

TRANS-TEXAS WATER PROGRAM

SOUTHEAST AREA

Technical Memorandum

Wastewater Reclamation

March 19, 1998

**Sabine River Authority of Texas
Lower Neches Valley Authority
San Jacinto River Authority
City of Houston
Brazos River Authority
Texas Water Development Board**

Preface

This document is a product of the Trans-Texas Water Program: Southeast Area. The program's mission is to propose the best economically and environmentally beneficial methods to meet water needs in Texas for the long term. The program's three planning areas are the Southeast Area, which includes the Houston-Galveston metropolitan area, the South-Central Area (including Corpus Christi) and the West-Central Area (including San Antonio).

The Southeast Area of the Trans-Texas Water Program draws perspectives from many organizations and citizens. The Policy Management Committee and its Southeast Area subcommittee guide the program; the Southeast Area Technical Advisory Committee serves as program advisor. Local sponsors are the Sabine River Authority of Texas, the Lower Neches Valley Authority, the San Jacinto River Authority, the City of Houston and the Brazos River Authority.

The Texas Water Development Board is the lead Texas agency for the Trans-Texas Water Program. The Board, along with the Texas Natural Resource Conservation Commission, the Texas Parks & Wildlife Department and the Texas General Land Office, set goals and policies for the program pertaining to water resources management and are members of the Policy Management Committee.

This is the final version of this document.

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1. Introduction

The Trans-Texas Water Program (TTWP) Southeast Area Phase I Report identified thirteen water management alternatives for possible inclusion in its final TTWP Southeast Area Water Management Plan. This current memorandum analyzes the viability of implementing one of these alternatives, wastewater reclamation.

The TTWP Planning Information Update report indicates that within the entire 32 county study area, the largest sub-area of water supply need is within the Houston region. Water supply shortages within the Houston region are projected to occur as early as year 2020 in the Brazos basin, and significant shortages are projected to occur within the San Jacinto basin by year 2040. This technical memorandum summarizes the results of the feasibility of implementing a wastewater reclamation plan for industrial water users within the San Jacinto basin.

Two earlier studies which investigated wastewater reuse in the Houston area are The Houston Water Master Plan (1), and the Feasibility of Wastewater Reuse (2). Both studies evaluated several alternative reuse plans. The specific alternative with the most potential included using wastewater effluent solely for industrial cooling water needs of industries along the Houston Ship Channel. This alternative called for supplying wastewater from the City of Houston 69th Street Wastewater Treatment Plant (WWTP). A new reclaimed water transmission line was proposed under this

plan to extend from the 69th Street WWTP to supply reclaimed water to industries in the State Highway 225 (SH-225) corridor. Under this alternative, the existing Coastal Water Authority (CWA) system would continue to supply raw water for process needs. Thus two separate water supply systems would be proposed. The total capital cost of the conceptual alternative in 1985 dollars was estimated to be \$66 million. This cost was viewed as excessive and the reclamation alternative was not recommended within the Houston Water Master Plan.

There are two conceptual distinctions between the two previous reclamation studies and this current TTWP analysis:

- Previous efforts focused on providing reclaimed wastewater for industrial cooling water use only. **This current TTWP effort is based on providing reclaimed wastewater for both industrial cooling and process water use.**
- Previous studies proposed a new separate reclaimed wastewater transmission main system, maintaining the existing CWA system for non-cooling water purposes and to act as a backup to the reuse system. **This TTWP effort proposes to use a portion of the existing CWA B-1 transmission main system in an effort to reduce the initial reclamation system capital cost.**

These two distinctions are related and may result in a facility cost trade-off. That is,

use of reclaimed wastewater for industrial process water use requires additional treatment requirements and therefore additional costs in relation to only supplying industrial cooling water. Use of existing CWA mains for the reclaimed water system, however, should result in less transmission main construction and lower hydraulic system costs.

2. Wastewater Reuse

Wastewater reuse systems vary widely in effluent quality and reuse applications. Groundwater recharge, agricultural and landscape programs, as well as industrial reuse are some of the more common wastewater reuse programs. Wastewater reuse for agricultural irrigation or landscape purposes is generally the principal type of effluent application within the United States. Industrial reuse programs are relatively few in comparison to irrigation reuse programs. In general, wastewater reuse programs are a result of regional and/or municipal needs to meet identified water supply shortages.

2.1. Application

The following are some examples of existing industrial wastewater reuse programs:

- Harlingen, Texas. The City of Harlingen provides approximately 2.1 million gallons per day (mgd) of reclaimed wastewater to the Fruit of the Loom Corporation. Secondary effluent from the City's wastewater treatment plant receives additional treatment which includes filtration followed by reverse osmosis.
- Lubbock, Texas. The City of Lubbock supplies about 20 mgd of secondary effluent for irrigation and industrial uses. Approximately 15 mgd is used for irrigation purposes while 5 mgd is used for industrial cooling water demands.

- Odessa, Texas. The City of Odessa delivers approximately 2-3 mgd of secondary effluent for irrigation purposes and industrial cooling water needs.
- San Francisco, California. The East Bay Municipal Water District (EBMWD) delivers approximately 5.5 mgd of reclaimed water to the Chevron Richmond refinery. Secondary effluent from the West Contra Costa sanitary district treatment plant is diverted to a water reclamation plant where lime/soda ash softening produces a quality makeup water for the refinery's cooling towers. The reclaimed water meets the California Department of Health Services (DHS) Title 22 requirements for the most stringent use of reclaimed water.

2.2. Regulatory Issues

Chapter 210, Sections 210.1-210.55 of the Texas Administrative Code (TAC) (3) establishes reclaimed water quality criteria, and design and operational requirements for reclaimed water systems. Reclaimed water is defined as "Domestic municipal wastewater which has been treated to a quality suitable for beneficial use."

The major points addressing industrial reuse applications, contained in Chapter 210 of the TAC are: Texas Natural Resources and Conservation Commission (TNRCC) notification and authorization; general requirements for the production; and facility design criteria for conveyance, storage and use.

Section 210.4 of the TAC stipulates that prior to the reuse of reclaimed water, the Executive Director of the TNRCC must be notified by both the reclaimed water provider and end user. State regulatory approval must be obtained. The notification shall describe the intent for wastewater reuse, the origin and reuse location of wastewater, a description of quantity and quality of wastewater, a description of the means for compliance with TAC 210, and an operations and maintenance plan. The operations and maintenance plan shall contain:

- Signed contracts between provider and user;
- Measures to prevent cross connections and unauthorized access to reclaimed facilities;
- A plan for monitoring reclaimed water;
- Descriptions on how to minimize potential human exposure;
- Schedules for maintenance programs;
- Employee training programs and contingency plans for system failures or upsets.

Section 210.31-36 of the TAC contains water quality requirements for two types of reclaimed water uses: Type I use includes irrigation and other uses where the public may be present or come into contact with the reclaimed water; Type II use includes irrigation or other uses where the public is not present or may not come into contact with the reclaimed water. Section 210.51-55 contain special requirements for use of industrial reclaimed water. For both use

types, the only constituents with definitive minimum quality requirements are Biochemical Oxygen Demand (BOD₅) and Fecal Coliform. Reclaimed water may be used in place of a freshwater source if the BOD₅ is at a minimum quality of 20 mg/l for non-ponding systems, and/or 30 mg/l for pond systems, while Fecal Coliform is not to exceed 200 CFU/100ml (CFU-colony forming unit of fecal coliform test). Additionally, Section 210.21-25 of the TAC stipulates general requirements as to the conveyance and use of and public exposure to reclaimed water.

Minimum facility design requirements of the reclamation system are discussed throughout TAC Chapter 210. Some of the major design requirements include required separation distances between reclaimed piping and potable pipelines and prior approval by the TNRCC Executive Director of materials to be used in the construction of reclaimed systems.

TAC Section 210 principally addresses agricultural and landscape uses of reclaimed wastewater. The TNRCC does not maintain detailed hydraulic, water quality, or treatment standards specific to industrial use of reclaimed wastewater. The definition of reclamation system design is left to the project designer. The following proposed plan therefore is designed to meet the above listed TNRCC minimum standards. Additionally, a set of design standards for hydraulic, water quality, water treatment and waste stream discharge are proposed and discussed in the following sections.

3. Conceptual Plan

Determining a wastewater reclamation strategy is a function of:

- The quantity and quality of the source wastewater supply, and
- The location and demand characteristics of the receiving water customer base.

Based on identification of these two parameters, resultant treatment, conveyance and discharge systems can be configured for the reclamation system. Conceptually, the TTWP wastewater reclamation strategy consists of:

- Diverting effluent from three City of Houston wastewater treatment plants (WWTP's),
- Treating this wastewater to a quality acceptable to industrial customers for process and cooling water uses, and
- Transmitting the treated wastewater to the customers through a system of pump stations and pipelines.

This section will discuss each of these areas and propose a potential system.

3.1. Source Water Supply

The wastewater reclamation system under study includes diverting effluent from the 69th St. WWTP and the Sims Bayou North and South WWTP's to a new regional Wastewater Reclamation Plant (WRP). The selected wastewater treatment plants are the nearest municipal treatment facilities to the potential industrial customer-base along the

Houston Ship Channel. Figure 1 illustrates the location of the existing WWTP's and the CWA transmission main system.

The Coastal Water Authority is a government agency of the State of Texas whose purpose is to finance, construct, own and operate raw surface water facilities for use in Harris, Liberty and Chambers counties. The CWA system provides Trinity River water to agricultural, industrial, and municipal customers. The CWA industrial raw water distribution system begins at the Lynchburg Pump station and contains approximately 30 miles of pressure pipe ranging from 48-inches to 108-inches in diameter.

The 69th St. WWTP is Houston's largest municipal wastewater treatment facility and is located in the vicinity of Clinton Drive and North 69th St. The process train consists of a pre-treatment head-works, a pure oxygen activated sludge system, filtration, followed by chlorination and dechlorination. Figure 2: 69th Street Wastewater Treatment Plant shows a schematic diagram of the 69th St. WWTP and the capacities of the major process systems.

The City of Houston also operates two wastewater treatment plants in the Sims Bayou wastewater service area. The original "North" plant is located at the confluence of Plum Creek and Sims Bayou. The more recently constructed "South" plant is located south of the Charles H. Milby Park along Sims Bayou. Both treatment plant process trains consist of a pre-treatment head-works, activated sludge systems, followed by chlorination and dechlorination (see Figure 3 and Figure 4).

Figure 1: Existing Coastal Water Authority Raw Water System

Figure 2: 69th Street Wastewater Treatment Plant

Figure 3: Sims Bayou North WWTP

Figure 4: Sims Bayou South WWTP

A sludge plant is located at the Sims Bayou North facility. To determine wastewater supply availability, an analysis of existing and future WWTP flow was conducted for these three facilities. In order to determine existing flow, monthly summaries of the City of Houston Wastewater Treatment Operations were analyzed for two years of data, Jan. 1993 to December 1994 (See

Table 1).

At present, the 69th St. WWTP has a service area of approximately 98 sq. mi. while both Sims Bayou WWTP's serve an area of approximately 41 sq. mi. The combined existing monthly average daily dry-weather flow (ADF) of the three WWTP's is approximately 115 mgd, while the historical

Table 1: Wastewater Treatment Plant Monthly Average Flows

<i>Date</i>	Flow (mgd)			
	<i>Sims-North</i>	<i>Sims-South</i>	<i>69th St.</i>	<i>Combined</i>
Jan-93	15.4	36.0	94.8	146.2
Feb-93	13.7	31.5	83.3	128.5
Mar-93	15.0	33.4	94.2	142.6
Apr-93	14.1	31.0	84.5	129.6
May-93	13.3	30.4	87.7	131.4
Jun-93	14.1	32.0	94.8	140.9
Jul-93	10.6	24.6	66.1	101.3
Aug-93	10.3	24.5	67.5	102.3
Sept-93	10.0	23.6	65.5	99.1
Oct-93	10.8	26.8	68.6	106.2
Nov-93	10.8	29.2	76.0	116.0
Dec-93	8.5	24.4	69.2	102.0
Jan-94	11.6	23.5	68.2	103.3
Feb-94	11.0	23.0	79.5	113.6
Mar-94	10.2	21.8	75.4	107.4
Apr-94	10.6	21.0	69.7	101.3
May-94	13.2	23.0	84.6	120.8
Jun-94	13.1	27.0	83.3	123.4
Jul-94	9.3	21.9	66.8	98.0
Aug-94	11.4	23.1	68.1	102.6
Sept-94	11.0	20.6	68.5	100.2
Oct-94	15.6	28.9	96.2	140.7
Nov.-94	7.8	20.7	66.5	95.0
Dec-94	11.5	22.9	84.0	118.5
Average	11.8	26.0	77.6	115.5
Maximum	15.6	36.0	96.2	147.9
Minimum	7.8	20.6	65.5	93.9

Figure 5: Potential Industrial Facilities

combined minimum ADF is approximately 94 mgd. Based on wastewater treatment plant operations reports, minimum daily effluent averages were observed to be approximately 85% of monthly averages, while minimum hourly flows may fall to 75% of daily average flows.

Determination of future WWTP flows for the three facilities consists of projecting population and wastewater generation estimates within the service area of each WWTP. The Texas Water Development Board (TWDB) projected a total population for the City of Houston in 2050 to be 3,220,889. The total population growth from 1990 through 2050 within the WWTP's service area is projected to be 305,140 persons. Despite this increase in population over the study period, indoor water consumption is expected to be significantly reduced due to the effects of the Energy Policy Act of 1992. The Act mandates use of efficient low-flow water use fixtures in households. Significant planning implications are expected from the new standards on water demand and wastewater volumes (5). Future wastewater rates are based on a 34% reduction in indoor water consumption. Applying a per capita wastewater flow rate to the projected population increase within the WWTP service area results in an increase of approximately 20 mgd by the year 2050. Therefore combined wastewater ADF of 115 mgd is expected to rise to 135 mgd in the year 2050.

3.2. Potential Customers and Demands

Based on the estimated quantity of available wastewater supply, a review of potentially viable industrial customers was conducted. The purpose of the review was to determine the projected water quality and quantity requirements of the industries and compare those requirements to the available wastewater supply.

The industries targeted are CWA raw water users with existing contracts along the CWA B-1 line from Rohm & Haas Rd. westward to Sims Bayou (see Figure 5). The targeted area contains industries engaged in the following industrial activities:

- Petroleum refining
- Chemical manufacturing (specialty, synthetic organics, etc.)
- Co-generation
- Air separation

- Pulp & paper manufacturing

3.2.1. Wastewater Reuse Survey

The selected industrial customers along SH-225 are currently supplied with raw water from the CWA B-1 line, via the Lynchburg pumping station. A survey was sent to the eighteen (18) industries listed in Figure 5. In addition to requesting basic information (consumptive use, future expansions and conservation programs) the main purpose of the survey was to determine the issues and concerns which their facility would have in using reclaim wastewater as a replacement of their existing raw water supply. Of the 18 industries surveyed, 13 (over 70%) responded.

The following represents a synopsis of the industrial customer response to the survey:

- Existing on-site industrial water treatment facilities (precipitators, softeners, demineralizers) are designed based upon average Trinity River water quality.
- Any increase in nitrogen levels in the form of ammonia and nitrates, will result in increased chlorine demands, causing stress corrosion cracking of brass condensers. Additionally, increased nitrogen levels could increase industrial wastewater discharge concentrations of ammonia nitrogen to unacceptable levels. Some industries indicated difficulties treating wastewater containing nitrogen.
- Any increase in heavy metals (zinc, copper, chromium) will raise concerns regarding discharge permit limitations. Concerns were also raised on the potential increase in corrosion by sending tramp copper through their process systems.
- Concerns were raised regarding the increase in Total Dissolved Solids (TDS) on the operation of their cooling towers (lower cycles of operation, potential scaling and fouling). Higher TDS values would also increase their on-site cost for demineralization programs.
- Several industries stated that organic constituents would also need to be evaluated as well, since organics tend to foul ion-exchange resins.
- Any increase in water hardness would increase on-site plant treatment cost due to softener resin life.

In general, most industries reported that they would consider using wastewater effluent in place of their current raw water needs if their total cost of doing business would not increase. The survey respondents anticipated that increases in costs would occur for new equipment, process materials, and effluent treatment. Additionally, water quality changes were expected to increase manpower requirements for onsite industrial treatment operations and maintenance programs, which would add to their site-specific costs.

Most industries stated that since their raw water treatment facilities were designed to accommodate Trinity River water quality, the industries would require that reclaimed wastewater be equal in quality to CWA raw water, otherwise industry costs were thought to increase.

3.2.2. Design Factors: Water Quality and Demand

As a result of the industrial response to the survey, a conceptual reclamation plan was developed such that effluent from the City of Houston WWTP's would be treated to a quality equal to or better than the current CWA raw water supply. Table 2 provides a comparison of CWA water quality versus the effluent discharge quality from the referenced City of Houston WWTP's.

The CWA system provides raw water for the cooling and process needs for the 18 industries within the targeted area. Potable water needs are met by other sources. Analysis of City of Houston water billing records show that demands for the targeted industries have not changed significantly since 1990. The industrial facilities within the targeted area represent approximately 50% of the total existing heavy manufacturing raw water consumption within the San Jacinto watershed basin.

Table 3 shows the raw water consumption and the distribution of use of the 18 industries. Average raw water consumptive use for individual industries ranges from 0.033 mgd to 28.5 mgd. The raw water use of those industries that responded represented over 90% of the total existing consumption within the targeted area. Industrial demands for the targeted industries are fairly constant. Fluctuations in use are primarily a function of the manufacturing process at each facility. Heat loads developed in process units, ambient temperatures and level of production all tend to impact water consumption. Records of the Lynchburg pumping station show that

monthly variations in demands are approximately 10-12%. Industry response to the survey showed a weighted peaking factor for maximum day consumption to be approximately equal to 1.2 times average daily use.

Future industrial demands are based on projections from the Consensus Water Planning effort for the manufacturing use category within Harris County, based on two-digit Standard Industrial Classification (SIC) codes (3). Consensus Water Planning numbers project that by the year 2050 there would be:

- A 97% increase in water use for chemicals and allied product industries,
- An 89% increase for rubber and miscellaneous plastics facilities,
- A 43% increase for petroleum refineries, and
- A 21% decrease in water use for paper and allied product industries.

These percentages were applied to each of the listed industries to determine their future projected demands. Industrial water use for the industries are projected for each study decade and are shown Table 4. As shown, the projected 2050 average water demand for the targeted industries is approximately 135 mgd.

Table 2: Water Quality of CWA Raw Water and Wastewater Effluent

<i>Parameter</i> (1)	<i>Raw Water</i> (2)		<i>Wastewater</i> (3)	
	<i>Mean</i>	<i>Max</i>	<i>Mean</i>	<i>Max</i>
Total Dissolved Solids (TDS)	246	300	440	470
Calcium	39	44	26.7	27.9
Chloride	25	32	69.5	74.4
Sulfate (SO ₄)	29	37	57	62
Hardness (as CaCO ₃)	112	130	151	156
Total Alkalinity (as CaCO ₃)	95	112	154	211
CBOD ₅			3.00	3.00
NH ₃ -N			1.00	1.50
NO ₃ -N	0.34	0.81	10.7	11.1
Magnesium	4.32	4.92	7.289	8.514
Phosphate (as PO ₄)	0.3	3.2	1.289	3.504
Silver	0.01		0.004	0.011
Arsenic	< 0.003		0.0038	0.008
Beryllium	< 0.02		0.0016	0.01
Cadmium	0.01		0.004	0.011
Chromium	< 0.02		0.0122	0.11
Copper	< 0.03		0.008	0.035
Mercury	< 0.0002		0.0002	0.0002
Nickel	0.02		0.0172	0.023
Lead	0.003		0.0025	0.009
Antimony	< 0.01		0.0242	0.035
Selenium	< 0.02		0.0035	0.005
Thallium	< 0.1		0.0023	0.005
Zinc	< 0.01		0.0479	0.1
Silica	7.20	13.00	8.90	11.00
Total Organic Carbon (TOC)	6.60	9.80	7.50	8.60
pH	8.00	8.20	7.30	7.30

(1) All units mg/l except pH

(2) COH Water Quality Control 1993 Annual Report, Trinity River Quality

(3) 69th St. & Sims Bayou WWTP Effluent

3.3. System Design Criteria

Two types of system design criteria are used to configure the wastewater reclamation plan: process treatment and hydraulics. The basic water treatment process criteria consist

of designing the system to deliver a reclaimed water equal to or better than the current CWA raw water quality for all constituent parameters. Hydraulic criteria are defined for the facility component capacities.

In general, system facilities are designed using the same parameters as conventional water system high service pump stations and transmission mains. Due to the type of industrial customers served by this plan, a totally reliable supply system is proposed. The design criteria are configured to supply 100 percent of the demand, 100 percent of the time.

Hydraulic criteria are established for the proposed pump stations and treatment facilities proposed within the system as follows.

- Wastewater supply—the total amount of combined wastewater diverted to the

WRP (135 mgd) based upon the projected year 2050 average daily dry-weather flow (ADF) available from the three WWTP's.

- Wastewater reclamation plant—treatment capacity equivalent to future average WWTP ADF.
- Transfer pump stations—firm capacity equivalent to future average WWTP ADF.
- Augmentation pump stations—capacity based on delivering the difference between peak demand and minimum

Table 3: Water Demand by Industry:

<i>Industry</i>	1993 Average Consumptive Use (mgd)			
	<i>Monthly Use</i>	<i>Cooling</i>	<i>Process</i>	<i>Other</i>
1 Lubrizol Corp. ⁽¹⁾	0.96	0.53	0.14	0.29
2 Praxair, Inc	0.49	0.35	0.00	0.15
3 Abelman Corp. ⁽¹⁾	3.56	1.96	0.53	1.07
4 Georgia Gulf Corp. ⁽¹⁾	0.56	0.31	0.08	0.17
5 Occidental Chemical Corp.	4.61	0.74	3.88	0.00
6 Shell Oil Co.	22.85	11.65	2.28	8.91
7 Phillips Petroleum ⁽¹⁾	3.74	2.06	0.56	1.12
8 Mobil Mining & Minerals	2.31	1.11	0.39	0.81
9 Crown Central Petroleum	3.31	2.02	2.98	0.99
10 Simpson Pasadena Paper	28.39	1.42	26.97	0.00
11 Applied Energy Services	2.71	2.71	0.00	0.00
12 Lyondell PetroChemical Co.	12.61	7.19	2.40	3.03
13 Mobil Chemical ⁽¹⁾	1.87	0.28	1.59	0.00
14 Miles Inc.	0.61	0.26	0.35	0.00
15 Goodyear Tire & Rubber	1.31	0.30	0.99	0.03
16 Texas PetroChemical Co.	5.53	3.98	0.66	0.89
17 Phibro	2.84	1.11	1.65	0.06
18 Hickson Kerley Inc.	0.03	0.00	0.02	0.01
Total	98.28	37.96	45.47	17.51

⁽¹⁾ Distribution of consumptive use estimated.

diurnal wastewater flow.

- Wastewater reclamation transmission mains—pipelines are sized based on ADF with velocities ranging from 6-8 feet per second.

3.4. Proposed Reclamation System

The proposed wastewater reclamation system includes diverting effluent from three City of Houston Wastewater Treatment Plants to a proposed new Regional Water Reclamation Plant. Proposed pump stations and transmission lines will lift and convey effluent from the three WWTP's to the new

WRP located north of the Sims Bayou North WWTP. A raw water pumping station, located at the East Water Purification Plant forebay would augment the reclaimed supply with raw water, to offset the shortfall between reclaimed water supply and industrial peak demands. After treatment at the WRP, the reclaimed water, or permeate, is pumped to users using CWA's B-1 main for distribution. The wastewater reclamation plan requires that the portion of the CWA B-1 raw water main which parallels State Highway 225 (SH-225) be converted to a reclaimed water main. Other transmission mains are included to convey water from the WRP to the CWA B-1 line and from the East

Table 4: Industrial Water Demand Projections:

Projected Industrial Demands For Each Study Decade (mgd)							
<i>Industry</i>	<i>1990</i>	<i>2000</i>	<i>2010</i>	<i>2020</i>	<i>2030</i>	<i>2040</i>	<i>2050</i>
Lubrizol Corp.	0.96	1.11	1.28	1.39	1.51	1.70	1.89
Praxair, Inc	0.49	0.57	0.66	0.72	0.77	0.88	0.97
Abelmarle Corp.	3.56	4.13	4.75	5.17	5.59	6.31	7.01
Georgia Gulf Corp.	0.56	0.65	0.74	0.81	0.87	0.99	1.10
Occidental Chemical Corp.	4.61	5.35	6.15	6.71	7.24	8.19	9.09
Shell Oil Co.	22.85	24.70	26.43	27.48	28.31	30.57	32.71
Phillips Petroleum	3.74	4.34	4.99	5.44	5.88	6.64	7.37
Mobil Mining & Minerals	2.31	2.68	3.08	3.35	3.62	4.09	4.54
Crown Central Petroleum	3.31	3.57	3.82	3.98	4.10	4.42	4.73
Simpson Pasadena Paper	28.39	26.40	24.29	23.32	21.92	22.14	22.36
Applied Energy Services	2.71	3.15	3.62	3.94	4.26	4.81	5.34
Lyondell PetroChemical Co.	12.61	13.63	14.58	15.17	15.62	16.87	18.05
Mobil Chemical	1.87	2.17	2.49	2.71	2.93	3.31	3.68
Miles Inc.	0.61	0.71	0.81	0.89	0.96	1.08	1.20
Goodyear Tire & Rubber	1.31	1.52	1.74	1.90	2.05	2.32	2.57
Texas PetroChemical Co.	5.53	5.98	6.40	6.66	6.86	7.41	7.92
Phibro	2.84	3.07	3.28	3.42	3.52	3.80	4.07
Hickson Kerley Inc.	0.03	0.04	0.04	0.05	0.05	0.06	0.07
Total	98.28	103.75	109.17	113.11	116.06	125.60	134.67

Water Purification Plant to the WRP (See Figure 6). At a flow of 106 mgd, velocities at the connection to the CWA B-1 transmission main will be approximately 8 feet per second.

The WRP includes the treatment components indicated below and as shown in Figure 7. The preferred WRP treatment process method is membrane treatment (reverse osmosis). However, pre-treatment filtering is required to prevent membrane fouling and supplement membrane treatment removals. Reverse osmosis (RO) is required to address the concerns voiced by the industries within the survey. RO is an extremely advanced treatment process that essentially removes all identified pollutants. Particularly, RO is

needed to address the industry concerns regarding acceptable TDS, Nickel, and nitrogen (specifically nitrate-nitrogen; NO₃-N) concentrations.

The process treatment train at the WRP would consist of a rapid mix chamber, flocculation, filtration with denitrification followed by reverse osmosis. In addition to the treatment processes listed above, auxiliary facilities are needed to support the operation and maintenance of the WRP. Such facilities include: administration, control and laboratory buildings, chemical storage and feed facilities, a maintenance building and a vehicle parking garage.

Figure 6: Wastewater Reclamation Facilities

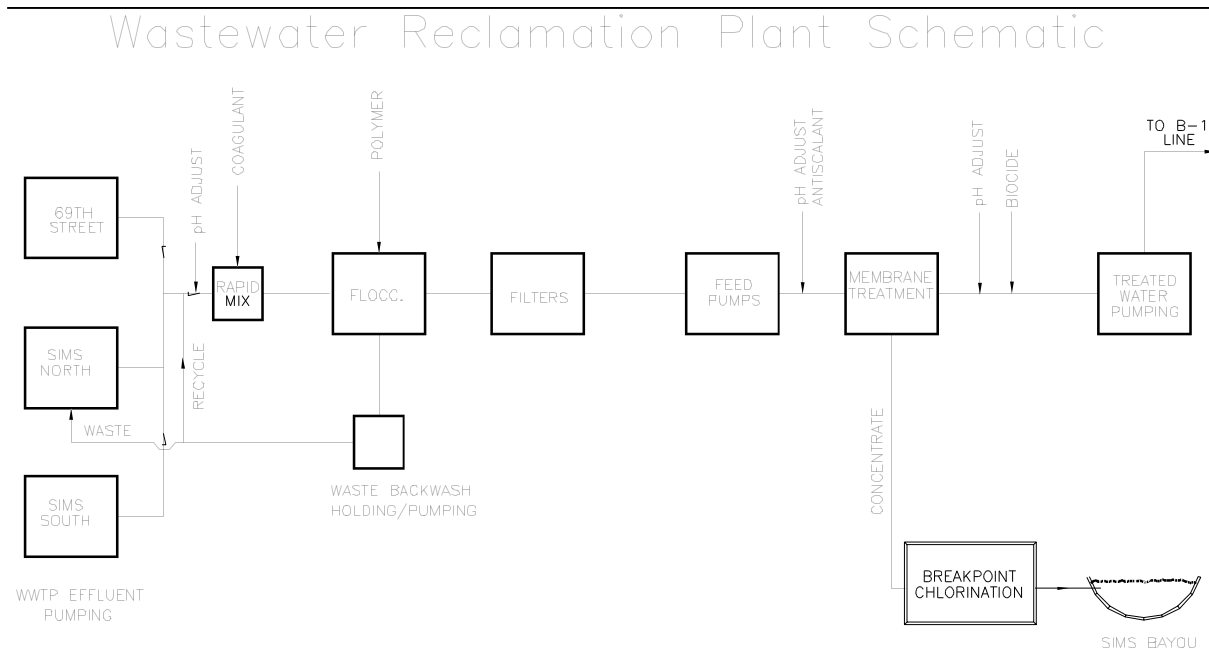


Figure 7: Wastewater Reclamation Plant Schematic

The rapid mix chamber serves as the critical contact or coagulation step in the treatment process. A coagulant (lime, ferric sulfate, or alum) is added and thoroughly mixed with the secondary effluent. Lime or sulfuric acid are added ahead of the coagulant to adjust pH to optimize the coagulation/filtration process.

Following the rapid mix chamber, flocculation or slow mixing provides for the agglomeration of particles and builds the particles into larger “floc” which is subsequently removed in the filtration process. To improve flocculation, a polymer may be added to the flocculation basins to enhance the process.

After flocculation the water is conveyed to filters which, operating in the “direct” filtration mode, remove the flocculated particles, clarifying the water. In addition, the filter media will also serve to assist the subsequent membrane treatment in the removal

of nitrates. The filters are configured in several rectangular shaped basins containing granular mixed media consisting of coal and sand. This “dual media” is particularly designed to store relatively large quantities of solids that can be generated by wastewater treatment plant upsets. The effluent from the filters is conveyed to a sump which serves as storage of filter backwash supply. Periodically, the filters are backwashed to remove accumulated solids and nitrogen gas. The waste backwash is routed to a sump that serves to equalize the flow and allows for recycling to the head of the reclamation plant. Accumulated solids will be pumped to the Sims North WWTP for co-processing.

After the filtration pretreatment step, water is pumped to the RO membrane treatment complex. The membranes are configured in a cylindrical form as elements. Several elements are placed in pressure vessels or tubes. These tubes are then grouped

Table 5: Reverse Osmosis Permeate Quality (mg/l, mean)

<i>Parameter</i>	<i>Raw Water (1)</i>	<i>RO Permeate (2)</i>
Total Dissolved Solids (TDS)	246	12.4
Calcium	39	0.2
Chloride	25	1.6
Sulfate (SO ₄)	29	0.2
Total Alkalinity (as CaCO ₃)	95	9
NH ₃ -N		0.2
NO ₃ -N	0.34	0.34
Magnesium	4.32	0.1
Silica	7.2	0.3

(1) COH Water Quality Control 1993 Annual Report, Trinity River Quality

(2) Based on R.O. 85% Recovery Performance Projection

together into an array and mounted on skids in modular fashion. An appropriate number of skids is supplied to provide the needed flow capacity.

The treated water, or permeate, flows on to the finished water pump station for distribution to users. The proposed system uses an 85% recovery rate from the R.O. process. The wastestream from the reverse osmosis process, called concentrate or brine, will require treatment to remove ammonia nitrogen before being discharged to the receiving body of water.

The wastestream brine will be deposited into Sims Bayou after treatment to remove ammonia nitrogen. To meet the anticipated discharge requirement of 3 mg/l ammonia nitrogen (4), facilities for breakpoint chlorination are included in the treatment costs. A total of 18.4 mgd of brine (15% of flow) would be produced from the configured treatment facility.

The conceptual plan produces, on average, a permeate available to industrial customers of 106 mgd in year 2050. This amount of permeate supply results in a corresponding reduction of surface water demand on a daily basis meeting 79 percent of the computed industrial demand need of 135 mgd in year 2050. The configured system includes introduction of 29 mgd of supplemental raw river water to achieve the total projected industrial water demand need.

Table 5 presents a comparison of anticipated permeate quality to the current CWA quality for key parameters. For all parameters except for nitrate-nitrogen the permeate water quality is significantly better than the currently provided Trinity River water. The survey revealed that each industry is incurring a significant additional on-site cost to treat the Trinity River water to achieve necessary industrial process water quality standards. It is anticipated that the enhanced quality may become an incentive for industries to accept reclaimed water since their on-site pre-treatment costs would be

expected to drop. Additionally, it is expected that improved cooling tower operations resulting from the improved quality may reduce water demand needs.

Increased cycles of concentration may be achieved through use of the reclaimed water. Scaling within the cooling towers may be decreased thereby allowing multiple use (cycles) of cooling tower water.

4. Environmental Impacts

The potential impacts on water quality resulting from the wastewater reclamation project were examined. First, one effect of the project would be to divert existing discharges of secondary effluent from Buffalo Bayou, and Sims Bayou and the Houston Ship Channel to the WRP. (The short reach of Sims Bayou between the Sims WWTP and the Houston Ship Channel is hydrologically linked with the Ship Channel and is not considered here.) Secondly, additional impacts on water quality may be associated with the discharge of brine concentrate from the WRP into the Houston Ship Channel. The potential impacts on aquatic species in the Houston Ship Channel from potential changes to water quality have not been addressed at this stage. Future studies may be required to address this issue based on the final resolution of the water quality issues.

4.1. Water Quality Impacts to Receiving Water Bodies

The proposed reclamation strategy would redirect to the WRP secondary effluent discharges from the three WWTP's which are currently flowing into Buffalo Bayou and Sims Bayou. During wet-weather events some of the effluent from these plants would continue to discharge through existing outfalls to Buffalo Bayou (69th Street) and Sims Bayou (Sims North and Sims South). Current levels of wastewater discharges by industries into the Houston Ship Channel would remain unchanged.

The municipal (reclaimed) effluent would flow to the WRP. The WRP treatment processes will:

- filter suspended solids (including oxygen-demanding particulate organic matter);
- reduce the volume to 15 percent of the flow, creating a brine concentrate;
- treat concentrate to remove excess ammonia.

After RO treatment, the resulting brine concentrate will be discharged into Sims Bayou. Potential impacts from this strategy result from changes in the location, quantity and quality of effluent discharged to these bayous. Changes in water quality and quantity could impact the aquatic habitat of Buffalo and Sims Bayous and the Houston Ship Channel.

The approximate location of the waste concentrate discharge would be to designated Stream Segment No. 1006-“Houston Ship Channel.” This segment consists of the Houston Ship Channel from its confluence with the San Jacinto River upstream to a point just upstream of Greens Bayou. Stream Segment No. 1006 is designated for two use types: Industrial Water Supply and Navigation. Currently, Segment No. 1006 maintains a stream classification as “Water Quality Limited” which requires that wastewater discharges use advanced wastewater treatment processes. Texas Clean Rivers Program data indicate that

historically, there has been some concern regarding heavy metals and dioxin in this segment. Segment No. 1006 water uses and stream standard criteria however are generally being attained.

Stream Segment No. 1006 is a sluggish, tidally influenced bayou. The water column consists of a pronounced stagnant salt wedge under a flowing freshwater layer. The salt wedge will have a salt concentration equivalent to seawater (35,000 ppm).

The discharge of a salt concentrate is classified as an industrial waste. It is regulated as part of the NPDES permitting program by the U.S. Environmental Protection Agency (EPA) and the Texas Natural Resource Conservation Commission (TNRCC). The proposed discharge is subject to the provisions of Section 403c of the Clean Water Act (Ocean Discharge Criteria) and must comply with the Texas Water Quality Criteria for Marine Discharges.

The brine concentrate primarily consists of dissolved solids and heavy metals. Dissolved solids and metals are conservative water pollutants and as such do not degrade into other substances once discharged into the water column. The brine concentrate would have an approximate concentration of 2,384 ppm of Total Dissolved Solids (TDS). Impacts of the brine to Stream Segment 1006 could potentially occur within the freshwater component of the water column where initial mixing of the concentrate would occur.

4.2. Environmental Conclusions

Simple stream models were developed in order to estimate the impacts of removing secondary effluent from the receiving streams. These models assume fully mixed reaches of receiving streams to estimate general impacts to ambient water quality; the models do not estimate local impacts within effluent mixing zones. This study used stream water quantity and quality data for July and August, typically the driest months in the Houston region. This study also estimates impacts at extreme (record) low flow periods for comparison. Details of the methodologies used to determine water quality impacts and results are presented in Appendix A.

Based upon these models several conclusions are drawn.

1. Effluent discharge from the 69th Street and Sims South and North wastewater treatment plant create both beneficial and adverse water quality impacts on Buffalo Bayou and the Houston Ship Channel. The benefits include reduced concentration of suspended solids and increased amounts of dissolved oxygen. The potentially adverse impacts are increased levels of nitrate and ammonia. While the benefits of the current wastewater discharges appear to be small, except perhaps near the discharge point, the adverse impacts are significant for at least several miles downstream. Reclaiming this effluent in conjunction with the proposal strategy would result in shifting the discharge of nitrogen downstream. This shift of discharge points relocates but does not eliminate

- nutrient enrichment (and its associated algae blooms) in Buffalo Bayou and the Houston Ship Channel.
2. Withdrawal of wastewater effluent from either of the two bayous will have little effect on terrestrial habitats or terrestrial organisms living in areas adjacent to the bayous. The incised nature of the bayous within the project area, the lack of adjacent wetland within the area of potential impact, and the small contribution of sewage treatment to stream elevations within the receiving streams support this conclusion.
 3. Locating brine discharge outfalls near the bottom of the Stream Segment No. 1006 may mitigate potential negative impacts. Introducing the TDS and metals into the salt water wedge component of the streamflow could potentially reduce the impacts to the freshwater layer. Further analysis of the brine discharge impacts and possible mitigation strategies would have to be studied if this reclamation strategy were pursued further in the future.

5. Cost Estimate

The total construction cost is estimated as approximately \$153.4 million with an associated annual operations and maintenance cost of approximately \$24.9 million. The annual average water cost is approximately \$850 per acre-foot. Table 6 summarizes the probable project costs for the reclamation system.

A life cycle cost analysis was performed to illustrate the present worth cost of this strategy. The following financial factors were used in the life cycle cost analysis:

- Capital costs were assumed to be financed over 30 years at an interest rate of 8.5 percent per year.
- The discount rate was set at 4.5 percent.
- The inflation rate was set at 4.5 percent.

Table 7 shows that the total present worth cost of the wastewater reclamation strategy ranges from \$1.01 per thousand gallons in the first year of operation to \$0.75 per thousand gallons in the last year.

Table 7 assumes initial operation of the wastewater reclamation facility in year 2005. This period was used to equitably compare the total cost of this strategy to the other TTWP water management strategies. In fact, the reclamation strategy would not be put into operation until actually needed in year 2030. A reclamation facility constructed in year 2030 would have a significantly higher capital, and operation

and maintenance cost than is shown in Table 7. Projecting unit cost values inflated to year 2030 for this strategy would show very large capital costs which would appear excessive in comparison to the other TTWP water strategies. The computed present value cost, shown in Table 7, represents the approximate present worth cost to begin operation of the reclamation facility in year 2005. The present value cost therefore can be used to compare this strategy to the other TTWP management strategies.

Table 6: Probable Costs of Wastewater Reclamation Facilities

Cost (Thousands of Dollars)			
<i>Facility</i>	<i>Size</i>	<i>Construction</i>	<i>O & M</i>
Pump Stations			
	(mgd)		
69 th Street	87	\$3,423	\$2,042
Sims South	34	\$1,700	\$444
Sims North	14	\$1,050	\$207
Augmentation	102	\$4,000	\$868
WRP	106	\$4,000	\$2,679
Subtotal		\$14,173	\$6,240
Transmission Mains			
	(Dia., Inch)		
Reclaimed	66	\$3,819	\$19
69 th Street	60	\$15,188	\$76
Sims South	36	\$1,625	\$8
Sims North	24	\$250	\$1.3
Subtotal		\$20,882	\$104.3
WRP Treatment			
Filters & Flocculation		\$18,775	\$4,787
Membrane Treatment		\$75,074	\$13,723
Chemical Storage & Feed		\$7,908	(1)
Lab & Admin. Bldgs.		\$3,143	(1)
Land		\$545	
Maintenance Bldg.		\$2,318	(1)
Site Work & Yard Piping		\$8,261	(1)
Treated Water line		\$2,383	\$38
Subtotal		\$118,407	\$18,548
TOTAL		\$153,462	\$24,892

(1) Cost included in Filter and Flocculation O&M

Table 7: Life Cycle Cost Analysis

YEAR	YIELD (ac-ft / yr)	BOND PAYMENTS (\$1,000)	O & M COSTS (\$1,000)	TOTAL COST (\$1,000)	UNIT COST (\$/1,000 gal)	PRESENT VALUE (1995\$ / 1,000 gal)
2005	118,700	\$22,176	\$38,657	\$60,832	\$1.57	\$1.01
2006	118,700	\$22,176	\$40,396	\$62,572	\$1.62	\$1.00
2007	118,700	\$22,176	\$42,214	\$64,390	\$1.66	\$0.98
2008	118,700	\$22,176	\$44,114	\$66,289	\$1.71	\$0.97
2009	118,700	\$22,176	\$46,099	\$68,275	\$1.76	\$0.95
2010	118,700	\$22,176	\$48,173	\$70,349	\$1.82	\$0.94
2011	118,700	\$22,176	\$50,341	\$72,517	\$1.87	\$0.93
2012	118,700	\$22,176	\$52,606	\$74,782	\$1.93	\$0.91
2013	118,700	\$22,176	\$54,973	\$77,149	\$1.99	\$0.90
2014	118,700	\$22,176	\$57,447	\$79,623	\$2.06	\$0.89
2015	118,700	\$22,176	\$60,032	\$82,208	\$2.13	\$0.88
2016	118,700	\$22,176	\$62,734	\$84,910	\$2.19	\$0.87
2017	118,700	\$22,176	\$65,557	\$87,733	\$2.27	\$0.86
2018	118,700	\$22,176	\$68,507	\$90,683	\$2.34	\$0.85
2019	118,700	\$22,176	\$71,590	\$93,766	\$2.42	\$0.84
2020	118,700	\$22,176	\$74,811	\$96,987	\$2.51	\$0.83
2021	118,700	\$22,176	\$78,178	\$100,354	\$2.59	\$0.83
2022	118,700	\$22,176	\$81,696	\$103,872	\$2.69	\$0.82
2023	118,700	\$22,176	\$85,372	\$107,548	\$2.78	\$0.81
2024	118,700	\$22,176	\$89,214	\$111,390	\$2.88	\$0.80
2025	118,700	\$22,176	\$93,228	\$115,404	\$2.98	\$0.80
2026	118,700	\$22,176	\$97,424	\$119,600	\$3.09	\$0.79
2027	118,700	\$22,176	\$101,808	\$123,984	\$3.21	\$0.78
2028	118,700	\$22,176	\$106,389	\$128,565	\$3.32	\$0.78
2029	118,700	\$22,176	\$111,177	\$133,353	\$3.45	\$0.77
2030	118,700	\$22,176	\$116,180	\$138,356	\$3.58	\$0.77
2031	118,700	\$22,176	\$121,408	\$143,584	\$3.71	\$0.76
2032	118,700	\$22,176	\$126,871	\$149,047	\$3.85	\$0.76
2033	118,700	\$22,176	\$132,580	\$154,756	\$4.00	\$0.75
2034	118,700	\$22,176	\$138,546	\$160,722	\$4.15	\$0.75
TOTAL	3,561,000	\$665,279	\$2,358,321	\$3,023,600		

6. Water Supply and Availability

The TTWP *Planning Information Update* determined the period of time for which existing water supplies (groundwater and surface water) within the Southeast Area can satisfy future projected water needs. This analysis as conducted for each river basin is shown in Table 12 of that report. Table 13 of that report then assessed the availability of existing Southeast Area water supplies to meet the future projected water demands for the state-wide TTWP region. These two referenced tables are shown in Appendix B. Tables 12 and 13 support the following conclusions:

- Current existing Southeast Area water supplies can meet all projected Southeast Area demands through year 2010.
- The Brazos river basin will experience the earliest water supply shortfalls within the Southeast Area by year 2020.
- The San Jacinto River basins (San Jacinto, San Jacinto-Brazos, and Trinity-San Jacinto) within the Houston Metro region will experience initial water supply shortages by year 2030 and these shortfalls will become increasingly significant thereafter.

The value of the wastewater reclamation strategy can be measured by assessing its impact on the above referenced Tables 12 and 13.

The wastewater reclamation strategy will supply approximately 118,700 afy beginning

in year 2030 to the San Jacinto basin. This strategy will therefore satisfy the projected water demand needs of the San Jacinto basin for an approximately 10 year period through year 2040. Even after implementing this strategy, water supply deficits will remain in all of the coastal basins, the Brazos basin and the San Jacinto basin at the end of the planning period. Table 12 illustrates that the total shortfall in basins serving the Houston region (Trinity - San Jacinto, San Jacinto, and San Jacinto-Brazos) in year 2050 is approximately 256 afy. This wastewater reclamation strategy will provide 46 percent of the Houston region shortage thereby reducing, but not eliminating, the supply shortfall.

Use of this strategy will increase the total Southeast Area's projected year 2050 water supply surplus from 670,400 afy to 789,100 afy (see Appendix B.) For the entire State of Texas TTWP, under Scenario 1, the worst case scenario, after meeting all of the projected water demands, an additional 189,100 acre-feet per year would exist in year 2050 within the Southeast Area using this strategy.

7. Conclusions

unit water cost of approximately \$850 per acre-foot.

This analysis evaluated delivering reclaimed water to industries at a quality which would not impact their existing treatment programs, as well as plant process equipment. Thus, the approach was to deliver reclaimed water at a quality equal to or better than current Trinity river quality through the use of filtration and reverse osmosis demineralization.

The key findings of the wastewater reclamation management strategy analysis consist of the following:

- The wastewater reclamation system would exist within the San Jacinto River basin, situated to supply the Highway 225 corridor industries with reclaimed wastewater.
- A 106 mgd capacity facility was investigated. This facility would provide approximately 118,700 acre-feet per year of water to meet future demands of approximately 18 industries.
- The environmental impacts associated with this strategy appear to be potentially significant. The additional salt concentrate disposal into the Houston Ship Channel may cause localized aquatic environmental impacts from the discharge of heavy metals and nitrate-nitrogen.
- This wastewater reclamation plan would have a total capital cost of \$153.4 million. This equates to an average per

8. References
