regional topographic and geologic maps of the greater Houston and Gulf Coast area, and our geologic experience with depositional environments within the Gulf Coastal Plain of Texas.

Regional Geologic Setting. The regional setting includes geologic formations of the Quaternary and upper Tertiary Gulf Coastal Plain of Texas. The geologic formations addressed in this section comprise the primary hydrogeologic units in the Sugar Land - Stafford vicinity. These formations include the following:

TABLE 1
GEOLOGIC SCALE

PERIOD	EPOCH	FORMATION	AQUIFER
Quaternary	Holocene		
	Pleistocene	Beaumont	
		Lissie	Chicot
		Willis	Evangeline
Tertiary	Pliocene	Goliad	Evangeline
	Miocene	Fleming	Jasper

Upper Tertiary, Fleming and Goliad sediments were deposited by fluvial and deltaic processes approximately 2 to 5 million years ago. The Fleming crops out approximately 45-50 miles north of the study area (Fisher, 1974). The estimated thickness of the Fleming Formation is on the order of 1100 ft. The surface outcrop of the Goliad Formation is not found east of the Colorado River due to erosion and subsequent burial of the Goliad by Willis sediments. The estimated thickness of the Goliad is on the order of 250 ft.

The model area (Figure 2) lies within surficial sediments of the Quaternary Period. Quaternary sediments consist of series of coalescing alluvial, deltaic and coastal interdeltaic plains deposited principally by the major river systems and coastal processes.

The youngest Quaternary plain is a recent (post-glacial) depositional surface 10,000 years of age. The recent sediments are primarily located along the coast and present flood basins. Older Quaternary plains were deposited during the Pleistocene Epoch. These plains include the following: Beaumont (25,000 to 65,000 years old), Lissie (100,000 to 675,000 years old), and the Willis Formations (750,000 to 1,250,000 years old).

<u>Site Geology</u>. Geology for the model area was developed from a review of geologic literature and geophysical logs of water and petroleum wells in the Sugar Land - Stafford vicinity.

Alluvium and the Beaumont formation comprise the geologic surface units of the investigated area. The alluvial sediments are clay, silt and sand deposited predominantly from the Brazos River. The older Beaumont formation is made up of similar types of materials. The underlying Lissie formation consists of sediments which have been deposited in distributary channel fill and interdistributary flood basin depositional environments. The sources of these sediments were abandoned channel systems of the Brazos River. The Lissie consists of a series of alternating sand and clay sequences with an average thickness of approximately 250 ft throughout the model area.

The Willis Formation underlies the Lissie and consists primarily of fluvial sands and interbedded clays. The average thickness of the Willis is on the order of 670 ft, encountered between elevations of approximately -150 to -850 ft.

The Willis Formation is underlain by the Goliad Formation. Sediments of the Goliad Formation consist predominantly of sands which resemble those of the overlying Willis. The thickness of the Goliad is on the order of 120 ft in the model area, encountered between elevations of -850 to -1000 ft.

Sediments of the Fleming Formation underlie the Goliad between elevations of approximately -1000 to 1800-ft. The Fleming Formation consists predominantly of a clay section with interlayered sands. The sand units vary in thickness and exhibit lateral transitions from sand to clay.

Geologic Faulting. This section presents an evaluation of the geologic fault conditions in the vicinity of the project area. The Sugar Land - Stafford Study Area is situated within the Gulf Coastal Plain physiographic region. The sediments of this region have been affected by the movement of faults which originated with Tertiary period deposition of delta-front sands against prodelta clays (Kreitler, 1976) over ancient continental slopes. The fault planes started as slump failures and continued forming contemporaneously and continuously with deposition. Due to this contemporaneous development the term "growth fault" has been given to the faults located along the Gulf Coastal Plain.

The locations of documented surface faults in the general vicinity of the ground water evaluation area are illustrated on Figure 2.

Based upon our analysis of the surface traces of faults in the site vicinity and subsurface stratigraphy, the existing wells in the Sugar Land - Stafford area are not impacted by faults.

HYDROGEOLOGY

Introduction

The Texas Coastal Plain is characterized by several hydrogeologic units spanning Tertiary and Quaternary time periods (Table 1). Hydrogeologic units are distinguished by characteristic hydrologic and stratigraphic properties. Variations in lithology both laterally and vertically results in unit boundaries which are time-stratigraphic.

Hydrogeologic unit boundaries are identified by evaluation of formation outcrops, geophysical log interpretation, and analysis of well production data including static water levels, water level fluctuation, and aquifer properties. Delineation and correlation of hydrogeologic units is focused on post-Oligocene strata which are predominate in supplying groundwater to the Texas Coastal Plain. As outlined by Baker (1979), post-Oligocene hydrogeologic units include the Catahoula confining system, Jasper aquifer, Burkeville confining system, Evangeline aquifer and Chicot aquifer.

The Jasper, Evangeline, and Chicot Aquifers were deposited in shallow waters by rivers and riverene deltas along the coast. What is seen in profile is not a single, thick water bearing layer confined by impermeable clay layers, but dozens of sand and clay layers. The Chicot, Evangeline, and Jasper aquifers fit the definition of an aquifer system of Lofgren and Klausing (1969) as a heterogeneous body of intercalated permeable and poorly permeable material that functions regionally as a water yielding hydraulic unit.

Regional Hydrogeology

The Catahoula Confining System. The Catahoula confining system is composed predominantly of clay and tuff and acts as a hydrologic barrier between the overlying Jasper aquifer and underlying aquifers. The base of the Catahoula confining system is a time-stratigraphic unit corresponding to the base of the Catahoula formation. The top of the Catahoula confining system, however, is delineated lithologically on the basis of hydrologic properties and does not coincide with the top of the Catahoula formation which in many areas contains abundant amounts of sand.

Jasper Aquifer. The Jasper aquifer is recognized as a rock-stratigraphic unit delineated on the basis of lithology. As a result, the aquifer is geometrically irregular with boundaries which are independent of formation contacts. The lower boundary of the Jasper aquifer ranges from the base of the Fleming Formation to lying within the Catahoula. The top of the aquifer ranges from the Fleming Formation to the Oakville Sandstone. The Jasper aquifer exhibits several distinct sand layers containing zones of fresh to highly saline water varying with aquifer thickness and proximity to the coastline. The Jasper is brackish in the study area.

Burkeville Confining System. The Burkeville confining system acts as a hydrologic barrier inhibiting groundwater flow between the underlying Jasper and overlying Evangeline aquifers. The unit is composed predominately of clay and silt yet contains individual sand layers permeated with fresh to slightly saline water. The Burkeville confining system is delineated lithologically with boundaries which fall within the Fleming Formation and at the Fleming/Oakville Sandstone contact where the Oakville is present.

Evangeline Aquifer. The Evangeline aquifer is delineated as a rock-stratigraphic unit composed typically of the Goliad Sand and the upper Fleming Formation which contains interbedded sand and clay layers. In some areas the Evangeline includes lower Pleistocene sands which are lithologically similar to the underlying Goliad. Characteristic thick sands within the Evangeline yield abundant supplies of good quality groundwater throughout most of the Texas Coastal Plain.

Chicot Aquifer. The Chicot aquifer is the youngest aquifer in the Texas Coastal Plain and is characterized by high percentages of sand which diminish southwest of Goliad County. The base of the Chicot is typically delineated at the base of the Pleistocene which includes the Willis, Lissie, and Beaumont Formations. At many locations, however, the base of the Pleistocene is difficult to distinguish from strata of the Goliad and Fleming Formations. In these instances, prominent marker beds located on well logs are used to delineate the base of the Chicot.

Site Hydrogeology

General. Site hydrogeology was evaluated with analysis of ground water publications pertaining to the Sugar Land - Stafford vicinity, United States Geological Survey (U.S.G.S.) well records and publications, and interpretation of electric geophysical logs of water and petroleum wells in the site area. The extent of hydrologic unit delineation is limited to the upper 2500 feet of sediments which have historically produced ground water of good quality and supply.

Hydrogeologic evaluation of the study area has revealed a system of two aquifers: the Chicot and Evangeline. The aquifers are characterized by distinct transmissivities resulting from variation in sand and clay composition.

Jorgensen (1975), subdivides the Chicot aquifer into upper and lower units. This differentiation is based on a predominance of clay in the upper portions of the Chicot and a massive heavily pumped sand zone in the lower portions of the Chicot aquifer. It has also been found that the upper portions of the Chicot aquifer (approximately 100 to 200 feet below ground surface) is only partially saturated and typically more highly mineralized groundwater than that in deeper zones (Gabrysch, 1980). Because of the limited availability of quality ground water in the upper Chicot aquifer, description of aquifer characteristics and ground water modeling pertains only to the lower Chicot aquifer.

<u>Burkeville Confining System</u>. The Burkeville confining system constitutes basal strata of the Fleming formation and, as shown by wells penetrating the Burkeville, consists predominately of clay with sand interbeds typically 5 to 10 feet thick. Transmissibility values are considerably lower than those of the overlying Evangeline aquifer, thus the Burkeville acts as a barrier retarding the flow of ground water from the Evangeline to units below.

<u>Evangeline Aquifer</u>. The lower surface of the Evangeline aquifer correlates with the top of the Fleming Formation. Sediments are characterized dominantly as clays with sand interbeds ranging from 10 to 50 feet thick in the lower 500 feet while the upper 800 to 1000 ft is dominantly characterized as sands with clay

interbeds of 5 to 50 feet. The Evangeline aquifer ranges from about 1700 to 1900 ft in thickness, but the basal 300 ft, which is dominantly clays, is brackish.

Chicot Aquifer. The top of the Chicot aquifer is interpreted to lie at the Lissie-Willis formation contact. Indicated by electric well log data, the Chicot is characterized by a predominance of sand with clay interbeds from 10 to 50 feet thick. The Chicot aquifer ranges from about 400 ft to 450 ft in thickness in the area, and contains fresh water throughout.

Aquifer Recharge

Chicot Aquifer. Water levels in wells penetrating the Chicot at various depths indicate a decrease in aquifer head with depth. This suggests that the Chicot is a recharge aquifer system characterized by downward flow of groundwater in response to a hydraulic gradient.

The alluvial valley of the Brazos River has been mapped as recharge zone for the Chicot aquifer (Gabrysch, 1977). Based upon analyses of stratigraphy, water quality, and water levels there is no evidence to support this conclusion relative to the Chicot aquifer zone. Recharge to the Chicot is chiefly based on lateral flow through the aquifer.

Groundwater Discharge. Groundwater discharge in the study area is due to groundwater withdrawal from wells and leakage to the underlying Evangeline Aquifer. Historic pumpage will be discussed in a later section.

Evangeline Aquifer. Like the Chicot, water wells penetrating the Evangeline aquifer indicate a zone of ground water recharge. The Evangeline does not outcrop in the study area. Recharge to the

Evangeline occurs as the result of groundwater leakage from the overlying Chicot aquifer.

Historic Pumpage, Groundwater Decline, and Historic Subsidence
Prior to 1940 the chief utilization for groundwater throughout the greater portion of the study area and surrounding environs was for agricultural purposes. The Fort Bend County Area was a major center for sugarcane as well as rice cultivation. Both crops were irrigated within the area. The agricultural use of the groundwater supplies remained relatively consistent until the later 1960's and early 1970's. The growth of greater Houston area brought urban development into the Fort Bend County area such that major pumpage began in southwestern sectors of Houston as well as the Cities of Sugarland, Stafford, and Missouri City. Several utility districts were created in the late 1970's up and through the 1980's which draw upon groundwater as a chief water supply.

The current pumpage in the model area is about 20 million gallons per day. The pumpage immediately to the east in the greater Houston area is about 250-300 mgpd. Groundwater levels have been declining in both the Chicot and Evangeline Aquifers in response to this pumpage. Water levels have declined between 100-150 ft within the Chicot Aquifer within the greater study area and 175-200 ft within the Evangeline Aquifer since 1940.

Historic Subsidence has been about 2 ft in the model area since 1940 to the period of about 1975.

Historic Hydrologic Modelling and Subsidence Modelling
Since about the middle sixties, considerable emphasis has been placed upon the construction of ground water models. Some, such as the Gulf Coast Model Study (Carr, Meyer, Sandeen & McLane, 1974), covered the area from Lake Charles, Louisiana to

Falfurrias, Texas. Due to the unavailability of data in Mexico, it was not possible to carry that model as far south as had been originally intended. The Houston Area was included in all of the models listed (Table 2).

Authors	Year Published	Type	Size of Area Modeled (Sq. Miles)	Period of Years Covered	No. of Layers	Comments
Wood & Gabrysch	1965	Analog	5000	1890-1965	2 4	Drawdown, Distribution
Jorgensen	1975	Elect. Analog	9100	1890-1970	4	Drawdown, Dis. & Subsidence
Meyer & Carr	1979	Digital Analog	27000	1890-1975	5	Subsidence Distribution
Muller & Price	1979	DO	61500	1960-1969	2	Added sub-areas Drawdown: 2020
Espey Huston Associates	1982	DO	8400	1960-1980	20	Added 2 scen-arios: 2020
Carr, Meyer Sandeen, & McLane	1984	Digital Analog	100000	1890-1975 1900-1975	5	Covered area: Lake Charles to Falfurrias
Law Engineering	1986-7	Modular 3/D-Fin.	22000	1900-1983	7a	Covered 22 counties.

Note:
a: Includes the Jasper aquifer.

Table 2 - Comparison of representative model studies which include the Houston Area.

Most models contain scenarios which predict subsidence and decline. Substantial overlap occurs on some models.

Such studies developed a means for predicting water level declines in the Chicot and Evangeline aquifers. They also simulated declines of the potentiometric surfaces and subsidence of the land-surface. Some scenarios projected water level declines far into the future (year 2020). Now that eastern Harris County has turned to the use of surface water some of these projections are merely academic.

Nearly all of these studies were cooperative projects that were funded in part by one or more of the following agencies: U.S. Geological Survey, Harris Galveston Subsidence District, Texas

Water Development Board and the City of Houston.

Description of the Hydrologic Model and Subsidence Model for this Investigation

Hydrologic Model

The groundwater model, MODFLOW, selected for the program was authored by McDonald and Harbough (1985) of the U.S. Geological Survey.

MODFLOW is a finite-difference model simulating ground water flow in three dimensions. Groundwater flow within the aquifer is simulated using a block-centered finite-difference approach. Layers can be simulated as confined, unconfined, or a combination of confined and unconfined. Flow from external stresses, such as flow to wells, areal recharge, evapotranspiration, flow to drains, and flow through riverbeds, can also be simulated. The finite-difference equations can be solved using either the Strongly Implicit Procedure of Slice-Successive Overrelaxation.

The computer program is written in a modular form. It consists of a main program and a series of highly independent subroutines called "modules". The modules are grouped into "packages". Each package deals with a specific feature of the hydrologic system which is to be simulated.

The model grid utilized was a 33 x 33 x 2 grid, Figure 3. The Chicot and Evangeline aquifers were modeled as one layer each with the clays separating the layers as a leakance between the two layers. A 15 x 15 cell area in the center of the grid was utilized in the model area with the size of the cell in this area being 6000 ft on a side. The cells increase in size away from the central area by a factor of 1.4 until the boundary which is about 80 miles away from the study area. The boundary was placed this far away to minimize the influence of artificial model boundaries on the area of interest.

<u>Subsidence Modelling</u>

The model utilized for subsidence analyses was the PRESS Model. The PRESS Model utilized by McBride-Ratcliff is essentially the same as that utilized by Espey Huston and Associates for their study for the Harris Galveston County Subsidence District (HGCSD) in 1982. The program has been modified such that program execution can be accomplished on a personal computer.

The program was initially developed by Dr. Donald C. Helm for one-dimensional simulation of aquifer system compaction using constant parameters (Helm, 1975). The input requirements have been modified to increase the flexibility of the program for handling multiple aquifers and to simplify input preparation. Out options have been added to accept empirical correlations of computed with observed results.

The program computes the ground surface subsidence resulting from a given change in potentiometric head within a system of aquifers. Both virgin and rebound compressibilities of the clay layers (aquitards) existing within aquifers are taken into account. The aggregate ground surface subsidence as a function of time is computed by summing the individual contributions of the clay layers. The program uses one-dimensional Terzaghi consolidation theory with some simplification of parameter descriptions to relate a time history of potentiometric head change to a time history of subsidence. Calibration of the model to historically measured subsidence and potentiometric head changes in a given area allows predictions of future subsidence to be made for various input conditions of projected head changes.

The subsidence resulting from groundwater withdrawal is assumed to be attributable only to the consolidation of clay layers within the aquifers experiencing changes in potentiometric head. The consolidation of sand strata is assumed to be insignificant compared to that of the fine-grained materials.

The consolidation (or compaction) of the clay layers is assumed to be one-dimensional and related to the changes in effective vertical stress in the clay. This concept is generally referred to as "Terzaghi one-dimensional consolidation theory" soils loaded by structures (Terzaghi and Peck, 1967; Terzaghi, 1925). This approach has been shown to be well-suited to determination of subsidence of the ground surface as a result of loading the clays by drawing down the potentiometric surface of the water within an aquifer.

Properties and Parameters Input to Model

Hydrologic Properties

The hydrologic properties input for the model were based upon published data from the U.S. Geological Survey and analyses of pump tests, geophysical logs, and drillers logs. The geometry and hydrologic properties beyond the study area were obtained from published U.S. Geological Survey Reports. The hydrologic properties with the study area published in the U.S.G.S. reports were analyzed against on-site data and were often modified slightly as a result of having a more intensive data base.

Outlined in the following are data sources and a discussion of the properties assigned.

Aquifer Geometry

The geometry of the Chicot Aquifer was obtained in the study area by analyses of 50 drillers logs, geophysical logs, and oil field logs. The basis for the geometric evaluation was a check of a map published by Wesselman, 1972 for the aquifer base. The aquifer top was assigned from analyses of logs. The Blue Ridge and Sugarland salt domes were both within the study area. The Blue Ridge (Figure 2) dome is a total piercement done through the aquifer, therefore no aquifer is present in this area, while the Sugarland Dome does not pierce the aquifer but does deform the sediments over the done.

The geometry of the Chicot Aquifer beyond the study area was obtained from Meyer and others, 1985.

The geometry of the Evangeline Aquifer in the study area was identified for analyses of maps published by Wesselman, 1972 and geophysical logs. The geometry beyond the study area was obtained from Meyer and others, 1985.

Transmissivity, Storage Coefficients, and Leakage

Transmissivity values and storage coefficients for the Chicot and Evangeline Aquifers in the study area were based principally on values assigned by Meyer and Carr, 1975 with checking based on pump test data for the study area. The Meyer and Carr data was utilized for the area beyond the intense study grid area. This information was obtained on tape and transferred to the model grid area. Values of transmissivity for the Chicot Aquifer and Evangeline Aquifer ranged from 7000 to 9000 ft^2/day in the study area.

Leakage values between the Chicot and Evangeline Aquifers where assigned for the study and surrounding area were obtained from Meyer and Carr, 1975. No vertical leakage from ground surface to the lower Chicot aquifer was assigned therefore no vertical recharge was modelled.

Geotechnical Parameter for Subsidence Evaluation

Key factors which contribute to the evaluation of subsidence are:

- o hydraulic conductivity
- o virgin specific storage and
- o elastic specific storage

The hydraulic conductivity is the ability of the layer to transmit water per unit time per unit area. The elastic specific storage and virgin specific storage define terms that identify elastic compressibility of layers at low stresses, and virgin compressibility of layers that exceed preconsolidation stress.

The goals of the subsidence analyses for the study area were to reproduce the historical subsidence as closely as possible with PRESS, and use this calibrated model to predict future subsidence. Development of the model involved integration of the results of the area geology, base hydrogeologic modelling and the geotechnical data. The geologic analyses were used to evaluate the subsurface stratigraphy, and stress history of the relevant zones. The hydrogeologic model was used to estimate historical stress changes due to groundwater withdrawal, and to predict future stress conditions.

Historic pumpage and resultant groundwater declines were utilized to calibrate the hydrologic models for the years 1973 and 1984. Historic pumpage was allocated per grid cell per aquifer based upon well and pumpage data from Meyer and Carr, 1979 for the year 1974. The pumpage was cast upon water level input that simulated water levels in the Chicot and Evangeline aquifers at the end of 1973. The results for the 1974 calibration analysis are shown on Figures 4 and 5.

Historic pumpage for the period 1975 to 1984 was obtained from file data from the Texas Water Commission. Individual wells and historic pumpage were assigned per each grid for the area of study. The model was then run to calibrate the potentiometric surface for 1984.

The geotechnical model parameters were developed using Harris Galveston County Subsidence District (HGCSD) PRESS data values for the USGS Addicks compaction monitor site. Regression analyses were performed on the values of permeability, elastic specific storage, and virgin specific storage with respect to depth. The resulting fitted values are judged to be reasonable first approximations with respect to magnitude and variation with depth and were used directly in this study. Preconsolidation stresses in the HGCSD data ranged from 0 (normally consolidated) to 100 feet of water. An average value of 50 feet of water was used as the preconsolidation stress, since it was judged that this value was more representative.

Three well locations were selected around the study area for calibration of the PRESS model. Selection of the locations was based on the availability of relatively deep geophysical well logs together with historic benchmark leveling data near the wells. The geophysical logs were interpreted to obtain clay layer thicknesses with depth, and values estimate of hydraulic conductivity elastic specific storage and virgin specific storage were assigned to each layer based on the regression analyses for each soil property.

The historical aquifer declines developed during the hydrologic study were estimated for each well location, and the PRESS model was used to predict historical subsidence. The predictions of rate of subsidence were quite good, with the predicted rates ranging from about 80 to 130 percent of the typical observed rates. The calibrated PRESS model was then used for prediction of subsidence for future hydrologic scenarios.

Hydrologic Model Cases

Pate/Jones and Carter furnished a map of Census tracts within the model area together with future well locations. The census tracts were normalized to the model grid (Figure 6).

The future well locations were then assigned within the representative grids of the model area. Each future well was assumed to be completed in the Evangeline aquifer, and assumed to pump at rate of 800 gallons per minute (gpm). The 800 gpm average is representative of a well that pumps intermittently but at a rate of 2000 gallons per minute.

Demands for water were then specified for future years based on census tract demand projections. A subroutine was used in the program such that future wells would be added to the pumpage when demand required but no single well pumped greater than 800 gpm. The census tracts had more than adequate well capacity to meet present demand, thus no new wells were required until in the future. The future demand per census tract utilized for the model is shown on Table 3.

Demands outside the model area remained static, unless otherwise specified, since the future pumpage increases were insignificant or too distant to significantly affect the modelling area.

Three cases have been evaluated in the hydrologic model. Each case is outlined in the following:

Case 1 - Pumping in the model area increases to meet future demand, pumpage in Harris County adjacent to the model area, shown on Figure 7 increases to meet future demands as does Harris, Galveston County Subsidence

District (H.G.C.S.D.) areas 3 and 4, are 2 follows the H.G.C.S.D. Proposed Conversion to surface water with pumpage listed below until the Eastside Water Purification Plant capacity of 310 M.G.D. is reached at which point groundwater pumpage is increased to meet total demands.

Area 2 Demand (mgd)

Year	1990	1998	1999	2000	2006	2009
	64.28	92.56	70.64	74.17	96.50	76.56
	2010	2014	2015	2019	2020	2030
	87.72	101.41	101.06	114.74	118.17	155.04

Area 3 Demand (mgd)

Year	1990	1994	1995	2000	2010	2011
	98.48	103.12	104.28	110.08	118.62	118.62
	2012	2019	2020	2030		
	119.23	123.48	124.09	131.07		

Area 4 Demand (mgd)

Year	1990	1999	2000	2010	2019	2020
	27.16	36.15	37.15	45.08	49.33	49.80
	2030					
	54.18					

The remainder of the area pumps at rates equal to 1984.

Case 2 - Pumping in the site area increases to meet future demand to the year 1999 then pumpage is reduced to 20% of demand pumpage in Harris County adjacent to the model area, shown on Figure 7 follows a trend to meet the Harris Galveston County Subsidence Districts Proposed Conversion to Surface Water in the future. The groundwater pumpage in the adjacent areas is outlined in the following:

Area 2 Demand(mgd)

Year	1990	1998	1999	2000	2006	2007
	64.28	92.56	70.64	74.17	96.50	76.56
	2010	2014	2015	2019	2020	2030
	87.72	101.41	82.21	95.90	85.63	122.50

Area 3 Demand(mgd)

Year	1990	1994	1995	2000	2010	2011	2012	2019	202
	98.48	103.12	20.86	26.65	34.59	35.20	23.85	28.10	24.
	2020	2030							
	24.82	31.79							

Area 4 Demand(mgd)

Year	1990	1999	2000	2010	2019	2020	2030
	27.16	36.15	7.43	15.36	19.61	9.96	14.33

The remainder of the area pumps at rates equal to 1984.

Hydrologic Modelling Results

The cases that were modelled have resulted in predicted changes in the potentiometric surface of the Chicot and Evangeline Aquifers. The resultant altitude of the potentiometric surface has been calculated per grid node in each aquifer for each case. Contour maps have been constructed to illustrate the altitude of common potentiometric surface predicted. It must be stated that the modeling results and the contouring are approximations of future conditions and become less accurate when projected further into the future. The model results are representative of the center of each node, thus in the study area, the results are castinto the center of the 6000 ft of 6000 ft grid. The modeling effort has not predicted drawdown at specific wells pumping in a particular grid.

Figures 8 through 15 represent contours of head (or elevation of potentiometric surface) for the Evangeline aquifer predicted from the cases modelled for the years 1990, 2000, 2010 and 2030. Case 1 represents the most severe case relative to groundwater withdrawal and consequently greatest change in the potentiometric surface while Case 2 represents the least sever case with the smallest change in potentiometric surface. The altitude of the potentiometric surface is similar in the year 1990 ranging from about -100 to about -200 feet. As the years progress the difference in the potentiometric surface between the two cases becomes more pronounced; the potentiometric surface of Case 1 ranges from about -130 ft to about -250 ft while in Case 2 the surface ranges from about -110 ft to about -175 ft in the year 2000, in the year 2010 the Case 1 potentiometric surface ranges from about -175 ft to about -310 ft while in Case 2 the surface ranges from about -125 ft to about -190 ft, and in the year 2030 the potentiometric surface in Case 1 ranges from about -250 ft to about -430 ft while in Case 2 the surface ranges from about -150 ft to about -225 ft.

The maximum areas of concentrated pumpage remain to the northeast of the study area for all cases modeled, which mimics the current pumpage trends. Groundwater flow, through the study area is from the south and west, to the northeast. The Evangeline aquifer has the most desirable water quality, and aquifer properties, therefore it is most utilized for domestic supply and thus changes in the potentiometric surface for this aquifer have been shown. The Chicot aquifer does respond due to pumpage of the Evangeline aquifer, and as well as regional withdrawals which have been modeled outside the study area. Potentiometric surfaces within the Chicot have not been illustrated but are an input factor to subsidence modelling.

In all cases modelled, the withdrawals do not result in the Evangeline aquifer changing from an artesian condition to a gravity condition.

Subsidence Modelling Results

Subsidence has been modelled based upon the changes in potentiometric head with time for Cases 1, and 2.

Figures 16 through 21 represent contours of equal settlement in ft for the cases modelled. The predicted subsidence for both cases in early years is about the same. Beyond the year 2000, less subsidence is predicted from Case 2 than Case 1. The greatest change in slope of the land surface is realized in Case 1 followed by Case 2. The predicted subsidence for Case 1 for the period 1987 to 2030 ranges from about 4.5 in the south ft to slightly greater than 7 ft in the north while the range of Case 2 in this same period is 3.9 to 4.3 ft.

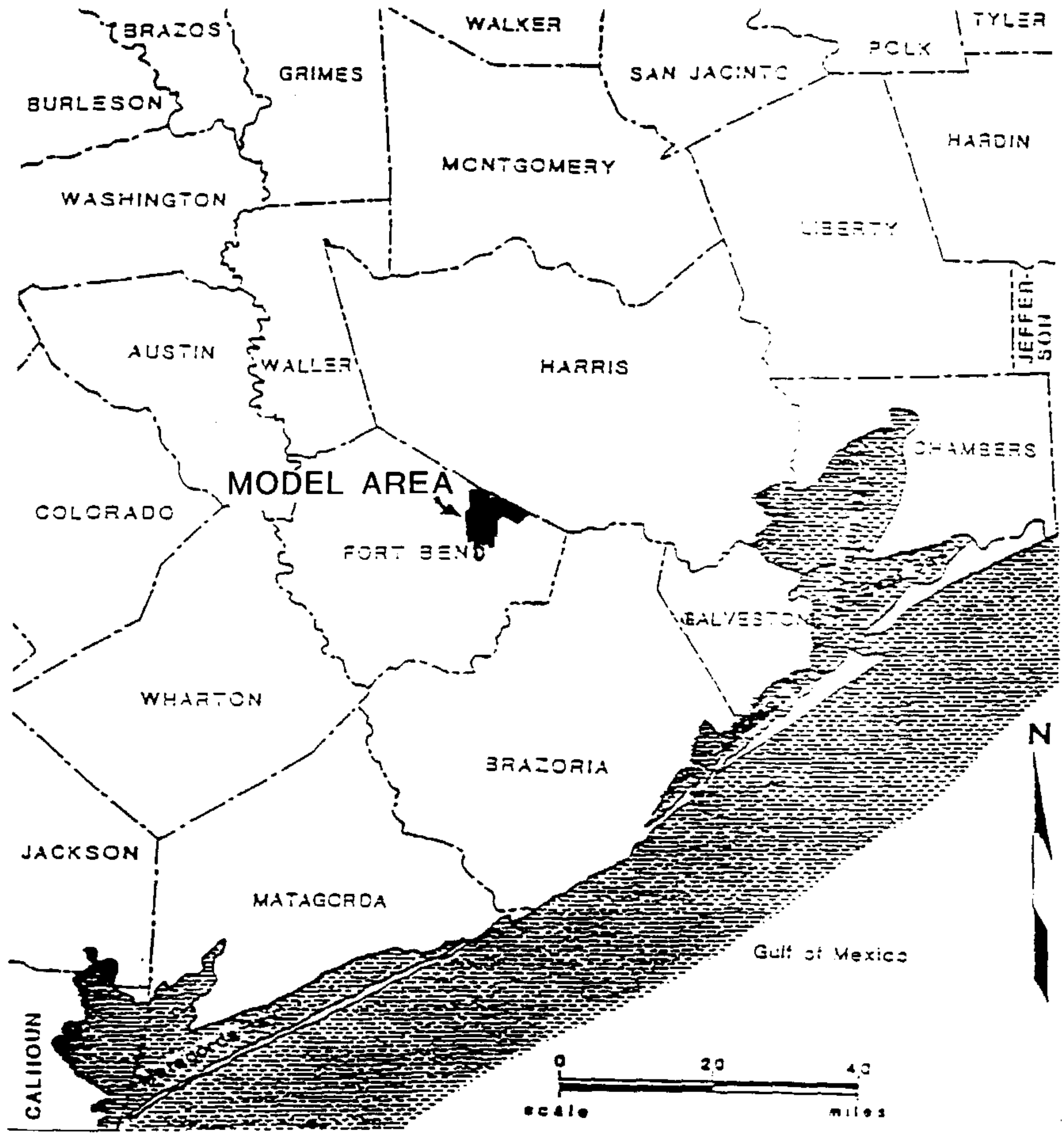
The predicted subsidence results conform to historic trends throughout the greater Houston Area. The subsidence analysis can be compared and contrasted with the results of the subsidence analysis in the Phase II Water Management Study of the HGCSD prepared by Espey Huston in 1982. The present study has a more intense data base in the study area and this is a more detailed effort. Hydrologic Case 2 closely relate to scenario B of the Phase II Study to the year 2020. The predicted subsidence for the 40 year period of these study was greater than 3 ft. The predicted subsidence for the present study for the 23 year period ranges between 2 to 3 ft. The results appear to conform to the Phase II Study Program.

Salt Water Migration

There is some concern relative to water quality and salt water migration from the Blue Ridge Salt Dome to the study area (Figure 2). Previous investigations by Wesselmen, 1972 have shown a plane south of the Blue Ridge Dome, but no plan associated with the Sugarland Dome. An analysis of the groundwater flow velocity from the dome to the study area was conducted. Based upon this analysis, which used a gradient directed toward the study area, the salt water plume could migrate about one half mile in 20 years. It should be noted that the groundwater gradient in all cases modelled was from the dome northward, thus the plume is not directed toward the study area.

TABLE 3
PROJECTED WATER DEMANDS
SUGARLAND AREA CENSUS TRACTS

Year	Census	Projected Daily Demand (mgd)
1985	701.01	0.66
1985	701.02	1.66
1985	701.03	2.31
1985	701.06	2.48
1985	702.01	0.44
1985	702.02	1.68
1985	702.03	1.67
1985	703.02	2.47
1985	703.03	1.44
1985	434.02	0.78
2000	701.01	2.92
2000	701.02	2.55
2000	701.03	3.96
2000	701.06	3.11
2000	702.01	0.73
2000	702.02	3.43
2000	702.03	4.9
2000	703.02	4.65
2000	703.03	2.39
2000	434.02	0.72
2030	701.01	6.07
2030	701.02	4.13
2030	701.03	5.07
2030	701.06	5.69
2030	702.01	1.16
2030	702.02	6.7
2030	702.03	13.93
2030	703.02	8.84
2030	703.03	4.19
2030	434.02	0.63



GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NO.

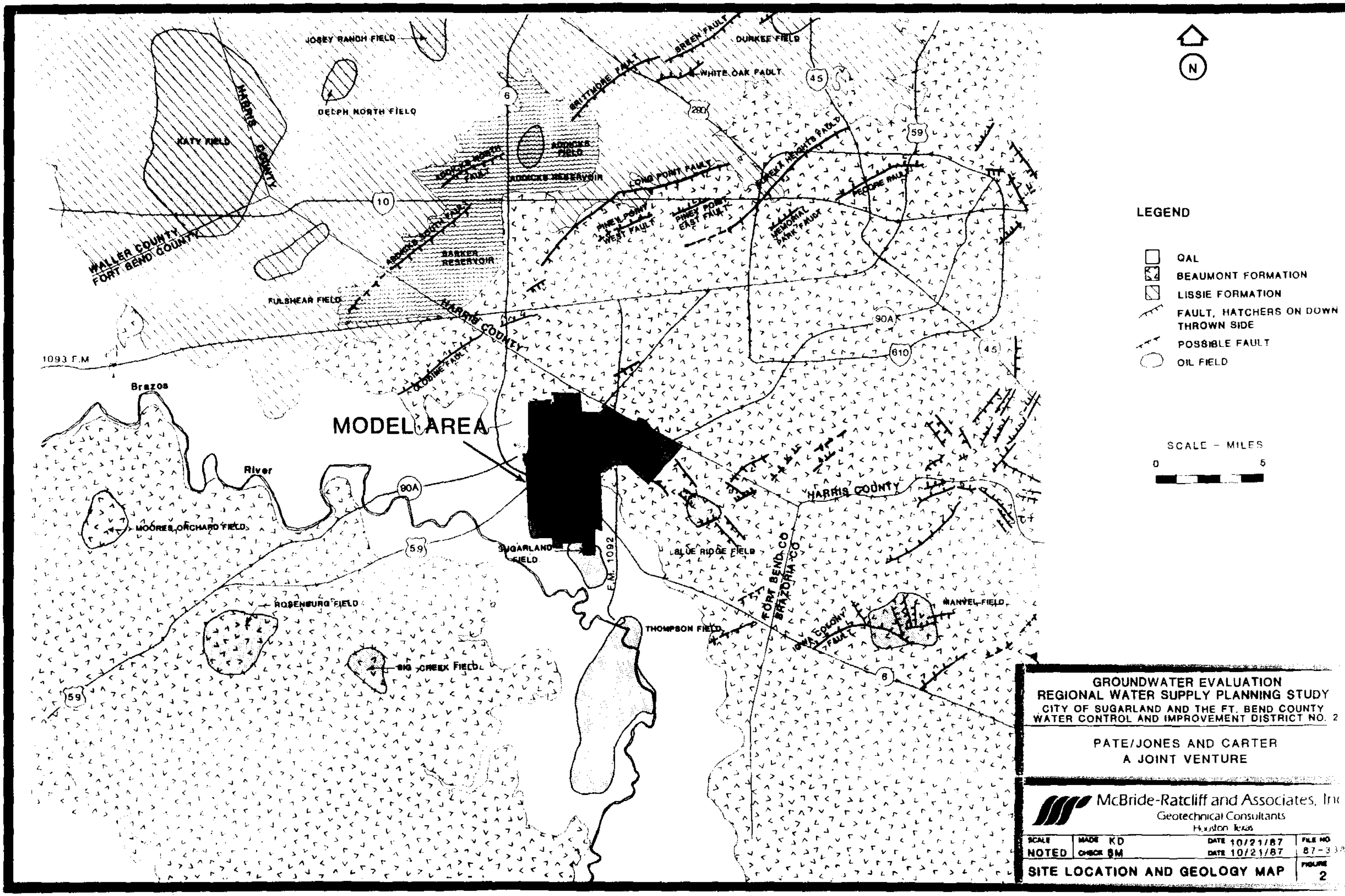
PATE/JONES AND CARTER
A JOINT VENTURE

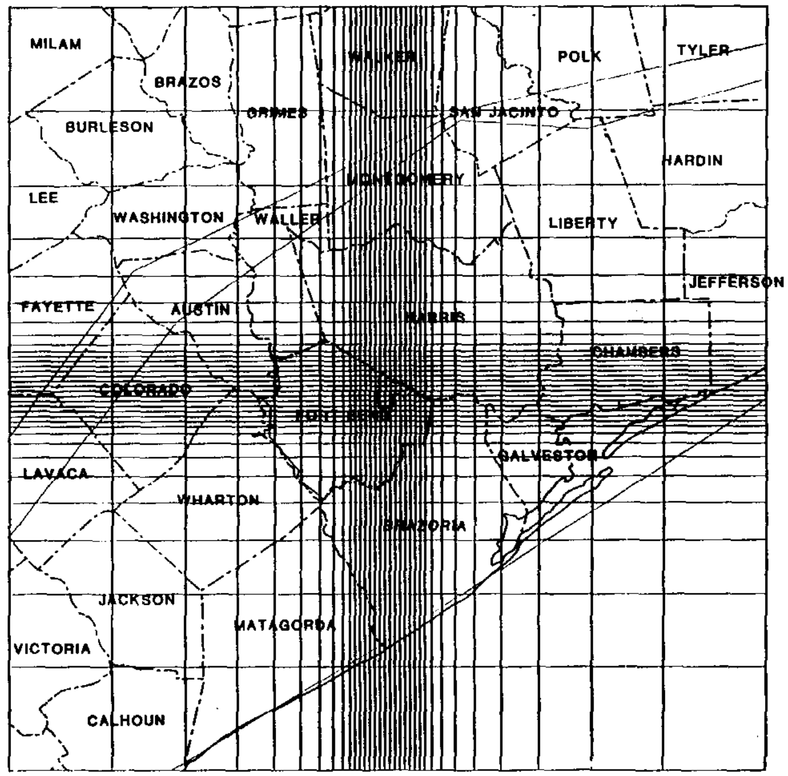
McBride-Ratcliff and Associates, inc
Geotechnical Consultants
Houston, Texas

SCALE	MADE		DATE	FILE NO.
NOTED	DLQ		4-7-88	87-33
	CHECK	JLI	4-7-88	

LOCATION MAP

FIGURE 1


JOSEY RANCH FIELD
DURKEE FIELD
GREEN FAULT
WHITE OAK FAULT
BRITTMORE FAULT
DELPH NORTH FIELD
KATY FIELD
HARRIS COUNTY
ADDICKS FIELD
ADDICKS RESERVOIR
LONG POINT FAULT
PINEY POINT WEST FAULT
PINEY POINT EAST FAULT
MEMORIAL PARK FAULT
HEIGHTS FAULT
BARKER RESERVOIR
WALLER COUNTY
FORT BEND COUNTY
FULSHEAR FIELD
1093 F.M.
Brazos
River
MODEL AREA
SUGARLAND FIELD
F.M. 1092
BLUE RIDGE FIELD
FORT BEND CO
BRAZORIA CO
HARRIS COUNTY
MOORES ORCHARD FIELD
ROSENBURG FIELD
BIG CREEK FIELD
THOMPSON FIELD
MANVEL FIELD
IOWA COLONY FAULT
N
LEGEND
QAL
BEAUMONT FORMATION
LISSIE FORMATION
FAULT, HATCHERS ON DOWN THROWN SIDE
POSSIBLE FAULT
OIL FIELD
SCALE - MILES
0
5
GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NO. 2
PATE/JONES AND CARTER
A JOINT VENTURE
McBride-Ratcliff and Associates, Inc
Geotechnical Consultants
Houston Texas
SCALE NOTED
MADE KD
CHECK BM
DATE 10/21/87
DATE 10/21/87
FILE NO 87-33
SITE LOCATION AND GEOLOGY MAP
FIGURE 2

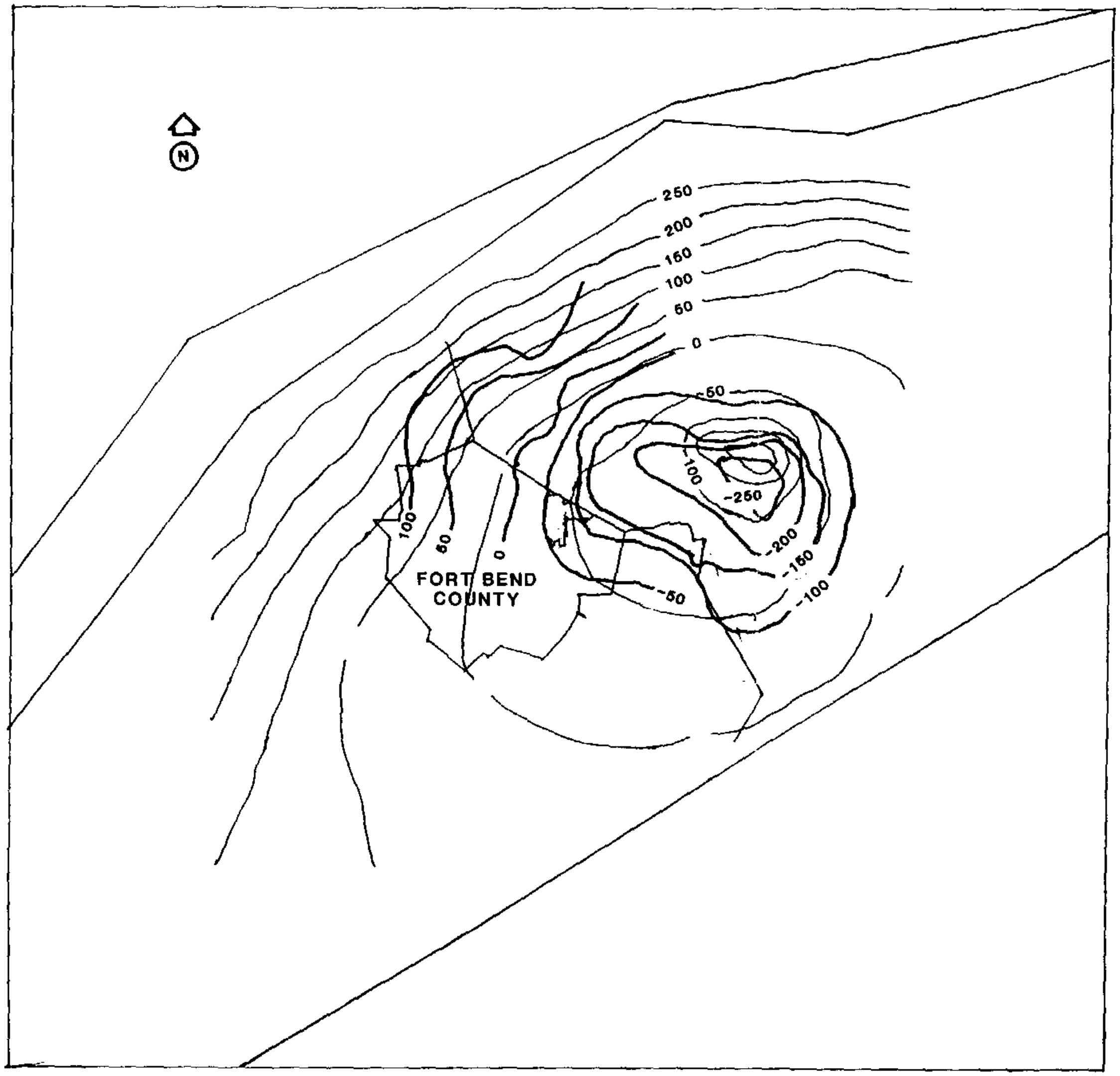


GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NO. 2

PATE/JONES AND CARTER
A JOINT VENTURE

McBride-Ratcliff and Associates, Inc.
Geotechnical Consultants
Houston, Texas

SCALE	MADE DLQ	DATE 4-8-88	FILE NO 87-338
	CHECK JLI	DATE 4-8-88	
MODEL GRID			FIGURE 3



1975 CHICOT HEADS
ft. m.s.l.

MODEL CONTOURS

USGS HISTORICAL DATA

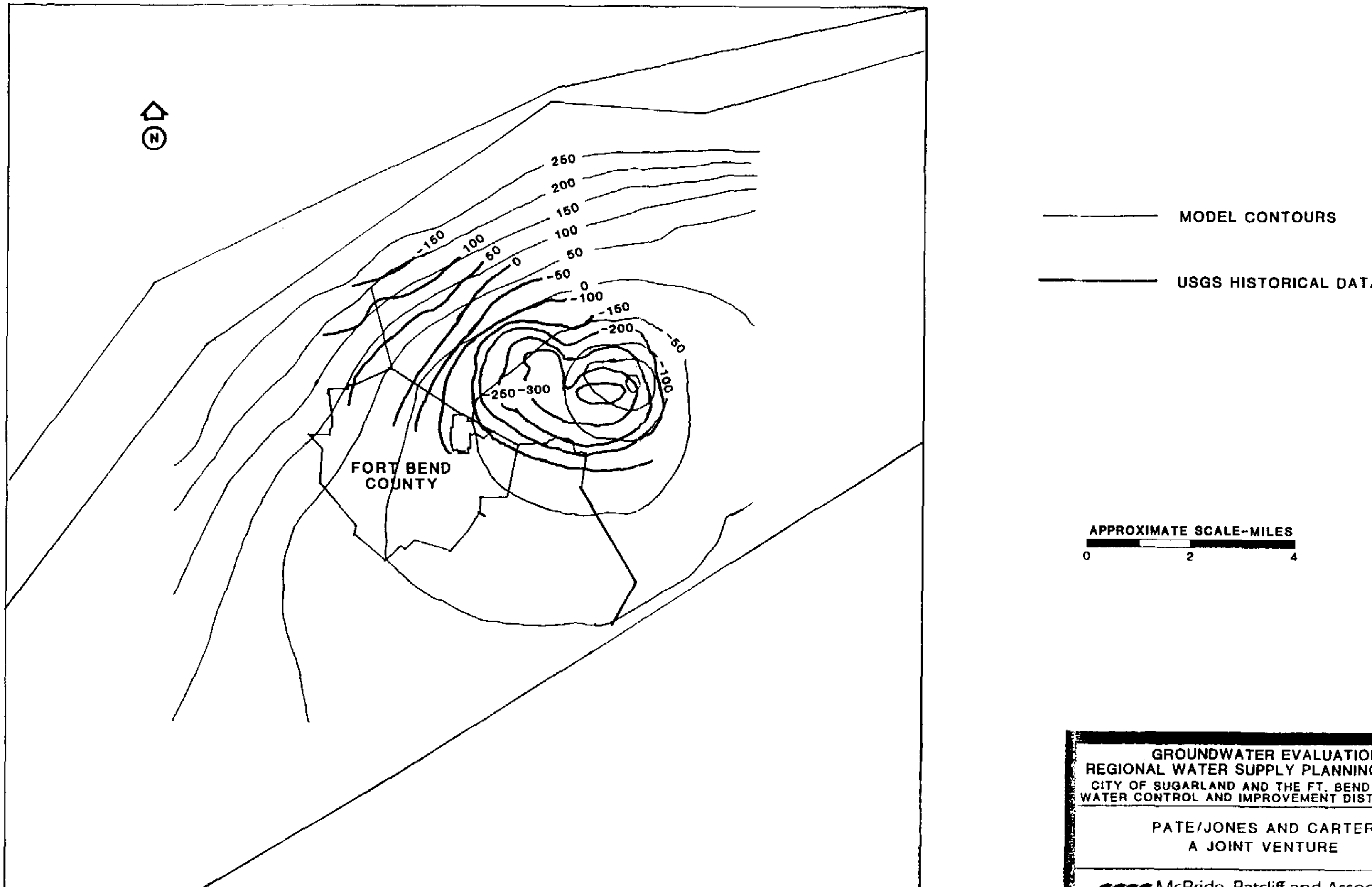
APPROXIMATE SCALE-MILES
0 2 4

GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY
WATER CONTROL AND IMPROVEMENT DISTRICT NO. 2

PATE/JONES AND CARTER
A JOINT VENTURE

McBride-Ratcliff and Associates, Inc.
Geotechnical Consultants
Houston, Texas

SCALE NOTED	MADE DLQ DATE 4-8-88 CHECK JLI DATE 4-8-88	FILE NO. 87-338
RESULTS OF 1974 CALIBRATION (CHICOT)		FIGURE 4



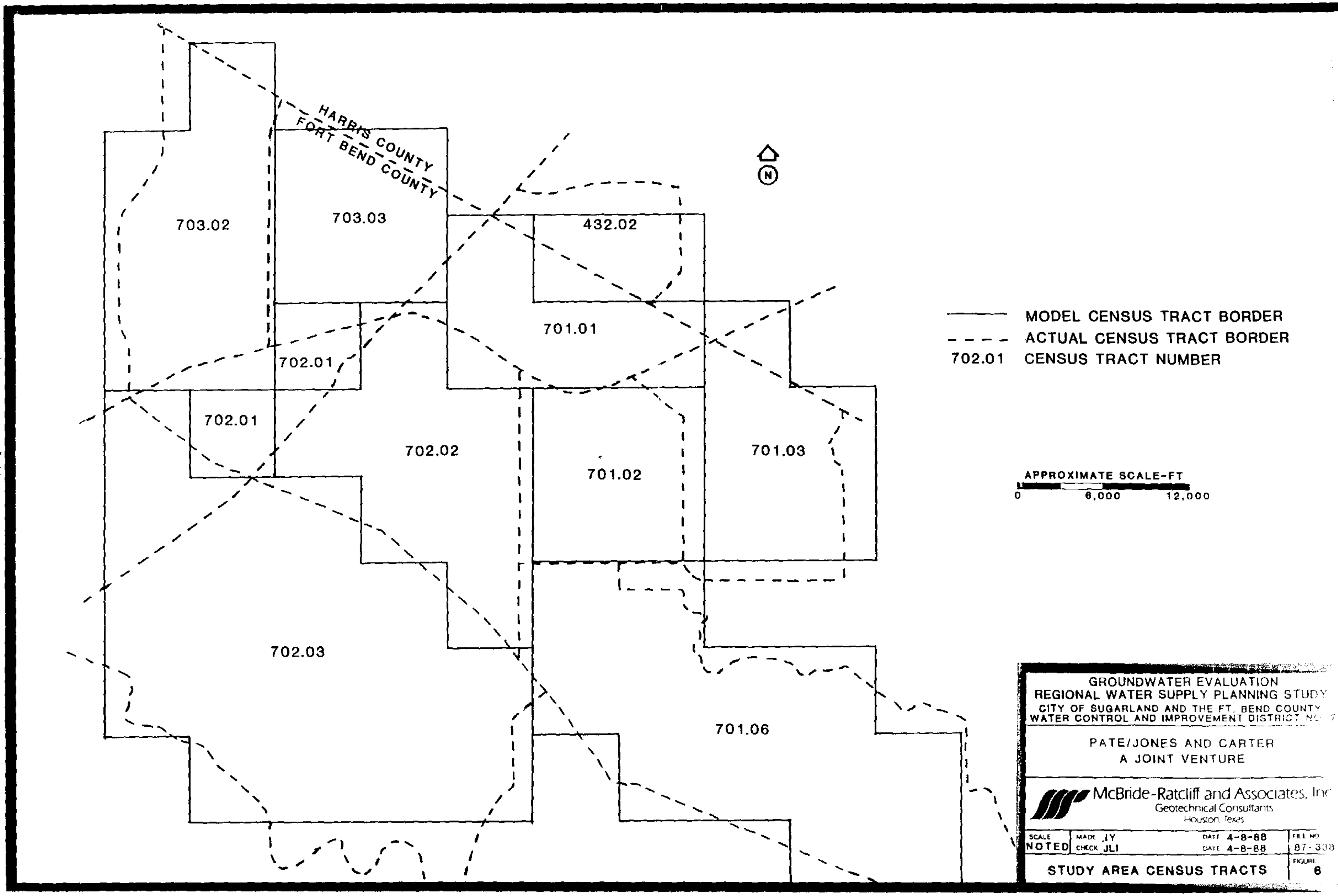
1975 EVANGELINE HEADS
ft. m.s.l.

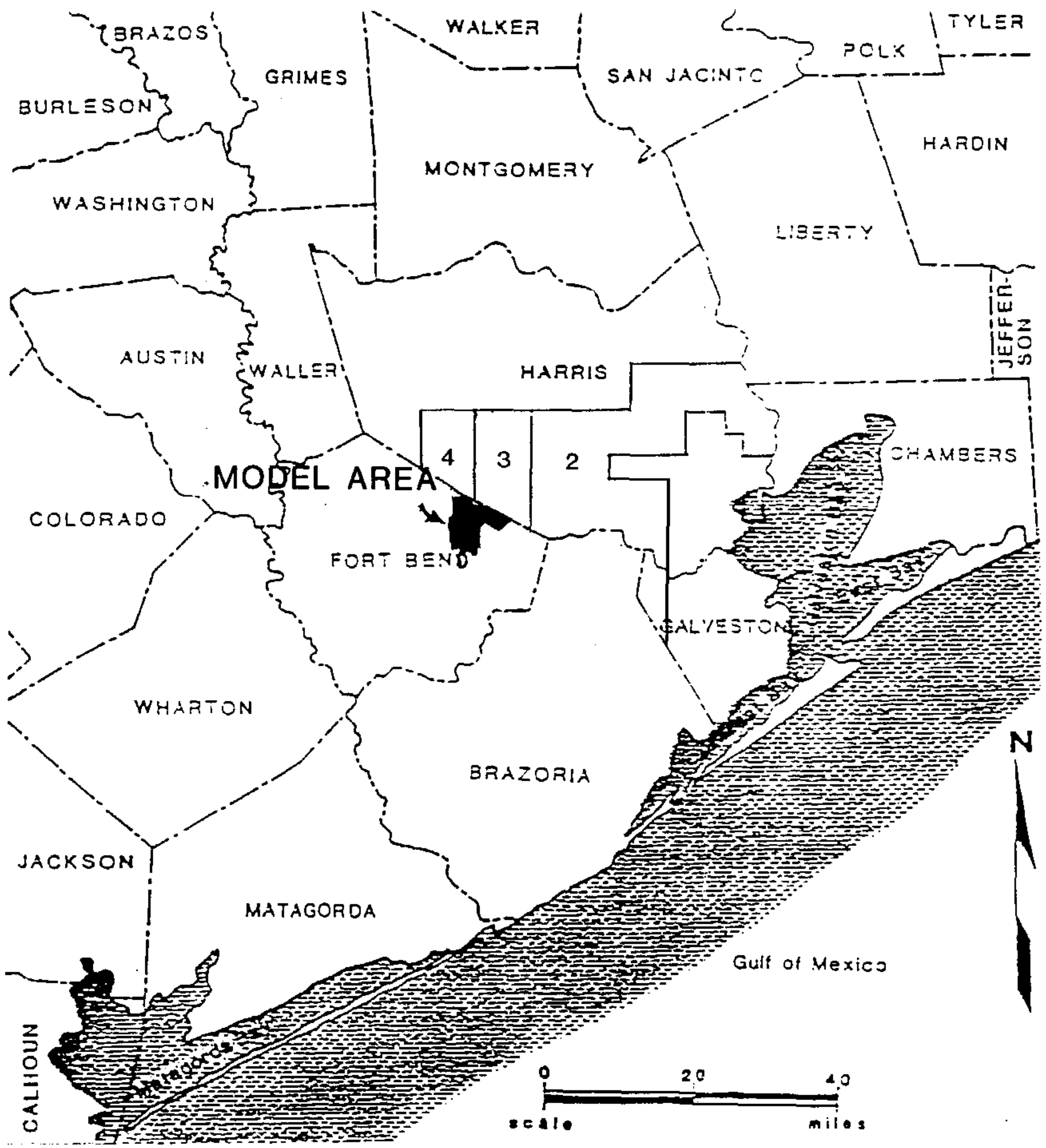
GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY
WATER CONTROL AND IMPROVEMENT DISTRICT NO. 2

PATE/JONES AND CARTER
A JOINT VENTURE

McBride-Ratcliff and Associates, Inc.
Geotechnical Consultants
Houston Texas

SCALE	MADE DLQ	DATE 4-8-88	FILE NO
NOTED	CHECK JLI	DATE 4-8-88	87-338
RESULTS OF 1974 CALIBRATION (EVANGELINE)			FIGURE 5


HARRIS COUNTY
FORT BEND COUNTY
N
703.02
703.03
432.02
701.01
702.01
702.01
702.02
701.02
701.03
702.03
701.06
MODEL CENSUS TRACT BORDER
ACTUAL CENSUS TRACT BORDER
702.01 CENSUS TRACT NUMBER
APPROXIMATE SCALE-FT
0
6,000
12,000
GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY
WATER CONTROL AND IMPROVEMENT DISTRICT No. 2
PATE/JONES AND CARTER
A JOINT VENTURE
McBride-Ratcliff and Associates, Inc
Geotechnical Consultants
Houston, Texas
SCALE NOTED
MADE JY DATE 4-8-88
CHECK JLI DATE 4-8-88
FILE NO 87-338
STUDY AREA CENSUS TRACTS
FIGURE 6



GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NO. 2

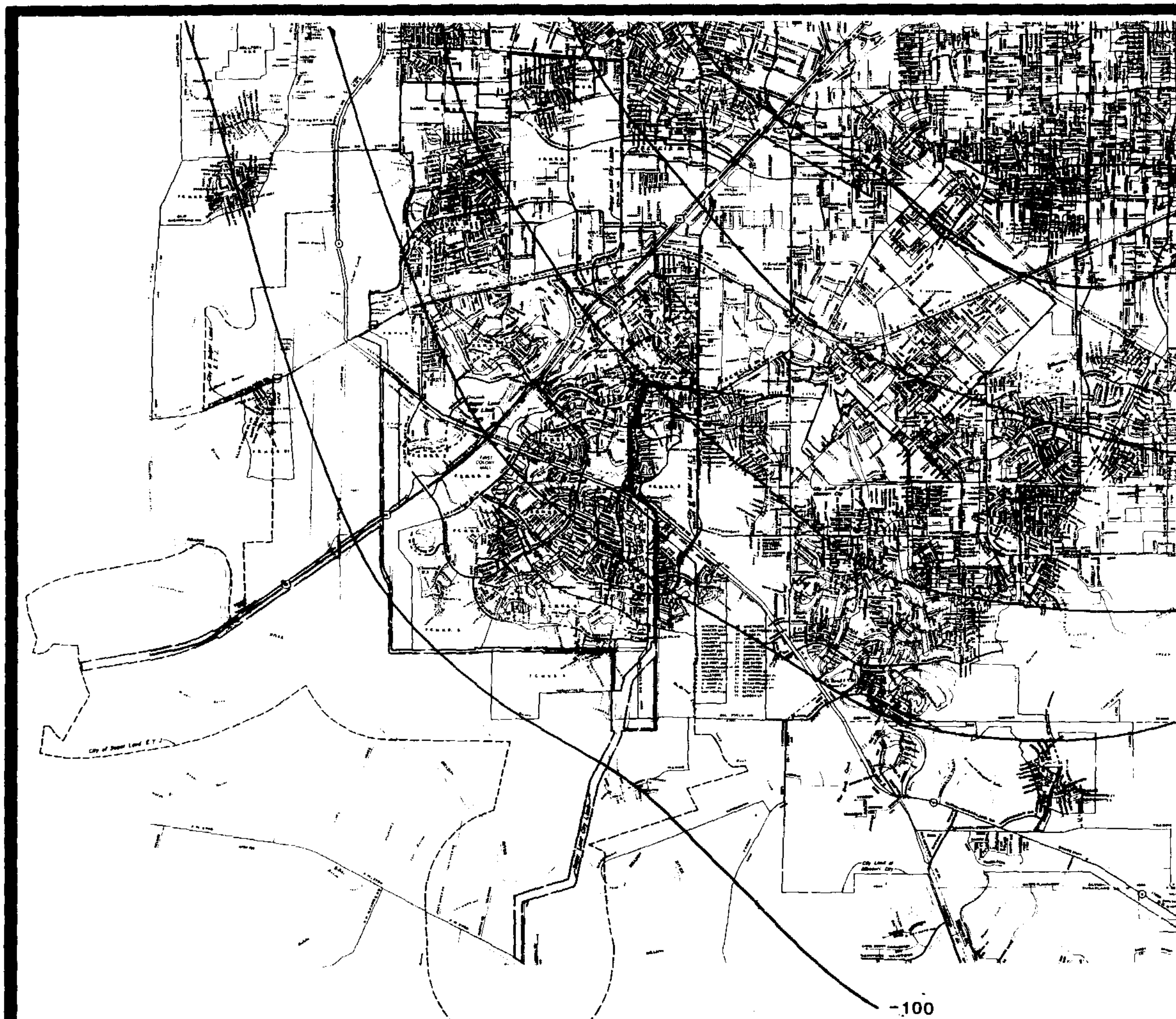
PATE/JONES AND CARTER
A JOINT VENTURE

McBride-Ratcliff and Associates, Inc.
Geotechnical Consultants
Houston, Texas

SCALE	MADE	DATE	FILE NO
NOTED	DLQ	4-7-88	87-338
	CHECK JLI	4-7-88	

STUDY AREA & SUBSIDENCE DISTRICT AREAS 2,3,&4

FIGURE 7



CASE 1
1990
EVANGELINE HEADS
ft. m.s.l.

N

HEAD CONTOURS WERE INTERPRETED FROM GROUNDWATER MODEL DATA
ELEVATIONS IN FT. m.s.l.

APPROXIMATE SCALE-FT

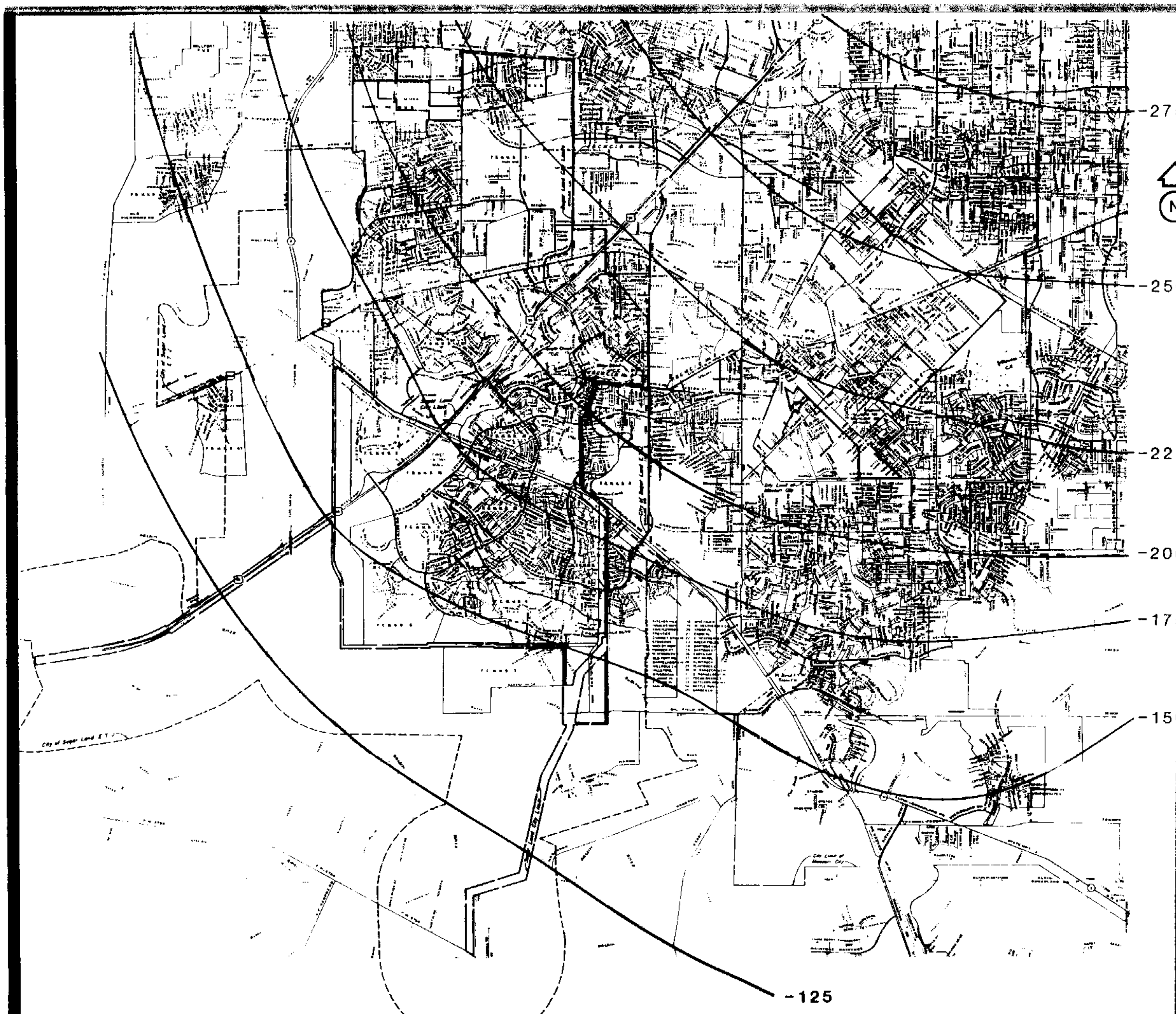
0 6,000 12,000

GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NO. 2

PATE/JONES AND CARTER
A JOINT VENTURE

McBride-Ratcliff and Associates, Inc
Geotechnical Consultants
Houston, Texas

SCALE	MADE DLQ	DATE 4-6-88	FILE NO
NOTED	CHECK JLI	DATE 4-6-88	87-338
	CASE 1 1990 EVANGELINE HEADS		FIGURE 8



CASE 1
2000
EVANGELINE HEADS
ft. m.s.l.

HEAD CONTOURS WERE INTERPRETED FROM GROUNDWATER MODEL DATA

ELEVATIONS IN FT. m.s.l.

APPROXIMATE SCALE-FT
0 6,000 12,000

GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NO. 2

PATE/JONES AND CARTER
A JOINT VENTURE

McBride-Ratcliff and Associates, Inc
Geotechnical Consultants
Houston, Texas

SCALE NOTED	MADE DLQ	DATE 4-8-88	FILE NO. 87-338
	CHECK JLI	DATE 4 8 88	
CASE 1 2000 EVANGELINE HEADS			FIGURE 9

CASE 1
2010
EVANGELINE HEADS
ft. m.s.l.

HEAD CONTOURS WERE INTERPRETED FROM GROUNDWATER MODEL DATA

ELEVATIONS IN FT. m.s.l.

APPROXIMATE SCALE-FT

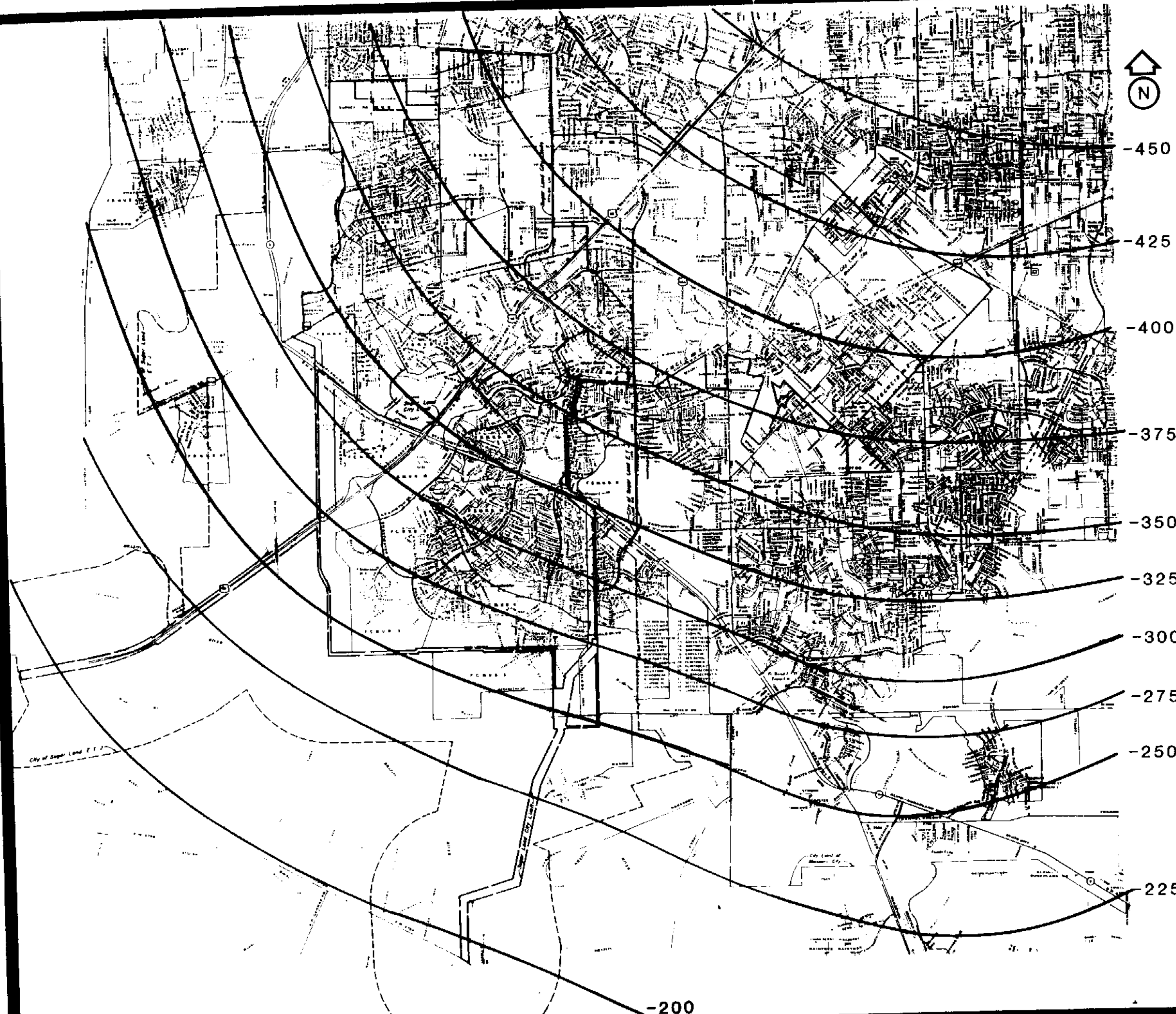
0 6,000 12,000

GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NO. 2

PATE/JONES AND CARTER
A JOINT VENTURE

McBride-Ratcliff and Associates, Inc.
Geotechnical Consultants
Houston, Texas

SCALE	MADE DLQ	DATE 4-8-88	FILE NO
NOTED	CHECK JLI	DATE 4-6-88	87-338
	CASE 1		FIGURE
	2010 EVANGELINE HEADS		10



CASE 1
2030
EVANGELINE HEADS
ft. m.s.l.

HEAD CONTOURS WERE INTERPRETED FROM GROUNDWATER MODEL DATA

ELEVATIONS IN FT. m.s.l.

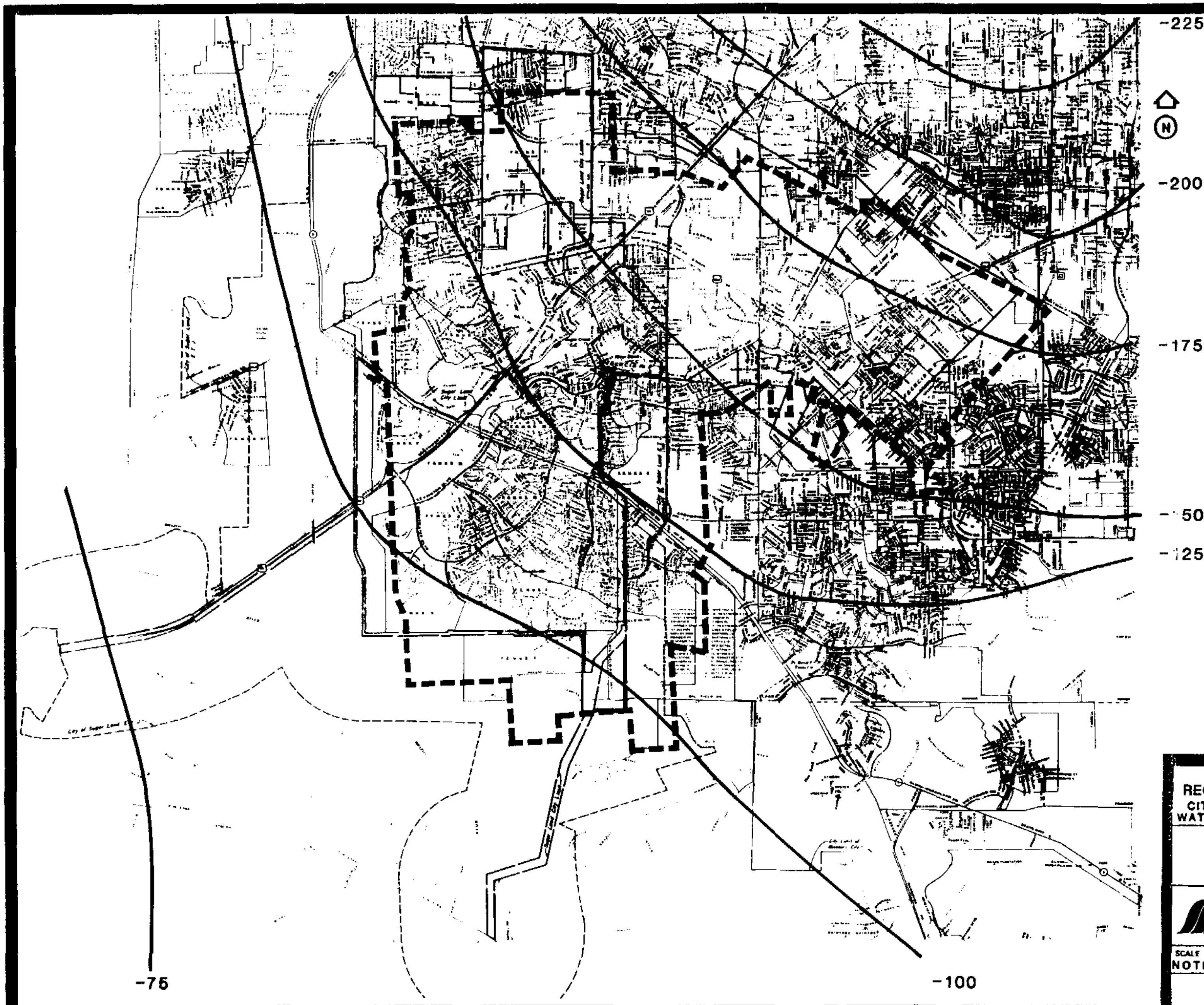
APPROXIMATE SCALE-FT
0 6000 12000

GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NO. 2

PATE/JONES AND CARTER
A JOINT VENTURE

McBride-Ratcliff and Associates, Inc.
Geotechnical Consultants
Houston, Texas

SCALE NOTED	MADE DLQ CHECK JLI	DATE 4-8-88 DATE 4-8-88	FILE NO 87-338
CASE 1 2030 EVANGELINE HEADS			FIGURE 11



CASE 2
1990
EVANGELINE HEADS
ft. m.s.l.

HEAD CONTOURS WERE INTERPRETED FROM GROUNDWATER MODEL DATA

ELEVATIONS IN FT. m.s.l.

APPROXIMATE SCALE-FT

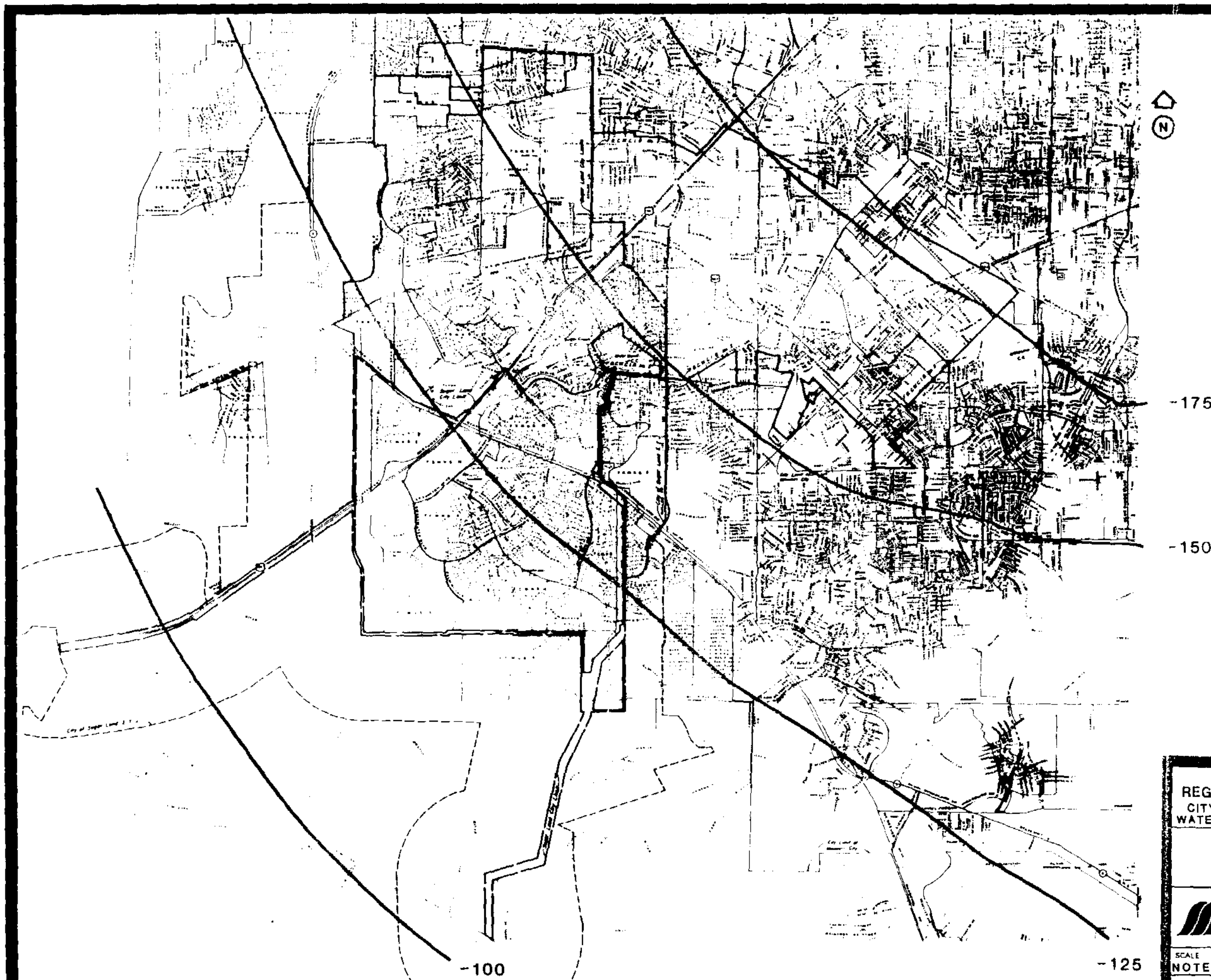
0 6,000 12,000

GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NO. 2

PATE/JONES AND CARTER
A JOINT VENTURE

McBride-Ratcliff and Associates, Inc.
Geotechnical Consultants
Houston, Texas

SCALE	MADE DLO	DATE 4-8-88	FILE NO
NOTED	CHECK JLI	DATE 4-8-88	87-338
CASE 2 1990 EVANGELINE HEADS			FIGURE 12



CASE 2
2000
EVANGELINE HEADS
ft. m.s.l.

HEAD CONTOURS WERE INTERPRETED FROM GROUNDWATER MODEL DATA ELEVATIONS IN FT. m.s.l.

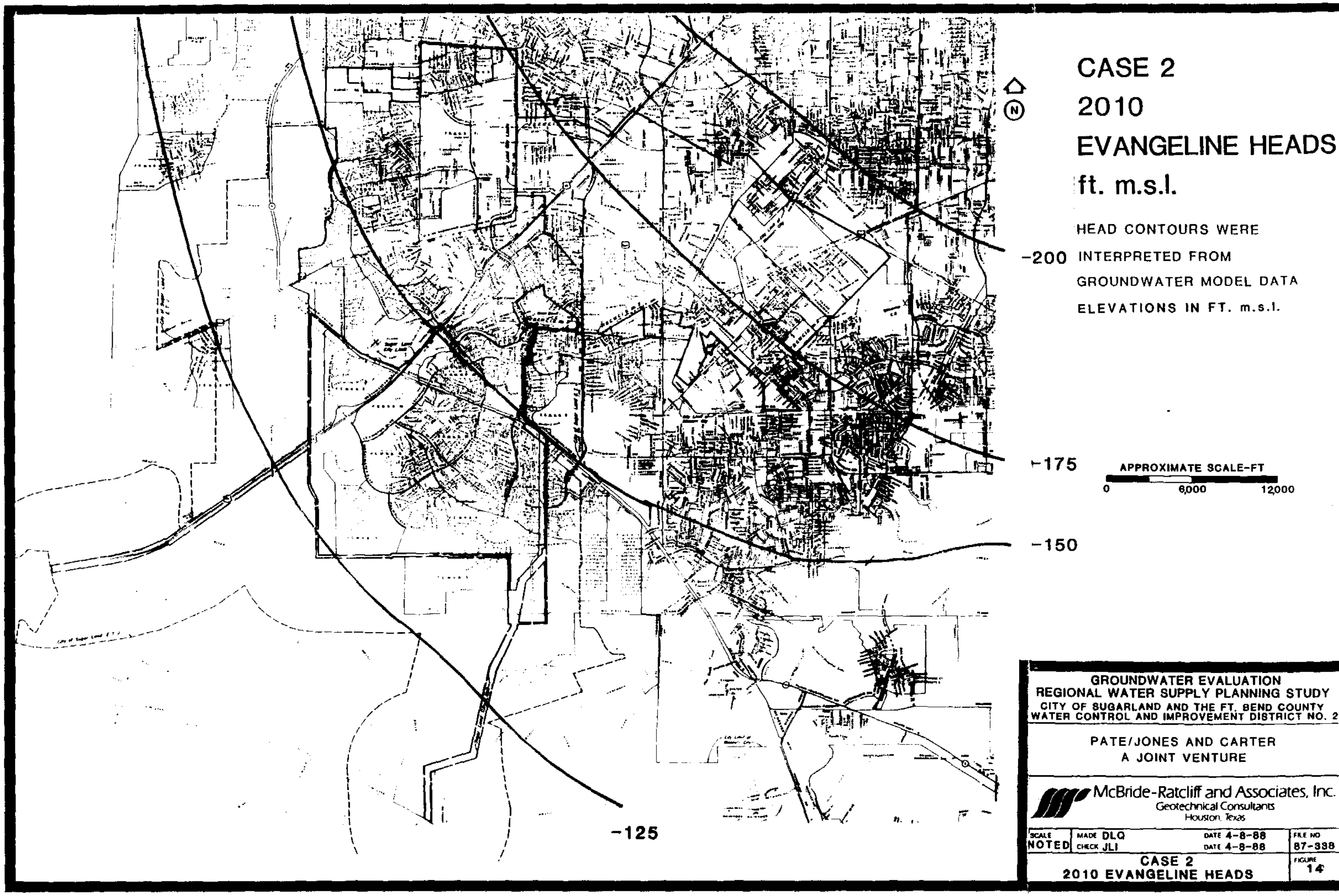
APPROXIMATE SCALE-FT
0 6,000 12,000

GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY
WATER CONTROL AND IMPROVEMENT DISTRICT NO

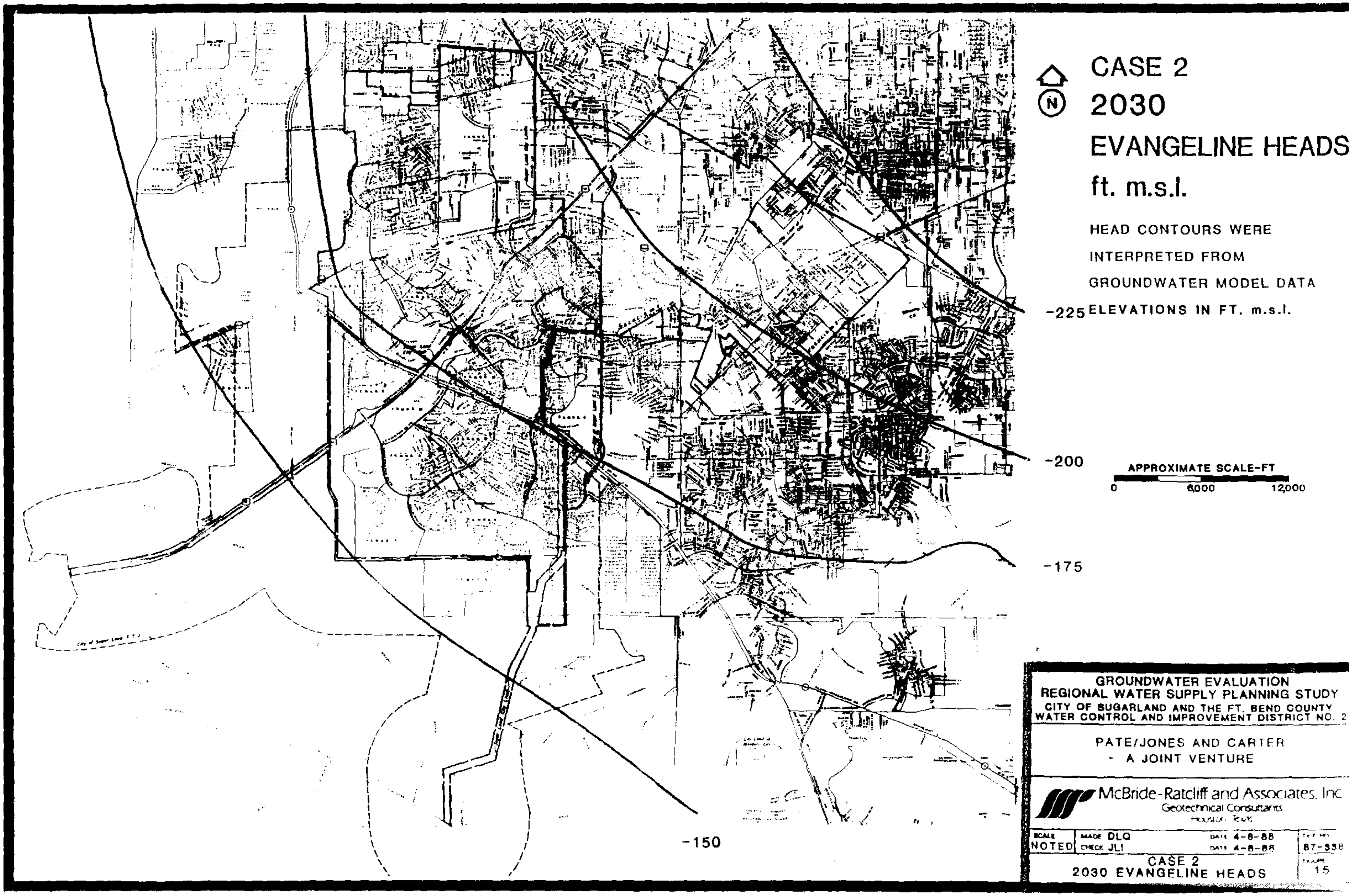
PATE/JONES AND CARTER
A JOINT VENTURE

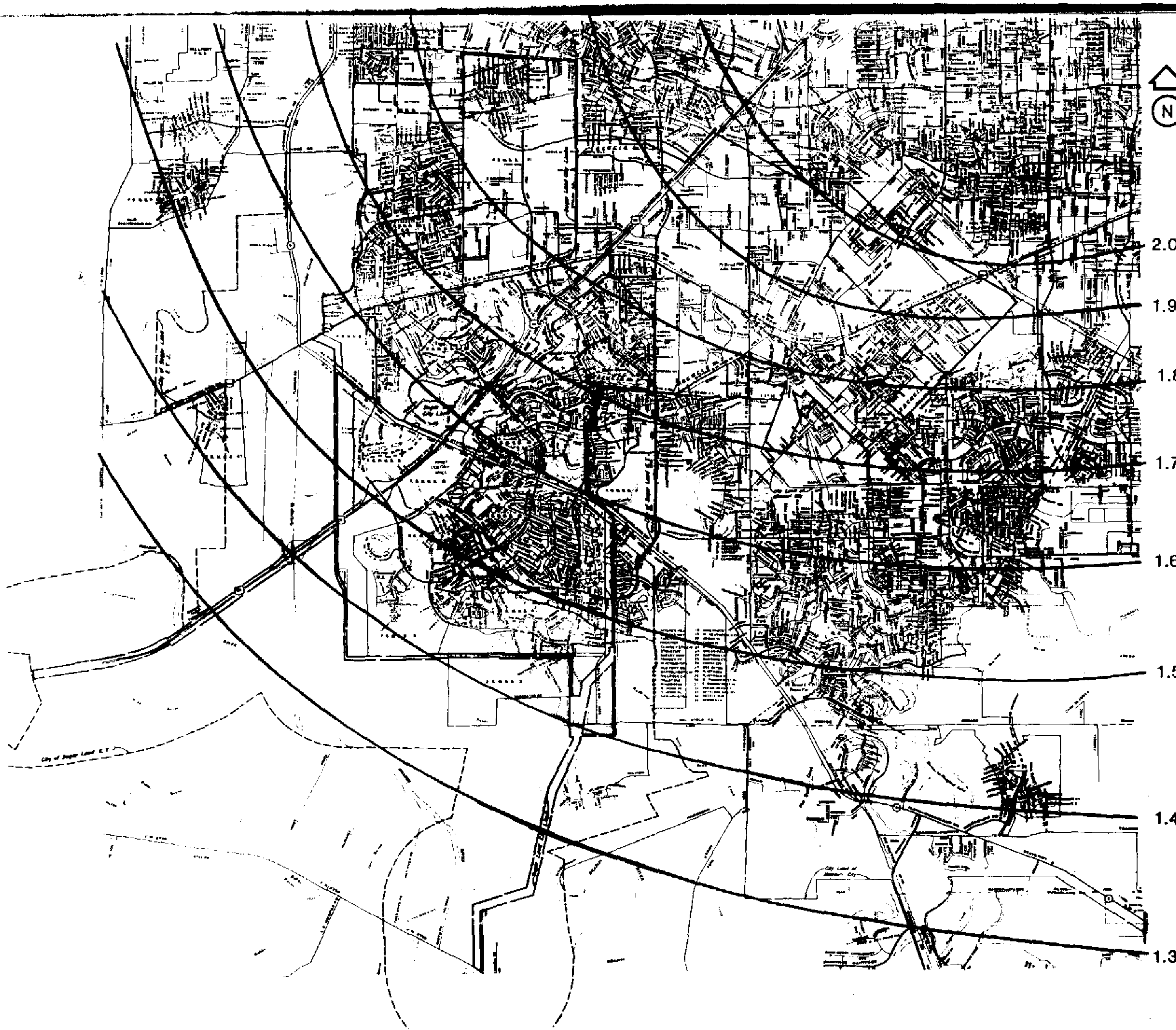
McBride-Ratcliff and Associates, Inc
Geotechnical Consultants
Houston Texas

SCALE	MADE DLQ	DATE 4-8-88	FILE NO
NOTED	CHECK JLI	DATE 4-8-88	87-338
	CASE 2 2000 EVANGELINE HEADS		FIGURE 13



CASE 2
2010
EVANGELINE HEADS
ft. m.s.l.
HEAD CONTOURS WERE INTERPRETED FROM GROUNDWATER MODEL DATA
ELEVATIONS IN FT. m.s.l.
-200
-175
-150
-125
APPROXIMATE SCALE-FT
0
6,000
12,000
GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NO. 2
PATE/JONES AND CARTER
A JOINT VENTURE
McBride-Ratcliff and Associates, Inc.
Geotechnical Consultants
Houston, Texas
SCALE NOTED
MADE DLQ
DATE 4-8-88
CHECK JLI
DATE 4-8-88
FILE NO 87-338
CASE 2
2010 EVANGELINE HEADS
FIGURE 14


CASE 2
2030
EVANGELINE HEADS
ft. m.s.l.
HEAD CONTOURS WERE
INTERPRETED FROM
GROUNDWATER MODEL DATA
ELEVATIONS IN FT. m.s.l.
-225
-200
-175
-150
APPROXIMATE SCALE-FT
0
6,000
12,000
GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY
WATER CONTROL AND IMPROVEMENT DISTRICT NO. 2
PATE/JONES AND CARTER
- A JOINT VENTURE
McBride-Ratcliff and Associates, Inc
Geotechnical Consultants
Houston, Texas
SCALE
NOTED
MADE DLQ
DATE 4-8-88
CHECK JLI
DATE 4-8-88
87-338
CASE 2
2030 EVANGELINE HEADS
15



CASE 1
1987-2000

SETTLEMENT CONTOURS WERE INTERPRETED FROM PRESS MODEL AND GROUNDWATER MODEL DATA

SETTLEMENT IN FT.

APPROXIMATE SCALE-FT

0 6,000 12,000

GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NO. 2

PATE/JONES AND CARTER
A JOINT VENTURE

McBride-Ratcliff and Associates, Inc.
Geotechnical Consultants
Houston, Texas

SCALE NOTED	MADE DLQ	DATE 4-8-88	FILE NO 87-336
	CHECK JLI	DATE 4-8-88	
CASE 1 1987-2000 SETTLEMENT CONTOURS			FIGURE 16

CASE 1
1987-2030

SETTLEMENT CONTOURS WERE INTERPRETED FROM PRESS MODEL AND GROUNDWATER MODEL DATA SETTLEMENT IN FT.

APPROXIMATE SCALE-FT

0 6,000 12,000

GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT N

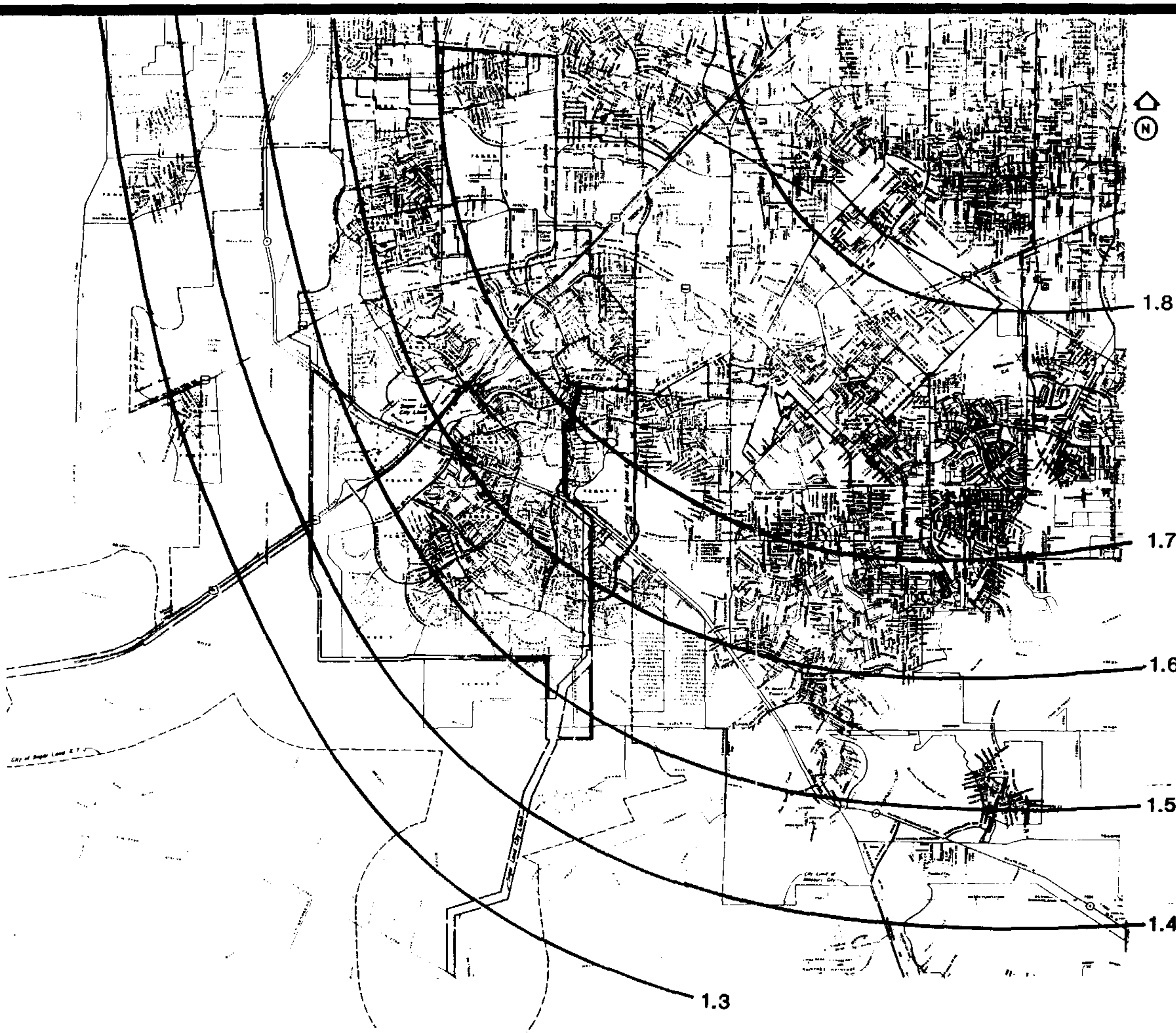
PATE/JONES AND CARTER
A JOINT VENTURE

McBride-Ratcliff and Associates, Inc
Geotechnical Consultants
Houston, Texas

SCALE	MADE DLQ	DATE 4-8-88	FILE NO
NOTED	CHECK JLI	DATE 4-8-88	87-338

CASE 1
1987-2030 SETTLEMENT CONTOURS

FIGURE 18



CASE 2
1987–2000

SETTLEMENT CONTOURS WERE INTERPRETED FROM PRESS MODEL AND GROUNDWATER MODEL DATA

SETTLEMENT IN FT.

APPROXIMATE SCALE-FT

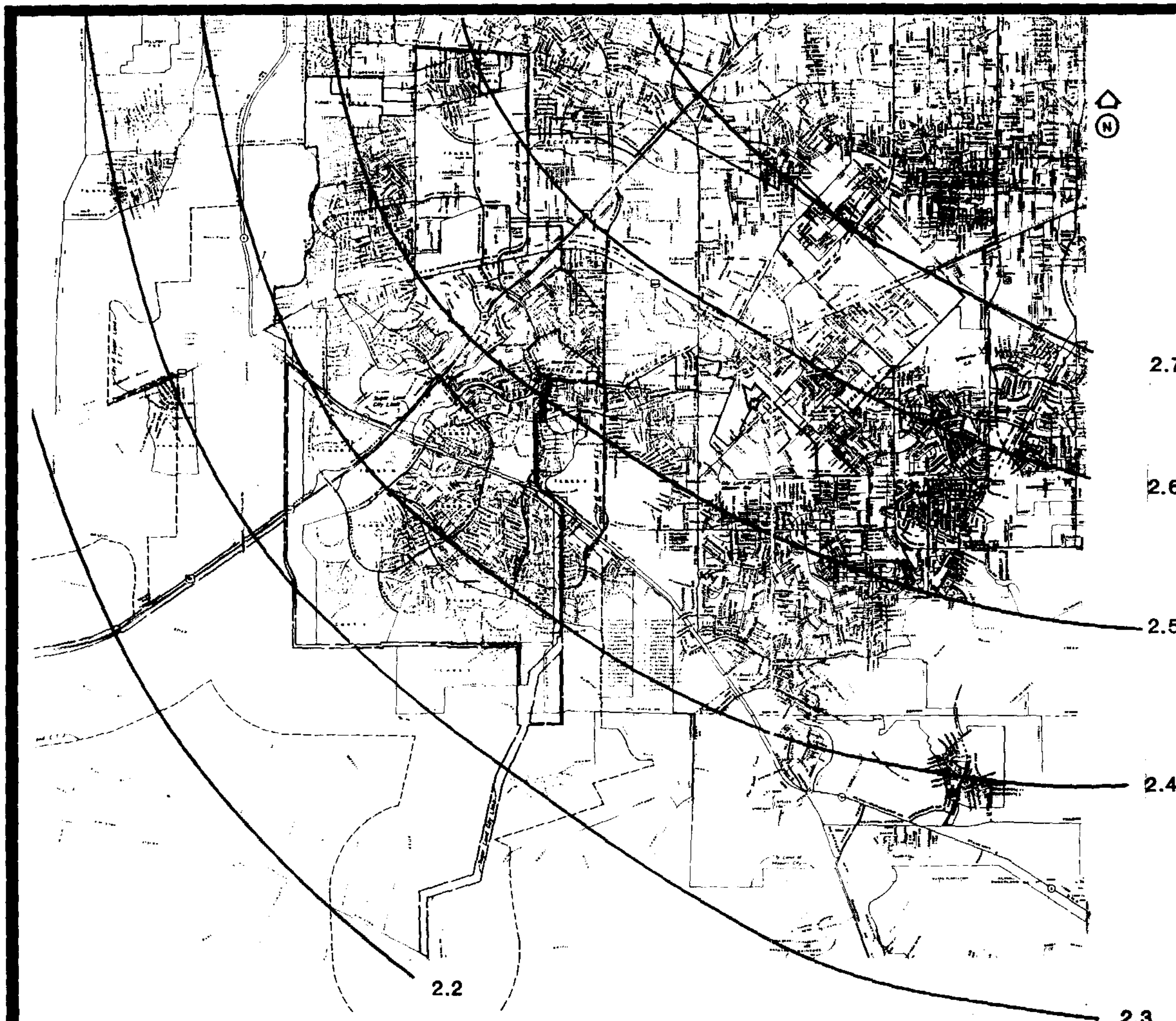
0 6,000 12,000

GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NO. 2

PATE/JONES AND CARTER
A JOINT VENTURE

McBride-Ratcliff and Associates, Inc.
Geotechnical Consultants
Houston, Texas

SCALE	MADE DLQ	DATE 4-8-88	FILE NO
NOTED	CHECK JLI	DATE 4-8-88	87-338
CASE 2 1987-2000 SETTLEMENT CONTOURS			FIGURE 19



CASE 2
1987-2010

SETTLEMENT CONTOURS WERE INTERPRETED FROM PRESS MODEL AND GROUNDWATER MODEL DATA

SETTLEMENT IN FT.

APPROXIMATE SCALE-FT

0 6,000 12,000

GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY
WATER CONTROL AND IMPROVEMENT DISTRICT NO. 2

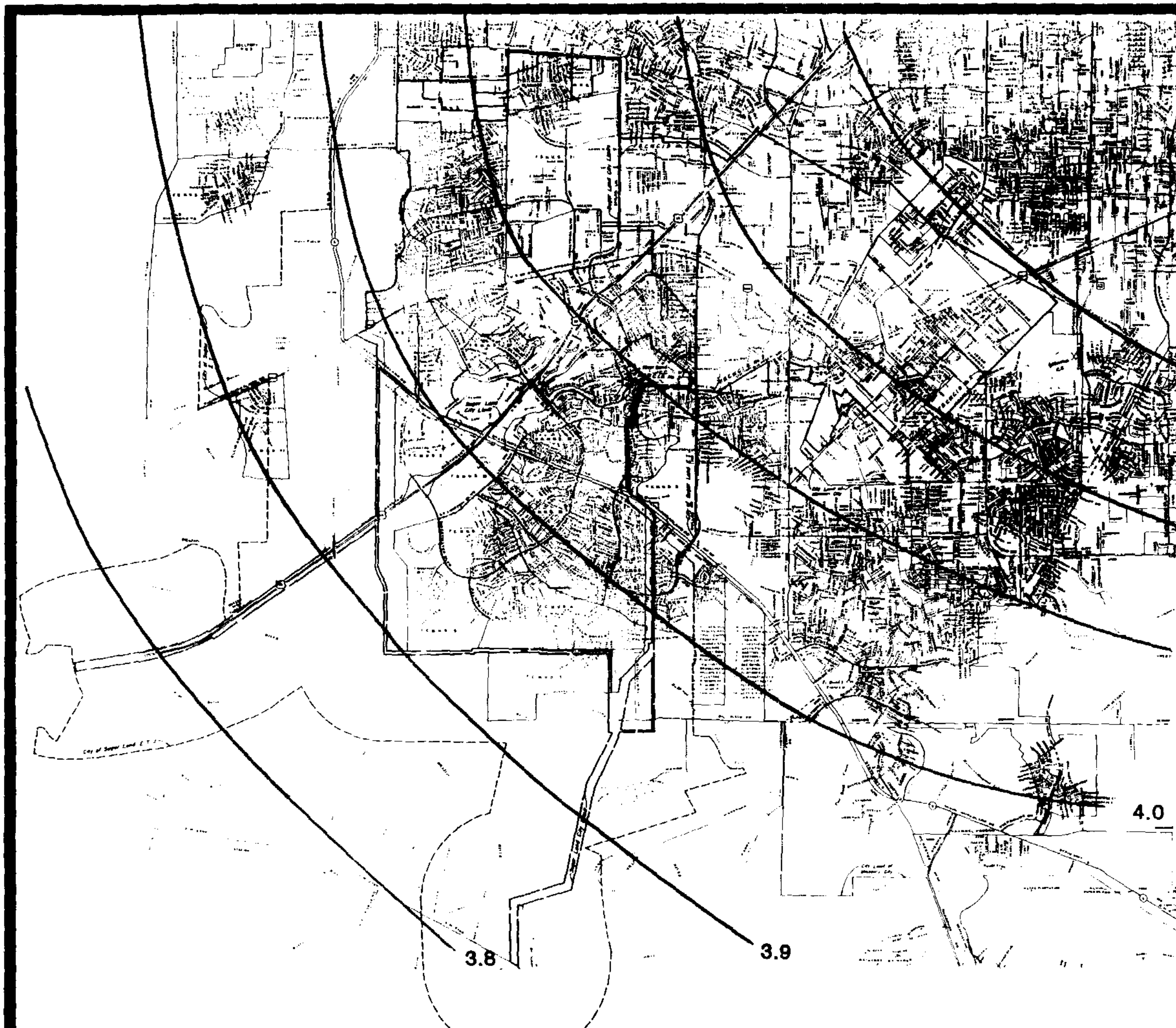
PATE/JONES AND CARTER
A JOINT VENTURE

McBride-Ratcliff and Associates, Inc.
Geotechnical Consultants
Houston, Texas

SCALE NOTED	MADE DLQ	DATE 4-8-88	FILE NO 87-338
	CHECK JLI	DATE 4-8-88	

CASE 2
1987-2010 SETTLEMENT CONTOURS

FIGURE 20



CASE 2

1987-2030

SETTLEMENT CONTOURS WERE INTERPRETED FROM PRESS MODEL AND GROUNDWATER MODEL DATA

SETTLEMENT IN FT.

APPROXIMATE SCALE-FT

0 6,000 12,000

GROUNDWATER EVALUATION
REGIONAL WATER SUPPLY PLANNING STUDY
CITY OF SUGARLAND AND THE FT. BEND COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NO.

PATE/JONES AND CARTER
A JOINT VENTURE

McBride-Ratcliff and Associates, Inc
Geotechnical Consultants
Houston, Texas

SCALE	MADE DLQ	DATE 4-8-88	FILE NO.
NOTED	CHECK JLI	DATE 4-8-88	87-552
CASE 2 1987-2030 SETTLEMENT CONTOURS			FIGURE 21