The Economics of Desalting Brackish Waters for Regional, Municipal and Industrial Water Supply in West Texas

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The Economics of Desalting Brackish Waters for Regional, Municipal and Industrial Water Supply in West Texas

By The Ralph M. Parsons Company, Los Angeles, California, and the Texas Water Development Board, Austin, Texas for the Office of Saline Water; J. A. Hunter, Director; Joseph J. Strobel, Chief, Desalting Feasibility and Economic Studies Staff; E. F. Miller, Project Manager.

Contract No. 14–01–0001–1459

UNITED STATES DEPARTMENT OF THE INTERIOR • Stewart L. Udall, Secretary
Max N. Edwards, Assistant Secretary for Water Pollution Control

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FOREWORD

This is one of a continuing series of reports designed to present accounts of progress in saline water conversion and the economics of its application. Such data are expected to contribute to the long-range development of economical processes applicable to low-cost demineralization of sea and other saline water.

This report presents the results of a study of the preliminary feasibility and economics of desalting brackish waters for municipal and industrial water supply in candidate regions of West Texas. The study was initiated in June, 1967 by contract with the Texas Water Development Board. The Ralph M. Parsons Company, Engineers-Constructors of Los Angeles was the sub-contractor. Except for minor editing, the data and narrative herein are as contained in the final report submitted under Contract No. 14-01-0001-1459. The data and conclusions given in the report are essentially those of the contractor and are not necessarily endorsed by the Department of the Interior.

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INTRODUCTION

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1. INTRODUCTION

1.1 PURPOSE

The study, initiated in June, 1967, was conducted by The Ralph M. Parsons Company for the Texas Water Development Board under the Board's contract with the Office of Saline Water, U.S. Department of the Interior. The purpose of the study is to obtain information on the type and characteristics of desalting plants most suitable to the treatment of saline waters in West Texas and to compare the economics of desalting these saline waters with the alternative sources of water supply. The office of Saline Water needs this type of information to assist in guidance of its research and development program on processes for low-cost desalting and to further advance the development of methodology for effectively comparing the economics of desalting with alternative means of providing potable water in a variety of locations and water demand circumstances. The Texas Water Development Board has need for this information in developing part of the comprehensive long-range water plan for Texas. This report presents the results of the study of the preliminary engineering economics of supplying municipal and industrial water from desalting plants in the 2 to 20 MGD size range in candidate areas of West Texas.

Water resources in Texas are poorly distributed, most of them occurring in the eastern part of the state. The West Texas region is the major water-short region in Texas. This region is primarily dependent on ground water as a source of supply, most of which is being mined from storage. An intermediate to large-scale desalting plant, servicing either a single municipality or a regional system encompassing a number of municipalities, may be an alternative solution to projected water shortages in some areas of West Texas.

The preliminary engineering economics of desalted water supply for Texas communities as developed by the Texas Water Development Board and the Southwest Research Institute under Office of Saline Water Contract 14-01-0001-603 provides a basis for this study. Information from the 1965-66 study is summarized in a report titled "The Potential Contribution of Desalting to Future Water Supply in Texas", Office of Saline Water R&D Report No. 250, November 1966. This information, and data from advanced water planning studies which have been conducted by the Texas Water Development Board since the later part of 1966, was used to determine which geographical areas of West Texas were potential candidates for municipal and industrial water supply from intermediate to large-scale desalting plants.

Candidate areas identified for study are shown in Figure 1-1. None of the study areas are in that geographical area referred to as the High Plains of Texas. Ground water from the Ogallala aquifer in this area is being mined at an increasing rate for irrigation, and a major decline in available water will occur in the near future in the irrigation areas. However, according to the Texas Water Development Board, studies indicate that a sufficient volume of ground water from the aquifer will be available, coupled with surface water from Lake Meredith in the Canadian River Basin, to adequately supply the projected municipal and industrial needs of the High Plains to the year 2020.

The county groupings into six study areas is based on similarity of present or potential water supply problems. These problems range from present availability and quality to limited alternative sources and future water quality problems. Desalting offers an alternative or supplemental source of supply as a solution to these problems. Chapter 3 of this report describes the water resources problems of West Texas while Chapters 4 through 9 describe the conditions for each study area.

SUMMARY OF REPORT

This report explores the preliminary feasibility and costs of operating desalting plants on brackish feedwaters and furnishing the product water as a source of municipal and industrial water supply, comparing these costs with the cost of water supply from alternative sources.

In several instances the regions under study were associated with large water supply agencies, namely:

- Colorado River Municipal Water District in the Ector-Midland Region
- West Central Texas Municipal Water District in the Taylor Region
- Greenbelt Municipal and Industrial Water Authority in the Childress-Hardeman-Vernon Region

These agencies have contracts and agreements with various cities within the regions studied in this report and also with cities outside the regions. Because the extent of the facilities of these agencies goes beyond the limits of the regions, the scope of this study was interpreted to include consideration of the cities which had agreements with the agencies.

In the cases for the Ector-Midland Region, the mass diagram shows the water requirements for the Ector-Midland Region plus the cities of Big Spring and Snyder which receive their water supply from the CRMWD. In the case for the Taylor Region the mass diagram shows

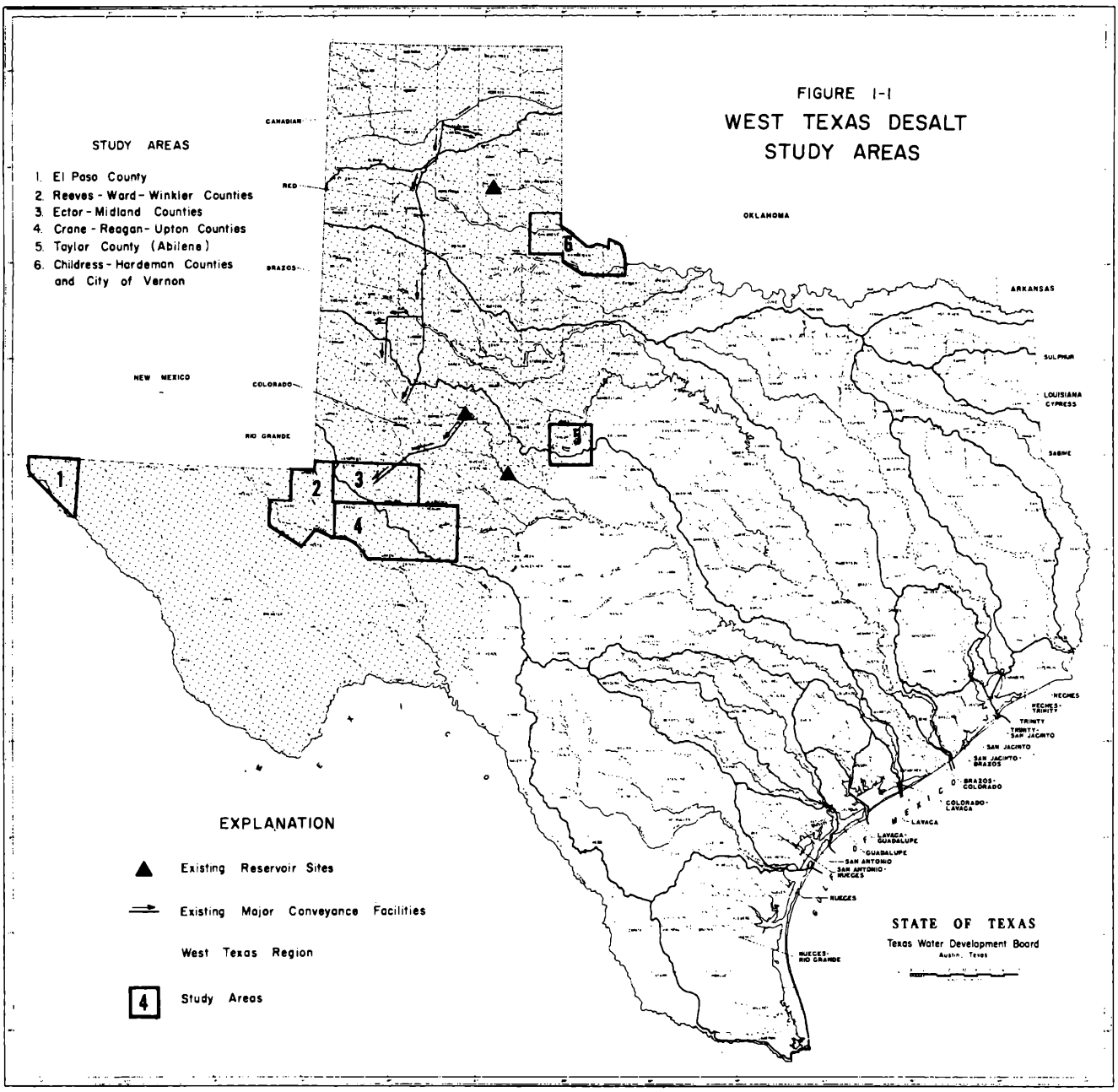
FIGURE I-1
WEST TEXAS DESALT
STUDY AREAS
STUDY AREAS
1. El Paso County
2. Reeves - Ward - Winkler Counties
3. Ector - Midland Counties
4. Crane - Reagan - Upton Counties
5. Taylor County (Abilene)
6. Childress - Hardeman Counties and City of Vernon
CANADIAN
RED
BRAZOS
COLORADO
RIO GRANDE
NEW MEXICO
OKLAHOMA
ARKANSAS
SULPHUR
LOUISIANA
CYPRESS
SABINE
NECHES
NECHES-TRINITY
TRINITY
TRINITY-SAN JACINTO
SAN JACINTO
SAN JACINTO-BRAZOS
BRAZOS-COLORADO
COLORADO-LAVACA
LAVACA
LAVACA-GUADALUPE
GUADALUPE
SAN ANTONIO
SAN ANTONIO-NUECES
NUECES
NUECES-RIO GRANDE
EXPLANATION
Existing Reservoir Sites
Existing Major Conveyance Facilities
West Texas Region
Study Areas
STATE OF TEXAS
Texas Water Development Board
Austin, Texas

the appropriation to the City of Abilene from the Hubbard Creek Reservoir which is owned by the West Central Texas Municipal Water District. For the Childress-Hardeman-Vernon Region the mass diagram also includes the water requirements for the cities of Clarendon, Crowell, Hedley, Memphis, and Wellington.

For the purposes of this report it was assumed that the desalting plants would operate as part of the various water agencies associated with the regions under study. Preliminary discussions indicated that the agencies would look favorably toward consideration of the application of desalting plants without, however, making any commitments at this time.

This report contains the summary results of the preliminary desalting feasibility and economic data for the regions studied. If a decision is reached by any of the regions to proceed with an engineering feasibility report, the determination of all factors affecting plant location, feedwater supply brine disposal, cost of energy, and pre- and post-treatment requirements should be included to arrive at more precise estimates of plant and desalted water costs.

In order to study the application of desalting plants on a regional basis, it was necessary to considered the available water resources on a regional basis. However, it should be emphasized that most of the water resources in the regions are under separate ownership and are being treated on a regional basis only for purposes of analysis in this report.

It is recognized that water requirements for a city follow a daily and also a seasonal variation, thereby imposing a fluctuating demand on the water supply system. For the purposes of this report it was assumed that the system on which the desalting plant was applied would have sufficient storage capacity and water reserves to take account of the water demand fluctuations, thereby permitting the desalting plant to operate at a uniform production capacity for 330 days out of each year (90% operating factor). The computations for the determination of water costs were therefore based on average water requirement figures.

The large projected per capita per day use indicated for several cities is attributed to a large projected industrial water requirement. For simplicity in handling projected requirements of water used by industry located within a county but not within the confines of any city, the Texas Water Development Board allocated these requirements to the nearest city. This has the effect of showing a large water requirement for some of the cities in this report.

The following is a summary of some important economic parameters used as a basis for determination of costs:

- Interest Rate . . . . . 3-1/2% per year
- Desalting Plant Lifetime. . . . . 30 years
- Pipeline Facilities . . . . . 50 years
- Chemical Treatment Facilities . . . . 10 years
- Taxes . . . . . Not Included
- Insurance . . . . . Not Included
- Payroll Extras. 15%
- General and Administrative Costs. . . 30%
- Supplies and Maintenance Materials. . 0.5%-1% of Capital Investment
- Working Capital . . . . . 60 days requirement
- Fuel Costs. . . . . 22¢ to 28¢ per 10^6 Btu
- Electric Power (Municipal Rates). . . 10 to 12 mills per kilowatt hour (KWH)

Capital and operating cost estimates were calculated for December, 1967 costs.

The West Texas regions included in this report are located in an area where the feedwater, with one exception, comprises brackish water with salinities ranging from approximately 1100 ppm to approximately 6700 ppm. The one exception is Estelline Springs which has a salinity of approximately 47,000 ppm.

The desalting processes selected for study were adapted to the salinities and chemical compositions of the feedwaters. Concentration ratios were adjusted on the basis of judgment to take advantage of the lower salinity while at the same time recognizing that the presence of calcium and magnesium requires brine concentration that will avoid scaling problems.

The most serious feedwater problem was occasioned by the use of the Capitan Reef supply. The constituents of this water include hydrogen sulfide as well as high total hardness as calcium carbonate. Utilization of Capitan Reef feedwater necessitated extensive chemical treatment which involved a high cost in terms of each thousand gallon of product water even after crediting the revenue derived from the sale of by-product sulfur.

Brine disposal represented an appreciable cost for each 1,000 gallons of product water.

In order to bring the results of the entire study into focus, Figure 1-2 has been prepared. This shows all of the component costs which make up the total water costs for each of the cases studied. Total costs for delivered water range from 35.6¢ per thousand gallons for a 10 MGD electrodialysis plant in the El Paso Region utilizing Hueco Bolson feedwater to $1.147 per thousand gallons for a 1.8 MGD vacuum-freezing vapor-compression plant in the Childress-Hardeman-Vernon region utilizing Estelline Spring feedwater.

Also shown on Figure 1-2 is the ratio of the total water cost to the product water cost at the plant for each of the cases studied. In 11 of the 18 cases studied this ratio exceeds 1.5, illustrating the importance of careful investigation into costs beyond the desalting plant boundary which go to make up the total cost of delivered water to a water system.

A team comprising representatives of the Texas Water Development Board, the Office of Saline Water and The Ralph M. Parsons Company visited with officials of water agencies and cities in the areas included in the study; also with officials of Shell Oil Co., Gulf Oil Corp., El Paso Natural Gas Co. and El Paso Electric Co. Their fine cooperation and the valuable information which they provided is gratefully acknowledged.

This report includes material obtained from the Texas Water Development Board, the Office of Saline Water, Oak Ridge National Laboratory, and manufacturers, as follows:

Prepared by Mr. Harold D. Holloway, Texas Water Development Board:

- Section 1.1, Purpose
- Section 2.5, Brine Disposal
- Entire Chapter 3 /67/(1)
- Section 4.9, Brine Disposal
- Section 5.9, Brine Disposal
- Section 6.9, Brine Disposal
- Section 7.9, Brine Disposal
- Section 8.9, Brine Disposal
- Section 9.9, Brine Disposal

(1) This designation refers to the numbered references included in the Bibliography at the end of this report.

Prepared by Mr. E. F. Miller, Office of Saline Water

- Section 2.2.2, Electrodialysis Process
- Section 2.2.3, Reverse Osmosis Process
- Section 2.2.4, Vacuum Freezing Vapor Compression Process
- Section 2.2.5, Multistage Flash Process
- Section 2.4, Chemical Pretreatment of Capitan Reef Feedwater [68]

Also, Mr. Miller prepared projections which were used in connection with the development of capital and operating and maintenance costs for the reverse osmosis process.

Prepared by Mr. S. J. Senatore, Oak Ridge National Laboratory [65].

- Section 2.2.6, Vapor Compression Vertical Tube Evaporator Process
- Section 2.2.7, VC-VTE Plant Design for West Texas

Furnished by Mr. William E. Katz, Ionics Inc., Watertown, Mass.

- Electrodialysis plant data, capital costs and operating and maintenance costs. [61] [66]

Furnished by Mr. Paul Weiss, Colt Industries, Beloit, Wis.

- Vacuum-freezing, vapor-compression plant data, capital costs and operating and maintenance costs. [44] [46] [63]

Furnished by Dr. Glenn Havens, Havens Industries, San Diego, Calif.

- Reverse osmosis plant data, capital costs and operating costs. [38]

Also, valuable technical and economic information was obtained in visits to facilities of Gulf General Atomics Corporation and Aerojet General Corporation and from published information of E. I. DuPont de Nemours & Co., Inc.

WEST TEXAS DESALTING STUDY

SUMMARY OF ALL CASES STUDIED

REGION	CASE NO	PROCESS	PLANT SIZE MGD	(SEE NOTE*) 500 PPM WATER MGD	WATER COST - CENTS PER KILOGALLON						RATIO: TOTAL ÷ 500 PPM WATER AT PLANT	¢/Kgal COST FROM ALTER-NATIVE SOURCES
					500 PPM WATER AT PLANT	FEED-WATER TREAT-MENT	FEED WATER SUPPLY	BRINE DISPOSAL	POTABLE WATER CONVEY-ANCE	TOTAL COST		
EL PASO	I-1b	VC-VTE	6.1*	8.7	25.0	0	7.3	6.1	1.0	39.4	1.57	45-50
	I-2b	VC-VTE	10*	14.3	26.6	0	7.0	6.7	0.8	41.1	1.56	
	I-3	E/D	10	10	32.3	0.1	6.1	2.5	2.0	43.0	1.33	
	I-4	E/D	10	10	25.7	0	6.5	2.5	0.9	35.6	1.38	
REEVES-WARD-WINKLER	II-1	R/O	5	5	31.7	8.5	8.5	5.9	10.5	65.1	2.05	40-45
	II-2	VF-VC	5	5	61.4	0	7.3	3.0	10.5	82.2	1.34	
ECTOR-MIDLAND	III-1	MSF	3*	3*	79.1	0	20.8	5.6	0	105.5	1.33	30-35
	III-1	MSF	3*	5	54.1	0	14.2	3.5	0	71.8	1.33	
	III-1	R/O	5	5	36.7	0	12.5	3.5	0	52.7	1.43	
	III-1	E/D	5	5	24.5	0	12.2	2.7	0	39.4	1.60	
	III-2	VC-VTE	20*	20*	32.4	29.4	7.9	8.4	7.7	85.8	2.64	
CRANE-REAGAN-UPTON	IV-1	E/D	2	2	35.2	0.2	11.0	5.8	18.9	71.1	2.02	50
	IV-2	E/D	4	4	33.2	0.2	10.7	4.9	17.7	66.7	2.01	
TAYLOR	V-1	E/D	10	10	23.6	0.1	3.7	2.2	8.3	37.9	1.60	30-35
CHILDRESS-HARDEMAN-VERNON	VI-1	R/O	2	2	42.8	31.7	9.7	12.2	9.2	105.6	2.46	26
	VI-2	VF-VC	1.8	1.8	88.1	0	0	24.1	2.7	114.9	1.30	
FIVE COUNTY REGION	VII-1	E/D	7	7	24.2	0	12.2	2.5	20.4	59.3	2.45	
EIGHT COUNTY REGION	VII-2	VC-VTE	20*	20*	32.4	29.4	7.9	8.4	14.4	92.5	2.84	

Note* - This quantity represents 25 ppm water produced by distillation. Where a greater quantity appears in the "500 ppm water" column, the distilled water was blended with a calculated quantity of feed-water to provide 500 ppm water.

FIGURE 1 - 2

DESALTING PROCESSES AND ECONOMICS

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DESALTING PROCESSES AND ECONOMICS

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2. DESALTING PROCESSES AND ECONOMICS

2.1 INTRODUCTION

This chapter describes briefly the various desalting processes considered in this study. They were selected on account of their applicability and potential for providing desalted water at minimum cost.

The methods used for determining costs are also presented.

2.2 PROCESSES CONSIDERED

The technology of desalting has progressed sufficiently so that a variety of processes are now available or under engineering development for application to various conditions. Five of the more promising processes for which the Office of Saline Water is providing developmental support funds were considered for use in desalting brackish and saline waters in West Texas. These processes are the following: electrodialysis (ED), reverse osmosis (RO), vacuum freeze-vapor compression (VFVC), multi-stage flash distillation (MSF), and vapor compression-vertical tube distillation (VC-VTE).

The capital and operating costs and performance characteristics differ for each of these five processes: one process may be more economical for one application whereas another may produce lower cost water of equivalent quality under other circumstances. Also, the developmental state-of-the-art is more advanced for some of these processes than for others. For example, the MSF process has demonstrated successful performance in plant applications in the multi-million gallon per day size range whereas the RO and VFVC processes have not yet been applied in plant sizes as high as one million gallons of fresh water per day. The ED process has demonstrated reliable operation over many years and there is no apparent technical limitation to its application in sizes up to 20 MGD, the largest single plant application considered in this study. The largest VFVC plant in operation today is a test unit at Wrightsville Beach, North Carolina rated at 0.1 MGD. The largest RO systems installed to date are test stands located in Southern California, operated at rates less than 0.1 MGD of fresh water production. For purposes of this preliminary feasibility study and because of the relatively less advanced state of development of the RO and VFVC processes the Office of Saline Water has recommended that potential application of these processes be limited to plant sizes up to 5 MGD capacity for fresh water production.

2.2.1 Summary of Characteristics

The five processes were selected since the technology involved has been demonstrated sufficiently to permit their use by operating utilities. Each desalting process requires a theoretical minimum amount of energy to separate water and salt after the salt has been completely dissolved in the water. Generally the amount of energy required depends upon

the form of the energy, i.e, high grade electrical or mechanical energy or low grade thermal energy, and on salinity of the feedwater, the quality of product water desired, process employed, and design details of the plant.

On account of the high energy input required for thermal distillation processes it is necessary to reject large quantities of heat which usually requires large flows of cooling water. Heat rejection requirements for other processes are usually much less, permitting rejection by increased temperature of the product water and/or the concentrated brine blowdown.

Electrodialysis employs electrical energy to cause a migration of ions from one part of the feedwater to another part through a semi-permeable membrane material, thereby reducing salinity in one part and increasing salinity in the other. That part from which ions have been removed is the product water. The energy required is approximately proportional to the reduction of salinity achieved, so the process is most economical where feedwater salinity is low and the product water need not be distilled. Life of the membranes is sensitive to some salts, so ion exchange treatment of the feedwater is required if these salts are present.

Reverse osmosis requires mechanical energy to pump feedwater to pressures greater than the osmotic pressure. Pumping energy bears some relationship (not proportional) to the salinity of the feedwater so it is more economical for use with brackish water than with seawater. There is a small quantity of salt carried over into the product water, so the product water is of acceptable quality for most purposes except those requiring highest purity. Life of membranes is sensitive to some salts, which may necessitate pretreatment of the feedwater.

Vacuum freezing is accomplished at low temperatures by use of a vapor compressor to evaporate part of the feedwater. Heat of vaporization reduces the temperature and freezes part of the remainder. The vapor and ice portions are nearly pure water except for small droplets of brine which may be entrained. The method uses high grade mechanical energy to drive the vapor compressor and refrigeration machinery. The energy required depends on salinity and temperature of feedwater. High purity product is theoretically possible if practical problems can be resolved. Since separation of water from the brine occurs at low temperature and from the liquid surface there is no scaling of heat exchange surfaces. This process shows best economic advantage where the feedwater has high salinity and hardness, and where mechanical drive energy is inexpensive.

Multistage flash distillation uses thermal energy from low-grade heat to evaporate water vapor from a saline solution. Since the energy used is of a low grade, it usually has a lower unit cost than mechanical or electrical energy. In fact, it may be obtained at very low cost if it is waste heat from another process. The energy consumption is nearly independent of salinity, so seawater can be distilled at about the same cost as brackish water. The product water is of inherently high purity. Thermal distillation plants are usually constructed as multistage flash or multiple effect evaporation using long tube vertical or submerged tube configuration. Since brine is heated by heat transfer through a metallic surface, scale can form unless the water is properly treated.

Combined vapor compression and multistage flash distillation uses both thermal and mechanical energy so it can utilize both the mechanical drive and waste heat from a heat engine such as a steam turbine, gas turbine, or diesel engine. The vapor compression portion of this combination uses mechanical energy to drive a compressor which reduces the pressure over the surface of saline water. The reduced pressure causes some of the water to evaporate. The compressed vapor, at a temperature higher than that of the saline water, condenses on a heat exchange surface to provide the heat of evaporation. The process usually operates at an elevated temperature in order to reduce the volume of vapor. The energy consumption is nearly independent of feedwater salinity. Product water can have salinity of 25 ppm or less if the plant is properly designed and operated. Since the process involves the irreversibility associated with heat transfer, the energy consumption is greater than in electrodialysis and reverse osmosis processes. If the feedwater contains scaling salts, treatment may be required to prevent scale formation on heat transfer surfaces. The multistage flash portion of this combination is used to preheat the feedwater stream by recovering the heat from the concentrated brine stream.

The following sections describe these processes in more detail.

2.2.2 Electrodialysis (ED) Process

Electrodialysis is an established process for the desalination of brackish waters, and a number of plants have been constructed throughout the world.

From a standpoint of research and development accomplished to date, electrodialysis is the most advanced of the membrane processes. An electrodialysis conversion assembly is essentially an electrolytic cell which contains two different types of

ion-selective membranes. One of the membrane types allows passage of positive ions (cations), and the other allows passage of the negative ions (anions). The electric current imposed on the electrolytic cell provides the driving force for the ions. The principle of electrodialysis is shown in Figure 2-1. The cation-permeable membrane allows passage of the positive ions, and the anion-permeable membrane allows passage of the negative ions, yielding fresh water between the membranes.

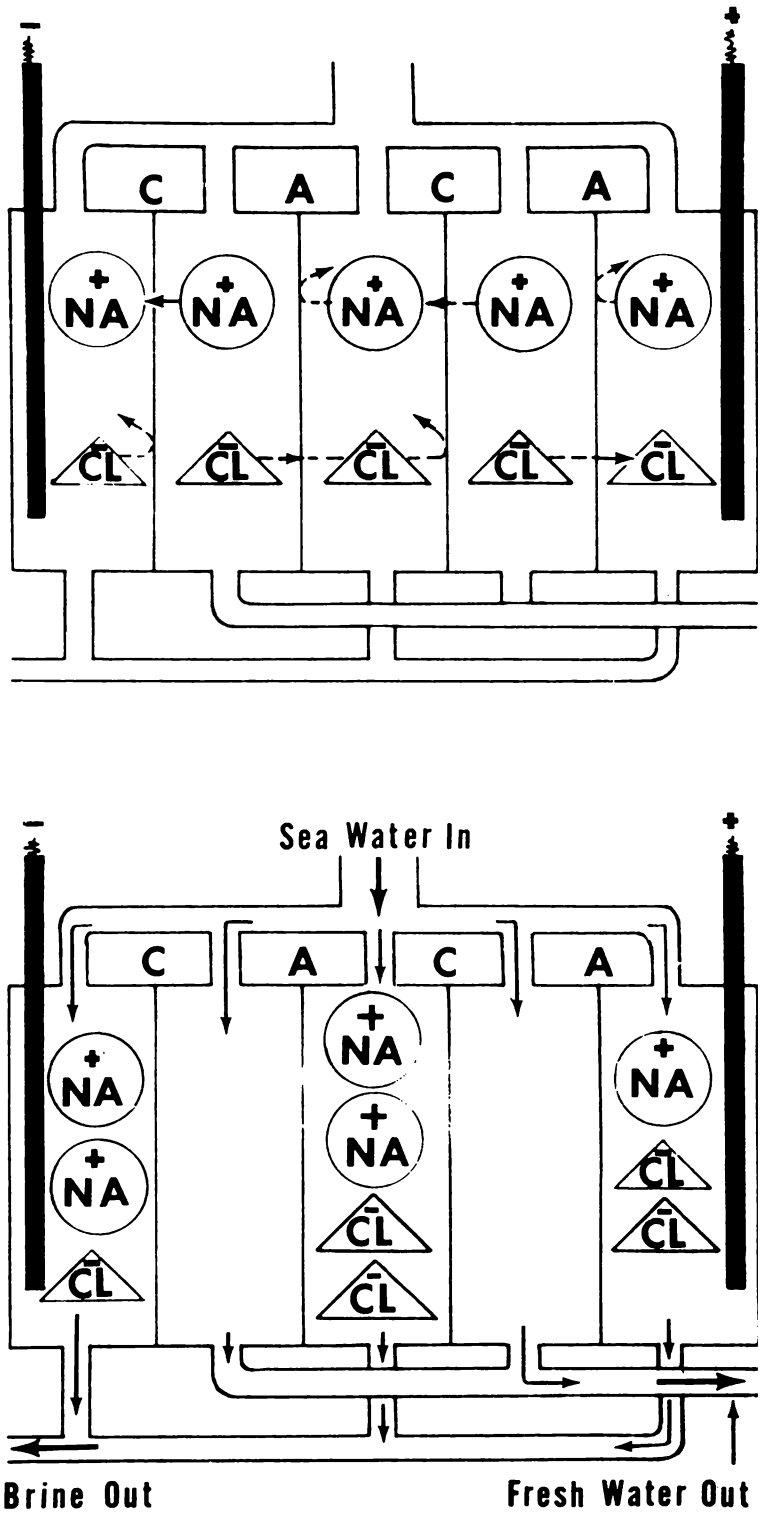
The amount of electric current required in the unit depends on the amount of salt to be removed. Therefore, the cost of the energy consumed in the process depends on the concentration of salt in the feedwater.

The application of electrodialysis to brackish water presents a problem not usually associated with sea water conversion. The chemical analysis of sea water is relatively constant, whereas that of brackish water varies greatly from aquifer to aquifer. Variations in the mineral content of the brackish water require that an electrodialysis unit be very versatile. For example, the pretreatment needed, scale-forming tendencies, limits in brine concentration, and number of stages required are influenced by the amount and type of constituents present.

As a result of the great range in feedwater characteristics plus the interdependence of membrane properties and hydrodynamic flow in the ED cell, the design of electrodialysis plants is usually based on empirical relationships that have been developed by the equipment manufacturers. Some of these relationships are proprietary and require submitting the exact feedwater analysis and properties to the equipment manufacturer for evaluation. In some cases, it is necessary that critical parameters such as maximum polarization current and membrane scaling properties be established in an extended field test.

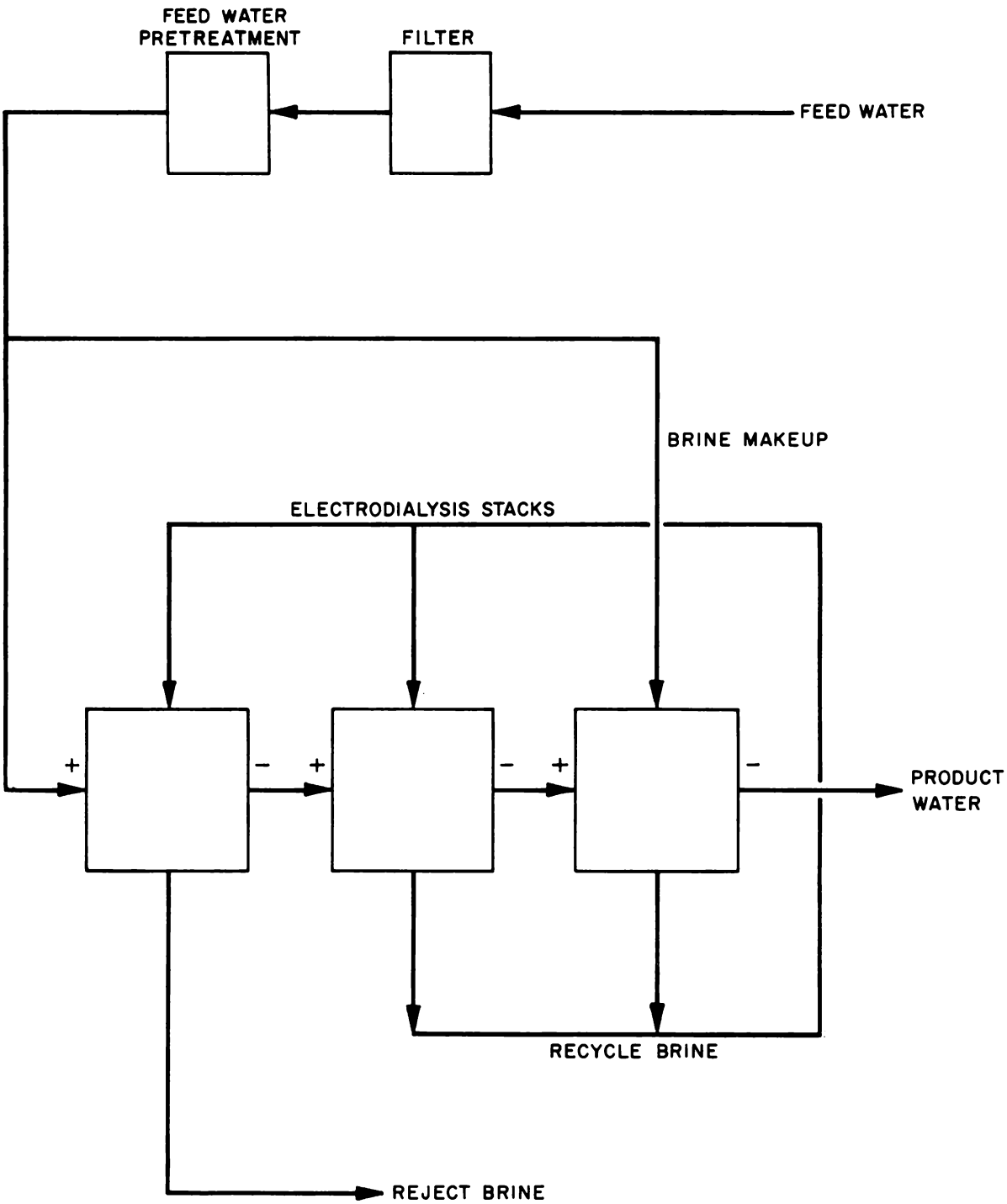
Commercially available modules (or stacks as they are usually called) are limited by present market demands to a small number of designs with relatively low capacities. Undoubtedly, as the process is selected for larger capacity plants, stacks with much more membrane area will become available, which could result in some cost reductions.

The design of the reference electrodialysis plant prepared for this report was based primarily on the methods and relationships presented in OSW-257. The calculations utilize a feedwater rating system developed by Ionics Inc. for estimating the percent of total solubles that will be removed in each stack from the feedwater analysis and temperature. The MK III Ionics stack was assumed as the basic module for the reference plant used in this study. A schematic flow diagram of the process is shown in Figure 2-2.



PRINCIPLE OF ELECTRODIALYSIS

Figure 2-1



SCHEMATIC FLOW DIAGRAM
FOR THE ELECTRODIALYSIS PROCESS

Figure 2-2

2.2.3 Reverse Osmosis (RO) Process

Reverse osmosis is a relatively new and promising process for the conversion of saline water. The process consists of pumping saline feedwater into a pressure cell that is divided into two compartments by a thin semipermeable membrane that transports water more readily than salt. When the pressure in the saline water compartment exceeds the osmotic pressure the normal osmotic fluid flow is reversed and water flows from the saline compartment through the membrane to the fresh water side. See Figure 2-3. Even from this brief description, it is evident that the membrane characteristics and properties are the key factors in this process.

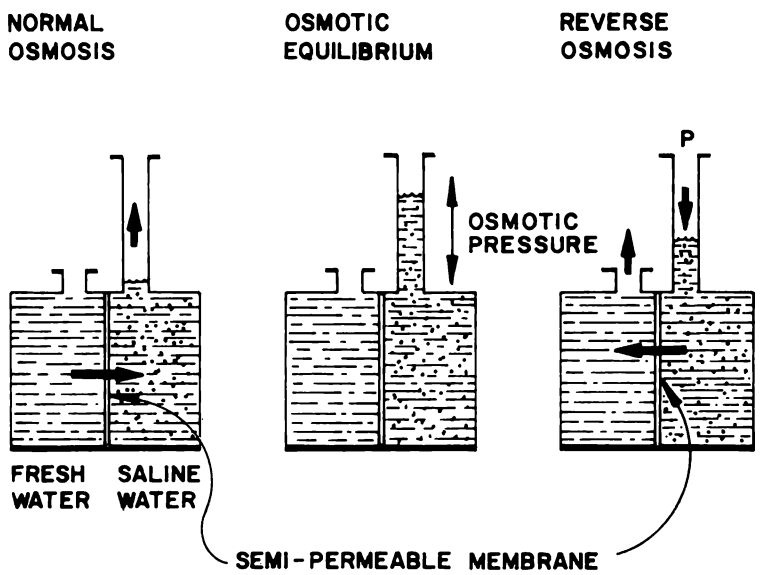
Basically, reverse osmosis is a simple process of high pressure filtration through a special filter called a semipermeable membrane. The performance potential of reverse osmosis, that is the ability to remove almost any dissolved material from water, is limited only by the properties and performance of the membranes.

The theoretical energy required to desalinate sea water by reverse osmosis is 3.5 kwh/1000 gallons as compared to over 100 kwh/1000 gallons required for present distillation processes. The large difference in energy requirements is due to the fact that there is no phase change, liquid to gas or liquid to solid, in the reverse osmosis process. Additionally, reverse osmosis operates at room temperature. The ability to perform close to the theoretical energy requirement is greater at room temperature than for the high temperature processes such as distillation. Thus, reverse osmosis is inherently more economical than distillation.

A schematic flow diagram of the reverse osmosis process is shown in Figure 2-4. The saline feedwater is first pumped through a filter to remove any solid particles which would damage the membranes. If iron is present in amounts greater than 0.1-0.3 ppm the feedwater is next subjected to iron removal by a suitable process (e.g. manganese zeolite). The feedwater is then pumped to the pressure level which will exceed the osmotic pressure for the feedwater salinity and reverse the normal osmotic fluid flow. The portion of the feedwater that becomes depleted in salinity as it permeates the membranes is collected as product water. The remaining portion of the feedwater becomes enriched in salinity and is termed the brine reject stream. This stream is reduced in pressure through an energy recovery turbine and discarded to waste.

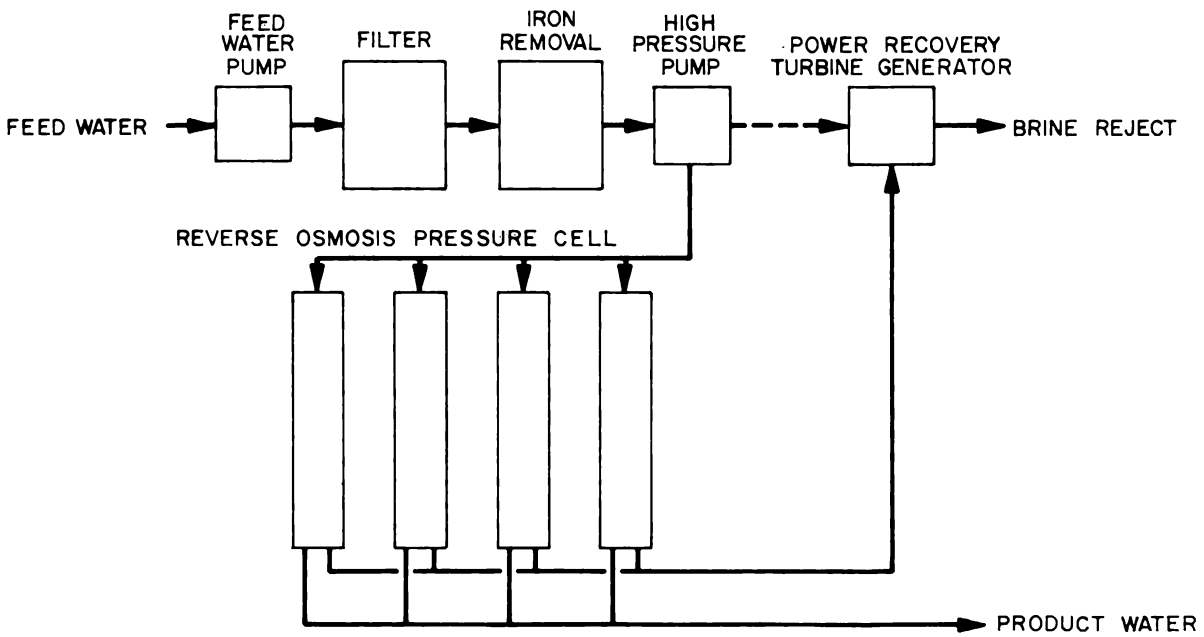
2.2.4 Vacuum-Freeze Vapor-Compression (VFVC) Process

It has long been recognized that saline waters can be purified by various freezing processes. When a saline solution is frozen. fresh water ice crystals are formed, and the salts are concentrated in the remaining brine solution. The ice crystals can then be



PRINCIPLES OF REVERSE OSMOSIS

Figure 2-3



SCHEMATIC FLOW DIAGRAM
FOR THE REVERSE OSMOSIS PROCESS

Figure 2-4

separated from the brine, washed, and melted to yield fresh water. Several water conversion processes utilizing a freezing step have been developed and investigated in pilot plants. These processes have used a variety of methods for freezing including direct contact between the feedwater and a secondary insoluble refrigerant such as butane and refrigeration by absorption of the water vapor with lithium bromide solution. In probably the most successful freeze process that has been developed to date, the saline water is cooled below its freezing point in one compartment by vacuum evaporation. The water vapor evolved is compressed so that in a separate compartment it will condense upon and melt the ice crystals. A number of groups have carried out research on the vacuum-freeze process; the cost estimates used in this report were prepared by Colt Industries Inc. on the basis of their design of vacuum-freeze vapor compression process.

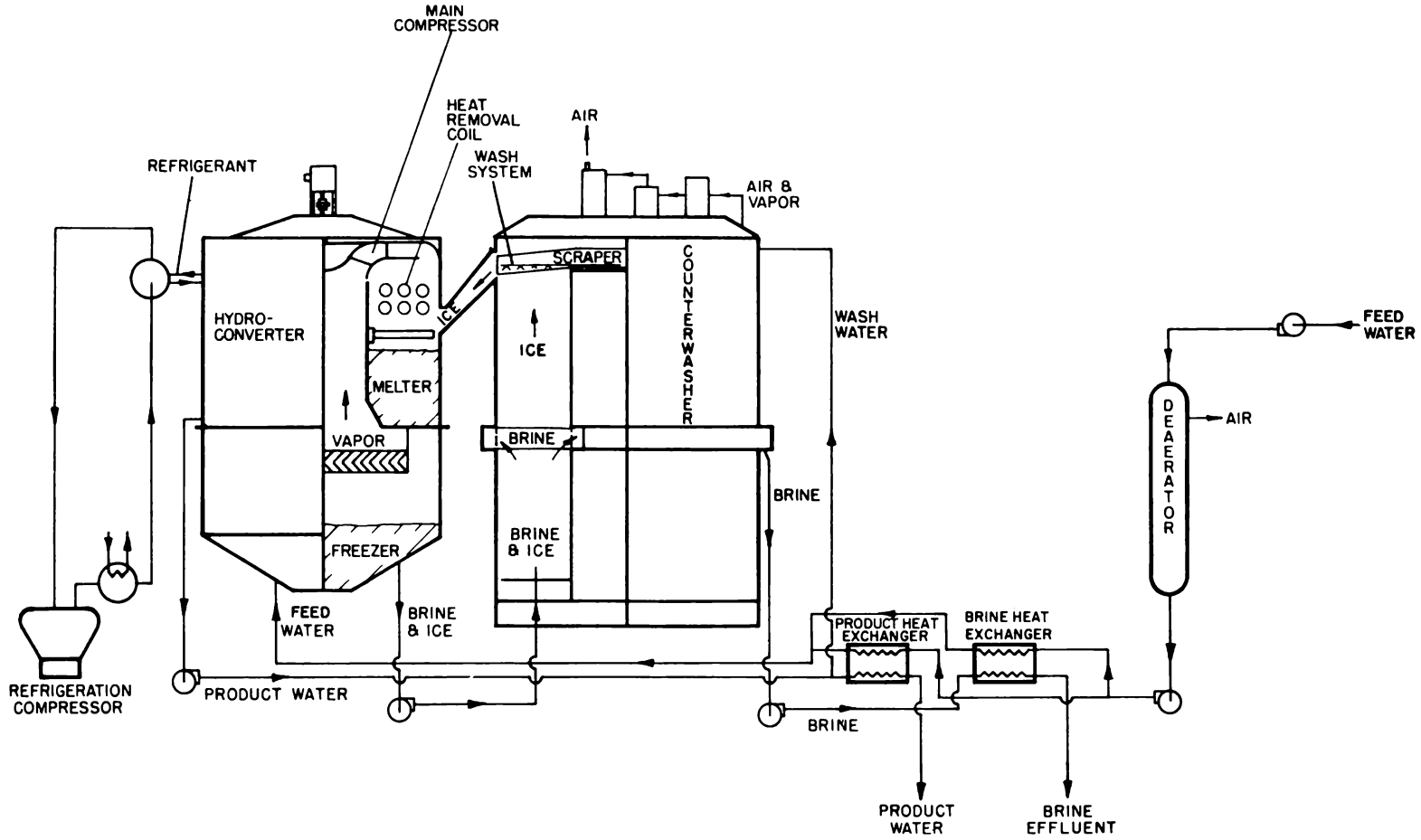
The principles discussed above, applied to a practical VFVC desalting system, are illustrated in the schematic flow diagram, Figure 2-5. This simplified diagram shows both the essential components of the process and the flow paths of the various fluids in the system.

Saline water is pumped at ambient temperature from the sea, from wells, or some other source through a filter to remove entrained solids. This water then flows through a vacuum deaerator that removes the dissolved gases that could otherwise interfere later with the heat transfer in the melter.

From the deaerators, the now-deaerated saline feedwater flows into the system through heat exchangers where it is cooled by heat exchange with the cold brine and the cold product water flowing separately out of the system. This deaerated feedwater, now cooled almost to its freezing point, is then pumped into the freezer.

Under the influence of the low pressure in the freezer (about 3.4 mm of mercury) the feedwater boils so that part flashes into vapor. In so doing the vapor extracts its heat of vaporization from the rest of the feedwater since no external heat is supplied to cause the boiling. But the bulk of the feedwater is already at its freezing point. Therefore, the removal of additional heat from this cold feedwater causes a portion of it to freeze, and to give up its heat of crystallization. About 7.5 pounds of ice are formed for each pound of vapor.

Between 30 and 40 percent of the saline feedwater is converted into pure ice and vapor. Because the salts in this converted portion of the feedwater are left behind, the remaining feedwater becomes more and more concentrated until it contains 5 to 7 percent of salts.



SCHEMATIC FLOW DIAGRAM
Colt Industries (Fairbanks Morse) VFVC Process

Figure 2-5

The slurry, or mixture, of brine and ice crystals is removed continuously from the freezer and is pumped into the counterwasher. Here the ice crystals are propelled counter-currently to the stream of wash water distributed on the top of the ice pack, and the ice crystals are washed free of all adhering brine solution. The washed ice, now free of salts, is scraped via a chute into the melter.

The water vapor produced in the freezer by the simultaneous boiling-freezing process is removed from the freezer by the vapor compressor, is compressed to an absolute pressure 4.8 mm of mercury, and is discharged into the melter. At a pressure of 4.8 mm of mercury the vapor condenses when brought into contact with the washed ice. As the vapor condenses it gives up its heat of vaporization, and this heat is absorbed by the ice in melting. The condensed vapor and melted ice form cold product water.

The heat transfer in the freezer, during the formation of the ice and vapor, takes place at the surface of the feedwater; and in the melter the heat transfer, as the vapor condenses and the ice melts, takes place at the surface of the ice.

The cold product water from the melter and the cold brine effluent from the counterwasher are discharged through the heat exchangers to cool the incoming feedwater. However, some heat still enters the system with the feedwater. Also, the energy of the pumps and compressors utilized in the process shows up as heat, and some heat enters the system through the insulation. To maintain thermodynamic balance a refrigerated coil in the melter is used to condense the excess vapor resulting from the loss of ice due to this heat input.

Because the operating pressure is well below atmospheric, some air inevitably enters the system. This air is removed continuously by a combination blower-condenser-vacuum pump system.

2.2.5 Multistage Flash Process (MSF)

The MSF process uses low-grade thermal energy for desalting; energy consumption is high and large quantities of heat must be rejected. This process makes use of the fact that water boils at progressively lower temperatures as it is subjected to progressively lower pressures.

The saline feedwater is heated through a series of condenser tubes and a brine heater and is then introduced into a chamber where the pressure is sufficiently low to cause some of the water to boil instantly or "flash" into steam. Vaporization of some of the water results in a lowering of temperature of the

remaining brine. The brine then flows into the next chamber where the pressure is lower than in the previous chamber and more of the water flashes into steam; the temperature is again reduced. Condensation occurs when the steam comes into contact with the heat exchanger tubes through which the incoming saline water flows before passing through the brine heater. In this way the heat which must be removed from the steam in order to condense it into fresh water is transferred to the saline feedwater, supplying it with some of the heat energy required to cause it to boil. A schematic flow diagram of the MSF process is shown in Figure 2-6.

The water produced by this process has very high purity, and the process can use feedwater of high salinity. The presence of scaling salts may necessitate pretreatment of the feedwater.

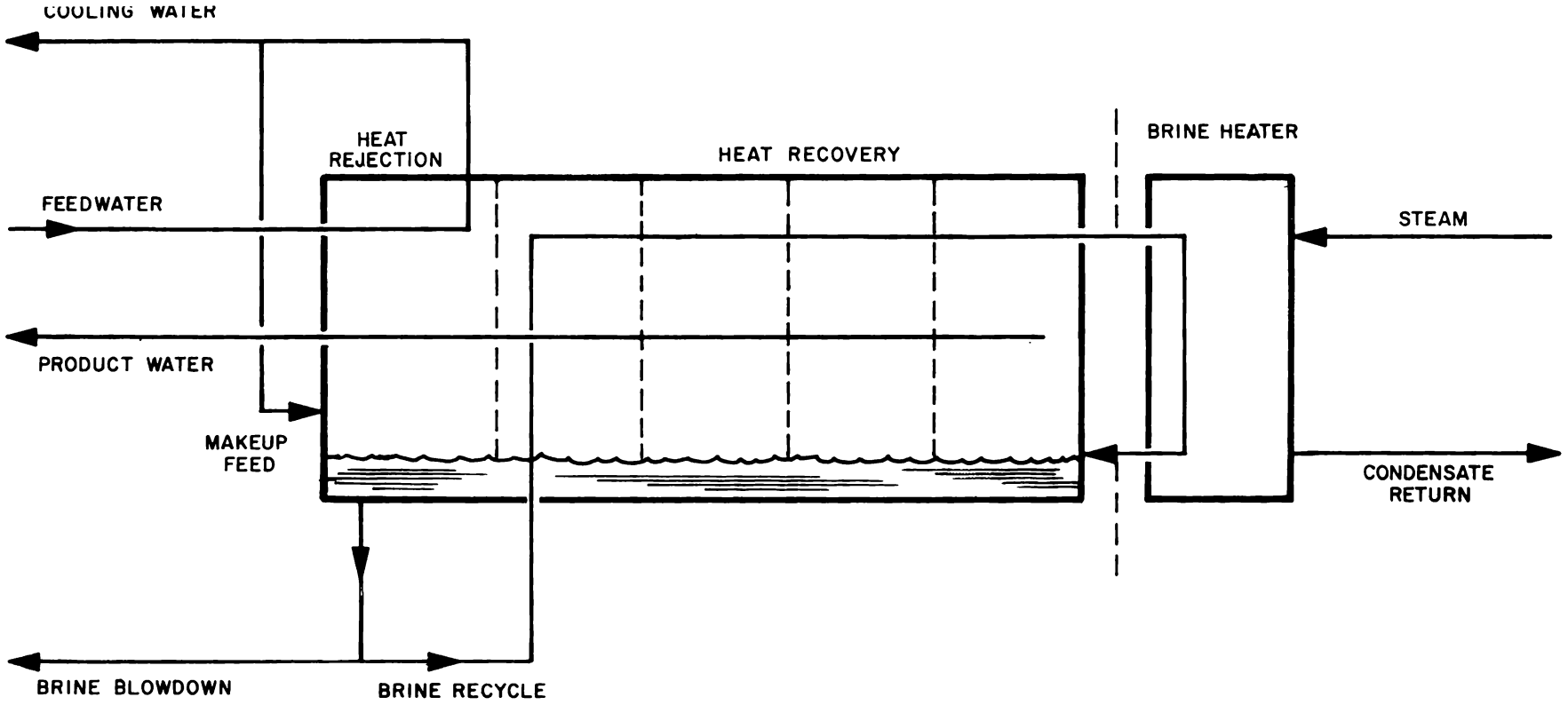
Plants using this process have been built in larger capacities than plants using other processes.

2.2.6 Vapor Compression-Vertical Tube Evaporator (VC-VTE) Process (Contributed by S. J. Senatore, ORNL)

The hybrid VC-VTE process is a combination of the long-tube vertical (LTV) distillation process, a regenerative vapor compression (VC) cycle and the multistage flash (MSF) distillation process.

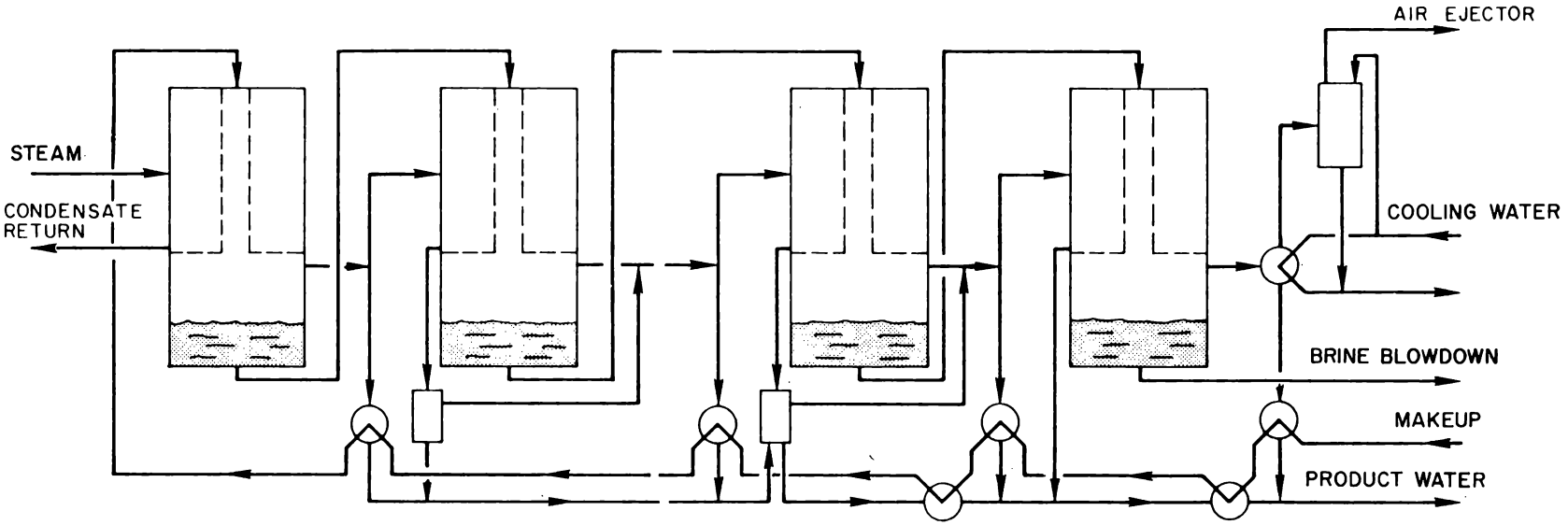
In the LTV process (see Figure 2-7) saline feedwater falls through a bundle of long metal tubes located inside a large cylindrical chamber. As the salt water falls through the tubes, it is heated by steam which surrounds the tubes. This heat exchange operation converts some of the water from the saline solution inside the tubes into steam, and at the same time condenses some of the steam which surrounds the tubes into fresh water.

To obtain high efficiency in the recovery of heat energy, the process is repeated in several chambers which are arranged in series. The steam for the first chamber is supplied by a steam generator plant, and the condensed water from the first chamber is returned to the steam generator plant to be reconverted into steam. Steam generated inside the tubes of the first chamber flows to the second chamber where it surrounds the second bundle of tubes. The brine that did not vaporize in the first chamber enters at the top of the second chamber and flows downward through the second tube bundle. The steam which surrounds the tubes heats the brine as it falls, converting some of the water inside of the tubes into steam, and condensing some of the steam outside



SCHEMATIC FLOW DIAGRAM
FOR THE MULTISTAGE FLASH DISTILLATION PROCESS

Figure 2-6



SCHEMATIC FLOW DIAGRAM
LTV EVAPORATOR PROCESS

Figure 2-7

of the tubes into fresh water. The pressure in each chamber is also progressively reduced to permit vaporization to occur at lowest temperatures. The brine which collects at the bottom of the last chamber is returned to the sea.

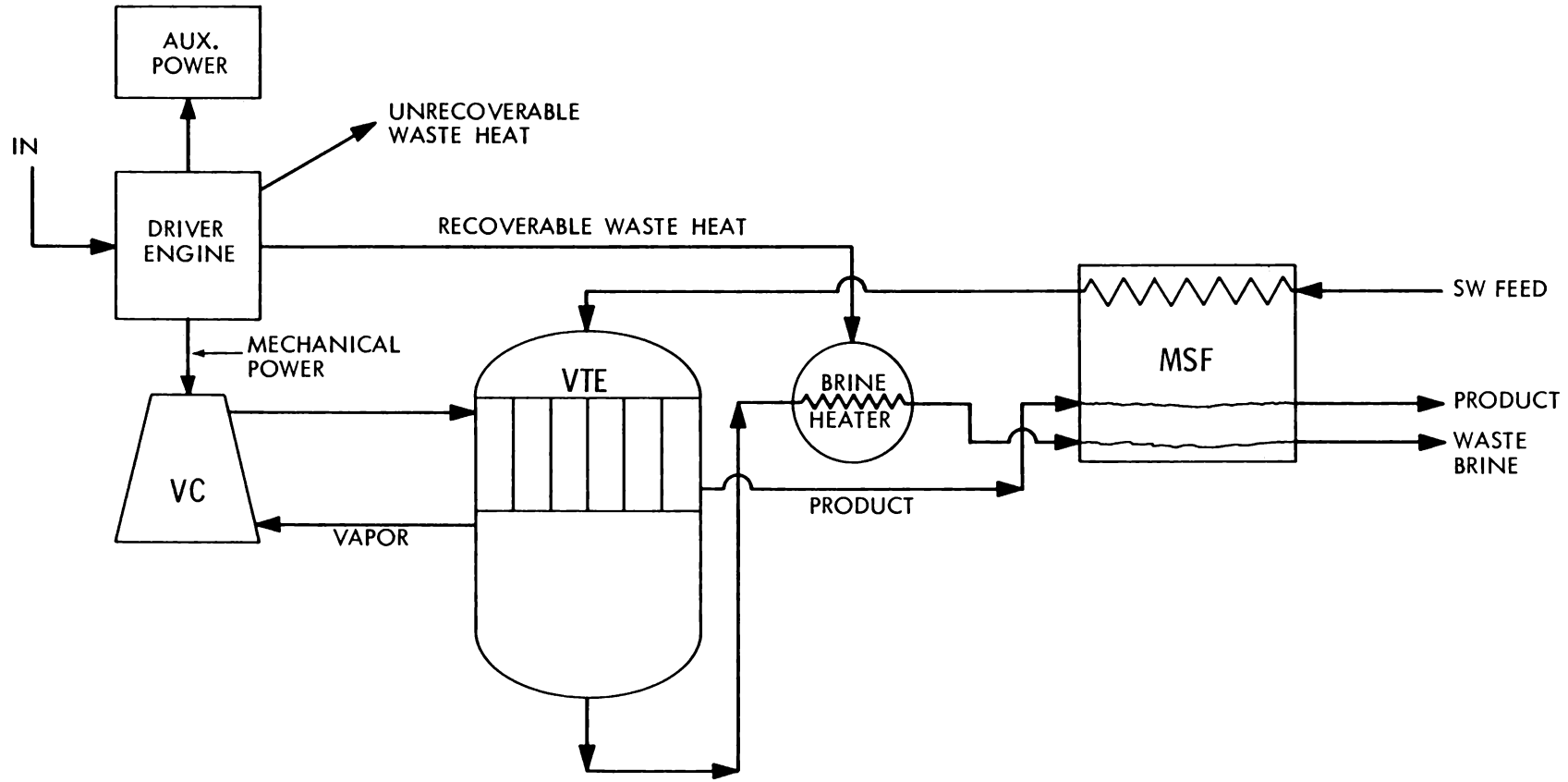
Each separate chamber in which distillation occurs is called an "effect". Thus, this process is sometimes called the long-tube vertical multiple effect distillation process.

In the VC-VTE process, the MSF process (see Section 2.2.5) and the LTV process are associated in a manner which employs the MSF process as a combined feedwater preheater and concentrated brine heat recovery system in series with a VTE system which incorporates a vapor-compression "heat pump" cycle.

A further modification of this hybrid "VC-VTE" system for application to certain of the candidate saline feedwaters in this study employs gas turbine-driven vapor-compressors, including utilization of the waste heat from the gas engines to perform supplemental desalting.

A gas turbine-driven engine burns natural gas to produce mechanical or electrical energy. At the same time, the engine rejects a relatively large fraction of the fuel heat input as waste heat. In some engines, much of the waste heat can be recovered at temperatures high enough to be useful in a flash evaporator, thereby permitting the engine to serve as a heat source for supplementary production of product water. The high-grade mechanical or electrical energy is most efficiently used for water production (in an evaporative process) by driving vapor compressors operating across single- or multi-effect evaporators. The water vapor-compression cycle is best used at relatively high temperatures to minimize the volume pumped by the compressor. It is usually operated over a fairly limited temperature range. This means that the feed to the evaporator must be heated regeneratively to the operating temperature. This is accomplished in a flash (MSF) evaporator which also uses the engine waste heat and product sensible heat.

The combined process flow sheet in its simplest form is shown schematically in Figure 2-8. Saline feedwater passes through the heat recovery tubes of the MSF and is heated to a temperature a few degrees below the operating temperature of the VC-VTE unit. Not shown on this diagram is the chemical pretreatment equipment necessary for the prevention of alkaline scale deposition in the tubes of the MSF and of the VTE. After being preheated in the MSF, the saline feed stream is sent to the VTE where it may be evaporated in one effect or in several effects; each effect may be operated once-through or with brine recycle, depending upon the brine loading, upon the concentration limits (to avoid calcium sulfate scale), and upon the heat-transfer performance



SCHEMATIC BLOCK DIAGRAM
VAPOR COMPRESSOR -
VERTICAL TUBE EVAPORATOR PLANT
Feed Pre-heated by Once-thru MSF

Figure 2-8

requirements of the condenser tubing in the VTE. The temperatur potential for heat transfer in the VTE is supplied by the vapor compressor which takes the vapor produced in the last effect and compresses it to the saturation pressure required by the heating steam for the first effect. If there is only one VTE effect, the vapor compressor must recirculate an amount of steam equal to the product output of the VTE. The temperature potential for heat transfer in the single VTE effect will be the same as the temperature rise imparted by the compressor to the recirculating vapor stream (after desuperheating to saturation temperature) minus thermodynamic losses such as those due to boiling point elevation and pressure drop of the vapor through the circuit.

2.2.7 VC-VTE Plant Design for West Texas

The following is a detailed description of the VC-VTE plant designs developed specifically for this study [65]:

Introduction - Several distillation flow sheets were developed for the West Texas Study for purifying specified sources of brackish water. This contribution to the overall study is restricted to the plant battery limits and does not include costs for a feed supply, a sink for rejection of heat, or a product conveyance system. The flow sheets are preliminary in nature and do not necessarily represent a minimum water cost plant but do show the trend in water cost with plant size. Because of the composition of some brackish water, it is necessary to apply a method of feed treatment prior to introduction to the distillation plant.

In the El Paso region, it was assumed that there will be available waste heat from gas turbines which will be used to drive compressors in the gas fields. There are two basic distillation systems which are considered for the production of potable water using the waste heat. The first system is a conventional multistage flash process, and the second system is one that uses a vapor compressor system operating across several effects of vertical-tube evaporators in conjunction with a conventional multistage flash feed heater and heat recovery concept.

The primary difference in the two flow sheets is that the conventional MSF would operate at a relatively lower performance ratio than the vapor compressor system. The vapor compression system is more complex than the conventional MSF concept, and to date there are no systems of this type in operation which utilize all the concepts that are considered here. The vapor compressors required in this concept are not shelf items but

are within current-day technology. For a single-purpose plant under 25 MGD, this concept appears to have potential to reduce water costs below the conventional MSF system. The vertical-tube evaporator in this concept is under test by the OSW.

Process Flow Sheets - In the waste heat recovery case for the El Paso region, the two flow sheets that have been considered both employ a waste heat recovery boiler which operates from the gas turbine exhaust of approximately 900°F. It was assumed that the exhaust temperature from the boiler would be about 300°F. To estimate the available heat, we assumed that exhaust gas came from two General Electric 8000-hp gas turbines. From these two units, the available heat for the distillation plant is approximately 1.17×10^8 Btu/hr. The effect of the waste heat boiler back pressure on the gas turbine efficiency has been neglected in all cases studied.

In the case of the conventional MSF system, two performance ratios were selected, the first being 10 lbs. product/1000 Btu and the alternate being 15 lbs. product/1000 Btu. The potable water that can be produced from these MSF plants is 3.36 MGD for the performance ratio 10 plant and 5.04 MGD for the performance ratio 15 plant. Based on the assumed ground rules, the resulting water costs, assuming no penalty for waste heat recovery, are 35.4¢/Kgal and 31.4¢/Kgal, respectively. The capital costs for these facilities are estimated at $3.05 and $4.56 million.

The alternate flow sheet incorporates the vapor compressor, the vertical-tube evaporator, the multistage flash, and a back-pressure steam turbine. In this concept, a two-effect vertical-tube evaporator was used. A waste heat boiler was selected that will produce steam at 650°F and 415 psia. This steam is used to power a back-pressure steam turbine which, in turn, drives a vapor compressor which operates across the vertical-tube evaporator. The turbine exhaust steam plus additional 260° saturated steam from the waste heat boiler is used for the brine heater. The MSF portion of the plant that is used in this concept recovers the sensible heat from the VTE product water and produces additional water from the VTE blowdown. The water analysis that was provided for this study indicates that with proper acid treatment the blowdown concentration can be increased to 6.4 percent total dissolved solids based on a feed concentration of 1.6 percent. Auxiliary power for this concept is produced by operating a generator from the backpressure turbine. The flow sheet previously referenced, Figure 2-8, presents the basic components. In alternate cases that were studied, supplemental gas firing is used to produce more water.

West Texas Cases - The following is a description of the actual cases that have been studied for West Texas:

Case I

Waste heat is available from two 8000-hp gas turbines at a rate of 1.17×10^8 Btu/hr. A conventional MSF system is used in conjunction with a low-temperature waste heat recovery boiler which produces 260° saturated steam for the brine heater. The performance ratio selected was 15 lbs. product/10^3 Btu, producing 5.04 MGD. The capital cost of this facility is $4.56 million, and the corresponding water cost is about 31.4¢/1000 gallons without any penalty for waste heat recovery. On the basis of the feedwater analysis containing 1600 ppm total dissolved solids, this plant can operate at a blowdown concentration ratio of 4:1.

Case IIa

In this concept, the available waste heat is similar to Case I (1.17×10^8 Btu/hr); however, an intermediate pressure boiler operating at 650°F is used on the waste heat recovery system. This prime steam is used to supply the backpressure turbine which, in turn, drives the vapor compressor. The vapor compressor selected operates at a pressure ratio of 1.3. This facility could produce 6.1 MGD water at an estimated cost of 29.2¢/Kgal and a capital cost of $5.92 million. The overall performance ratio of this plant is 18.2 lbs. product/1000 Btu of heat input, and the concentration ratio is 4:1 as in Case I.

Case IIc

This flow sheet is similar to Case IIa except that the target production rate has been increased to 10 MGD. This was accomplished by supplemental firing of the waste heat boiler at a rate of 7.0×10^7 Btu/hr. Assuming a fuel cost of about 28 cents for the supplemental heat, the average water cost is 31.6 cents at a capital cost of $8.86 million. The concentration ratio is 4:1, and the performance ratio is 18.6. The advantage of supplemental firing is that essentially 100 percent heat conversion is attained from the fuel because of the excess oxygen in the exhaust gases from the gas turbine.

Case III

This flow sheet is similar to Case II; however, in this concept we do not have any waste heat available. A gas-fired boiler is used which operates a backpressure steam

turbine with the VC-VTE-MSF concept. The concentration ratio is 4:1. The performance ratio selected for this plant is 18.6 and the fuel cost is 20¢/MBtu. The associated water cost is 38.8¢/1000 gallons, and the capital cost is $8.86 million. We assumed that the boiler cost for this case was the same as that for Case IIc; however, we assumed 75 percent boiler efficiency.

Case IV

This case is for a 20-MGD facility and assumes a flow sheet as in Case III with a performance ratio of 18.6. It utilizes the VC-VTE-MSF concept with an all-gas-fired boiler. Based on the corresponding fuel cost of 20¢/MBtu, the water cost is 30.3¢/Kgal, and the capital cost is $15.63 million. This plant also operates with a concentration ratio of 4:1. The boiler efficiency is assumed to be 75 percent.

Case IVa

This case is similar to Case IV, producing 20 MGD, with the exception of the concentration ratio of the blowdown is increased to 6:1. This results in a slight savings in acid cost, and the corresponding water is reduced to 30.2¢/Kgal. The capital cost of this facility is slightly lower, $15.59 million. The boiler efficiency is also assumed to be 75 percent.

Case V

This case is the same as Case IVa except for a 14-MGD water production rate. The blowdown concentration ratio is 6:1, and the plant performance ratio is 18.6. Again, we use an all-gas-fired boiler with the corresponding VC-VTE-MSF concept. The water cost for this facility is 32.6¢/Kgal, and the capital cost is $11.6 million.

Water Plant and Annual Operating Costs - Table I lists the capital cost for the cases studied. The conventional MSF is not included since these cost estimates are based on the bids for the St. Thomas Island 2.5-MGD facility. An exponent of 0.8 was used for extrapolating the capital cost of the MSF plant from the reference 2.5-MGD plant which averaged about 90¢/daily gallon. For Case I, the direct cost of the 3.36-MGD MSF plant extrapolates to $2,323,000. The waste heat boiler is estimated at $254,000 and, assuming an indirect cost of 18.5 percent, the total plant capital cost is about $3,054,000. The MSF plant for the other cases were costed on the same basis. However, in each case the extra MSF duty required by the flashing product from the VTE was considered.

TABLE I
WEST TEXAS STUDY
CAPITAL COSTS

	Case IIa VC, VTE, MSF Waste Heat Only Conc. Ratio 4:1 Comp. Ratio 1.3 6.1 Mgd	Case IIc VC, VTE, MSF Waste & Sup. Heat Conc. Ratio 4:1 Comp. Ratio 1.3 10 Mgd	Case III VC, VTE, MSF 100% Sup. Heat Conc. Ratio 4:1 Comp. Ratio 1.3 10 Mgd	Case IV VC, VTE, MSF 100% Sup. Heat Conc. Ratio 6:1 Comp. Ratio 1.3 20 Mgd	Case V VC, VTE, MSF 100% Sup. Heat Conc. Ratio 6:1 Comp. Ratio 1.3 14 Mgd
Site	$ 180,000	$ 296,000	$ 296,000	$ 591,000	$ 414,000
Buildings	86,000	151,000	151,000	300,000	210,000
Chem. Treat. & Misc. Systems	43,000	64,000	64,000	69,000	48,000
Pumps & Drives	55,000	81,000	81,000	142,000	106,000
Piping & Valves	140,000	217,000	217,000	404,000	293,000
Evaporator Shell	109,000	175,000	175,000	343,000	243,000
Demisters	27,000	44,000	44,000	87,000	61,000
Tubes & Tube Sheets	333,000	543,000	534,000	1,067,000	715,000
Waste Heat or Package Boiler	235,000	415,000	415,000	680,000	515,000
Steam Turbine & Auxiliaries	190,000	230,000	230,000	330,000	275,000
Generator	32,000	46,000	46,000	92,000	69,000
Vapor Compressor & Piping	99,000	111,000	111,000	134,000	123,000
Desuperheater	3,000	4,000	4,000	8,000	6,000
MSF Plant Package	3,245,000	4,750,000	4,750,000	8,230,000	6,200,000
Product Water Conditioning	60,000	98,000	98,000	196,000	137,000
Spare Parts	28,000	49,000	49,000	98,000	69,000
Electrical	107,000	175,000	175,000	350,000	245,000
Instrumentation	21,000	35,000	35,000	70,000	49,000
Direct Subtotal	$ 4,993,000	$ 7,475,000	$7,475,000	$13,191,000	$9,778,000
Indirects (18.5%)	924,000	1,383,000	1,383,000	2,440,000	1,809,000
Grand Total	$ 5,917,000	$ 8,858,000	$8,858,000	$15,631,000	$11,587,000
Cost, $/Daily Gallon	.970	.886	.886	.782	.828

The direct capital costs include the selling price by manufacturers of the major components. The indirect charges of 18.5 percent are added to the total direct capital costs. These indirect charges are broken down as follows:

Temporary Construction, Supervision and Engineering	4
Contingency	8
Interest During Construction	5.5
Owner's Cost	1
Total	18.5

Table II summarizes the annual operating costs and the resultant water costs. The annual costs are based on the following:

Sulfuric Acid	$40/ton
Chlorine	$130/ton
Antifoam	$0.42/lb
Fixed Charge Rate	5.44 percent
Maintenance and Supplies	1% of direct capital
Power	1.2 cents/Kwhr

Table III shows the manpower requirements for these facilities with the associated annual rates and overhead.

TABLE II

WEST TEXAS STUDY
ANNUAL AND UNIT COST BREAKDOWN

Item	Case I MSF Waste Heat Only Conc. Ratio 4:1 Perf. Ratio 15 5.04 Mgd	Case IIa VC, VTE, MSF Waste Heat Only Conc. Ratio 4:1 Comp. Ratio 1.3 6.1 Mgd	Case IIc[a] VC, VTE, MSF Waste and Sup. Heat Conc. Ratio 4:1 Comp. Ratio 1.3 10 Mgd	Case III[b] VC, VTE, MSF 100% Sup. Heat Conc. Ratio 4:1 Comp. Ratio 1.3 10 Mgd	Case IV[c] VC, VTE, MSF 100% Sup. Heat Conc. Ratio 4:1 Comp. Ratio 1.3 20 Mgd	Case IVa[c] VC, VTE, MSF 100% Sup. Heat Conc. Ratio 6:1 Comp. Ratio 1.3 20 Mgd	Case V[d] VC, VTE, MSF 100% Sup. Heat Conc. Ratio 6:1 Comp. Ratio 1.3 14 Mgd
Heat	0	0	$ 154,500	$ 392,000	$ 784,000	$ 784,000	$ 549,000
Chemical Acid, $40/ton	$ 17,900	$ 70,500	115,000	115,000	(e)	(e)	(e)
Power (12 mills per Kwh)	87,500	(f)	(f)	(f)	(f)	(f)	(f)
Total Capital @ 5.44%	248,000	321,900	480,800	480,800	852,500	850,300	630,300
Operating Cost	130,500	146,600	217,900	217,900	229,300	229,300	229,300
Maintenance & Supplies	38,500	49,900	74,600	74,600	132,300	131,900	97,800
Total*	$522,400	$588,900	$1,042,800	$1,280,300	$1,998,100	$1,995,500	$1,506,400
Water Cost ¢/Kgal	31.4	29.2	31.6	38.8	30.3	30.2	32.6

Notes:

(a) Supplemental heat 5.52×10^{11} Btu/yr (100% efficiency) at $\$0.28/10^6$ Btu.

(b) Supplemental heat 1.96×10^{12} Btu/yr (75% efficiency) at $\$0.20/10^6$ Btu.

(c) Supplemental heat 3.92×10^{12} Btu/yr (75% efficiency) at $\$0.20/10^6$ Btu.

(d) Supplemental heat 2.74×10^{12} Btu/yr (75% efficiency) at $\$0.20/16^6$ Btu.

(e) Chemical acid costs are included in Capitan Reef chemical treatment cost estimates shown on Cost Breakdown Figures.

(f) Vapor compressor is steam turbine driven; auxiliary power is obtained from generator driven by back-pressure steam turbine.

*Not including cooling tower costs, working capital and land cost, which are included in cost data shown in Sections 4 and 6.

TABLE III

MANNING TABLE WEST TEXAS STUDY

Position	Annual Rate	NUMBER REQUIRED FOR EACH SIZE PLANT - MGD 3.36 and 5.04	6.1	10	14	20
Plant Superintendent	$15,000	0	0	1	1	1
Plant Engineer	12,000	1	1	1	1	1
Technician/Chemist	6,500	0	0	1	1	1
Operator	8,700	5	5	8	8	8
Maint. Foreman	10,800	0	1	1	1	1
Maint. Man	7,800	3	3	3	4	4
Instrument Tech.	8,400	1	1	1	1	1
Total		10	11	16	17	17
Total Direct, $1000		87.3	98.1	145.7	153.5	153.5
Payroll Extras 15%		13.1	14.7	21.9	22.9	22.9
Sub Total		100.4	112.8	167.6	176.4	176.4
30% G&H		30.1	33.8	50.3	52.9	52.9
Grand Total, $1000		130.5	146.6	217.9	229.3	229.3

2.3 COST METHODOLOGY /64/

2.3.1 Annual Cost and Cost of Water

For purposes of comparisons, product water unit costs are calculated and reported in cents per kilogallon (¢/Kgal). To determine these unit costs of water, annual costs actually expended or accrued are divided by the quantity of water produced annually.

Annual water production is taken as 365 times daily rated plant capacity multiplied by an operating factor of 0.90 corresponding to approximately 330 days of actual operation. The remaining 10 percent of the year is an allowance for plant down time.

Annual costs are comprised of three principal categories:

a. Capital Cost
b. Recurring Costs
c. Operation and Maintenance Costs

The annual cost of the invested capital is taken as a uniform annual charge required to repay money borrowed to construct the desalting plant and related facilities. The charge includes interest at 3.5 percent plus sinking fund payment depending on maturity of the bonds. For this study it is assumed that the payoff period is equal to the life of the equipment or facilities involved. In this way a sum is accumulated to repay bonds at the same time that the facility has depreciated its full capital cost.

Desalting plants and equipment and brine disposal facilities are assumed to have a life of 30 years for which the annual cost is then 0.0544 times the capital cost. Well fields, feedwater supply and product water conveyance pipelines are assumed to have a 50-year life giving an annual cost factor of 0.0426. Water treatment facilities were assumed to have a ten-year lifetime for which the annual cost factor is 0.1202.

Certain components of some plants require periodic replacement at intervals much shorter than the plant lifetime. These replaceable items include membranes, separators, electrodes, and miscellaneous components of electrodialysis stacks, whose life is assumed to be 5 years, so the annual cost factor is 0.2215. Membranes for reverse osmosis plants are assumed to have a life of one year, and an annual cost factor of 1.035.

Non-depreciable items such as land and working capital are assumed to retain their initial value at the end of their period of use; this is equivalent to an infinite lifetime for which the annual cost factor is equal to the interest rate of 0.035 assumed for this study.

2.3.2 Capital Costs

The capital cost of a facility represents the amount of money which must be invested in fixed assets and indirect costs to provide a completed operable facility; in addition, for the purposes of this report, capital cost includes the working capital required to pay for the materials and services needed to operate and maintain the plant.

Construction costs for processing and related facilities were determined from sources appropriate to the particular facility. Indirect capital costs, estimated at 17 percent of construction costs, were added to include the costs of engineering and design, interest during construction, and the miscellaneous and administrative costs incurred to bring the facilities to completion and operation. Since some of the construction, materials, and labor costs were based on different dates of construction, all were adjusted to the common basis of December 1967, using Engineering News Record "Building Cost Index", Bureau of Labor Statistics "Labor Cost Index" and other indexes where appropriate.

Sources of data on capital costs are as follows:

Electrodialysis plant size and equipment were based on the use of Mark III stacks manufactured by Ionics Incorporated, Watertown, Massachusetts. These were chosen on account of availability of performance and cost data from operating plants. That combination of stacks was used in series and parallel to give lowest capital cost relative to each application based on the specific water analysis of the feedwater in the region being considered. Capital cost data were obtained from Reference /61/. The cost of replaceable items was taken as $3.00 per square foot of membrane. Membrane life was assumed to be five years.

Reverse Osmosis costs and operating characteristics were provided by the Office of Saline Water, and from discussions with equipment manufacturer. Capital costs for 1 MGD and 10 MGD, were determined. For other capacities

an exponential scaling factor was used. It was assumed that plants would operate at 50 to 80 percent recovery factor while producing water at 500 ppm maximum salinity. Replaceable membranes were assumed to require a cost of five cents per thousand gallons based on a lifetime of one year.

Vacuum Freeze Vapor Compression was based on the pilot plant at Wrightsville Beach, North Carolina. Cost and operating data are based on References /43/44/46/ and on data provided by the Office of Saline Water. Brine concentration ratios of 1.25 and 8.2 were used.

Multistage Flash plants were estimated from data in Reference /62/, which included the costs of steam plants and cooling towers.

Vapor Compression, Vertical Tube Evaporator capital costs were obtained from Reference /65/.

Feedwater estimated yields and costs of developing sources were provided by the Texas Water Development Board. Capital cost includes construction of the wells and interconnecting piping and the cost of interim financing during construction. Interconnecting piping was estimated from $25,000 to $45,000 per mile, and interest during construction was based on 3.5 percent per annum for a six-month period. Right-of-way and easement costs to develop water rights are not included in this study.

Brine Disposal costs were developed and provided by the Texas Water Development Board. A detailed discussion furnished by TWDB is included in Section 2.5 of this chapter.

Product Conveyance costs were estimated from data in in Reference /62/.

Land, a non-depreciable capital cost, is assumed to retain a constant value at $100 to $500 per acre, in accordance with information provided by the Texas Water Development Board. Pipeline right-of-way is taken as approximately 12 feet wide, or 1.5 acres per running mile, for installation and maintenance.

Working Capital includes inventory and cash kept on hand for payment of current expenses. The amount of working capital is assumed equal to costs for a two-month period, amounting to one-sixth of the total of all other annual costs.

2.3.3 Recurring Costs

These costs include taxes and insurance. They have not been included, since it is assumed that water agencies involved are tax-exempt and self-insuring.

2.3.4 Operating and Maintenance Costs

These cost centers include labor for operation and maintenance, consumable supplies and materials, chemicals for treatment of feedwater, and energy in the form of fuel, steam, or electric power.

Operating and maintenance labor costs are based on 24-hour operation of the plant with part attendance by operating personnel where feasible. These costs include direct wages plus payroll extras of 15 percent for fringe and welfare benefits and for payroll taxes and insurance. The following table summarizes the labor costs used in this study:

Process	MGD Size	Operating Labor	Maintenance Labor
ED	2	$ 13,600	$ 8,400
ED	4	27,300	16,800
ED	5	32,200	15,200
ED	7	42,100	20,000
ED	10	49,400	26,500 - 30,400
RO	2	52,000	*
RO	5	74,000	*
VF-VC	1.8	35,200	13,800
VF-VC	5	80,000	18,000
MSF	3	90,900	53,700
VC-VTE	6.1	112,800	*
VC-VTE	10	167,600	*
VC-VTE	20	176,400	*

* Included in operating labor costs

Operating and maintenance labor costs for pipelines was taken as 0.29 percent of total capital costs and includes 15 percent for payroll extras.

For well fields, annual costs of operating and maintenance including 15 percent payroll extras are taken from Reference [62].

General and administrative costs are taken as 30 percent of labor costs to cover plant and office expenses not directly chargeable to a maintenance or operation function.

Supplies and maintenance materials include all expendable materials other than fuels, chemicals and replaceable items. The annual cost was estimated as one percent of total capital costs, except for the multistage flash plants for which this cost was taken as 0.5 percent.

Chemicals are used for treating feedwater to remove or replace concentrations of calcium and magnesium salts, iron, manganese, or for pH adjustment. For the Capitan Reef and Blaine-Gypsum feedwaters with high calcium concentrations the cost of soda ash treatment was calculated. For calcium concentrations in the brine between 440 ppm and 900 ppm, Calgon (a trade name for sodium hexametaphosphate) was employed to prevent calcium precipitation. At concentrations below 440 ppm, no treatment was provided.

For reverse osmosis, chemicals for pH control were estimated at five cents per thousand gallons.

For the multistage flash process, sulfuric acid treatment was estimated at three cents per thousand gallons of product water.

Fuel where required consisted of natural gas; in the El Paso region the cost of natural gas was assumed at 28 cents per million Btu; elsewhere, the cost was assumed at 22 cents per million Btu. Waste heat from natural gas compressors was used in some of the El Paso region cases as an alternative to fuel. Waste heat energy was considered to be free of charge, but appropriate increases in capital costs were included to provide for waste heat recovery boilers and associated equipment.

Electric power from commercial sources is assumed for all cases, with local rates of 1.2 cents per KWH in the El Paso area and 1.0 cents per KWH elsewhere.

For electrodialysis, electric power consumption was provided in accordance with Reference /61/.

In reverse osmosis plants it was estimated that power for pumping and other plant operations is 10 KWH per kilogallon based on recovering 2 KWH per kilogallon.

The vacuum-freeze, vapor-compression plant was assumed to consume 49 KWH per kilogallon to operate the compressor and refrigeration machinery for the 1.8 MGD plant and 29.5 KWH per kilogallon for the 5.0 MGD plant in accordance with References /46/ and /63/.

For the multistage flash process, electric power consumption is based on Reference /62/.

In the well fields, pumping power was based on a well head pressure of 100 feet with a total developed head of 400 feet. With a pump efficiency of 85 percent and motor efficiency of 93 percent, the power required is 0.004 KWH per 1,000 gallons per foot of head, or 1.6 KWH per 1,000 gallons pumped.

Pipeline pumping also was based on a power consumption of 0.004 KWH per 1,000 gallons per foot of head, where the head includes pipe friction losses, plus increase in elevation, plus increase in pressure head. For pipelines from a well field to a desalting plant, a well head pressure of 100 feet and a delivery head of 10 feet at the plant was assumed. Product water conveyance and brine disposal pipelines were assumed to receive water or brine at 10 feet head and deliver the water or brine at 10 feet head.

2.4 CHEMICAL PRETREATMENT OF CAPITAN REEF FEEDWATER /68/

2.4.1 Introduction

According to information fornished by TWDB, the Capitan Reef aquifer in Winkler and Ward Counties is the only known source of brackish water large enough in this region of West Texas to serve as a reliable feed supply for a desalting plant designed to produce 20 million gallons of fresh water daily over a 30-year period, corresponding to the assumed life of desalting systems. A detailed study of the aquifer is now in progress by USGS. Unfortunately, the chemical composition of this water is such that extraordinary chemical pretreatment will be required to reduce the quantities of certain dissolved solids to levels tolerable for subsequent desalting by currently known techniques and to achieve a product water that will be both potable and palatable. This Capitan Reef water, which is used extensively in secondary recovery operations in oil fields as far away from the source as Andrews, Ector, and Crane Counties, is known locally as "brackish sulfide water". /47/ In addition to containing about 200 ppm hydrogen sulfide, which must be reduced to levels less than 0.5 ppm to make the water taste-palatable, this water also contains high levels of carbonate and non-carbonate hardness. The carbonate hardness must be eliminated to preclude the deposition of calcium carbonate and magnesium hydroxide scale on heat transfer surfaces in desalting systems employing evaporation-distillation.

The non-carbonate hardness must be reduced below the solubility limit of calcium sulfate at the brine concentrations and temperatures which would be experienced in applications of the reverse osmosis, and also distillation systems. Chemical and physical analysis of a representative sample of Capitan Reef water reveals the following:

	Capitan Reef Water				Seawater
	Cation		Anion		Ions
Element	ppm	MEQ	ppm	MEQ	ppm
Ca	780	39			400
Mg	310	25			1242
Na+K	950	45			10561
HCO_3			335	6	142

Element	Capitan Reef Water Cation ppm	MEQ	Anion ppm	MEQ	Seawater Ions ppm
SO_4			2635	55	2649
Cl			1700	48	
Totals	2040	109	4670	109	34483

pH	7.3
Sp. Gr.	1.1056
Temp. (^{o}F)	90
$CaCO_3$ Hardness	2980
TDS	6710

2.4.2 Recommended Pretreatment Procedures for Desalting by Evaporation-Distillation

Numerous alternative procedures and processes have been considered for the removal of H_2S and carbonate hardness to the level at which desalting plant operations can be conducted at an appropriate product-to-brine ratio in the absence of calcium sulfate scaling.

Based on the extent of this preliminary investigation and the information available the following pretreatment procedures are recommended:

1. Add sulfuric acid to the feedwater as required to react stoichiometrically with the bicarbonate and hydrosulfide alkalinity and to reduce the Langlier index to -1.0.

2. Pump the acidulated feedwater directly to a vacuum degasifier of the Aqua-Chem conceptual design, utilizing steam from the flashing feedwater as the stripping medium. (This unit is similar to Permutit's "vacuum deaerator".) [48] [49] [50]

3. Exhaust the released CO_2 and H_2S through vacuum pumps directly to a modified Claus-Chance dry oxidation process for conversion of the H_2S to elemental sulfur for sale and credit to the cost of desalting. [51] [52] [53]

4. Add chlorine to the degassed feedwater as required to react stoichiometrically with the remaining traces of dissolved H_2S (assume 2 ppm H_2S), and to passivate any anaerobic bacteria which may remain. /54/

5. Add soda ash /55/ (sodium carbonate) to the degassed, chlorinated feedwater as required stoichiometrically to reduce the non-carbonate (calcium sulfate) hardness to a value less than the saturation value of $CaSO_4$ ($\sim$ 1200 ppm as calcium sulfate, $\sim$ 500 ppm as calcium ion) in the concentrated brine from the desalting plant. (Note: Solubility of $CaSO_4$ in pure water is assumed here as a safety factor for the uncertainty of the higher solubility which may obtain for $CaSO_4$ in the presence of other salts in solution.)

6. Pump the degassed, chlorinated soda-softened water to a Dorr clarifier (or equivalent) for removal of the calcium carbonate precipitate. Route the overflow to the brine heater of the desalting plant. Route the underflow to the waste brine stream for disposal either in an evaporation pond or to underground injection.

2.4.3 Recommended Pretreatment Procedures for Desalting by the Vacuum Freeze and Reverse Osmosis Processes

The concentrations and solubilities /56/ of calcium carbonate and magnesium hydroxide in the concentrated brine solution from the reverse osmosis process do not present a scaling problem. Thus no acid addition is needed to eliminate bicarbonate hardness. However, the water is saturated (in fact, somewhat supersaturated) in calcium sulfate and thus extensive soda softening treatment is required to reduce the calcium ion concentration to the level required to preclude calcium sulfate precipitation at the assumed concentration levels of the waste brine solutions. A cheaper, but less positive alternative may be the addition of sodium tri-poly-phosphate as a solubilizing ("sequestering") agent. Preliminary reverse osmosis tests by Gulf General Atomics /59/ on Capitan Reef water have shown that 20 ppm addition of sodium tri-poly-phosphate is adequate to prevent calcium sulfate precipitation at a feed concentration factor of 2:1.

But the problem created by dissolved hydrogen sulfide in the feedwater for desalting by distillation may be avoided in the reverse osmosis process, it is believed, by stabilizing the H_2S in solution in the form of sodium sulfides. However, the preliminary tests performed by Gulf General Atomics /59/ on this water indicate that the product water

contains over 100 ppm H_2S. Thus, pretreatment for H_2S removal, as prescribed for distillation processing, may be required and is prescribed for the reverse osmosis process in this preliminary evaluation.

The flowsheet developed by Colt Industries for application to Capitan Reef water assumes an 8.2 feed-to-brine concentration. The need for soda softening as a pretreatment step is not reflected in the preliminary cost estimates provided by Colt Industries for desalting Capitan Reef feedwater. On the basis of private communication /60/, Colt engineers indicates that such treatment may not be required to successfully desalt this feedwater. However, the validity of this claim should be determined by testing Capitan Reef and also Estelline Spring saline water with the portable freeze process unit now being constructed. In the absence of such test performance data it should be assumed that the pH should be maintained in the range of 7.3 - 7.5 to retain the dissolved sulfides in solution and to avoid the release of highly toxic hydrogen sulfide to the surrounding area.

The preliminary recommendations of pretreatment needs for each of these processes are the following:

(a) Freeze Process

Tentatively, maintain pH in the range of 7.3 - 7.5 pending results of actual tests to determine whether pretreatment is necessary.

(b) Reverse Osmosis Process

A typical flowsheet for a reverse osmosis plant would assume 80 percent water recovery efficiency equivalent to a feed-to-brine ratio of 5/1. The indicated pretreatment would be Steps 1-4 as specified for the distillation process, followed by the addition of 20 ppm of sodium tri-poly-phosphate.

2.4.4 Essential Material Requirements and Costs

Based on the chemical analysis of the representative sample, the following essential material requirements and costs are estimated for each desalting process:

20 MGD PLANT (DISTILLATION PROCESS)

Sulfuric Acid (66° Baume)

55,000 lb/day	=	27.5 tons/day
27.5 t/d x $40/t	=	$1,100/day
1100.00/20 x 10^3	=	5.5¢/Kgal

Chlorine (100%)

3,600 lb/day	=	1.8 tons/day
1.8 t/d x $130/t	=	$234/day
234.00/20 x 10^3	=	1.2¢/Kgal

Soda Ash

216,000 lb/day	=	108 tons/day
108 x $37/t	=	$3996/day
3996.00/20 x 10^3	=	20¢/Kgal

5 MGD PLANT (REVERSE OSMOSIS)

Sulfuric Acid (66° Baume)

14,500 lbs/day	=	7.25 tons/day
7.25 t/d x $40/t	=	$290/day
290.00/5 x 10^3	=	5.8¢/Kgal

Chlorine (100%)

1000 lb/day	=	0.5 tons/day
0.5 t/d x $130/t	=	$65.00/day
65.00/5 x 10^3	=	1.3¢/Kgal

Sodium Tri-Poly-Phosphate

1050 lb/day	=	0.525 tons/day
0.525 t/d x $140/t	=	$74.20/day
74.20/5 x 10^3	=	1.5¢/Kgal

2.4.5 Capital and Operating Costs

For the 20 MGD distillation process plant, the equipment requirements to support the pretreatment are estimated, from preliminary information provided by the Permutit Company [57] and the Pan American Petroleum Corporation [58] at $1,400,000. This includes the cost of the modified Claus-Chance process equipment employed to recover an estimated 5000 long tons of elemental sulfur annually from the dissolved H_2S in the feedwater. The operating costs for this equipment are estimated at $70,000

annually (not including the cost of chemicals). If the by-product sulfur production is sold at $38 per long ton, corresponding to the current market price, the net annual capital and operating costs based on 3 1/2 percent interest and 10-year write-off and including the cost of chemical additives is $1,808,000, corresponding to a unit cost of 27.4 cents per 1000 gallons of product water.

For the 5 MGD reverse osmosis process, the capital investment requirements for pretreatment chemicals addition and sulfur removal and recovery equipment are estimated at $210,000 and the annual operating cost are estimated at $18,000. After credit for by-product sulfur sales, the unit pretreatment cost would be 8.3 cents per 1000 gallons of product water.

2.4.6 Summary of Pretreatment Costs

20 MGD PLANT (DISTILLATION PROCESS)

(a)	Capital Investment, Pretreatment Equipment:	$1,400,000
(b)	Annual Costs:	
	Capital Amortization	169,000
	Operating Costs	70,000
	Chemicals:	
	Sulfuric Acid	363,000
	Soda Ash	1,319,000
	Chlorine	77,000
	Subtotal	$1,998,000
	Less By-Product Sulfur Credit	- 190,000
	Net Total	$1,808,000
(c)	Unit Pretreatment Cost	
	$1,808,000/20 \times 10^3 \times 330$ =	27.4¢/Kgal

5 MGD PLANT (REVERSE OSMOSIS PROCESS)

(a)	Capital Investment Pretreatment Equipment:	$210,000

(b) Annual Costs:

Capital Amortization	$ 25,400
Operating Costs	18,000
Chemicals:	
Sulfuric Acid	95,700
Sodium Tri-Poly-Phosphate	24,500
Chlorine	21,500
Subtotal	$185,100
Less By-Product Sulfur Credit	-48,500
Net Total	$136,600

(c) Unit Pretreatment Cost

$136,000/5 \times 10^3 \times 330$ = 8.3¢/Kgal

2.5 BRINE DISPOSAL

All desalting processes discharge a waste stream which contains the concentrated dissolved minerals originally present in the feedwater. This concentrated waste stream generally is referred to as the "brine" effluent. The term brine does not necessarily indicate the chemical quality of the effluent but only designates the concentrated waste water from the process. The chemical quality of the brine effluent from a desalt plant will depend on the quality of the feedwater to the plant, the kind and quantity of pretreatment chemicals added, and the ratio between the desalted water and the brine effluent.

One of the major components of the cost of a desalting system is the cost of disposing of the brine effluent. Handling and the ultimate disposal of the brine can be a major problem especially at interior locations, and can increase considerably the cost of the converted water. Generally, the effluent volume is large and is of a chemical quality that makes it unsuitable for municipal, industrial, or agricultural purposes. The handling and disposal of the brine in such a manner as to prevent pollution or damage to other natural resources is an important factor that must be taken into consideration in evaluating the overall feasibility of desalting.

Previous studies by the Texas Water Development Board and others for the Office of Saline Water have dealt with methods of disposal or utilization of the brine effluent from desalting plants. For the purposes of this study two methods of brine disposal, deep well injection (subsurface injection) and evaporation ponds, have been considered. Preliminary design and cost estimates were developed for each study case. Procedures outlined in Office of Saline Water R&D Report No. 257 were used with some modification for design and cost estimating of the two types of disposal systems. Costs were adjusted from January 1966 to December 1967 using the Engineering News Record Building Construction Index.

An important consideration in analyzing the impact of brine disposal in desalting is the influence of various State of Texas laws on disposal procedures. Three State of Texas agencies - the Railroad Commission of Texas, the Texas Water Development Board, and the Texas Water Quality Board - are responsible for regulating the disposal of industrial and municipal wastes. The Oil and Gas Division of the Railroad Commission has the responsibility of regulating the disposal of salt water resulting from the exploitation of oil and gas resources. The Texas Water Quality Board is the regulatory agency controlling the discharge of municipal and industrial wastes into ponds or waterways. The Texas Water Development Board - the third regulatory body - is the agency which controls the disposal of municipal and industrial wastes into underground formations.

Regulatory criteria have not been developed for the construction and lining of waste disposal ponds (evaporation ponds) in Texas. In general, ponds are lined to prevent seepage of the waste from the pond and subsequent degradation of other natural resources. The Railroad Commission, in enforcing stricter controls over salt water disposal ponds, generally requires that the material used for lining ponds should have a thickness of not less than 30 mil. However, previous experience in Texas indicates that linings deteriorate with time and require diligent and continuous maintenance.

In calculating the cost of evaporation ponds for the present study, the assumption was made that the ponds would be lined with 20 mil polyvinyl chloride (PVC) at an estimated cost of 11 cents per square yard installed. This thickness was selected based on data which indicate that many brine storage ponds in the West Texas region are lined with vinyl material having a thickness of 20 to 30 mil. The cost estimating procedure outlined in OSW Report No. 257 suggests 6 mil polyethylene lining at a cost of 3.1 cents per square yard installed; however, this material generally does not have the life expectancy of the thicker PVC material.

A modification was made in the design procedure of the injection system outlined in Report No. 257 for determining the desirable injection conduit diameter versus the number of injection wells required in order to allow for better optimization of the injection well field and thus provide a more reliable cost estimate for the system. For the purpose of this study it has been assumed that injection of the brine will be through plastic lined production casing without tubing and that the production casing will be set with cement circulated to the surface. Also, it has been assumed that a closed system will be maintained from the desalt plant to the injection well and that no treatment of the brine will be necessary prior to injection. All injection well fields are assumed to be located within one mile of the desalt plant unless otherwise required. Total cost of disposal by injection includes the costs for the injection well field, well field pipeline distribution system, pipeline from the plant to the well field, and pump station and storage.

Generally, cost calculations indicate that the unit cost of injection without tubing is reduced by less than one-half cent to as much as 1.5 cents compared to the cost with tubing, while the unit cost of injection without treatment of the brine is reduced by one-third or more. However, it is noted in making these assumptions that detailed engineering economic feasibility studies may indicate that injection tubing should be used and/or treatment will be required.

The unit cost of brine disposal is less expensive for injection than for evaporation ponds in all cases under study except the two in the Crane-Reagan-Upton region. In these two cases the cost of injection was 1.1¢ and 5 mills higher than the cost for ponds. However, the capital investment for ponds in these two cases was 60 percent and 115 percent higher than for injection. Chapters 4 through 9 have discussions on brine disposal for each area in the study.

The cost of a properly designed and constructed evaporation pond generally is more expensive than the cost of subsurface injection in addition to the aesthetic problem where such a pond is located near the community. The potential pollution hazard to fresh ground and surface water supplies from brine disposal in evaporation ponds is of primary consideration in evaluating the alternative methods of brine disposal. Very stringent criteria for disposal wells will be needed to prevent pollution where subsurface injection is selected as a means of disposal.

WATER RESOURCES

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WATER RESOURCES

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3. WATER RESOURCES /67/

3.1 INTRODUCTION

West Texas is one of the major water short regions in the State. Physiographically the region is in parts of the Basin and Range, Great Plains and Central Lowland Provinces. Generally, the climate ranges from semiarid on the east side of West Texas to arid on the west. The average annual rainfall decreases from about 25 inches in the Abilene area to less than 10 inches at El Paso, while the average annual net lake-surface evaporation loss increases from about 50 inches near Abilene to more than 70 inches at El Paso and 90 inches in southern Presidio and Brewster Counties as shown in Figure 3 - 1.

3.2 SURFACE WATER

West Texas lies within parts of five major river basins. From north to south they are the Canadian River, Red River, Brazos River, Colorado River and the Rio Grande basins, as shown in Figure 3 - 1. All five basins head in eastern New Mexico.

Figure 3 - 2 indicates that a large part of the West Texas region is noncontributing to surface water runoff. In the contributing part of the region, Figure 3 - 2 indicates that the average annual runoff generally is less than 50 acre-feet per square mile. This average annual runoff is not the runoff that may be expected in the future. The runoff varies widely from year to year and between periods of wet and dry years. However, the noncontributing area will remain essentially the same.

The chemical quality of the water is one of the principal problems in the development and use of the surface-water resources in West Texas. The primary cause of the water quality problem is natural pollution. Large volumes of surface, and some ground water are being polluted by salt from salt-water springs and seep areas in the Red River basin, Brazes River basin, Colorado River basin, and Pecos River of the Rio Grande basin. In some areas the natural pollution is aggravated by further degradation of the water quality from inflow of oil-field-brine from the oil fields of the area or from the inflow of saline irrigation return flow.

Studies have indicated that one possible solution to the salinity problem would be construction of low-flow dams, pumping plants and pipelines to capture and transport the saline flows to off-channel storage reservoirs. Figure 3 - 3 illustrates the discharge-weighted averages of dissolved-solids concentration of the major rivers and some of their tributaries in West Texas.

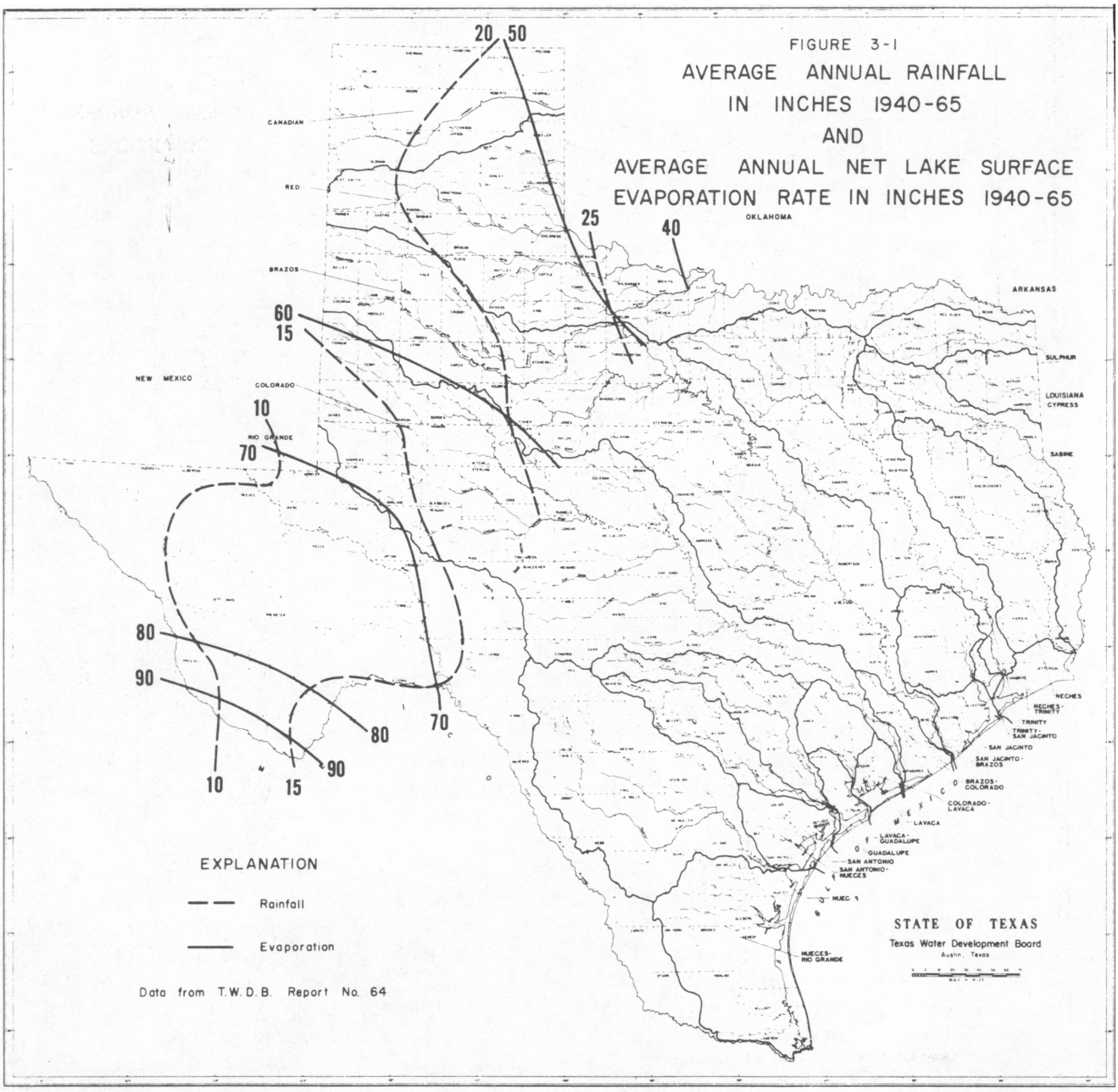


FIGURE 3-1
AVERAGE ANNUAL RAINFALL
IN INCHES 1940-65
AND
AVERAGE ANNUAL NET LAKE SURFACE
EVAPORATION RATE IN INCHES 1940-65
20
50
25
40
60
15
10
70
80
90
10
15
80
70
90
CANADIAN
RED
BRAZOS
COLORADO
RIO GRANDE
NEW MEXICO
OKLAHOMA
ARKANSAS
SULPHUR
LOUISIANA
CYPRESS
SABINE
NECHES
NECHES-TRINITY
TRINITY
TRINITY-SAN JACINTO
SAN JACINTO
SAN JACINTO-BRAZOS
BRAZOS-COLORADO
COLORADO-LAVACA
LAVACA
LAVACA-GUADALUPE
GUADALUPE
SAN ANTONIO
SAN ANTONIO-NUECES
NUECES
NUECES-RIO GRANDE
MEXICO
EXPLANATION
Rainfall
Evaporation
Data from T.W.D.B. Report No. 64
STATE OF TEXAS
Texas Water Development Board
Austin, Texas

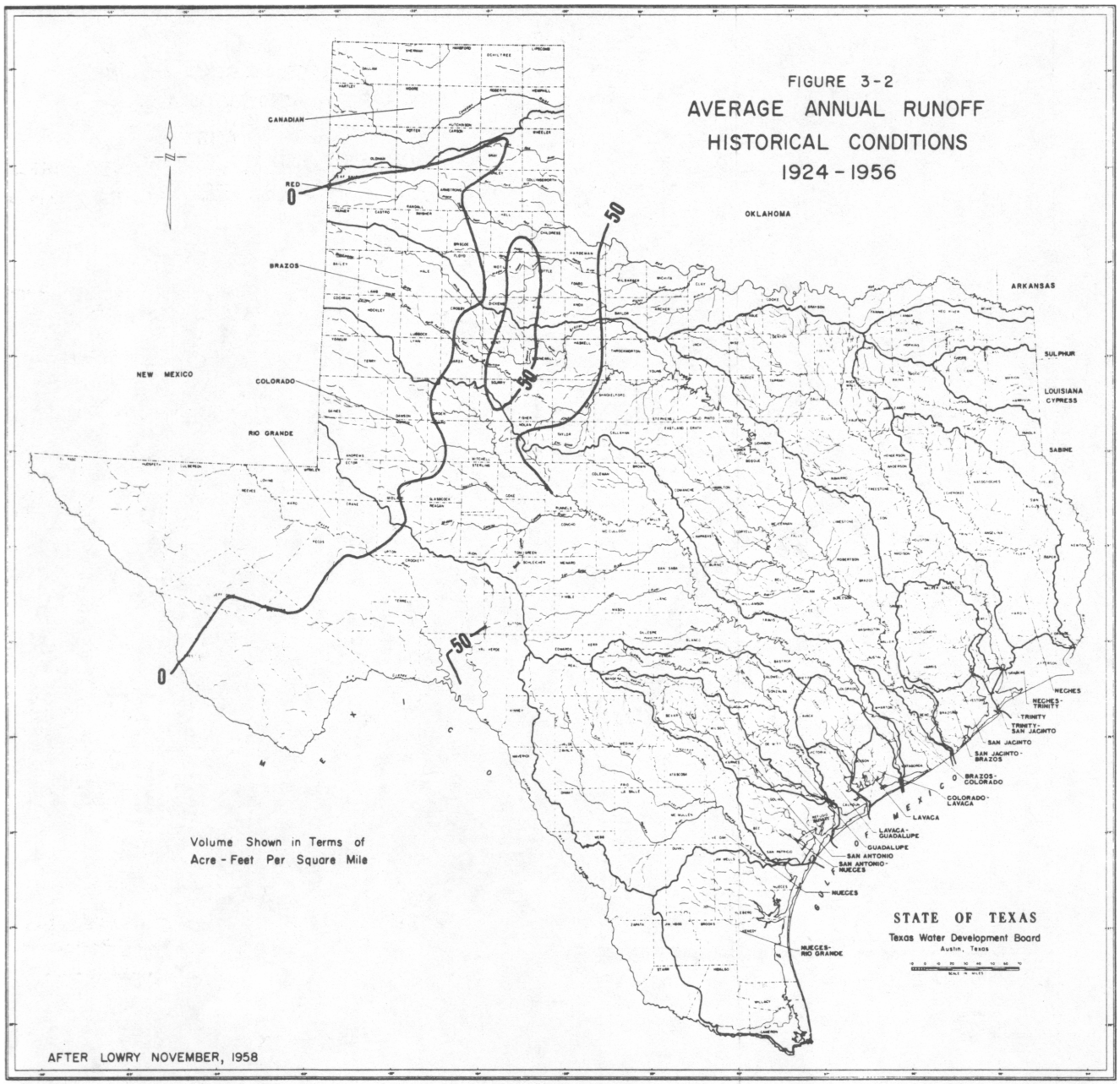


FIGURE 3-2
AVERAGE ANNUAL RUNOFF
HISTORICAL CONDITIONS
1924 - 1956
CANADIAN
RED
BRAZOS
COLORADO
RIO GRANDE
NEW MEXICO
OKLAHOMA
ARKANSAS
SULPHUR
LOUISIANA
CYPRESS
SABINE
NECHES
NECHES-TRINITY
TRINITY
TRINITY-SAN JACINTO
SAN JACINTO
SAN JACINTO-BRAZOS
BRAZOS-COLORADO
COLORADO-LAVACA
LAVACA
LAVACA-GUADALUPE
GUADALUPE
SAN ANTONIO
SAN ANTONIO-NUECES
NUECES
NUECES-RIO GRANDE
0
50
Volume Shown in Terms of
Acre - Feet Per Square Mile
STATE OF TEXAS
Texas Water Development Board
Austin, Texas
AFTER LOWRY NOVEMBER, 1958

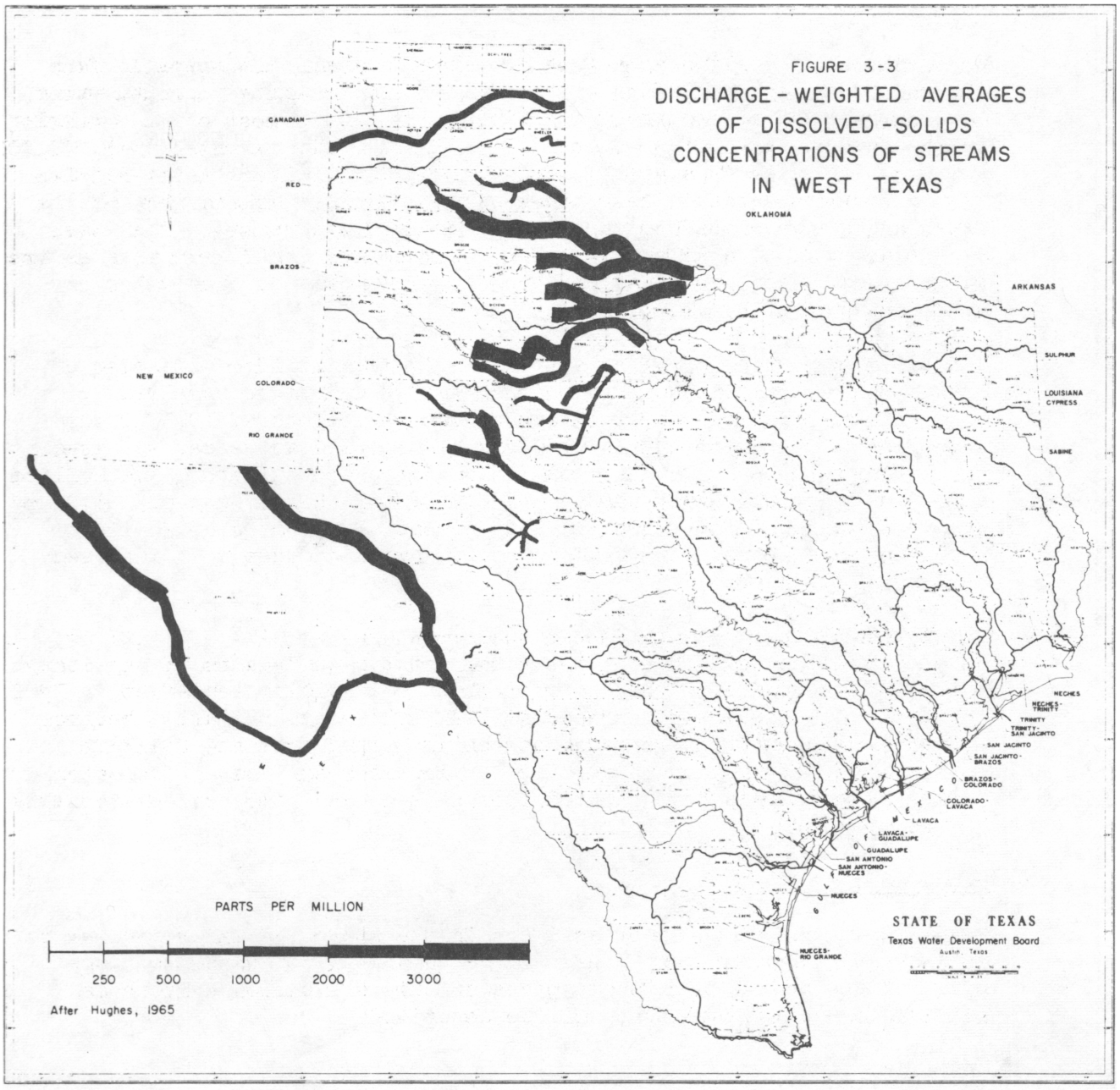


FIGURE 3-3
DISCHARGE-WEIGHTED AVERAGES OF DISSOLVED-SOLIDS CONCENTRATIONS OF STREAMS IN WEST TEXAS
OKLAHOMA
CANADIAN
RED
BRAZOS
NEW MEXICO
COLORADO
RIO GRANDE
ARKANSAS
SULPHUR
LOUISIANA
CYPRESS
SABINE
NECHES
NECHES-TRINITY
TRINITY
TRINITY-SAN JACINTO
SAN JACINTO
SAN JACINTO-BRAZOS
BRAZOS-COLORADO
COLORADO-LAVACA
LAVACA
LAVACA-GUADALUPE
GUADALUPE
SAN ANTONIO
SAN ANTONIO-NUECES
NUECES
NUECES-RIO GRANDE
MEXICO
PARTS PER MILLION
250
500
1000
2000
3000
After Hughes, 1965
STATE OF TEXAS
Texas Water Development Board
Austin, Texas

3.3 GROUND WATER

Approximately 5 million acre-feet of water is available annually from the major and minor aquifers of the State. Unfortunately ground water, like surface water, is poorly distributed in Texas, most of it occurring in the eastern part of the State. In addition, approximately 365,000,000 acre-feet of water is available from storage in aquifers which receive little or no recharge. These are generally in the western part of the State and are developed primarily for irrigation purposes. The water in storage will be available to meet requirements until such time as the water levels become too deep for economical pumpage of this water or until the aquifer has been depleted.

In 1960 ground water provided approximately 12.2 million acre-feet of Texas' water requirements. Of this amount ground water supplied 1.5 million acre-feet for municipal and industrial purposes, 10.3 million acre-feet was used for irrigation, and 0.4 million acre-feet was used for mining purposes. In the West Texas region approximately 9.8 million acre-feet of ground water was used in 1960. Of this amount 0.3 million acre-feet was used for municipal and industrial purposes, 9.2 million acre-feet was used for irrigation, and 0.3 million acre-feet was used for mining purposes.

By the year 2020, it is projected that ground water will be supplying only 5.4 million acre-feet of the total water requirements of the State. The reduction in use of ground water from 12.2 million acre-feet in 1960 to 5.4 million acre-feet by the year 2020 will occur primarily because of the large quantities of water now being pumped from the Ogallala formation for irrigation on the High Plains in West Texas. The water from the Ogallala is being pumped from storage and will not be available by the year 2020.

3.4 MAJOR AQUIFERS

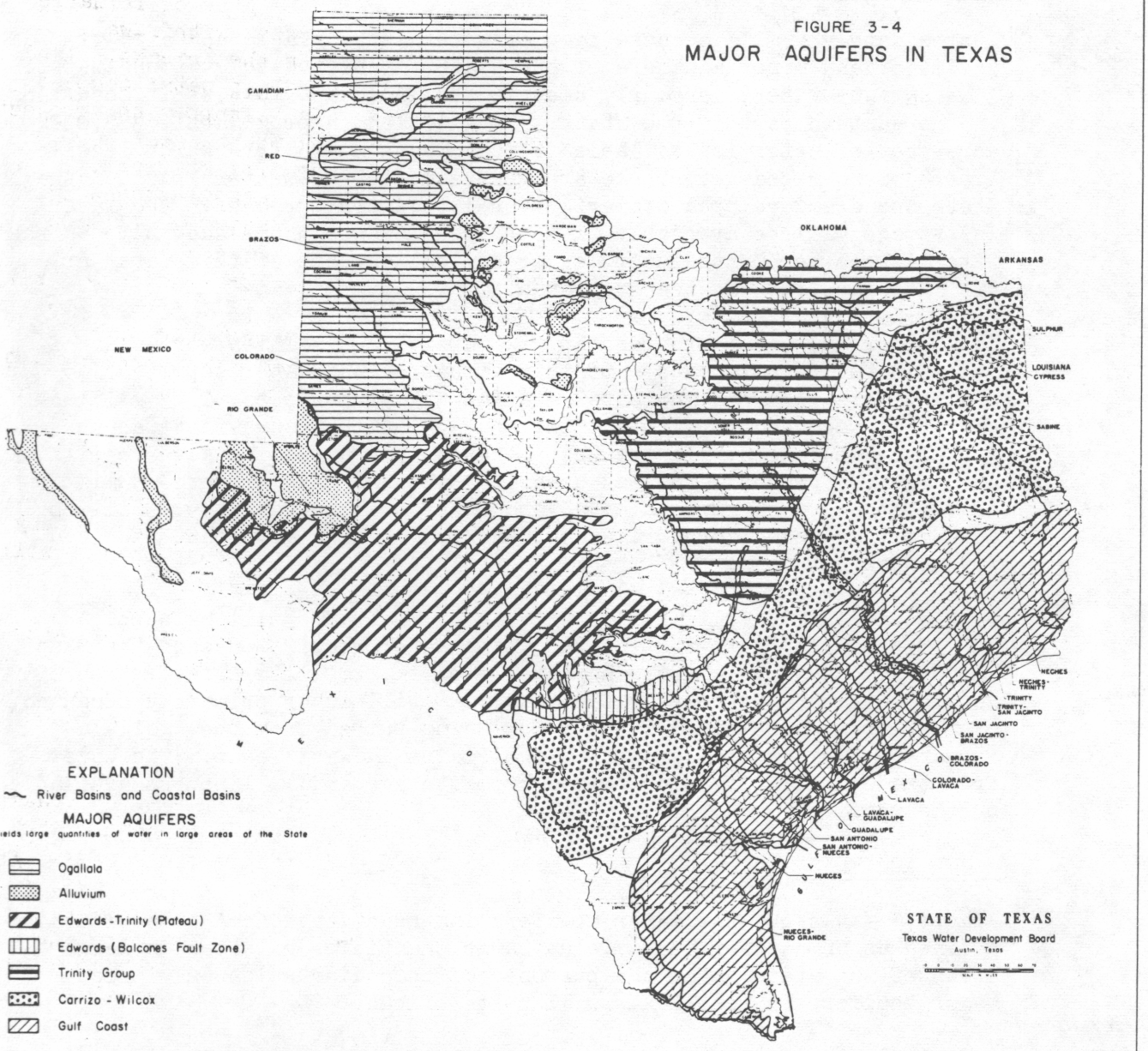
Figure 3 - 4 shows the major aquifers in the state. A major aquifer is defined as an aquifer that yields large quantities of water in large areas of the State. For the purposes of this discussion only those major aquifers in West Texas will be described.

3.4.1 Ogallala Aquifer

The Ogallala Formation is composed of interconnected sand and gravels mixed with clay, silt, and caliche, forming a large unconfined ground water reservoir. The formation ranges in thickness from 0 to about 900 feet, with generally less than 300 feet of saturation. The thickest part of the aquifer occurs in the northern part of the High Plains, with lesser amounts of saturation and heavier development in the southern part. Ground water in the aquifer generally occurs under water table conditions. Well yields range from less than 100 gallons per minute to more than 2,000 gallons per minute with the average being about 500 gallons per minute.

FIGURE 3-4

MAJOR AQUIFERS IN TEXAS



Approximately 280 million acre-feet of water in the Ogallala is considered economically recoverable from storage. The rate of recharge to the Ogallala is very small compared to the present withdrawal. Approximately 1/3 of the available water occurs in the "breaks," land which is not considered suitable for irrigation. This water coupled with surface water from Lake Meredith is adequate to supply the projected municipal and industrial needs of the High Plains to the year 2020. The decrease in available water will occur in the irrigation area, where in 1960 a total of 7.6 million acre-feet of water was used for irrigation; it is projected that for the year 2020 only 1.5 million acre-feet will be available.

Generally, the water contains less than 1,000 parts per million dissolved solids; however, in the southern part of the aquifer the dissolved solids concentration ranges up to about 3,000 parts per million. The water is hard and has an objectionably high fluoride content.

3.4.2 Alluvium Aquifer

The alluvium aquifer as shown on Figure 3 - 4 is present in five different areas which are completely separated but yet hydrologically similar. Collectively they are shown under a single heading, but will be discussed separately.

Alluvium (Seymour Formation) - Remnants of the Seymour Formation and other alluvial sediments in 13 areas of the Red and Brazos River basins have sufficient thickness to constitute an aquifer. They are presently being used for irrigation and some public supplies. The thickness of the deposits ranges from a few feet to as much as 360 feet of sand, gravel, silt, and clay with the saturated part of the formation generally being less than 100 feet thick. The yields of large capacity wells range from less than 100 gallons per minute to as high as 1,300 gallons per minute with the average being about 300 gallons per minute.

It is estimated that approximately 100,000 acre-feet is available annually from the 13 areas. In some of the areas, the 1960 pumpage exceeded the annual recharge, and thus water is being pumped from storage. It will be necessary that the amount of pumpage in these areas be reduced in the future.

The water generally contains from 500 to 3,000 parts per million dissolved solids. Nitrate is high, making the water in many cases unsuitable for public supply.

Cenozoic Alluvium and Bolson (El Paso) - Ground water in the El Paso area occurs in the unconsolidated bolson deposits of the Hueco and La Mesa bolson and in the river alluvium of the Lower Mesilla and El Paso Valleys. The deposits consist of unconsolidated sand, gravel, clay and caliche, and range in thickness from a few feet to more than

5,000 feet. Water in the aquifer generally is under water-table conditions with the base of fresh water extending in some areas to 1,400 feet below land surface. Yields from large-capacity wells are generally from 1,000 to 1,500 gallons per minute, with some reaching 3,000.

Recharge to the Hueco and La Mesa bolson aquifers is estimated to average 15,000 acre-feet annually to each aquifer, or a total of 30,000 acre-feet. Recharge to the river alluvium in the Lower Mesilla Valley is principally by infiltration of surface water applied to the land surface for irrigation and has been estimated to be at least 36,000 acre-feet annually when surface water supplies for irrigation are adequate and storage space is available in the alluvium. Recharge to the alluvium in the Mesilla Valley has been estimated to average 15,000 to 20,000 acre-feet annually. For the purpose of this tudy, the recharge is assumed to be 15,000 acre-feet Therefore, the total average annual recharge to the aquifers in the El Paso area is estimated to be approximately 45,000 acre-feet. In general, the water in the river alluvium in the El Paso Valley is unsuitable for public supply, therefore recharge is not considered in this study.

In addition to the recharge, large quantities of fresh water are stored in the aquifers. The theoretically recoverable fresh water from storage in the Texas part of the Hueco and La Mesa bolson deposits has been estimated to be about 8 million acre-feet. It is conservatively estimated that of this volume only 50 percent or about 4 million acre-feet can be recovered because of the probability of saline water encroachment into the fresh water part of the aquifers.

Ground water in the El Paso area ranges from fresh to very saline. Where fresh ground water is available, it is underlain, overlain, or adjoined by slightly saline water, the water becoming increasingly mineralized with depth as well as laterally. In the El Paso area ground water containing less than 250 ppm of chloride is classified as fresh.

Cenozoic Alluvium and Bolson (Salt Basin) - The alluvial and bolson deposits of the Salt Basin extend from Dell City in northeast Hudspeth County near the Texas-New Mexico border southward to Presidio County. The deposits consist of unconsolidated sand, gravel, clay, and caliche, with the thickness ranging from 0 at the edge of the basin to as much as 1,600 feet. The large capacity wells produced from this aquifer yield from 250 to 2,500 gallons per minute.

The amount of water received by the aquifer each year through recharge is not known. Based on the thickness of the fresh water bearing part of the bolson that underlies the Wildhorse Draw and Lobo Flats Area in Culberson County, there is estimated to be at least 400,000 acre-feet of water available from storage. Most of this water is used for irrigation and will be depleted before the year 2020.

Most of the water withdrawn from the aquifer in these areas is of good quality and is satisfactory for most industrial, municipal, and irrigation purposes. In the Lobo Flats area the water typically is low in dissolved solids, chloride, and sulfate. The water increases in mineralization as it moves northward into the Wildhorse Draw irrigation area, where it contains from 400 to 2,900 parts per million dissolved solids. In the Dell City area the water generally has a dissolved solids concentration in excess of 1,000 parts per million.

Cenozoic Alluvium (Pecos Valley) - The alluvial deposits of the Pecos River Valley consist of unconsolidated to partly consolidated sand, silt, gravel, boulders, clay, gypsum, and caliche. The thickness of the alluvium is from 100 to 300 feet in most of the area. However, there are two troughs where the thickness generally ranges from 600 to 1,500 feet. The yields of large capacity wells range from 200 to 2,500 gallons per minute with the average being about 1,000 gallons per minute.

There is estimated to be approximately 70,000 acre-feet of water received as recharge each year, and the quantity is available on a perennial basis. Most of this water is being discharged from the underlying Edwards-Trinity (Plateau) aquifer. In addition, there is estimated to be 60 million acre-feet of water which can be economically recovered from storage.

There seems to be sufficient water in the aquifer to meet the needs of the area, but quality deterioration will limit its use in some areas.

The quality of the water ranges from less than 200 parts per million dissolved solids to as much as 13,000 parts per million. However, most of the water that is used ranges from 1,000 to 4,000 parts per million dissolved solids, and it is generally used for irrigation purposes. As the water levels decline in some of the heavily pumped areas, poor quality water from the Pecos River is being drawn into the aquifer. Although there is an adequate supply of water in the alluvium to meet the municipal and industrial needs, it may be necessary for some cities to extend their well fields for some distance from the town or go to a desalting process to obtain their drinking water.

3.4.3 Edwards-Trinity (Plateau) Aquifer

The Edwards-Trinity (Plateau) aquifer covers a large area of the Rio Grande and Colorado River basins. The aquifer is composed of water-bearing sand and limestones of the Washita, Frederickburg, and Trinity Groups. The upper part of the aquifer is made up of the Georgetown, Edwards, and Comanche Peak Formations which are limestones, and the lower part of the aquifer is made of the sands of the Trinity Group. The thickness of the aquifer ranges up to 1,000 feet, with the sand thickness generally less than 100 feet. The water in the aquifer generally occurs under water-table conditions in fractures in solution cavities in the limestone and in the underlying Trinity sands. The yields of wells completed in the aquifer range from a few gallons per minute to as much as 3,000 gallons per minute.

There is estimated to be approximately 650,000 acre-feet of water annually which could be intercepted and developed from the aquifer. However, most of the available recharge water occurs in the areas of little need. In addition to the water available annually from recharge, approximately 12 million acre-feet of water is available for development from storage in the aquifer north of the Middle Concho River. Any large scale development of ground water from the aquifer would result in a reduction of the base flow of streams draining the plateau and thus reducing the surface water supply.

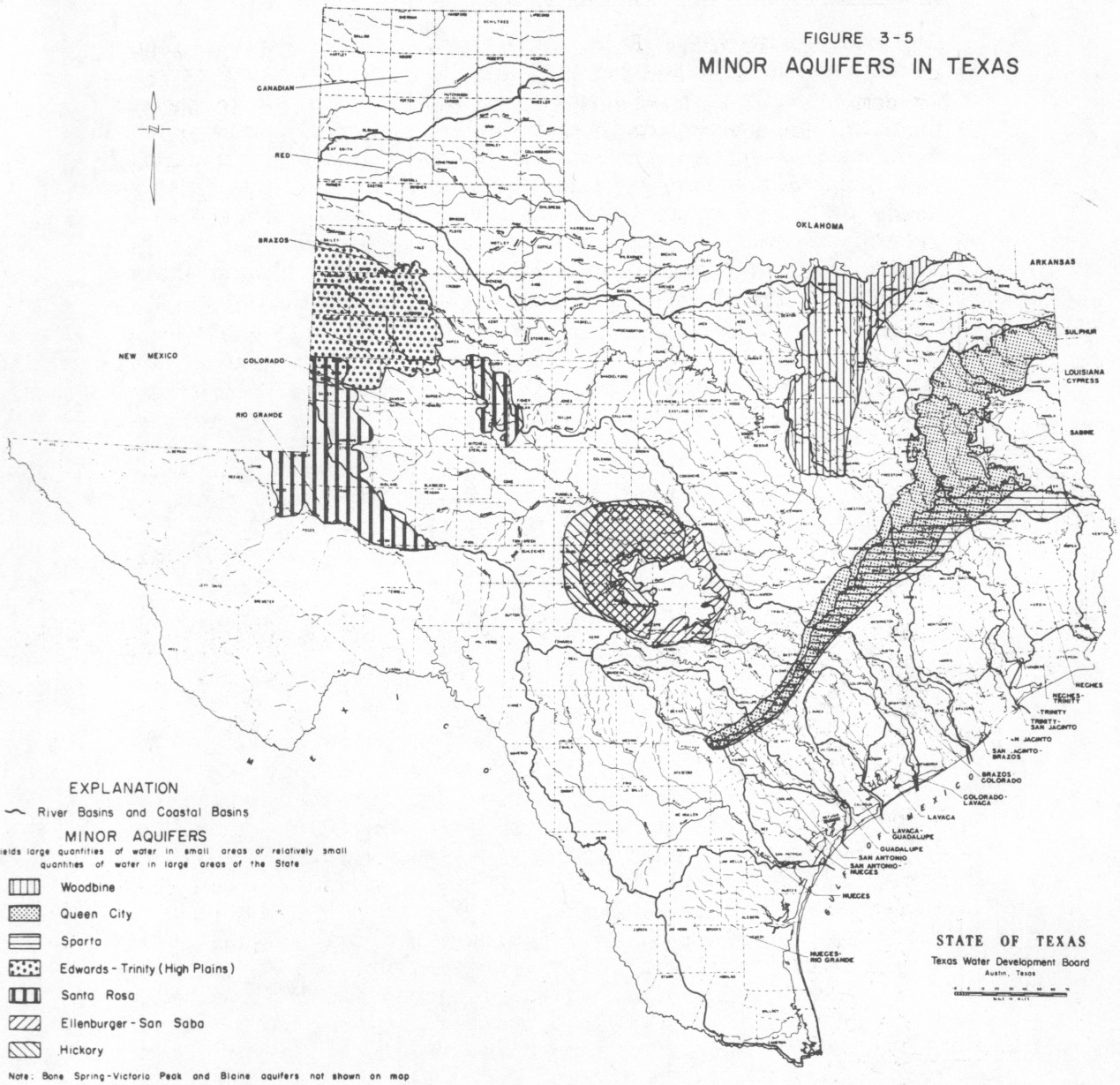
Water in the aquifer generally is very hard. In the northwest part of the aquifer the water generally contains 1,000 to 3,000 parts per million dissolved solids; in the southern part, the water ranges from less than 200 to about 2,900 parts per million dissolved solids, usually having less than 1,000 parts per million.

3.5 MINOR AQUIFERS

Not as much information is available on the minor aquifers of the State, and in some cases, not enough information is available to make an estimate of the amount of water available or to know the exact areal extent of the aquifer. A minor aquifer is defined as one that yields large quantities of water in small areas or relatively small quantities of water in large areas of the State. Although they do not contain the quantities of water found in the major aquifers, they are sometimes capable of supplying requirements in areas where no other supply is available and thus are of local importance. Figure 3 - 5 shows the location of the minor aquifers in Texas. Only those minor aquifers in the West Texas region are discussed.

FIGURE 3-5

MINOR AQUIFERS IN TEXAS



EXPLANATION

River Basins and Coastal Basins

MINOR AQUIFERS

Yields large quantities of water in small areas or relatively small quantities of water in large areas of the State

- Woodbine
- Queen City
- Sparta
- Edwards - Trinity (High Plains)
- Santa Rosa
- Ellenburger - San Saba
- Hickory

Note: Bone Spring-Victorio Peak and Blaine aquifers not shown on map

STATE OF TEXAS

Texas Water Development Board

Austin, Texas

3.5.1 Edwards-Trinity (High Plains) Aquifer

Edward-Trinity (High Plains) aquifer occurs in the subsurface under the Ogallala formation in parts of the Brazos and Colorado River basins. It consists of a thin sand overlain by shale and limestone, with water occurring in the limestone only on the western edge of the aquifer. The amount of water available from the aquifer is not known; however, the recharge would be small and would be derived from the Ogallala aquifer. Water that could be pumped from storage in the Edwards-Trinity (High Plains) aquifer probably is not more than 2 million acre-feet.

3.5.2 Santa Rosa Aquifer

Water in the Santa Rosa aquifer is contained in interbedded lenses of sand, hard sandstone, gravel, and shale. The aquifer contains usable quality water in two different areas, one on the Texas-New Mexico border in the Rio Grande and Colorado River basins and the other in the Mitchell, Nolan and Scurry Counties to the east.

In the eastern part of the aquifer the thickness ranges from 0 to approximately 400 feet, with wells yielding up to 1,150 gallons per minute and averaging about 250 gallons per minute. The water generally contains less than one thousand parts per million dissolved solids. There is estimated to be 35,000 acre-feet of water available annually in the eastern part of the aquifer with water being used primarily for irrigation in Mitchell, Nolan, and Scurry Counties.

In the western area, the aquifer is about 300 feet thick and well yields generally average less than 300 gallons per minute, the dissolved solids contained in the water range from 100 to 4,000 parts per million with most of the water containing more than 1,000 parts per million.

3.6 SALINE WATER AQUIFERS

Very little information is available on the saline water aquifers of the State. In most cases, not enough information is available to make an estimate of the amount of water available or to know the exact areal extent of the aquifers. A saline water aquifer is defined as one that yields moderate to large quantities of water with a dissolved solids content in excess of 1,000 parts per million. All of the major and minor aquifers previously discussed contain and are capable of yielding moderate to large quantities of saline water; however, there is very little information on their saline water characteristics except as previously discussed. Figure 3 - 6 shows the location of the saline water aquifers in the West Texas region.

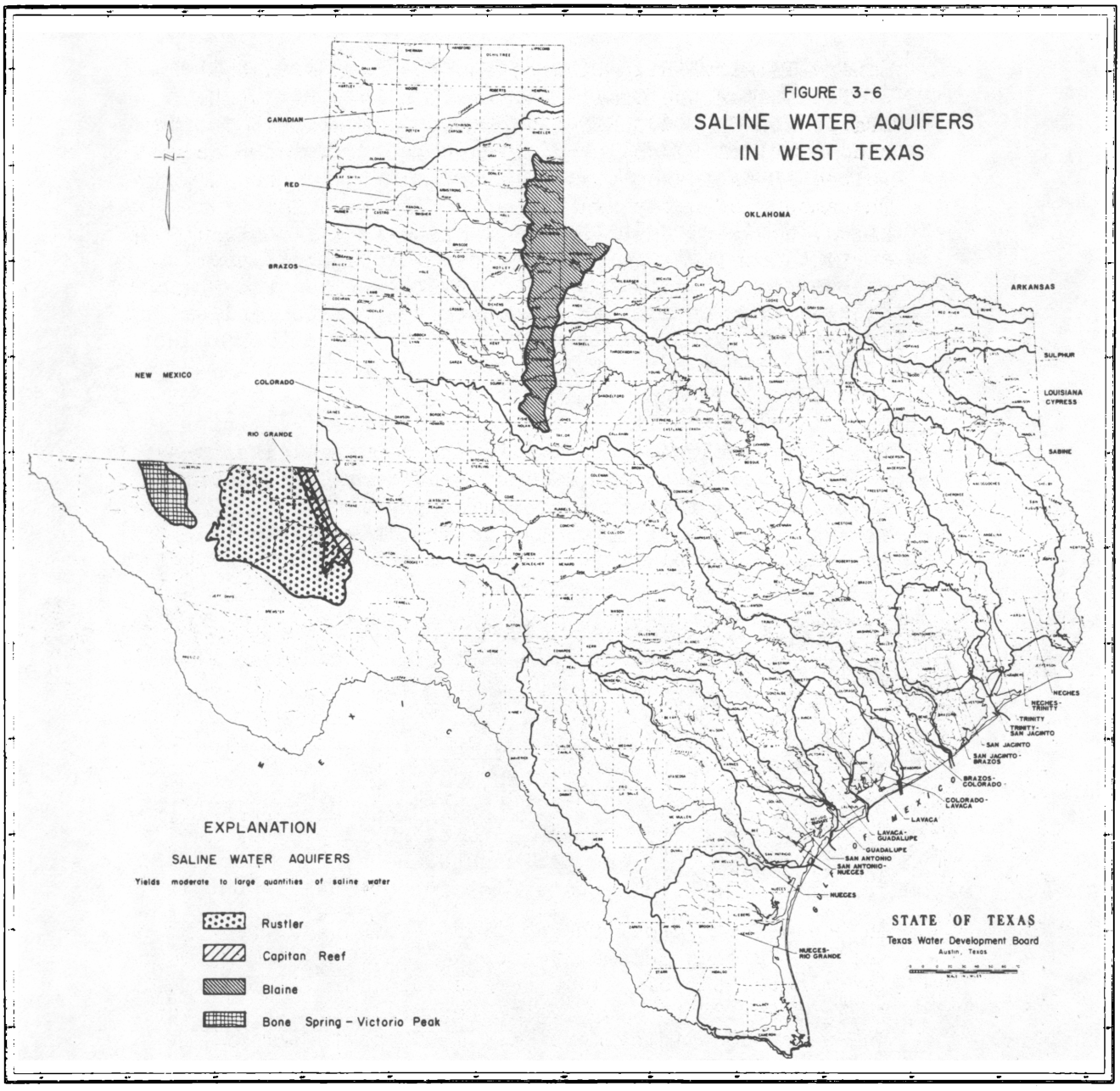


FIGURE 3-6
SALINE WATER AQUIFERS
IN WEST TEXAS
CANADIAN
RED
BRAZOS
COLORADO
RIO GRANDE
NEW MEXICO
OKLAHOMA
ARKANSAS
SULPHUR
LOUISIANA
CYPRESS
SABINE
NECHES
NECHES-TRINITY
TRINITY
TRINITY-SAN JACINTO
SAN JACINTO
SAN JACINTO-BRAZOS
BRAZOS-COLORADO
COLORADO-LAVACA
LAVACA
LAVACA-GUADALUPE
GUADALUPE
SAN ANTONIO
SAN ANTONIO-NUECES
NUECES
NUECES-RIO GRANDE
EXPLANATION
SALINE WATER AQUIFERS
Yields moderate to large quantities of saline water
Rustler
Capitan Reef
Blaine
Bone Spring – Victorio Peak
STATE OF TEXAS
Texas Water Development Board
Austin, Texas

3.6.1 Bone Spring-Victoria Peak Aquifer

The Bone Spring-Victorio Peak aquifer is located in the northeast corner of Hudspeth County. Water occurs in fractures and solution cavities in the limestone which is about 1,300 feet thick. Well yields range from 150 gallons per minute to 2,200 gallons per minute.

The quality of water in the aquifer generally ranges from 1,000 to 8,000 parts per million dissolved solids and is good only for irrigation use. However, Dell City is using water from this aquifer as feedwater to a 50,000 gallon per day electrodialysis desalting plant from which the product water is used for municipal purposes in the community.

It is estimated that there is 50,000 acre-feet of water annually available as recharge to the aquifer. The present pumpage of about 100,000 acre-feet for irrigation purposes exceeds the annual recharge and it will be necessary to reduce the pumpage in the future to equal that of the recharge.

3.6.2 Blaine Aquifer

The exact boundaries of the Blaine aquifer are not known. However, Figure 3 - 6 shows the approximate areal extent of the aquifer. Water from the aquifer is being used in the Red River basin in Collingsworth, Childress, Hardeman, Cottle, and King Counties. The aquifer consists of up to 250 feet of anhydrite, gypsum, shale, and dolomite. Wells yield up to 1,500 gallons per minute and average about 400 gallons per minute. The water is of poor quality but is currently being used for irrigation. The dissolved solids content ranges from 2,000 to 5,000 parts per million with sulfate ranging from 1,000 to 2,000 parts per million and calcium up to about 600 parts per million. It is estimated that about 40,000 acre-feet of water is available annually from this aquifer.

3.6.3 Capitan Reef Complex and Associated Limestones Aquifer

The Capitan Reef is composed of the Capitan Limestone, the reef limestone underlying the Capitan, and the back reef deposited San Andres Limestone and White Horse Group which are known to yield water of useable quality in some areas. The White Horse Group consists of alternating beds of dolomite, limestone, sand, shale, and evaporites; however, the dolomite and limestone are predominent. Lithologically, the aquifer consists of limestone and dolomite strata deposited as reef, fore-reef, and back-reef facies.

The reef facies of the aquifer, the location of which is shown on Figure 3 - 6, occurs in a belt about 5 or 6 miles wide extending in a south-southeastern direction through western Winkler, central Ward, and western Pecos Counties. The back-reef limestones of the aquifer occur east of the reef belt. The equivalent Delaware Mountain group that was deposited west of the reef belt in the Delaware Basin yields only small amounts of water. The aquifer occurs to depths up to 5,000 feet and attains a thickness of up to 3,500 feet. Ground water in the Capitan Reef occurs under artesian conditions.

Most wells drawing from the Capitan Reef aquifer flowed when drilled. However, due to uncontrolled discharge and heavy development in local areas the hydrostatic pressures have declined considerably. Some wells which penetrate the aquifer in Ward, Winkler, and northern Pecos Counties flow at rates ranging from 300 to over 1,000 gallons per minute. In addition to the large quantities the water produced from the aquifer for beneficial use, large quantities of water are produced from the aquifer for use in connection with oil production.

Water from the Capitan Reef is not suitable for human consumption. The water generally contains concentrations of dissolved solids, sulfate, and chloride. Concentrations of dissolved solids range from about 3,000 to 6,000 parts per million. Sulfate ranges from about 1,000 to 2,600 ppm, and chloride ranges from about 500 to 2,600 ppm. The water contains hydrogen sulfide and is very corrosive.

Water from the aquifer is used primarily for irrigation and industrial purposes. Irrigation from the aquifer is primarily in Pecos County. The water is applied on very permeable soil, and only salt-tolerant crops, principally cotton, are grown. In some areas water from the aquifer is mixed with water from other aquifers for irrigation. Pumpage for industrial purposes is primarily in Ward and Winkler Counties for water-flooding in secondary oil recovery operations.

The Capitan Reef aquifer is capable of yielding considerable quantities of water. Because the aquifer lies at considerable depth below the surface, the cost of completing wells will probably limit its development. At the present time, sufficient data are not available to make a valid estimate of the quantity of water available from the aquifer. A detailed study of the reef complex in Texas and and New Mexico presently is being made by the U. S. Geological Survey.

3.6.4 Rustler Aquifer

The Rustler aquifer consists mainly of dolomite and anhydrite with a basal zone of sand, conglomerate, and shale. Locally, the Rustler formation contains minor amounts of halite and limestone. The dolomite and limestone beds have vugular porosity and in some places are reported to be cavernous. Its thickness ranges up to 500 feet.

Water from the Rustler aquifer occurs under artesian conditions. Most production from the Rustler is reported from solution openings in the dolomite or limestone. Some water is also withdrawn form the basal sand. Wells tapping the basal sand usually yield highly mineralized water and have comparitively small yields. Many attempts to obtain water from the Rustler were unsuccessful before the practice of acidizing wells drilled into the formation became common in the mid 1950's. The yields of pumped wells penetrating cavernous carbonate rocks of the aquifer generally range from 500 to 1,000 gallons per minute.

The water in the Rustler aquifer is generally high in mineral concentration in the northern part of the aquifer. Rustler water is unsuitable for human consumption but is used for irrigation and livestock in some parts of eastern Reeves County and central and northern Pecos County. In these areas the mineralization of the water differs from place to place, ranging from a little less than 2,000 to about 6,000 parts per million dissolved solids. Normally the water has about 2,000 parts per million sulfate and not lower than 200 to 300 parts per million chloride; however, in many analyses the chloride concentration is less than 100 parts per million. Hydrogen sulfide is commonly present in the water.

Water from the Rustler aquifer is used for irrigation, industrial and livestock purposes. The annual withdrawal from the Rustler is about 9,000 acre-feet, of which irrigation accounts for about 8,000 acre-feet. Data are not available at the present time to determine the amount of water available from storage or the amount that can be produced annually from the aquifer.

3.7 ALTERNATIVE SOURCES OF WATER

The foregoing discussion on ground and surface water resources in the West Texas region includes those sources that are and will be available for meeting future municipal, industrial, agricultural and mining water requirements for the region. Present and projected

requirements exceed the safe annual yield of the aquifers, the major source of water, and ground water is being mined from storage. As water requirements increase, it is evident that large volumes of water will be needed in the future for the West Texas region.

Figure 3 - 3 indicates that generally surface water in the region is of poor quality. However, previous state, federal, and local water plans have proposed several possible reservoir sites for future construction that will have sufficient yield of suitable quality to supply some of the municipal and industrial water demands. Figure 3 - 7 shows the location of these proposed reservoirs. Because the reservoirs have been proposed is no indication that they will be constructed. Figure 3 - 8 lists the suggested alternative sources of water supply for each study area in this investigation. These alternatives are based on data presented in the Preliminary Texas Water Plan-1966, and advanced water resources planning studies conducted by the Texas Water Development Board since the release of the Preliminary Plan.

In some areas where ground water supplies are limited from a quantity or quality standpoint, it might be possible for municipalities or industry to establish well fields in other areas of the aquifer or to establish well fields in another aquifer at some distant point. Generally, most of the municipalities have already had to take this step in order to meet their water requirements. In some cases these "step-out" developments have not improved the quality of water being used by a city, although the total of water reserve might have been increased considerably.

Studies for the Texas Water Plan have indicated that there is not sufficient surplus water in East Texas without out-of-state import to make it economically feasible to transport water from those sources for use, primarily irrigation, in West Texas. Therefore, Texas must look to out-of-state import projects to supply the future water requirements of that portion of Texas lying generally west of 99° west longitude.

The Texas Water Development Board has under active consideration the possibility of importing water to areas in Texas from the Mississippi River to meet municipal, industrial, irrigation and mining water needs. Volumes of water potentially available, possible routings and costs of moving water to and across Texas from the Mississippi River presently are under study by the Board, the U.S. Army Corps of Engineers, and the Bureau of Reclamation, U.S. Department of the Interior.

Imported water would be conveyed westward through the Cypress or Sabine Basins to West Texas. The Board's studies have assumed that a sufficient volume of imported water would be available to meet the annual irrigation requirements of West Texas, supply Eastern New Mexico with 1.5 million acre feet annually, and supply the municipal and industrial requirements

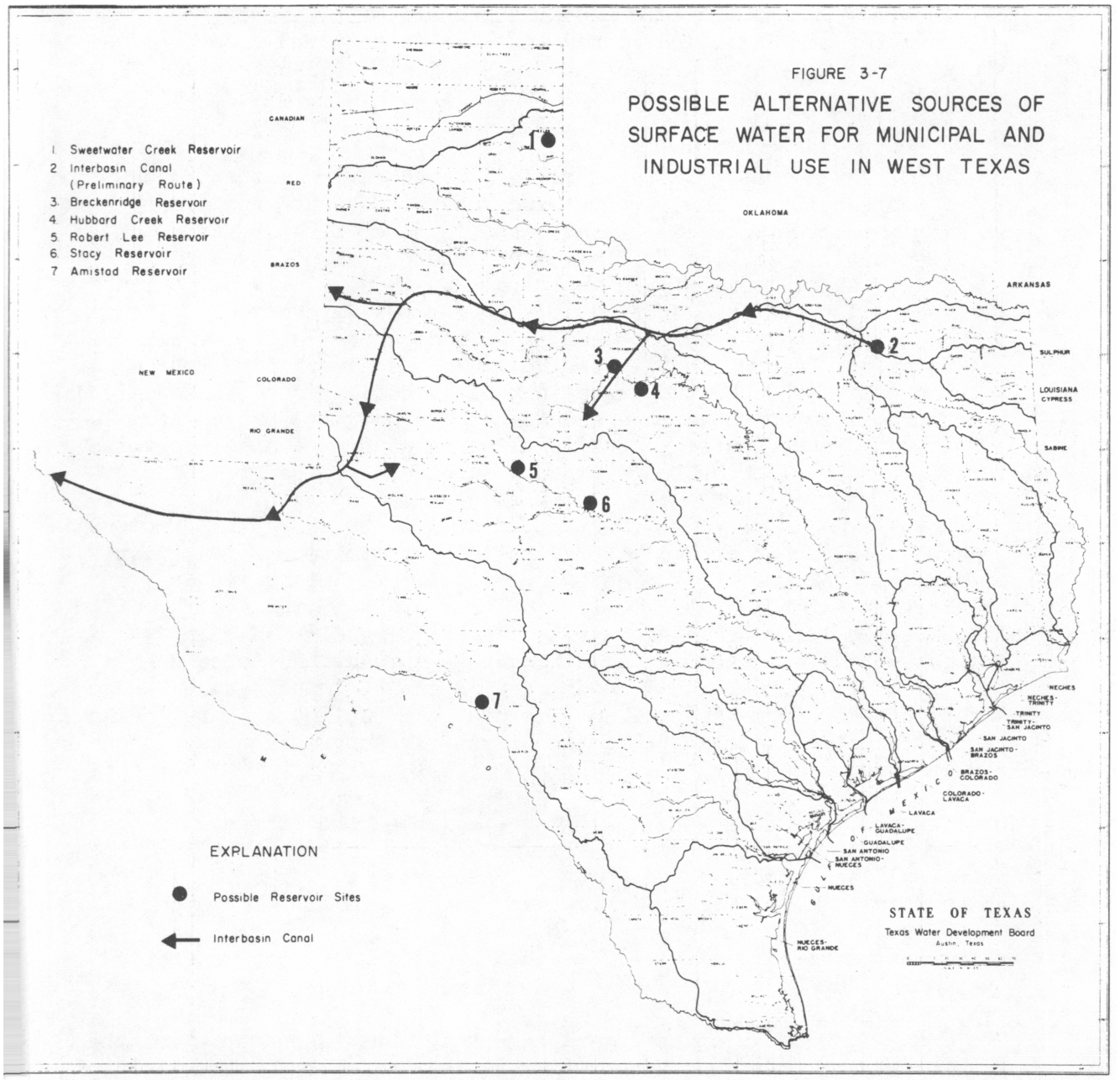


FIGURE 3-7
POSSIBLE ALTERNATIVE SOURCES OF SURFACE WATER FOR MUNICIPAL AND INDUSTRIAL USE IN WEST TEXAS
1. Sweetwater Creek Reservoir
2. Interbasin Canal (Preliminary Route)
3. Breckenridge Reservoir
4. Hubbard Creek Reservoir
5. Robert Lee Reservoir
6. Stacy Reservoir
7. Amistad Reservoir
CANADIAN
RED
BRAZOS
NEW MEXICO
COLORADO
RIO GRANDE
OKLAHOMA
ARKANSAS
SULPHUR
LOUISIANA
CYPRESS
SABINE
NECHES
NECHES-TRINITY
TRINITY
TRINITY-SAN JACINTO
SAN JACINTO
SAN JACINTO-BRAZOS
BRAZOS-COLORADO
COLORADO-LAVACA
LAVACA
LAVACA-GUADALUPE
GUADALUPE
SAN ANTONIO
SAN ANTONIO-NUECES
NUECES
NUECES-RIO GRANDE
MEXICO
EXPLANATION
Possible Reservoir Sites
Interbasin Canal
STATE OF TEXAS
Texas Water Development Board
Austin, Texas

SUGGESTED ALTERNATIVE SOURCES OF WATER SUPPLY
FOR WEST TEXAS DESALTING STUDY REGIONS

REGION	SOURCE G-Ground S-Surface	AQUIFER, RESERVOIR OR STREAM	DISTANCE	QUALITY PPM	REMARKS
El Paso	G	Alluvium & Bolson (El Paso)	Local	500-1000	Blend brackish water with good quality water.
	S	Rio Grande	Local	500-1000	City would have to obtain additional first class water rights to Rio Grande water.
	S	Amistad Reservoir	400 miles+	500-1000	City would have to obtain water right, and in addition, water would have to be replaced in the Lower Rio Grande Valley.
	S	Importation	800 miles+	Less than 500	Several possible out-of-state sources. Preliminary studies have been made on importation of water from Mississippi River through High Plains and Trans-Pecos to El Paso.
Reeves-Ward-Winkler	G	Alluvium (Pecos Valley)	8 miles	500-1000	Block 16 University Land Several cities will compete for this source.
	S	Importation	600 miles+	Less than 500	Several possible out-of-state sources. Preliminary studies have been made on importation of water from Mississippi through High Plains to Pecos.

FIGURE 3 - 8

REGION	SOURCE G-Ground S-Surface	ACQUIFER, RESERVOIR OR STREAM	DISTANCE	QUALITY PPM	REMARKS
Ector-Midland	G	Alluvium (Pecos Valley)	75 miles Winkler-Loving County Line	500-1000	City of Midland owns water rights on over 20,000 acres in this area.
	S	Colorado River Municipal Water District	90 miles+	500-1000	District presently supplies City of Odessa from Lake J. B. Thomas and has Robert Lee Reservoir under construction. District will supply City of Midland part of its requirements starting in 1970. Proposed Stacy Reservoir at confluence of the Concho and Colorado Rivers is a possible alternative source.
	S	Importation	600 miles+	Less than 500	Several possible out-of-state sources. Preliminary studies have been made on importation of water from Mississippi River through High Plains to Midland-Odessa.
Crane-Reagan-Upton	G	Edwards-Trinity (Plateau)	N.E. corner Crockett County	Less than 500	Area could supply Big Lake and Rankin. Water rights would have to be purchased. Crane and McCamey can expand existing source by purchase of additional water rights.
Taylor	S	Hubbard Creek Reservoir	40 miles	Less than 500	Reservoir existing and is owned by West Central Texas Municipal Water District. Abilene is a member of the District and is committed to purchase water from the reservoir.

FIGURE 3 - 8. (Cont...)

REGION	SOURCE G-Ground S-Surface	ACQUIFER, RESERVOIR OR STREAM	DISTANCE	QUALITY PPM	REMARKS
Taylor	S	Brechenridge Reservoir	48 miles	Unknown	Reservoir proposed in the Preliminary Texas Water Plan-1966. Water quality studies will be needed to determine projected water quality in reservoir.
	S	Importation	400 miles+	Less than 500	Several possible out-of-state sources. Preliminary studies have been made on importation of water from Mississippi River.
Childress-Hardeman-Vernon	S	Sweetwater Creek Reservoir	50 miles	Less than 500	Reservoir proposed in the Preliminary Texas Water Plan-1966.

FIGURE 3 - 8. (Continued)

of the cities of Abilene, Sweetwater, Colorado City, Snyder, San Angelo, Lubbock, Odessa, Midland, Big Spring, Pecos and El Paso. Preliminary estimates by the Board indicate that the cost of water delivered to West Texas from East Texas and out-of-State sources can be as much as 30¢ to 50¢ per thousand gallons. To this estimated cost would have to be added conventional water treatment costs after delivery. Although these costs may seem low at today's prices it is emphasized that if the Texas Water Program is adopted many years would lapse before water delivery could be made for the West Texas area.

Figure 3 - 9 shows the calculated cost of raw water for those areas of this study assuming importation from the Mississippi River. The costs shown include the cost of amortization, interest on construction, operation and maintenance, and replacement. It is emphasized that these cost are "Preliminary" and are subject to revision following detailed engineering and economic feasibility studies.

A final alternative source of water for West Texas, for which maximum use must be made, is the large volume of municipal and industrial return flows that will be available at the major population centers. Re-use of municipal return flows for industrial and agricultural purposes is presently being practiced in some areas of West Texas. An excellent example of waste water re-use is at Odessa where the El Paso Products Company treats the treated sewage effluent from the City of Odessa for multiple use in its petrochemical complex. Following use in the complex the waste water is then passed on to the oil industry for secondary oil recovery operations.

Reclaiming waste water requires employment of some process to condition the water to make it satisfactory for municipal and industrial use. Return flows can also serve as a source of feedwater for desalination plants, particularly in areas where brackish or saline water supplies are limited.

Extensive research in the treatment of return flows has been in progress in the Federal Water Pollution Control Administration and other agencies. The feasibility of reclamation has been demonstrated and emphasis is being placed on efforts to reduce costs. It appears that the reclaimed product can meet U. S. Public Health Service Standards from municipal and industrial water; however, there may remain esthetic objections to be overcome to gain public acceptance of this source.

PRELIMINARY COST OF IMPORTED WATER
TO WEST TEXAS DESALT STUDY SREAS
FOR MUNICIPAL AND INDUSTRIAL USE

Region	Volume of Water Delivered-AC.Ft.	Unit Cost* cents/K gal
El Paso	200,000	45-50
Reeves-Ward-Winkler	40,000	40-45
Ector-Midland	185,000	30-35
Crane-Reagan-Upton	None	-
Taylor	20,000	30-35
Childress-Hardeman-Vernon	None	-

*Raw water cost. Additional cost of conventional treatment will have to be added to obtain total unit cost.

FIGURE 3 - 9

3.8 QUALITY OF WATER

The suitability of a water supply depends upon the chemical and biological quality of the water and the limitations imposed by the comtemplated use of the water. Various water quality criteria have been developed which include physical characteristics, such as turbidity, color, odor, and temperature; chemical substances; bacterial content; and, radioactivity. Because this study is concerned primarily with the removal of undesirable chemical constituents through the application of a desalting process, no detailed discussion of water quality criteria will be given in this report. However, for clarity, certain terms referring to the chemical quality of water are defined for the purposes of this study.

Product water is the output of a water treatment plant. For the desalting processes discussed in Chapter 2, it is assumed that the distillation and membrane plants will produce a water containing 25 and 500 parts per million (ppm) total dissolved solids (TDS) respectively.

Municipal grade water contains 500 ppm total dissolved solids or less and is chemically suitable for use in a municipal water supply system. This term is in accord with the drinking water standards established by the U.S. Public Health Service (1962) applicable to water to be used on common carriers engaged in interstate commerce. These standards are designed to protect the traveling public and are used to evaluate public supplies. According to the standards adopted by the U.S. Public Health Service (1962), chemical substances should not be present in a water in water in excess of the concentrations listed below whenever more suitable supplies are available or can be made available at reasonable cost. /115/

Substance	Concentration (ppm)
Chloride	250
Sulfate	250
Total dissolved solids	500

The salinity of a water is defined in this report as being an indication of the total dissolved solids content of the water. Total dissolved solids, commonly expressed in parts per million, is a measure of the number of milligrams of soluble chemical material per kilogram of solution.

Saline water is herein defined as water containing more than 1,000 ppm total dissolved solids. Saline waters can further be classified as follows: /19/

Classification	Dissolved Solids (ppm)
Slightly saline	1,000 to 3,000
Moderately saline	3,000 to 10,000
Very saline	10,000 to 35,000

Brackish water is a term generally applied to saline water containing in the range from 1,000 ppm to 35,000 ppm dissolved solids; however, in this report brackish water is defined as water containing between 1,000 ppm and 10,000 ppm dissolved solids.

Sea water contains on the average about 35,000 ppm dissolved solids. Some inland waters in Texas approach or exceed this concentration of dissolved solids and are referred to as highly saline or highly mineralized waters, or brine. An example of this is discussed in Chapter 9 where the Estilline Spring feedwater used for the desalt plant cost calculations has an average dissolved solids content of about 50,000 ppm.

3.9 CONVENTIONAL WATER COST

An integral part of the economic justification of a water supply project is the cost a city will have to pay for the raw water at its source. This cost has been considered in developing the estimated total cost of the conventional water supply for comparison with the estimated total cost of desalted water for the areas studied.

In water resources evaluation, it is often necessary to consider both the financial costs and the economic costs of providing raw water. In this study only the financial cost - the actual cash cost to the city - is considered. This cost differs from the economic cost in that no consideration is given to the potential salvage value of a reservoir, the cost of replacement of a reservoir, or placing a value of the alternate use of water. The latter would include such benefits as recreation and conservation derived from the existence of a reservoir or lake.

Several methods were used to determine a cost of raw water for a given area. Generally, these costs were obtained from preliminary engineering reports or were based on the cost experience of cities presently using the raw water source under consideration.

Ground Water Cost. Texas has no ground water law; therefore, waters found in various aquifers and underground reservoirs are subject to withdrawal and use by the owner of the surface area above the ground water source. This is important to note because communities in Texas have no special right to ground water supplies. If a city seeks a ground water supply, it may be obtained in one of three ways: (1) purchase surface land in fee and thus acquire rights to the underlying water; (2) purchase from the land owner only the rights to underlying water; or (3) pay the land owner a royalty or fee for the water extracted.

In all of these arrangements, the price paid for water is negotiable and will vary depending on a number of factors. Where water is a scarce commodity the negotiated price may reflect this condition. On the other

hand, there are instances of land owners providing water to cities for a nominal cash charge or for other considerations. For these reasons, no attempt has been made in this study to establish a cost figure for alternate ground water sources.

Surface Water Cost. Surface water in Texas is defined as that water which occurs in a watercourse, lake, or pond. Title to this water is in the State to be held in trust for the public. /117/ The legal right to surface water in Texas is very complex and the subject will not be discussed in detail in this Section.

Basically, two water rights are recognized: one is the riparian right which is incident to the ownership of the land adjoining the watercourse; the other is the appropriative right which is established by statute. There are also other water rights which are held subordinate and are considered to be of secondary importance to this study. Texas statutes set out an order of priority of use in the allotment and appropriation of surface water in which domestic and municipal uses are classified as superior.

Surface water reservoirs in Texas generally are constructed by cities, river authorities, water districts, private entities or federal agencies such as the U.S Bureau of Reclamation and U S Army Corps of Engineers. Raw or treated water is then sold by the constructing entity or agency to cities in the area at a negotiated price. Usually the price paid by the cities is an annual minimum charge based on a fixed quantity with a rate schedule applicable to water consumed beyond this quantity. The purchase price is usually FOB the reservoir.

If water presently is being bought from the source considered in this study for a given area, then the existing sale price of the water has been assumed to be the cost of raw water to the specific city or area. In those cases where the alternate source is a proposed reservoir, the data on cost of water to specific cities or areas were taken from preliminary engineering studies.

Economic analysis of water projects proposed in the preliminary Texas Water Plan and those made in advance water resources studies are based on the standards of formulations and evaluation of plans set forth in U.S. Senate Document 97. /118/ These standards were followed to the extent feasible and consistent with the overall plans and objectives of the Texas Water Development Board. The discount rate adopted for purposes of the analysis was 3-1/2 percent in all cases. This is the same rate used in this study for both desalt and conventional water supplies.

EL PASO REGION

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4. EL PASO REGION

4.1 INTRODUCTION AND SUMMARY

The El Paso region for purposes of this report comprises El Paso County and includes the cities of El Paso, Anthony, Canutillo, Fabens and San Elizario. This region was selected for study to determine the role which desalination of underlying brackish ground water could serve toward the fulfillment of future water requirements of the area. For this purpose estimates were prepared to show the costs of desalted water in relationship to the cost of water from alternative sources.

Projections of water requirements for the El Paso region indicate that the estimates for municipal and industrial water in 2020 will be over three times as great as the estimates for 1968. In order to provide for these needs it has been recognized that the application of desalting technology should be considered as one of the possible sources of future water supply. This study is a preliminary investigation of the feasibility and cost of desalting brackish ground water in the El Paso region.

Plant size was selected on a more or less arbitrary basis, keeping in mind water resources and future requirements. The information presented herein can be used to make an appraisal of the relationship of plant size to total water requirements.

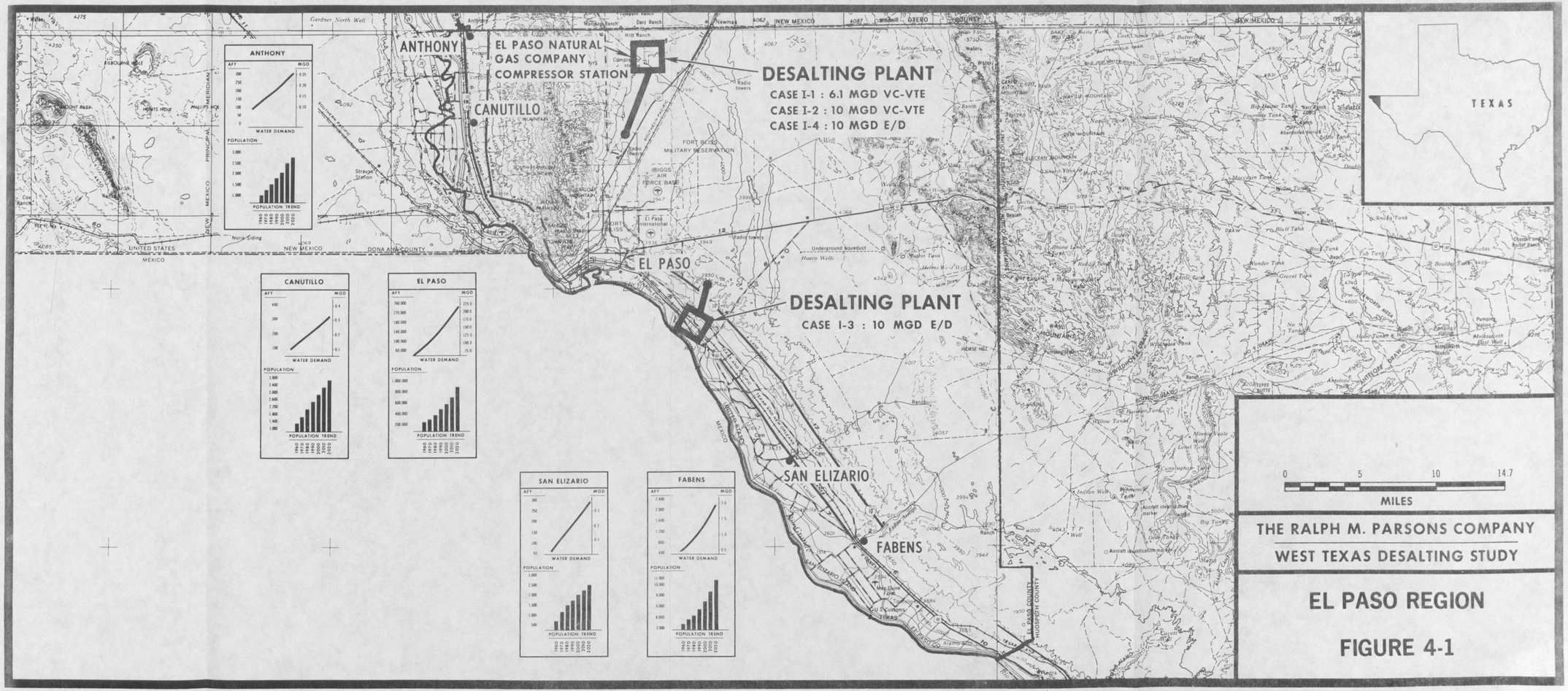
Problems associated with feedwater supply, brine disposal and integration of desalted water into the present system have been investigated only briefly. Detailed investigation of various solutions and their costs should be included in any future study.

4.1.1 Summary

Figure 4-1 shows a map of the El Paso Region with two desalting plant locations utilizing saline feedwater from the Hueco Bolson and Rio Grande Alluvium.

The El Paso Region appeared to lend itself to the consideration of a desalting plant in the 10 MGD size range. A plant in this size range produces an increment of water supply which approaches the estimated recharge (15,000 AFY) to the Hueco or La Mesa bolson aquifers. Also, the 10 MGD desalting plant provides almost 3 times the amount of water per year as the 2,000 acres of water rights land now owned by the city, based on an average allocation of 2 feet per acre per year.

The Hueco Bolson and also the Rio Grande Alluvium were considered to provide the source of saline feedwater for desalination. Presently known feedwater supplies, however,


ANTHONY
EL PASO NATURAL GAS COMPANY COMPRESSOR STATION
CANUTILLO
DESALTING PLANT
CASE I-1 : 6.1 MGD VC-VTE
CASE I-2 : 10 MGD VC-VTE
CASE I-4 : 10 MGD E/D
EL PASO
DESALTING PLANT
CASE I-3 : 10 MGD E/D
SAN ELIZARIO
FABENS
TEXAS
ANTHONY
CANUTILLO
EL PASO
SAN ELIZARIO
FABENS
AFY
MGD
WATER DEMAND
POPULATION
POPULATION TREND
0 5 10 14.7
MILES
THE RALPH M. PARSONS COMPANY
WEST TEXAS DESALTING STUDY
EL PASO REGION
FIGURE 4-1

are limited so that this source can furnish the feedwater for only approximately 15 MGD of desalting plant capacity unless new sources of saline feedwater are discovered. If return flows are utilized as feedwater, then a total of 40 MGD additional desalting plant capacity could be installed by 2020.

All of the existing commercial desalting processes were considered. In addition, a vapor compression-vertical tube evaporator process (VC-VTE) was studied, utilizing the waste heat from gas turbines proposed to be installed at the El Paso Natural Gas Company compressor station.

A review of the applicability of all processes enabled the selection to be narrowed down to the VC-VTE distillation process and the electrodialysis process. Based on today's status of development and the cost assumptions used herein, the application of the reverse osmosis process when applied to these relatively low salinity feedwaters results in a somewhat higher cost per thousand gallons of product water (assumed 500 ppm TDS) compared to the electrodialysis and VC-VTE processes. Application of a multi-stage flash desalting plant operating on recoverable waste heat, on the basis of the costing procedures used in this study, yields product water at a unit cost which can be reduced (as shown in Table II of Section 2.2.9) by utilizing a combined vertical tube and multi-stage flash distillation system employing vapor compression (VC-VTE). However, this process is only now under development by the Office of Saline Water and will have to be proven through prototype testing. The lower cost of product water plus the effective utilization of waste heat led to the selection of the VC-VTE process for development of cost figures for distillation.

The two desalting processes were studied in a variety of applications, with product water costs as follows:

Vapor Compression-Vertical Tube Evaporator Process

- Case I-1a, 6.1 MGD plant utilizing waste heat from two 8,000 horsepower gas turbines; furnishing distilled water. . . 50.4¢ per Kgal.

- Case I-1b, 8.7 MGD utilizing the 6.1 MGD distilled water from Case I-1a plant for blending with 2.6 MGD feedwater to furnish 500 ppm water . . . . . 39.4¢ per Kgal.

- Case I-2a, 10 MGD utilizing supplemental gas firing together with waste heat from two 8,000 horsepower gas turbines; furnishing distilled water . . . . . 53.0¢ per Kgal.

- Case I-2b, 14.3 MGD utilizing the 10 MGD distilled water from Case I-2a for blending with 4.3 MGD feedwater to provide 500 ppm water . . . . . 41.1¢ per Kgal.

Electrodialysis Process

- Case I-3, 10 MGD electrodialysis plant utilizing Rio Grande Alluvium feedwater; furnishing 500 ppm water . . . . . 43.0¢ per Kgal.

- Case I-4, 10 MGD electrodialysis plant utilizing Hueco Bolson feedwater; furnishing 500 ppm water . . . . . 35.6¢ per Kgal.

Case I-4 electrodialysis plant using Hueco Bolson feedwater shows lowest water costs because it has the advantage of higher temperature with approximately the same salinity. Costs at the desalting plant boundary are over 7¢ per thousand gallons cheaper than 500 ppm water costs utilizing Rio Grande Alluvium feedwater.

The Texas Water Development Board has under active consideration the possibility of importing water to areas in Texas from the Mississippi River to meet municipal, industrial, irrigation and mining water needs. Preliminary estimates by the Board indicate that the cost of water delivered to El Paso from East Texas, and out-of-State sources can be as much as 45¢ to 50¢ per thousand gallons. To this cost would have to be added the cost of conventional water treatment after delivery to El Paso. Volumes of water potentially available, possible routings and costs of moving water to and across Texas from the Mississippi River presently are under study by the Board, the U.S. Army Corps of Engineers and the Bureau of Reclamation, U.S. Department of the Interior.

It appears that a desalting plant in the size range studied herein should be given serious consideration in the future planning for additional water supplies in the El Paso Region.

4.2 WATER ADMINISTRATION AND FACILITIES

There are several agencies which are responsible for water management in the El Paso region. These include agencies primarily concerned with furnishing municipal and industrial (M & I) water as well as agencies that supply irigation water. This section includes a brief summary of the several agencies which are active in the El Paso area.

4.2.1 City of El Paso

The City of El Paso is an incorporated city with an estimated 1967 population of 320,200. Responsibility for the municipal and industrial water supply is vested in the Public Service Board - El Paso Water Utilities.

This organization is responsible for providing M&I water to the metropolitan area with the exception of Fort Bliss and some industry. The water production facilities have a capacity of 160.8 MGD and a firm yield capacity of 109.5 MGD when Rio Grande water is not available.

In early 1965, the city owned 6 well fields with a total of 76 producing wells. During 1965, six new wells were added. In 1966 two additional wells were scheduled to be completed. Total well pumping capacity is approximately 125 MGD. The system has about 60,000 metered connections for residences, 4400 for commercial and 400 for industrial customers.

Storage facilities in the City of El Paso are listed for easy reference in the following tabulation:

Fred Miller	2	MG	Thomason	3	MG
Coronado #1	0.5	MG	Rosemont	1	MG
Coronado #2	0.5	MG	Summit	4.5	MG
Coronado #3	0.25	MG	To be Built	10	MG
Crown Point	1	MG	Mesa	1	MG
Fiesta	2	MG	Mt. Park #1	1.1	MG
Mission Hills	2	MG	Joe Card	4	MG
Piedmont	2	MG	Nevins	1	MG
Jackson	2	MG	Airport	4	MG
Woods	40	MG	Cielo Vista	2	MG
Sunset	8	MG	Eastwood	10	MG
Davis	11	MG	Faragoza	3	MG

A water treatment plant for coagulation and filtration of Rio Grande water is located near the downtown section of the City on the Franklin Canal. In addition, El Paso has facilities for chlorinating ground water.

Sewage treatment is accomplished in three plants utilizing high rate trickling filters:

	Design Capacity	Present Operation
Delta St Plant	20 MGD	17.5 MGD
Ysleta St Plant	1.8 MGD	.35 MGD
Ascarate Plant	.66 MGD	.34 MGD

In addition, three oxidation ponds are now treating about 11.5 MGD.

4.2.2 Other Cities of El Paso County

Anthony is an incorporated city with an estimated 1967 population of 1380. The water supply for this community is privately owned. Facilities consist of 7 wells located north of town with a total capacity of 819 GPM or 1.2 MGD. Five wells are 104 to 165 feet deep and two wells are 277 and 287 feet deep. Water is pumped from the Alluvium and the La Mesa Bolson. Recent data on chemical quality of water from these wells are not available; however, data collected in 1955 indicates dissolved solids in the range of 840 to 1070 ppm. Total annual water consumption in 1965 was 53 million gallons.

Canutillo is an unincorporated town with an estimated 1967 population of 1740. The water supply for this community is supplied by the El Paso County WC and ID-Westway. The District has one well and in 1966 supplied about 51 million gallons.

Fabens /33/ is an unincorporated town with an estimated 1967 population of 3610. The agency responsible for the water supply to Fabens is the El Paso County W.C.I.D. No. 4. Five wells supply the needs of the City. Well depths vary from 225 to 330 feet deep. Annual water use has increased from 0.3 MGD in 1959 to 0.4 MGD in 1965. Average dissolved solids for the five city wells, from 1965 data, was 684 ppm.

The City uses ground water from the bolson deposit; however, the supplies appear to be limited in extent and in ultimate yield. Water level declines have been occurring at the rate of about four feet per year. There is considerable competition from irrigation users in the area.

It is estimated that the City can depend on the present ground water facilities to meet their requirement until the year 1980. After that time, presuming that there is only barely enough water to last 5 years, the City has several alternatives:

- Explore for ground water in other parts of the area, going as far as perhaps 10 miles from the City

- Buy up irrigation areas

- Purchase water from the City of El Paso

San Elizario is an unincoprorated town with an estimated 1967 population of 1,300. Residents obtain their water supply from individually owned water wells.

4.2.3 Irrigation Water Agencies /30/

The major source of irrigation water in the area is provided by facilities of the U.S. Bureau of Reclamation Rio Grande Project. The Rio Grande Compact, which provides for the allocation of upper Rio Grande water between the states of Colorado, New Mexico and Texas including the treaty allowance to Mexico, was signed in 1938. By International Treaty, an annual allowance of 60,000 acre-feet of water from Project sources is made available for diversion to Mexico near the City of Juarez across the Rio Grande from El Paso when there is sufficient water.

The Project is operated in three divisions:

- The Power and Storage Division with field headquarters at Elephant Butte, New Mexico

- The Las Cruces Division with field headquarters at Las Cruces, New Mexico for the New Mexico portion of the Project in Rincon and Mesilla Valleys, and for about 11,000 acres of the Texas portion in the lower end of the Mesilla Valley

- The Ysleta Division with field headquarters at El Paso, Texas for the El Paso Valley in Texas

The main Project administrative office is located at El Paso, Texas.

The Project includes two major reservoirs, both in New Mexico, for impounding Rio Grande water:

- Elephant Butte Reservoir with a storage capacity of 2,200,000 acre feet, completed in 1916

- Caballo Reservoir, capacity of 340,000 acre feet, completed in 1938

The Rio Grande Project /30/ occupies the river bottom land of the Rio Grande Valley in south-central New Mexico and extreme west Texas, extending from 100 miles north to 40 miles southeast of the City of El Paso, Texas with a maximum width of only 4.5 miles. The irrigable land in the Project is approximately 178,000 acres of which the water-right acreage is approximately 69,400 acres in Texas. The irrigation season extends from March to September. Duty of water averages 3 acre feet per acre per year.

Water districts in Texas that receive water from the Project are:

- El Paso County Water Improvement District No. 1, El Paso, Texas

- Hudspeth County Conservation and Reclamation District No. 1, Ft. Hancock, Texas

The Ysleta Irrigation Field Branch of the Rio Grande Project, located in El Paso, is responsible for operation and maintenance of the irrigation and drainage facilities in the El Paso Valley from El Paso to the Hudspeth County line.

During 1965, approximately 505,600 AF were released from Caballo Reservoir. Of this total, 127,900 AF were delivered in New Mexico, 110,700 AF were delivered in Texas, 36,600 AF were delivered to Mexico and the remainder was lost to evaporation and percolation, waste from system and non-beneficial consumptive use.

A Warren Act contract with the Hudspeth County Conservation and Reclamation District No. 1 with headquarters at Ft. Hancock, Texas provides for use by the District of Project operating waste and drainage return flow reaching the lower end of the Project on approximately 18,000 acres of land below the Project.

Irrigation /10/ in the vicinity of El Paso is practiced in two areas. The upper section, mostly on the west side of the Rio Grande channel above El Paso, extends both north (on both sides of the river near Anthony) and west to the New Mexico state line. It contains only about 15,000 acres of irrigable land, of which about 10,000 acres were irrigated in 1964. The section lying southeast of El Paso flanks the rectified channel (The Mexican border) in the Ysleta Fabens-Tornillo area and extends downriver as a very narrow alluvial band into Hudspeth County below Fort Hancock. It contains nearly 87,000 acres of irrigable land, of which 54,200 acres were irrigated in 1964. Downstream scattered small irrigated farms and fields totalling about 6,800 acres in 1964 are supplied by diverted river flows.

The Project and scattered nonproject irrigation farther down stream make use of Rio Grande streamflow, the amount of which fluctuates greatly. Consequently, in seasons with insufficient surface water to meet the full irrigation needs, irrigators apply supplemental water pumped from shallow alluvial water wells. In 1964, a dry year, 85 percent of the irrigation water used in the El Paso area was pumped from shallow wells. In contrast, in 1958, a year of generally ample river flow, 95 percent of the water used was diverted from the Rio Grande.

Irrigation in these far West Texas zones is used to produce a variety of locally consumed and marketed fruits and vegetables, forage and feed crops, alfalfa, and pasture. Regular and special long staple varieties of cotton are produced on most of the irrigated acreage. These are prime producing areas for the special kinds of cotton grown.

Essentially no change in the amount of irrigation is planned here. There may be some shifting of acreage into the area downstream from El Paso, as municipal and industrial return flows from metropolitan El Paso are expected to increase in the future providing some additional water supply below the city that can be used for irrigation. Overall, however, irrigation acreage is expected to remain about the same through the year 2020, about 72,000 acres.

4.3 POPULATION AND WATER REQUIREMENTS

Planning for the development of municipal and industrial water facilities depends upon projections of future population and industrial growth. In this report, the quantity of fresh water required by each region is based on projections by the Texas Water Development Board.

The intent of the projections is to provide guidelines for orderly planning and development of future water supply facilities. The near term projections, i.e: the next 10 to 20 years, should be more reliable than those in the more distant future. In the near term interval, growth rates slower or faster than are anticipated are not likely to effect large changes in the dates at which projected population data are reached. On the other hand, for spans of 20 years in the future and beyond, the variation of actual population figures from present day estimates may become significant.

The large projected per capita per day use indicated for several cities is attributed to a large projected industrial water requirement. For simplicity in handling projected requirements of water used by industry located within a county but not within the confines of any city, the Texas Water Development Board allocated these requirements to the nearest city. This has the effect of showing a large water requirement for some of the cities in this report.

Where per capita consumption growth appears abnormal, it is anticipated that the availability of sufficient quantities of good quality water in the future will attract industry, thus modifying the historical growth pattern of per capita consumption.

Data on population and water requirements for cities as well as county and region totals have been developed by the Texas Water Development Board as shown on Figure 4-2.

POPULATION AND WATER REQUIREMENT ESTIMATES
El Paso Region

	1970	1980	1990	2000	2010	2020
POPULATION						
City of El Paso	338,857	413,946	504,393	614,603	748,894	912,527
Anthony	1,479	1,811	2,064	2,342	2,645	2,969
Canutillo	1,873	2,293	2,613	2,965	3,348	3,759
Fabens	3,809	4,674	5,789	7,171	8,881	11,000
San Elizario	1,398	1,711	1,950	2,213	2,498	2,805
Sub Total	347,380	424,435	516,809	629,294	766,266	933,060
Other	40,347	49,349	56,239	63,814	72,056	80,900
County Total	387,727	473,784	573,048	693,108	838,322	1,013,960
M & I WATER REQUIREMENTS	Acre Feet Per Year					
City of El Paso	84,055	106,804	132,282	163,906	203,172	251,944
Anthony	132	171	198	226	257	290
Canutillo	167	217	250	287	326	367
Fabens	652	861	1,098	1,400	1,787	2,279
San Elizario	125	162	187	214	243	274
Sub Total	85,131	108,215	134,015	166,033	205,785	255,154
Other	3,591	4,660	5,376	6,162	7,004	7,884
County Total	88,722	112,875	139,391	172,195	212,789	263,038
	Million Gallons Per Day					
City of El Paso	75.04	95.35	118.09	146.33	181.38	224.92
Anthony	0.12	0.15	0.18	0.20	0.23	0.26
Canutillo	0.15	0.19	0.22	0.26	0.29	0.33
Fabens	0.58	0.77	0.98	1.25	1.60	2.04
San Elizario	0.11	0.14	0.17	0.19	0.22	0.24
Sub Total	76.00	96.60	119.64	148.23	183.72	227.79
Other	3.21	4.17	4.80	5.50	6.24	7.03
County Total	79.21	100.77	124.44	153.73	189.96	234.82

Source: Texas Water Development Board

FIGURE 4 - 2

4.4 ECONOMIC AND FINANCIAL DATA

El Paso County has two distinctive parts; (1) irrigated Rio Grande valley and (2) mountainous, arid uplands between the Franklin and Hueco mountains. The population is concentrated in the valley, but is spreading to the uplands as El Paso grows.

Commerce and industry of metropolitan El Paso dominate the economy. The county is second in Texas in livestock income, and high in crop revenue. About 55,000 acres are irrigated. Crops include cotton, alfalfa, corn, small grains and truck crops. Manufacturing plants include ore smelting, oil refining, copper, large clothing plants, regional gas and electric plants, process plants for cotton, livestock and feed.

The military installation of Fort Bliss is located in El Paso County. It is the home of the U. S. Army Air Defense Center, coordinating and supervisory organization for eight major commands. In mid 1965 there were 15,000 military men and women stationed at Fort Bliss as well as a civilian force of 2,900. William Beaumont General Hospital adjoining Fort Bliss treats more than 400,000 outpatients and 16,000 inpatients a year.

The economy of El Paso County has been expanding rapidly. The following table /17/ /18/ shows certain interesting economic data for El Paso County:

Bank Deposits (1964)	$ 359,036,000
Effective Buying Income (1964)	$ 610,966,000
Retail Sales (1963)	$ 380,228,000
Wholesale Sales (1963)	$ 505,166,000
Farm Products Sold (1964)	$ 32,738,000
Services Receipts (1963)	$ 49,660,000
Mineral Industry Receipts (1964)	$ 4,687,000
Building Permits (1964)	$ 46,305,847
Total Vehicles Registered (1964)	148,554
Passenger Cars Registered (1964)	114,720
Total Employment (1965)	96,200
Wages (1st Quarter 1965 x 4)	$ 268,978,000
Manufacturing Establishments, (1965)	227
Manufacturing Establishments with 20 or more Employees	83
Manufacturing Establishments, Employees (1965)	16,068
Manufacturing Establishments, Payroll (1965)	65,864,000
Value Added by Manufacturing (1963)	$ 127,962,000
Total Local Bonded Debt (1963)	$ 64,777,000

A plot of the trend of certain economic and financial factors is shown on Figure 4-3. This shows a healthy condition in that all factors shown, with the exception of "Mineral Industry Receipts",

EL PASO REGION

ECONOMIC AND FINANCIAL DATA 17

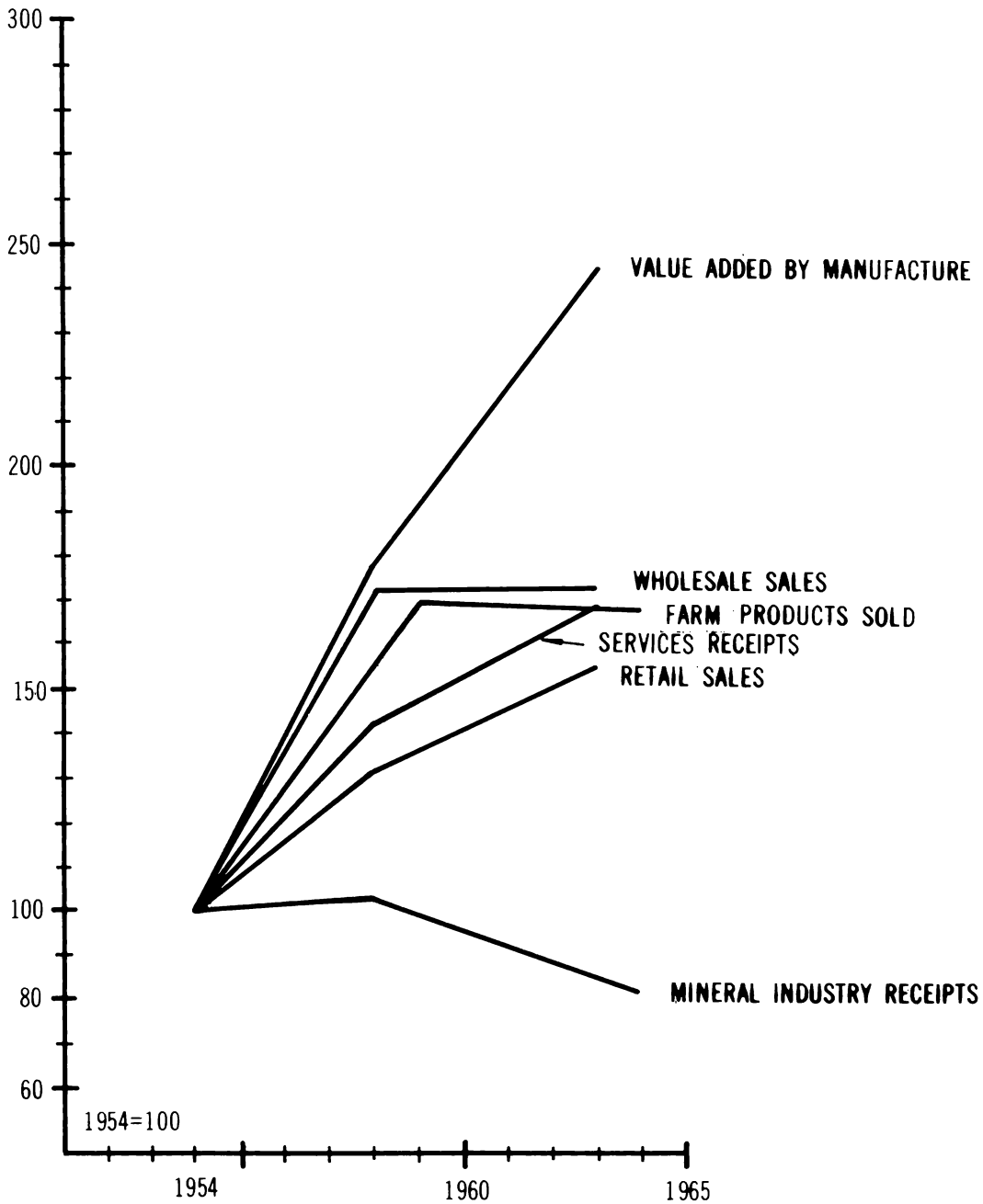


FIGURE 4-3

trend upward. The downward trending "Mineral Industry Receipts" amounted to $4,687,000 in 1964; by comparison the rapidly uptrending "Value Added By Manufacturing" amounted to $127,962,000 in 1963, thereby overshadowing by a large factor the comparatively minor dollar reduction of "Mineral Industry Receipts".

4.5 MUNICIPAL AND INDUSTRIAL WATER RESOURCES

4.5.1 Ground Water [8] [10]

Ground water in the El Paso area occurs in the unconsolidated bolson deposits of the Hueco and La Mesa bolson and in the river alluvium of the Lower Mesilla and El Paso Valleys. The deposits consist of unconsolidated sand, gravel, clay and caliche, and range in thickness from a few feet to more than 5,000 feet. Water in the aquifers generally is under water-table conditions with the base of fresh water extending in some areas to 1,400 feet below land surface. Yields from large-capacity wells are generally from 1,000 to 1,500 gallons per minute, with some reaching 3,000.

The amount of fresh ground water available in and the proportion that might be recovered from the aquifers underlying the El Paso area depends on many factors, among which is the movement of salt water that overlies, underlies, or adjoins the fresh-water body. It depends also on the distribution of pumpage, the rate of withdrawal, the amount of recharge to the aquifer, the amount of natural discharge that can be salvaged, and the amount of water that moves into the area from outside the district.

The Hueco bolson extends from the Hueco mountains on the east to the Franklin Mountains on the west and into New Mexico on the north and Mexico on the south. The theoretically recoverable fresh water in the Texas part of the Hueco bolson has been estimated to be about 7.5 million acre-feet. It is conservatively estimated that of this volume only 50 percent or 3.75 million acre-feet can be recovered because of the probability of saline water encroachment.

The La Mesa bolson of the Lower Mesilla Valley is on the west side of the Franklin Mountains. The fresh water available from storage in the bolson deposits in the Texas part of the Lower Mesilla Valley has been estimated to be over 400,000 acre-feet. Of this volume only 50 percent or 200,000 acre-feet can be recovered because of the probability of saline water encroachment. However, this volume is probably conservative because of incomplete data used to make the estimate.

Recharge to the Hueco and La Mesa bolson aquifers is estimated to average 15,000 acre-feet annually to each aquifer, or a total of 30,000 acre-feet. Recharge to the river alluvium in the Lower Mesilla Valley is principally by infiltration of surface water applied to the land surface for

irrigation and has been estimated to be at least 36,000 acre-feet annually when surface water supplies for irrigation are adequate and storage space is available in the alluvium. Recharge to the alluvium in the Mesilla Valley has been estimated to average 15,000 to 20,000 acre-feet annually. For the purpose of this study, the recharge is assumed to be 15,000 acre-feet. Therefore, the total average annual recharge to the aquifers in the El Paso area is estimated to be approximately 45,000 acre-feet. In general, the water in the river alluvium in the El Paso Valley is unsuitable for public supply, therefore recharge is not considered in this study.

Ground water in the El Paso area ranges from fresh to very saline. Where fresh ground water is available, it is underlain, overlain, or adjoined by slightly saline water, the water becoming increasingly mineralized with depth as well as laterally. In the El Paso area ground water containing less than 250 ppm of chloride is classified as fresh.

In 1960, withdrawals of ground water in El Paso County plus a small northwestern portion of Hudspeth County were estimated as follows:

	No. of Wells	AFY	MGD
Public Supply	79	51,578	46.05
Industrial	2	8,200	7.32
Irrigation	97	18,600	16.9
Total	178	78,378	70.27

Water Analyses for the wells in each area have been averaged, and are shown on Figure 4-4.

4.5.2 Surface Water

In addition to ground water, the sources of water for the City of El Paso [31] include an allocation of surface water from the Rio Grande. Approximately 90% of the present water requirements are provided by well fields in the Hueco Bolson, the La Mesa Bolson (Lower Mesilla Valley) and the Rio Grande Alluvium. The remaining requirements are supplied by surface water from the Rio Grande, providing a source of water to the City resulting from various agreements covering water rights, excess "wild water" and water right leases.

WATER SOURCE ANALYSIS /41/
CITY OF EL PASO
(AVERAGE PARTS PER MILLION)

	Down Town	Mesa	Airport	Canutillo Shallow	Canutillo Inter. & Deep	Lower Valley	River
No. of Wells	7	27	9	10	10	13	0
Calcium - Ca	32	32	21	64	4	23	34
Magnesium - Mg	10	11	8	18	1	7	18
Sulfate - SO_4	69	76	81	282	75	74	220
Chloride - Cl	134	81	88	163	43	116	152
Fluoride - F	0.9	1.0	0.8	0.7	0.5	1.0	
Dissolved Solids	533	433	462	900	299	491	813
Total Hardness as $CaCO_3$	126	128	83	214	16	86	150
Percent Sodium as total cations	76	67					

FIGURE 4 - 4

The City owns the maximum amount of 2,000 acres of first class water rights land, as provided in an agreement executed in 1941, between the City, the Bureau of Reclamation and the El Paso Improvement District No. 1. The average allocation of water is about 2 feet per acre per year or a total of 4,000 acre-feet per year. This water must be used during the irrigation season from April through September.

A 1949 agreement permits the City to divert excess "wild water" from the Rio Grande. This source has provided an average of 1,000 acre-feet per year.

Lease of First Class Water Rights of small (2 acres or less) tracts within the City limits was permitted by agreement in 1962. The production from these leases averages 2 acre-feet per acre per year. Two hundred acres were leased in 1965, and it is assumed that an average of 120 acres per year can be leased through 1980 when a total of 2,000 acres will ultimately be under lease for a total yield of 4,000 AFY.

4.5.3 Water Resources Data

Figure 4-5 provides a summary of municipal and industrial water resources information as of 1965 for the City of El Paso. Inasmuch as the City of El Paso accounts for approximately 95 percent of the total water requirements for the El Paso region, these data were used as the basis for desalting in the El Paso region. /31/

4.5.4 Mass Diagram

Analysis of water supply and demand data can be simplified by use of a mass diagram which shows cumulative quantities of water with respect to time. Figure 4-6 shows mass diagrams for the water resources now available to the City plus additional resources from assumed procurement of additional leases at an average of 120 acres per year. Also shown is a mass curve for water demand based on data provided by the Texas Water Development Board.

Figure 4-6 also shows the effect of utilizing the water which is available in storage in the Hueco bolson. At present, El Paso owns or controls land from which approximately 1,500,000 acre-feet can be removed. If this storage is mined completely and assuming no inflow from surrounding areas, it will be used

WATER RESOURCES EL PASO REGION

Sources	Aquifer Recharge AFY	Recoverable[1] Storage AF	Remarks
Hueco Bolson	15,000	3,750,000	
Lower Mesilla Valley			
La Mesa Bolson (Canutillo Deep and Intermediate)	15,000	200,000	The City of El Paso owns water rights to 36,000 acres.
River Alluvium (Canutillo Shallow)	15,000[2]	75,000	
Rio Grande[4]			
2,000 Acres Water Rights Land Owned by City of El Paso			4,000 AFY[3]
Excess "Wild Water"			1,000 AFY (Average)
Leased Water Rights			400 AFY[3] in 1965 4,000 AFY[3] by 1980 based on leasing an average of 120 acres per year

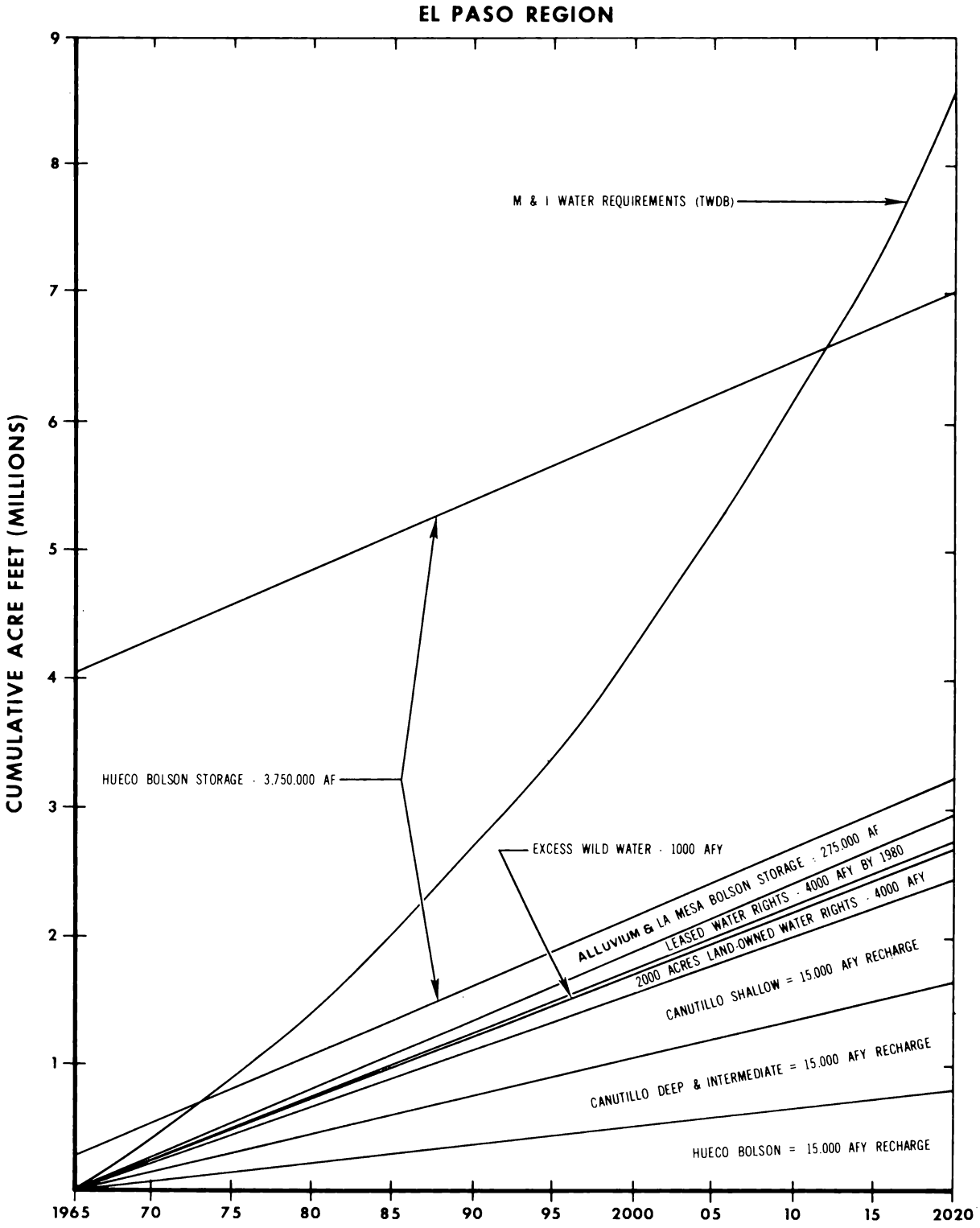
(1) Based on 50 percent of theoretically recoverable fresh water because of the probability of saline water encroachment.

(2) Primarily from applied irrigation water.

(3) Based on average allocation of 2 feet per acre per year.

(4) Available to the City of El Paso. Other cities in the region have no rights to Rio Grande water.

FIGURE 4 - 5



MASS DIAGRAM

ESTIMATED WATER RESOURCES AND REQUIREMENTS

FIGURE 4-6

up in approximately 1995 on the basis of the water demand figures furnished by the Texas Water Development Board. However, a recent analog study indicated that inflow from areas adjacent to the land now owned or controlled by the City of El Paso can contribute a major part of the pumped water, thus permitting the City to take advantage of almost the full storage potential of the bolson even with present limited ownership except for removals by the military and others. /109/ In this case, the mass diagram shows potential storage supplies used up in approximately 2010.

4.6 POSSIBLE FUTURE WATER SOURCES /31/

The following list shows the possibilities for providing additional water sources to meet prospective growth in water demand:

- Continue to mine the reserves in the Bolson.
- Import water from other areas.
- Endeavor to increase the amount received from the Rio Grande.
- Desalt local brackish water.
- Blend local brackish water with local superior quality water.
- Reclaim waste water.

The effect of mining the reserves in the bolson aquifers is shown graphically on Figure 4-6 and is discussed in Section 4.5.4. Although the City of El Paso owns water rights from which approximately 1,500,000 acre-feet of the water in storage can be removed, and although additional water will move into the area as this water is withdrawn from storage, it appears that there might be an advantage for the City if it expanded its water rights in the Hueco bolson area.

The Texas Water Development Board has under active consideration the possibility of importing water to areas in Texas from the Mississippi River to meet municipal, industrial, irrigation and mining water needs. Preliminary estimates by the Board indicate that the cost of water delivered to El Paso from East Texas, and out-of-State sources can be as much as 45¢ to 50¢ per thousand gallons. To this cost would have to be added the cost of conventional water treatment after delivery to El Paso. Volumes of water potentially available, possible routings and costs of moving to and across Texas from the Mississippi River presently are under study by the Board, the U. S. Army Corps of Engineers and the Bureau of Reclamation, U. S. Department of the Interior.

A considerable amount of water exists in the north portion of the Bolson in New Mexico, and from the La Mesa area west of the Rio Grande in New Mexico. New Mexico state law presently prohibits the removal of water from the state. It is estimated that these two possibilities would offer over 3 million acre feet of available water. Additionally, there appear to be appreciable quantities of water of somewhat inferior quality in the Dell City and Van Horn area. It is estimated that importation costs of this water would be approximately 25 cents per thousand gallons. This water either would have to be blended or treated.

Increased amounts from the Rio Grande is a possibility which could be explored. This possibility is under consideration by the City of El Paso in connection with existing contracts.

Desalting has demonstrated its increasing importance for supplying water of good quality as costs have been reduced significantly during the last ten years. This report explores the state of the art of this technology and presents data in the subsequent sections of this chapter on the application of desalting in the El Paso area.

Blending brackish water with water of superior quality to provide a consumer product of good quality (e.g. 500 ppm) will have the effect of increasing the life of water reserves if there is sufficient quantity of local fresh water which has a salinity significantly lower than the target goal for the blended supply.

Reclaiming waste water from return flows has the potential for significantly increasing the life of water resources. This requires employment of some process to condition this water to make it satisfactory for municipal and industrial use. Return flows can also serve as a source of feedwater for desalination, particularly in areas where brackish or saline water supplies are limited.

A significant percentage of the water used in an area is available as return flow. Extensive research into treatment of return flows has been in progress in the Federal Water Polution Control Administration and other agencies. The feasibility of reclamation has been demonstrated and emphasis is being placed on efforts to reduce costs. It appears that the reclaimed product can meet U.S. Public Health Service Standards for municipal and industrial water, but there may remain esthetic objections to be overcome to gain public acceptance of this source.

One of the interesting advantages derived from reclamation of return flows is that it is estimated that salinity increases only 300 to 400 ppm for each use. Desalting the return flows only by this amount permits application of desalting systems which will yield low cost water.

Figure 4-7 shows return flow data furnished by the Texas Water Development Board.

RETURN FLOWS

El Paso County

RETURN FLOW	1970	1980	1990	2000	2010	2020
	Acre Feet Per Year					
El Paso	26,723	33,494	40,893	49,977	61,137	74,858
Fabens	201	264	335	425	539	684
Other	1,238	1,597	1,834	2,090	2,362	2,644
County Total	28,162	35,355	43,062	52,492	64,038	78,186
	Million Gallons Per Day					
El Paso	23.86	29.90	36.51	44.62	54.58	66.83
Fabens	0.18	0.24	0.30	0.38	0.48	0.61
Others	1.10	1.42	1.63	1.86	2.11	2.36
County Total	25.14	31.56	38.44	46.86	57.17	69.80

Source: Texas Water Development Board

FIGURE 4 - 7

4.7 DESALTING POSSIBILITIES

For purposes of this study, four different desalting installations have been considered for the El Paso Region, three having a capacity of 10 million gallons a day (MGD) and one with a capacity of 6.1 MGD. Desalting Cases No. I-1 and I-2 employ a distillation process which produces water having salinity in the order of 25 parts per million (ppm). For cost comparison, calculations were made with results shown for sub-cases I-1b and I-2b providing for blending the distilled product water with feedwater to provide a delivered product of 500 ppm quality. Cases I-3 and I-4 utilize a membrane process which produces potable water of 500 ppm total dissolved solids (TDS) or less.

Descriptions of the desalting processes and of the basis of the economics associated with desalting are included in Chapter 2, Desalting Processes and Economics. Feedwaters for the desalting cases considered for the El Paso region are derived from saline water in the Hueco Bolson and in the Rio Grande Alluvium. Analyses for the feedwaters are shown on Figure 4-8.

Case No. I-1 provides a 6.1 MGD plant employing a distillation process embodying the vapor compression vertical tube evaporator (VC-VTE) process which has been under study by Oak Ridge National Laboratories (ORNL) and shows promise for providing lower water costs. For application of this process in the El Paso region, discussions have been held with El Paso Natural Gas Co. regarding consideration of installing equipment for such a process in the vicinity of their compressor station for the purpose of utilizing the waste heat in the stacks of the gas turbines. Their cooperation in connection with consideration of this desalting possibility has permitted the determination of preliminary estimated costs without, however, a commitment on anyone's part at this time.

This size plant utilizes the waste heat which is available from two 8,000 horsepower gas turbines at a rate of 1.17×10^8 Btu/hr. An intermediate pressure boiler operating at 650F is used on the waste heat recovery system. This prime steam is used to supply the back-pressure turbine which in turn, drives the vapor compressor. The overall performance ratio of this plant is 18.2 lbs. product per 1,000 Btu of heat input; concentration ratio is 4:1. The feedwater for this case is derived from the Hueco Bolson with the well field nearby the desalting plant.

Water conveyance cost are based on delivery of 500 ppm water to the nearest El Paso water system pipeline. This is a 36 inch line terminating east of the Fort Bliss Military Reservation as shown on Figure 4-1. No investigation was made for purposes of this report

EL PASO REGION

ANALYSIS OF
SALINE WATER FOR DESALTING PLANT
FEED

	HUECO BOLSON	RIO GRANDE ALLUVIUM
Temperature ^{o}F	78	70
Silica - SiO_2	22 ppm	35 ppm
Iron - Fe	0.03	0.03
Manganese - Mn	0.14	0.03
Calcium - Ca	121	163
Magnesium - Mg	21	51
Sodium & Potassium (Na+K)	455	292
Bicarbonate - HCO_3	94	275
Sulfate - SO_4	96	336
Chloride - Cl	830	492
Fluoride - F	0.03	0.08
Nitrate - NO_3	0	1.5
Boron - B	0.18	0.23
Dissolved Solids(TDS)	1617	1611
Total Hardness as $CaCO_3$	389	616
Specific Conductance (Micromhos at 25°C)		2490
pH	7.5	8.1

FIGURE 4 - 8

to determine the feasibility of delivering product water at this location; this feature should be carefully investigated in any future feasibility study.

The components of the cost of water for Case I-1 delivered to the City of El Paso water system are as follows:

	6.1 MGD Distilled Water	8.7 MGD 500 ppm Blend
- Desalting Plant	32.5 ¢/Kgal.	25.0 ¢/Kgal.
- Water Treatment	0 ¢/Kgal.	0 ¢/Kgal.
- Feedwater Supply	8.0 ¢/Kgal.	7.3 ¢/Kgal.
- Brine Disposal	8.7 ¢/Kgal.	6.1 ¢/Kgal.
- Product Water Conveyance	1.2 ¢/Kgal.	1.0 ¢/Kgal.
Total	50.4 ¢/Kgal.	39.4 ¢/Kgal.

Case I-2 is identical in process and location as in Case I-1 but provides for a larger size plant of 10 MGD by means of supplemental firing of the waste heat boiler at a rate of 7.0×10^7 Btu. Concentration ratio is 4:1, and the performance ratio is 18.6. The advantage of supplemental firing is that essentially 100 percent heat conversion is attained from the fuel because of the excess oxygen in the exhaust from the gas turbine.

The components of the cost of water for Case I-2 delivered to the City of El Paso water system are as follows:

	10 MGD Distilled Water	14.3 MGD 500 ppm Blend
- Desalting Plant	34.8 ¢/Kgal.	26.6 ¢/Kgal.
- Water Treatment	0 ¢/Kgal.	0 ¢/Kgal.
- Feedwater Supply	7.7 ¢/Kgal.	7.0 ¢/Kgal.
- Brine Disposal	9.6 ¢/Kgal.	6.7 ¢/Kgal.
- Product Water Conveyance	0.9 ¢/Kgal.	0.8 ¢/Kgal.
Total	53.0 ¢/Kgal.	41.1 ¢/Kgal.

Case I-3 employs an electrodialysis desalting process. The desalting plant was sized for 10 MGD and was assumed to be located at a suitable but undetermined site over the Rio Grande Alluvium as shown on Figure 4-1 in order to keep feedwater supply lines to a minimum. Brine disposal was assumed to be accomplished in the general vicinity of the desalting plant.

Water delivery was assumed to be made to the 30 inch pipeline approximately three miles north of the plant location, but no investigation was made for purposes of this report to determine the feasibility of delivering product water at this location.

The cost of 500 ppm water for Case I-3 delivered to the City of El Paso water system is estimated at 43.0 cents per thousand gallons. This water cost is broken down into the following components:

- Desalting Plant	32.3 ¢/Kgal.
- Water Treatment	0.1 ¢/Kgal.
- Feedwater Supply	6.1 ¢/Kgal.
- Brine Disposal	2.5 ¢/Kgal.
- Product Water Conveyance	2.0 ¢/Kgal.
Total	43.0 ¢/Kgal.

Case I-4 also provides for a 10 MGD desalting plant employing electrodialysis. Its location, however, was assumed at a suitable but undetermined location near the El Paso Natural Gas Co. facility where the VC-VTE plant was located. Brine disposal was provided for in the general vicinity of the desalting plant. 500 ppm water delivery was assumed to be made in the same manner as for the VC-VTE plant.

The cost of 500 ppm water for this case delivered to the City of El Paso is estimated at 35.6 cents per thousand gallons. This water cost is broken down into the following components:

- Desalting Plant	25.7 ¢/Kgal.
- Water Treatment	0 ¢/Kgal.
- Feedwater Supply	6.5 ¢/Kgal.
- Brine Disposal	2.5 ¢/Kgal.
- Product Water Conveyance	0.9 ¢/Kgal.
Total	35.6 ¢/Kgal.

4.8 ANALYSIS AND COMPARISONS

Cost breakdown figures for each of the processes are included at the end of this section as Figures 4-9, 4-10, 4-11 and 4-12. In addition, component cost figures were calculated for the cases employing the distillation process, based on producing a 500 ppm blend by utilizing the 25 ppm distillation product and the 1617 ppm Hueco Bolson saline water.

The total unit costs for each component of the facilities required for each case are summarized as follows in comparison with imported water costs preliminarily estimated at 45¢ to 50¢ per thousand gallons from the Mississippi River as indicative of the lowest cost alternative source.

Case		I-1	I-1b	I-2	I-2b	I-3	I-4
Feedwater Source (See Note)		HB	HB	HB	HB	A	HB
Process		VC-VTE	VC-VTE	VC-VTE	VC-VTE	E/D	E/D
MGD		6.1	8.7	10	14.3	10	10
Product Water, approx. ppm.		25	500	25	500	500	500
Product Water at Plant	¢/Kgal.	32.5	25.0	34.8	26.6	32.3	25.7
Water Treatment	¢/Kgal.	0	0	0	0	0.1	0
Feedwater Supply	¢/Kgal.	8.0	7.3	7.7	7.0	6.1	6.5
Brine Disposal	¢/Kgal.	8.7	6.1	9.6	6.7	2.5	2.5
Product Conveyance	¢/Kgal.	1.2	1.0	0.9	0.8	2.0	0.9
Total	¢/Kgal.	50.4	39.4	53.0	41.1	43.0	35.6

Note: HB = Hueco Bolson; A = Alluvium

The total dissolved soilds of the Hueco Bolson feedwater are about the same as for the alluvium feedwater; their compositions differ from each other, but there is a significant advantage to the electrodialysis process in utilizing Hueco Bolson feedwater because its higher temperature of 78F compared with 70F for the alluvium allows for a plant having lower capital cost. An electrodialysis plant using Hueco Bolson feedwater requires a significantly smaller capital investment, $2,984,000 vs $3,923,000, representing a saving of approximately $1,000,000 equal to 25% of the alluvium plant. Operation and maintenance costs are also moderately lower due primarily to lower acid costs and reduced maintenance and replacement materials and supplies.

There have been some considerations regarding the possibility of achieving lower costs of product water from the electrodialysis process by utilizing the waste heat from the gas turbines in the El Paso Natural Gas Co. compressor station to heat the feedwater to 100F. The 11 million

gallons per day feedwater would require 85,000,000 Btu per hour to raise the temperature from 78F to 100F. The waste heat from two 8,000 horsepower gas turbines amounts to 117,000,000 Btu per hour, so that sufficient heat is available with some to spare to raise the temperature.

As a rough approximateion for purposes of analysis, assume a waste heat recovery boiler installation costing $250,000 having annual costs of $14,000 and O & M costs of $6,000 for a total annual cost of $20,000. On the assumption of no cost waste heat, this installation amounts to an additional cost of approximately 0.6¢ per kilogallon. The desalting plant operating at the higher temperature shows a significant saving in capital cost, possibly 20% to 30% but due to much larger influence of O & M costs the cost of product water may show a reduction of only approximately 2 cents per kilogallon. The product water will be at an elevated temperature slightly higher than the 100F feedwater temperature and the cost of lowering the temperature to acceptable levels may offset all or more than the savings, depending on the desired temperature for delivery of water to the system.

A check of the application of a reverse osmosis desalting plant showed cost of product water at the plant boundary amounting to 29¢ per thousand gallons /38/. This is 3.5 cents per thousand gallons higher than the conventional electrodialysis plant. The costs of the two processes are close enough to make it desirable to give careful consideration to both processes in more detailed feasibility studies.

It may appear that the desalting plants considered in this report are not very large in relation to the municipal and industrial supply problems in the El Paso region. Nevertheless, 8.7 to 14.3 MGD of 500 ppm water amounts to approximately 10,000 AFY to 16,000 AFY which bears a reasonable relationship to the 15,000 acre feet per year recharge derived from the Hueco Bolson, for example. From this point of view, the quantities considered in this report represent a significant addition to the water resources of the El Paso region.

A serious problem concerning the application of desalting to the El Paso region appears to lie in the lack of information concerning the location, quantity and continued availability of large quantities of saline water for desalting purposes. In addition, the problem associated with disposal of the concentrated brine derived from the desalting process deserves careful attention. The costs associated with these two problems represent a significant portion of the total costs of desalted water.

Regarding the possible availability of saline water for desalting purposes, it is interesting to consider the use of return flows for this purpose. Utilizing the entire quantity available from this source as shown on Figure 4-7 would permit the installation of a 10 MGD desalting plant in 1970, 1975, 1995 and 2010 for a total installed capacity at that time of 40 MGD. It is recognized that there is at the present time a general lack of public acceptance of municipal water derived from this source; however, additional research into this resource may lead to consideration of its use in the future.

COST BREAKDOWN

EL PASO CASE I - 1

THE RALPH M. PARSONS COMPANY

PROCESS VC-VTE ; CAPACITY 6.1 MGD; OUTPUT 2,013,00 Kgal/yr; INTEREST 3-1/2 %; PLANT LIFE 30 YRS; PIPELINE LIFE 50 YRS

	CARRYING CHARGE MULTIPLIER	DESALT PLANT		WATER TREATMENT		FEEDWATER		BRINE DISPOSAL		PRODUCT CONVEY.	
		CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3
CAPITAL COST CENTERS											
1. Plant & Equipment	.0544	4,993	272								
2. Replaceable Items											
3. Water Treatment											
4. Well Field	.0426					824.2	35.1				
5. Pipeline	.0426									541.5	23.1
6. Pumping Station											
7. Brine Disposal											
8. Indirect Capital Costs	.0544	924	50								
9. Land Costs	.035	.5								.9	
10. Working Capital	.035	112.5	4			26.7	1.0			4.1	0.1
11. Cooling Towers	.0544	324	17								
TOTAL CAPITAL COSTS →		6354.0		0		850.9		1,385		546.5	
RECURRING COST CENTERS	PERCENT										
12. Taxes											
13. Insurance											
TOTAL ANNUAL FIXED COSTS →			343		0		36.1		75.3		23.2
OPERATION & MAINTENANCE COST CENTERS											
15. Operating Labor			146.6				70.0				1.6
16. Maintenance Labor											
17. General & Administrative 30%											
18. Supplies & Maintenance Materials			49.9								
19. Chemicals			70.5								
20. Fuel											
21. Electric Power for cooling tower			43.4				54.8				0
TOTAL O & M COSTS →			310.4		0		124.8		100.2		1.6
TOTAL FIXED PLUS O & M COSTS →			653.4		0		160.9		175.5		24.8
COMPONENT WATER COSTS, ¢/Kgal →		32.5		0		8.0		8.7		1.2	
TOTAL WATER COST → 50.4 ¢/Kgal											

Feedwater costs provide for wellfield in proximity to VC-VTE plant

Electric power purchased for cooling tower operation and pumping @ $.012 per KWH.

Product conveyance - 6 mi. @ minus 100' static head

Brine disposal by injection wells

FIGURE 4 - 9

COST BREAKDOWN

THE RALPH M. PARSONS COMPANY

EL PASO CASE I - 2

PROCESS VC-VTE ; CAPACITY 10 MGD; OUTPUT 3,300,000 Kgal/yr; INTEREST 3-½ %; PLANT LIFE 30 YRS; PIPELINE LIFE 50 YRS

	CARRYING CHARGE MULTIPLIER	DESALT PLANT		WATER TREATMENT		FEEDWATER		BRINE DISPOSAL		PRODUCT CONVEY.	
		CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3
CAPITAL COST CENTERS											
1. Plant & Equipment	.0544	7,475	406								
2. Replaceable Items											
3. Water Treatment											
4. Well Field	.0426					1,307.5	54.7				
5. Pipeline	.0426									663.4	28.3
6. Pumping Station											
7. Brine Disposal											
8. Indirect Capital Costs	.0544	1,383	75								
9. Land Costs	.035	1								.9	
10. Working Capital	.035	181	6.3			42.0	1.5			5.0	.2
11. Cooling Towers	.0544	520	28								
TOTAL CAPITAL COSTS →		9,560		0		1,349.5		3,044		669.3	
RECURRING COST CENTERS	PERCENT										
12. Taxes											
13. Insurance			515.3		0		56.2		165.5		28.5
TOTAL ANNUAL FIXED COSTS →											
OPERATION & MAINTENANCE COST CENTERS											
15. Operating Labor											
16. Maintenance Labor			217.9				108.0				1.9
17. General & Administrative 30%											
18. Supplies & Maintenance Materials			74.6								
19. Chemicals			115.0								
20. Fuel			154.5								
21. Electric Power for cooling tower			71.2				89.5				0
TOTAL O & M COSTS →			633.2		0		197.5		151.4		1.9
TOTAL FIXED PLUS O & M COSTS →			1148.5		0		253.7		316.9		30.4
COMPONENT WATER COSTS, ¢/Kgal →		34.8		0		7.7		9.6		0.9	
TOTAL WATER COST → 53.0 ¢/Kgal											

Feedwater costs provide for wellfield in proximity to VC VTE plant

Electric power purchased for cooling tower operation and pumping @ $.012 per Kwh

Product water conveyance line 6 mi. @ minus 100 ft. static head

FIGURE 4 - 10

COST BREAKDOWN

THE RALPH M. PARSONS COMPANY

EL PASO CASE I - 3

PROCESS E/D ; CAPACITY 10 MGD; OUTPUT 3,300,000 Kgal/yr; INTEREST 3 1/2 %; PLANT LIFE 30 YRS; PIPELINE LIFE 50 YRS

	CARRYING CHARGE MULTIPLIER	DESALT PLANT		WATER TREATMENT		FEEDWATER		BRINE DISPOSAL		PRODUCT CONVEY.	
		CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3
CAPITAL COST CENTERS											
1. Plant & Equipment	.0544	1,940	105.5								
2. Replaceable Items	.2215	1,260	279.0								
3. Water Treatment											
4. Well Field	.0426					854.7	36.4				
5. Pipeline	.0426									331.7	14.2
6. Pumping Station											
7. Brine Disposal											
8. Indirect Capital Costs	.0544	545	29.6								
9. Land Costs	.035	3	.1							.5	
10. Working Capital	.035	175	6.0			33.2	1.2			10.5	.4
11. Cooling Towers											
TOTAL CAPITAL COSTS →		3,923		0		887.9		648.3		342.7	
RECURRING COST CENTERS	PERCENT										
12. Taxes											
13. Insurance											
TOTAL ANNUAL FIXED COSTS →			420.2		0		37.6		35.2		14.6
OPERATION & MAINTENANCE COST CENTERS											
15. Operating Labor			49.4				)				)
16. Maintenance Labor			30.4				) 90.0				) 48.2
17. General & Administrative 30%			23.9				)				)
18. Supplies & Maintenance Materials			128.6								
19. Chemicals			99.0		3.3						
20. Fuel											
21. Electric Power			315.0				72.8				1.4
TOTAL O & M COSTS →			646.3		3.3		162.8		47.5		49.6
TOTAL FIXED PLUS O & M COSTS →			1066.5		3.3		200.4		82.7		64.2
COMPONENT WATER COSTS, ¢/Kgal →		32.3		0.1		6.1		2.5		2.0	
TOTAL WATER COST → 43.0 ¢/Kgal											

1. Desalt plant costs per Ionics ref. ltr. 3/9/68
   a. Indirect costs revised from 10% to 17%
   b. Power costs revised from 1.0¢/Kwh to 1.2¢/Kwh
2. Water treatment per Ionics provide calgon treatment @ 6 ppm.
3. Feedwater costs for wellfield in proximity to plant - 11.0 MGD
4. Product water conveyance line assumed 3 miles, 0 static head
5. This case utilizes Rio Grande Alluvium feedwater.

FIGURE 4 - 11

COST BREAKDOWN
EL PASO CASE I - 4

THE RALPH M. PARSONS COMPANY

PROCESS E/D ; CAPACITY 10 MGD; OUTPUT 3,300,000 Kgal/yr; INTEREST 3-1/2 %; PLANT LIFE 30 YRS; PIPELINE LIFE 50 YRS

	CARRYING CHARGE MULTIPLIER	DESALT PLANT		WATER TREATMENT		FEEDWATER		BRINE DISPOSAL		PRODUCT CONVEY.	
		CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3
CAPITAL COST CENTERS											
1. Plant & Equipment	.0544	1.605	87.3								
2. Replaceable Items	.2215	825	183								
3. Water Treatment											
4. Well Field	.0426										
5. Pipeline	.0426					1,206	51.5				
6. Pumping Station										663.4	28.3
7. Brine Disposal											
8. Indirect Capital Costs	.0544	413	22.5								
9. Land Costs	.035	2	.1							.9	
10. Working Capital	.035	139	4.8			36	1.2			5.0	.2
11. Cooling Towers											
TOTAL CAPITAL COSTS →		2,984				1,242		648.3		669.3	
RECURRING COST CENTERS	PERCENT										
12. Taxes											
13. Insurance											
TOTAL ANNUAL FIXED COSTS →			297.7				52.7		35.2		28.5
OPERATION & MAINTENANCE COST CENTERS											
15. Operating Labor			49.4								
16. Maintenance Labor			26.5								
17. General & Administrative			22.7								
18. Supplies & Maintenance Materials			105.5								
19. Chemicals			33								
20. Fuel											
21. Electric Power			315				72.8				0
TOTAL O & M COSTS →			552.1				162.8		47.5		1.9
TOTAL FIXED PLUS O & M COSTS →			849.8				215.5		82.7		30.4
COMPONENT WATER COSTS, ¢/Kgal →		25.7		0		6.5		2.5		0.9	
TOTAL WATER COST → 35.6 ¢/Kgal											

This case utilizes Hueco Bolson feedwater

FIGURE 4 - 12

4.9 BRINE DISPOSAL

Cost of brine disposal of deep well injection for this area was calculated for various depths and formational characteristics of the Hueco Bolson as the disposal zone for volumes ranging from 1.5 MGD to 4.15 MGD. The lowest calculated cost for injection for each study case is tabulated in Figure 4 - 13.

EL PASO REGION

BRINE DISPOSAL DATA

INJECTION RESERVOIR CHARACTERISTICS AND DESIGN AND COST DATA FOR BRINE DISPOSAL BY SUBSURFACE INJECTION IN SELECTED CASES

Item	VC-VTE Case I-1	VC-VTE Case I-2	ED Cases I-3, I-4
Product Water			
Capacity, MGD	6.1	10.0	10.0
Quality, TDS (ppm)	25	25	500
Brine Effluent			
Volume, MGD	2.55	4.15	1.0
Quality, TDS (ppm)	5,770	5,805	9,030
Disposal Zone			
Formation or geologic age	- - - - - -	Hueco Bolson	- - - - -
Lithology	- - - - - -	Sandstone	- - - - -
Depth below surface	- - - - - -	2,600 ft.	- - - - -
Thickness	- - - - - -	100 ft.	- - - - -
Well Field Data			
Number of wells	20	25	8
Distance to plant	1 mi.	1 mi.	1 mi.
Total Cost (Million Dollars)			
Capital	$1.385	$3.044	$0.648
Annual	$0.175	$0.317	$0.083
Total Unit Costs			
Brine basis per thousand gallons	20.86¢	23.14¢	25.06¢
Product basis, per thousand gallons	8.71¢	9.6¢	2.51¢

Note: Above figures include cooling water blowdown for VC-VTE cases.
Source: Texas Water Development Board

FIGURE 4 - 13

REEVES - WARD - WINKLER REGION

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REEVES - WARD - WINKLER REGION

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5. REEVES - WARD - WINKLER REGION

5.1 INTRODUCTION AND SUMMARY

For purposes of this report, Reeves, Ward and Winkler Counties have been combined into one region. The major cities in the region are Kermit, Monahans, Pecos and Wink. This region was selected for study to determine the role which desalination of underlying brackish ground water could serve toward the fulfillment of future water requirements of the area. For this purpose estimates were prepared to show the costs of desalted water in relationship to the cost of water from alternative sources.

Projections of water requirements of the Reeves Ward-Winkler Region indicate that the estimates for municipal and industrial water in 2020 will be over twice as great as the estimates for 1970. In order to provide for these needs it has been recognized that the application of desalting technology should be considered as one of the possible sources of future water supply. This study is a preliminary investigation of the feasibility and cost of desalting brackish ground water in the Reeves-Ward-Winkler region.

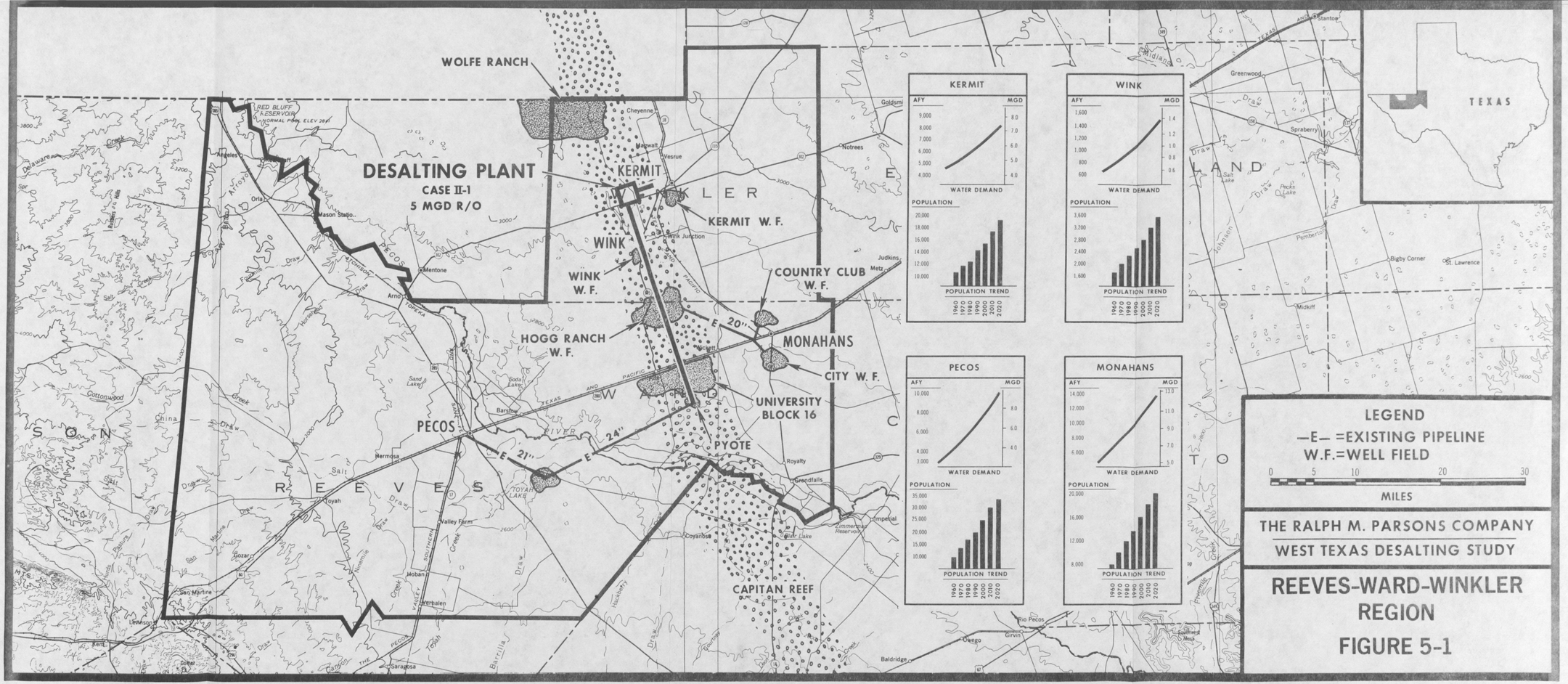
Plant size was selected on a more or less arbitrary basis, keeping in mind water resources and future requirements. The information presented herein can be used to make an appraisal of the relationship of plant size to total water requirements.

Problems associated with feedwater supply, brine disposal and integration of desalted water into the present system have been investigated only briefly. A detailed investigation of various solutions and their costs should be included in any future study.

5.1.1 Summary

Figure 5 - 1 represents a map of the Reeves-Ward-Winkler Region showing a 5 MGD desalting plant utilizing Capitan Reef feedwater.

In exploring the possibilities for the application of desalting plants in the Reeves-Ward-Winkler Region, full advantage was taken of existing pipelines owned and operated by the cities of Kermit, Wink, Monahans and Pecos. It was found that a desalting plant could be located near the City of Kermit, utilizing Capitan Reef feedwater. The product water pipeline from the desalting plant was routed direct to Wink, thence through the Hogg Ranch Well Field and continuing to the Pyote Well Field; a branch supplied Kermit. This routing utilized the existing 20 inch pipeline from


WOLFE RANCH
DESALTING PLANT
CASE II-1
5 MGD R/O
KERMIT
KERMIT W. F.
WINK
WINK W. F.
COUNTRY CLUB W. F.
HOGG RANCH W. F.
MONAHANS
CITY W. F.
UNIVERSITY BLOCK 16
PECOS
PYOTE
CAPITAN REEF
E 20"
E 21"
E 24"
RED BLUFF RESERVOIR
NORMAL POOL ELEV 2631
KERMIT
AFY
MGD
WATER DEMAND
POPULATION
POPULATION TREND
WINK
PECOS
MONAHANS
TEXAS
LEGEND
—E— =EXISTING PIPELINE
W.F.=WELL FIELD
0 5 10 20 30
MILES
THE RALPH M. PARSONS COMPANY
WEST TEXAS DESALTING STUDY
REEVES-WARD-WINKLER REGION
FIGURE 5-1

Hogg Ranch to Monahans and the existing 24 inch and 21 inch pipelines from Pyote Well Field to Pecos.

In studying the application of desalting plants for this region utilizing Capitan Reef feedwater, it was determined that all processes with the exception of the vacuum freezing, vapor compression process (VF-VC) required extensive feedwater treatment. The equipment manufacturer for the vacuum freeze vapor compression process advises that only a small amount of the dissolved hydrogen sulfide will be liberated in the freezer. The product water will be chlorinated and filtered for removal of the 2.3 ppm remaining hydrogen sulfide. However, the validity of this claim should be checked by test in any further considerations.

The delivered water costs amount to 65.1 cents per thousand gallons for reverse osmosis process and 82.2 cents per thousand gallons for VFVC.

The lowest cost of desalted product water for a 5 MGD reverse osmosis plant of approximately 65.1 cents per thousand gallons compares with an estimated cost of 8 to 10 cents per thousand gallons when University Block 16 supply is developed, and with a preliminarily estimated 40¢ to 45¢ per thousand gallons for water supplied by the importation plan from the Mississippi River.

Comparison of desalted water costs with costs from alternative sources at this time appears to indicate that desalted water costs would be considerably higher.

5.2 WATER ADMINISTRATION AND FACILITIES

There are several agencies which are responsible for water mangement in the Reeves-Ward Winkler Region. These include agencies primarily concerned with furnishing municipal and industrial water.

5.2.1 Pecos

Pecos is an incorporated city with an estimated 1967 population of 15,000.

The City presently has two well fields. Worsham well field is located about 10 miles southeast of the City in Reeves County, and the Southeast Pyote well field is located about 25 miles east of the City in Ward County. Water from the Southeast Pyote field is piped to the Worsham field, then into Pecos.

The Worsham well field has 15 wells and the Pyote well field has 4 wells. The pumping capacities of wells in the Pyote well field range from 150 to 750 gallons per minute, for a total of 4,000 gallons per minute for the field.

Water storage facilities owned by the City are tabulated below:

Capacity	Type Storage	Location
250,000 Gallons	Ground	Southeast Pyote Well Field
250,000 Gallons	Ground	At Pipeline Crossing of Pecos River
1,125,000 Gallons	Ground	Worsham Well Field
200,000 Gallons	Ground	City
800,000 Gallons	Elevated	City

The present treatment consists of chlorination.

5.2.2 Kermit

Kermit is an incorporated city with an estimated 1967 population of 11,200.

The City owns and operates a total of 14 wells with a maximum pumping capacity of 5,300 gpm.

Water storage facilities consist of one 150,000 gallon elevated tank, one 500,000 gallon ground storage tank, and two 1,300,000 gallon underground storage tanks.

5.2.3 Monahans

Monahans is an incorporated city with an estimated 1967 population of 10,100. The City leases water rights at Hogg Ranch well field, its principal water source, and owns and operates gathering, storage, treatment and distribution facilities.

The City has three water well fields. The Hogg Ranch well field, located northwest of the community of Wickett, has 4 wells with a total pumping capacity of some 3,000 gallons per minute; 8 wells are located within the city limits on the south and southwest side of town with a total pumping capacity of 500 to 600 gallons per minute, and 6 wells are located northeast of town at the Country Club with a total pumping capacity of about 1,000 gallons per minute. However, the wells at the Country Club have not been used in about 8 years. Wells within the city limits are used only in the summertime.

Water storage facilities consist of 5 tanks; 3 ground storage tanks with a total capacity of 1.6 million gallons and 2 elevated tanks having a total capacity of 0.75 million gallons.

5.2.4 Irrigation Water Agencies /10/

The major source of irrigation water in this region is provided by facilities of the Red Bluff Water Power Control District. Lake Balmorhea, located in southern Reeves County, is also a source of irrigation water in the area.

In 1964 a total of 806,000 acre-feet of water was used for irrigation. Most of this was obtained from water in storage in the Cenozoic Alluvium of the Pecos Valley, and surface water from Lake Balmorhea and Red Bluff Reservoir. The 2020 estimated water requirements for irrigation will be 125,100 acre-feet annually, with most of the decrease being due to the depletion of water in storage in the ground-water aquifer, the deep pumping lifts, and the intrusion of poor quality water as the water levels are lowered. Of the 125,100 acre-feet of water for irrigation, 54,900 acre-feet will be ground water and 70,200 acre feet surface water. There is an additional potential for profitable irrigation of 285,700 acres in this region by 2020, which would need to be supplied with an estimated 990,400 acre-feet annually of imported water. A large part of the irrigation which depends on the Cenozoic Alluvium of the Pecos Valley will have to be reduced greatly by the year 2020 because of encroaching poor quality water as the water levels decline. The amount of water available from the Cenozoic Alluvium by the year 2020 will be limited to the amount of water that the aquifer

receives as recharge, some of which enters the alluvium from The Edwards-Trinity (Plateau) aquifer in the subsurface.

Water districts in Texas that receive water from the Red Bluff Water Power Control District are:

- Loving County W I D No. 1
- Reeves County W I D No. 2
- Ward County W I D No. 3
- Ward County W I D No. 1
  Ward County W I D No. 2
- Pecos County W I D No. 3
- Pecos County W I D No. 2

5.3 POPULATION AND WATER REQUIREMENTS

Planning for the development of municipal and industrial water facilities depends upon projections of future population and industrial growth. In this report, the quantity of fresh water required by each region is based on projections by the Texas Water Development Board.

The intent of the projections is to provide guidelines for orderly planning and development of future water supply facilities. The near term projections, i.e: the next 10 to 20 years, should be more reliable than those in the more distant future. In the near term interval, growth rates slower or faster than are anticipated are not likely to effect large changes in the dates at which projected population data are reached. On the other hand, for spans of 20 years in the future and beyond, the variation of actual population figures from present day estimates may become significant.

The large projected per capita per day use indicated for several cities is attributed to a large projected industrial water requirement. For simplicity in handling projected requirements of water used by industry located within a county but not within the confines of any city, the Texas Water Development Board allocated these requirements to the nearest city. This has the effect of showing a large water requirement for some of the cities in this report.

Where per capita consumption growth appears abnormal, it is anticipated that the availability of sufficient quantities of good quality water in the future will attract industry, thus modifying the historical growth pattern of per capita consumption.

Data on population and water requirements projected to the year 2020 for cities as well as county and region totals have been developed by the Texas Water Development Board as shown on Figure 5 - 2.

POPULATION AND WATER REQUIREMENT ESTIMATES
Reeves - Ward - Winkler Region

	1970	1980	1990	2000	2010	2020
POPULATION						
Winkler County						
Kermit	11,465	12,689	14,190	15,867	17,743	19,840
Wink	2,040	2,258	2,525	2,824	5,158	3,532
Other	2,499	628	4,481	5,496	4,699	8,043
Total	16,001	18,575	21,196	24,187	27,600	31,415
Ward County						
Grandfalls	1,420	1,845	2,192	2,603	3,088	3,661
Monahans	10,725	12,689	14,190	15,867	17,743	19,840
Other	7,624	9,909	11,772	13,975	16,580	19,659
Total	19,769	24,443	28,154	32,445	37,411	43,160
Reeves County						
Pecos	16,036	19,363	22,407	25,928	30,004	34,700
Other	5,266	5,760	6,535	7,413	8,404	9,546
Total	21,302	25,123	28,943	33,341	38,408	44,246
Region Total	57,072	68,141	78,292	89,873	103,419	118,821
M & I WATER REQUIREMENTS	Acre Feet Per Year					
Winkler County						
Kermit	4,740	5,310	5,968	6,707	7,539	8,474
Wink	843	945	1,062	1,194	1,342	1,509
Other	1,070	1,203	1,392	1,612	1,864	6,847
Total	6,653	7,458	8,423	9,513	10,745	12,136
Ward County						
Grandfalls	183	245	292	344	408	484
Monahans	6,717	8,134	9,299	10,629	12,150	13,889
Other	1,120	1,512	1,784	2,113	2,504	2,971
Total	8,020	9,891	11,375	13,086	15,062	17,344
Reeves County						
Pecos	4,536	5,674	6,582	7,646	8,896	10,365
Other	391	496	597	718	869	1,028
Total	4,927	6,170	7,179	8,364	9,756	11,393
Region Total	19,600	23,519	26,977	30,963	35,563	40,873
	Million Gallons Per Day					
Winkler County						
Kermit	4.23	4.74	5.33	5.99	6.73	7.56
Wink	.75	.84	.95	1.06	1.20	1.35
Other	.96	1.08	1.24	1.45	1.65	1.92
Total	5.94	6.66	7.52	8.50	9.58	10.83
Ward County						
Grandfalls	0.21	0.28	0.33	0.39	0.46	0.54
Monahans	6.00	7.26	8.30	9.49	10.85	12.40
Other	.95	1.30	1.53	1.80	2.14	2.54
Total	7.16	8.84	10.16	11.68	13.45	15.48
Reeves County						
Pecos	4.05	5.07	5.88	6.83	7.94	9.25
Other	.35	.44	.53	.64	.77	.92
Total	4.40	5.51	6.41	7.47	8.71	10.17
Region Total	17.50	21.01	24.09	27.65	31.74	36.48

Source: TWDB

FIGURE 5 - 2

5.4 ECONOMIC AND FINANCIAL DATA [17] [18]

Reeves, Ward and Winkler Counties are mostly rolling plains covered with grass and brush and broken by numerous draws. Winkler and Ward counties have some shifting sand hills. Population is concentrated in Pecos, Monahans and Kermit.

Commerce and industry of the area is heavily dependent on the petroleum and mineral industry with lesser emphasis on farming and ranching. Approximately 160,000 acres are irrigated.

The following table shows certain interesting economic data for the three county area:

Bank Deposits (1964)	$ 43,607,000
Retail Sales (1963)	$ 57,517,000
Wholesale Sales (1963)	$ 39,003,000
Farm Products Sold (1964)	$ 17,866,000
Service Receipts (1963)	$ 8,916,000
Mineral Industry Receipts (1963)	$178,903,000
Total Vehicles Registered (1963)	30,709
Passenger Vehicles Registered (1964)	17,740
Total Employment (1965)	15,080
Wages (1st Quarter 1965 x 4)	$ 37,763,580
Manufacturing Establishments, Employees - - - (1st Quarter 1965)	416
Value Added by Manufacturing (1963)	$ 4,491,000
Total Local Bonded Debt (1963)	$ 16,152,000

By far the largest dollar volume shown in the above table is accounted for by "Mineral Industry Receipts". Referring to Figure 5-3, the two down-trending factors of "Value Added by Manufacture" and "Farm Products Sold" totaled less than 23,000,000 dollars which is only approximately 13% of the rapidly up-trending "Mineral Industry Receipts". This indicates a sugnificant economic growth situation.

REEVES - WARD - WINKLER

REGION

ECONOMIC AND FINANCIAL DATA 17

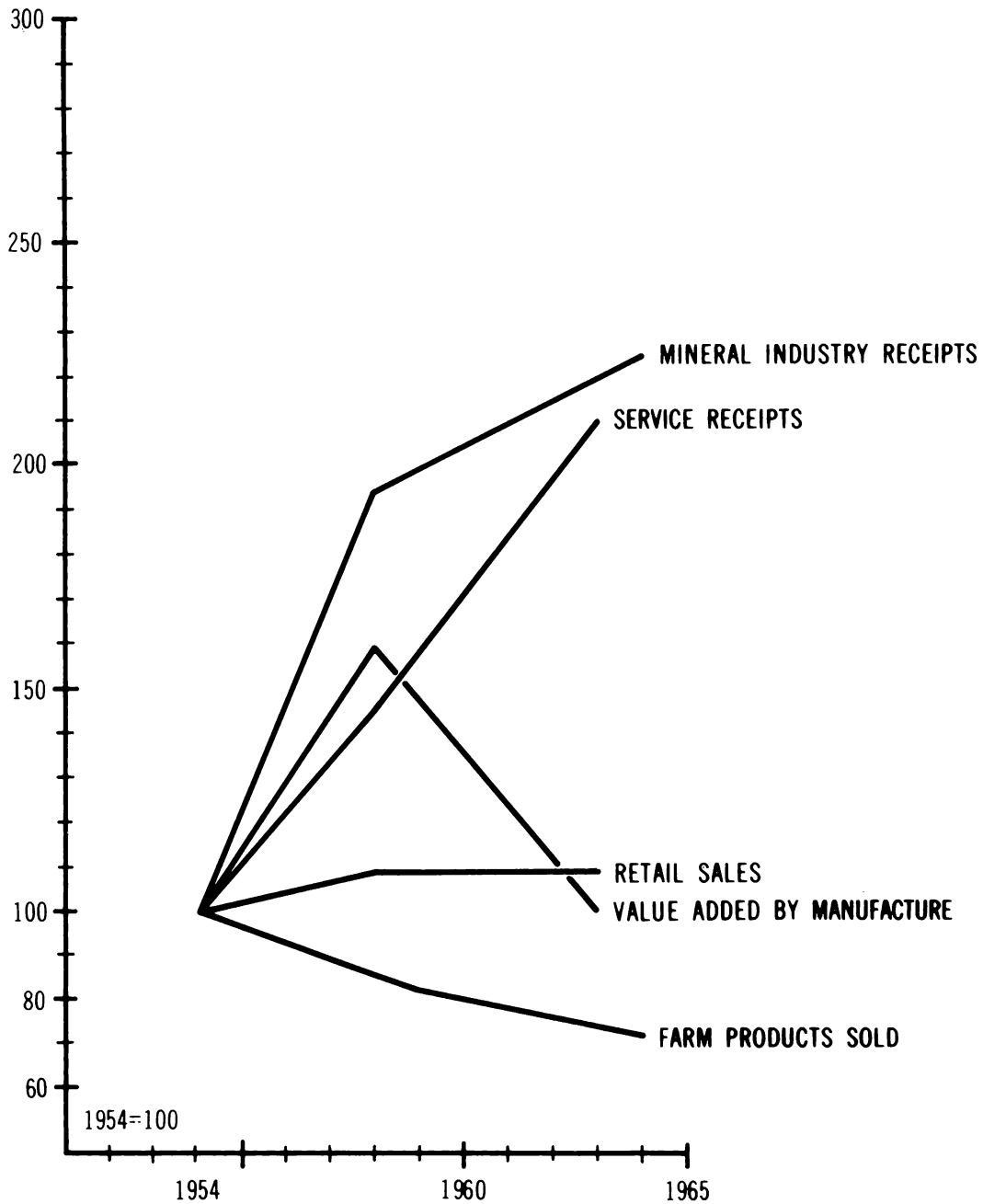


FIGURE 5-3

5.5 MUNICIPAL AND INDUSTRIAL WATER RESOURCES

5.5.1 Ground Water [8]

The Reeves-Ward-Winkler Region is located in the Rio Grande Basin. The primary aquifer in this region is the Cenozoic Alluvium. Secondary aquifers in the region are the Santa Rosa Sandstone, Rustler Formation and the Capitan Reef Complex and Associated Limestones.

Ground water in the Cenozoic Alluvium usually occurs under water table conditions; however, in places it is confined and exhibits artesian characteristics. The movement of ground water in the alluvium is generally towards the Pecos River. However, because of heavy development of irrigation wells, the direction of ground water movement has been altered in some areas. Heavy pumpage of ground water in central Reeves County, northwestern Pecos County, and other extensively developed areas has lowered the water table so that the hydraulic gradient slopes toward these areas. This results in ground water moving toward the heavily pumped areas from all directions.

5.5.2 Surface Water

Surface water in this region generally is slightly to moderately saline and is not suitable for municipal and industrial use. However, surface water is of a quality suitable for irrigating some crops and is used primarily for this purpose.

5.5.3 Water Resources Data [8] [33]

Figure 5-4 provides data on the most recent analysis of water in the distribution systems and at the wells, as shown.

Figure 5-5 provides a summary of municipal and industrial water resources for the Reeves-Ward-Winkler Region. Data covering aquifer storage and recharge rate were not available for Winkler County so that resources were assumed equal to water requirements in this county only.

Pecos makes use of ground water as the principal source of its municipal and industrial water.

Southeast Pyote well field located in Ward County, 25 miles east of the City produces ground water from the Cenozoic Alluvium which overlays the Santa Rosa Aquifer. Recent data indicate that the Southeast Pyote well field has recoverable storage of 53,000 acre-feet and recharge of 300 acre-feet per year.

WATER SOURCE ANALYSIS

REEVES - WARD - WINKLER REGION

	Kermit (Dist. Sys.)	Pecos (Dist. Sys.)	Monahans City Wells	Monahans Country Club	Monahans Hogg Ranch
Iron - Fe	0.02ppm	0.04ppm	0.15ppm	0.15ppm	0.30ppm
Manganese - Mn		0.05			
Calcium - Ca	40	62	407	378	117
Magnesium - Mg	0.05	30	153	76	83
Sodium & Potassium (Na+K)	14	249	97	166	44
Bicarbonate - HCO_3	126	233			
Sulfate - SO_4	32	264	318	335	71
Chloride - C	13	247	202	222	50
Fluoride - F	1.4	3.7		0.7	
Nitrate - NO_3		6.0			
Dissolved Solids	236	1100	1004	1077	414
Total Hardness as $CaCO_3$	328	277	560	454	200
Specific Conductance (Micromhos at 25°C)	336	1914			
pH	8	7.8	7.3	7.3	7.6

FIGURE 5 - 4

REEVES - WARD - WINKLER REGION

	Aquifer Yield* AFY	Recoverable Storage* AF	TDS (Average)	Available in Region	Remarks
Pecos Half of Block 16 University Land		250,000	1,000	0	Well Field Not Developed
Southeast Pyote Well Field Ward County - 1962	300	53,500	969	53,500 AF + 300 AFY	Used in summer months only
Worsham Well Field Reeves County	700		474	700 AFY	Used in winter months only
Kermit City Well Field			236		
Monahans Hogg Ranch Well Field	1,000	150,000	414	150,000 AF + 1,000 AFY	As of 1957
City Wells			1,004	480 AFY	Used Summer Months Only
Country Club Wells			1,007		Not in Use Since 1957
Half of University Block 16		250,000	1,000	0	Well Field Not Developed

* The numbers in these columns refer to that part of the aquifer in the well field or land under lease.

FIGURE 5 - 5

Worsham well field located in Reeves County 10 miles southeast of the City produces ground water from the Santa Rosa aquifer. The quantity of water recoverable from storage is unknown. However, it is estimated that the field can produce 700 acre-feet per year perennially.

Kermit's principal source of water is from the City well field which produces water from the Santa Rosa aquifer. Available data suggests that the average coefficient of transmissibility in the Kermit area is about 25,000 gpd/ft. The high transmissibility for the Santa Rosa is possibly due to fracturing of the formation associated with the geologic structural pattern of the area. This transmissibility decreases considerably outside the city, and since the exact locations of the fractures are not known, an estimate of ground water availability to meet the city's future requirements cannot be made. The Santa Rosa receives recharge through the overlying Cenozoic Alluvium, which itself is rather easily infiltrated by precipitation. Present static water levels are about 90 feet below land surface, and the top of the water bearing interval of the Santa Rosa is about 230 feet below land surface.

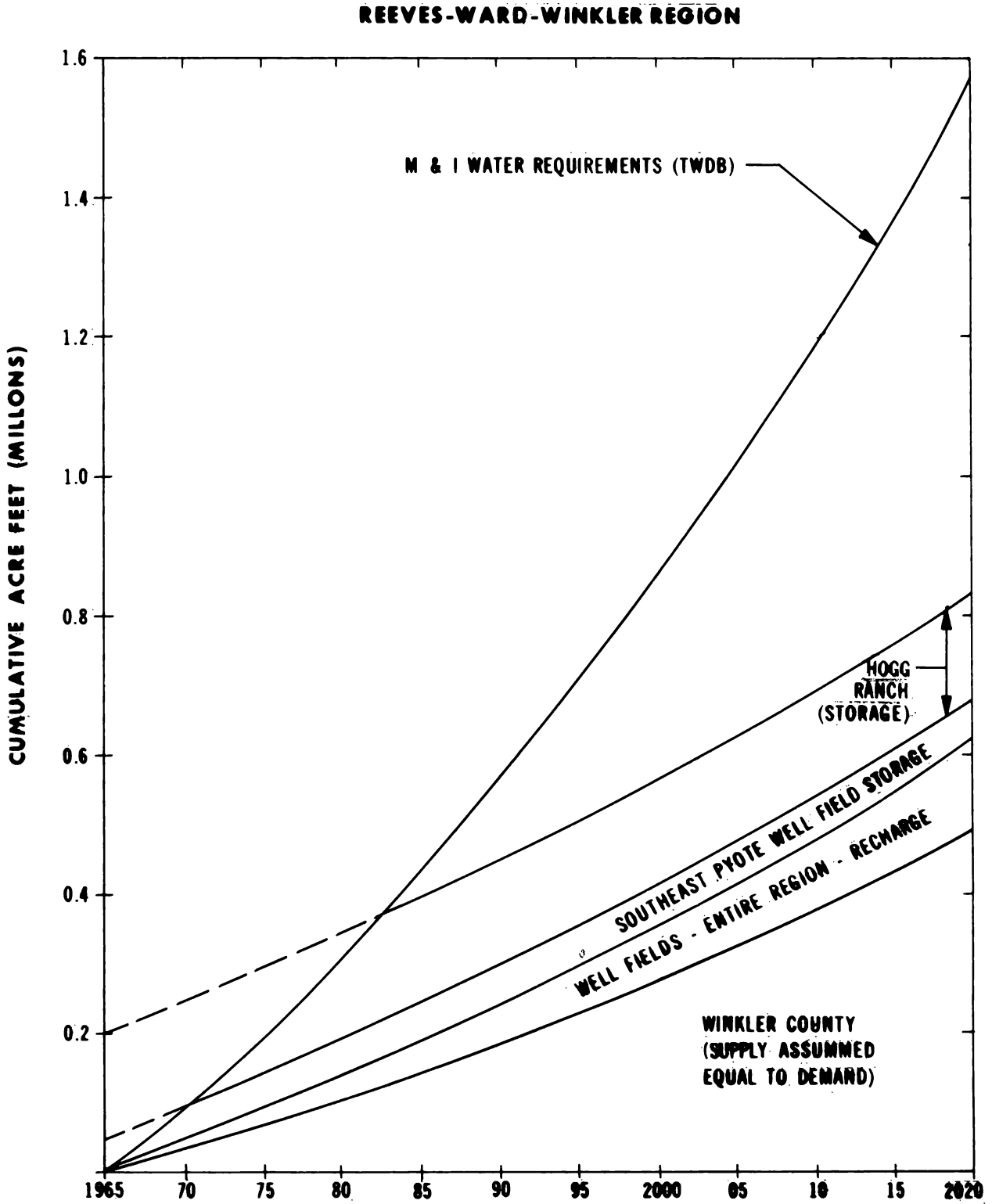
Monahan's principal source of water is from the City's Hogg Ranch well field /21/ which produces water from the Cenozoic Alluvium aquifer with well depths about 400 feet deep. In 1957, in was estimated that 150,000 acre feet of water were in storage under the Hogg Ranch tract./33/ The annual recharge of the field is estimated to be 1,000 acre feet per year. The static water level has declined 3 feet in the last 5 years. The City has 11,000 acres under lease in the Hogg Ranch field. Lease fee is $1 per acre per year. The field is presently under a 10 year lease with an option for a 10 year renewal.

West Monahans well field is located within the city limits. The wells penetrate shallow sand and gravel of the Alluvium and Santa Rosa Formation. This well field produces water only in the summer time.

Country Club well field is located northeast of the City. The wells at the Country Club have not been used for about eight years. The field is presently under lease to the Monahan's Country Club but could be returned to city use in an emergency.

5.5.4 Mass Diagram

Analysis of water data can be simplified by use of a mass diagram which shows cumulative quantities of water with respect to time. Figure 5-6 shows mass diagrams for the water resources of the region. Also shown is a mass curve for water demand based on data provided by the Texas Water Development Board.



MASS DIAGRAM

FIGURE 5-6

The mass diagrams of Figure 5-6 have been drawn on the basis that the Winkler County supply is equal to its water requirements; this was done because of lack of specific data regarding the water supply resources in Winkler County. This expedient enabled the preparation of mass diagram data for analysis.

The mass diagram shows that the total region well field recharge is inadequate to meet the municipal and industrial water requirements of the region, so that the deficiency is being supplied from storage.

The mass diagram shows separate quantities of storage for convenience. However, this should not be interpreted to mean that the storage from one well field, such as the Southeast Pyote well field, would be drawn down and exhausted completely whereupon the Hogg Ranch storage would be utilized. Instead normal operations would diversify the draw-down from the separate well fields even if they were operated as a single system which at present they are not.

The mass diagram shows that present water resources in the region will have to be supplemented by approximately 1983.

5.6 POSSIBLE FUTURE WATER SOURCES

The following list shows the possibilities for providing additional water sources to meet prospective growth in water demand:

- Import water from other areas.
- Desalt local brackish water.
- Reclaim waste water.

Importation of water - the Texas Water Development Board has under active consideration the possibility of importing water to areas in Texas from the Mississippi River to meet municipal, industrial, irrigation and mining water needs. Preliminary estimates by the Board indicate that the cost of water delivered to Reeves-Ward-Winkler area from East Texas, and out-of-State sources can be as much as 40¢ to 45¢ per thousand gallons. To this cost would have to be added the cost of conventional water treatment after delivery to Reeves-Ward-Winkler region. Volumes of water potentially available, possible routings and costs of moving water to and across Texas from the Mississippi River presently are under study by the Board, the U. S. Army Corps of Engineers and the Bureau of Reclamation, U. S. Department of the Interior.

Desalting has demonstrated its increasing importance for supplying water of good quality; costs have been reduced significantly during the last ten years. This report explores the state of the art of the technology and presents data in the subsequent sections of this chapter on the application of desalting in the Reeves-Ward-Winkler Counties area.

Reclaiming waste water from return flows has the potential for significantly increasing the life of water reserves. This requires employment of some process to condition this water to make it satisfactory for municipal and industrial use. Return flows can also serve as a source of feedwater for desalination, particularly in areas where brackish or saline water supplies are limited. A significant percentage of the water used in an area is available as return flow. Extensive research into treatment of return flows has been in progress in the Federal Water Polution Control Administration and other agencies. The feasibility of reclamation has been demonstrated and emphasis is being placed on efforts to reduce costs. It appears that the reclaimed product can meet U.S. Public Health Service Standards for municipal and industrial water, but there may remain esthetic objections to be overdome to gain public acceptance of this source.

One of the interesting advantages derived from reclamation of return flows is that it is estimated that salinity increases only 300 to 400 ppm for each use. Desalting the return flows only by this amount permits application of desalting systems which will yield low cost water.

Figure 5-7 shows return flow data furnished by the Texas Water Development Board.

RETURN FLOWS

REEVES - WARD - WINKLER REGION

RETURN FLOW	1970	1980	1990	2000	2010	2020
	Acre Feet Per Year					
Kermit	1,936	2,108	2,304	2,515	2,745	2,991
Other	683	747	819	917	1,013	1,119
Winkler County Total	2,619	2,855	3,132	3,432	3,758	4,110
Monahans	2,505	2,954	3,275	3,627	4,013	4,436
Other	457	599	688	790	911	1,049
Ward County Total	2,962	3,553	3,963	4,417	4,924	5,485
Pecos	1,466	1,797	2,046	2,336	2,675	3,070
Other	130	162	190	221	257	299
Reeves County Total	1,596	1,959	2,236	2,557	2,932	3,369
Region Total	7,177	8,367	9,331	10,406	11,614	12,964
	Million Gallons Per Day					
Kermit	1.73	1.88	2.06	2.25	2.45	2.67
Other	.61	.67	.74	.82	.91	1.00
Winkler County Total	2.34	2.55	2.80	3.07	3.36	3.67
Monahans	2.24	2.04	2.924	3.24	3.58	3.96
Other	.40	.53	.616	.70	.82	.94
Ward County Total	2.64	3.17	3.54	3.94	4.40	4.90
Pecos	1.31	1.60	1.83	2.09	2.39	2.74
Other	.12	.15	.17	.23	.32	.27
Reeves County Total	1.43	1.75	2.00	2.28	2.62	3.01
Region Total	6.41	7.87	8.34	9.29	10.38	11.58

Source: Texas Water Development Board

FIGURE 5 - 7

5.7 DESALTING POSSIBILITIES

For purposes of this study in estimating preliminary costs for supplying desalted water on a regional basis, a case was assumed which considered that the cities of Kermit, Monahans, Pecos and Wink would be tied together in a common system which would include a desalting plant in the vicinity of Kermit.

Full advantage was taken of existing pipelines operated by present authorities of the cities of Kermit, Wink, Monahans, and Pecos. The lengths and sizes of additional pipeline facilities and pumping facilities were approximated to establish preliminary costs. No investigation was made of capacities or conditions of existing pipelines and pumping stations. This determination is left for investigation in any future study.

Figure 5-1 shows an approximate desalting plant location and assumed pipeline and facilities for inter-connection with existing pipelines. Plant location and straight line pipeline routing are shown only for the purpose of arriving at approximate preliminary costs.

After investigation into available saline water supplies, it was decided that consideration should be given to the feasibility and cost of utilizing Capitan Reef water. Figure 5-8 shows a recent analysis of Capitan Reef well water as furnished by the Texas Water Development Board. This water, when used as feedwater for a desalting plant has several undesirable qualities in addition to its high salinity content (6715 TDS) and for most desalting processes will require treatment prior to desalination.

The water has a high non-carbonate hardness (calcium sulfate) which necessitates soda-ash treatment to prevent precipitation even with modest concentration ratios. Some water sample analyses indicated that hydrogen sulfide may be present in a concentration as high as 400 ppm compared with 180 ppm for a recent sample A recent analysis has shown chemical oxygen demand as 170 ppm.

For purposes of this report, chemical treatment of the Capitan Reef feedwater has been investigated [39] and a preliminary determination of the required treatment has been derived. (Refer to Chapter 2). For the reverse osmosis process, feedwater treatment costs provide for the removal of hydrogen sulfide and the addition of sodium tripolyphosphate (STPP) [40] .

For purposes of this study, it was assumed that a well field would be established approximately three miles from the City of Kermit. The feedwater costs provide for the installation of a suitable well

REEVES - WARD - WINKLER REGION

ANALYSIS OF
SALINE WATER FOR DESALTING PLANT
FEED

	KERMIT CAPITAN REEF
Temperature	90
Iron - Fe	0.02 ppm
Manganese - Mn	0.05
Calcium - Ca	780
Magnesium - Mg	310
Sodium & Potassium (Na+K)	950
Bicarbonate - HCO_3	335
Sulfate - SO_4	2,635
Chloride - Cl	1,700
Fluoride - F	4.2
Nitrate - NO_3	0.4
Hydrogen Sulfide H_2S	180
Chemical Oxygen Demand	170
Dissolved Solids (TDS)	6,715
Total Hardness as $CaCO_3$	2,980
Specific Conductance (Micromhos at 25°C)	15,120
pH	7.3

FIGURE 5 - 8

field and facilities to convey the feedwater to the desalting plant site. However, it should be noted that there are two major oil companies having pipeline facilities near Kermit handling Capitan Reef water for injection into oil bearing zones for recovery of oil. Preliminary discussions were held with representatives of these companies regarding purchase of Capitan Reef feedwater for the desalting plant. No final figures were discussed. In any subsequent feasibility study for desalting utilizing Capitan Reef water, it would be desirable to renew discussions to determine the relationship of price of brackish water delivered by them to the cost of brackish water from a municipal well field to supply feedwater for a desalting plant.

No investigation was made regarding problems associated with integrating the desalted water supply with the conventional supply of water. This should be explored in future feasibility studies.

The 6,715 ppm salinity is low enough to indicate application of a membrane process. The salinity is of a high enough order to burden the electrodialysis process with the need for probably five stages with resulting higher capital costs. Also, due to the large amount of salts which must be removed, the power costs are higher than for feedwater having lower salinity.

The cost of product water for a 5 MGD reverse osmosis plant at the assumed location amounts to 65.1 per thousand gallons. This water cost is broken down into the following components:

- Desalting Plant	31.7 ¢/Kgal.
- Water Treatment	8.5 ¢/Kgal.
- Feedwater Supply	8.5 ¢/Kgal.
- Brine Disposal	5.9 ¢/Kgal.
- Product Water Conveyance	10.5 ¢/Kgal.
Total	65.1 ¢/Kgal.

The cost of product water for a 5 MGD VFVC desalting plant at the assumed location amounts to 82.2¢ per thousand gallons. This water cost is broken down into the following components:

- Desalting Plant	61.4 ¢/Kgal.
- Water Treatment	0 ¢/Kgal.
- Feedwater Supply	7.3 ¢/Kgal.
- Brine Disposal	3.0 ¢/Kgal.
- Product Water Conveyance	10.5 ¢/Kgal.
Total	82.2 ¢/Kgal.

5.8 ANALYSIS AND COMPARISONS

Detailed cost breakdown figures for the application of the reverse osmosis and vacuum freeze vapor compression processes to the utilization of Capitan Reef feedwater are included at the end of this section as Figures 5-9 and 5-10.

The lowest cost of product water delivered to the cities in this region is 65.1 cents per thousand gallons by use of the reverse osmosis process. This compares with 8 to 10 cents per thousand gallons for University Block 16 supply and the estimated 40¢ to 45¢ per thousand gallons from the previously described importation plan.

The high cost of desalted water is primarily due to the need to utilize Capitan Reef as feedwater. The high salinity does not make it economical to employ the electrodialysis process.

The chemical constituents in the feedwater including hydrogen sulfide necessitate the application of extensive feedwater treatment to make it suitable for the reverse osmosis process. Total cost of feedwater treatment amounts to 11.4 cents per thousand gallons; when credited with 2.9 cents per thousand gallons for by-product sulfur the cost of treatment is reduced to 8.5 cents per thousand gallons.

The remaining components of total water cost include the well field for feedwater supply, the cost of the pipelines for product water conveyance and the cost of brine disposal. All of these component costs are of considerable magnitude, which results in the high cost of delivered product water.

In studying the application of desalting plants to this region, consideration was given to all processes that appeared to have applicability. The distillation processes required feedwater treatment for a greater quantity due to necessity of lower concentration ratios, and also additional feedwater requirements for cooling tower operation. Electrodialysis also requires extensive feedwater treatment and due to the high salinity, requires high capital investment and large power costs.

Data secured from a manufacturer [44] on the application of the vacuum-freezing-vapor-compression (VFVC) process for a 5 MGD plant yielded delivered costs of 82.2 cents per thousand gallons. Manufacturer's engineers are of the opinion that feedwater treatment will not be necessary. Because of the absence of actual test information, the need for feedwater treatment should be carefully investigated before any application of desalting employing Capitan Reef feedwater.

COST BREAKDOWN

THE RALPH M. PARSONS COMPANY

REEVES - WARD - WINKLER CASE II-1

PROCESS R/O ; CAPACITY 5 MGD; OUTPUT 1,650,000 Kgal/yr; INTEREST 3-1/2%; PLANT LIFE 30 YRS; PIPELINE LIFE 50 YRS

	CARRYING CHARGE MULTIPLIER	DESALT PLANT		WATER TREATMENT		FEEDWATER		BRINE DISPOSAL		PRODUCT CONVEY.	
		CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3
CAPITAL COST CENTERS											
1. Plant & Equipment	.0544	2,370	126.1								
2. Replaceable Items	1.035	80	82.5								
3. Water Treatment	.1202			210	25.4						
4. Well Field	.0426					1,246	53.0				
5. Pipeline	.0426									1,930.4	82.3
6. Pumping Station											
7. Brine Disposal											
8. Indirect Capital Costs	.0544	408	22.2	36	2.0						
9. Land Costs	.035	4	.1	1						4.3	.1
10. Working Capital	.035	87	3.1	36	1.3	23.3	.8			28.5	1.0
11. Cooling Towers											
TOTAL CAPITAL COSTS →		2,899		283		1,269.3		693		1,963.2	
RECURRING COST CENTERS	PERCENT										
12. Taxes											
13. Insurance											
TOTAL ANNUAL FIXED COSTS →			234.0		28.7		53.8		37.7		83.4
By-Product Sulfur Credit					(48.5)						
OPERATION & MAINTENANCE COST CENTERS											
15. Operating Labor			74.0								
16. Maintenance Labor					18.0		52.0				88.1
17. General & Administrative			22.2								
18. Supplies & Maintenance Materials			28.1		141.7						
19. Chemicals											
20. Fuel											
21. Electric Power			165				33.8				2.4
TOTAL O & M COSTS →			289.3		159.7		85.8		59.2		90.5
TOTAL FIXED PLUS O & M COSTS →			523.3		139.9		139.6		96.9		173.9
COMPONENT WATER COSTS, ¢/Kgal →		31.7		8.5		8.5		5.9		10.5	
TOTAL WATER COST → 65.1 ¢/Kgal											

Treatment costs include H_2S removal and sodium-tripolyphosphate treatment. The acid used for feedwater treatment lowers the pH, and is assumed to obviate the need for process chemicals.

Feedwater treatment plant life, 10 yrs.

FIGURE 5 - 9

COST BREAKDOWN

REEVES - WARD - WINKLER REGION

THE RALPH M. PARSONS COMPANY

PROCESS VFVC ; CAPACITY 5.0 MGD; OUTPUT 1,650,000 Kgal/yr; INTEREST 3.5 %; PLANT LIFE 30 YRS; PIPELINE LIFE 50 YRS

	CARRYING CHARGE MULTIPLIER	DESALT PLANT		WATER TREATMENT		FEEDWATER		BRINE DISPOSAL		PRODUCT CONVEY.	
		CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3
CAPITAL COST CENTERS											
1. Plant & Equipment	.0544	5,605	305								
2. Replaceable Items											
3. Water Treatment											
4. Well Field	.0426					1,145	48.9				
5. Pipeline	.0426									1,930.4	82.3
6. Pumping Station											
7. Brine Disposal											
8. Indirect Capital Costs	.0544	952	51.8								
9. Land Costs	.035	14	.5							4.3	.1
10. Working Capital	.035	145	5.1			21.3	.7			28.5	1.0
11. Cooling Towers											
TOTAL CAPITAL COSTS →		6,716				1,166.3		320		1,963.2	
RECURRING COST CENTERS	PERCENT										
12. Taxes											
13. Insurance											
TOTAL ANNUAL FIXED COSTS →			362.4				49.6		17		83.4
OPERATION & MAINTENANCE COST CENTERS											
15. Operating Labor			80.1								
16. Maintenance Labor			17.9				48.0				
17. General & Administrative			29.4								88.1
18. Supplies & Maintenance Materials			49.5								
19. Chemicals			43.8								
20. Fuel											
21. Electric Power			515.0				30.7				2.4
TOTAL O & M COSTS →			735.7				78.7		32		90.5
TOTAL FIXED PLUS O & M COSTS →			1098.1				128.3		49		173.9
COMPONENT WATER COSTS, ¢/Kgal →		61.4		0		7.3		3.0		10.5	
TOTAL WATER COST → 82.2 ¢/Kgal											

FIGURE 5 - 10

5.9 BRINE DISPOSAL

The cost of brine disposal by deep well injection for this area was calculated using the Bell Canyon Formation as the disposal zone for volumes ranging from 0.68 MGD to 1.4 MGD. The lowest calculated cost for injection for this case is tabulated in Figure 5-11.

REEVES - WARD - WINKLER REGION

BRINE DISPOSAL DATA

INJECTION RESERVOIR CHARACTERISTICS AND DESIGN AND COST DATA FOR BRINE DISPOSAL BY SUBSURFACE INJECTION IN SELECTED CASES

Item	Case II-1 RO	Case II-2 VFVC
Product Water		
Capacity, MGD	5.0	5.0
Quality, TDS (ppm)	500	500
Brine Effluent		
Volume, MGD	1.4	0.68
Quality, TDS (ppm)	30,070	55,000
Disposal Zone		
Formation or geologic age	Bell Canyon	Bell Canyon
Lithology	Sandstone	Sandstone
Depth below surface	4,500 ft.	4,500 ft.
Thickness	500 ft.	500 ft.
Well Field Data		
Number of wells	6	2
Distance to plant	1 mi.	1 mi.
Total Cost (million dollars)		
Capital	$0.693	$0.320
Annual	0.097	0.049
Total Unit Costs		
Brine basis per thousand gallons	20.97¢	22.02¢
Product basis, per thousand gallons	5.87¢	3.0¢

FIGURE 5 - 11

ECTOR - MIDLAND REGION

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ECTOR - MIDLAND REGION

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6. ECTOR - MIDLAND REGION

6.1 INTRODUCTION AND SUMMARY

For the purposes of this report, Ector and Midland counties have been combined into one region to determine the costs of desalted water in relationship to the cost of water from alternative sources to supply the future water requirements of the area. This region is located on the western edge of the Colorado River basin. The major cities in the region are the City of Odessa, located in Ector County and the City of Midland, located in Midland County.

This region was selected for study to determine the cost consideration of providing desalted water for improving the quality of the supply to the City of Midland and for supplementing the supply of the Colorado River Municipal Water District which serves Odessa and other cities nearby.

Projections of water requirements for the Ector-Midland Region indicate that the estimates for municipal and industrial water in 2020 will be twice as great as the estimates for 1968. In order to provide for these needs it has been recognized that the application of desalting technology should be considered as one of the possible sources of future water supply. This study is a preliminary investigation of the feasibility and cost of desalting brackish ground water in the Ector-Midland region.

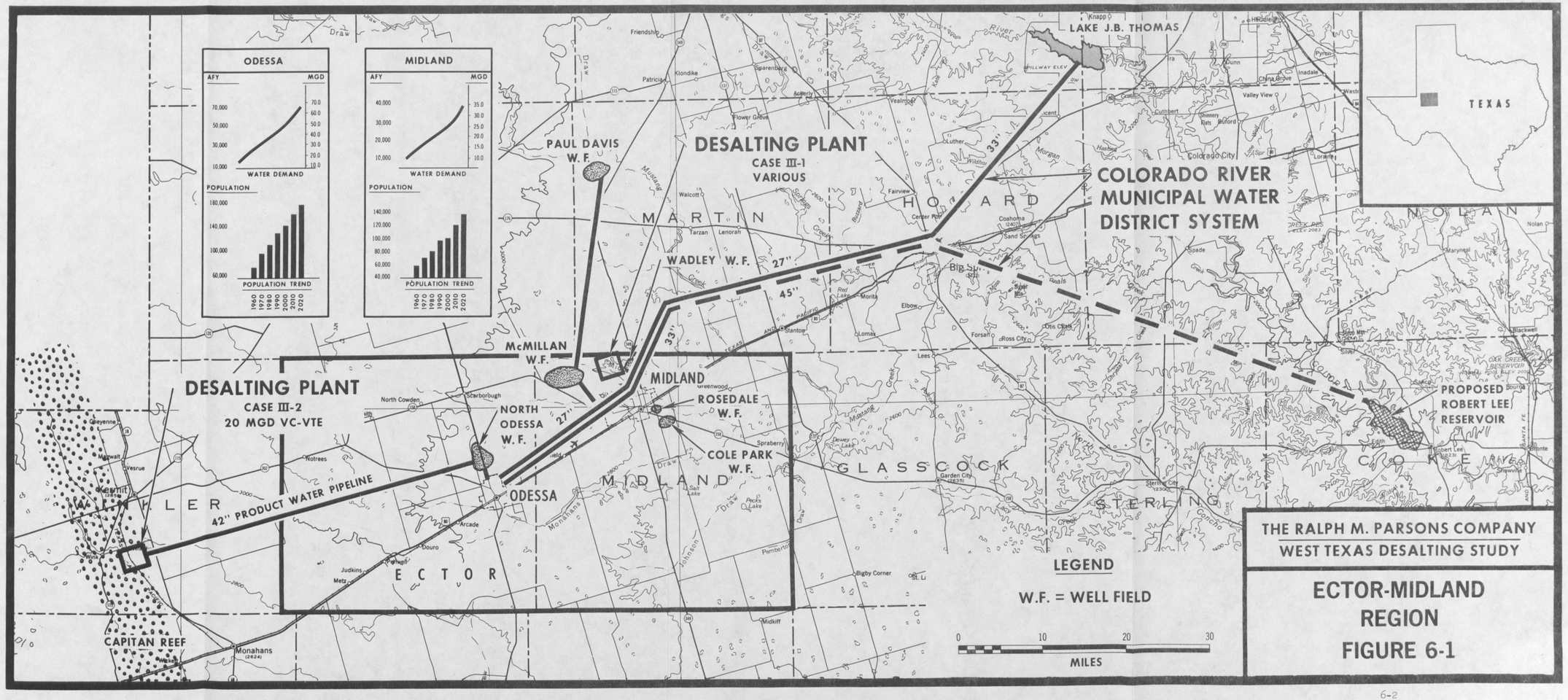
Plant size was selected on a more or less arbitrary basis, keeping in mind water resources and future requirements. The information presented herein can be used to make an appraisal of the relationship of plant size to total water requirements.

Problems associated with feedwater supply, brine disposal and integration of desalted water into the present system have been investigated only briefly. A detailed investigation of various solutions and their costs should be included in any future study.

6.1.1 Summary

Figure 6-1 represents a map of the Ector-Midland region showing a 5 MGD desalting plant at Midland and a 20 MGD desalting plant in Winkler County for supplying Odessa.

In exploring the possibilities for the application of desalting plants in the Ector-Midland Region, it appeared that these plants should be considered in relationship to the existing system of the Colorado River Municipal Water District and its contracts with the City of Odessa and the City of Midland.


ODESSA
AFY
MGD
70,000
50,000
30,000
10,000
70.0
60.0
50.0
40.0
30.0
20.0
10.0
WATER DEMAND
POPULATION
180,000
140,000
100,000
60,000
POPULATION TREND
1960
1970
1980
1990
2000
2010
2020
MIDLAND
AFY
MGD
40,000
30,000
20,000
10,000
35.0
30.0
25.0
20.0
15.0
10.0
WATER DEMAND
POPULATION
140,000
120,000
100,000
80,000
60,000
40,000
POPULATION TREND
1960
1970
1980
1990
2000
2010
2020
PAUL DAVIS W.F.
DESALTING PLANT
CASE III-1
VARIOUS
LAKE J.B. THOMAS
COLORADO RIVER MUNICIPAL WATER DISTRICT SYSTEM
WADLEY W.F.
27"
45"
33"
McMILLAN W.F.
DESALTING PLANT
CASE III-2
20 MGD VC-VTE
NORTH ODESSA W.F.
ROSEDALE W.F.
COLE PARK W.F.
42" PRODUCT WATER PIPELINE
CAPITAN REEF
PROPOSED ROBERT LEE RESERVOIR
TEXAS
MARTIN
HOWARD
MITCHELL
NOLAN
COKE
GLASSCOCK
STERLING
ECTOR
MIDLAND
ODESSA
Knapp
Hobbs
Dunn
Inadale
Pyron
Valley View
Cuthbert
Colorado City
Loraine
Maryneal
Spade
Big Spring
Coahoma
Sand Springs
Center Point
Fairview
Walcott
Tarzan
Lenorah
Morita
Elbow
Lomax
Forsan
Ora Chalk
Ross City
Stanton
Blackwell
Sweetwater
Lees
Greenwood
North Cowden
Scarborough
Notrees
Cheyenne
Maxwalt
Wesrue
Gardendale
Arcade
Douro
Powell
Judkins
Metz
Monahans
(2624)
Wickett
Pembertor
Johnson
Bigby Corner
Midkiff
Garden City
Sterling City
Spraberry
Dewey Lake
Peck's Lake
Big Spring
Robert Lee
Oak Creek Reservoir
Elev. 2070
Elev. 2083
Elev. 2077
Elev. 2000
Elev. 2083
Elev. 2070

The CRMWD supplies the entire needs of the City of Odessa, but has contracted to supply only certain stipulated quantities to the City of Midland begining in 1970. On this basis two cases were established: (1) providing a desalting plant primarily for the City of Midland to improve the quality of its water supply to 500 ppm as recommended by the United States Public Health Service (USPHS); (2) providing a desalting plant primarily for the City of Odessa to supplement CRMWD supply when the existing 27 inch and 33 inch pipelines are operating at their maximum capacities.

* * * * * * * * * * *

Regarding quality improvements for the City of Midland, it was calculated that city water would have a salinity ranging from 675 ppm in 1970 to 770 ppm in the year 2020. These calculations were based on CRMWD water containing 500 ppm total dissolved solids. The quality of city water after CRMWD begins deliveries in 1970 will be greatly improved over present quality. The data on quality improvement for Midland in this report will provide city planners with an estimate of costs for further reducing salinity to USPHS standards.

Feedwater was assumed to be obtained from the Paul Davis well field. When these supplies become exhausted it will be necessary to develop T-Bar Ranch. The plant was assumed to be located near a proposed water-treatment plant [24]. Inasmuch as water is being supplied over an existing 33 inch pipeline from the Paul Davis well field, assumed values of capital and operating costs were established to permit determination of the cost of feedwater supplies.

Detailed cost breakdowns were developed for three different processes which yielded the following costs of 500 ppm product water:

- Distillation Process . . . . . 63.4¢ per Kgal.
- Reverse Osmosis Process . . . . . 52.7¢ per Kgal.
- Electrodialysis Process . . . . . 39.4¢ per Kgal.

When product water from the electrodialysis process was mixed with CRMWD 500 ppm water to meet the total water requirements of the City of Midland, it was calculated that delivered water would cost 30.0 cents per thousand gallons compared with 20.4 cents per thousand gallons of higher salinity water derived from a blend of CRMWD and Paul Davis water. In other words, the cost of improving the quality of delivered water amounts to 9.6 cents per thousand gallons.

* * * * * * * * * * *

For the City of Odessa the vapor compression, vertical tube evaporator (VC-VTE) process now under development by the office of Saline Water is assumed for application. This process shows promise of providing water at lower cost than other distillation processes. The Capitan Reef is the only known large supply of saline ground water in the region and was assumed to supply the feedwater for this process. The plant costs were based on its location in Winkler County so that pipeline costs would be lower due to conveying the smaller quantity of product water compared with the larger quantity of feedwater.

Use of Capitan Reef feedwater presented the need for extensive and costly feedwater treatment to remove the high concentration of hydrogen sulfide and reduce the calcium ion concentration to acceptable limits. The treatment process results in recovery of by-product sulfur, the revenue from which was credited to the feedwater treatment costs.

Fuel for the VC-VTE plant was assumed to be purchased at 22 cents per million Btu. However, in any specific application of a desalting plant requiring natural gas for fuel, consideration should be given to the possibility of obtaining gas at the well field before it is introduced into interstate pipelines. It is possible that such gas could be obtained at lower cost delivered to the desalting plant provided that satisfactory arrangements can be worked out between all parties concerned. The importance of this is emphasized by the fact that the cost of fuel accounts for over 57 percent of the O & M costs and almost 31 percent of the total cost of product water.

The total cost of water from the desalting plant delivered to the City of Odessa 85.8 cents per thousand gallons. For comparison, the Texas Water Development Board has under active consideration the possibility of importing water to areas in Texas from the Mississippi River to meet municipal, industrial, irrigation and mining water needs. Preliminary estimates by the Board indicate that the cost of water delivered to Odessa from East Texas, and out-of-State sources can be as much as 30¢ to 35¢ per thousand gallons. To this cost would have to be added the cost of conventional water treatment after delivery to Odessa. Volumes of water potentially available, possible routings and costs of moving water to and across Texas from the Mississippi River presently are under study by the Board, the U.S. Army Corps of Engineers and the Bureau of Reclamation, U.S. Department of the Interior.

Additionally, for purposes of comparing costs of product water with the cost of water supplied by CRMWD, rough estimates were made on the cost of delivering 20 MGD of CRMWD water from Robert Lee Reservoir to Odessa. This amounted to a total of approximately 34 cents per thousand gallons including 14 cents per thousand gallons for the cost of water itself.

6.2 WATER ADMINISTRATION AND FACILITIES

6.2.1 City of Odessa [25]

The City of Odessa, Texas is an incorporated city located in Ector County with an estimated 1967 population of 93,450.

The City of Odessa owns and operates the water distribution system and the treatment facilities. Water is provided by the Colorado River Municipal Water District derived from the north Odessa water well field, from Lake J. B. Thomas and from Martin County water well field. The cost of water from the Colorado Municipal Water District averages approximately 22 cents per thousand gallons prior to treatment and distribution. Treatment and distribution cost is estimated to be approximately 6 cents per thousand gallons.

Prior to 1951, the water supplies to Odessa were obtained from city owned wells north of the city in Ector County. The City experienced water shortages from 1945 to 1951, which required curtailment of summertime lawn irrigation.

Odessa is one of the founding cities of the Colorado Municipal Water District, which provides the City with its entire water supply. Odessa has turned over the city-owned wells to CRMWD. These wells still supply a small volume of water to the city during peak demand.

Storage Facilities in the City of Odessa includes 160 million gallons of surface storage, 3 million gallons of elevated storage and 7 million gallons of underground storage.

The Water Treatment Plant was completed in May, 1958 at a cost of $1,500,000. It is located at Gold and 42nd Streets, has a design capacity of 33 million gallons a day, and can handle 45 million gallons a day in overload condition. Treatment consists of floculation, slow and rapid mix, rapid sand filtration and chlorination.

The Sewage Treatment Plant is city owned and operated. It has a design capacity of 6 million gallons per day. The actual load at present is approximately 5.1 million gallons per day. Treatment consists of pre-aeration, primary clarification, final clarification, and sludge drying. All of the effluent is discharged for industrial users and irrigation use.

6.2.2 City of Midland

The City of Midland, Texas is an incorporated city located in Midland County with an estimated 1967 population of 70,400.

The City of Midland owns and operates several well fields, pipelines, and the water distribution system. Recently the City of Midland entered into a contract with the Colorado River Municipal Water District providing for water deliveries to the City of Midland to begin on January 1, 1970. The water to be delivered by the District will be untreated. To produce water of suitable quality, the CRMWD water will have to be processed in a treatment plant in contrast to the well water which is only disinfected prior to use. A recent engineering report /24/ recommends consideration of the installation of a treatment plant and a filter plant.

Storage facilities in the City of Midland include the following:

Edgewood	two 5.0 MG ground storage tanks
Edgewood	one 1.0 MG elevated tank
Shell Ave.	one 1.0 MG elevated tank
Roosevelt Ave.	one 2.25 MG ground storage tank
Weatherford St	one 0.3 MG elevated tank
McMilland Field. . . .	two 2.5 MG tank
Paul Davis Field . . .	one 3.0 MG tank

Note--MG = million gallons

6.2.3 Colorado River Municipal Water District

The Colorado River Municipal Water District (CRMWD) is a political subdivision which was organized by the Cities of Snyder, Big Spring and Odessa, Texas to provide adequate water for the three cities. Revenue bonds were sold to provide funds to construct the man made J. B. Thomas Lake.

The District completed its 14th full year of operation in 1966, furnishing 7.465 billion gallons of municipal water and 4.288 billion gallons of water for use in secondary oil recovery operation./37/

The CRMWD utilizes its Martin County well field aquifer for underground storage of surface water. The third year of this underground storage program ended March 21, 1966 with a total of 347 million gallons of water being stored in the aquifer. This program was resumed October 1, 1966. This method of storage has proved to be both economical and a satisfactory method of operation.

The CRMWD estimates that 100 percent of the surface water injected into the aquifer will be recovered. Water is recovered for approximately six months out of the year to meet summertime peak requirements of the City of Odessa.

Water is impounded in Lake J. B. Thomas by a dam located in the southwestern corner of Scurry County. At spillway level the reservoir contains 204,000 acre feet of water covering an area of about twelve and one-half square miles. The flow of the river into the reservoir is augmented by water diverted from Bull Creek /35/.

The surface water supply is supplemented by 29 district-owned wells in the southern portion of the Martin County well field. Additional supplies are provided by well fields at Odessa, Big Spring and Snyder, member cities of the district, from which they previously derived their water supplies.

The main water conveyance system consists of a sixteen mile 27" diameter pipeline from the reservoir to Snyder, a twenty-six mile, 33" diameter pipeline from the reservoir to Big Spring, a 45" diameter pipeline from Big Spring to the Martin County well field, and both a 27" diameter and 33" diameter pipeline from the Martin County well field to Odessa.

The Colorado River Municipal District has secured the necessary permits and has started construction of Robert Lee Dam and reservoir on the Colorado River in the northern portion of Coke County. Plans for the new lake show a capacity of 488,760 acre-feet of water; the lake, when filled, will yield an estimated 57,000,000 gallons per day. Cost of the new reservoir is estimated at $14,000,000 and total cost of the new project including pipelines, etc., will approximate $30,000,000 for which revenue bonds were sold September 8, 1966. A target date of early 1969 has been set for completion of the reservoir and certain water lines.

On May 10, 1966 a water sales contract was executed by the CRMWD and the City of Midland. Water deliveries to Midland will begin on January 1, 1970. The contract provides for 10,000 acre feet to be delivered during the year 1970, increasing annually to 20,000 acre feet during the 60th year.

Figure 6-2 shows the contract quantities of surface water to be furnished to the City of Midland by the Colorado River Municipal Water District.

City of Midland

Contract Quantities of Surface Water To Be Furnished To Midland

By The Colorado River Municipal Water District

And Estimated Total Water Demand

Year	Contract Quantities (AFY)	Contract Quantities (MGD)	Total Demand (MGD)	Year	Contract Quantities (AFY)	Contract Quantities (MGD)	Total Demand (MGD)
1970	10,172	9.08	13.11	1995	14,483	12.93	21.43
1971	10,345	9.28	13.50	1996	14,655	13.05	21.75
1972	10,517	9.36	13.89	1997	14,838	13.24	22.07
1973	10,690	9.54	14.29	1998	15,000	13.39	22.39
1974	10,862	9.70	14.68	1999	15,167	13.54	22.72
1975	11,034	9.85	15.07	2000	15,333	13.65	23.04
1976	11,207	9.98	15.46	2001	15,500	13.84	23.42
1977	11,379	10.16	15.85	2002	15,500	13.99	23.79
1978	11,552	10.31	16.25	2003	15,833	14.13	24.17
1979	11,724	10.47	16.64	2004	16,000	14.24	24.54
1980	11,897	10.62	17.03	2005	16,167	14.43	24.92
1981	12,069	10.77	17.31	2006	16,333	14.58	25.30
1982	12,241	10.93	17.59	2007	16,500	14.73	25.67
1983	12,414	11.08	17.86	2008	16,667	14.84	26.05
1984	12,586	11.20	18.14	2009	16,833	15.03	26.42
1985	12,759	11.39	18.42	2010	17,000	15.18	26.80
1986	12,931	11.54	18.70	2011	17,176	15.32	27.24
1987	13,103	11.70	18.98	2012	17,333	15.43	27.68
1988	13,276	11.82	19.25	2013	17,500	15.62	28.11
1989	13,448	12.00	19.53	2014	17,667	15.77	28.56
1990	13,621	12.16	19.81	2015	17,833	15.92	29.00
1991	13,793	12.31	20.13	2016	18,000	16.02	29.43
1992	13,966	12.43	20.46	2017	18,167	16.22	29.87
1993	14,138	12.62	20.78	2018	18,333	16.37	30.30
1994	14,310	12.77	21.10	2019	18,500	16.51	30.74
				2020	18,667	16.62	31.18

FIGURE 6 - 2

6.3 POPULATION AND WATER REQUIREMENTS

Planning for the development of municipal and industrial water facilities depends upon projections of future population and industrial growth. In this report, the quantitiy of fresh water required by each region is based on projections by the Texas Water Development Board.

The intent of the projections is to provide guidelines for orderly planning and development of future water supply facilities. The near term projections, i.e: the next 10 to 20 years, should be more reliable than those in the more distant future. In the near term interval, growth rates slower or faster than are anticipated are not likely to effect large changes in the dates at which projected population data are reached. On the other hand, for spans of 20 years in the future and beyond, the variation of actual population figures from present day estimates may become significant.

The large projected per capita per day use indicated for several cities is attributed to a large projected industrial water requirement. For simplicity in handling projected requirements of water used by industry located within a county but not within the confines of any city, the Texas Water Development Board allocated these requirements to the nearest city. This has the effect of showing a large water requirement for some of the cities in this report.

Where per capita consumption growth appears abnormal, it is anticipated that the availability of sufficient quantities of good quality water in the future will attract industry, thus modifying the historical growth pattern of per capita consumption.

Data on population and water requirements projected to the year 2020 for cities as well as county and region totals have been developed by the Texas Water Development Board as shown on Figure 6-3.

POPULATION AND WATER REQUIREMENT ESTIMATES
Ector - Midland Region

	1970	1980	1990	2000	2010	2020
POPULATION						
Ector County						
Odessa	99,061	116,611	131,049	147,275	165,510	186,002
Other	9,067	8,548	9,733	11,081	12,615	14,360
Total	108,128	125,159	140,782	158,356	178,125	200,362
Midland County						
Midland	73,730	84,886	95,573	107,604	121,150	136,402
Other	5,774	6,787	8,241	9,960	11,986	14,372
Total	79,504	91,673	103,814	117,564	133,136	150,774
Region Total	187,632	216,832	244,596	275,920	311,261	351,136
Big Spring*	48,264	60,000	70,984	79,335	88,714	99,201
Snyder*	15,470	17,218	19,094	21,174	23,481	26,040
M & I WATER REQUIREMENTS						
	Acre Feet Per Year					
Ector County						
Odessa	24,219	34,354	41,264	49,665	59,901	72,398
Other	1,173	1,267	1,437	1,622	1,819	2,023
Total	25,392	35,621	42,701	51,287	61,720	74,421
Midland County						
Midland	14,683	19,076	22,186	25,805	30,018	34,924
Other	476	598	697	814	948	1,104
Total	15,159	19,674	22,883	26,619	30,966	36,028
Region Total	40,551	55,295	65,584	77,906	92,686	110,449
Big Spring*	12,270	15,885	19,764	22,865	26,455	30,612
Snyder*	3,418	4,007	4,519	5,100	5,760	6,508
	Million Gallons Per Day					
Ector County						
Odessa	21.62	30.67	36.84	44.34	53.48	64.63
Other	1.05	1.14	1.30	1.44	1.62	1.81
Total	22.67	31.81	38.14	45.78	55.10	66.44
Midland County						
Midland	13.11	17.03	19.81	23.04	26.80	31.18
Other	0.42	0.53	0.62	0.73	0.85	0.98
Total	13.53	17.56	20.43	23.77	27.65	32.16
Region Total	36.20	49.37	58.57	69.55	82.75	98.60
Big Spring*	10.9	14.2	17.6	20.4	23.6	27.2
Snyder*	3.0	3.6	4.0	4.5	5.1	5.8

* Cities Not in Ector-Midland Region

Source: Texas Water Development Board

FIGURE 6 - 3

6.4 ECONOMIC AND FINANCIAL DATA

The cities of Midland and Odessa are the population centers of Midland and Ector Counties. The economy has long been based on oil. Farm production has remained fairly stable while value added by manufacture has been increasing. The area produces large mineral industry receipts, about 10 times the value of farm products and value added by manufacture together.

Midland is the home of over 250 petroleum related firms. Principal occupations include banking, wholesaling and distribution of oil and cattle.

Odessa is the location of a large new petrochemical complex. Major industries are natural gas, metal fabricating, and carbon-black plants.

The following table of economic data shows some interesting statistics of the two-county area:

Bank Deposits (1964)	$ 281,739,000
Effective Buying Income (1964)	$ 384,872,000
Retail Sales (1963)	$ 236,517,000
Wholesale Sales (1963)	$ 298,967,000
Farm Products Sold (1964)	$ 5,350,000
Service Receipts (1963)	$ 44,024,000
Mineral Industry Receipts (1964)	$ 286,098,000
Building Permits	$ 17,167,909
Total Vehicles Registered (1964)	106,203
Passenger Vehicles Registered (1964)	74,523
Total Employment (1965)	33,306
Wages (1st Quarter 1965 x 4)	$ 219,123,548
Manufacturing Establishments (1st Qtr.1965)	153
Manufacturing Establishments, 20 or more employees, (1st Qtr. 1964)	38
Manufacturing Establishments, Employees - (1st Qtr., 1965)	3,256
Manufacturing Establishments, Payroll - (1st Qtr., 1965 x 4)	$ 20,792,000
Value Added by Manufacturing (1963)	$ 70,225,000
Total Local Bonded Debt (1963)	$ 33,587,000

Referring to Figure 6-4, it can be seen that all of the factors show an up-trend with the exception of "Mineral Industry Receipts" showing a small down-trend due to receipts in Midland County having stabilized since 1958.

ECTOR - MIDLAND REGION
ECONOMIC AND FINANCIAL DATA 17

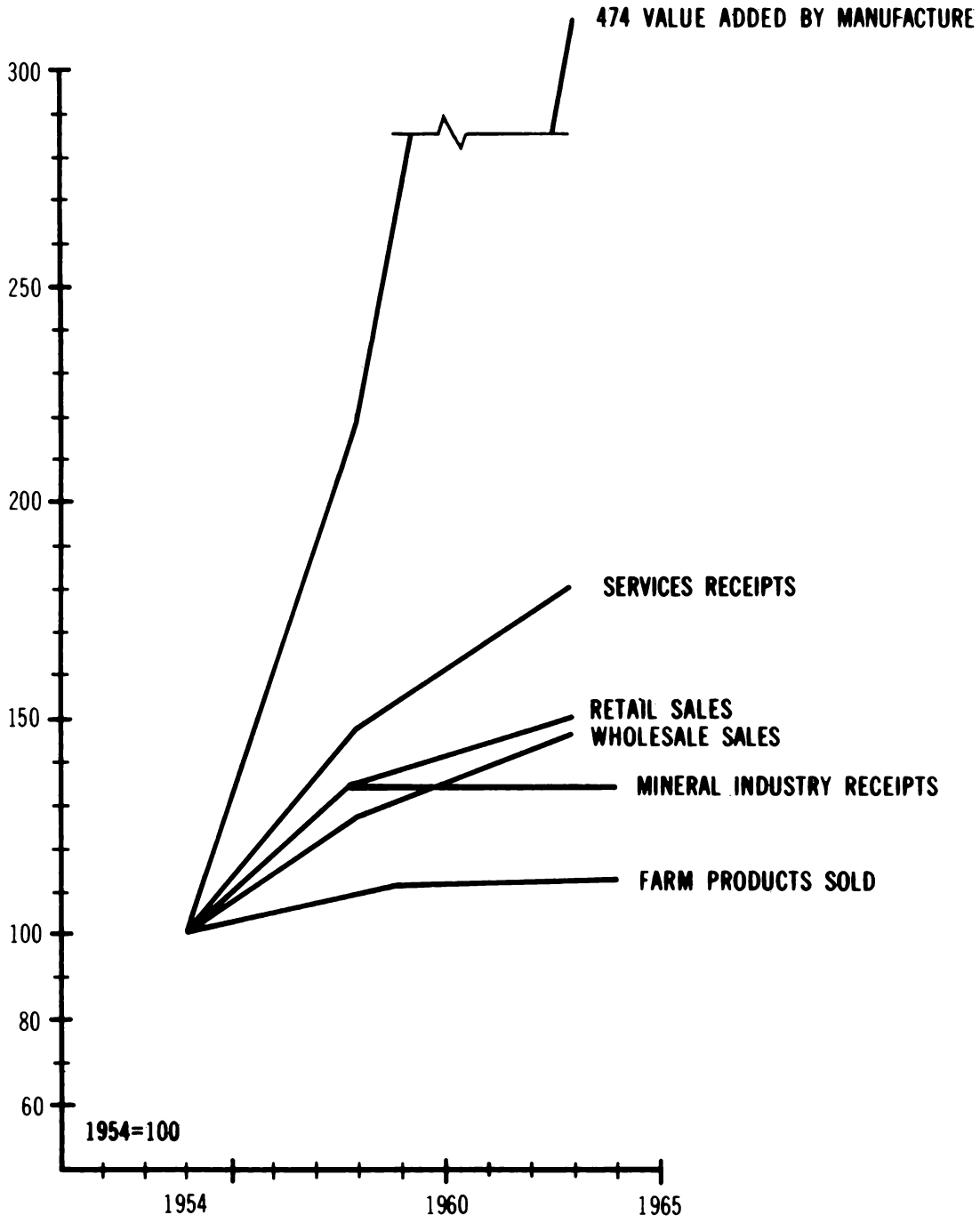


FIGURE 6-4

6.5 MUNICIPAL AND INDUSTRIAL WATER RESOURCES

6.5.1 Ground Water [11]

The Ector - Midland region is located on the western boundary of the Colorado River Basin. The aquifers underlying the region are the Ogallala, the Edwards Trinity (Plateau) and the Santa Rosa.

The Ogalalla aquifer covers about 7,500 square miles of the Colorado River Basin, extending into the Brazos River Basin on the north to Andrews, Ector, Midland and Glasscock counties on the south. The Ogallala aquifer constitutes the lower, saturated portion of the Ogallala Formation, but in some parts of the southern half of the aquifer's occurence in this region, saturated Cretaceous sediments are included within the Ogallala aquifer. Approximately 92 percent of the total ground water pumped in this region in 1960 was produced from the Ogallala aquifer.

The Ogallala consists of sand, clay, silt, gravel, and caliche, with 60 to 70 percent being sand. Saturated thickness of the Ogallala generally is less than 100 feet; however, in some isolated areas it is as much as 150 feet. Water in the Ogallala aquifer is under water-table conditions. Yields of large capacity wells can reach 2,000 gallons per minute, but most range from 200 to 900 gallons per minute with an average of 400.

The small amount of water received as recharge each year is insignificant compared to the amount of water pumped, principally for irrigation. It is estimated that about 15 million of the 30 million acre-feet stored in the Ogallala in the Colorado River Basin in Texas is economically recoverable and considered available.

The water contains dissolved solids ranging from about 300 to 3,000 parts per million. The water generally is hard and has an objectionably high concentration of fluoride.

The Edwards Trinity (Plateau) aquifer underlies the northern portion of Ector and Midland counties. It consists of saturated Comanche Peak and Edwards Limestones and the saturated Paluxy Sand of the Trinity Group. Some underlying fresh-water bearing (containing water having less than 3,000 ppm dissolved solids) sands of Triassic age have been included with the aquifer, where they are not readily distinguishable from Cretacous sediments.

Saturated intervals of the Edwards-Trinity (Plateau) aquifer range in thickness from very thin in some places to more than 275 feet in the Pecks Lake collapsed area in eastern Midland County. Thin saturated intervals are indicated in some areas in Ector and Midland counties. Notable saturated intervals, some exceeding 100 feet in thickness, occur in northwestern Ector County in some conformity to the present surface drainage system.

The amount of natural recharge to the Edwards-Trinity (Plateau) aquifer of this region is not known, but is probably small. Recharge probably occurs by precipitation on outcrop areas and by water percolating downward through overlying sediments.

Pumpage from the Edwards-Trinity (Plateau) aquifer is small in comparison with the pumpage from the Ogallala aquifer. Nevertheless, because the Edwards-Trinity (Plateau) aquifer is the major source of ground water in its area of occurrence conditions affecting the water that is stored in the aquifer are extremely important to this study. In 1960, approximately 73 municipal, 120 industrial, and 3 irrigation wells produced water from the Edwards-Trinity (Plateau) aquifer in this region. Twenty-two of the industrial wells were producing potable water for oil-field water flooding operations.

The Santa Rosa aquifer underlying Ector County comprises those areas of the Santa Rosa Formation known to produce usable water.

In some parts of the aquifer's extent, rocks of Triassic age other than those of the Santa Rosa Formation, and rocks of Cretaceous age have been included with the Santa Rosa Aquifer where they are hydraulically associated with the Santa Rosa.

In general, the Santa Rosa Formation is composed of interbedded lenses of sand, hard sandstone, gravel, and red, green, and blue shale. The primary recharge areas are probably in the Santa Rosa outcrop in New Mexico and in the adjacent Rio Grande Basin where sands of the Santa Rosa Formation are truncated against overlying saturated sediments.

The City of Midland utilizes ground water from wells as the source for its municipal water supply. Continued withdrawal of ground water over the years coupled with increased water requirements has resulted in severe depletion of existing well fields.

According to a recent engineering report /24/, the annual yield of Wadley field which is located north of Midland and began production in 1950, has steadily declined from

216 million gallons in 1960 to 117 million gallons in 1965 and 73.7 million through October, 1966. It is estimated that by January 1970 the productive capability will have declined to something less than 0.75 million gallons per day.

McMillan Well Field, located 12 miles northwest of Midland began producing in 1953. Prior to full scale artificial recharge injection operations during 1963, the average water level declined at a rate of about 3.6 feet per year. Projecting this decline indicates that, without annual recharge injection, the entire field would have a capability of about 2.16 MGD by Mid-1969.

The Paul Davis field began production in 1958. The original design capacity of the first 18 wells was 18,510 gallons per minute. This has declined to 17,250 gallons per minute in 1965. It has been recommended that 5 new wells should be added. Thirteen and one-tenth percent of the original reserves were depleted through November, 1966, with 395,500 acre-feet remaining in 1966.

In 1965 the City of Midland purchased the surface and water rights for 20,230 acres of land in northwestern Winkler and northeastern Loving counties known as the T-Bar Ranch Supply. Total reserves within acceptable limits of water quality with an average chloride concentration of 250 ppm are estimated to be approximately 920,000 acre-feet. Development of this source may be required by 1985.

In late 1959, approximately 40 million gallons of water were transferred from the Paul Davis field and injected into the central portion of McMillan field to establish compatibility of the two waters. On the basis of this experimental program it was concluded that recharge of the McMillan field during periods of low demand on the Paul Davis field would be practical. During the winter of 1965-1966, approximately 452 million gallons were transferred and injected into 11 wells over a 108 day period. During the 1966 pumping season, 551 million gallons were withdrawn from McMillan field with a resulting water table decline of only 0.2 feet. It has been estimated that 95% or more of the water injected into McMillan field can be recovered.

The Rosedale and Cole Park well fields are located in the east part of the City. Rosedale has 5 wells which are in standby service. Cole Park has 7 wells that provide water for the park and have been abondoned for municipal use because of poor water quality.

Figure 6-5 shows analyses of ground water for the Midland well fields.

CITY OF MIDLAND WELLS

WATER ANALYSIS

	Rosedale	Wadley	Paul Davis	Cole Park	McMillan
Iron - Fe	0.02ppm	0.02ppm	0.02ppm	0.06ppm	0.02ppm
Manganese - Mn	0.2	0.2	0.2	0.2	0.2
Calcium - Ca	250	190	76	375	96
Magnesium - Mg	129	135	75	222	58
Sodium & Potassium (Na+K)	243	247	158	466	156
Bicarbonate - HCO_3	206	178	274	279	198
Sulfate - SO_4	1,010	780	222	1,440	282
Chloride - Cl	313	405	246	730	223
Fluoride - F	5.1	4.8	5.5	5.1	4.1
Nitrate - NO_3	13	16	8	40	9
Dissolved Solids	2,170	1,960	1,070	3,560	1,030
Total Hardness as $CaCO_3$	1,160	1,030	500	1,850	476
Specific Conductance (Micromhos at 25°C)	4,011	3,696	1,980	6,840	1,864
pH	7.2	7.6	7.6	7.2	7.4

FIGURE 6 - 5

6.5.2 Surface Water /11/

The Ector-Midland region as established for purposes of this report derives its surface water from the Colorado River drainage basin which heads in eastern New Mexico and trends southeasterly throughout southwest and south-central Texas to the Gulf of Mexico. That part of the basin west of a north-south line from Lamesa, Dawson County to Rankin, Upton County, contributes no effective runoff. Some areas east of that line also are mostly noncontributing.

The average annual runoff per square mile in the Colorado River Basin ranges from a maximum of 350 acre-feet near the mouth of the river to less than 50 acre-feet west of an approximate north-south line through San Angelo. This run off decreases more or less uniformly from east to west along with the decrease in rainfall.

One of the major reservoirs on the Colorado River is Lake J. B. Thomas, owned by the Colorado River Municipal Water District, and serving members cities of Big Spring, Odessa, and Snyder, and industries in these areas. The Robert Lee Reservoir on the Colorado River is under construction by the Colorado River Municipal Water District, and is scheduled for completion in 1969.

Figure 6-6 shows the estimated reservoir yields for J. B. Thomas and Robert Lee Reservoirs; of the CRMWD. These yields are based on the assumption that the period of drought, as it applies to a particular reservoir, becomes defined only as a result of hypothetically operating the water supply system through a historic or synthetic sequence of supply and demand events. The Texas Water Development Board has used the 17 year period 1941-1957 for this historic sequence of events in-as-much-as periods of both drought and water plentitude lasting several consecutive years occurred during this time. Figure 6-6 also shows certain water analysis data.

6.5.3 Water Resources Data

Figure 6-7 provides a summary of municipal and industrial water resources information for the Ector-Midland region. The data includes ground water and CRMWD supplied water quantities.

6.5.4 Mass Diagram

Water resources available to the Ector-Midland region and corresponding water requirements of the communities are indicated on mass diagram Figure 6-8, which shows cumulative quantities of water with respect to time.

CRMWD RESERVOIR DATA AND WATER ANALYSIS

Ector - Midland Region

	J. B. Thomas Reservoir	Robert Lee Reservoir	CRMWD Composite* (Odessa)	Martin County Well Field
FIRM YIELD (Acre-Feet)				
1960	15,214	---		
1970	14,071	75,800		
1980	12,928	72,600		
1990	11,785	69,400		
2000	10,642	66,200		
2010	9,500	63,000		
2020	8,356	59,800		
STORAGE CAPACITY (Acre-Feet)				
Sediment	29,000	46,000		
Conservation	175,000	310,000		
WATER ANALYSIS (ppm)				
Date of Collection	5-7-66		5-24-67	7-27-66
Iron - Fe	0.18		0.04	0.02
Manganese - Mn	0.05		0.05	0.05
Calcium - Ca	25		45	62
Magnesium - Mg	7		23	39
Sodium - Na	61		93	134
Bicarbonate - HCO_3	159		199	226
Sulfate - SO_4	54		100	198
Chloride - Cl	24		94	151
Fluoride - F	0.8		1.4	2.4
Nitrate - NO_3	0.4		7	7.0
Dissolved Solids (TDS)	331		560	820
Total Hardness as $CaCO_3$	91		207	315
Specific Conductance (Micromhos at 25°C)	477		895	1392
pH	8.2			7.6

* Odessa Tap Water Composite From 58 City Wells, Martin County Wells and Lake J. B. Thomas by SDH

FIGURE 6 - 6

WATER RESOURCES

ECTOR - MIDLAND REGION

	Aquifer Yield* AFY	Recoverable Storage* AF	TDS (Avg.)	Available	Remarks
City of Midland					
Paul Davis Well Field		395,500	1070	395,500 AF	Available as of 1966
McMillan Well Field			1030	1,540 AFY	1540 AFY represents peaking capacity based on 5 MGD for 100 days each summer obtained by artificial recharge from Paul Davis well field. Therefore this capacity is not shown on mass diagram.
Wadley Well Field			1960	840 AFY	Based on 0.75 MGD in 1970
Rosedale Field			2170	Poor Quality	
Cole Park Field			3560	Poor Quality	
T-Bar Ranch	1,600	920,000	1070		Not Developed; TDS estimated
C.R.M.W.D.					
J. B. Thomas Reservoir			331	15,214 AFY to 8,356 AFY	Figures show the range of firm yields from 1960/70 to 2020
Robert Lee Reservoir			1025	75,800 AFY to 59,800 AFY	
Odessa Well Field			649	4,500 AFY	Based on Estimated 4 MGD
Martin County Well Field			420	See Remarks	Used for underground storage with 100% recovery

*The numbers in these columns refer to that part of the aquifer in the well field or land under lease.

FIGURE 6 - 7

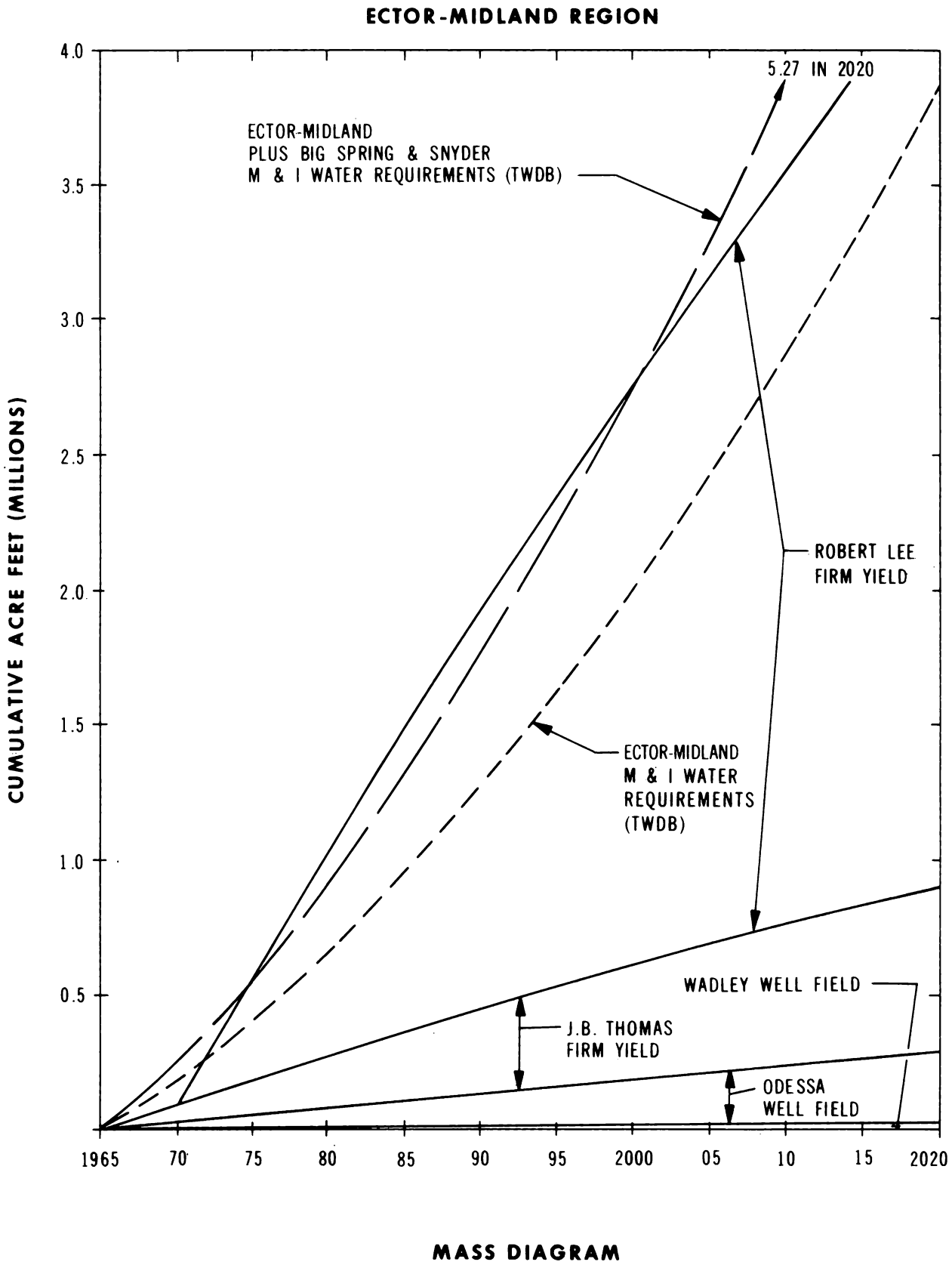

ECTOR-MIDLAND REGION
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
CUMULATIVE ACRE FEET (MILLIONS)
5.27 IN 2020
ECTOR-MIDLAND
PLUS BIG SPRING & SNYDER
M & I WATER REQUIREMENTS (TWDB)
ROBERT LEE
FIRM YIELD
ECTOR-MIDLAND
M & I WATER
REQUIREMENTS
(TWDB)
WADLEY WELL FIELD
J.B. THOMAS
FIRM YIELD
ODESSA
WELL FIELD
1965
70
75
80
85
90
95
2000
05
10
15
2020
MASS DIAGRAM

FIGURE 6-8

The municipal and industrial water requirements curve shown by the long-dash line on the mass diagram has been plotted to show the quantity of water required for the Ector-Midland region plus Big Spring and Snyder. This has been done inasmuch as the two cities not in the Ector-Midland region have firm contracts with CRMWD for their water requirements, and thus the resources shown on the diagram must supply the total demand represented by the solid curve. For information only, the Ector-Midland region M & I water requirements are shown as a short-dash line, but this curve should not be used to interpret the regional resources.

The mass diagram shows that presently developed and planned water sources will be adequate to meet the requirements represented by the long-dash curve, not including the estimated storage in Paul Davis Well Field, and provided that adequate pipeline and pumping facilities are added to the system as required.

The mass diagram does not provide information as to water quality. This information can be approximated on the basis of judgment by use of the data given on Figure 6-7.

6.6 POSSIBLE FUTURE WATER SOURCES

The following list shows possibilities for providing additional water sources to meet prospective growth in water demand.

- Completion of Robert Lee Reservoir, including product conveyance lines
- Development of T Bar Ranch in Loving and Winkler counties by the City of Midland
- Desalt local brackish water in the Midland area
- Desalt Capitan Reef water for Odessa
- Blend desalted water with local brackish water in the Midland area
- Reclaim waste water
- Import water from other areas

Future Sources - Starting in 1970 the Colorado River Municipal Water District will supply Midland with water from Colorado River. CRMWD water is stored in Lake J. B. Thomas and Robert Lee Reservoirs and as ground water in the Martin Well Field.

Water quality of the combined CRMWD water supply is dependent on yearly intensity of rainfall and on the proportion of water delivered from each location of storage. Water from Lake J. B. Thomas has a total dissolved solids (TDS) content of approximately 330 ppm while the TDS content of Robert Lee Reservoir is expected to be higher.

Development of ground water reserves on the T-Bar Ranch can supplement the Paul Davis well field supplies of ground water.

Desalination - A potential source of additional water is desalted brackish water. A distillation plant could be built in or near the City of Midland to supply as much fresh water as may be required to supplement water from other sources. Product water from a distillation process contains practically no dissolved solids, and ideally could be blended with existing water supplies to improve the overall water quality for the community. Membrane desalting processes provide product water having dissolved solids in the neighborhood of 500 ppm to meet USPHS recommended standards.

Reclaiming waste water from return flows has the potential for significantly increasing the life of water reserves. This requires employment of some process to condition this water to make it satisfactory for municipal and industrial use including using it as a source of feedwater for desalination, particularly in areas where brackish or saline water supplies are limited.

A significant percentage of the water used in an area is available as return flow. Extensive research into treatment of return flows has been in progress in the Federal Water Polution Control Administration and other agencies. The feasibility of reclamation has been demonstrated and emphasis is being placed on efforts to reduce costs. It appears that the reclaimed product can meet U.S. Public Health Service Standards for drinking water, but there may be some problems which remain to be solved before public acceptance of this source.

One of the interesting advantages derived from reclamation of return flows is that it is estimated that salinity increases only 300 to 400 ppm for each use. By desalting the return flows, it is only necessary to reduce the salinity by this amount, thus permitting application of a desalting process that lends itself to low product water costs under this condition.

Figure 6 - 9 shows return flow data furnished by the Texas Water Development Board.

Consideration of the use of return flows from the City of Odessa sewage treatment plant appear to be out of the picture inasmuch as the entire output of this plant is being supplied to the El Paso Natural Gas Co. complex in Odessa for their source of industrial water.

Importation - The Texas Water Development Board has under active consideration the possibility of importing water to areas in Texas from the Mississippi River to meet municipal, industrial, irrigation and mining water needs. Preliminary estimates by the Board indicate that the cost of water delivered to Odessa from East Texas, and out-of-State sources can be as much as 30¢ to 35¢ per thousand gallons. To this cost would have to be added the cost of conventional water treatment after delivery to Odessa. Volumes of water potentially available, possible routings and costs of moving water to and across Texas from the Mississippi River presently are under study by the Board, the U.S Army Corps of Engineers and the Bureau of Reclamation, U.S. Department of the Interior.

RETURN FLOWS

Ector and Midland Counties

RETURN FLOW	1970	1980	1990	2000	2010	2020
	Acre Feet Per Year					
Odessa	9,772	13,169	15,300	17,793	20,712	24,132
Other	442	455	501	549	598	646
Ector County Total	10,214	13,624	15,801	18,342	21,310	24,778
Midland	6,400	8,000	9,076	10,291	11,662	13,209
Other	189	234	268	288	349	397
Midland County Total	6,589	8,234	9,344	10,579	12,011	13,606
Region Total	16,803	21,858	25,145	28,921	33,321	38,384
	Cities Not in Ector - Midland Region					
Big Spring	5,024	6,480	7,795	8,812	9,955	11,242
Snyder	1,434	1,571	1,825	2,017	2,230	2,464
	Million Gallons Per Day					
Odessa	8.72	11.76	13.66	15.88	18.49	21.54
Other	.40	.40	.45	.50	.55	.58
Ector County Total	9.12	12.16	14.11	16.38	19.04	22.12
Midland	5.71	7.14	8.10	9.19	10.41	11.79
Other	.17	.21	.24	.27	.31	.36
Midland County Total	5.88	7.35	8.34	9.46	10.72	12.15
Region Total	15.00	19.51	22.45	25.84	29.76	34.27
	Cities Not In Ector - Midland Region					
Big Spring	4.5	5.8	6.9	7.9	8.9	10.0
Snyder	1.3	1.4	1.6	1.8	2.0	2.2

Source: Texas Water Development Board

FIGURE 6 - 9

6.7 DESALTING POSSIBILITIES

In considering the possibilities for desalting in this region, it appears desirable to analyze the region water situation from the standpoint of (1) water quality and (2) additional pipeline and treatment facilities which may be required in the future to bring the water from the source to the point of use.

The regional water picture with respect to desalting was explored primarily from the point of view that the Colorado River Municipal Water District at present has contracts to supply the City of Odessa and the City of Midland. On this basis it was assumed that the desalting possibilities would be investigated in relationship to the water furnished by CRMWD on the basis of quality improvement at Midland and comparison with an additional pipeline when needed for Odessa.

6.7.1 Quality Improvement - Midland

The CRMWD contract with the City of Midland provides for furnishing a quantity of water somewhat less than the total water requirements of the City of Midland. The difference between the CRMWD supply and the total requirements for the City of Midland will have to be made up by water from the Paul Davis well field, supplemented as required in 15 to 20 years by development of the T-Bar well field and necessary conveyance facilities.

On the basis of available information it is assumed that the salinity from Paul Davis and T-Bar will be in the vicinity of 1070 ppm. It is assumed that the supply to the City of Midland from CRMWD will have a salinity of 500 ppm. Blending 500 ppm CRMWD water with 1,070 ppm well field water will result in a product having a salinity in excess of 500 ppm.

In order to determine costs, it was assumed that a desalting plant could be installed to improve the quality to USPHS recommended standards of 500 ppm total dissolved solids for the water distributed to consumers in the City of Midland. Three processes were considered in order to determine which process would result in lowest costs.

- A distillation process which provides product water in the order of 25 ppm; this distilled water could be blended with 1070 ppm well water from the Paul Davis well field to yield a blended product of 500 ppm water which could be mixed with CRMWD water for distribution to consumers.

- Two membrane processes which provide product water in the order of 500 ppm; more water must be desalted in the application of these processes necessitating more desalting plant capacity.

Figure 6-1, Case No. III-1 shows a desalting plant located at an undetermined site near the City of Midland; the plant location is the same for all processes considered. The feedwater supply is derived from the existing 33-inch pipeline from the Paul Davis well field. Costs were based on estimates for the additional water required for desalination. Brine disposal is assumed to be accomplished by means of deep well injection.

The costs of 500 ppm product water from various desalting processes, delivered to the city water system for mixing with CRMWD water are broken down into the following components, the figures representing cents per thousand gallons:

	Distillation	Reverse Osmosis	Electro-dialysis
- Desalting Plant	54.1	36.7	24.5
- Water Treatment	0	0	0
- Feed Water Supply	14.2	12.5	12.2
- Brine Disposal	3.5	3.5	2.7
- Product Water Conveyance	0	0	0
Total	71.8	52.7	39.4

Detailed data and results for these cases are provided in Section 6.8., Analysis and Comparisons.

6.7.2 Desalting Plant in Place of Additional Pipeline - Odessa

In exploring the applicability of desalting in the Ector-Midland region in connection with the water requirements of the City of Odessa, it appeared that a desalting plant could be considered for comparison with the costs associated with additional pipeline facilities required to meet the increased requirements of the City of Odessa in the future.

An advanced state of the art, vapor compression, vertical tube evaporator (VC-VTE) distillation process was selected to furnish maximum product water at the lowest possible cost particularly if low cost heat is available. Feed water supply was assumed to be derived from Capitan Reef. Discussions have been held with representatives of Shell Oil

Company in connection with furnishing Capitan Reef feedwater from their existing pipeline facilities in the vicinity of Odessa. No costs were discussed for furnishing Capitan Reef water for use as feedwater for a desalting plant. In any more detailed feasibility study for desalting utilizing Capitan Reef water, it would be desirable to renew discussions with Shell Oil Company in this connection to determine the relationship of costs of water delivered by them to the cost of water from a well field to supply feedwater for a desalting plant. In order to arrive at an approximation of the cost of feedwater for the purposes of this report, it has been assumed that a well field would be established at Capitan Reef to furnish water to a desalting plant; analysis is shown on Figure 6-10.

Capitan Reef water as a source of feed water for desalting process has some undesirable characteristics, namely, high calcium sulphate content and high hydrogen sulfide content. The calcium sulphate represents a limitation in the application of a high concentration ratio for the distillation process in that the concentration must be limited to avoid scaling. The hydrogen sulfide content is an extremely undesirable constituant of feedwater because of its carryover into the product water. A method of pre-treatment was employed to remove the hydrogen sulfide and to reduce the carbonate and calcium hardness.

Figure 6 - 1, Case No. III-2 shows a desalting plant located in Winkler County so that the pipeline to Odessa will have lower cost in conveying the smaller quantity of product water compared with feedwater. The product water pipeline ties into the pipeline from the north Odessa well field on the assumption that this pipeline will convey the desalted product water into a storage tank for blending with the remaining water supply. Brine disposal is assumed to be accomplished by means of injection wells.

The cost of 25 ppm water delivered to the city water system is estimated at 85.8 per thousand gallons. This water cost is broken down into the following components:

ECTOR - MIDLAND REGION

ANALYSIS OF
CAPITAN REEF FEEDWATER

Temperature	90
Iron - Fe	0.02
Manganese - Mn	0.05
Calcium - Ca	780
Magnesium - Mg	310
Sodium / Potassium - Na / K	950
Bicarbonate - HCO_3	335
Sulfate - SO_4	2,635
Chloride - Cl	1,700
Fluoride - F	4.2
Nitrate - NO_3	0.4
Total Dissolved Solids - TDS	6,715
Total Hardness as $CaCO_3$	2,980
Specific Conductance (Micromhos @ 25°C)	15,120
pH	7.3
Hydrogen Sulphide - H_2S	180
Chemical Oxygen Demand - COD	170

Note: Chemical constituents shown in ppm.

Figure 6 - 10

- Desalting Plant	32.4¢/Kgal.
- Water Treatment	29.4¢/Kgal.
- Feedwater Supply	7.9¢/Kgal.
- Brine Disposal	8.4¢/Kgal.
- Product Water Conveyance	7.7¢/Kgal.
Total	85.8¢/Kgal.

Details of the process costs and other associated costs as well as analysis with relation to additional pipeline facilities are furnished in Section 6.8, Analysis and Comparisons.

6.8 ANALYSIS AND COMPARISONS

6.8.1 Quality Improvement - Midland

Water now being used in Midland contains approximately 1230 ppm TDS; after introduction into the system of CRMWD water, salinity is calculated to range from 675 ppm in 1970 to 770 ppm in the year 2020.

Three desalting processes have been investigated to determine their suitability for use in the Midland area : distillation, electrodialysis, and reverse osmosis. The following assumptions were made to establish the bases for deriving costs in connection with various alternatives for the future water supply in the City of Midland:

- Water from the Colorado River Municipal Water District will be delivered in quantities as scheduled under present contract through the year 2020 at an average cost of 25.5 cents per 1,000 gallons.

- Water purchased from CRMWD will contain 500 ppm total dissolved solids.

- Paul Davis well field has a reserve of 355,175 acre-feet as of January 1, 1970.

- Ground water from Paul Davis wells contains 1070 ppm TDS.

- T-Bar Ranch water rights will be developed when required by constructing wells and pipeline facilities to provide additional water supplies.

- T-Bar well water contains 1070 ppm TDS.

- For purposes of analyzing the application of desalting plants, it is assumed that the first plant will be operable on January 1, 1970 concurrently with initiation of CRMWD supply.

- Desalting plants are assumed to operate 330 days per year.

- Water supplied to consumers in the City of Midland will be blended to achieve approximately 500 ppm total dissolved solids.

- The product water from the desalting plant will be blended with feedwater where applicable to provide 500 ppm water or better.

It was assumed that any desalting plant would be located north of the city adjacent to the proposed filtration plant /24/ for future CRMWD supplies. Combining both facilities would result in savings from elimination of product water conveyance pipelines and would provide a convenient location for blending the total water supply.

In all cases plant construction was staged to result in lowest capital investment consistent with the capacity required. Full operation of all plants was assumed to begin in January, 1970 to coincide with initial surface water deliveries from CRMWD.

The staged construction of desalting plants is based on bringing additional capacity into production when a quantity of desalted product water greater than the rated plant capacity is required. In this study no attempt was made for optimizing stage construction; but engineering judgement was applied to arrive at reasonable plant sizes and intervals.

To determine the required size and the timing for installation of the sequentially staged desalting plants, the estimated City of Midland average annual water demand was compared with the amount of water received under contract with CRMWD as shown in Figure 6-2. The difference was taken as the amount of the deficiency which had to be supplied by either furnishing well water from Paul Davis well field and/or T-Bar as required, or else by desalination and blending where applicable.

For the purposes of this preliminary report it has been assumed that the costs derived on the basis of full capacity operation for 330 days per year for the full 30 year lifetime of the desalting plant will yield satisfactory answers for comparative purposes.

For a distillation plant, this is the actual method of operation on which the analysis has been based and water quality is better than 500 ppm for those periods of time when there is some excess capacity.

For the membrane process, the staged plants have been assumed to be installed every five years. For the first five years of the life of each staged plant increment there is some excess capacity. This means that during the first several years of operation the plant will produce less product water than it is capable of producing, which would tend to result in somewhat increased cost per thousand gallons. However, for the remaining 25 years of plant life it will be operating at capacity. In this preliminary study it is assumed that the minor effect of the five years of excess capacity on costs can be considered negligible.

In applying the distillation process which produces distilled water, it is possible to blend the product water with an almost equal amount of 1070 ppm Paul Davis feedwater to achieve 500 ppm blended water. Calculations were made to take maximum advantage of distilled water blending possibilities. This has the effect of requiring less distillation plant capacity to make up the difference between water demand and the amount supplied by CRMWD, and still provide the consumer with approximately 500 ppm water.

In the reverse osmosis and electrodialysis processes, it was assumed that the product water will have a salinity of 500 ppm.

The results of calculations are shown on Figure 6-11 for the application of staged desalting plants to supply the computed deficiency between CRMWD supply and water demand for the City of Midland. Table 1 Figure 6-11 shows the computed plant sizes for sequential stage construction required by application of three different desalting processes. Table 2, Figure 6-11 shows the capital costs for desalting plant sizes of Table 1.

It can be seen from Figure 6-11 that the distillation process requires the smallest total desalting capacity. However, the capital cost is much higher than for electrodialysis or reverse osmosis, even though plant capacity for the two membrane processes is greater than distillation.

Providing M & I water to consumers at 500 ppm quality by application of desalting plants will increase the cost of delivered water. Calculations have been made for the average water demand in 1975 to estimate these costs, based on full desalting plant output; in the case of distillation advantage was taken of blending potential. CRMWD was assumed to supply their contract quantity. A comparison of costs is shown below:

	Cost of Delivered Water ¢/Kgal.	Cost of Desalted Water Only* ¢/Kgal.
Without Desalting	20.4	---
With Blended Distillation Product	40.8	71.8
With Reverse Osmosis Product	34.4	52.7
With Electrodialysis Product	30.0	39.4

* Refer to Section 6.7.1 for Summary and component costs.

CITY OF MIDLAND

APPLICATION OF STAGED DESALTING PLANTS

TABLE 1

PLANT SIZES -- MGD

Year	Distillation	Electrodialysis	Reverse Osmosis
1970	3	5.0	5.0
1975		1.2	1.2
1976	1		
1980		0.65	0.65
1985		0.6	0.6
1987	1		
1990		0.85	0.85
1995		0.09	0.9
1998	4*		
2000		6.3*	6.3*
2005		2.35*	2.35*
2006	2*		
2010		2.1*	2.1*
2014	2*		
2015		2.1*	2.1*
TOTAL	13	21.95	22.05

*Includes replacement for plant installed earlier

- -

TABLE 2

CAPITAL COST - THOUSANDS OF DOLLARS

Year	Distillation	Electrodialysis	Reverse Osmosis
1970	$ 4,796	$ 1,757	$ 2,900
1975		600	800
1976	1,972		
1980		400	500
1985		350	500
1987	1,972		
1990		470	700
1995		510	700
1998	6,060		
2000		2,150	3,600
2005		960	1,600
2006	3,440		
2010		900	1,400
2014	3,440		
2015		900	1,400
	$ 21,680	$ 8,997	$ 14,100

FIGURE 6 - 11

For further comparison, the Texas Water Development Board has under active consideration the possibility of importing water to areas in Texas from the Mississippi River to meet municipal, industrial, irrigation and mining water needs. Preliminary estimates by the Board indicate that the cost of water delivered to Midland from East Texas, and out-of-State sources can be as much as 30¢ to 35¢ per thousand gallons. To this cost would have to be added and the cost of conventional water treatment after delivery to Midland. Volumes of water potentially available, possible routings and costs of moving water to and across Texas from the Mississippi River presently are under study by the Board, the U.S. Army Corps of Engineers and the Bureau of Reclamation, U.S. Department of the Interior.

In preparing the cost estimates for these two figures, the 33 inch pipeline and development of the Paul Davis well field was assumed to have cost $3,420,000. It is believed that the difference between this assumption and the actual cost will not change the relative positions of the various methods studied.

Figures 6-12, 6-13, and 6-14 at the end of this section provide the detailed cost breakdowns for the three processes based on the size plant that would have to be installed in 1970 as shown in Table 1, Figure 6-10. A comparison of the data on the three cost breakdown figures shows that electrodialysis provides the lowest cost desalted water for the three desalting methods investigated. Electrodialysis also shows the lowest requirements for capital investment.

The combined cost of water, comprising the cost of CRMWD water together with the cost of water for supplying the deficiency by various methods, shows a cost of 9.6 cents per kilogallon for improving the quality of water to USPHS recommendations by employing the electrodialysis process.

Cost data are shown only for the first stage of staggered construction in this preliminary report because it is unlikely that costs for subsequent years will vary enough to effect a change in relative positions.

6.8.2 Desalting Plant in Place of Additional Pipeline - Odessa

Figure 6-15 shows the cost breakdown for a 20 MGD VC-VTE process produces distilled water at the plant boundary at what appears to be a reasonable cost for desalination. However, total water cost is over two and one half times greater due primarily to high costs for feedwater well field, feedwater treatment and product water conveyance.

The high feedwater treatment costs illustrate the difficulties involved in utilizing Capitan Reef as feedwater.

The 85.8 cents per thousand gallons desalted water cost compares with the 1966 average cost of water supplied by CRMWD amounting to 22.08 cents per thousand gallons for an average delivery of approximately eleven MGD. The Texas Water Development Board has under active consideration the possibility of importing water to areas in Texas from the Mississippi River to meet municipal, industrial, irrigation and mining water needs. Preliminary estimates by the Board indicate that the cost of water delivered to Odessa from East Texas, and out-of-State sources can be as much as 30¢ to 35¢ per thousand gallons. To this cost would have to be added and the cost of conventional water treatment after delivery to Odessa. Volumes of water potentially available, possible routings and costs of moving water to and across Texas from the Mississippi River presently are under study by the Board, the U.S. Army Corps of Engineers and the Bureau of Reclamation, U.S. Department of the Interior.

If the distilled water from the desalting plant is used to blend with Capitan Reef water to provide a blended product of 500 ppm, the total quantity of blended product was calculated to be 21.5 MGD. The cost of the 500 ppm product would be approximately 30.7 cents per thousand gallons at the desalting plant, or a reduction of 1.7 cents per thousand gallons from the unblended product. This saving would be offset to some extent by higher well field and pumping costs for feedwater supply and by higher product conveyance costs. The overall delivered cost for desalted water thus would not be reduced significantly. Furthermore, the distilled water delivered to Odessa may be considered to have greater value for blending purposes at the City system.

An order of magnitude estimate was made for the costs in connection with a pipeline that could convey 20 MGD from Robert Lee Reservoir to Odessa. It is recognized that in the planned development of the CRMWD system a pipeline of larger capacity would probably be installed resulting in lower unit cost for the 20 MGD required for comparison with the desalting plant at Odessa. However, this pessimistic approach showed costs of approximately 20 cents per thousand gallons for conveyance costs. Adding this cost to the 14 cents per thousand gallons of CRMWD water for Odessa gives a cost of approximately 34 cents per thousand gallons which is significantly lower than the cost of desalted water.

COST BREAKDOWN

MIDLAND CASE III-1

THE RALPH M. PARSONS COMPANY

PROCESS MSF ; CAPACITY 3 MGD; OUTPUT 990,000 Kgal/yr; INTEREST 3-1/2 %; PLANT LIFE 30 YRS; PIPELINE LIFE 50 YRS

	CARRYING CHARGE MULTIPLIER	DESALT PLANT		WATER TREATMENT		FEEDWATER		BRINE DISPOSAL		PRODUCT CONVEY.	
		CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3
CAPITAL COST CENTERS											
1. Plant & Equipment	.0544	3,988	217.3								
2. Replaceable Items											
3. Water Treatment											
4. Well Field						Assumed					
5. Pipeline	.0426					3,420	146.5				
6. Pumping Station											
7. Brine Disposal											
8. Indirect Capital Costs	.0544	680	37.0								
9. Land Costs	.035	2	.1								
10. Working Capital	.035	126	4.4								
11. Cooling Towers											
TOTAL CAPITAL COSTS →		4,796		0		Exist		290			
RECURRING COST CENTERS	PERCENT										
12. Taxes											
13. Insurance											
TOTAL ANNUAL FIXED COSTS →			258.8		0		146.5		15.7		
OPERATION & MAINTENANCE COST CENTERS											
15. Operating Labor			90.9								
16. Maintenance Labor			53.7								
17. General & Administrative			43.4								
18. Supplies & Maintenance Materials			23.4								
19. Chemicals			29.7								
20. Fuel			193.0								
21. Electric Power			90.6								
TOTAL O & M COSTS →			524.7		0		59.3		40.2		
TOTAL FIXED PLUS O & M COSTS →			783.5		0		205.8		55.9		
COMPONENT WATER COSTS, ¢/Kgal →		79.1;	54.1	0		20.8;	14.2*	5.6;	3.5*	0	
TOTAL WATER COST → 105.5 ¢/Kgal ; 71.8¢*/Kgal.											

*Based on Blended Product of 5 MGD

Desalt Plant costs include costs of steam generation and cooling tower.

Power is purchased at 1.0¢ per KWH; Fuel is purchased at 22.0¢ per MBtu's.

Feedwater conveyance pipeline from Paul Davis Well Field is existing, and is assumed to cost $3,420,000.

FIGURE 6 - 12

COST BREAKDOWN

THE RALPH M. PARSONS COMPANY

MIDLAND CASE III-1

PROCESS R/O ; CAPACITY 5 MGD; OUTPUT 1,650,000 Kgal/yr; INTEREST 3-1/2 %; PLANT LIFE 30 YRS; PIPELINE LIFE 50 YRS

	CARRYING CHARGE MULTIPLIER	DESALT PLANT		WATER TREATMENT		FEEDWATER		BRINE DISPOSAL		PRODUCT CONVEY.	
		CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3
CAPITAL COST CENTERS											
1. Plant & Equipment	.0544	2,320	126.1								
2. Replaceable Items	1.035	80	82.5								
3. Water Treatment											
4. Well Field											
5. Pipeline	.0426					Assumed					
6. Pumping Station						3,420	146.5				
7. Brine Disposal											
8. Indirect Capital Costs	.0544	408	22.2								
9. Land Costs	.035	4	.1								
10. Working Capital	.035	100	3.5								
11. Cooling Towers											
TOTAL CAPITAL COSTS →		2,912		0		Exist.		309			
RECURRING COST CENTERS	PERCENT										
12. Taxes											
13. Insurance											
TOTAL ANNUAL FIXED COSTS →			234.4				146.5		16.8		
OPERATION & MAINTENANCE COST CENTERS											
15. Operating Labor											
16. Maintenance Labor			74								
17. General & Administrative			22.2								
18. Supplies & Maintenance Materials			28.1								
19. Chemicals			82.5								
20. Fuel											
21. Electric Power			165								
TOTAL O & M COSTS →			371.8		0		59.8		41.0		
TOTAL FIXED PLUS O & M COSTS →			605.2		0		206.3		57.8		
COMPONENT WATER COSTS, ¢/Kgal →		36.7			0	12.5		3.5			
TOTAL WATER COST → 52.7 ¢/Kgal											

Feedwater costs include supply from Paul Davis Well Field

Feedwater conveyance pipeline is existing and is assumed to cost $3,420,000

FIGURE 6 - 13

COST BREAKDOWN
MIDLAND CASE III-1

THE RALPH M. PARSONS COMPANY

PROCESS E/D ; CAPACITY 5 MGD; OUTPUT 1,650,000 Kgal/yr; INTEREST 3-1/2 %; PLANT LIFE 30 YRS; PIPELINE LIFE 50 YRS

	CARRYING CHARGE MULTIPLIER	DESALT PLANT		WATER TREATMENT		FEEDWATER		BRINE DISPOSAL		PRODUCT CONVEY.	
		CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3
CAPITAL COST CENTERS											
1. Plant & Equipment	.0544	1,068	58.1								
2. Replaceable Items	.2215	432	95.7								
3. Water Treatment											
4. Well Field											
5. Pipeline	.0426					Assumed					
6. Pumping Station						3,420	146.5				
7. Brine Disposal											
8. Indirect Capital Costs	.0544	255	13.9								
9. Land Costs	.035	1.0									
10. Working Capital	.035	67.2	2.4								
11. Cooling Towers				0							
TOTAL CAPITAL COSTS →		1,823.2				Exist		255			
RECURRING COST CENTERS	PERCENT										
12. Taxes											
13. Insurance											
TOTAL ANNUAL FIXED COSTS →			170.1		0		146.5		13.9		
OPERATION & MAINTENANCE COST CENTERS											
15. Operating Labor			32.2								
16. Maintenance Labor			15.2								
17. General & Administrative			14.2								
18. Supplies & Maintenance Materials			54.5								
19. Chemicals			19.8								
20. Fuel											
21. Electric Power			99.0								
TOTAL O & M COSTS →			234.9		0		54.6		30.7		
TOTAL FIXED PLUS O & M COSTS →			405.0		0		201.1		44.6		
COMPONENT WATER COSTS, ¢/Kgal →			24.5		0		12.2		2.7		0
TOTAL WATER COST → 39.4 ¢/Kgal											

Feedwater conveyance is existing and is assumed to cost $3,420,000

Feedwater costs include supply from Paul Davis Well Field

FIGURE 6 - 14

COST BREAKDOWN

THE RALPH M. PARSONS COMPANY

ODESSA CASE III-2

PROCESS VC-VTE ; CAPACITY 20 MGD; OUTPUT 6,600,000 Kgal/yr; INTEREST 3-1/2 %; PLANT LIFE 30 YRS; PIPELINE LIFE 50 YRS

	CARRYING CHARGE MULTIPLIER	DESALT PLANT		WATER TREATMENT		FEEDWATER		BRINE DISPOSAL		PRODUCT CONVEY.	
		CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3
CAPITAL COST CENTERS											
1. Plant & Equipment	.0544	13,191	717.6								
2. Replaceable Items											
3. Water Treatment	.120			1,400	168						
4. Well Field	.0426					4,580	195				
5. Pipeline	.0426									6,878	292.8
6. Pumping Station											
7. Brine Disposal											
8. Indirect Capital Costs	.0544	2,440	132.7	228	27.4*						
9. Land Costs	.035	4	0.1	2	.1						.2
10. Working Capital	.035	355	12.4	349	12.2	84.7	3			84	2.9
11. Cooling Towers	.0544	997	55.2								
TOTAL CAPITAL COSTS →		16,987		1,919		4,664.7		4,711		6,969	
RECURRING COST CENTERS	PERCENT										
12. Taxes											
13. Insurance											
TOTAL ANNUAL FIXED COSTS →			918.0		207.7		198		256.2		
Credit for Sulfur Recovery					(190.0)						
OPERATION & MAINTENANCE COST CENTERS											
15. Operating Labor			)		)		)				)
16. Maintenance Labor			)229.3		) 70.0		) 182				) 102
17. General & Administrative					)		)				)
18. Supplies & Maintenance Materials			131.9		)		)				)
19. Chemicals					1,850						
20. Fuel @ 22¢ per 10^6 Btu			862.0								
21. Electric Power							138				108
TOTAL O & M COSTS →			1,223.2		1,920		320		294.9		210
TOTAL FIXED PLUS O & M COSTS →			2,141.2		1,937.7		518		551.1		505.9
COMPONENT WATER COSTS, ¢/Kgal →		32.4		29.4		7.9		8.4		7.7	
TOTAL WATER COST → 85.8 ¢/Kgal											

Desalt Plant Concentration Ratio = 6.0; *Carrying charge multiplier is 0.120 for Feedwater Treatment

Feedwater Treatment Plant Provides H_2S Removal and Calcium Hardness Reduction; 10 Yr. Life Assumed.

Chemicals (acid) costs are included in water treatment cost.

Desalt Plant is Located in Vicinity of Well Field Whose Costs are Shown Under "Feedwater".

FIGURE 6 - 15

6.9 BRINE DISPOSAL

Cost of brine disposal by deep well injection for this area was calculated using the Yates and San Andress Formation as the disposal zone for volumes ranging from 0.8 MGD to 8.65 MGD. The lowest calculated costs for injection for each study case were for the Yates Formation and are tabulated in Figure 6 - 16.

In those cases where the desalt plant for this area was located in Winkler County, cost of brine disposal was calculated using the Bell Canyon Formation as the disposal zone.

ECTOR - MIDLAND REGION

BRINE DISPOSAL DATA

INJECTION RESERVOIR CHARACTERISTICS AND DESIGN AND COST DATA FOR BRINE DISPOSAL BY SUBSURFACE INJECTION IN SELECTED CASES

Item	ED Case III-1	RO Case III-1	MSF Case III-1	VCVTE Case III-1
Product Water				
Capacity, MGD	5.0	5.0	3.0	20.0
Quality, TDS (ppm)	500	500	25	25
Brine Effluent				
Volume, MGD	0.8	1.3	1.25	6.1
Quality TDS (ppm)	4,870	3,380	3,850	30,700
Disposal Zone				
Formation or geologic age	Yates	Yates	Yates	Bell Canyon(1)
Lithology	Sandstone	Sandstone	Sandstone	Sandstone
Depth below surface	2,750 ft.	2,750 ft.	2,750 ft.	4,500 ft.
Thickness	200 ft.	200 ft.	200 ft.	500 ft.
Well Field Data				
Number of wells	2	4	4	25
Distance to plant	1 mi.	1 mi.	1 mi.	1 mi.
Total Cost (million dollars)				
Capital	$0.255	$0.309	$0.290	$4.711
Annual	0.045	0.058	0.056	0.551
Total Unit Costs				
Brine basis per thousand gallons	16.89¢	13.47¢	13.55¢	27.38¢
Product basis, per thousand gallons	2.70¢	3.50¢	5.65¢	8.35¢

(1) Injection well field located in Winkler County

FIGURE 6-16

CRANE - REAGAN - UPTON REGION

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CRANE - REAGAN - UPTON REGION

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7. CRANE - REAGAN - UPTON REGION

7.1 INTRODUCTION AND SUMMARY

For purposes of this report, Crane, Reagan and Upton counties have been combined into one region to determine the costs of desalted water in relationship to the cost of water from alternative sources to supply the future water requirements of the area. The major cities in the region are Big Lake, Crane, McCamey and Rankin.

This region was selected for study to determine the role which desalination of underlying brackish ground water could serve toward the fulfillment of future water requirements of the area. For this purpose estimates were prepared to show the costs of desalted water in relationship to the cost of water from alternative sources.

Projections of water requirements for the Crane - Reagan - Upton Region indicate that the estimated requirements for municipal and industrial water in 2020 will be three times as great as the estimates for 1960. In order to provide for these needs it has been recognized that the application of desalting technology should be considered as one of the possible sources of future water supply. This study is a preliminary investigation of the feasibility and cost of desalting brackish ground water in the Crane - Reagan - Upton region.

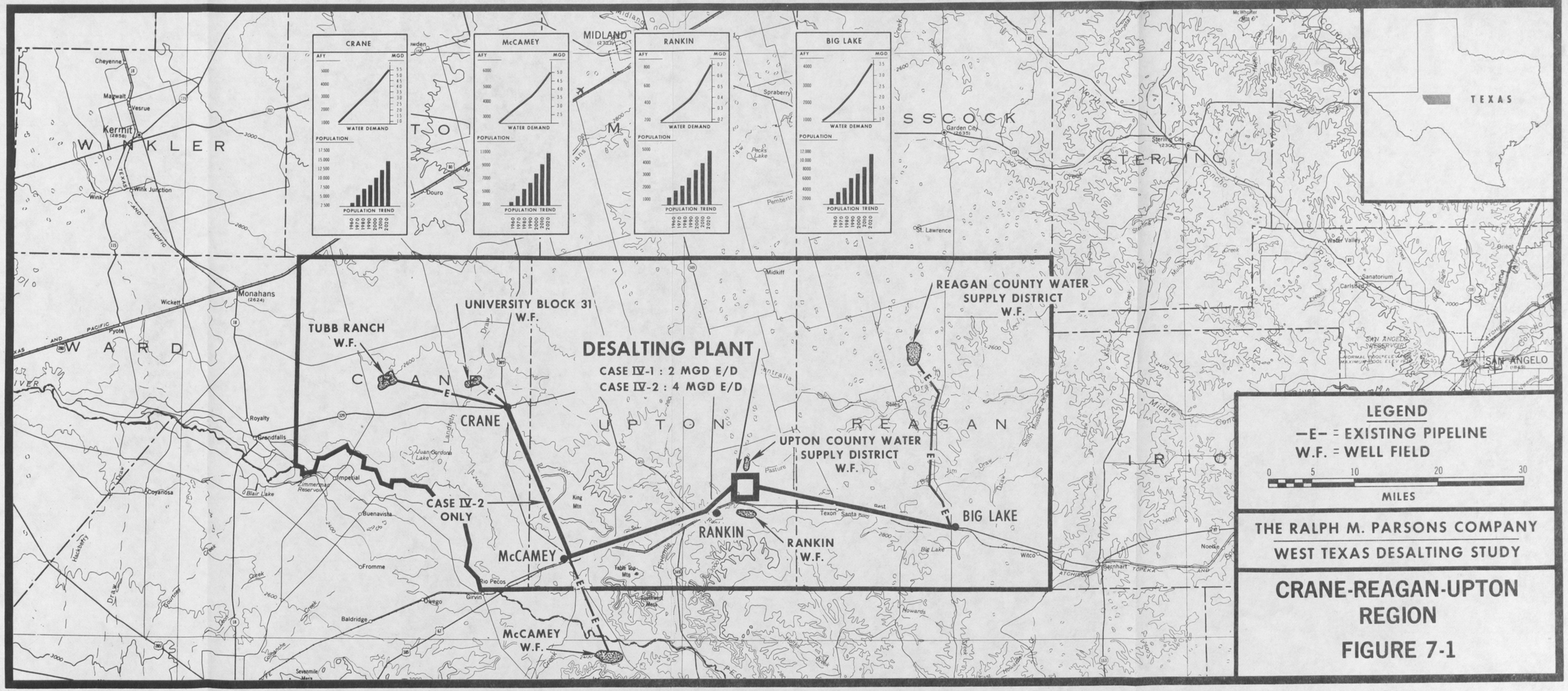
Plant size was selected on a more or less arbitrary basis, keeping in mind water resources and future requirements. The information presented herein can be used to make an appraisal of the relationship of plant size to total water requirements.

Problems associated with feedwater supply, brine disposal and integration of desalted water into the present system have been investigated only briefly. A detailed investigation of various solutions and their costs should be included in any future study.

7.1.1 Summary

Figure 7-1 shows a map of the Crane-Reagan-Upton Region with a 2 MGD and also a 4 MGD desalting plant located east of the City of Rankin.

In exploring the possibilities for the application of desalting plants in the Crane-Reagan-Upton Region two cases were established, one comprising a 2 MGD plant to provide water to Big Lake, Rankin and McCamey, and the other comprising a 4 MGD plant to extend the water pipeline to the City of Crane.


CRANE
AFY
MGD
WATER DEMAND
POPULATION
POPULATION TREND
McCAMEY
RANKIN
BIG LAKE
MIDLAND
TEXAS
DESALTING PLANT
CASE IV-1 : 2 MGD E/D
CASE IV-2 : 4 MGD E/D
TUBB RANCH W.F.
UNIVERSITY BLOCK 31 W.F.
REAGAN COUNTY WATER SUPPLY DISTRICT W.F.
UPTON COUNTY WATER SUPPLY DISTRICT W.F.
RANKIN W.F.
McCAMEY W.F.
CASE IV-2 ONLY
CRANE
McCAMEY
RANKIN
BIG LAKE
WINKLER
WARD
CRANE
UPTON
REAGAN
IRION
STERLING
SCOCK
Kermit
Wink
Wink Junction
Monahans
Royalty
Grandfalls
Imperial
Coyanosa
Buenavista
Fromme
Girvin
Iraan
Baldridge
Midkiff
Spraberry
Douro
Garden City
Sterling City
St. Lawrence
Water Valley
Sanatorium
Carlsbad
SAN ANGELO
Big Lake
Texon
Santa Rosa
Witco
Barnhart
Noeke
Nowards
Midland
Cheyenne
Magwall
Vesrue
Wickett
Yote
Blair Lake
Juan Gordon Lake
Landrith
Pecos
Rio Pecos
Sheffield
Sevenmile Draw
Pembrook
Pecks Lake
Fisher
Sulphur Draw
Pasture
Dam
Creek
River
LEGEND
—E— = EXISTING PIPELINE
W.F. = WELL FIELD
0 5 10 20 30
MILES
THE RALPH M. PARSONS COMPANY
WEST TEXAS DESALTING STUDY
CRANE-REAGAN-UPTON REGION
FIGURE 7-1

The characteristic feature of this region is the relatively large distance between cities with very low density population between cities. This means that a regional water supply system would have fairly long pipelines. Also, the water requirements of the cities in this region are relatively small due to the relatively small populations of the cities. The two cases which were selected for study represented an approach to the installation of a reasonably sized desalting plant together with reasonable pipeline sizes. Total pipeline lengths vary from approximately 47 miles for Case IV-1 to approximately 80 miles for Case IV-2.

The saline feedwater was obtained from the Edwards-Trinity aquifer east of the City of Rankin with a salinity of 1,230 ppm. The salinity of the feedwater was suitable for application of a membrane process, and favored the electrodialysis process. The following table summarizes the water costs for the two cases studied:

- Case IV-1, 2 MGD electrodialysis plant supplying McCamey, Rankin, and Big Lake. . . . . .71.1¢ per Kgal.

- Case IV-2, 4 MGD electrodialysis plant supplying McCamey, Rankin, Big Lake plus Crane . . . . . 66.7¢ per Kgal.

The individual cities in this region were studied in a previous report /42/ and for the City of Rankin delivered water costs amounting to 50.5 cents per thousand gallons were developed for providing 750 ppm desalted water from a 0.5 MGD plant. No detailed costs were developed in the previous report for the remaining cities in the region inasmuch as they appeared to have adequate alternative supplies of fresh water.

The above cost comparison indicates that for the City of Rankin it would prove more economical for them to install an individual desalting plant to take care of their own requirements. For the remaining cities, based on information which is available at the present time, it appears unlikely that the cost of water from a desalting plant will be competitive with alternative supplies.

7.2 WATER ADMINISTRATION AND FACILITIES

7.2.1 Big Lake

Big Lake, Texas, is an incorporated city located in Reagan County with an estimated population of 3,600 in 1967.

The city operates its own water distribution, storage and sewage facilities. There are about 800 meters. The school district is the principal customer and the local hospital is second.

The city purchases its water from the Reagan County Water Supply District. The Reagan County Water Supply District's water well field is located about 11 miles north of town. There were initially 5 wells in the field which were developed in the late 1950's. However, at the present time, there are 11 wells with a total pumping capacity of 1.5 million gallons per day. There has been a decline in water levels of about 10 to 12 feet since the wells were drilled. There is considerable irrigation development north of the District's well field.

The District has purchased water rights on 10 sections of land for a 30 year term at $.25 an acre.

Storage Facilities

The city has 250,000 gallons of elevated storage and 300,000 gallons of ground storage. In addition to the city's storage, the Water Supply District has one million gallons of ground storage at the well field.

Water Treatment consists of chlorination.

The Sewage Treatment Plant consists of an Imhoff tank, with a normal throughput of 140,000 GPD, and a maximum capacity of one million GPD. Effluent is discharged to an old lake bed south of the city and a portion is used to water the golf course.

7.2.2 Rankin

Rankin, Texas, is an incorporated city located in Upton County with an estimated population of 1,600 in 1967.

The city purchases water from Upton County. The Upton County well field that serves Rankin is located 4 miles east of the city and contains 13 wells. There is also a small well field south of the city containing 3 wells used for standby supply.

Storage Facilities include:

No.	Capacity (Gallons)	Type	Location
1	100,000	Grade	Well Field
1	300,000	Grade	1 Mile North of City
1	65,000	Grade	City
1	75,000	Grade	City

Water Treatment Plant - None

The Sewage Treatment Plant includes an Imhoff tank and sludge drying beds.

7.2.3 McCamey

McCamey, Texas is an incorporated city located in Upton County with an estimated population of 4,200 in 1967.

The city owned and operated water department obtains its water supplies from a well field located approximately 15 miles south of the city in Pecos County. The wells are located in an area where there is no irrigation development.

Water is pumped from the well field to the City through two 6" diameter and one 10" diameter pipelines.

Storage Facilities include

No.	Capacity (Gallons)	Type	Location
1	100,000	Ground	Well Field
1	100,000	Ground	Intermediate Pump Station
1	100,000	Elevated	In City
1	250,000	Elevated	In City

A report /28/ completed in June 1965, recommended the construction of a 500,000 gallon capacity ground storage tank at the intermediate pump station.

Water Treatment consists of chlorination.

Sewage Treatment consists of settling basin and digester. Effluent is discharged to lagoons, the golf course, and the ball park.

7.2.4 Crane

Crane, Texas, is an incorporated city located in Crane County with an estimated population of 5,000 in 1967.

The City obtains its water supply from the Crane County Water Control and Improvement District. The City of Crane is the only district customer. The district produces water from two well fields:

(a) Tubb Ranch - located 22 miles northwest of the City, contains 10 wells and a 14" diameter water pipeline to the City.

(b) University Block No. 31 - located 7 miles north of Crane, has 21 wells. The pipeline to the City is 8" diameter.

Storage Facilities in or near the City of Crane include one 200,000 gallon capacity and one 50,000 gallon capacity elevated storage tanks, and two 500,000 gallon capacity ground storage tanks. Storage at University Block No. 31 well field includes three 200,000 gallon capacity and one 125,000 gallon capacity ground storage tanks. One 1,000,000 gallon ground storage tank is located at the Tubb Ranch well field.

Water Treatment consists of chlorination.

The Sewage Treatment plant is city owned and operated. It has a design capacity of 140,000 GPD and the present load is 130,000 GPD. Facilities include a bar screen, grit chamber, rectangular Imhoff, oxidation ponds, and sludge drying beds.

7.3 POPULATION AND WATER REQUIREMENTS

Planning for the development of municipal and industrial water facilities depends upon projections of future population and industrial growth. In this report, the quantity of fresh water required by each region is based on projections by the Texas Water Development Board.

The intent of the projections is to provide guidelines for orderly planning and development of future water supply facilities. The near term projections, i.e; the next 10 to 20 years, should be more reliable than those in the more distant future. In the near term interval, growth rates slower or faster than are anticipated are not likely to effect large changes in the dates at which projected population data are reached. On the other hand, for spans of 20 years in the future and beyond, the variation of actual population figures from present day estimates may become significant.

The large projected per capita per day use indicated for several cities is attributed to a large projected industrial water requirement. For simplicity in handling projected requirements of water used by industry located within a county but not within the confines of any city, the Texas Water Development Board allocated these requirements to the nearest city. This has the effect of showing a large water requirement for some of the cities in this report.

Where per capita consumption growth appears abnormal, it is anticipated that the availability of sufficient quantities of good quality water in the future will attract industry, thus modifying the historical growth pattern of per capita consumption.

Data on population and on water requirements projected to the year 2020 for cities as well as county and region totals have been developed by the Texas Water Development Board as shown on Figure 7-2.

POPULATION AND WATER REQUIREMENT ESTIMATES
Crane - Reagan - Upton Region

	1970	1980	1990	2000	2010	2020
POPULATION						
Upton County						
McCamey	4,560	5,748	6,761	7,952	9,352	11,000
Rankin	1,808	2,246	2,905	3,479	4,166	4,087
Other	5,170	3,544	4,028	4,823	5,776	6,914
Total	8,875	11,538	13,694	16,254	19,294	22,901
Reagan County						
Big Lake	3,939	5,250	6,316	7,599	9,143	11,000
Other	1,421	1,703	1,936	2,196	2,483	2,799
Total	5,360	6,953	8,252	9,795	11,626	13,799
Crane County						
Crane	5,572	7,376	8,808	10,519	12,561	15,000
Other	1,094	1,276	1,462	1,670	1,906	2,173
Total	6,666	8,652	10,270	12,189	14,467	17,173
Region Total	20,901	27,140	32,216	38,238	45,387	53,873
M & I WATER REQUIREMENTS	Acre Feet Per Year					
Upton County						
McCamey	3,059	3,544	3,924	4,370	4,900	5,533
Rankin	324	391	456	540	647	785
Other	541	654	754	904	1,082	1,313
Total	3,924	4,589	5,134	5,814	6,629	7,631
Reagan County						
Big Lake	1,464	1,936	2,299	2,739	3,273	3,925
Other	62	85	101	119	170	163
Total	1,526	2,021	2,400	2,858	3,413	4,088
Crane County						
Crane	2,113	2,748	3,249	3,847	4,565	5,424
Other	77	97	109	177	136	151
Total	2,190	2,845	3,358	3,970	4,701	5,575
Region Total	7,640	9,455	10,892	12,642	14,743	17,264
	Million Gallons Per Day					
Upton County						
McCamey	2.73	3.16	3.50	3.90	4.38	4.94
Rankin	0.29	0.35	0.41	0.48	0.58	0.70
Other	.48	.59	.68	.81	.96	1.17
Total	3.50	4.10	4.59	5.19	5.92	6.81
Reagan County						
Big Lake	1.31	1.73	2.05	2.44	2.92	3.50
Other	.05	.03	.10	.12	.13	.15
Total	1.36	1.80	2.15	2.56	3.05	3.65
Crane County						
Crane	1.89	2.45	2.90	3.44	4.08	4.84
Other	.07	.09	.10	.10	.11	.14
Total	1.96	2.54	3.00	3.54	4.19	4.98
Region Total	6.82	8.44	9.74	11.29	13.16	15.44

Source: TWDB

FIGURE 7 - 2

7.4 ECONOMIC AND FINANCIAL DATA

The counties of Crane, Reagan and Upton are oil producing areas with some manufacturing and ranching. The larger cities are commercial centers for oil field and ranching supplies.

The following table contains economic data of interest concerning the area:

Bank Deposits (1964)	$ 14,842,000
Retail Sales (1963)	$ 13,820,000
Wholesale Sales (1963)	$ 11,696,000
Farm Products Sold (1964)	$ 2,860,000
Service Receipts (1963)	$ 1,372,000
Mineral Industry Receipts (1964)	$ 225,511,000
Total Vehicles Registered (1964)	9,517
Passenger Vehicles Registered (1964)	5,636
Total Employment (1965)	4,875
Wages (1st Quarter 1965 x 4)	$ 13,310,432
Manufacturing Establishments, (1st Quarter, 1965)	11
Manufacturing Establishments, 20 or more Employees, (1st Quarter, 1965)	0
Manufacturing Establishments, Employees (1st Quarter, 1965)	58
Total Local Bonded Debt (1963)	$ 6,690,000

By far the largest dollar volume shown in the above table is accounted for by "Mineral Industry Receipts". Referring to Figure 7-3, the three down trending factors of "Wholesale Sales" "Service Receipts" and "Retail Sales" totaled less than 27,000,000 dollars, which is only approximately 12% of the up-trending "Farm Products Sold" and "Mineral Industry Receipts". This indicates a significant dollar growth situation which bears further watching in the future to observe the possibility of changes in pattern.

CRANE - REAGAN - UPTON

REGION

ECONOMIC AND FINANCIAL DATA 17

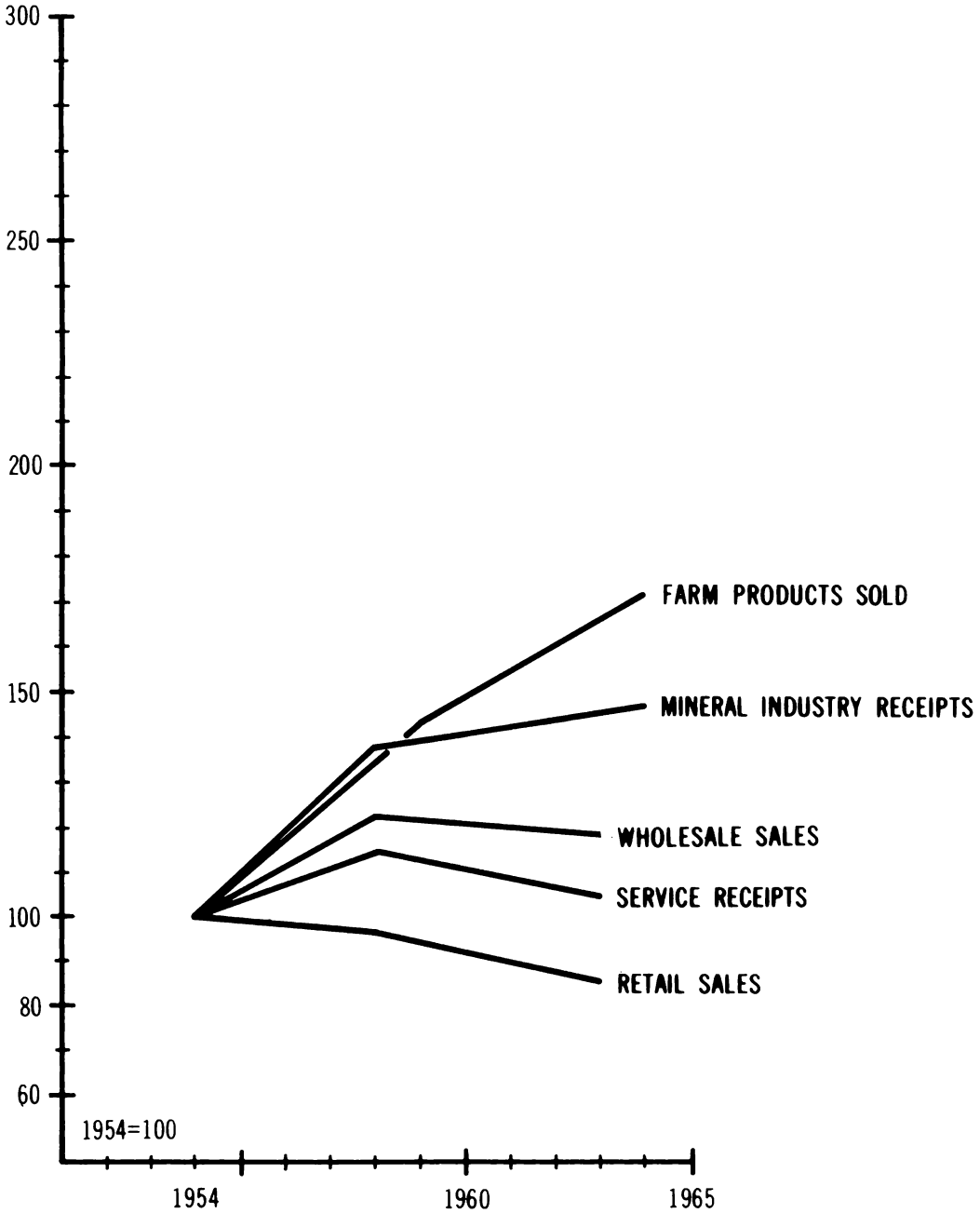


FIGURE 7-3

7.5 MUNICIPAL AND INDUSTRIAL WATER RESOURCES

7.5.1 Ground Water [8] [10] [11]

The Crane-Reagan-Upton Region lies in both the Colorado River basin and the Rio Grande basin. The basin boundary is along a southeast-northwest diagonal through Upton County; therefore, the cities of Crane, McCamey and Rankin are located in the Rio Grande basin, and the City of Big Lake is located in the Colorado River basin.

The primary aquifers that underlie the region are the Edwards-Trinity (Plateau) aquifer and the Cenozoic Alluvium aquifer. The Cenozoic Alluvium aquifer underlies Crane County and does not extend into Reagan and Upton counties. The Santa Rosa Sandstone aquifer is a secondary aquifer that extends into the western part of the region.

The following table indicates ground water data for cities in the region.

City	Producing Aquifer	Well Depth (Ft.)
Crane	Cenozoic Alluvium	70 to 150
McCamey	Edwards-Trinity (Plateau)	350
Rankin	Edwards-Trinity (Plateau)	250
Big Lake	Edwards-Trinity (Plateau)	250 to 350

7.5.2 Surface Water

Surface water runoff is virtually non-existent in the region. That part of the Colorado River basin west of a north-south line from Lamesa, Dawson County to Rankin, Upton County, contributes no effective runoff.

7.5.3 Water Resources Data

Figure 7-4 provides a summary of municipal and industrial water resources information as of 1965 for the region. Recharge rates and aquifer storage for the cities of Big Lake, Rankin and McCamey are unavailable.

WATER RESOURCES

CRANE - REAGAN UPTON REGION

	Aquifer Yield* (AFY)	Recoverable Storage* (AF)	TDS (ppm)	Available*	Remarks
Big Lake					
Reagan County W.S.D. Well Field		75,000	1070	1800 AFY Plus 75,000 AF	Data indicates supply adequate to 1990. Available supply based on cumulative demand to 1990 divided by 25 years.
Rankin					
Upton County Well Field		16,600	1500	16,600 AF	Available data indicates water supply is of poor quality.
McCamey					
Pecos County			600	850 AFY	Average of 600 AFY in 1960 and 1200 AFY in 2020 per McCamey typed data from TWDB
Crane					
Tubb Ranch	900	20,000	179**	900 AFY Plus 20,000 AF	Ref: [26]
Block 31 University Land					
Existing 21 Wells	400	6,500		460 AFY Plus 8,600 AF	Ref: [27]

* The numbers in these columns refer to that part of the aquifer in the well field or land under lease.

** Distribution System

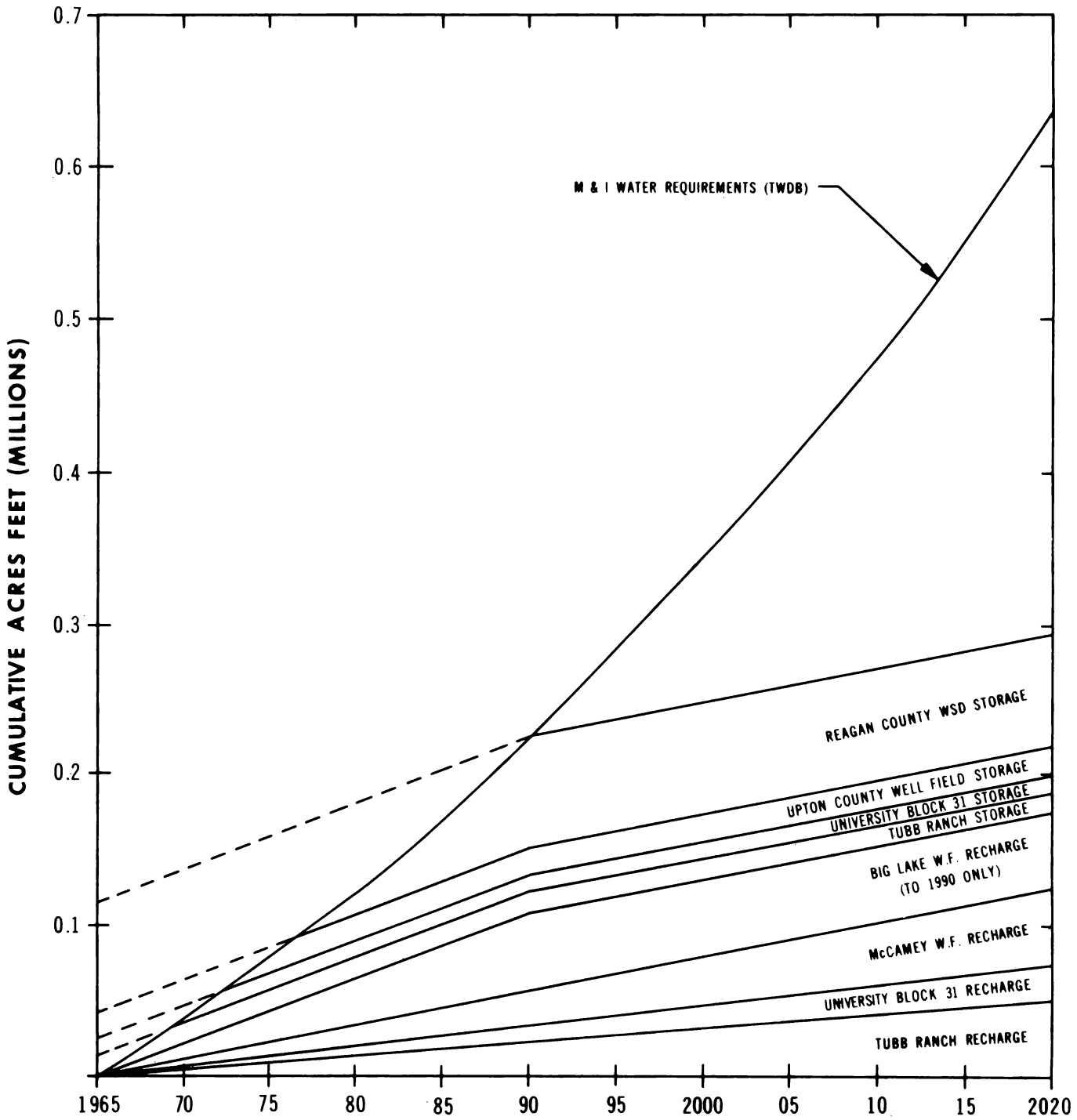
FIGURE 7 - 4

7.5.4 Mass Diagram

Analysis of water data can be simplified by use of a mass diagram which shows cumulative quantities of water with respect to time. Figure 7-5 shows mass diagrams for the water resources of the region. Also shown is a mass curve for water demand based on data provided by the Texas Water Development Board.

The mass diagram shows that existing water resources will be used up by 1990. Some time prior to 1990 additional sources will have to be developed if the estimated water resources and water requirements remain as shown.

CRANE-REAGAN-UPTON REGION



MASS DIAGRAM

FIGURE 7-5

7.6 POSSIBLE FUTURE WATER SOURCES

The following list shows the possibilities for providing additional water sources to meet prospective growth in water demand.

- Additional development of existing source at Crane and McCamey.
- Import water from other areas.
- Desalt local brackish water.
- Blend brackish water with superior quality of water.

Available data indicate that additional development of the existing source at Crane and McCamey is possible. This will necessitate the purchase of additional water rights and the expansion of existing well fields. It appears that this source will be adequate to meet these cities projected 2020 water requirements.

Importation of water to Big Lake and Rankin from northeast Crockett County appears to be feasible. Preliminary evaluation indicate the occurance of very good quality ground water in the Edwards-Trinity (Plateau) aquifer in this area; however, detailed ground water studies will be required to determine the volume of water that can be produced on a sustained basis.

Desalting has demonstrated its increasing importance for supplying water of good quality as costs have been reduced significantly during the last ten years. This report explores the state of the art of this technology and presents data in the subsequent sections of this chapter on the application of desalting in the Crane-Reagan-Upton Region.

Blending brackish water with imported water of superior quality to provide a consumer product of good quality (e.g., 500 to 750 ppm) will have the effect of increasing the life of water reserves if there is sufficient quantity of imported fresh water which has a salinity significantly lower than the target goal for the blended supply.

Return flows represent a potential resource for re-use after suitable treatment. Return flow data for this region furnished by the Texas Water Development Board are shown on Figure 7-6.

RETURN FLOW

Crane - Reagan - Upton Region

RETURN FLOW	1970	1980	1990	2000	2010	2020
	Acre Feet Per Year					
Upton County						
McCamey	1,071	1,118	1,263	1,353	1,464	1,599
Rankin						
Other						
Total	1,457	1,631	1,757	1,912	2,106	2,348
Reagan County						
Big Lake	869	1,086	1,228	1,394	1,588	1,816
Other	27	36	43	49	56	64
Total	896	1,122	1,271	1,443	1,644	1,880
Crane County						
Crane	828	1,061	1,227	1,420	1,647	1,912
Other	34	41	45	250	54	58
Total	862	1,102	1,272	1,470	1,701	1,970
Region Total	3,215	3,855	4,300	4,825	5,451	6,198
	Million Gallons Per Day					
Upton County						
McCamey	0.96	1.06	1.13	1.21	1.31	1.43
Rankin						
Other						
Total	1.30	1.46	1.57	1.71	1.88	2.10
Reagan County						
Big Lake	0.78	0.97	1.10	1.24	1.42	1.62
Other	.02	.03	.04	.05	.05	.06
Total	0.80	1.00	1.14	1.29	1.47	1.68
Crane County						
Crane	0.74	0.95	1.10	1.27	1.47	1.71
Other	.03	.03	.04	.043	.05	.049
Total	0.77	0.98	1.14	1.313	1.52	1.759
Region Total	2.87	3.44	3.85	4.313	4.87	5.539

Source: Texas Water Development Board

FIGURE 7 - 6

7.7 DESALTING POSSIBILITIES

The application of desalted water for supplying the municipal and industrial water requirements of this region offers an interesting opportunity for evaluating various features of providing desalted water from a single plant to widely separated users with moderate water requirements. Distances between cities vary from approximately 19 miles to 28 miles. The present total requirements in the region are estimated to be only slightly over six million gallons a day (MGD); the 2020 requirements are over 15 MGD. Total pipeline lengths vary from approximately 47 miles for Case IV - 1 to approximately 68 miles for Case IV - 2.

The City of Rankin appears to have the most serious water supply problem in this region and a previous report /42/ already has recommended Rankin as one of the candidate cities that would benefit from desalting. The cities of Big Lake, Crane and McCamey appear to be in a much better position with respect to their municipal and industrial water resources.

Two individual cases were considered for a regional approach to desalted water. For Case No. IV - 1 a two MGD membrane desalting plant was considered, utilizing the saline water from the Edwards - Trinity aquifer having an analysis as shown on Figure 7 - 7. This saline water is available east of the City of Rankin.

Figure 7 - 1 shows the approximate plant location and the assumed pipeline and facilities to furnish water to the cities of Big Lake, McCamey and Rankin. Plant location and straight line pipeline routing are shown only for the purpose of arriving at preliminary costs.

The cost of product water for the assumed plant size and location, including the well field, product water pipelines and brine disposal amounts to 71.1¢ per thousand gallons. This water cost is broken down into the following components:

- Desalting Plant	35.2¢/Kgal.
- Water Treatment	0.2¢/Kgal.
- Feedwater Supply	11.0¢/Kgal.
- Brine Disposal	5.8¢/Kgal.
- Product Water Conveyance	18.9¢/Kgal.
Total	71.1¢/Kgal.

As a matter of interest, the following cost of product water is shown for the City of Rankin taken from a previous report /42/.

CRANE - REAGAN - UPTON REGION

ANALYSIS OF
SALINE WATER FOR DESALTING PLANT
FEED

	EDWARDS TRINITY (PLATEAU AQUIFER)
Temperature ^{o}F	68
Silica - SiO_2	13ppm
Iron - Fe	0.02
Calcium - Ca	154
Magnesium Mg	86
Sodium & Potassium (Na+K)	129
Bicarbonate - HCO_3	336
Sulfate - SO_4	580
Chloride - Cl	77
Fluoride - F	2.9
Nitrate - NO_3	22
Chemical Oxygen Demand	10
Dissolved Solids (TDS)	1,387
Total Hardness as $CaCO_3$	740
Specific Conductance (Micromhos at 25°C)	1,700
pH	7.5

FIGURE 7 - 7

- Desalting Plant	42.8¢/Kgal.
- Water Treatment	--
- Feedwater Supply	6.0¢/Kgal.
- Brine Disposal	1.7¢/Kgal.
- Product Water Conveyance	--
Total	50.5¢/Kgal.

It should be noted that the above costs are for a 0.5 MGD plant providing product water having salinity of 750 ppm compared with a product water salinity of 500 ppm provided for in the present study.

Case IV-2 represents an extension of Case IV-1 to include the City of Crane by extending the pipeline from McCamey; plant size is increased to 4 MGD. The cost of product water for the assumed plant size and location including the well field, product water pipelines and brine disposal amounts to 66.7¢ per thousand gallons. This water cost is broken down into the following components:

- Desalting Plant	33.2¢/Kgal.
- Water Treatment	0.2¢/Kgal.
- Feedwater Supply	10.7¢/Kgal.
- Brine Disposal	4.9¢/Kgal.
- Product Water Conveyance	17.7¢/Kgal.
Total	66.7¢/Kgal.

7.8 ANALYSIS AND COMPARISONS

The mass diagram, Figure 7-5, shows that additional supplies of M & I water will be required about 1990. However, even though the regional water requirements include those of the City of Rankin, the mass diagram does not include resources for Rankin due to the poor quality of water. The City of Rankin appears to represent the neediest location in the region for the supply of fresh water.

If a regional plant were installed in the near future, the average cost of desalted water is estimated to be 71.1 cents per thousand gallons for a 2 MGD desalting plant and 66.7 cents per thousand gallons for a 4 MGD desalting plant as shown in detail on Figures 7-8 and 7-9 at the end of this section. This cost compares with the 50.5 cents per thousand gallons determined in a previous report /42/ . It appears that for the City of Rankin, further consideration should be given to data presented in the previous report /42/.

Alternative supplies for Rankin and Big Lake can be obtained from wells in northeast Crockett County. The Texas Water Development Board estimates the cost of each well at $15,000 with wells on one half mile centers and producing 150 GPM. The distance to Big Lake is estimated at 35 miles plus an additional 28 miles to Rankin. Determination of a suitable economic design for exploiting this source is beyond the scope of this study.

For the cities of McCamey and Crane it appears that the best alternative supply would consist of expanding present resources /45/.

Due to the indeterminate nature of the cost of water from alternative sources, comparison of costs cannot be quantified.

COST BREAKDOWN

THE RALPH M. PARSONS COMPANY

CRANE - REAGAN - UPTON REGION CASE IV - 1

PROCESS E/D ; CAPACITY 2 MGD; OUTPUT 660,000 Kgal/yr; INTEREST 3-1/2 %; PLANT LIFE 30 YRS; PIPELINE LIFE 50 YRS

	CARRYING CHARGE MULTIPLIER	DESALT PLANT		WATER TREATMENT		FEEDWATER		BRINE DISPOSAL		PRODUCT CONVEY.	
		CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3
CAPITAL COST CENTERS											
1. Plant & Equipment	.0544	849.8	46.2								
2. Replaceable Items	.2215	270	59.8								
3. Water Treatment											
4. Well Field	.0426					895.4	38.2				
5. Pipeline	.0426									1,996.9	85.0
6. Pumping Station										126.2	5.4
7. Brine Disposal											
8. Indirect Capital Costs	.0544	191	10.4								
9. Land Costs	.035	.3	.1							7.1	.2
10. Working Capital	.035	37.3	1.3			12.0	.4			20.4	.7
11. Cooling Towers											
TOTAL CAPITAL COSTS →		1,348.4		0		907.4		289		2,150.6	
RECURRING COST CENTERS	PERCENT										
12. Taxes											
13. Insurance											
TOTAL ANNUAL FIXED COSTS →			117.8		0		38.6		15.7		91.3
OPERATION & MAINTENANCE COST CENTERS											
15. Operating Labor			13.6								
16. Maintenance Labor			8.4				)				)
17. General & Administrative			5.9				) 22.5				) 29.8
18. Supplies & Maintenance Materials			27.1				)				)
19. Chemicals			19.8		1.3						
20. Fuel											
21. Electric Power			39.6				12.2				3.8
TOTAL O & M COSTS →			114.4		1.3		34.7		22.8		33.6
TOTAL FIXED PLUS O & M COSTS →			232.2		1.3		73.3		38.5		124.9
COMPONENT WATER COSTS, ¢/Kgal →		35.2		0.2		11.0		5.8		18.9	
TOTAL WATER COST →	71.1 ¢/Kgal										

Water Treatment Provides Calgon @ 6 PPM

Feedwater Based on 2.3 MGD Requirement

FIGURE 7 - 8

COST BREAKDOWN

THE RALPH M. PARSONS COMPANY

CRANE - REAGAN - UPTON REGION CASE IV - 2

PROCESS E/D ; CAPACITY 4 MGD; OUTPUT 1,320,000 Kgal/yr; INTEREST 3-1/2 %; PLANT LIFE 30 YRS; PIPELINE LIFE 50 YRS

	CARRYING CHARGE MULTIPLIER	DESALT PLANT		WATER TREATMENT		FEEDWATER		BRINE DISPOSAL		PRODUCT CONVEY.	
		CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3
CAPITAL COST CENTERS											
1. Plant & Equipment	.0544	1,180.0	64.1			-					
2. Replaceable Items	.2215	540	119.6								
3. Water Treatment											
4. Well Field	.0426					1,790.8	76.4				
5. Pipeline	.0426									3,648.4	155.5
6. Pumping Station										67.5	2.9
7. Brine Disposal											
8. Indirect Capital Costs	.0544	292	15.9								
9. Land Costs	.035	.6	.0							10.2	.4
10. Working Capital	.035	72.0	2.5			23.1	0.8			39.2	1.4
11. Cooling Towers											
TOTAL CAPITAL COSTS →		2,084.6		0		1,813.9		437		3,765.3	
RECURRING COST CENTERS	PERCENT										
12. Taxes											
13. Insurance											
TOTAL ANNUAL FIXED COSTS →			202.1		0		77.2		23.8		160.2
OPERATION & MAINTENANCE COST CENTERS											
15. Operating Labor			27.3								
16. Maintenance Labor			16.8				40.0				62.0
17. General & Administrative			11.8								
18. Supplies & Maintenance Materials			54.1								
19. Chemicals			39.6		2.6						
20. Fuel											
21. Electric Power			79.2				24.3				11.2
TOTAL O & M COSTS →			228.2		2.6		64.3		40.9		73.2
TOTAL FIXED PLUS O & M COSTS →			430.9		2.6		141.5		64.7		233.4
COMPONENT WATER COSTS, ¢/Kgal →		33.2		0.2		10.7		4.9		17.7	
TOTAL WATER COST → 66.7 ¢/Kgal											

Water Treatment Provides Calgon @ 6 PPM

FIGURE 7 - 9

7.9 BRINE DISPOSAL

Cost of brine disposal by deep well injection for this area was calculated using the San Andress Formation as the disposal zone. The lowest calculated cost for injection for each study case is tabulated in Figure 7 - 10.

The unit cost of brine disposal by evaporation pond was less than the unit cost by injection by 1.1 cents for Case 1 and by 5 mills for Case 2. However, the capital cost for the pond was about 60 percent higher in Case 1 and 115 percent higher in Case 2 than the capital cost for injection. Because of the small unit cost differential and the higher capital investment for the evaporation pond, it is recommended that injection be the method of disposal.

CRANE - REAGAN - UPTON REGION

BRINE DISPOSAL DATA

INJECTION RESERVOIR CHARACTERISTICS AND DESIGN AND COST DATA FOR BRINE DISPOSAL BY SUBSURFACE INJECTION IN SELECTED CASES

Item	ED Case IV-1	ED Case IV-2
Product Water		
Capacity, MGD	2.0	4.0
Quality, TDS (ppm)	500	500
Brine Effluent		
Volume, MGD	0.30	0.60
Quality, TDS (ppm)	7,300	7,300
Disposal Zone		
Formation or geologic age	San Andres	San Andres
Lithology	Limestone	Limestone
Depth below surface	4,400 ft.	4,400 ft.
Thickness	200 ft.	200 ft.
Well Field Data		
Number of wells	2	5
Distance to plant	1 mi.	1 mi.
Total Cost (million dollars)		
Capital	$0.289	$0.437
Annual	0.038	0 065
Total Unit Costs		
Brine basis per thousand gallons	38.89¢	32.68¢
Product basis, per thousand gallons	5.83¢	4.90¢

Source: Texas Water Development Board

FIGURE 7 - 10

TAYLOR REGION

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8. TAYLOR REGION

8.1 INTRODUCTION AND SUMMARY

For purposes of this report, Taylor Region has been established as the subject of a regional study embodying the entire Taylor County. The City of Abilene is the largest city in this region. This region was selected for study to determine the role which desalination of brackish surface water could serve toward the fulfillment of future water requirements of the area. For this purpose estimates were prepared to show the costs of desalted water in relationship to the cost of water from alternative sources.

Projections of water requirements for the Taylor Region indicate that the estimates for municipal and industrial water in 2020 will be over three times as great as the estimates for 1960. In order to provide for these needs it has been recognized that the application of desalting technology should be considered as one of the possible sources of future water supply. This study is a preliminary investigation of the feasibility and cost of desalting brackish ground water in the Taylor region.

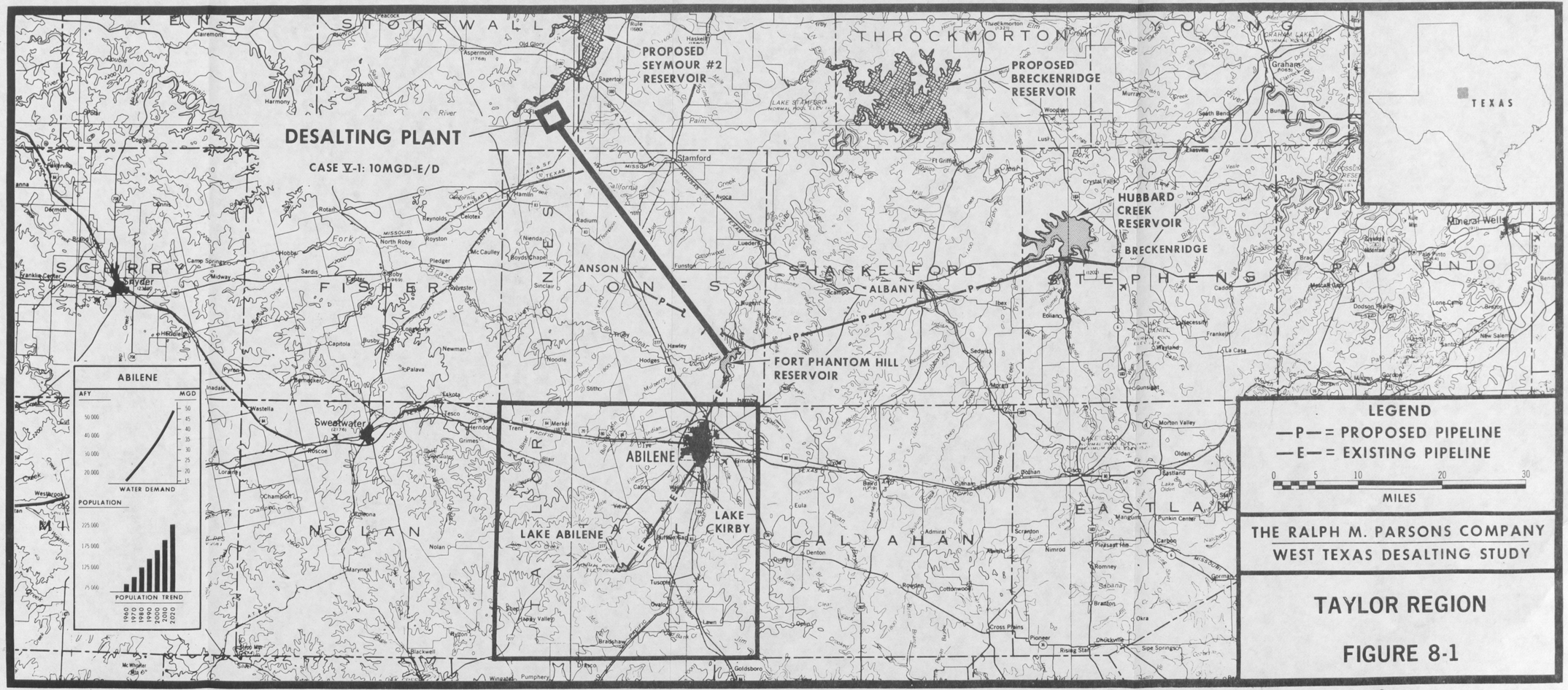
Plant size was selected on a more or less arbitrary basis, keeping in mind water resources and future requirements. The information presented herein can be used to make an appraisal of the relationship of plant size to total water requirements.

Problems associated with feedwater supply, brine disposal and integration of desalted water into the present system have been investigated only briefly. A detailed investigation of various solutions and their costs should be included in any future study.

8.1.1 Summary

Figure 8-1 is a map of the Taylor Region showing a possible location for a 10 MGD electrodialysis plant in the vicinity of the proposed Seymour No. 2 Reservoir site. This reservoir site has been proposed in previous plans for the development of water resources in the Brazos River Basin.

The availability of brackish ground water in the Taylor Region is limited. In exploring the possibilities for the application of a desalting plant in this region, it was noted from previous studies that a reservoir constructed at the proposed Seymour No. 2 site would contain brackish water. Water Quality records indicate that the discharge-weighted average of the total dissolved solids in the water would be about 1120 ppm. A reservoir at this site would provide water in excess of the recommended U. S. Public Health Service Drinking Water


DESALTING PLANT
CASE V-1: 10MGD-E/D
PROPOSED SEYMOUR #2 RESERVOIR
PROPOSED BRECKENRIDGE RESERVOIR
HUBBARD CREEK RESERVOIR
FORT PHANTOM HILL RESERVOIR
LAKE ABILENE
LAKE KIRBY
ABILENE
SWEETWATER
BRECKENRIDGE
ALBANY
STAMFORD
ANSON
HAMLIN
ROBY
ROTAN
HASKELL
THROCKMORTON
YOUNG
KENT
STONEWALL
JONES
SHACKELFORD
STEPHENS
PALO PINTO
SCURRY
FISHER
NOLAN
CALLAHAN
EASTLAND
MITCHELL
TAYLOR
JONES
ABILENE
AFY
MGD
WATER DEMAND
POPULATION
POPULATION TREND
1960
1970
1980
1990
2000
2010
2020
TEXAS
LEGEND
—P— = PROPOSED PIPELINE
—E— = EXISTING PIPELINE
0 5 10 20 30
MILES
THE RALPH M. PARSONS COMPANY
WEST TEXAS DESALTING STUDY
TAYLOR REGION
FIGURE 8-1

Standards; however, it would be an excellent source of low salinity feedwater for a membrane process desalting plant to produce 500 ppm water.

Due to the low salinity of the feedwater the electrodialysis process proved lower in cost than the reverse osmosis process during preliminary consideration.

The plant was located near the source of the feedwater in order to arrive at the lowest cost pipeline based on conveying product water rather than feedwater. The product water pipeline was terminated near Lake Fort Phantom Hill for the purpose of utilizing an existing pumping station and pipeline to continue conveying the product water to the City of Abilene.

The cost of product water delivered to the City of Abilene was calculated to be 37.9 cents per kilogallon. This compares with Hubbard Creek water which will be available to the City of Abilene from the West Central Texas Municipal Water District at a cost of 11 cents per thousand gallons. The City presently pays the District a fixed charge of $128,000 per year; however, this charge will be discontinued when the City starts purchasing water.

On the basis of estimated requirements, known supplies and the availability of Hubbard Creek Reservoir supply, it appears that consideration of the application of a desalting plant would be many years away.

8.2 WATER ADMINISTRATION AND FACILITIES

8.2.1 City of Abilene

Abilene, Texas is an incorporated city located in Taylor County with an estimated population of 105,100 in 1967.

The Abilene Water Department is a branch of the municipal government. The combined number of residential, commercial and industrial meters in use is an estimated 27,500.

The City has contracted to supply water to Dyess AFB, the City of Merkel and the towns of Potosi, View, Hamby, Hawley, and Impact.

Storage Facilities

The total storage capacity in the water system is 15,750,000 gallons including 4 elevated storage tanks with a total capacity of 4,500,000 gallons.

Water Treatment Plants

The City owns two water treatment plants. The Grimes plant has a nominal capacity of 32 mgd and the Abilene plant has a nominal capacity of 3 to 4 mgd.

A report /36/ has proposed construction of a new treatment plant, the Northeast plant, with a nominal capacity of 16 mgd. This is now under construction.

Sewage Treatment Plants

Sewage facilities owned and operated by the City have a capacity of 12,000,000 gpd and an average load of 8,000,000 gpd. Some of the effluent is used for agricultural irrigation.

8.2.2 West Central Texas Municipal Water District

The West Central Texas Municipal Water District, with headquarters in Abilene, is comprised of the cities of Abilene, Anson, Albany, and Breckenridge. The district's principal source of water is Hubbard Creek Reservoir. The reservoir is on Hubbard Creek in the Brazos River Basin in Stephens County, 6 miles northwest of the City of Breckenridge. Hubbard Creek dam and reservoir are owned and operated by the District.

Water rights obtained by the District from the State Board of Water Engineers in 1957 and 1959 allow diversion of 50,400 AFY for M and I use, and 5600 AFY for mining.

8.3 POPULATION AND WATER REQUIREMENTS

Planning for the development of municipal and industrial water facilities depends upon projections of future population and industrial growth. In this report, the quantity of fresh water required by each region is based on projections by the Texas Water Development Board.

The intent of the projections is to provide guidelines for orderly planning and development of future water supply facilities. The near term projections, i.e; the next 10 to 20 years, should be more reliable than those in the more distant future. In the near term interval, growth rates slower or faster than are anticipated are not likely to effect large changes in the dates at which projected population data are reached. On the other hand, for spans of 20 years in the future and beyond, the variation of actual population figures from present day estimates may become significant.

The large projected per capita per day use indicated for several cities is attributed to a large projected industrial water requirement. For simplicity in handling projected requirements of water used by industry located within a county but not within the confines of any city, the Texas Water Development Board allocated these requirements to the nearest city. This has the effect of showing a large water requirement for some of the cities in this report.

Where per capita consumption growth appears abnormal, it is anticipated that the availability of sufficient quantities of good quality water in the future will attract industry, thus modifying the historical growth pattern of per capita consumption.

Data on population and water requirements projected to the year 2020 for cities as well as region totals have been developed by the Texas Water Development Board as shown on Figure 8-2.

POPULATION AND WATER REQUIREMENT ESTIMATES
Taylor County

	1970	1980	1990	2000	2010	2010
POPULATION						
Taylor County						
Abilene	111,468	132,929	153,256	176,690	203,709	234,859
Other	10,640	10,764	11,348	11,900	12,393	12,800
Total	122,108	143,693	164,604	188,590	216,102	247,659
M & I WATER REQUIREMENTS			Acre Feet Per Year			
Taylor County						
Abilene	23,283	29,044	34,000	39,863	46,802	55,017
Other (See Note)	--	--	--	--	--	--
Total	23,283	29,044	34,000	39,863	46,802	55,016
			Million Gallons Per Day			
Taylor County						
Abilene	20.79	25.93	30.35	35.59	41.78	49.12
Other (See Note)	--	--	--	--	--	--
Total	20.79	25.93	30.35	35.59	41.78	49.12

Note: Water requirements not shown separately because City of Abilene presently furnishes water to almost all of the population centers in Taylor County.

Source: Texas Water Development Board

FIGURE 8 - 2

8.4 ECONOMIC AND FINANCIAL DATA

The City of Abilene is the County Seat and population center of Taylor County. Diversified industries include cottonseed processing, apparel, millwork, food, musical instruments, watches, and clay products. Several large oil firms are headquartered here. Oil production and cattle and sheep ranching are important activities.

The following table shows interesting economic data for Taylor County:

Bank Deposits (1964)	$ 146,471,000
Retail Sales (1963)	$ 140,794,000
Wholesale Sales (1963)	$ 148,456,000
Farm Products Sold (1964)	$ 6,173,000
Service Receipts (1963)	$ 17,994,000
Mineral Industry Receipts (1964)	$ 16,197,000
Building Permits (1964)	$ 1,010,041
Total Vehicles Registered (1964)	64,239
Passenger Vehicles Registered (1964)	46,051
Total Employment (1965)	34,253
Wages (1st Quarter 1965 x 4)	$ 81,649,000
Manufacturing Establishments, Number, - (1st Quarter 1965)	99
Manufacturing Establishments, 20 or more Employees, (1st Quarter 1965)	35
Manufacturing Establishments, Number, - Employees (1st Quarter 1965)	3,467
Manufacturing Establishments, - - Payroll (1st Quarter 1965 x 4)	$ 16,484,000
Value Added by Manufacturing (1963)	$ 31,843,000
Total Local Bonded Debt (1963)	$ 47,616,000

The total dollars represented by the four up-trending factors is approximately thirty percent greater than the dollar volume of the two down-trending factors. There appears to be no simple explanation for the significant decline in "Wholesale Sales". The future trends of the various economic factors should be carefully watched to endeavor to establish the long-term pattern.

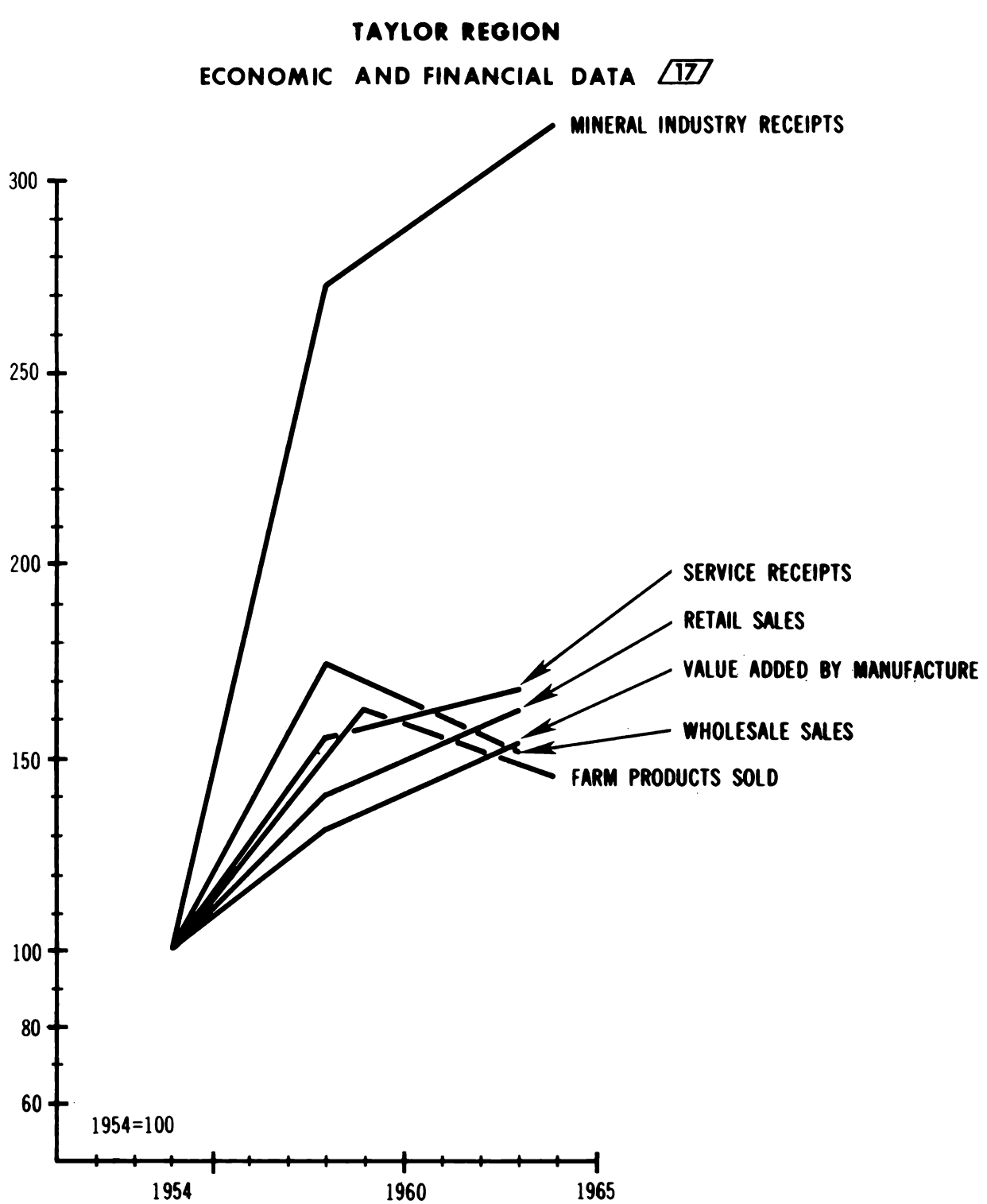

TAYLOR REGION
ECONOMIC AND FINANCIAL DATA 17
MINERAL INDUSTRY RECEIPTS
SERVICE RECEIPTS
RETAIL SALES
VALUE ADDED BY MANUFACTURE
WHOLESALE SALES
FARM PRODUCTS SOLD
300
250
200
150
100
80
60
1954=100
1954
1960
1965

FIGURE 8-3

8.5 MUNICIPAL AND INDUSTRIAL WATER RESOURCES /7/ /9/ /11/

8.5.1 Ground Water

The major portion of Taylor Region is located in the Brazos River basin. The extreme southern portion of the region lies in the Colorado River basin.

There are no major aquifers in the Brazos River basin or the Colorado River basin that underly Taylor Region. Ground water of suitable quality is limited throughout the region, and where present the quantity generally is insufficient for M & I supply on a firm yield or standby basis.

8.5.2 Surface Water

The Taylor Region derives its surface water from the Brazos River basin. Abilene currently obtains its water supply from the following three reservoirs:

- Lake Fort Phantom Hill. This reservoir is 10 miles northeast of the city and has a capacity of 24 billion gallons of water. Surface area is 4,200 acres. It holds 73,960 acre feet of water and has a shoreline of 29 miles.

- Lake Abilene. This reservoir is 19 miles southwest of the city. The lake has a surface area of 635 acres and has a capacity of 3.25 billion gallons. It holds 9,210 acre feet of water and has a shoreline of 8.14 miles.

- Lake Kirby. This reservoir is one mile south of Abilene. It has a surface area of 795 acres and has a capacity of 2.85 billion gallons. It holds 8,746 acre feet of water, and the length of the shoreline is 5.8 miles.

8.5.3 Water Resources Data

Figure 8-4 indicates the firm yield of existing reservoirs and the annual appropriation permitted the City of Abilene from Lake Abilene, Lake Fort Phantom Hill and Lake Kirby. Also shown is the firm yield for Hubbard Creek Reservoir although no pipeline is available at present to Abilene. These yields are based on the assumption that the period of drought, as it applies to a particular reservoir, becomes defined only as a result of hypothetically operating the water supply system through a historic or synthetic sequence of supply and demand events. The Texas Water Development Board has used the 17 year period 1941-1957

WATER RESOURCES

TAYLOR REGION

	Firm Yield (AFY)	Appropriation by Permit (AFY)	TDS (Average)	Availabile	Remarks
Lake Abilene		1,675	330		
Lake Fort Phantom Hill	25,000	30,690	372	25,000AFY	
Lake Kirby		14,284	254		
Hubbard Creek Reservoir	20,000	17,375		17,375AFY	There are no water conveyance facilities between Abilene and Hubbard Creek Reservoir at Present.

FIGURE 8 - 4

for this historic sequence of events inasmuch as periods of both drought and water plentitude lasting several consecutive years occurred during this time.

8.5.4 Mass Diagram

Analysis of water data may be simplified by use of a mass diagram which shows cumulative quantities of water with respect to time. Figure 8-5 shows mass diagrams for the water resources of the region. Also shown in a mass curve for water demand based on data provided by the Texas Water Development Board.

The mass diagram shows that the firm yields from Lake Kirby, Lake Abilene and Lake Fort Phantom Hill are adequate to meet the municipal and industrial water requirements of the region to the year 1975. If Hubbard Creek water is available at that time, its 17,375 acre feet per year appropriation added to existing supplies will provide adequate supplies to meet the projected demands within the range of this study. During years of no drought when adequate runoff exists, there should be significant quantities of water available in excess of the projected water demand.

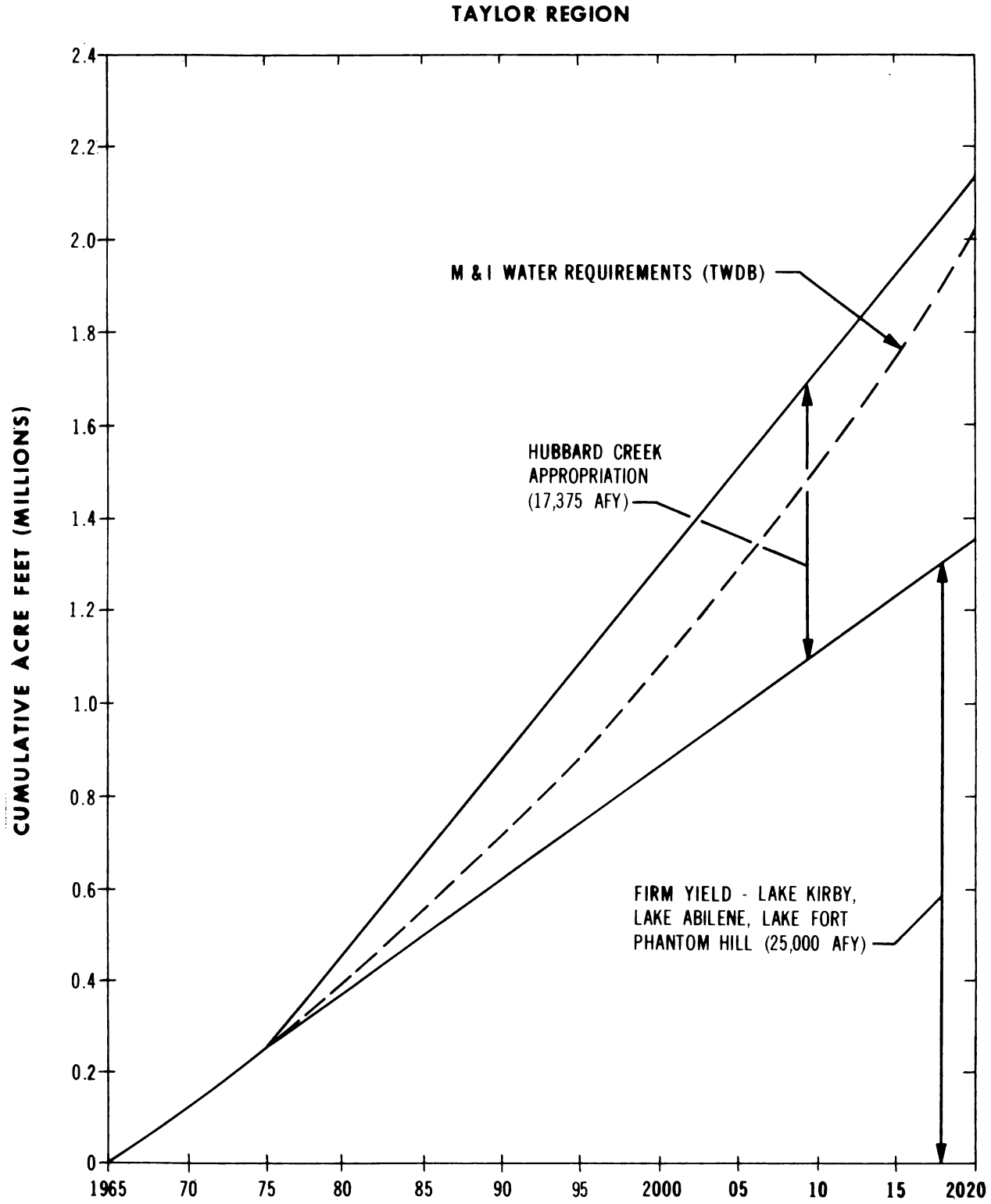

TAYLOR REGION
CUMULATIVE ACRE FEET (MILLIONS)
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
M & I WATER REQUIREMENTS (TWDB)
HUBBARD CREEK
APPROPRIATION
(17,375 AFY)
FIRM YIELD - LAKE KIRBY,
LAKE ABILENE, LAKE FORT
PHANTOM HILL (25,000 AFY)
1965
70
75
80
85
90
95
2000
05
10
15
2020
MASS DIAGRAM

FIGURE 8-5

8.6 POSSIBLE FUTURE WATER SOURCES

The following list shows the possibilities for providing additional water sources to meet prospective growth in water demand:

- Import water from other areas.
- Desalt brackish water.
- Reclaim waste water.

Importation of water. The Texas Water Development Board has under active consideration the possibility of importing water to areas in Texas from the Mississippi River to meet municipal, industrial, irrigation and mining water needs. Preliminary estimates by the Board indicate that the cost of water delivered to Abilene from East Texas, and out-of-State sources can be as much as 30¢ to 35¢ per thousand gallons. To this cost would have to be added the cost of conventional water treatment after delivery to Abilene. Volumes of water potentially available, possible routings and costs of moving water to and across Texas from the Mississippi River presently are under study by the Board, the U.S. Army Corps of Engineers and the Bureau of Reclamation, U.S. Department of the Interior.

Hubbard Creek Reservoir was constructed by the West Central Texas Municipal Water District in 1962. The City of Abilene has a contract with the District to purchase raw water from the reservoir when it is needed by the City. The Reservoir is about 40 miles northeast of Abilene, and it will be necessary for the district to construct a pipeline to deliver the water to the City's treatment plant.

The Preliminary Texas Water Plan - 1966 proposed the construction of Breckenridge Reservoir at a site on the Clear Fork of the Brazos River about 40 miles north of Abilene. Previous state, federal, and local water plans have proposed several alternative reservoir sites.

Desalting has demonstrated its increasing importance for supplying water of good quality as costs have been reduced significantly during the last ten years. This report explores the state of the art of this technology and presents data in the subsequent sections of this chapter on the application of desalting in the Taylor County area. The availability of local brackish ground water supplies in this area is limited. For the purposes of this study it has been assumed that Seymour No. 2 Reservoir, a reservoir previously proposed for this area would be constructed at the confluence of the Salt and Double Mountain Forks of the Brazos River. Preliminary studies indicate that the water in a reservoir at this site would have a dissolved-solids content of about 1,100 parts per million.

Reclaiming waste water from return flows has the potential for significantly increasing the life of water reserves. This requires employment of some process to condition this water to make it satisfactory for municipal and industrial use. Return flows can also serve as a source of feedwater for desalination, particularly in areas where brackish or saline water supplies are limited. A significant percentage of the water used in an area is available as return flow. Extensive research into treatment of return flows has been in progress in the Federal Water Pollution Control Administration and other agencies. The feasibility of reclamation has been demonstrated and emphasis is being placed on efforts to reduce costs. It appears that the reclaimed product can meet U. S. Public Health Service Standards for municipal and industrial water, but there may remain esthetic objections to be overcome to gain public acceptance of this source.

One of the interesting advantages derived from reclamation of return flows is that it is estimated that salinity increases only 300 to 400 ppm for each use. Desalting the return flows only by this amount permits application of desalting systems which will yield low cost water.

Figure 8 - 6 shows return flow data furnished by the Texas Water Development Board.

RETURN FLOW

Taylor Region

RETURN FLOW	1970	1980	1990	2000	2010	2020
	Acre Feet Per Year					
Abilene	12,808	15,595	17,825	20,403	23,383	26,825
Merkel						
North Park						
Taylor County						
Total						
	Million Gallons Per Day					
Abilene	11.43	13.92	15.91	18.21	20.88	23.95
Merkel						
North Park						
Taylor County						
Total						

Source: Texas Water Development Board

FIGURE 8 - 6

8.7 DESALTING POSSIBILITIES

In order to determine costs for desalting in this region, a search was made for a source of suitable feedwater supply for a desalting plant. This source should preferably have a salinity in excess of U.S. Public Health Service recommendations so that it would not be recommended for municipal and industrial water use in this region.

The proposed Seymour #2 reservoir appears to meet this requirement. The Texas Water Development Board provided an analysis of this feedwater as tabulated on Figure 8-7. This shows a discharge weighted average and represents the approximate composition of water that would be found in a reservoir containing all water passing a given station during the year, based on thorough mixing in the reservoir.

A desalting plant capacity of 10 MGD was arbitrarily selected on the basis of continued growth in the Taylor region. The desalting plant was assumed to be located in the vicinity of the Seymour #2 reservoir site so that the pipeline could be sized for conveyance of product water. This would be smaller than one sized to carry the feedwater which would have to be conveyed if the plant were located nearer Abilene.

The product water line was assumed to be terminated near Lake Fort Phantom Hill where there is an existing pumping station and pipeline to convey water to the City of Abilene. Details of the pumping station and pipeline are not known; additionally, the problems of integrating the desalted water supply with supplies of conventional water for the City of Abilene have not been investigated. These factors should be thoroughly explored in future studies involving application of desalting to this region.

Figure 8-1 shows plant location and the necessary pipeline and and facilities for conveying product water. Plant location and pipeline routes are not determined in the study. Approximate plant location and straight line pipeline routing are shown only for the purpose of arriving at approximate preliminary costs.

The cost of product water for the assumed plant size and location delivered to the vicinity of Lake Fort Phantom Hill reservoir is 37.9¢ per thousand gallons. This water cost is broken down into the following components:

- Desalting Plant	23.6¢/Kgal.
- Water Treatment	0.1¢/Kgal.
- Feedwater Supply	3.7¢/Kgal.
- Brine Disposal	2.2¢/Kgal.
- Product Water Conveyance	8.3¢/Kgal.
Total	37.9¢/Kgal.

TAYLOR REGION

ANALYSIS OF
SALINE WATER FOR DESALTING PLANT
FEED

	SEYMOUR #2 RESERVOIR
Temperature ^{o}F	65
Silica SiO_2	17 ppm
Calcium - Ca	159
Magnesium - Mg	24
Sodium & Potassium (Na+K)	182
Bicarbonate - HCO_3	124
Sulfate SO_4	457
Chloride - Cl	220
Nitrate NO_3	3
Dissolved Solids (TDS)	1,170
Total Hardness as $CaCO_3$	496
pH	7.1

Note: This analysis is a discharge-weighted average, and represents the approximate composition of water that would be found in a reservoi: containing all water passing a given station during the year after thorough mixing in the reservoir.

FIGURE 8 - 7

8.8 ANALYSIS AND COMPARISONS

Figure 8-8 at the end of this section shows the detailed cost breakdown for the total cost of 37.9 cents per thousand gallons of desalted water delivered to the Lake Fort Phantom Hill existing pumping station.

The Texas Water Development Board has under active consideration the possibility of importing water to areas in Texas from the Mississippi River to meet municipal, industrial, irrigation and mining water needs. Preliminary estimates by the Board indicate that the cost of water delivered to Abilene from East Texas, and out-of-state sources can be as much as 30¢ to 35¢ per thousand gallons. To this cost would have to be added the cost of conventional water treatment after delivery to Abilene. Volumes of water potentially available, possible routings and costs of moving water to and across Texas from the Mississippi River presently are under study by the Board, the U. S. Army Corps of Engineers and the Bureau of Reclamation, U. S. Department of the Interior.

Contractually, 17,375 acre feet per year is appropriated from Hubbard Creek Reservoir. The mass diagram, Figure 8-5 shows that availability of this appropriation will provide for the region's M & I water requirements beyond the year 2020. Hubbard Creek water will be available at a cost of 11 cents per thousand gallons. The City presently pays the District a fixed charge of $128,000 per year; however, this charge will be discontinued when the City starts purchasing water.

COST BREAKDOWN

THE RALPH M. PARSONS COMPANY

TAYLOR REGION, CASE NO.V-1

PROCESS E/D ; CAPACITY 10 MGD; OUTPUT 3,300,000 Kgal/yr; INTEREST 3-1/2 %; PLANT LIFE 30 YRS; PIPELINE LIFE 50 YRS

	CARRYING CHARGE MULTIPLIER	DESALT PLANT		WATER TREATMENT		FEEDWATER		BRINE DISPOSAL		PRODUCT CONVEY.	
		CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3
CAPITAL COST CENTERS											
1. Plant & Equipment	.0544	1689	91.9								
2. Replaceable Items	.2215	1080	239.0								
3. Water Treatment											
4. Well Field											
5. Pipeline	.0426									4424.2	188.5
6. Pumping Station	.0426					394.7	16.8				
7. Brine Disposal											
8. Indirect Capital Costs	.0544	471	25.6								
9. Land Costs	.035	1	-							6.0	0.2
10. Working Capital	.035	127	4.5			17.7	.6			44.5	1.6
11. Cooling Towers											
TOTAL CAPITAL COSTS →		3368		0		412.4		472		4474.7	
RECURRING COST CENTERS	PERCENT										
12. Taxes											
13. Insurance									25.7		
TOTAL ANNUAL FIXED COSTS →			361.0		0		17.4				190.3
OPERATION & MAINTENANCE COST CENTERS											
15. Operating Labor			49.5								
16. Maintenance Labor			30.2				)				)
17. General & Administrative			23.8				) 88.0				) 60.1
18. Supplies & Maintenance Materials			119.0				)				)
19. Chemicals			39.6		3.3		)				)
20. Fuel											
21. Electric Power			165.0				15.2				21.9
TOTAL O & M COSTS →			427.1		3.3		103.2		47.2		82.0
TOTAL FIXED PLUS O & M COSTS →			788.1		3.3		120.6		72.9		272.3
COMPONENT WATER COSTS, ¢/Kgal →		23.6		0.1		3.7		2.2		8.3	
TOTAL WATER COST → 37.9 ¢/Kgal											

Water treatment provides Calgon @ 6 ppm

Feedwater costs include intake structure and pumping plant at proposed Seymour #2 Reservoir

Product water conveyance: 40 mi, minus 100 ft. static hd. to Ft. Phantom Hill

FIGURE 8 - 8

8.9 BRINE DISPOSAL

Cost of brine disposal by deep well injection for this area was calculated using the Tannehill Formation as the disposal zone. The calculated cost for injection for this study case is tabulated in Figure 8 - 9.

TAYLOR REGION

BRINE DISPOSAL DATA

INJECTION RESERVOIR CHARACTERISTICS AND DESIGN AND COST DATA FOR BRINE DISPOSAL BY SUBSURFACE INJECTION IN SELECTED CASES

Item	ED Case V-1
Product Water	
Capacity, MGD	10.0
Quality, TDS (ppm)	500
Brine Effluent	
Volume, MGD	1.5
Quality, TDS (ppm)	5630
Disposal Zone	
Formation or geologic age	Tannehill
Lithology	Sandstone
Depth below surface	2300 ft.
Thickness	40 ft.
Well Field Data	
Number of wells	6
Distance to plant	1 mi.
Total Cost (million dollars)	
Capital	$0.472
Annual	0.073
Total Unit Costs	
Brine basis per thousand gallons	14.73¢
Product basis, per thousand gallons	2.21¢

FIGURE 8 - 9

CHILDRESS - HARDEMAN - VERNON REGION

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9. CHILDRESS - HARDEMAN - VERNON REGION

9.1 INTRODUCTION AND SUMMARY

For purposes of this report, Childress and Hardeman counties and the City of Vernon have been assumed to comprise one region. This region was selected for study to determine the role which desalination of underlying brackish ground water could serve toward the fulfillment of future water requirements of the area. For this purpose estimates were prepared to show the costs of desalted water in relationship to the cost of water from alternative sources.

Projections of water requirements for the Childress-Hardeman-Vernon Region indicate that the estimates for municipal and industrial water in 2020 will be twice as great as the estimates for 1960. In order to provide for these needs it has been recognized that the application of desalting technology should be considered as one of the possible sources of future water supply. This study is a preliminary investigation of the feasibility and cost of desalting brackish ground water in the Childress-Hardeman-Vernon Region.

Plant size was selected on a more or less arbitrary basis, keeping in mind water resources and future requirements. The information presented herein can be used to make an appraisal of the relationship of plant size to total water requirements.

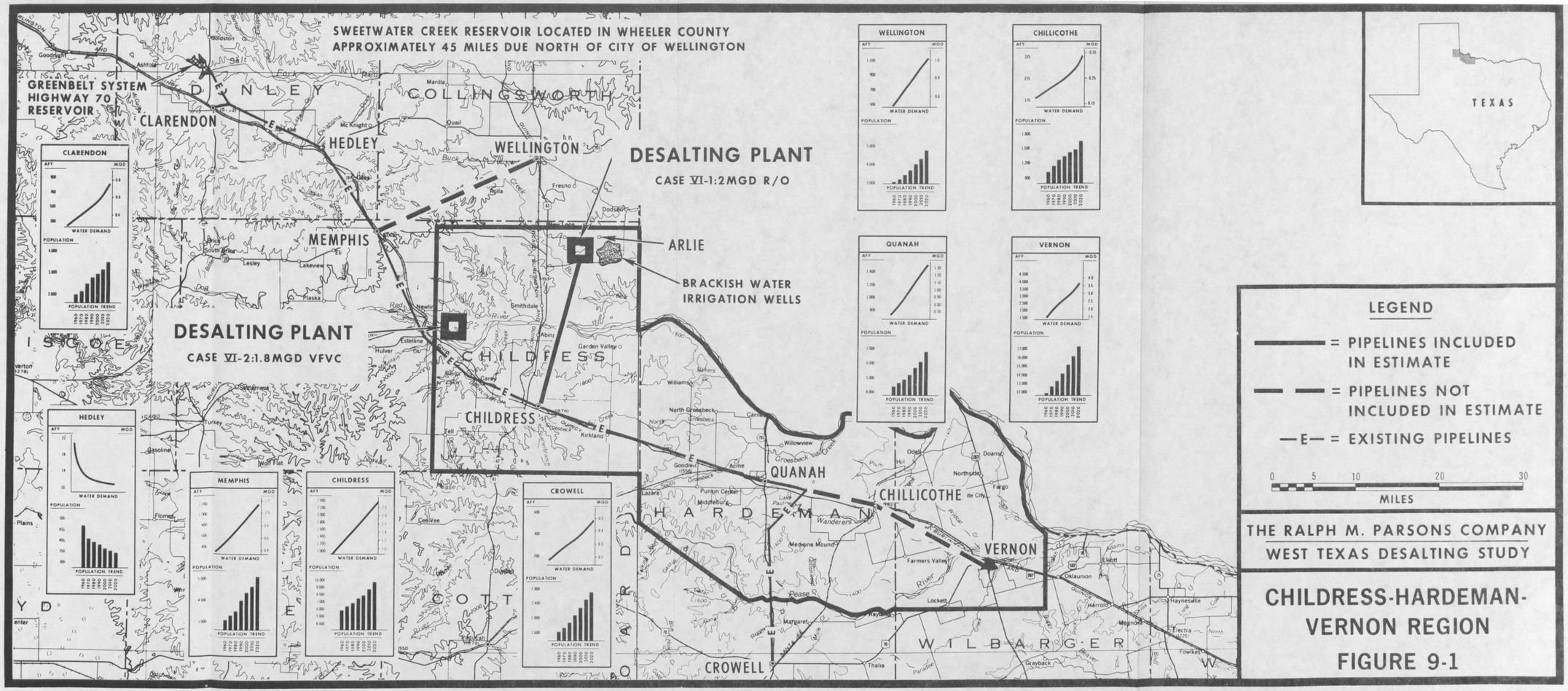
Problems associated with feedwater supply, brine disposal and integration of desalted water into the present system have been investigated only briefly. A detailed investigation of various solutions and their costs should be included in any future study.

9.1.1 Summary

Figure 9-1 shows a map of the Childress-Hardeman-Vernon Region with a 2 MGD Reverse Osmosis desalting plant located near a well field in the vicinity of Arlie and a 1.8 MGD vacuum-freezing, vapor-compression (VF-VC) desalting plant located near Estelline Springs.

In exploring the possibilities for the application of desalting plants in the Childress-Hardeman-Vernon Region, full advantage was taken of the extensive facilities of the Greenbelt Municipal and Industrial Water Authority system. The Greenbelt Authority is comprised of the cities of Childress, Clarendon, Crowell, Hedley, Memphis, Quanah and Wellington. It was created as a governmental agency by the State of Texas in 1954.

The extent of the Greenbelt system goes beyond the limits of the Childress-Hardeman-Vernon Region. Population and water requirement estimates were analyzed for the Childress-Hardeman-Vernon Region and also for the member cities of the Greenbelt


SWEETWATER CREEK RESERVOIR LOCATED IN WHEELER COUNTY
APPROXIMATELY 45 MILES DUE NORTH OF CITY OF WELLINGTON
GREENBELT SYSTEM
HIGHWAY 70
RESERVOIR
DESALTING PLANT
CASE VI-2:1.8MGD VFVC
DESALTING PLANT
CASE VI-1:2MGD R/O
ARLIE
BRACKISH WATER
IRRIGATION WELLS
CLARENDON
HEDLEY
WELLINGTON
MEMPHIS
CHILDRESS
QUANAH
CHILLICOTHE
VERNON
CROWELL
DENLEY
COLLINGSWORTH
HARDEMAN
FOARD
KNOX CITY
WILBARGER
TEXAS
LEGEND
= PIPELINES INCLUDED IN ESTIMATE
= PIPELINES NOT INCLUDED IN ESTIMATE
—E— = EXISTING PIPELINES
0 5 10 20 30
MILES
THE RALPH M. PARSONS COMPANY
WEST TEXAS DESALTING STUDY
CHILDRESS-HARDEMAN-VERNON REGION
FIGURE 9-1

system not located in the region, so that a complete area picture could be evaluated.

The cities of Vernon and Wellington do not presently receive water from the Greenbelt system. In considering the possibility that they may wish to obtain their water supplies from the Greenbelt system, the map on Figure 9-1 shows a dashed line to represent the pipelines for serving these cities. Costs for these pipelines are not included in the cost estimates prepared for this report, on the basis that if these cities wanted to purchase water from the Greenbelt system it would require the construction of the respective pipelines in any event irrespective of desalting plant installation.

The ground water from Blaine Gypsum has an average total dissolved solids content of about 3320 ppm in the Arlie area. Costs were calculated for reverse osmosis and electrodialysis; the electrodialysis process showed costs to be approximately 7 cents higher than reverse osmosis.

The Estelline Spring feedwater has total dissolved solids of 47,766 ppm. The high salinity of this feedwater was uniquely suitable for the vacuum-freezing, vapor-compression process.

In incorporating these two desalting plants into the Greenbelt system, the product water from the desalting plants was introduced into the existing pipeline system for purposes of developing costs for this report. It is recognized however, that in the case of the Arlie desalting plant it would probably prove feasible to extend the pipeline from the desalting plant north to Wellington with resulting lower costs than supplying Wellington from Memphis.

The cost of desalted 500 ppm water for a 2 MGD reverse osmosis plant was calculated to be approximately $1.056 per thousand gallons. The cost of product water from a 1.8 MGD vacuum freezing vapor compression desalting plant was calculated to be approximately $1.149 per thousand gallons.

The above costs for desalted water compare with an estimated cost of 11 cents per thousand gallons for alternative supplies from a proposed Sweetwater Creek Reservoir to which would have to be added the cost of installation and operation of a 56 mile pipeline to the Greenbelt system which may amount to approximately 15 cents per thousand gallons. The total cost of approximately 26 cents per thousand gallon for Sweetwater Creek water supply to the Greenbelt system thus appears to be considerably lower than the cost of delivering desalted water to the system.

9.2 WATER ADMINISTRATION AND FACILITIES

9.2.1 City of Childress

Childress, Texas is an incorporated city located in Childress County with an estimated 1967 population of 6,700.

The City of Childress owns and operates its own water distribution system and sewage treatment facilities. Water is provided by the Greenbelt Municipal and Industrial Water Authority. Supplemental water can be obtained from well fields west and northwest of town but it is poor quality water. There are approximately 2,600 metered connections in the city.

Storage Facilities in the City of Childress consists of one-200,000 gallon capacity elevated storage tank. Other storage tanks are located at the city well field, approximately seven miles northwest of the City, and consist of two 1,000,000 gallon capacity ground tanks, one - 1,500,000 gallon ground tank, and one - 200,000 gallon elevated tank.

Water Treatment is provided by Greenbelt B & I W A.

The Sewage Treatment plant is city owned and operated. The plant has a design capacity of 230,000 gallons per day. The actual load is 580,000 gallons per day. The facilities include a rectangular Imhoff tank and standard rate trickling filter. The point of effluent discharge is Grosbeck Creek.

9.2.2 City of Quanah

The City of Quanah, Texas is an incorporated city in Hardeman County with an estimated 1967 population of 4,700.

The City of Quanah owns and operates the water distribution and sewage disposal system. Water is provided by the Greenbelt M & I W A. A well field located north of town has been abandoned.

Storage Facilities in the City of Quanah consists of one 700,000 gallon capacity ground storage tank and one 500,000 gallon capacity elevated storage tank.

Water Treatment is provided by Greenbelt M & I W A.

Sewage Treatment - Quanah has a modified activated sludge plant. Approximately 280,000 gallons of effluent are discharged daily. The point of effluent discharge is Big Jim Creek.

9.2.3 City of Vernon

The City of Vernon, Texas is an incorporated city in Wilbarger County with an estimated 1967 population of 12,500.

The City of Vernon owns and operates its own well field, water distribution system, water treatment facilities and sewage treatment plant. Vernon relies on ground-water to meet its requirements, and has water wells in the city and in the Odell Sand Hills area approximately 19 miles north of the City. The Odell well field contains 13 wells, and water is conveyed to the City via a 21 inch diameter, reinforced concrete pipeline.

Storage Facilities in the City of Vernon consists of two 750,000 gallon capacity ground storage tanks, two 500,000 gallon capacity ground storage tanks, two 500,000 gallon capacity and one 100,000 gallon capacity elevated storage tanks.

Water Treatment consists of chlorination.

The Sewage Treatment Plant, located on the Pease River was constructed in 1953. The plant contains a bar screen, lift pumps, metering devices, a primary settler and digester, trickling filters, a final clarifer and sludge drying beds. The plant has a capacity of 1.3 million gallons per day and the average daily flow is approximately 0.9 million gallons per day.

9.2.4 City of Chillicothe

Chillicothe, Texas is an incorporated city, located in Hardeman County with an estimated 1967 population of 1,200.

The water supply for the City is provided by four wells. The system capacity is 1.6 million gallons per day.

9.2.5 Greenbelt Municipal and Industrial Water Authority

The Greenbelt Municipal and Industrial Water Authority, comprising the cities of Childress, Clarendon, Crowell, Hedley, Memphis, Quanah and Wellington was created as a governmental agency of the State of Texas in 1954 by the state legislature. The Authority was created for the purpose of providing surface water for M & I use by the member cities, and such other cities as may be interested in being served by the Authority.

A dam has been constructed on the Salt Fork of the Red River at Highway 70. The reservoir has an initial capacity of 59,800 acre-feet. A 40 year silt allowance of 9,500 acre-feet leaves a net conservation capacity of 50,300 acre feet.

The Water Treatment Plant, located near the damsite on Highway 70, has a rated capacity of 6 MGD and an overload capacity of 9 MGD. Raw water from the reservoir is delivered to the water treatment plant through a 27 inch water line from a 9 MGD pump station. The treatment plant has facilities for mixing, flocculation, coagulation, filtration and chlorination of water.

The water pipeline system originates at the treatment plant with a pipeline size of 27 inches. Reductions in line size occur at intervals along the system until the pipe diameter to Crowell is 12 inches.

9.3 POPULATION AND WATER REQUIREMENTS

Planning for the development of municipal and industrial water facilities depends upon projections of future population and industrial growth. In this report, the quantity of fresh water required by each region is based on projections by the Texas Water Development Board.

The intent of the projections is to provide guidelines for orderly planning and development of future water supply facilities. The near term projections, i.e., the next 10 to 20 years, should be more reliable than those in the more distant future. In the near term interval, growth rates slower or faster than are anticipated are not likely to effect large changes in the dates at which projected population data are reached. On the other hand, for spans of 20 years in the future and beyond, the variation of actual population figures from present day estimates may become significant.

The large projected per capita per day use indicated for several cities is attributed to a large projected industrial water requirement. For simplicity in handling projected requirements of water used by industry located within a county but not within the confines of any city, the Texas Water Development Board allocated these requirements to the nearest city. This has the effect of showing a large water requirement for some of the cities in this report.

Where per capita comsumption growth appears abnormal, it is anticipated that the availability of sufficient quantities of good quality water in the future will attract industry, thus modifying the historical growth pattern of per capita consumption.

Data on population and water requirements projected to the year 2020 for cities as well as county and region totals have been developed by the Texas Water Development Board. Figure 9-2 also provides similar data for member cities of Greenbelt Municipal and Industrial Water Authority which are located outside the Childress-Hardeman-Vernon Region.

POPULATION AND WATER REQUIREMENT ESTIMATES
Childress - Hardeman - Vernon Region

	1970	1980	1990	2000	2010	2020
POPULATION						
Childress County						
Childress	6,794	7,276	7,863	8,496	9,180	9,920
Other	1,974	1,993	2,084	2,179	2,276	2,374
Total	8,768	9,269	9,947	10,675	11,456	12,294
Hardeman County						
Chillicothe	1,198	1,267	1,369	1,479	1,598	1,727
Quanah	4,720	4,989	5,391	5,825	6,294	6,800
Other	2,149	1,786	1,748	1,587	1,399	1,182
Total	8,067	8,142	8,508	8,891	9,291	9,709
City of Vernon	12,707	13,425	14,316	15,366	16,279	17,360
Region Total	29,542	30,836	32,771	34,932	37,026	39,363
M & I WATER REQUIREMENTS	Acre Feet Per Year					
Childress County						
Childress	1,358	1,570	1,739	1,927	2,136	2,367
Other	1	2	2	2	2	2
Total	1,359	1,572	1,741	1,929	2,138	2,369
Hardeman County						
Chillicothe	213	243	271	300	334	372
Quanah	839	958	1,065	1,185	1,317	1,464
Other	520	432	452	474	496	515
Total	1,572	1,633	1,788	1,959	2,147	2,351
City of Vernon	2,300	2,647	2,934	3,253	3,609	4,003
Region Total	5,231	5,852	6,463	7,141	7,894	8,723
	Million Gallons Per Day					
Childress County						
Childress	1.21	1.40	1.55	1.72	1.91	2.11
Other	--	--	--	--	----	0.01
Total	1.21	1.40	1.55	1.72	1.91	2.12
Hardeman County						
Chillicothe	0.19	0.22	0.24	0.27	0.30	0.33
Quanah	0.75	0.86	0.95	1.06	1.18	1.31
Other	0.46	0.38	0.41	0.42	0.44	0.46
Total	1.40	1.46	1.60	1.75	1.92	2.10
City of Vernon	2.05	2.36	2.62	2.91	3.22	3.57
Region Total	4.66	5.22	5.77	6.38	7.05	7.79

FIGURE 9 - 2

(Continued on next page)

Source: Texas Water Development Board

POPULATION AND WATER REQUIREMENT ESTIMATES

Member Cities of Greenbelt Municipal and Industrial Water Authority
Not Located in Childress-Hardeman-Vernon Region

	1970	1980	1990	2000	2010	2020
POPULATION						
Clarendon	2,346	2,542	2,762	3,002	3,262	3,545
Crowell	1,800	1,937	2,124	2,329	3,554	2,800
Hedley	436	404	394	383	372	362
Memphis	3,508	3,766	4,121	4,510	4,935	5,400
Wellington	3,375	3,641	3,942	4,267	4,619	5,000
M & I WATER REQUIREMENTS						
	Acre Feet Per Year					
Clarendon	411	488	559	641	735	842
Crowell	278	325	367	416	471	533
Hedley	16	14	13	13	12	12
Memphis	578	686	793	917	1,061	1,228
Wellington	654	753	836	930	1,033	1,148
	Million Gallons Per Day					
Clarendon	0.37	0.44	0.50	0.57	0.66	0.75
Crowell	0.25	0.29	0.33	0.37	0.42	0.48
Hedley	0.02	0.01	0.01	0.01	0.01	0.01
Memphis	0.52	0.61	0.71	0.82	0.95	1.10
Wellington	0.58	0.67	0.75	0.83	0.92	1.03

Source: Texas Water Development Board

FIGURE 9 - 2 (Continued)

9.4 ECONOMIC AND FINANCIAL DATA

Childress, Hardeman and Wilbarger counties are predominantly farming areas with some cattle ranching. Approximately 42,000 acres are irrigated to produce chiefly wheat, grain sorghums and cotton.

Statistics of the three county area are shown in the following table:

Bank Deposits (1964)	$ 56,072,000
Retail Sales (1963) .	$ 45,609,000
Wholesale Sales (1963) . .	$ 48,500,000
Farm Products Sold (1964).	$ 24,033,000
Service Receipts (1963).	$ 4,924,000
Mineral Industry Receipts (1964)	$ 23,630,000
Total Vehicles Registered (1964) . .	24,368
Passenger Vehicles Registered (1964)	15,759
Total Employment (1st Quarter 1965).	4,499
Wages (1st Quarter 1965 x 4)	$ 16,962,000
Manufacturing Establishments, Number Employees (1st Quarter 1965)	1,064
Manufacturing Establishments - Payroll (1st Quarter 1965 x 4)	$ 4,044,000
Total Local Bonded Debt (1963) .	$ 7,436,000

Figure 9-3 shows an up-trend for each of the important economic parameters shown. The total amount for these parameters in 1954 was approximately $100,000,000; in 1963-64 the total amounted to over $146,000,000, indicating a significant growth pattern during this period.

CHILDRESS - HARDEMAN - VERNON

REGION

ECONOMIC AND FINANCIAL DATA 17

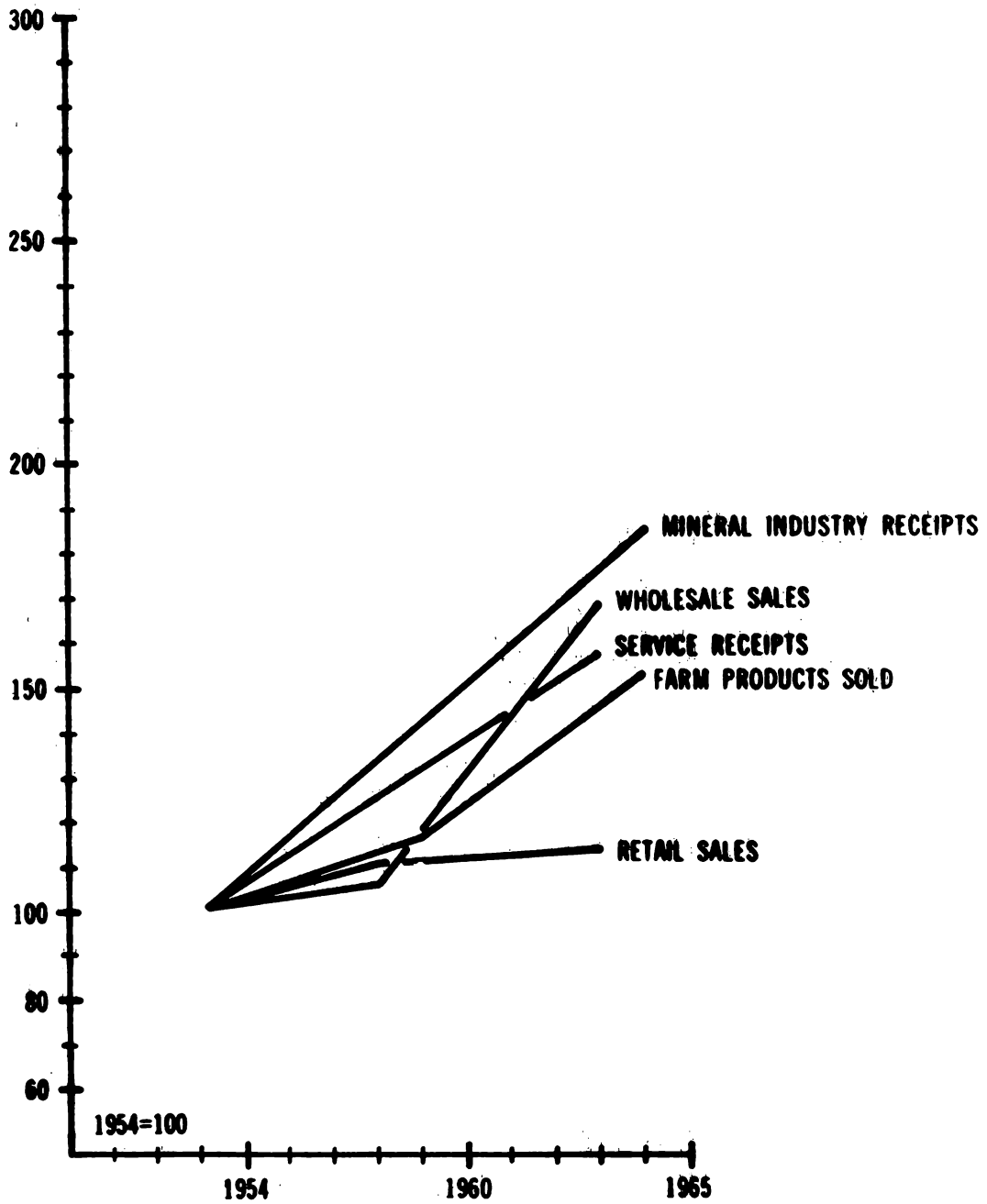


FIGURE 9-3

9.5 MUNICIPAL AND INDUSTRIAL WATER RESOURCES

9.5.1 Ground Water

The Childress-Hardeman-Vernon Region is located in the Red River Basin. The central part of the Red River Basin in Texas is in the Osage Plans province. The primary aquifers in this part of the Red River basin are the Blaine Gypsum and the Quaternary Alluvium.

The Blaine Gypsum consists of anhydrite, gypsum, shale, and dolomite. The gypsum is eroded easily by chemical weathering, and the beds containing gypsum generally are cavernous. The observed thickness of the Blaine Gypsum ranges from 0 to about 250 feet in the outcrop; in the subsurface the minimum thickness is about 200 feet.

Water from the Blaine Gypsum is not suitable for public supply; the sulfate content and, in some wells the chloride content as well, exceeds the 250 ppm limit recommended by the U. S. Public Health Service. The water from the Blaine is not suitable for many industrial uses; however, it may be acceptable for cooling and washing.

Remnents of the Seymour formation and other alluvial sediments are found in the Childress-Hardeman-Vernon Region. These deposits of sand, gravel, silt, and clay range in thickness from a few to as much as 360 feet. The water is under water table conditions, and saturated thickness generally is less than 100 feet. Yields of large-capacity wells average about 300 gallons per minute with some wells producing as high as 1300 gallons per minute. The water generally contains less than 1000 parts per million dissolved solids, although in some places it ranges up to more than 3000 parts per million.

9.5.2 Surface Water

The Red River basin drainage begins 40 miles west of the New Mexico-Texas line. The contributing area and runoff are small until the various branches of the stream leave the eastern edge of the Caprock about 150 miles east of the point of beginning of the drainage. The flow in many of the streams east of the Caprock in the Red River drainage is sustained in variable amounts by inflow from ground water.

The upper Salt Fork of the Red River is the most economical source of an adequate supply of surface water of usable and satisfactory quality for municipal and industrial use in a large area of Northwest Texas centering on the cities from the Greenbelt M & I Water Authority.

The Greenbelt Municipal and Industrial Water Authority, Highway 70 Reservoir is located on the Salt Fork of Red River near the City of Clarendon. Figure 9-4 shows the firm yields for this reservoir. These yields are based on the assumption that the period of drought, as it applies to a particular reservoir, becomes defined only as a result of hypothetically operating the water supply system through a historic or synthetic sequence of supply and demand events. The Texas Water Development Board has used the 17 year period 1941-1957 for this historic sequence of events inasmuch as periods of both drought and water plentitude lasting several consecutive years occurred during this time.

Water analyses for Greenbelt M & I Water Authority's Highway 70 Reservoir at the lake outlet and at the treatment plant discharge are shown on Figure 9-5.

9.5.3 Water Resources Data

Figure 9-6 provides a summary of municipal and industrial water resources information for the Childress-Hardeman-Vernon Region. The data includes ground water, surface water and Greenbelt M & I W A supplied water quantities.

9.5.4 Mass Diagram

Water resources available to the Greenbelt M & I W A member cities are indicated on mass diagram, Figure 9-7, which shows the cumulative quantities of water available from Highway 70 Reservoir with respect to time.

The municipal and industrial water requirements represent the total regional requirements including the cities of Childress, Chillicothe, Quanah and Vernon, plus the Greenbelt member cities of Hedley, Clarendon, Memphis, Wellington and Crowell.

The Highway 70 Reservoir mass curve based on firm yield can accommodate the M & I demand until approximately 1995. Thereafter, the M & I requirements exceed Highway 70 Reservoir firm yield, and additional sources of supply will be required.

RESERVOIR FIRM YIELDS
(Acre - Feet)

CHILDRESS - HARDEMAN - VERNON REGION

	1970	1980	1990	2000	2010	2020
Greenbelt M & I W A Highway 70 Reservoir	10,114	9,886	9,658	9,430	9,200	8,972

Source: TWDB

FIGURE 9 - 4

GREENBELT M & I WATER AUTHORITY
HIGHWAY 70 RESERVOIR WATER ANALYSIS

	Treatment Plant Discharge Jan. 24, 1968	Lake Outlet Dec. 4, 1967
Calcium	54 ppm	44 ppm
Magnesium	18	16
Sodium	37	35
Bicarbonate	179	161
Sulphate	74	73
Chloride	42	34
Dissolved Solids	405	364
Fluoride	0.9	0.8
Hardness as $CaCO_3$	209	177
pH	8.2	--

FIGURE 9 - 5

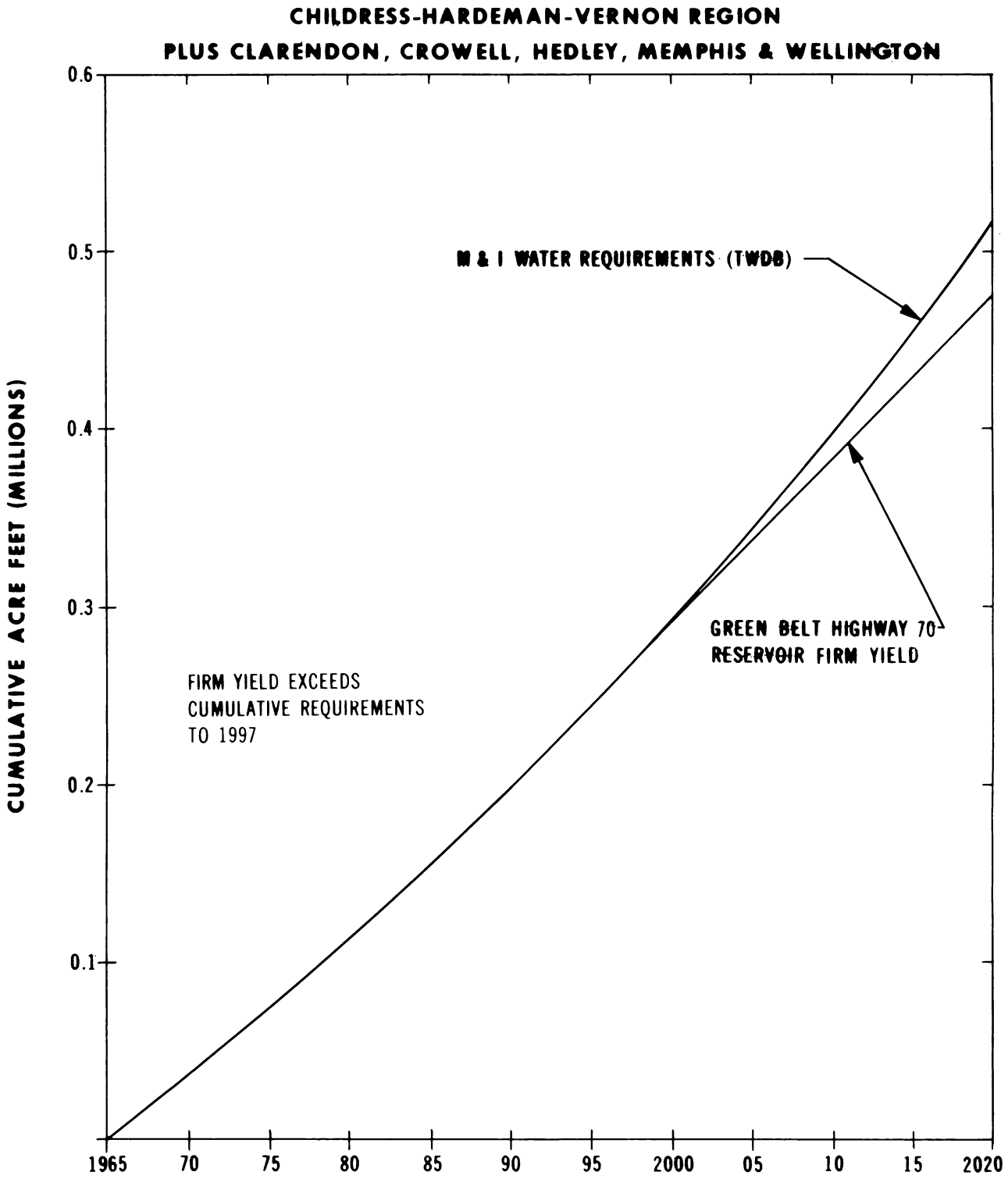
WATER RESOURCES

CHILDRESS - HARDEMAN - VERNON REGION

	Recharge* (AFY)	Storage* (AF)	TDS (Avg.)	Available	Remarks
City of Childress					
Well Field	1,000		1,070	1,000 AFY	Standby Source Only
Lake Childress			1,075	) 2,274 AFY) Permitted) Annual Use	Standby Source Only
Baylor Lake			1,827		
City of Quanah			1,000 to 2,500	300 AFY	Emergency Source Only
Well Field					
City of Vernon 34					
Well Field (Odell Sand Hills)	10,000	225,000	300 to 600		
Greenbelt Municipal and Industrial Water Authority					
Highway 70 Reservoir				9,650 AFY	Average Firm Yield

* The numbers in these columns refer to that part of the aquifer in the well field or land under lease.

FIGURE 9 - 6



MASS DIAGRAM

FIGURE 9-7

9.6 POSSIBLE FUTURE WATER SOURCES

The following list shows the possibilities for providing additional water sources to meet prospective growth in water demand:

- Import water from other areas.
- Desalt local brackish water.
- Blending local brackish water with superior quality water.

Importation of water has not been under study in this area. However, the Preliminary Texas Water Plan-1966 proposes the Sweetwater Creek Reservoir site on Sweetwater Creek in Wheeler County, and indicates the Reservoir can be constructed when needed. Water from a reservoir at this location could be supplied by pipeline to the existing Greenbelt M & I Water Authority pipeline, a distance of about 50 miles.

Desalting has demonstrated its increasing importance for supplying water of good quality as costs have been reduced significantly during the last ten years. This report explores the state of the art of this technology and presents data in the subsequent sections of this chapter on the application of desalting in the Childress-Hardeman-Vernon Region.

Blending brackish water with water of superior quality to provide a consumer product of good quality (e.g., 500 to 750 ppm) will have the effect of increasing the life of water reserves if there is sufficient quantity of fresh water which has a salinity significantly lower than the target goal for the blended supply.

Return flows represent a potential resource for re-use after suitable treatment. Return flow data for this region furnished by the Texas Water Development Board are shown on Figure 9-8.

RETURN FLOW

Childress-Hardeman-Vernon Region

RETURN FLOW	1970	1980	1990	2000	2010	2020
	Acre Feet Per Year					
Childress	634	714	770	830	895	964
Other	1	1	1	1	1	1
Childress County Total	635	715	771	831	896	965
Quanah	390	434	469	507	548	591
Other	328	291	299	307	314	319
Hardeman County Total	718	725	768	814	862	910
City of Vernon	1,073	1,202	1,298	1,400	1,510	1,627
Region Total	2,426	2,642	2,837	3,045	3,268	3,502
	Million Gallons Per Day					
Childress	0.57	0.64	0.69	0.74	0.80	0.86
Other	-	-	-	-	-	-
Childress County Total	0.57	0.64	0.69	0.74	0.80	0.86
Quanah	0.35	0.39	0.42	0.45	0.49	0.53
Other	.29	.26	.27	.28	.28	.35
Hardeman County Total	0.64	0.65	0.69	0.73	0.77	0.88
City of Vernon	0.96	1.07	1.16	1.25	1.35	1.45
Region Total	2.17	2.36	2.54	2.72	2.92	3.19

Source: Texas Water Development Board

FIGURE 9 - 8

9.7 DESALTING POSSIBILITIES

In order to determine the costs of furnishing desalted water in this region, it was assumed for purposes of this report that a desalting plant would tie into the Greenbelt system. Also, it was assumed that the Greenbelt system would provide municipal and industrial water to cities in Childress and Hardeman counties as well as the cities of Clarendon, Crowell, Hedley, Memphis, Wellington and Vernon.

Inasmuch as the City of Vernon is not presently being supplied with water from the Greenbelt system, a pipeline was assumed to be installed to convey Greenbelt water to Vernon. The cost of this pipeline was not included in the estimates for desalted water on the basis that if Vernon wanted to purchase water from Greenbelt, it would require the construction of this pipeline in any event, irrespective of desalting plant installation.

Two separate desalting cases were considered, one of which employs brackish water from the Blaine Gypsum aquifer with average total dissolved solids of 3,320 and the other utilizing Estelline Spring water with average total dissolved solids of 47,766. Water analyses for these two supplies are given on Figure 9-9 as furnished by the Texas Water Development Board.

It should be pointed out that a review of the mass diagram, Figure 9-7 shows adequate firm yield capacity to supply the estimated requirements of the cities of Childress, Clarendon, Crowell, Hedley, Memphis and Quanah to approximately 1995. Data for firm yield are based on records of stream flow during severest drought of record plus drawdown of storage. The value of the consideration of a regional desalting plant is in its use as a planning tool at such a time as the demand on the Greenbelt system appears to be approaching its firm supply.

Case VI-1 on Figure 9-1 shows a two MGD membrane desalting plant near the Arlie brackish water irrigation wells. A pipeline is shown extended to Wellington and down to Childress for connection to the Greenbelt system. The pipeline to Wellington is shown dotted for the same reason as the pipeline to Vernon. The product water line was terminated nearby the Greenbelt pipeline, but no investigation was made regarding any problems associated with blending the desalted water supply with the Greenbelt system supply. Details of combining desalted water with Greenbelt water should be thoroughly explored in any future feasibility study involving application of desalting on the Greenbelt system.

Figure 9-1 shows approximate plant locations and assumed pipeline and facilities for bringing desalted water to the Greenbelt system.

ANALYSIS OF
SALINE WATER FOR DESALTING PLANT
FEED

	ARLIE BLAINE GYPSUM	ESTELLINE SPRING
Temperature °F	68	68
Silica - SiO_2	16ppm	10ppm
Iron - Fe		0.34
Manganese - Mn		0.5
Calcium - Ca	606	1,520
Magnesium - Mg	129	470
Sodium & Potassium (Na+K)	204	16,590
Bicarbonate - HCO_3	201	
Sulfate - SO_4	1,850	4,233
Chloride - Cl	310	25,483
Fluoride - F		2.3
Nitrate	5.1	0.04
Boron B	0.78	
Chemical Oxygen Demand	10	
Dissolved Solids (TDS)	3,220	47,766
Total Hardness as $CaCO_3$	2,040	5,733
Specific Conductance (Micromhos at 25°C)	3,690	
pH	7.5	7.7

FIGURE 9 - 9

Plant location and straight-line pipeline routing are shown only for the purpose of arriving at approximate preliminary costs.

The process selected for a desalting plant utilizing brackish water in the Arlie area employs reverse osmosis. The cost of product water for the assumed plant size and location, including the well field, lime-soda water treatment, product water pipelines and brine disposal, amounts to 105.6¢ per thousand gallons. This water cost is broken down into the following components:

- Desalting Plant	42.8¢/Kgal.
- Water Treatment	31.7¢/Kgal.
- Feedwater Supply	9.7¢/Kgal.
- Brine Disposal	12.2¢/Kgal.
- Product Water Conveyance	9.2¢/Kgal.
Total	105.6¢/Kgal.

Case VI-2 on Figure 9-1 shows a 1.8 MGD desalting plant located nearby Estelline Spring, utilizing the vacuum-freezing, vapor-compression process. Information regarding this process was obtained from Colt Industries [46] based on a newly developed 450,000 gallon per day module. Two large scale desalting plants employing this vacuum-freezing, vapor-compression process have been installed to date, namely, a single module 60,000 gallon per day installation at Wrightsville Beach, North Carolina, and a four module 200,000 gallon per day installation at Eilat, Israel. These two installations both employ a much smaller module than the one on which costs in this study are based.

The plant is assumed to use feedwater from highly saline Estelline Spring. Only a short product water line is required to convey the product water to the Green Belt pipeline. Location and pipeline routing are shown only for the purpose of arriving at approximate preliminary costs.

It should be noted that the extremely high salinity of Estelline Spring feedwater represents a suitable application for the vapor-compression, vacuum-freezing process whereas this high salinity could introduce serious problems for most other proven processes.

The cost of product water for the assumed plant size and location, including product water pipeline and brine disposal amounts to 114.9 cents per thousand gallons. The cost is broken down into the following components:

- Desalting Plant	88.1¢/Kgal.
- Water Treatment	0 ¢/Kgal.
- Feedwater Supply	0 ¢/Kgal.
- Brine Disposal	24.1¢/Kgal.
- Product Water Conveyance	2.7¢/Kgal.
Total	114.9¢/Kgal.

9.8 ANALYSIS AND COMPARISONS

Detailed cost breakdown figures for the application of the reverse osmosis process utilizing Blaine Gypsum feedwater and the vacuum-freezing, vapor-compression process utilizing Estelline Spring feedwater are included at the end of this section as Figures 9-10 and 9-11.

The total cost of product water delivered to the Greenbelt system from the reverse osmosis plant amounts to $1.056 per thousand gallons. For the reverse osmosis process the water cost at the desalting plant site is approximately 42.8 cents per thousand gallons; the remaining 62.8 cents of total water costs is incurred mostly in water treatment costs and brine disposal costs, indicating the magnitude of the problems in these two cost center areas.

Calculations for the application of the electrodialysis process to the Blaine Gypsum feedwater showed costs approximately 7 cents per thousand gallons higher due primarily to the low temperature of the feedwater.

The VF-VC process utilizing Estelline Spring feedwater delivers product water to the Greenbelt system for approximately $1.149 per thousand gallons. For the VF-VC process the cost of product water at the desalting plant site is over twice as great as for reverse osmosis. However, the equipment manufacturer is of the opinion that this process can operate successfully without the need for feedwater treatment so that this represents an advantage which however, should be checked more thoroughly in any specific application of this process. Brine disposal costs also are lower for the VF-VC process because the plant location lends itself to brine disposal via a pipeline to a Corps of Engineers proposed off-channel reservoir in Cottle County instead of by deep well injection.

It appears that the most likely source of alternative supplies for the Greenbelt system is from a proposed Sweetwater Creek Reservoir. It is estimated that the cost of water at the reservoir site will be approximately 11 cents per thousand gallons. To this will have to be added the cost of installation and operation of a 56 mile pipeline to the Greenbelt system. Determination of costs for a suitably engineered pipeline for this purpose are beyond the scope of this study. However, order of magnitude estimates indicate that costs may approach 15 cents per thousand gallons, which would provide water for the Greenbelt system for approximately 26 cents per thousand gallons. This is significantly lower than the calculated costs for desalted product water so that consideration of a desalting plant does not appear to be economical on the Greenbelt system based on information available at the present time.

COST BREAKDOWN

THE RALPH M. PARSONS COMPANY

Childress-Hardeman-Vernon Region Case VI-1

PROCESS Reverse Osmosis; CAPACITY 2.0 MGD; OUTPUT 660,000 Kgal/yr; INTEREST 3-1/2 %; PLANT LIFE 30 YRS; PIPELINE LIFE 50 YRS

	CARRYING CHARGE MULTIPLIER	DESALT PLANT		WATER TREATMENT		FEEDWATER		BRINE DISPOSAL		PRODUCT CONVEY.	
		CAPITAL COSTS $ 10³	ANNUAL COSTS $ 10³	CAPITAL COSTS $ 10³	ANNUAL COSTS $ 10³	CAPITAL COSTS $ 10³	ANNUAL COSTS $ 10³	CAPITAL COSTS $ 10³	ANNUAL COSTS $ 10³	CAPITAL COSTS $ 10³	ANNUAL COSTS $ 10³
CAPITAL COST CENTERS											
1. Plant & Equipment	.0544	1,068	58.1								
2. Replaceable Items	1.035	32	33.0								
3. Water Treatment	.0426			890	38.0						
4. Well Field						144.8	6.2				
5. Pipeline	.0426									1030.0	43.9
6. Pumping Station	.0426										
7. Brine Disposal											
8. Indirect Capital Costs	.0544	187	10.2								
9. Land Costs	.035	2	.1	1	--					3.0	.1
10. Working Capital	.035	47	1.6	34	1.2	10.4	.4			10.1	.4
11. Cooling Towers											
TOTAL CAPITAL COSTS →		1336		925		155.2		616		1043.1	
RECURRING COST CENTERS	PERCENT										
12. Taxes											
13. Insurance											
TOTAL ANNUAL FIXED COSTS →			103.0		39.2		6.6		33.5		44.4
OPERATION & MAINTENANCE COST CENTERS											
15. Operating Labor					56.0		36.0				13.3
16. Maintenance Labor			52.0								
17. General & Administrative			15.6								
18. Supplies & Maintenance Materials			12.9								
19. Chemicals			33.0		112.2						
20. Fuel											
21. Electric Power			66.0		1.2		21.1				3.3
TOTAL O & M COSTS →			179.5		169.4		57.1		46.7		16.6
TOTAL FIXED PLUS O & M COSTS →			282.5		208.6		63.7		80.2		61.0
COMPONENT WATER COSTS, ¢/Kgal →			42.8	31.7		9.7		12.2		9.2	
TOTAL WATER COST → 105.6 ¢/Kgal											

Water treatment plant has 4.0 MGD capacity

Water treatment based on 2 lbs. lime, 3 lbs. soda ash per thousand gallons feed plus 1¢/Kgal. for Calgon

FIGURE 9-10

COST BREAKDOWN

THE RALPH M. PARSONS COMPANY

Childress-Hardeman-Vernon Region Case VI-2

PROCESS VFVC ; CAPACITY 1.8 MGD; OUTPUT 594,000 Kgal/yr; INTEREST 3-1/2 %; PLANT LIFE 30 YRS; PIPELINE LIFE 50 YRS

	CARRYING CHARGE MULTIPLIER	DESALT PLANT		WATER TREATMENT		FEEDWATER		BRINE DISPOSAL		PRODUCT CONVEY.	
		CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3
CAPITAL COST CENTERS											
1. Plant & Equipment	.0544	2257.1	122.8								
2. Replaceable Items											
3. Water Treatment											
4. Well Field											
5. Pipeline	.0426									57.1	2.4
6. Pumping Station	.0426										
7. Brine Disposal											
8. Indirect Capital Costs	.0544	393.0	21.4							1.0	
9. Land Costs	.035	.6	--							0.2	
10. Working Capital	.035	86.8	3.0							2.6	0.1
11. Cooling Towers											
TOTAL CAPITAL COSTS →		2737.5						2,360		60.9	
RECURRING COST CENTERS	PERCENT										
12. Taxes											
13. Insurance									105		
TOTAL ANNUAL FIXED COSTS →			147.2		0						2.5
OPERATION & MAINTENANCE COST CENTERS											
15. Operating Labor			35.2								
16. Maintenance Labor			13.8								13.1
17. General & Administrative			14.7								
18. Supplies & Maintenance Materials			22.0								
19. Chemicals											
20. Fuel											
21. Electric Power			291.1								0.2
TOTAL O & M COSTS →			376.8						38		13.3
TOTAL FIXED PLUS O & M COSTS →			524.0						143		15.8
COMPONENT WATER COSTS, ¢/Kgal →			88.1		0		0*		24.1		2.7
TOTAL WATER COST → 114.9 ¢/Kgal											

Brine disposal cost based on pipelines to corps of engineers proposed off-channel reservoir in Cottle County

*Feedwater supply costs included in desalt plant costs

FIGURE 9-11

9.9 BRINE DISPOSAL

Cost of brine disposal by deep well injection for this area was calculated using the Cisco Group as the disposal zone.

The cost of disposal by injection for Case VI-2 was not considered economically feasible. Brine disposal by evaporation pond for Case 2 would require a pond of 2,877 acres with a 10 foot dike which also was not considered feasible.

To arrive at the cost of disposal for Case 2, it has been assumed that the brine could be transported by pipeline to northern Cottle County for storage and evaporation. The Corps of Engineers has proposed an off-channel reservoir in this area for storage of low-flow brines in the salinity alleviation project for the Wichita River, a tributary to the Red River. However, detailed engineering economic studies would have to be made and coordinated with the Corps before this method of disposal could be considered. The cost of transporting the brine to the proposed reservoir site is tabulated in Figure 9-12.

CHILDRESS - HARDEMAN - VERNON REGION

BRINE DISPOSAL DATA

INJECTION RESERVOIR CHARACTERISTICS AND DESIGN AND COST DATA FOR BRINE DISPOSAL BY SUBSURFACE INJECTION IN SELECTED CASES

Item	RO Case VI-1	VFVC Case VI-2
Product Water		
Capacity, MGD	2.0	1.8
Quality TDS (ppm)	500	500
Brine Effluent		
Volume, MGD	0.5	7.2
Quality, TDS (ppm)	14,520	59,710
Disposal Zone		
Formation or geologic age	Cisco Group	See Note (1)
Lithology	Sandstone	
Depth below surface	3,700 ft.	
Thickness	50 ft.	
Well Field Data		
Number of wells	8	
Distance to plant	1 mi.	
Total Cost (Million Dollars)		
Capital	$0.616	$2.360
Annual	0.080	0.143
Total Unit Costs		
Brine basis, per thousand gallons	48.61¢	6.0¢
Product basis, per thousand gallons	12.15¢	24.1¢

(1) Calculated cost of injection for this case indicates that injection is not economically feasible. Cost of disposal for this case is for a pipeline to the site of a proposed Corps of Engineers off-channel reservoir in northern Cottle County recommended for storage of low-flow brines in the salinity alleviation project for the Wichita River, a tributary to the Red River. Detailed engineering economic studies would have to be made and coordinated with the Corps of Engineers before this method of disposal could be considered.

FIGURE 9 - 12

COMBINATIONS OF REGIONS

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COMBINATIONS OF REGIONS

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10. COMBINATIONS OF REGIONS

10.1 FIVE COUNTY REGION

In order to explore the potential and costs for providing desalted water to a larger area than the regions studied in earlier chapters, Case VII-1 was established comprising the five counties of Ector, Midland, Crane, Reagan and Upton.

It was assumed that a desalting plant would be located near Midland at the site of the proposed water treatment plant similar to Case No. III-1 included in Chapter 6. This plant would make use of Paul Davis feedwater supplemented by T-Bar Ranch development when required.

A 7 MGD electrodialysis desalting plant was selected on the basis of its proven lower cost water production in Chapter 6. The size was established to supply the water requirements for the cities of Big Lake; Crane, McCamey, and Rankin. The product water from the 7 MGD desalting plant was fed into the Colorado River Municipal Water District (CRMWD) system at Midland.

A new pipeline system was originated at the termination of the 27 inch and 33 inch CRMWD pipelines at Odessa. The new pipeline system was sized for purposes of this study to convey only the output of the 7 MGD desalting plant, although it is recognized that in any actual installation of a pipeline system, consideration would be given to the installation of larger size pipelines to account for future needs.

The cost of product water for this system was calculated to be 59.3 cents per thousand gallons, broken down into the following components:

- Desalting Plant	24.2¢/Kgal.
- Water Treatment	0 ¢/Kgal.
- Feedwater Supply	12.2¢/Kgal.
- Brine Disposal	2.5¢/Kgal.
- Product Conveyance	20.4¢/Kgal.
Total	59.3¢/Kgal.

It is interesting to compare this cost of 59.3 cents per thousand gallons with the cost of product water for Case IV-2 in the Crane-Reagan-Upton Region which amounts to 66.7 cents per thousand gallons. As would be expected, the product conveyance cost is somewhat higher for this five county region system, due to the additional pipeline between Odessa and Crane. However, the desalting plant cost of product water is considerably less due to the lower salinity of the Paul Davis feedwater in comparison with the higher salinity of the Edwards-Trinity feedwater in the Crane-Reagan-Upton case. Detailed cost breakdown is shown on Figure 10-1 at the end of this chapter.

Inasmuch as the reduction in the cost of delivered water is only approximately 10% less than the cost for the Crane-Reagan-Upton Case IV-2, it appears that the conclusions of Case IV-2 would probably not be altered. Namely, for the City of Rankin further consideration should be given to data presented in the previous report /42/ which estimates the delivered cost of water at 50.5¢ per thousand gallons. For the remaining cities it appears that the best alternative supply would consist of expanding present resources or exploiting new fresh water aquifers.

10.2 EIGHT COUNTY REGION

Case VII-2 was established to incorporate into one area the eight counties of Reeves, Ward, Winkler, Ector, Midland, Crane, Reagan and Upton.

It was assumed that a 20 MGD vapor-compression, vertical-tube evaporator plant would be installed west of Kermit utilizing Capitan Reef feedwater.

In addition to the pipelines of the five county region, Case VII-1, pipelines were provided between Kermit and Odessa and from Kermit to Wink and through the Hogg Ranch Well Field to Monahans similar to the pipelines described in Chapter 5. Pipeline sizes were established only sufficiently large to convey the quantity of water produced by the 20 MGD desalting plant, although, as in the five county region, it is recognized that an actual installation would give consideration to larger size pipelines to account for future needs.

The cost of delivered water for this system was calculated to be 92.2¢ per thousand gallons, broken down into the following components:

- Desalting Plant	32.4¢/Kgal.
- Water Treatment	29.4¢/Kgal.
- Feedwater Supply	7.9¢/Kgal.
- Brine Disposal	8.4¢/Kgal.
- Product Conveyance	14.4¢/Kgal.
Total	92.5¢/Kgal.

This cost of 92.5¢ per thousand gallons compares with 65.1¢ per thousand gallons for the Reeves, Ward Winkler Case II-1 and 66.7¢ per thousand gallons for the Crane-Reagan-Upton Region Case IV-2. The higher costs for this case are primarily due to the need for extensive water treatment of the Capitan Reef feedwater for the VC-VTE process amounting to 29.4¢ per thousand gallons. Cost breakdown is shown as Figure 10-2 at the end of this chapter.

Due to the significantly higher costs, it appears that the eight-county region system does not warrant further consideration.

COST BREAKDOWN

MULTI-REGION CASE VII-1

THE RALPH M. PARSONS COMPANY

PROCESS E/D ; CAPACITY 7 MGD; OUTPUT 2,310,000 Kgal/yr; INTEREST 3-1/2 %; PLANT LIFE 30 YRS; PIPELINE LIFE 50 YRS

	CARRYING CHARGE MULTIPLIER	DESALT PLANT		WATER TREATMENT		FEEDWATER		BRINE DISPOSAL		PRODUCT CONVEY.	
		CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3
CAPITAL COST CENTERS											
1. Plant & Equipment	.0544	1,500	81.6								
2. Replaceable Items	.2215	605	134.0								
3. Water Treatment											
4. Well Field											
5. Pipeline	.0426					)Assumed				7,551	321.6
6. Pumping Station						)3,420	146.5				
7. Brine Disposal											
8. Indirect Capital Costs	.0544	358	19.5								
9. Land Costs	.035	1									
10. Working Capital	.035	92.7	3.2								
11. Cooling Towers											
TOTAL CAPITAL COSTS →		2556.7		0		Exist		364		7,551	
RECURRING COST CENTERS	PERCENT										
12. Taxes											
13. Insurance											
TOTAL ANNUAL FIXED COSTS →			238.3		0		146.5		19.8		321.6
OPERATION & MAINTENANCE COST CENTERS											
15. Operating Labor			42.1								
16. Maintenance Labor			20.0								
17. General & Administrative			18.6								
18. Supplies & Maintenance Materials			74.0								94.9
19. Chemicals			27.7								
20. Fuel											
21. Electric Power			138.5								55
TOTAL O & M COSTS →			320.9		0		54.6		38.1		149.9
TOTAL FIXED PLUS O & M COSTS →			559.2		0		201.1		57.9		471.5
COMPONENT WATER COSTS, ¢/Kgal →		24 .2		0		12.2		2.5		20.4	
TOTAL WATER COST → 59.3 ¢/Kgal											

FIGURE 10 - 1

COST BREAKDOWN

THE RALPH M. PARSONS COMPANY

MULTI-REGION CASE VII-2

PROCESS VC-VTE ; CAPACITY 20 MGD; OUTPUT 6,600,000 Kgal/yr; INTEREST 3-1/2%; PLANT LIFE 30 YRS; PIPELINE LIFE 50 YRS

	CARRYING CHARGE MULTIPLIER	DESALT PLANT		WATER TREATMENT		FEEDWATER		BRINE DISPOSAL		PRODUCT CONVEY.	
		CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3	CAPITAL COSTS $ 10^3	ANNUAL COSTS $ 10^3
CAPITAL COST CENTERS											
1. Plant & Equipment	.0544	13,191	717.6								
2. Replaceable Items											
3. Water Treatment	.120			1400	168						
4. Well Field	.0426					4578.7	195				
5. Pipeline	.0426									14,301	610
6. Pumping Station											
7. Brine Disposal											
8. Indirect Capital Costs	.0544	2,440	132.7	228	27.4*						
9. Land Costs	.035	4	0.1	2	.1						
10. Working Capital	.035	355	12.4	349	12.2	84.7	3				
11. Cooling Towers	.0544	997	55.2								
TOTAL CAPITAL COSTS →		16,987		1919		4663.4		4,711		14,301	
RECURRING COST CENTERS	PERCENT										
12. Taxes											
13. Insurance											
TOTAL ANNUAL FIXED COSTS →			918.0		207.7		198		256.1		610
Credit for Sulfur Recovery					(190.0)						
OPERATION & MAINTENANCE COST CENTERS											
15. Operating Labor											
16. Maintenance Labor			229.3		70.0		182				203
17. General & Administrative											
18. Supplies & Maintenance Materials			131.9								
19. Chemicals					1850.0						
20. Fuel @22¢ / 10^6 Btu			862								
21. Electric Power											135
TOTAL O & M COSTS →			1223.2		1920.0		138		295.0		338
TOTAL FIXED PLUS O & M COSTS →			2141.2		1937.7		518		551.1		948
COMPONENT WATER COSTS, ¢/Kgal →		32.4		29.4		7.9		8.4		14.4	
TOTAL WATER COST → 92.5 ¢/Kgal											

Desalt Plant Concentration Ratio = 6.0.; *Carrying charge multiplier is 0.120 for Feedwater Treatment

Feedwater Treatment Plant Provides H_2S Removal and Calcium Hardness Reduction; 10 Yr. Life Assumed.

Chemicals (acid) Costs are Included in Water Treatment Costs.

Desalt Plant is Located in Vicinity of Wellfield, Whose Costs are Shown Under Feedwater.

FIGURE 10 - 2

MULTI-REGION

BRINE DISPOSAL DATA

INJECTION RESERVOIR CHARACTERISTICS AND DESIGN AND COST DATA FOR BRINE DISPOSAL BY SUBSURFACE INJECTION IN SELECTED CASES

Item	ED Case VII-1	VC-VTE Case VII-1
Product Water		
Capacity, MGD	7.0	20.0
Quality, TDS (ppm)	500	25
Brine Effluent		
Volume, MGD	1.12	6.1
Quality, TDS (ppm)	4,870	30,700
Disposal Zone		
Formation or geologic age	Yates	Bell Canyon
Lithology	Sandstone	Sandstone
Depth below surface	2,750 ft.	4,500 ft.
Thickness	200 ft.	500 ft.
Well Field Data		
Number of wells	3	25
Distance to plant	1 mi	1 mi
Total Cost (million dollars)		
Capital	$0.364	$4,711
Annual	0.058	0.511
Total Unit Costs		
Brine basis per thousand gallons	15.67¢	27.30¢
Product basis, per thousand gallons	2.51¢	8.35¢

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