PROJECT E/S-3

FINAL REPORT

IMPACT ON TEXAS WATER QUALITY AND RESOURCES OF ALTERNATE STRATEGIES FOR PRODUCTION, DISTRIBUTION, AND UTILIZATION OF ENERGY IN TEXAS IN THE PERIOD 1974-2000

for

GOVERNOR'S ENERGY ADVISORY COUNCIL

by

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SUMMARY

Analyses and assessment of the impact of projected energy and water demands, and alternate fuel strategies on the water resources of the state as a whole were made for three scenarios. In addition, analyses were made for the Colorado and Neches River Basins as representing relatively different regions with regard to water resources and industrial and population concentrations.

Two state overviews, the baseline scenario (Scenario I), and the market forces scenario (Scenario II) were based on data and assumptions provided by the Governor's Energy Advisory Council through the Governor's Office of Information Services. A comparison of these two scenarios is given in Appendix A.

The analyses for the third scenario are based on projections of water demand made by the Texas Water Development Board, and from water quality information obtained from the Texas Water Quality Board, and are summarized in Table 1.

Water requirements for this scenario are 4,511 billion gallons per year (BGY) in 1970 and increase by a factor of 2.6 to 11,726 BGY by 1985, and to 34,503 BGY by the year 2000. Using these projections, water consumption between 1970 and 1985 is projected to increase by a factor of 1.64 from 546 BGY to 893 BGY. Consumption is estimated to be 1,580 BGY by the year 2000.

It is estimated that the heat discharged to receiving streams from steam electric power plants will remain at the current level of about 174×10^{12} BTU's because of the use of cooling ponds or cooling towers at all new power plants.

In applying the 1977 EPA requirements of secondary treatment for municipalities, and best practicable treatment for industry, it is projected that the pollution load as measured by biochemical oxygen demand (BOD) to receiving waters will decrease from 196 million pounds in 1970 to 118 million pounds in 1977 despite an increase in return flows from these two sources of about 20 per cent.

Table 1 : IMPACT OF PL92-500 ENVIRONMENTAL CRITERIA ON WATER QUANTITY AND QUALITY

	1970	1977	1985		2000
			1983 Criteria	1985 Criteria	
Intake Water Requirements (Gallons x 10^9)	4,511	7,878	11,726	11,726	34,503
Water Consumption (Gallons x 10^9)	546	708	893	893	1,580
Heat Discharged to Receiving Streams from Steam Electric Power Industry (BTU x 10^{12})	125	174	174	174	174
Treated Wastewater Return Flows (Gallons x 10^9)	610	748	804	337	839
Biochemical Oxygen Demand Discharges (lbs x 10^6)	196	118	74	38	56
Suspended Solids Discharges (lbs x 10^6)	384	141	66	19	28
Capital Cost to Achieve Standards (over 1970) ($ x 10^6)	-	283	996	1,681	3,403
Yearly Operating Costs (over 1970) ($ x 10^6)	-	27	94	280	447
Energy Requirements (BTU x 10^{12})	21	37	62	386	633

NOTE: All cost data are expressed in 1967 dollars.

The EPA requirement of industry of "best available technology economically achievable" is to be attained by 1983. At that time the BOD loading to receiving waters would be 74 million pounds, or less than 40 per cent of the present waste load.

The 1985 goal for elimination of the discharge pollutants has not been defined, but on the assumption that zero BOD will be discharged from industrial point sources and a concentration of 8 mg/l in effluents from municipal plants, our analyses indicate that the pollution load will decrease to 38 million pounds of BOD discharged in 1985, but will rise to 56 million pounds of BOD by the year 2000 because of increasing population.

Incremental capital costs (1967 dollars) for construction of treatment facilities to achieve the effluent limitations prescribed by EPA will amount to $283 million in 1977. Cumulative costs to meet 1983 requirements over 1970 will amount to almost one billion dollars. To meet 1985 requirements, capital costs were computed on the assumption that multiple stage flash evaporation would be used for the total industrial wastewater flow. To accomplish this, the capital costs will amount to $1.68 billion dollars.

Annual operation and maintenance expenditures for waste treatment in 1967 dollars are estimated to be $94 million in 1983 and $280 million in 1985.

Energy requirements are estimated to increase from 21×10^{12} BTU's in 1970, to 37×10^{12} BTU's in 1977, and to 62×10^{12} BTU's in 1983. Although the 1983 requirement is almost three times the 1970 requirement, in order to meet the 1985 requirements, the projections indicate that a more than 18 fold increase in energy will be needed because of the electrical energy and fuel necessary for flash evaporation.

The analyses for the Colorado and Neches basins indicate that the increase in consumptive use in 1985 over that in 1970 is in about the same ratio. Consumptive use in the Colorado basin in 1985 is about 1.6 times the 1970 use, and in the Neches about 1.4 times. It is of interest to note, in a comparison of Table 22 (page 60) with Table 25 (page 71), that in the Colorado basin 84 per cent of the consumptive use is attributable to secondary oil production and municipalities on about an equal basis whereas in the Neches basin about

81 per cent of consumptive use is by industry. In the Colorado basin it is projected that for 1985 and 2000 the major increase in consumptive use will be because of increase in population, whereas in the Neches the principal increase in consumptive use will be by industry.

The analyses for these two basins further indicate that in the Colorado basin about 65 per cent of the wastewater effluent is used for irrigation, is evaporated from ponds or sold for industrial use, whereas in the Neches River basin, a water "rich" region, consumptive use is about 19 per cent of the fresh water intake requirement which is lower than the statewide average of 31 per cent, probably because of a lower reuse of effluents for irrigation.

CONCLUSIONS

During the next decade it is unlikely that, for the State as a whole, a critically adverse environmental impact on the water resource will occur. However, in making assessments, it is necessary to consider regional and highly localized areas where urban-industrial concentrations occur. In such locations serious adverse impacts may develop, particularly with regard to water availability. Although water quality management will continue to be of major importance, there should be an improvement in water quality as the requirements of PL 92-500 are realized.

Increasing attention should be directed towards the management of the State's ground water resource because this resource will become even more important as consumptive use of surface water increases.

Increased consumptive use of surface water resulting from industrial and municipal growth in upstream reaches of the major river basins may result in possible shortages of fresh water supply in the coastal zone.

1. Consumptive water use for the production of energy fuels will increase during the period 1974-2000 primarily due to increased use of secondary and enhanced oil recovery techniques.
2. Water consumption for the extraction of lignite and uranium ore will remain a minor concern in the overall water economy of the State.
3. Consumptive water use by the steam-electric power industry will increase significantly if the projected installed capacity of nuclear power plants is realized.
4. Consumptive water use by municipalities and industries will approximately double by the year 2000.
5. Heat discharges to receiving streams will remain at approximately the current levels based on the assumption that the future major cooling modes will consist of cooling ponds and cooling towers.

6. The best practicable technology and best available technology effluent limitations as set forth in PL 92-500 will significantly reduce the waste loads to receiving streams in the State by 1983.
7. The goal of elimination of discharge of pollutants by 1985 will require large capital expenditures and significant increases in annual operation and maintenance costs. Energy requirements to operate treatment facilities necessary to attain this goal will increase enormously.

INTRODUCTION

This report considers the impact on Texas water quality and resources of alternate strategies of energy production and utilization in Texas. The analyses presented include information and projections on water demands, water consumption, wastewater flows, and pollution loads, costs for control of thermal discharges and for waste treatment facilities, and energy requirements for control of environmental quality as related to the water resource.

The year 1970 was selected to establish baseline conditions. Projections have been made for several intervening periods with particular emphasis on the periods 1970 to 1977, 1977 to 1983, 1977 to 1985, and 1985 to 2000. The selection of the years 1977, 1983, and 1985 was considered necessary because for these years specific requirements were established by the Federal Water Quality Act Amendments of 1972 (PL 92-500).

In the analyses, the following major sectors are considered: production of energy, municipalities, and industries. The industrial sector includes separate analyses for steam electric power and for the manufacturing industries, pulp and paper, chemicals, petroleum refining, and primary metals. It is of interest to note that in 1970 the four latter industries accounted for more than 80 per cent of the manufacturing industrial water demand of the state.

The first part of the report presents an overview of the impact of projected energy and water demands and alternate fuel strategies on the water resources of the state.

The second part of the report presents analyses for two river basins, the Colorado and the Neches. These were selected to represent relatively different regions with regard to water resources and industrial and population concentrations.

The third part of the report (Appendix A) presents analyses and a comparison of a baseline scenario and a market forces scenario. The data and assumptions for these scenarios were provided by the Governor's Energy Advisory Council.

PRODUCTION AND PROCESSING OF ENERGY FUELS

Total water demands for the production of power must include those water requirements for the extraction or attainment of the energy fuels. Water demands for the primary production of oil and gas and the extraction of coal, lignite, and uranium are nominal. However, secondary oil production utilizing water flooding techniques requires a substantial quantity of water. Coal gasification and coal liquefaction have not yet been fully developed for operations on commercial scale, but initial studies indicate that a significant quantity of water will be necessary for such processes.

Operations that employ water injection or water flooding techniques for secondary oil recovery require approximately eight barrels of water to produce a single barrel of oil (1). Salt water can be used for flooding operations and is often provided from formation water produced with oil. In 1970 approximately 50 per cent of the oil produced in Texas was recovered by secondary methods (2). Ninety per cent of these operations utilized water flooding (3). Secondary oil production is predicted to constitute 70 per cent of the total oil production by 1985 and 90 per cent by 2000 (2).

The Texas Railroad Commission (TRC) has divided the state into 12 districts as outlined on Figure 1. The amount of oil produced in each district in 1970 was determined by using percentage values for each district as determined from values reported in Bulletin 72 of the TRC and multiplying these percentage values by the state's total oil production reported by the Governor's Office of Information Services (OIS) (4).

Figure 2 gives by districts, the quantity by type of water, i.e., fresh, brackish, and saline that was required in 1970 for secondary recovery operations. These values are based on percentages of type of water used in each district as determined from values reported by the Texas Railroad Commission (5).

Water requirements for 1985 and 2000 are based on the oil production levels as projected by OIS. Texas' total oil production and secondary oil production, and total water and fresh water requirements for 1970 and projections for 1985 and 2000 are given in Table 2.

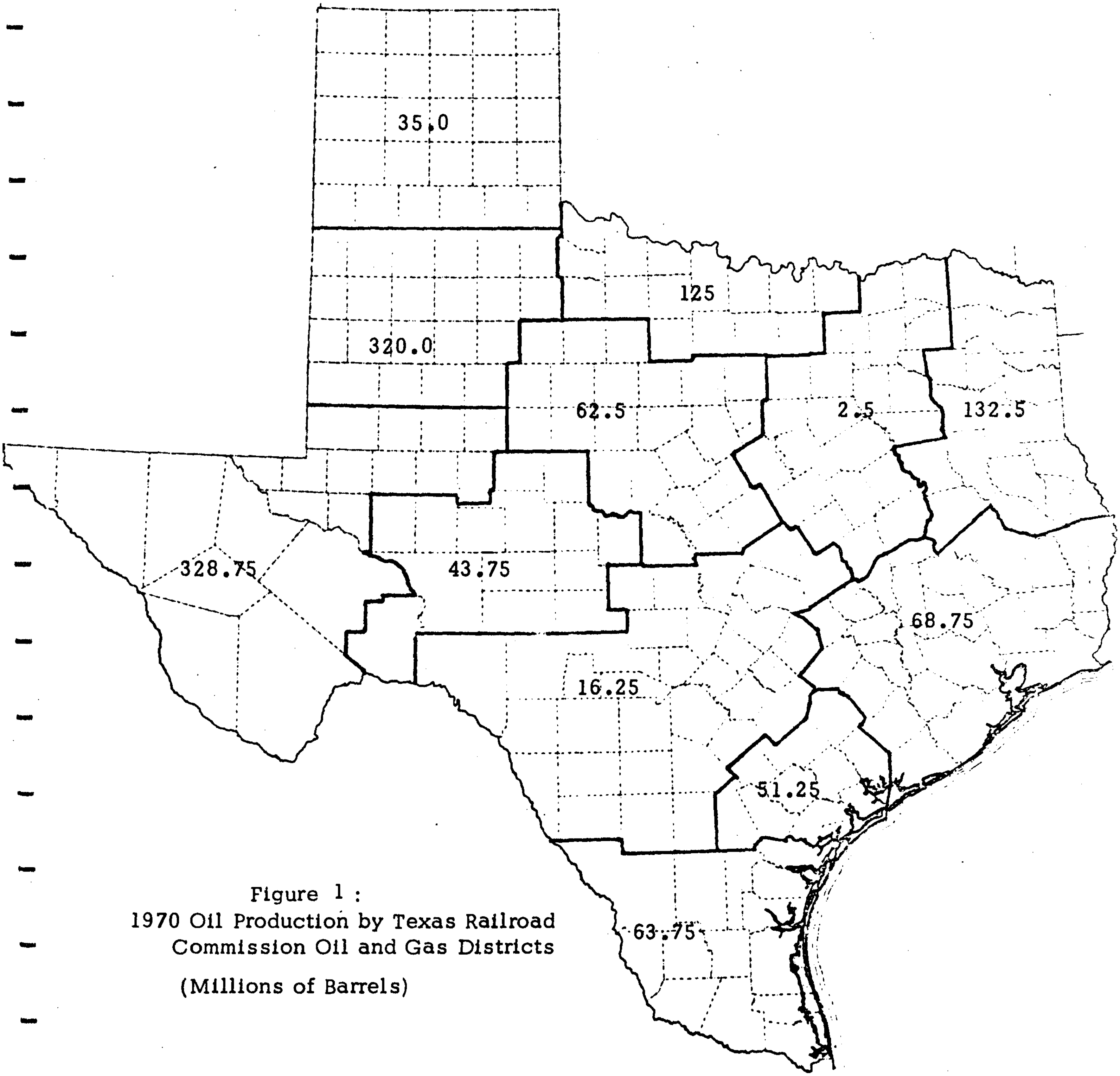

Figure 1 :
1970 Oil Production by Texas Railroad Commission Oil and Gas Districts

(Millions of Barrels)

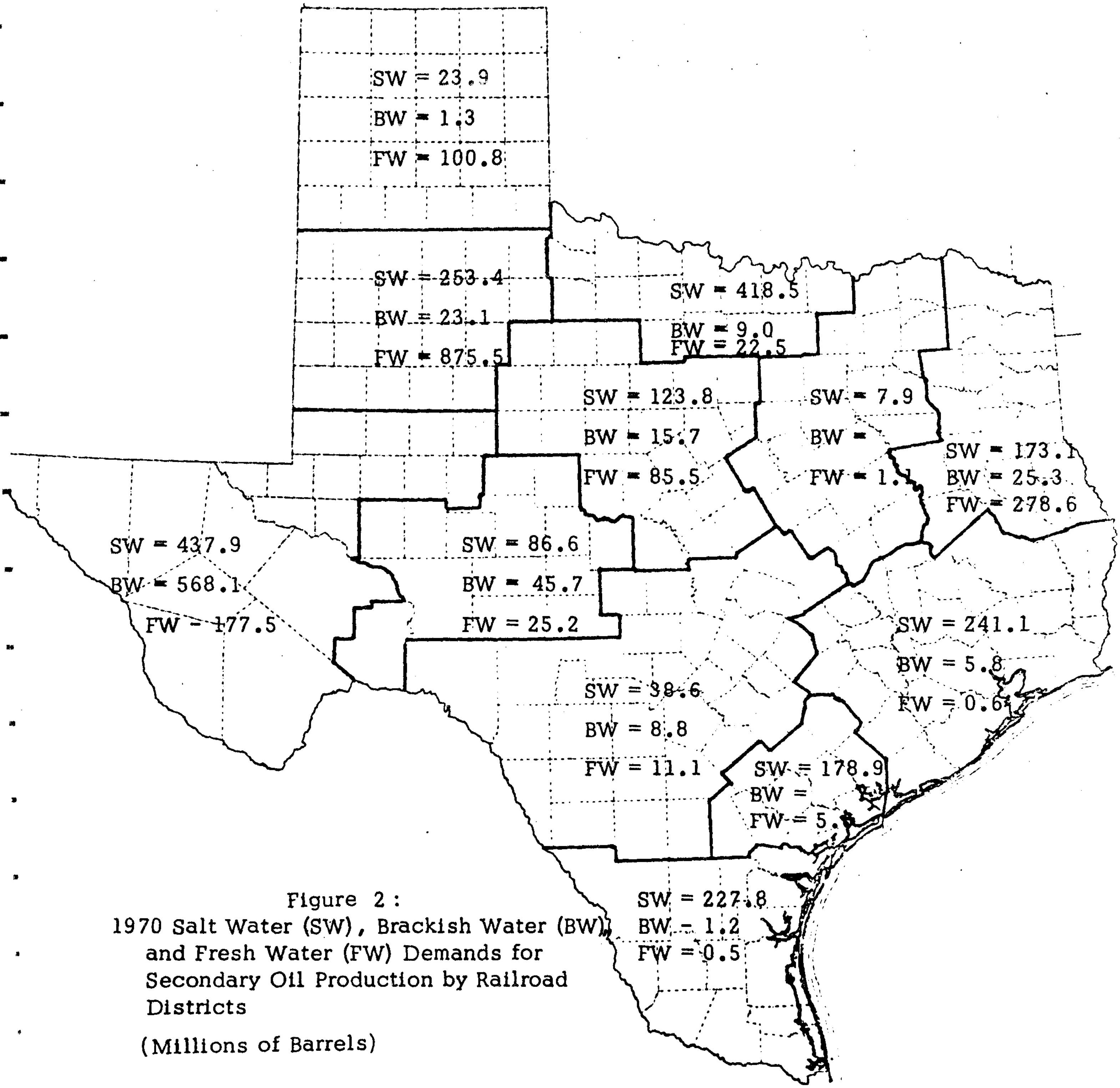

Figure 2 :
1970 Salt Water (SW), Brackish Water (BW), and Fresh Water (FW) Demands for Secondary Oil Production by Railroad Districts

(Millions of Barrels)

Table 2 : OIL PRODUCTION AND WATER REQUIREMENTS FOR SECONDARY RECOVERY OPERATIONS

	Billion Barrels		
	1970	1985	2000
Total Oil Production	1.25	1.16	0.83
Secondary Oil Production (using water flooding techniques)	0.56	0.73	0.67
Total Water Requirements	4.48	5.84	5.36
Fresh Water Requirements	1.58 (66 x 10^9 gals)	2.06 (86 x 10^9 gals)	1.87 (79 x 10^9 gals

Water produced from oil recovery operations must be disposed of either by injection back into a well or retention in a lined lagoon or evaporation pond. Discharge of this water into a river or stream is not authorized. Water production from oil recovery operations in 1970 was about 73.0 billion gallons and is predicted to be approximately 67.7 billion gallons by 1985 and 48.5 billion gallons by 2000. In computing these values, the ratio of water production to oil production was determined from values reported for 1971 and 1972 by the TRC (5). This ratio was then applied to the production figures given by OIS (6).

Significant quantities of water are required to process natural gas. Natural gas processing is that operation in which natural gas associated with crude-oil production, or gas from gas wells is put through a plant to extract liquid hydrocarbons from the gas (1). Approximately 5.46 gallons of fresh water is used to process one thousand cubic feet of gas. Of this, about 4.20 gallons is consumed through evaporative losses and about 1.26 gallons is discharged, generally to ground water (1). Water use, consumption, and return flows for natural gas production in 1970 and the projected natural gas production for 1985 and 2000 as reported by OIS for Scenario II as shown in Appendix B. The values are summarized in Table 3. For the purpose of this study, it was assumed that all natural gas produced in Texas is processed in Texas.

Texas lignite-bearing rock deposits are located primarily in East Texas. Figure 3 shows the location of known near-surface lignite deposits and Figure 4 shows the location of the known deep-basin lignite deposits. Near-surface lignite deposits can be readily extracted by stripping operations while the deep-basin lignite resources are not yet economically recoverable with current technology (4).

Bituminous-coal deposits have been found in North-Central, far West, and South Texas. This resource is generally of the deep basin type and is expensive to mine and therefore its use is limited. Location of the known deposits of bituminous-coal are shown in Figure 5 (4).

Water for coal or lignite extraction is required for dust control, fire protection and coal washing. Water quality is generally of little concern and is

Table 3 : WATER USE, CONSUMPTION, AND RETURN FLOWS FOR NATURAL GAS PROCESSING IN TEXAS

	Billion Gallons		
	1970	1985	2000
Water Use	45.65	44.39	30.03
Consumption	35.11	34.15	23.10
Return Flow	10.54	10.24	6.93

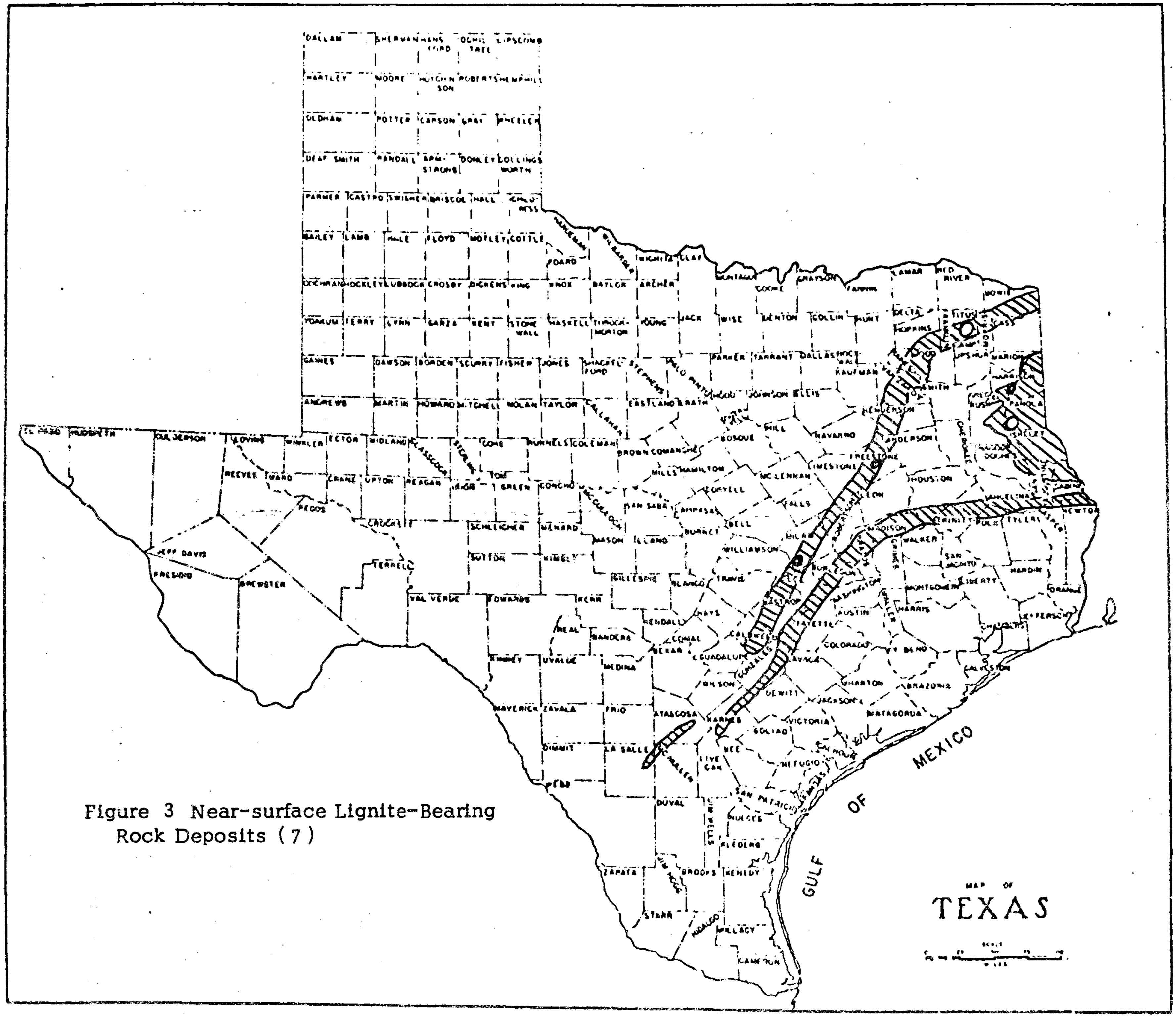

Figure 3 Near-surface Lignite-Bearing Rock Deposits (7)

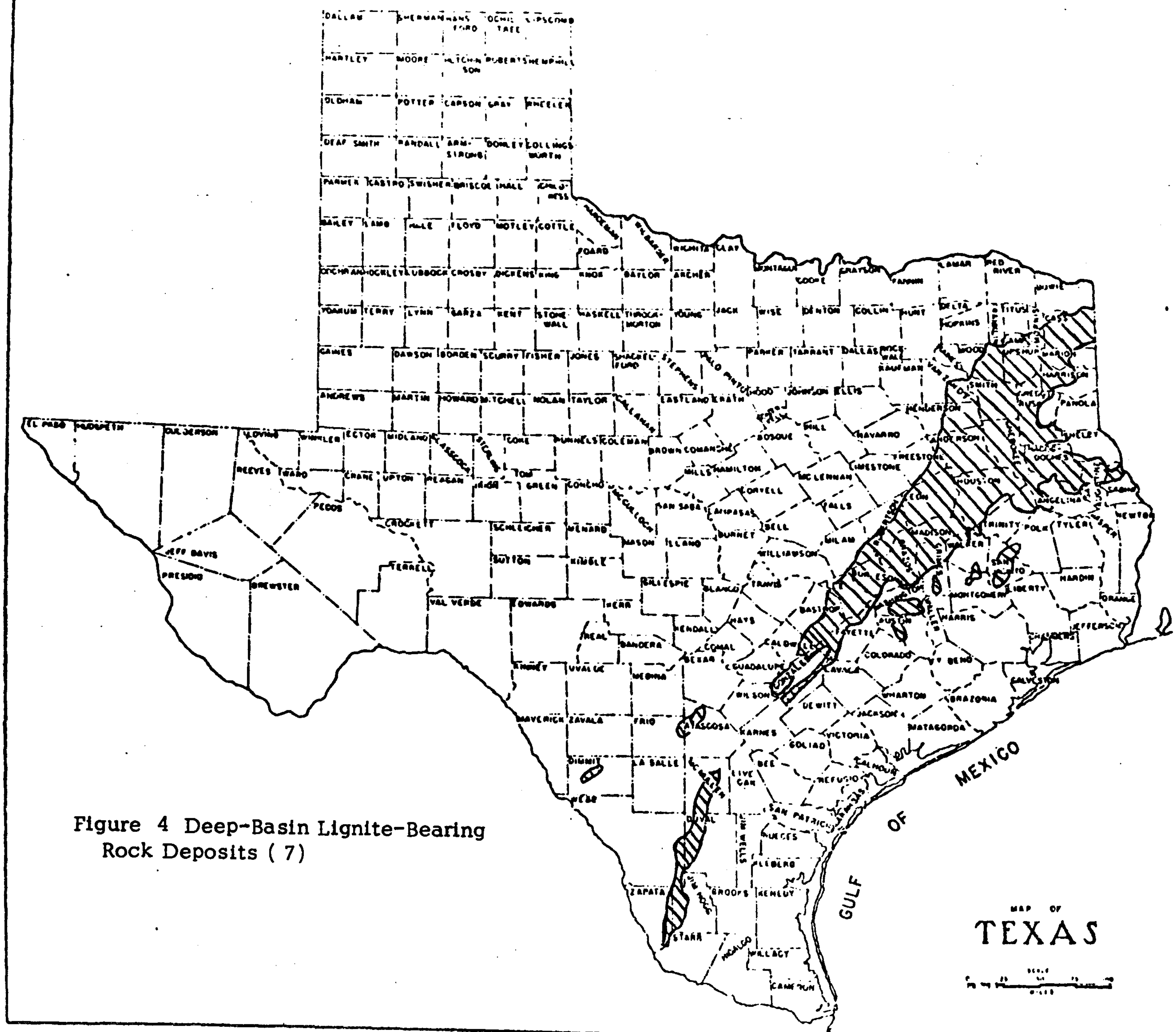

Figure 4 Deep-Basin Lignite-Bearing Rock Deposits (7)

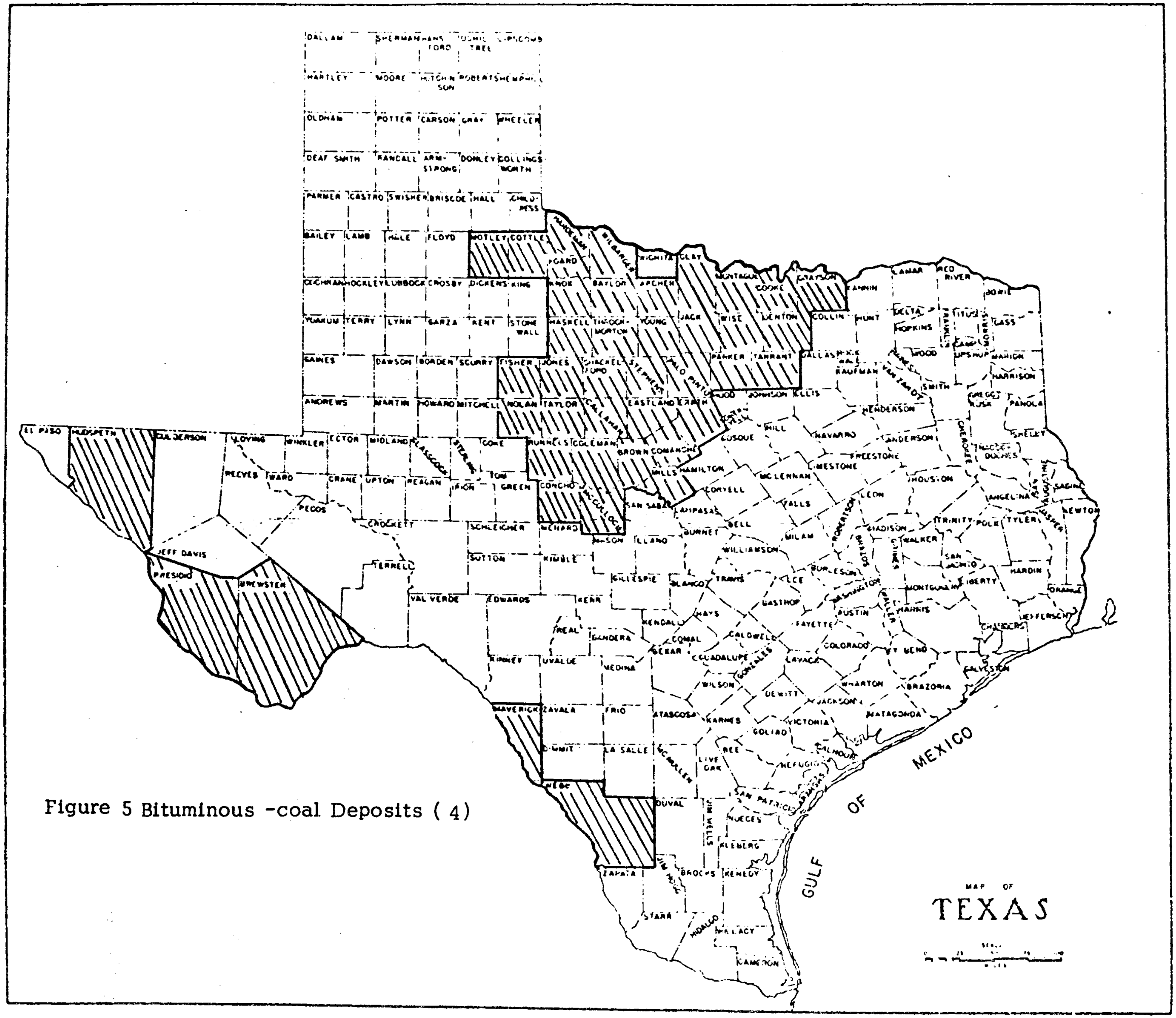

Figure 5 Bituminous -coal Deposits (4)

not limiting. The Texas Electric Service Company's Big Brown plant located in Anderson county reported an approximate use for dust control of 15 gallons of water per ton of coal extracted by stripping methods. However, the amount of water required varies and depends on natural precipitation and the amount of area disturbed.

Other possible energy sources in Texas include uranium, geothermal, wind, tidal, solar, and wood. Location of known uranium deposits in Texas are shown in Figure 6 but as of yet only small quantities have been mined (4). The water requirement for uranium extraction is similar to that required for coal mining and includes water for dust control, ore benefication, and revegetation. However, the tonnage of uranium that must be extracted and handled for equivalent fuel value is less than that for coal and therefore the water requirements are less. Approximately one-tenth as much area is disturbed mining an equal fuel value of coal (8). Water quality is generally not critical.

Geothermal energy has not been used in Texas but resources have been located and are shown in Figure 7. Waste waters produced from geothermal wells may give rise to water quality problems. In California waste waters from geothermal wells were found to contain ammonia which is harmful to fish and boran which is harmful to plants when used as an irrigant. Therefore these waste waters may have to be contained (9).

Coal gasification and coal liquefaction are processes which may be employed to convert coal into another form of useable energy. Water for the coal gasification process is of major importance and can only be estimated from research operations because there are no modern-design coal gasification plants of commercial scale in the U. S. The major source of water consumption results from that quantity of water required for the chemical reaction of coal with water and the quantity of water required for cooling (8). A minimum of 1 and closer to 1.5 tons of water are required to gasify a ton of coal (10). Water requirements for the coal gasification process are estimated to range from 0.36 gallons per kilowatt hour produced where water is at a premium to 1.6 gallons per kilowatt hour produced where water is abundant (8).

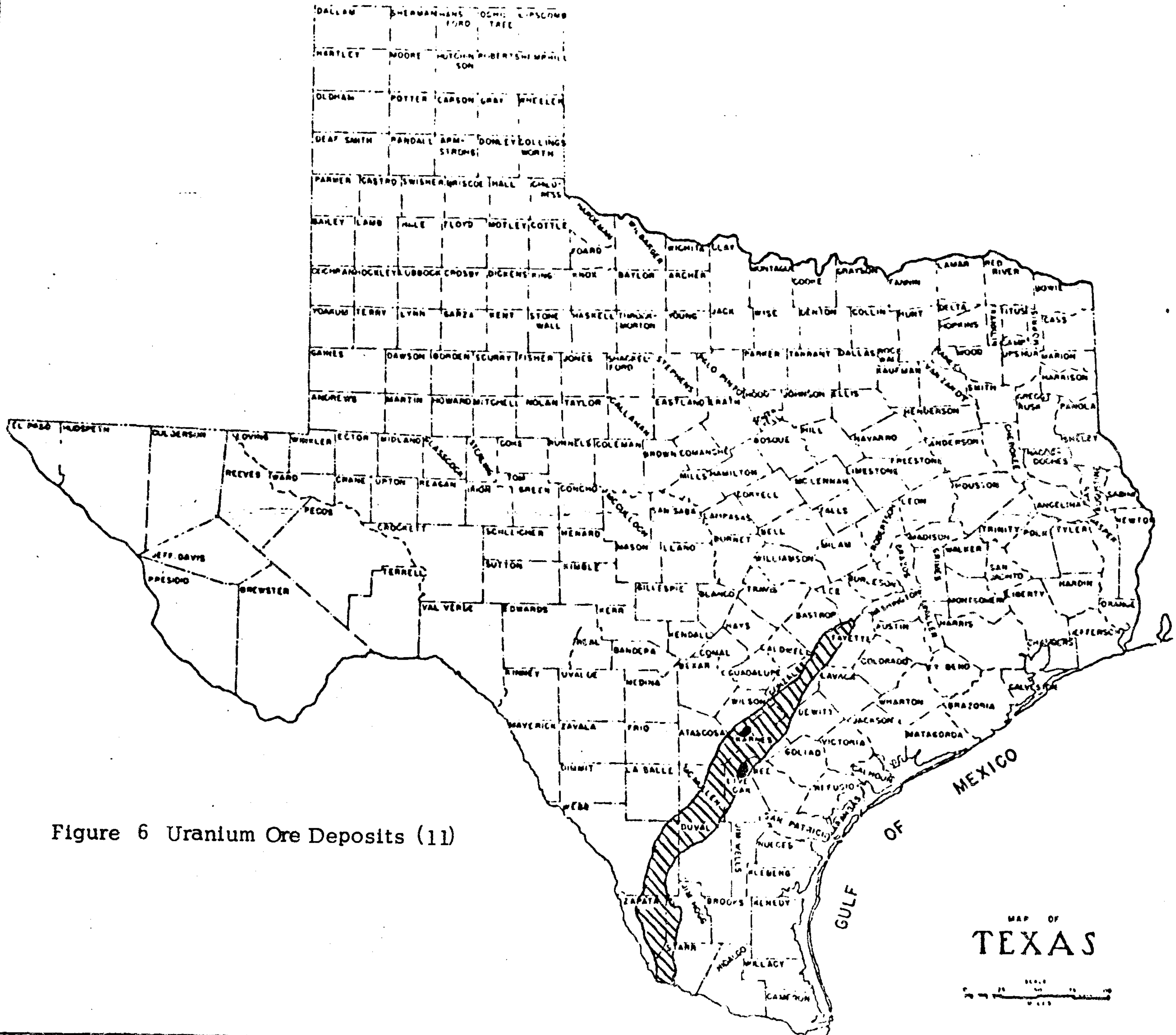

Figure 6 Uranium Ore Deposits (11)

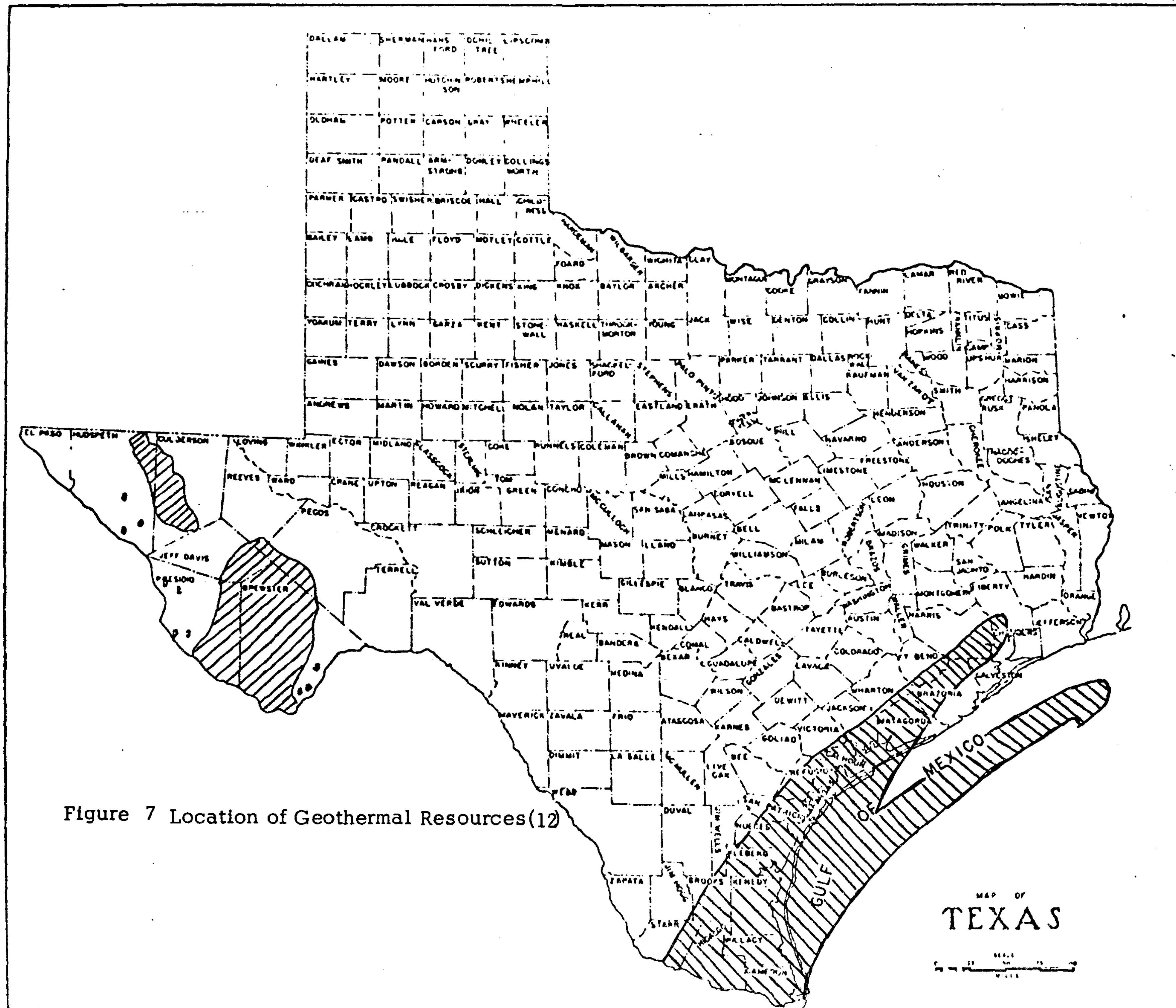

Figure 7 Location of Geothermal Resources(12)

Coal liquefaction is the process of converting coal into oil. Water consumption for this process can only be roughly estimated because no coal liquefaction plants of commercial scale exist in the U. S. today and none of several possible processes has been shown to be competitive with alternate fuels. However, the National Petroleum Council in 1973 adopted a unit consumptive-use value of 0.2 acre-feet per year per barrel per day capacity or about 0.32 gallons per kilowatt hour produced (8).

A summary of the quantity of water consumption for the extraction or attainment of energy fuels is given in Table 4 and Figure 8 .

Table 4 : WATER CONSUMPTION FOR EXTRACTION OR ATTAINMENT OF ENERGY FUELS

FUEL SOURCE	WATER CONSUMPTION GAL/KWH	GAL/MMBTU
OIL	0.6	60
NATURAL GAS PROCESSING	0.042	4.2
COAL	0.0043	0.43
GAS	nominal	nominal
URANIUM	0.00043	0.043
COAL GASIFICATION	0.4 - 1.6	40-60
COAL LIQUEFACTION	0.32	32

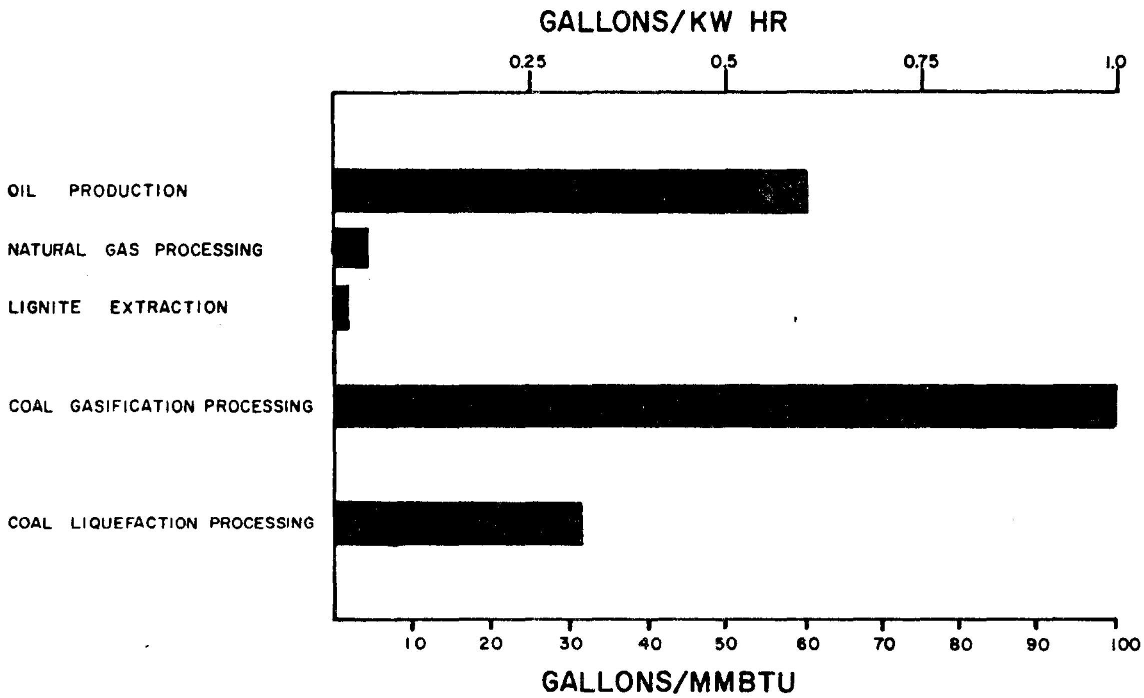

FIGURE- 8 AVERAGE WATER CONSUMPTION FOR PRODUCTION AND PROCESSING OF ENERGY FUELS.

STEAM ELECTRIC POWER INDUSTRY

In order to remove waste heat, steam electric power plants must circulate enormous volumes of water through condensers. Typically, the temperature of the cooling water is increased from $5^{o}F$ to $25^{o}F$ above the temperature of the intake water. In this report intake water requirements are calculated using a value of $15^{o}F$ increase for fossil-fuel plants and a value of $20^{o}F$ increase for nuclear power plants.

The amount of heat rejected to the cooling water depends on the overall efficiency of the power plant and the percentage of the heat rejected to the atmosphere. Efficiencies for fossil fuel plants (oil, gas, coal, lignite) vary from 32 to 40 per cent with respective heat rejection rates to condenser cooling waters in excess of 5,500 and 3800 BTU/KWH. However, nuclear plants operating at an overall efficiency of 33 per cent release in excess of 6400 BTU/KWH to condenser cooling waters because less heat is discharged directly to the atmosphere. A comparison of heat rejection rates for fossil-fuel and nuclear power plants is presented in Figure 9.

When waste heat carried by condenser cooling water is discharged into a water body, transfer to the atmosphere occurs by evaporation, radiation, convection, and conduction. However, when wet cooling towers are used, heat is rejected directly to the atmosphere primarily by evaporation.

The amount of cooling water consumed by steam electric power plants varies with the amount of heat rejected, the type of cooling system utilized, and climatic conditions. The three most common types of cooling systems utilized in Texas include: once-through, cooling ponds, and wet cooling towers. Other cooling modes include spray ponds, numerous combinations of once-through or cooling ponds with wet cooling towers and dry cooling towers.

Once-through systems involve a single pass of cooling water through the system with the waste heat being discharged into natural water bodies such as rivers, lakes, or coastal waters. Cooling ponds as defined by the Environmental Protection Agency (13) are man-made water impoundments which do not impede the flow of a navigable stream and are used to remove waste heat from heated

Figure 9 SCHEMATIC OF HEAT REJECTION RATES TO CONDENSER COOLING WATERS (14)

FOSSIL FUEL POWER PLANTS : Heat Rejected to Condenser Cooling Water in BTU/KWH = .85 x input heat rate (BTU/KWH) - 3413 $\frac{BTU}{KWH}$

Overall Plant Efficiency 32.5%

To Atmosphere 1575 BTU/KWH

Heat Input From Fuel 10,500 BTU/KWH → Efficiency = 32.5% → To Electricity 3413 BTU/KWH

To Condenser Cooling Water 5512 BTU/KWH

To Atmosphere 1280 BTU/KWH

Heat Input From Fuel 8,533 BTU/KWH → Efficiency = 40% → To Electricity 3413 BTU/KWH

To Condenser Cooling Water 3840 BTU/KWH

NUCLEAR POWER PLANTS : Heat Rejected to Condenser Cooling Water in BTU/KWH = .95 x input heat rate (BTU/KWH) - 3413 BTU/KWH

To Atmosphere 517 BTU/KWH

Heat Input From Fuel 10,342 BTU/KWH → Efficiency = 33% → To Electricity 3413 BTU/KWH

To Condenser Cooling Water 6412 BTU/KWH

condenser water prior to recirculating the water to the condenser. The surface area of these ponds typically ranges from one to two acres per megawatt (MW) of installed capacity. Wet cooling towers involve the pumpage of the heated condenser water to the top of an open tower from which it is released to fall to the bottom of the tower as air moves upward through the tower. This counter-current flow of air and water increases the surface exposure of the water to air and increases the evaporation enough to dissipate the required heat. The air movement in wet cooling towers may be by either mechanical or natural draft. The cooling water is continously recirculated in both cooling ponds and wet cooling towers.

Climatic conditions in Texas greatly affect the water consumption of cooling pond systems (15) (16). Analyses of data presented in the report "Prelimary Evaluation of Water Consumption by the Steam-Electric Power Generation Industry in Texas 1970-2000" by the TWDB (15) showed that in 1970 an average of approximately 0.5 gallons of water was consumed by natural evaporation from cooling ponds per kilowatt hour of electricity generated by those power plants using cooling pond systems. Evaporation of water from cooling ponds is dependent to a major degree on the location within the state, the surface area of the cooling ponds, and the load factor of the power plant. Calculations based on a 1000 MW unit operating at a 50 per cent load factor with a cooling pond having a surface area of 1 acre/MW show that the water consumption by natural evaporation ranges from .3 gal/KWH in the Toledo Bend area to over .6 gal/KWH in the Big Bend area. If other factors are held constant, an increase in the surface area of the cooling pond would tend to increase the natural evaporation while an increase in the operating load factor would tend to decrease the natural evaporation proportionately.

Table 5 presents the intake water requirements and water consumed for alternative cooling systems for both nuclear and fossil-fuel power plants. Intake water requirements vary from approximately 30 to 45 gal/KWH while water consumption varies from .25 to .92 gal/KWH.

Additional water consumption can be expected at fossil-fuel power plants burning high sulfur coal, lignite or fuel oil. A sulfur content in excess of 0.6

Table 5: INTAKE WATER AND WATER CONSUMPTION FOR ALTERNATIVE COOLING SYSTEMS

Type of Plant	NUCLEAR		FOSSIL-FUEL			
Plant Efficiency	33%		32%		40%	
Type of Cooling System	Intake (gal/KWH)	Consumed (gal/KWH)	Intake (gal/KWH)	Consumed (gal/KWH)	Intake (gal/KWH)	Consumed (gal/KWH)
ONCE-THROUGH (Fresh or Saline)	38	.42	44	.36	31	.25
PONDS	38	.92	44	.86	31	.75
TOWERS	38	.59	44	.51	31	.36

per cent by weight is considered high. It has been estimated that for wet scrubbing removal of sulfur dioxide approximately 1000 ac-ft/yr of water will be consumed by evaporation per 1000 MW, or approximately 0.037 gal/KWH (7).

The principal waste loads from the steam electric power industry are the discharge of heat in condenser cooling water return flows and materials contained in blowdown water. The principal source of heat discharge is from once-through cooling systems. Cooling ponds, in addition to cooling towers, are recognized in the effluent guidelines and standards of the EPA as constituting an acceptable process technology for the control of heat.

Amongst the characteristics for blowdown water, consideration must be given to total suspended solids, oil and grease, pH, copper, iron, free available chlorine, zinc, chronium, phosphorus, and other corrosion inhibiting materials that may be used at specific locations.

Capital costs for alternative cooling water systems as estimated by Healy (9) and Moseley (18) are summarized in Table 6. Costs are heavily site-dependent. Capital costs at fossil-fuel plants for the three most common types of cooling systems range from two to ten dollars per KW of installed capacity. Capital costs for nuclear plants are approximately 50 per cent higher than those reported for fossil-fuel plants. The overall costs of saltwater cooling systems are approximately 10 per cent greater than for freshwater cooling systems. The EPA has estimated capital costs of approximately $30/KW would be required to retrofit existing alternative cooling systems with mechanical draft wet cooling towers(13).

The energy requirements needed to operate alternative cooling water systems (13) (16) expressed as a per cent of plant capacity range from less than one per cent for once-through and cooling pond systems to three per cent for mechanical draft-wet cooling towers. Dry towers require from three to eight per cent of the total plant capacity.

<u>Current Water Use</u>: In 1970, steam electric power plants in Texas having installed capacities in excess of 22,000 MW generated over 98 billion KWH or approximately seven per cent of the total electric power generated in the U.S. (4) (15). Table 7 summarizes the intake fresh water requirements, fresh water consumption and heated discharged for the various cooling modes used by the steam electric

Table 6: COSTS OF ALTERNATIVE COOLING WATER SYSTEMS

	FOSSIL-FUEL Capital Cost ($/KW)		NUCLEAR Capital Cost ($/KW)	
Reference	(9)	(18)	(9)	(18)
Type of Cooling System				
ONCE-THROUGH	2-6	5	3-8	7.5
PONDS	5-8	10	7-12	15
WET COOLING TOWER				
(Mechanical Draft)	5-10	8	7-13	12
(Natural Draft)	6-14	8	8-20	12
DRY TOWER				
(Mechanical Draft)	20-50	15	30-65	22
(Natural Draft)		11		17

Table 7: STEAM ELECTRIC POWER INDUSTRY IN TEXAS - 1970 (15)

Cooling Mode	Installed Capacity (MW)	Electric Power Generated (KWH x 10^9)	Per Cent (*)	Intake Fresh Water (Gallons x 10^9)	Fresh Water Consumed (Gallons x 10^9)	Heat Discharged to Fresh Water (BTU x 10^{12})
ONCE-THROUGH (Fresh)	5154	22.6	23	996	8.1	125
PONDS	6004	26.4	27	1164	22.7	--
TOWERS	6770	25.4	26	1120	13.0	--
SALINE	4605	24.2	24	--	--	--
TOTAL	22,538	98.6		3280	43.8	125

* Based on KWH Generated

power industry. Fresh water intake requirements amounted to approximately 3300 billion gallons. However, water consumption amounted to only 1.3 per cent of the intake requirements or about 44 billion gallons. Heat released by once-through freshwater cooling systems amounted to about 125 trillion (125×10^{12}) BTUs.

In 1970, fuels used at Texas steam electric power plants were primarily natural gas with some supplementary fuel oil. By 1973, the installed capacity had increased to over 32,00 MW with lignite being used at one plant having an installed capacity of 1150 MW which is in excess of three per cent of the statewide capacity. Also, the use of fuel oil has increased significantly due to natural gas curtailments at several locations.

The locations of existing steam electric power plants and associated installed capacities as of 1973 are shown in Figure 10. As expected, steam electric power plants are located at the population-industrial centers of the state.

Growth Projections and Fuel Mixes

At the present time, the growth of the electric power industry in Texas is difficult to predict. However, according to recent projections made by the Texas Water Development Board an installed generating capacity approaching 70,000 MW is estimated by 1985 (15) (16). If a growth rate of doubling every ten years is assumed, it is estimated that by 2000, the installed generating capacity will be approximately 210,000 megawatts.

Not only is the growth rate difficult to predict but the fuel to be used is likewise difficult to predict. The type of fuel to be used until 1985 has been projected in some detail as shown in Table 8. Nuclear plants having an installed capacity of approximately 9000 MW are planned for by 1985. Power plants using coal and/or lignite are projected to approach an installed capacity of approximately 19,000 MW. Thus, oil and/or gas will be used at power plants having installed capacities of approximately 42,000 MW. In projecting the fuel to be used by the year 2000 the major difficulty lies in the extent to which nuclear power plants will be used. Table 8 summarizes three possible fuel mixes with nuclear power varying from 22 to 67 per cent of the projected installed capacity.

FIGURE- 10

LOCATION OF STEAM ELECTRIC POWER PLANTS - 1973 (15)

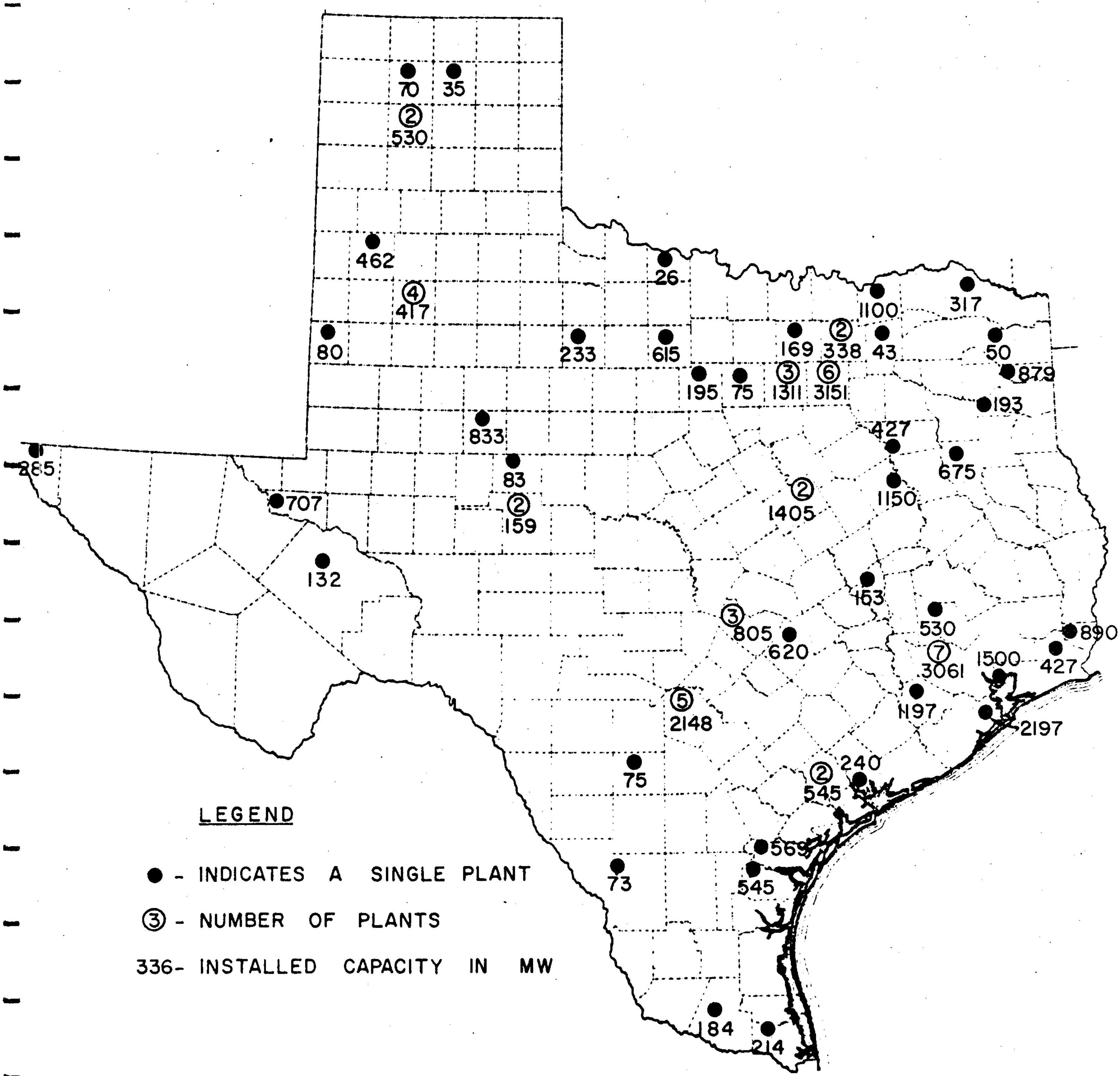

Table 8: PROJECTED FUEL MIX FOR TEXAS ELECTRIC POWER INDUSTRY 1985-2000

TYPE OF FUEL

	YEAR	OIL/GAS (1,000 MW)	OIL/GAS (%)	COAL/LIGNITE (1,000 MW)	COAL/LIGNITE (%)	NUCLEAR (1,000 MW)	NUCLEAR (%)
Case A	1985*	42	60	19	27	9	13
Case A	2000**	42	20	121.8	58	46.2	22
Case B	2000**	42	20	73.5	35	94.5	45
Case C	2000*	42	20	28	13	14	67

* Estimated percentages shown were obtained from (15)
** Estimated percentages shown were obtained from (19)

During the course of this study, alternative growth rates and fuel mixes to be used by the steam electric power industry for the years 1985 and 2000 were estimated by the Governor's Office of Information Services.

These estimates were presented as scenarios entitled:

Scenario I - Baseline Case
Scenario II - Market Forces Case

Evaluations of these scenarios are presented in detail in Appendix A.

The energy requirements as presented in Scenarios I and II yield much lower estimates of the installed capacity required of the steam electric power industry for the years 1985 and 2000.

Water Use and Waste Loads

A comparison of intake requirements, water consumption and heat discharged by the steam electric power industry for the years 1985 and 2000 are shown in Table 9. These comparisons were made using the following assumptions:

- 40 per cent overall efficiency for fossil-fuel plants installed after 1974 and a condenser water temperature rise of 15°F
- 33 per cent overall efficiency for nuclear plants and a condenser water temperature rise of 20°F
- once-through cooling systems would not be used at any power plants to be constructed but would be retained at existing plants
- power plants constructed after 1985 would use approximately 50 per cent cooling ponds and 50 per cent wet cooling towers
- all nuclear power plants would use freshwater for cooling purposes
- all coal and lignite power plants will be required to install sulfur dioxide removal equipment to meet air pollution new source performance standards. This may lead to a high estimate as sulfur dioxide removal equipment will not be required at plants using low sulfur content coal such as imported coal from Montana and Wyoming.

Projections presented in Table 9 indicate that by 1985 intake water requirements for Case A may increase by as much as a factor of three over the 1970 levels while the amount of water consumed may increase by as much as a factor of four. Less than two per cent of the water consumed in 1985 is attributable to sulfur dioxide removal. By the year 2000, intake water requirements for Cases A, B and C may reach a level eight to ten times greater than in 1970. Corresponding levels for

Table 9: INTAKE WATER, WATER CONSUMED AND HEAT DISCHARGED BY STEAM ELECTRIC POWER INDUSTRY
1970, 1985, and 2000

	1970	1985			2000				
		A	Scenario I	Scenario II	A	B	C	Scenario I	Scenario II
Intake Water* (10^9 Gallons)	3,280	9,940	4,428	4,089	27,660	29,300	32,000	5,943	5,761
Water Consumed* (10^9 Gallons)	44	175 (3)	65 (0)	62 (2)	522 (20)	545 (12)	610 (5)	92 (0)	95 (1)
Heat Discharged (BTU x 10^{12})	125	174**	168	125	174	174	174	226	125

* Based on a plant land factor of 0.5
**Increase from 1970 due to increase in plant capacity using once-through cooling systems during the period 1970-1974.

( ) Water consumed by SO_2 removal equipment included in total shown water consumption may be as high as 12 to 14 times the level experienced in 1970. Approximately one to four per cent of the estimated water consumption in the year 2000 may be attributable to the removal of sulfur dioxide.

The larger factors for water consumption as compared to water intake for both 1985 and 2000 are due primarily to the increased use of cooling towers and cooling ponds which consume more water than once-through cooling systems and also to the increased use of nuclear, coal and lignite as fuel substitutes for oil and gas.

Costs

The EPA (13) has estimated on a nationwide basis the capital costs and operating expenditures associated with both the thermal and chemical control of discharges for the period 1974-1983. The estimates were expressed in constant 1974 dollars. The capital requirements attributable to thermal control were estimated to be as high as $5.2 billion while the operating expenditures for thermal control were estimated to be $1.3 billion. The capital cost of construction of treatment facilities to comply with the restrictions on chemical discharges was estimated to total $1.4 billion and operating costs for chemical control were estimated to be $2 billion for the nine year period 1974-1983.

Texas' share of these costs, based on maintaining the current level of approximately seven per cent of the total electrical energy produced in the U. S., are summarized as follows:

	Capital Costs ($ x 10^6)
Thermal Control	364
Chemical Control	98
TOTAL	462

	Operating Costs ($ x 10^6)
Thermal Control	91
Chemical Control	140
TOTAL	231

The total capital costs of 462 million dollars divided by the projected installed capacity of 37,500 MW to be constructed during the period 1974-1985 results in capital costs of approximately $12/KW of installed capacity. The total operating costs of 231 million dollars for the period 1974-1983 expressed on an average annual basis is approximately 26 million dollars per year. Similar calculations show the average unit operating costs to be approximately 0.7 dollars per year per KW of installed capacity.

Thus, if these unit capital and operating costs of $12/KW and $0.7 KW-yr are applied to the 140,000 MW of installed capacity projected to be constructed during the period 1985-2000, capital costs of approximately 1,680 million dollars may be required for this period and operating costs by the year 2000 may increase to over 124 million dollars per year compared to the 26 million dollars per year projected for 1985. NOTE: Approximate equivalent costs in 1967 dollars based on the ENR Construction Cost Index may be obtained by multiplying given values by 0.5.

Energy Requirements

In 1970, the energy requirement needed to operate cooling systems based on one per cent of plant capacity for once-through and cooling ponds and three per cent for mechanical draft-wet cooling towers was approximately 1.5×10^9 KWH. Energy requirements may increase to 5.1×10^9 KWH by 1985 and 17.4×10^9 KWH by 2000 if projected installed capacities are constructed. These energy requirements may be converted to a BTU basis by multiplying by 10,000 resulting in a 1970 value of 15×10^{12} BTU and 1985 and 2000 values of 51×10^9 and 174×10^9 BTU, respectively.

INDUSTRY

This section considers the impact of industry, other than the steam electric power industry, on water resources under the following headings, fresh water intake requirements, fresh water consumption, wastewater flows and pollution loads, costs of wastewater treatment facilities, and energy requirements of wastewater facilities.

The analyses presented are based on information from several sources including the Texas Water Quality Board, the Texas Water Development Board, reports of the Environmental Protection Agency, the U. S. Department of Commerce Census of Manufactures, and the National Council of the Paper Industry for Air and Stream Improvement.

Four major industrial groups namely, pulp and paper, chemicals, petroleum refining and primary metals accounted for more than 80 per cent of the 1970 industrial water demand in Texas (20). The locations of the industrial plants for each group are shown in Figures 11 through 14, respectively (4) (21).

Fresh Water Intake Requirements

Industrial fresh water demand projections for industries other than the steam electric power industry are based on three series developed by the TWDB (20). The 1970 base year estimates of industrial water use and projections for 1985 and 2000 for Series A, B and C are summarized in Table 10. The 1970 base year estimates were derived from the 1971 Industrial Water Demand Survey and the 1971 Water Use Inventory. Although 21 Standard Industrial Classifications (SIC) were originally presented, the four SIC groups shown represented over 80 per cent of the 1970 industrial water demand. Therefore, the remaining SIC groups are shown as "All Others".

Certain assumptions are made for the three series based on observed trends in recirculation and technological innovation during the 1954-1968 period and on data collected during the 1971 Industrial Water Demand Survey relating to future water use estimates by industrial plant managers. The sum of the projected water demands for the five industrial groups for Series A lies between the values for Series A and B.

FIGURE-11

LOCATION OF PULP AND PAPER MILLS-SIC 26
(By County)

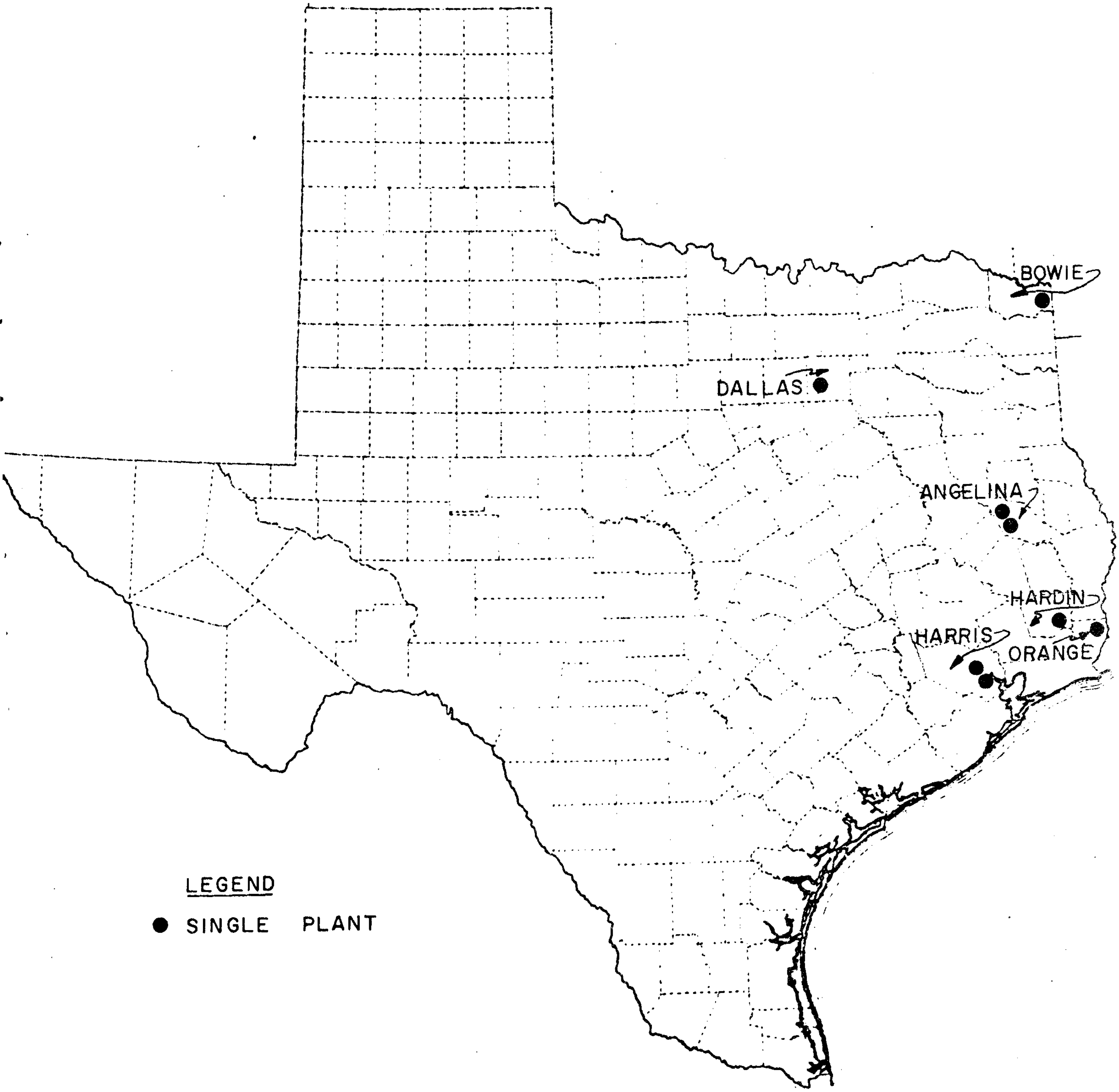

FIGURE-12

LOCATION OF CHEMICAL PLANTS - SIC 28
(By County)

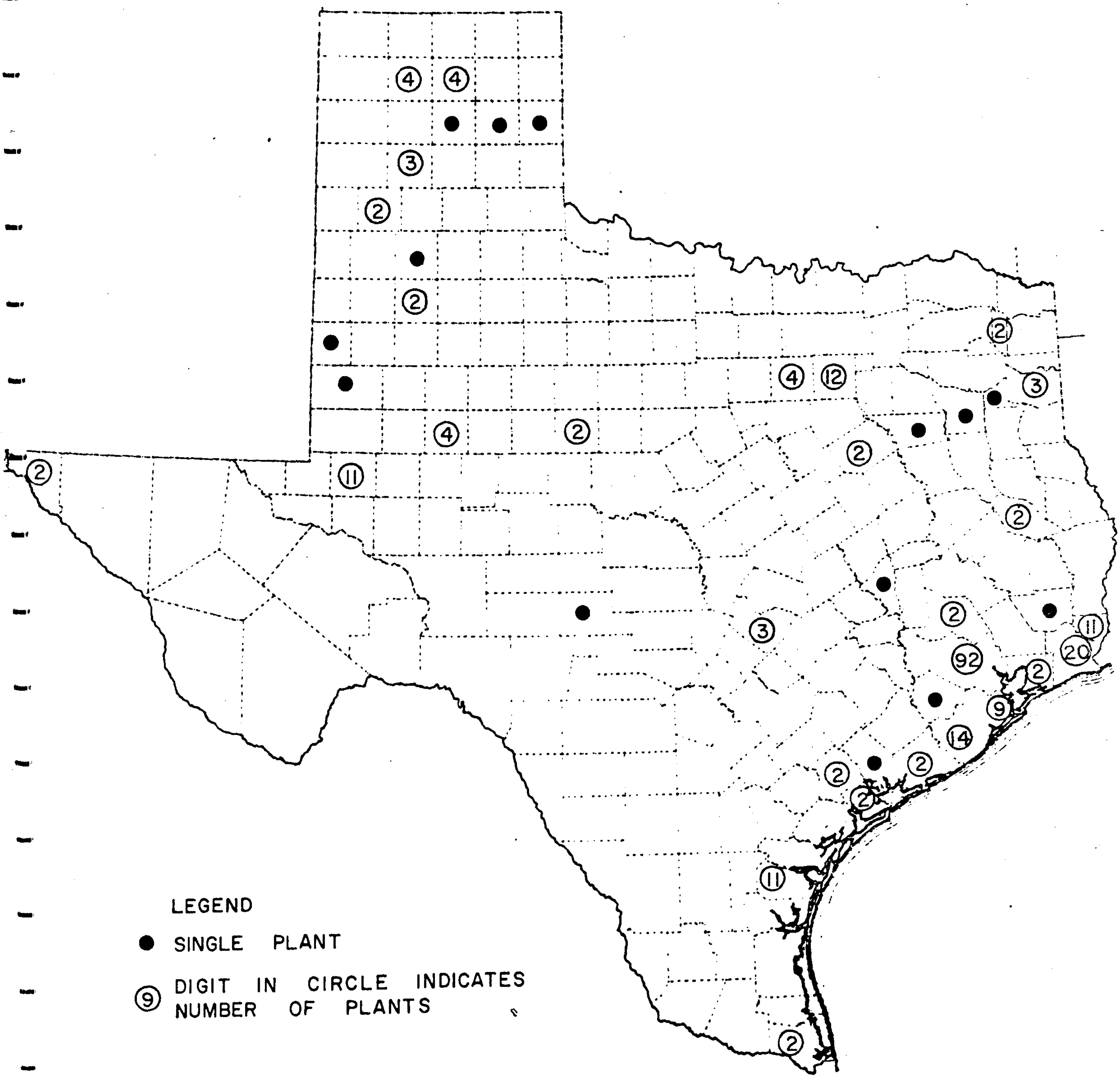

FIGURE-13

LOCATION OF PETROLEUM REFINERIES - SIC 29
(By County)

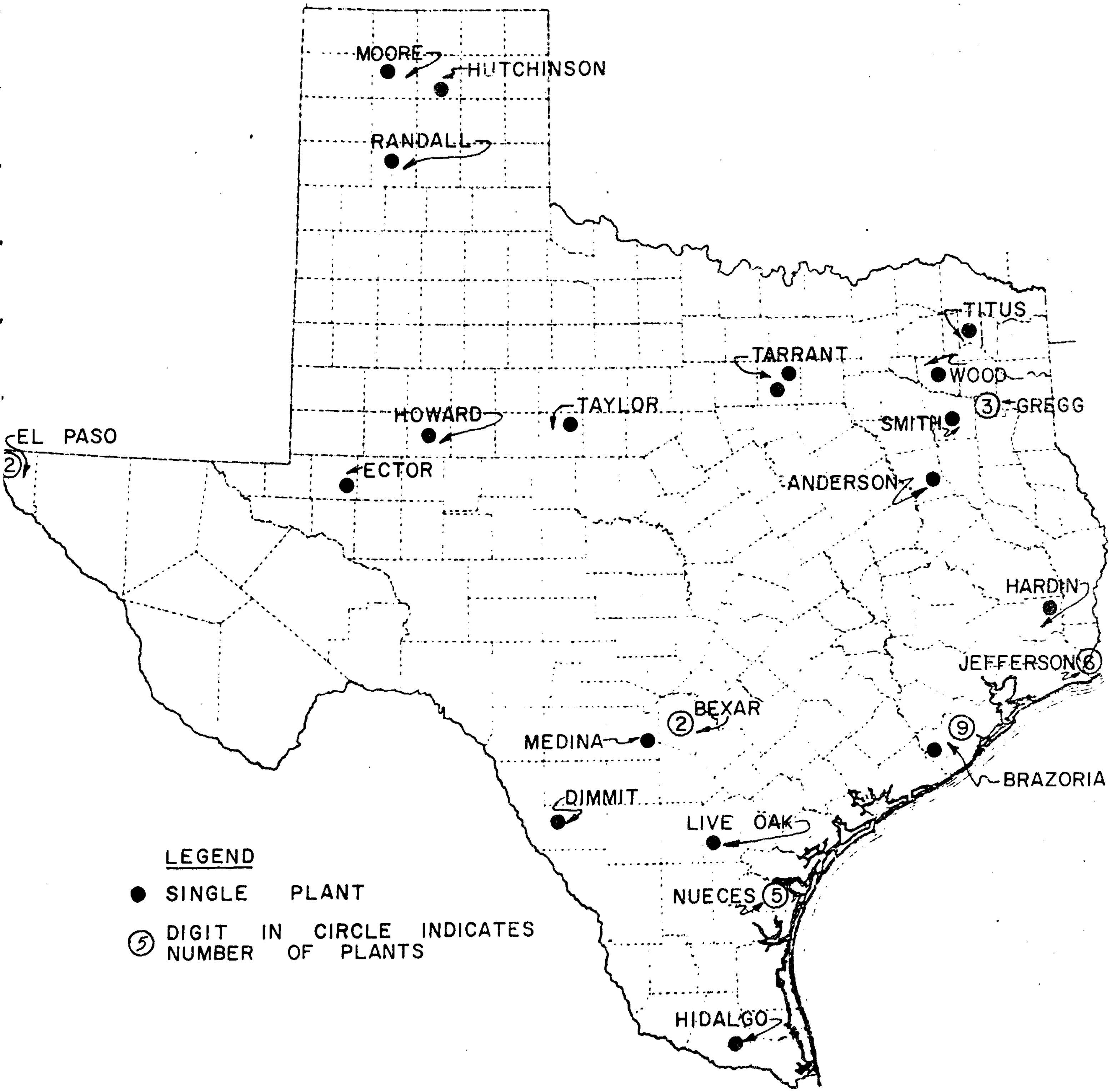

FIGURE - 14

LOCATION OF METAL INDUSTRIES - SIC 33
(By County)

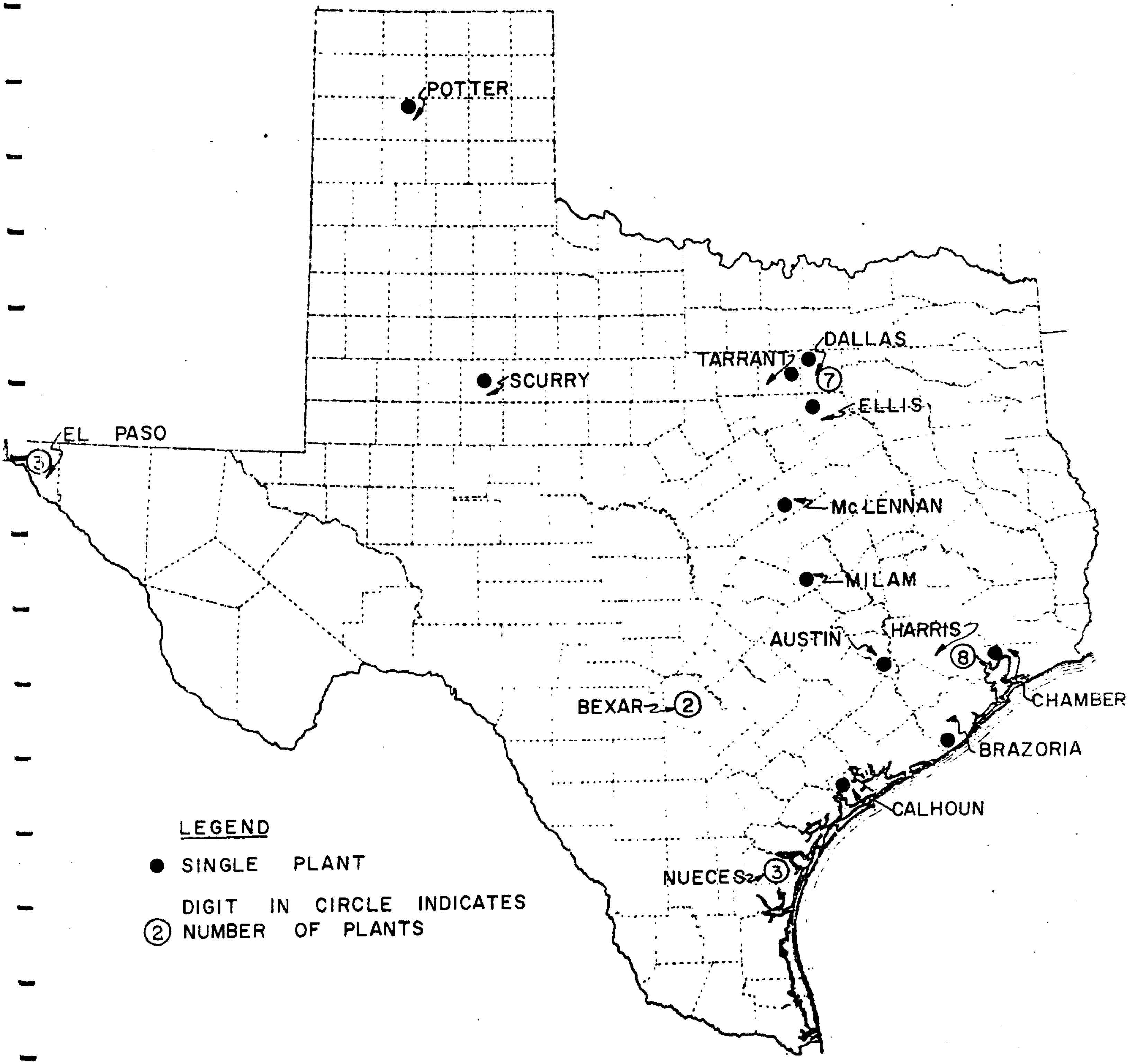

Table 10: INDUSTRIAL FRESH WATER DEMANDS 1970, 1985, and 2000 (20)

INDUSTRIAL WATER DEMANDS (10^9 Gallons)

SIC	INDUSTRY	1970	1985 Series A	1985 Series B	1985 Series C	2000 Series A	2000 Series B	2000 Series C
26	Paper and Allied Products	66	84	110	88	105	170	121
28	Chemicals and Allied Products	173	299	365	270	493	661	381
29	Petroleum Refining and Related Industries	113	131	132	111	153	161	111
33	Primary Metals	64	73	90	71	82	108	80
	All Others	96	124	158	138	162	236	196
	TOTAL	512*	711	855	678	995	1336	889

* Total 1970 Industrial Water Demand Revised to 520 x 10^9 Gallons by TWDB (22)

The 1985 projections based on Series A represent a 39 per cent increase over 1970 while Series B and C represent 67 and 32 per cent increases, respectively. By the year 2000, industrial water demands based on Series A will be approximately 94 per cent greater than the 1970 levels while Series B and C projections represent 160 and 74 per cent increases over 1970.

The Series A values are used throughout this analysis for purposes of example.

Water use in industry is mainly for cooling and process purposes with smaller amounts being used for boiler feed and sanitary purposes. Water use data by purpose as presented in the 1968 Census of Manufactures includes both fresh and brackish water (23). Table 11 summarizes the industrial water use by purpose as a per cent of the total water intake for the four major water using industries in Texas. Water use for cooling purposes exceeds 70 per cent for the chemical, petroleum refining and primary metals industries while water use for process purposes exceeds 90 per cent in the pulp and paper industry.

Fresh Water Consumption

Industrial water consumption in Texas varies with the type of industry, location within the State, cost of water, and type of water uses, that is, saline or fresh. The TWDB reported an average industrial return flow-water demand ratio of about 0.88 for industries using large quantities of saline water and 0.69 for industries not using saline water (24). If water consumption is taken to be the difference between intake and return flows, the total industrial fresh water consumption may be estimated as 31 per cent of the intake fresh water requirements.

Thus, based on a revised 1970 industrial water demand of 520×10^9 gallons (22), it is estimated that the fresh water consumption by industry in 1970 was approximately 161 billion gallons. Based on Series A industrial fresh water demand projections, it is estimated that industrial fresh water consumption will be about 220 billion gallons by 1985 and 308 billion gallons by the year 2000.

Table 11: INDUSTRIAL WATER USES IN TEXAS (23)

(per cent of total water intake)

SIC	INDUSTRY	COOLING	PROCESS	BOILER FEED AND SANITARY
26	PULP AND PAPER	4.3	93.6	2.1
28	CHEMICALS	73.2	24.5	2.3
29	PETROLEUM REFINING	78.6	5.7	15.7
33	PRIMARY METALS	79.2	19.4	1.4

Wastewater Flows and Pollution Loads

Estimates of waste flows and pollution loads attributable to industry are summarized in Table 12. The 1970 estimates are based on data from several sources including the 1968 Census of Manufactures, and industry self reporting data submitted to the Texas Water Quality Board.

Projections of waste flows for 1977, 1985 and 2000 have been computed assuming the waste flows will be in proportion to the water demand projections of Series A of the Texas Water Development Board. The effluent limitations prescribed by the Environmental Protection Agency (25) (26) (27) (28) (29) for 1977 are referred to as Best Practicable Control Treatment Currently Available (BPCTCA). For 1983 effluent limitations are for Best Available Treatment Economically Achievable (BATEA). Loadings from point sources for individual industry groups for both BPCTCA and BATEA for Biochemical Oxygen Demand (BOD) and Total Suspended Solids are specified by EPA on a pound per unit of production basis, (pound per unit of feed for petroleum refineries), and were used in making the projections shown in Table 12. Application of the effluent limitations necessitates the establishment of projected production levels. Current wastewater flow to production ratios were estimated and applied to projected wastewater flows in order to establish estimates projections of production levels. Estimates of current production levels were obtained from project S/D - 10 "Potential for Energy Conservation in Industrial Operations in Texas" (21).

The overall effect of the environmental criteria outlined in PL 92-500 on the receiving waters in the State would be reductions in industrial BOD loadings of approximately 70 per cent by 1977 and 85 per cent by 1985. Similar reductions of industrial suspended solids loadings would be realized by 1977 while the suspended solids loadings would be decreased by more than 90 per cent by 1985.

Costs of Wastewater Treatment Facilities

The cost estimates to achieve the effluent limitations for industry are shown in Table 13. Both incremental and cumulative values are presented. Because of variations in operating conditions amongst different industry groups and even for industries within the same category, the cost estimates presented are rough approximations. All cost projections were made considering expenditures for additions to existing treatment facilities and costs of new facilities using advanced treatment technology.

The assumptions used in making the cost estimates are as follows:

- present technology consists of secondary treatment
- total industrial flows to be treated as presented in Table
- BPCTCA will require a minimum of secondary treatment and filtration
- BATEA will require activated carbon adsorption in addition to BPCTCA
- Zero Discharge of Pollutants (ZDP) will require multiple stage flash evaporation (MSFE) in addition to BPCTCA. Unit costs for MSFE expressed in 1972 dollars are $1,645,000/MGD design capacity and $1.0 per 1,000 gallons treated (30). Adjustment of these unit costs (based on ENR Construction Cost Index) to 1967 dollars results in unit costs of $1,000,000 per MGD design capacity and $0.61/1000 gal treated. A summary of unit costs in given below (30) (31).

Unit Costs (1967 Dollars)

	Capital	Operation and Maintenance
	Dollars/MGD Design Capacity	Dollars/1000 Gallons Treated
Secondary Treatment	$ 450,000	$0.07
Filtration	77,000	0.047
Activated Carbon Adsorption	290,000	0.08
Multiple State Flash Evaporation	1,000,000	0.61

Table 12: WASTE FLOWS AND POLLUTION LOADS FROM INDUSTRY (1970-2000)

		FLOW* (Billions of Gallons)				BOD_5** (Millions of Pounds)			SUSPENDED SOLIDS** (Millions of Pounds)		
	Environmental Criteria	1970	1977	1985	2000	1970	1977 BPCTCA	1985 BATEA	1970	1977 BPCTCA	1985 BATEA
SIC	INDUSTRY										
26	PULP & PAPER	53	60	67	84	12	13.4	7.0	17	28.8	9.6
28	CHEMICAL	72	96	124	205	92	11.8	6.6	238	17.9	10.5
29	PETROLEUM REFINING	101	109	117	136	28	12.2	3.7	58	8.1	3.7
33	PRIMARY METALS	17	18	19	22	2	2.1	2.2	9	7.7	0.5
	ALL OTHERS	8	9	10	14	2	2.3	0.8	2	2.3	0.8
	TOTAL	251	292	337	461	136	41.8	20.3	324	64.8	25.1

* Values shown represent treated discharges. If the national goal of "Zero Discharge of Pollutants" (ZDP) is realized by 1985, the values for 1985 and 2000 represent wastewater to be treated and subsequently recirculated.

** 1970 values include BOD_5 and SS in all discharges including cooling waters

1977 values represent BPCTCA

1985 values represent BATEA.

There are no BOD_5 and Suspended Solids values shown for 1985 (ZDP) and 2000 (ZDP) as these values would represent only the BOD_5 and suspended solids in cooling waters.

Table 13 : CAPITAL AND OPERATION AND MAINTENANCE COSTS FOR INDUSTRY

(ALL 1967 DOLLARS)

Incremental

	1977 BPCTCA	1983 BATEA over BPCTCA	1985 ZDP over BPCTCA	2000 ZDP
Capital Costs ($\$ \times 10^6$)	106	332	980	493
Operation and Maintenance Costs ($\$ \times 10^6/45$)	17	32	209	84

Cumulative

	1977 BPCTCA	1983 BATEA	1985 ZDP	2000 ZDP
Capital Costs ($\$ \times 10^6$)	106	438	1086	1579
Operation and Maintenance Costs ($\$ \times 10^6/45$)	17	49	226	312

The capital costs to achieve BPCTCA by 1977 are approximately 106 million dollars as an addition to costs of existing facilities. The additional associated operating costs are approximately 17 million dollars per year. Incremental capital and operating costs for the period 1977-1983 to achieve BATEA by 1983 are about 332 million dollars and 32 million dollars per year, respectively. Capital costs for ZDP by 1985 would increase by 980 million dollars during the period 1977-1985. It is to be noted that this value is not incremental over 1983, but has been computed assuming that industry would achieve ZDP in place of a two phase program. Operating costs would increase by an additional 209 million dollars per year in 1985. Additional capital costs of ZDP for the period 1985-2000 would amount to 493 million dollars, and operating costs would increase an additional 84 million dollars per year by the year 2000.

Energy Requirements of Wastewater Treatment Facilities

Energy requirements for industrial wastewater treatment facilities are shown in Table 14. Both incremental and cumulative values are presented. These projections were based on unit process power consumptions of 1000 KWH per million gallons treated per day (KWH/MGD) for activated sludge; 100 KWH/MGD for filtration; and 391 KWH/MGD for activated carbon adsorption and regeneration (32). A power consumption of 1,330 KWH/MGD and a fuel consumption of 954 million BTU/MGD were used for multiple stage flash evaporation (30). Power consumption in KWH was converted to BTU by multiplying by 10,000.

The 1970 value was computed assuming 688 MGD of industrial wastewater received secondary treatment.

Energy requirements for industrial wastewater treatment facilities may total 3.2×10^{12} BTU by 1977, for BPCTCA, and 5.0×10^{12} BTU by 1985, for BATEA. The goal of "zero discharge of pollutants" for 1985 and 2000 would require an enormous increase in energy requirements due to the fuel consumption of flash evaporation. Total energy requirements for industrial wastewater treatment facilities may approach 329×10^{12} and 450×10^{12} BTU by the years 1985 and 2000. The projected energy required by 1985 is equivalent to the energy contained in more than 58 million barrels of crude oil.

Table 14: ENERGY REQUIREMENTS FOR INDUSTRIAL WASTEWATER TREATMENT FACILITIES

(10^{12} BTU'S PER YEAR)

Incremental

1970	1977 BPCTCA over 1970	1985 BATEA over BPCTCA	1985 ZDP over BPCTCA	2000 ZDP
2.5	0.7	1.8	326	121

Cumulative

1970	1977 BPCTCA	1985 BATEA	1985 ZDP	2000 ZDP
2.5	3.2	5.0	329	450

MUNICIPALITIES

Fresh Water Intake, Consumption, and Wastewater Flows

Per capita water use for 1970 and projections for 1985 and 2000 were determined using the TWDB's population and municipal water-use data and projections (33). Per capita water use for 1970 was approximately 147 gallons per day and is projected to increase to 181 gallons per day by 1985 and 211 gallons per day by 2000.

The ratio of municipal return flow to water use varies widely across the state, depending upon such factors as total population, population density, economic base, and cost and quality of the supply, with climate the most important single factor. The ratio decreases generally from east to west, ranging from more than 0.8 in Southeast Texas to about 0.13 in the El Paso area. In general, present return flow-water use ratios in most municipalities of the state range between 0.4 and 0.7, the weighted mean being 0.6 (24).

Municipal wastewater flows were determined by multiplying the TWDB's municipal water use values by the return-flow ratio of 0.6. Municipal water consumption was determined by subtracting the calculated return flows from the TWDB's water-use values. Total municipal water use, consumption, and wastewater flows in 1970 and projections for 1977, 1985, and 2000 are given in Table 15.

Pollution Loads

It is the national goal that the discharge of pollutants be eliminated by 1985 and that, wherever attainable, an interim goal of water quality for propagation of fish and shellfish and for recreation in and on the water be achieved by 1983 (34). However, since "zero discharge of pollutants" is yet to be defined, assumptions for the degree of treatment required have to be established to evaluate and project future waste loads to receiving bodies of water. Technology is presently available to design and construct wastewater treatment facilities capable of reclaiming an excellent quality of water from wastewater. To attain the 1985 national goal, the program of construction and funding is scheduled in phases with interim goals to be achieved in 1977 and 1983. A schedule for implementation of advanced wastewater treatment facilities was devised by the

Table 15: TOTAL FRESH WATER INTAKE, CONSUMPTION, AND WASTEWATER FLOWS FOR MUNICIPALITIES IN TEXAS

	1970		1977		1985		2000	
	BGY	MGD	BGY	MGD	BGY	MGD	BGY	MGD
WATER USE	599	1641	760.2	2083	944.9	2587	1399	3833
CONSUMPTION	239.6	656	304.1	833	377.8	1035	559.6	1533
RETURN FLOW	359.4	985	456.1	1250	566.6	1552	839.4	2300

Governor's Planning Committee and is used in this study as a guideline for determining future municipal waste loads (35).

PL 92-500 states that municipalities must provide secondary treatment of effluents by 1977 and "Best Practicable Treatment" (BPT) by 1983 as minimum requirements. A properly operating secondary wastewater treatment facility receiving domestic wastewater should produce an effluent containing 20 mg/l of Biochemical Oxygen Demand (BOD) and 20 mg/l of Suspended Solids (TSS).

According to the Governor's Planning Committee, BPT is accomplished using secondary treatment followed by slow-sand filtration of two-thirds of the total wastewater flow. The BOD concentration is reduced to approximately 12 mg/l and the TSS concentration is reduced to approximately 9 mg/l.

For the purpose of this study "zero discharge of pollutants" was assumed to imply the implementation of the "Best Treatment Feasible" (BTF) which would further reduce the BOD concentration to 8 mg/l and the TSS concentration to 4 mg/l. These levels are attained using secondary treatment followed by filtration of the total wastewater flow. A summary of the schedule for the implementation of wastewater treatment facilities and the effluent waste load concentrations used to project the 1977, 1983, 1985, and 2000 municipal waste loads are given in Table 16.

Waste loads were determined by applying the waste load concentrations as outlined above to their respective waste flows as projected by the TWDB. BOD and TSS waste loads for 1970 and projections for 1977, 1983, 1985, and 2000 are given in Table 17.

Cost for Municipal Wastewater Treatment Facilities

The costs to construct, operate, and maintain municipal wastewater treatment facilities to meet the requirements of PL 92-500 are based on a report by the Federal Water Pollution Control Administration and are adjusted to June, 1967 (31). For activated sludge plants with design capacities ranging from 100 million gallons per day to 1.0 million gallons per day, capital cost range from $200,000 to $550,000 per million gallons respectively and operating and maintenance costs range from three cents to nine cents per thousand gallons treated

Table 16: SCHEDULE FOR IMPLEMENTING WASTE TREATMENT FACILITIES AND EXPECTED WASTE LOAD CONCENTRATIONS - MUNICIPALITIES

	1977	1983	1985	2000
Degree of Treatment	Secondary	Best Practical Treatment (BPT)	Best Treatment Feasible (BTF)	Best Treatment Feasible (BTF)
BOD conc. in effluent (mg/l)	20	12	8	8
Suspended Solids conc. in effluent (mg/l)	20	9	4	4

Table 17: MUNICIPAL WASTE LOADS

Millions of Pounds

	1970	1977	1983	1985	2000
BOD	60	76.1	54.0	37.8	56.0
TSS	60	76.1	40.5	18.9	28.0

respectively. Cost for installation of filtration equipment and facilities range from $19,000 to $90,000 per million gallons per day of design capacity. Operation and maintenance costs range from one cent to six cents per thousand gallons treated for plants ranging from 100 million gallons per day to 1.0 million gallons per day respectively. Because the above values reflect economy of scale, cost estimates for this report are based on an assumed average municipal treatment plant design capacity of 2.0 million gallons per day. The capital cost of a 2.0 mgd activated sludge plant is approximately $450,000 per million gallons and the operation and maintenance cost is approximately seven cents per thousand gallons treated. The capital cost for filtration equipment is approximately $70,000 per million gallons for a 2.0 mgd facility while the operation and maintenance cost is approximately 4.7 cents per thousand gallons treated.

The capital cost and operation and maintenance cost to meet the requirements stated in PL 92-500 were determined on an incremental basis. The incremental capital and operation and maintenance costs required to meet the 1977 standards were calculated by applying the appropriate cost per unit volume treated, for secondary treatment, to the estimated flow increase from 1970 to 1977. The incremental capital and operation and maintenance costs required to meet the 1983 standards of BPT were determined as the total cost for secondary treatment plus cost for filtration. Secondary treatment costs were calculated by applying the appropriate unit cost to the estimated flow increase from 1977 to 1985. Costs for filtration were determined by applying the appropriate filtration cost per unit treated to two-thirds of the estimate flow. Similarly, the incremental capital and operation and maintenance cost required to meet the 1985 standards of BTF were determined as the total cost of secondary treatment and filtration. Costs for secondary treatment were determined by applying the appropriate cost per unit treated to the projected flow increase from 1977 to 1985. Filtration costs were determined by applying the appropriate costs per unit treated to the total estimated flow. The incremental capital and operating costs required to meet the 1985 standards for 2000 were determined as the total cost of secondary treatment and filtration cost for secondary treatment were determined by applying the appropriate cost per unit treated to the estimated flow increase from 1985 to 2000.

Filtration costs were determined by applying the appropriate cost per unit treated to the same estimated flow increase. A summary of the incremental costs required to construct, operate, and maintain municipal wastewater treatment facilities to meet the requirements of PL 92-500 are given in Tables 18 and 19.

Energy Requirements

The estimated electrical power consumption required to operate the necessary waste treatment facilities to attain the water quality requirements of PL 92-500 are based on the Environmental Protection Technology Series EPA - R2-73-281, July 1973 (32). The electrical power consumption varies from 1100 kilowatt hours per day for activated sludge plants of 1.0 mgd design capacity to 850 kilowatt hours per day for plants of 100 mgd design capacity. A typical 2.0 mgd activated sludge plant consumes approximately 1000 kilowatt hours per million gallons treated. Estimated electrical power consumption for multi-media filtration ranges from 100 kilowatt hours consumption per million gallons to 95.3 kilowatt hours consumption per million gallons for plant sizes ranging from 1.0 mgd design capacity to 10 mgd design capacity respectively. For purposes of this report an electrical consumption of 100 kilowatt hours per million gallons of waste treated is assumed for multi-media filtration.

Electrical power consumption was determined and is reported as total annual requirements. The electrical power required to operate treatment facilities to meet the 1977 standards of secondary treatment was determined by multiplying the consumption required per million gallons treated for secondary treatment by the estimated total municipal waste flow for 1977. The electrical power required to operate treatment facilities to meet the 1983 standards of BPT was determined by adding the energy consumptions for secondary treatment and filtration for 1985. Energy consumption for secondary treatment was calculated by applying the energy consumption required per million gallons treated for secondary treatment to the total annual waste flow in 1985. Energy requirements for filtration were calculated by applying the energy consumption per million gallons treated for filtration by two-thirds of the total waste flow in 1985. The electrical power consumption required to operate treatment facilities to meet the 1985 standards

Table 18: INCREMENTAL CAPITAL COST ESTIMATES FOR MUNICIPAL WASTE TREATMENT

Million Dollars

	1970	1977	1985 1983 (Criteria)	1985 1985 (Criteria)	2000
Secondary	--	119	136	136	336.6
Filtration	--	--	72.4	108.6	52.36
Total	--	119	208.4	244.6	389

Table 19: INCREMENTAL OPERATION AND MAINTENANCE COST FOR MUNICIPAL WASTE TREATMENT

Million Dollars

	1970	1977	1985 1983 (Criteria)	1985 1985 (Criteria)	2000
Secondary	--	6.8	7.7	7.7	19.1
Filtration	--	--	17.7	26.6	12.8
Total	--	6.8	25.4	34.3	31.9

of BTF in 1985 and 2000 was determined by adding the power requirements per million gallons treated for both secondary treatment and filtration and multiplying by the total annual flow for 1985 and 2000 respectively.

Table 20 summarizes the electrical power required to operate the wastewater treatment facilities necessary to meet the requirements of PL 92-500.

The projected energy requirement for 1977 is approximately 456 million kilowatt hours which is an increase of approximately 27 per cent over the approximate consumption of 360 million kilowatt hours in 1970. Energy requirements for 1985 are projected to be approximately 623 million kilowatt hours which indicates a projected increase over 1970 of approximately 73 per cent. The projected energy requirement for 2000 is approximately 924 million kilowatt hours which is an increase of approximately 157 per cent over the 1970 requirements.

Table 20: ENERGY REQUIREMENTS TO OPERATE MUNICIPAL WASTE TREATMENT FACILITIES

KILOWATT HOURS x 10^6

	1970 (Secondary)	1977 (Secondary)	1983 (BPT)	1985 (BTF)	2000 (BTF)
Secondary	359.5	456.3	566.5	566.5	839.5
Filtration	--	--	37.8	56.6	84.0
Total	359.5	456.3	604.3	623.1	923.5

COLORADO RIVER BASIN

The Colorado River Basin has been selected as one of the study areas for consideration in assessing the impact on Texas water quality and resources of alternate strategies for production, distribution, and utilization of energy in Texas in the period 1974-2000. Considerable data are available on this basin from reports of the Texas Water Development Board, the Texas Water Quality Board, other state agencies and from an extensive study managed by the U. S. Army Corps of Engineers, Fort Worth District with consulting engineering services provided by Turner, Collie and Braden Incorporated. Much of the general background information that follows has been obtained from the U. S. Army Corps of Engineers report (35).

The Colorado River Basin, which is the third largest in Texas, extends across the state from the Texas - New Mexico stateline to the central Texas Gulf Coast covering an area of approximately 40,000 square miles representing about 15 percent of the total area of the state (see Figure 15). The basin climate varies from semiarid in the High Plains to subtropical along the Gulf Coast. The annual precipitation covers a wide range from approximately 14 inches in the western portion to in excess of 40 inches in the eastern portion at the mouth of the river. The average annual runoff ranged from a maximum of 350 acre-feet per square mile near the mouth of the river to less than 50 acre-feet per square mile west of San Angelo.

The Colorado River system consists of approximately 900 river miles of main stream and has six major tributaries. There are currently 21 major reservoirs within the basin having capacities in excess of 5,000 acre-feet. The Highland Lakes network of impoundments having a combined capacity in excess of 2 million acre-feet is the primary regulating system in the basin. Streamflow can be characterized as intermittent in the upper 57 mile reach of the River; however, the streamflow begins to increase proportionately downstream with Bastrop having an average flow in excess of 2000 cfs. Surface water is scarce in a major portion of the basin and thus groundwater is utilized primarily to satisfy water requirements. Nine major and minor aquifers supply an annual yield of groundwater in excess of 500,000 acre-feet.

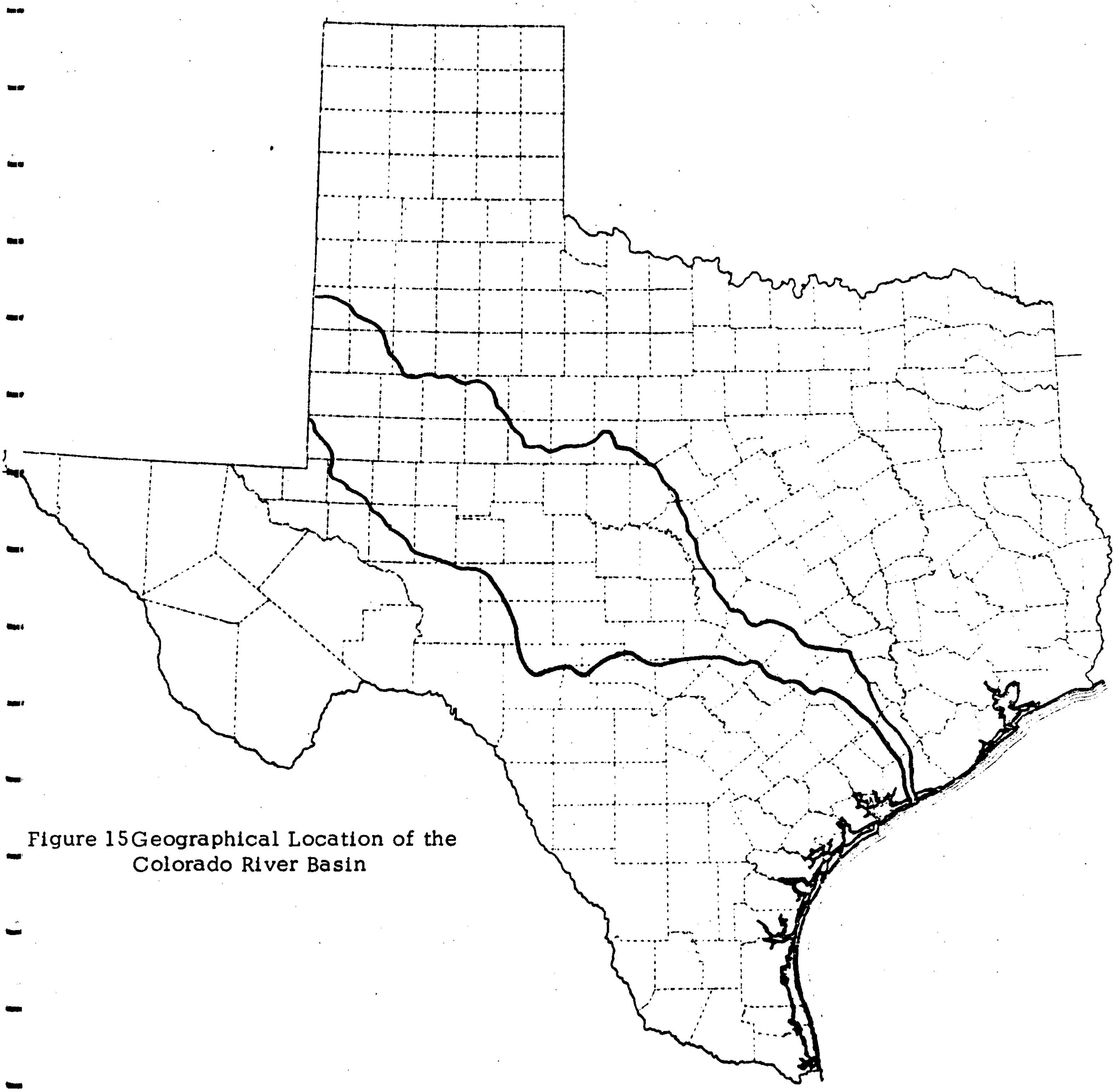

Figure 15 Geographical Location of the Colorado River Basin

In 1970, the population in the basin was 841,683 or approximately 7.5 per cent of the state population. Population projections by the TWDB show an estimated basin population of approximately 1,022,000 by 1985 and 1,261,000 by the year 2000 with 95 per cent of this growth projected to occur in the Austin and Midland-Odessa urban areas. The majority of the basin population is presently located in the cities of Austin, San Angelo, Midland, Odessa, Big Spring and Brownwood.

Approximately 60 per cent of the land in the basin consists of range and unimproved pastureland while an additional 30-35 per cent is used for farming. Agriculture land use in the basin is projected to remain stable, but irrigated acreage will decline mainly because of the projected depletion of groundwater supplies in the upper part of the basin. Large areas of the lower reach are being irrigated for rice production, and surface water supplies seem adequate for future use.

The main non-agricultural industries in the basin are related to petroleum production and petrochemicals. Oil and gas fields are scattered over approximately half the basin, but are mostly concentrated in the upper and lower reaches of the basin.

At present, there are comparatively few water quality problems of significant nature in the basin. Quality degradation by mineral salts from natural sources and oilfield operations along with disproportionate discharges of secondary effluent to streams having intermittent or minimal flows are the most serious water quality problems. Although other sources of stream contamination, namely industrial discharges, stream runoff, irrigation return flows, and lakefront contamination are present to some degree in the basin, these sources are insignificant when compared with the problems caused by effluent dominated streams and mineral salt contamination.

Fresh Water Intake Requirements

In 1970, the total fresh water intake requirements in the Colorado River Basin excluding irrigation amounted to 533 billion gallons. In 1985, the requirements are projected to be 1373 billion gallons and in the year 2000 the requirements will amount to 3943 billion gallons. The distribution of these intake requirements is shown in Table 21.

Production: Extensive petroleum production in the Colorado River Basin has resulted in significant usage of fresh water in secondary recovery techniques. In 1970, the use amounted to approximately 32 billion gallons which was nearly 50 per cent of that required statewide. Although groundwater has been used predominantly in the past, the use of surface water having a high chloride content, which prevents its use for municipal industrial, or irrigation needs, has increased recently. In 1972, the Colorado River Municipal Water District sold in excess of 3000 acre-feet of surface water to various oil companies in the upper Basin for this purpose. A small increase to 36 billion gallons is projected for 1985 while a decrease of approximately 25 per cent to 27 billion gallons is projected for the year 2000. It has been estimated that the use of secondary techniques in petroleum production will peak in approximately the year 1990.

Fresh water requirements for the production of lignite and uranium in the Colorado River Basin are negligible.

Steam Electric Power Industry: In 1970, the eight existing fossil-fuel steam electric power plants in the Colorado River Basin having an installed capacity of 1993 MW generated in excess of 10 billion hillowatt hours of electricity. Assuming an average increase of 15^{o}F in the temperature of water passing through condensers, the intake water requirements were estimated to be 443 billion gallons. It has been projected by the TWDB that by 1985 the installed capacity in the Colorado River Basin will increase to approximately 7500 MW of which 2500 MW will be nuclear. Assuming that all new fossil-fuel plants constructed will operate at 40 per cent efficiency and a 15^{o}F temperature rise and nuclear plants at 33 per cent efficiency and a 20^{o}F temperature rise, the intake water requirements are estimated to be 1250 billion gallons.

Assuming that the installed capacity will double every 10 years during the period 1985 to 2000 and that the new installed capacity will be all nuclear, the fresh water intake requirements in the year 2000 are estimated to be about 3800 billion gallons.

Table 21: FRESH WATER INTAKE REQUIREMENTS

(Colorado River Basin)

	Billions of Gallons		
	1970	1985	2000
PRODUCTION	32.1	36	27
STEAM ELECTRIC POWER INDUSTRY	443	1250	3789
INDUSTRY	8.9	14.4	21.2
MUNICIPALITIES	48.7	73.0	105.3
	533	1373	3943

Industry: In 1970, the industrial water demands in the basin were reported by the TWDB to be nearly 9 billion gallons. The TWDB has projected that the annual use will increase to over 14 billion gallons in 1985, and in excess of 21 billion gallons by the year 2000.

Municipalities: In 1970, the municipal water demands in the basin were reported by the TWDB to be in excess of 48 billion gallons. The TWDB has projected that the annual use will increase to 73 billion gallons in 1985 and in excess of 105 billion gallons by the year 2000.

Consumptive Use of Water

Consumptive use refers to that quanity of water that is not immediately available as a return flow. In 1970, the total consumptive use of fresh water in the Colorado River Basin excluding irrigation amounted to 82 billion gallons. In 1985, the consumptive use is projected to be 130 billion gallons and by 2000, 211 billion gallons. The distribution of the consumptive use is shown in Table 22.

Production: The consumptive use of fresh water for secondary recovery techniques of petroleum production is taken as 100 per cent of the fresh water intake requirements.

Steam Electric Power Industry: In 1970, the consumptive use was approximately 7 billion gallons which is about 1.6 per cent of the intake requirements. In 1985, it is projected that the annual use will increase to 25 billion gallons or 2 per cent of the intake requirements. By 2000, it is projected that the annual use will increase to 85 billion gallons or 2.2 per cent of the intake requirements. A large portion of the increased consumptive use during the period of 1985 to 2000 is due to the influence of nuclear generation plants which consume approximately 50 per cent more water than do fossil fuel plants.

Industry: In 1970, the consumptive use of fresh water by industry in the basin was about 6 billion gallons or approximately 72 per cent of the fresh water intake requirements. This is considerably higher than the statewide average of 31 per cent. This difference is due to the increased retention and evaporation of wastewater by most of the industries in the basin. If the 72 per cent consumptive use of fresh water intake requirements is applied to the projected 1985 and 2000

Table 22: CONSUMPTIVE USE OF WATER

(Colorado River Basin)

	Billions of Gallons		
	1970	1985	2000
PRODUCTION	32	36	27
STEAM ELECTRIC POWER INDUSTRY	7	25	85
INDUSTRY	6	10	15
MUNICIPALITIES	37	59	84
	82	130	211

annual requirements, the consumptive use of fresh water by industry will exceed 10 billion gallons by 1985 and 15 billion gallons by 2000.

Municipalities: In 1970, the consumptive use of fresh water by municipalities was about 37 billion gallons or approximately 76 per cent of the fresh water intake requirements. The statewide average for municipalities is about 40 per cent. The difference is due to the lack of readily available water supplies which has resulted in the extensive reuse of municipal wastewater effluent throughout the basin, but particularly in the upper and central portions of the basin. The effluent from 41 municipal wastewater treatment plants is used exclusively for irrigation while the effluent from an additional nine plants is partially used for irrigation. The effluent from two plants is purchased by industry and the effluent from five plants is disposed of by evaporation. By 1985, the consumptive use of fresh water is estimated to increase to 59 billion gallons or 81 per cent of the projected fresh water intake requirements. The increase is due to the increased reuse of water not only to meet the lack of readily available water supplies, but also as a means of meeting the "no discharge of pollutants" goal as set forth in PL 92-500. By 2000, the annual consumptive use is estimated to increase to 84 billion gallons which is approximately 80 per cent of the projected fresh water intake requirements.

Waste Loads from Point Sources

The two principal point sources of waste loads with regard to biochemical oxygen demand (BOD) and suspended solids (SS) are industry and municipalities. Present municipal and industrial wastewater treatment practices in a large measure account for the relatively pollution free conditions of the basin. However, many reaches of the Colorado River and tributaries in the upper Basin (above the Highland Lakes) are either intermittent or have frequent periods of minimal flow. As a result, many streams become heavily effluent-dominated, with subsequent degradation through parts of the year. Beals Creek below Big Spring and Pecan Bayou below Brownwood are examples. The distribution of waste loads is shown in Table 23.

Table 23: WASTE LOADS FROM POINT SOURCES
(Colorado River Basin)

	1970	1977	1985	2000
WASTE WATER FLOWS (Billion of Gallons)				
INDUSTRY	2.5	3.2	4	6
MUNICIPALITIES	12.2	13	14	21.6
BIOCHEMICAL OXYGEN DEMAND (Millions of Pounds)				
INDUSTRY	.04	.04	.04	.04
MUNICIPALITIES	2	2.2	1.4*(.9)	1.4
SUSPENDED SOLIDS (Millions of Pounds)				
INDUSTRY	.45	.5	.5	.5
MUNICIPALITIES	2	2.2	1*(.5)	0.7

* Using 1983 Environmental Criteria of Best Practicable Treatment

( ) Using 1985 Environmental Criteria of Best Treatment Feasible

Industry: Only eight of the approximate 92 industrial operations within the basin excluding the steam electric power industry reported a wastewater discharge. It has been assumed in the U.S. Army Corps of Engineers report that industrial wastewater discharges and waste loads within the basin will remain relatively constant through the planning period.

Municipalities: Currently there are 87 permitted municipal wastewater treatment systems in the basin. All municipal wastewater plants within the basin are designed to give secondary treatment. Approximately 65 per cent of these wastewater treatment plants either irrigate with all effluent, practice seasonal irrigation with some discharge, provide for total evaporation of effluent using ponds, or sell the effluent for industrial purposes. Thus, many municipalities within the basin are already meeting the national goal of "no discharge" of pollutants by the total reuse of their wastewater discharges. It has been estimated that the total reuse of wastewater effluent by all municipalities except Austin would provide the most effective means of meeting the 1985 national goal of "no discharge" of pollutants. The waste loads of municipalities presented in Table III reflect the projected growth of the Austin metropolitan area, and the following environmental criteria:

1977 - Secondary Treatment
1983 - Best Practicable Treatment (BPT): BOD = 12 mg/l
SS = 9 mg/l
1985 and 2000 - Best Treatment Feasible (BTF): BOD = 8 mg/l
SS = 4 mg/l

Although municipal wastewater flows are projected to increase by about 77 per cent, biochemical oxygen demand and suspended solids waste loads are estimated to decrease by 30 and 65 per cent respectively.

The other significant source of stream contamination in the basin is the non-point inflow of mineral salts into waters of the upper basin. Mean annual weighted averages of chlorides in a 300 mile reach of the Colorado River below Lake J. B. Thomas Dam have varied from almost 800 mg/l at the upper end to about 300 mg/l at the lower end. These chloride concentrations exceed the 250 mg/l U. S. Department of the Interior recommended permissible level for domestic raw water sources. Studies to date are not conclusive with regard to the origin of this pollution, that is whether it is natural or from oil field contamination.

Steam Electric Power Industry: The principal waste from the steam electric power industry is the discharge of heat in condenser cooling water return and materials contained in blowdown water. Most blowdown water is discharged with the cooling water, however, the highly acidic boiler cleaning wastes are disposed of by evaporation.

The principal source of heat discharge is from once-through cooling systems. In 1970 once-through cooling was used in the generation of approximately 33 per cent of the electric power in the basin. By 1985, it is projected that once-through cooling will be used in the generation of less than 18 per cent of the electric power in the basin. In 1970 an estimated 18 trillion BTU were discharged by once-through cooling. Planned additions to power plants already using once-through cooling and a new power plant constructed in 1974 will increase the BTUs discharged to 27 trillion by 1985. Assuming no additional once-through cooling will be allowed the above value of 27 trillion will remain constant during the period 1985-2000. It is noted that currently there is no known evidence of thermal pollution in the receiving reservoirs within the Colorado River Basin.

Capital Costs: In estimating the capital costs required by municipalities to meet the requirements of PL 92-500 the U. S. Army Corps of Engineers Report selected a single alternative for each facility, that is, either treatment with discharge or treatment with reuse. The following are estimates of the incremental capital costs required to meet the water quality objectives of PL 92-500: *

Capital Cost (Millions of Dollars)	1977	1983	1985
	26	24	8

It is assumed that the design capacities stated in the U. S. Army Corp of Engineers report will be sufficient for the projected wastewater flows during the period 1985-2000 resulting in a minimal expenditure of capital costs during this period.

The capital costs required by industry to meet the requirements of PL 92-500 are estimated to be minimal as most industrial water is currently being reused.

*Capital costs reported in 1972 dollars. Approximate equivalent costs in 1967 dollars can be obtained by multiplying values shown by 0.82.

Operation and Maintenance Costs: Estimated annual operating and maintenance costs for municipal wastewater treatment are expected to increase to 1.75 million dollars in 1977 from 1.5 million dollars in 1970. By 1985, these costs are projected to increase to 4.75 million dollars and by the year 2000 to 7 million dollars. The values estimated include secondary treatment for all wastewater treatment plants and the 1985 and 2000 values include filtration and biological tertiary treatment for the Austin metropolitan area.

Energy Requirements for Municipalities

Estimated annual energy requirements for municipal wastewater treatment are expected to increase 3.65 million kilowatt hours by 1977 over that required in 1970. By 1985 the energy requirement is projected to increase by 19.91 million kilowatt hours over the 1977 requirements and another 18.37 million kilowatt hours by 2000. The values estimated include the energy requirements for secondary treatment for all wastewater treatment plants and the 1985 and 2000 values include energy requirements for filtration and biological tertiary treatment for the Austin metropolitan area.

NECHES RIVER BASIN

The Neches River Basin has been selected as one of the study areas for this report because it represents a water-rich area having a high industrial concentration. Considerable data on this basin are available from reports by the Texas Water Development Board, Texas Water Quality Board and the Texas Water Rights Commission. Compilation of data and information for this study was performed by Espey, Huston and Associates, Inc. of Austin Texas (36). The Neches River Basin located in Southeast Texas can be characterized as a water rich area, meeting present water demands and having the potential to satisfy future water requirements. The Angelina and Neches Rivers are the main tributaries in the basin, their confluence occurring in the headwaters of B. A. Steinhagen Reservoir. Minor tributaries include Mud Creek, Striker Creek, East Fork Creek, Bayou La Nana, Attoyac Bayou, Ayish Bayou, and Indian Creek in the Angelina watershed, and Kickapoo Creek, Flat Creek, Cedar Creek, Piney Creek, Wolf Creek, Turkey Creek, Cypress Creek, Village Creek, Little Pine Island Bayou, and Pine Island Bayou in the Neches Watershed. Sam Rayburn Reservoir is the largest impoundment in the basin, containing a 1973 maximum of 3,293,000 acre-feet (37).

Rainfall in the basin averages approximately 48 inches annually and runoff ranges from about 400 to 1,000 acre-feet per year per square mile for the northern and southern reaches of the region, respectively (24). A runoff-to-rainfall ratio range of 0.16 to 0.39 is characteristic of the basin. Location of the Neches River Basin is shown in Figure 16.

Fresh Water Intake Requirements

Water requirements for production were determined from estimates of secondary oil production based on a transposition of the Neches River Basin on Figure 2 and applying the water required to oil produced ratio of eight to one. The water demand for 1970 was approximately 4.1 billion gallons. Approximately 78.6 billion gallons of water was used in 1970 by the steam electric power industry (38). Municipal water demands in 1970 included a surface water use of approximately 13.9 billion gallons and a ground water use of approximately 10.6 billion gallons for a total use of approximately 24.5 billion gallons (38) (39). Water demands

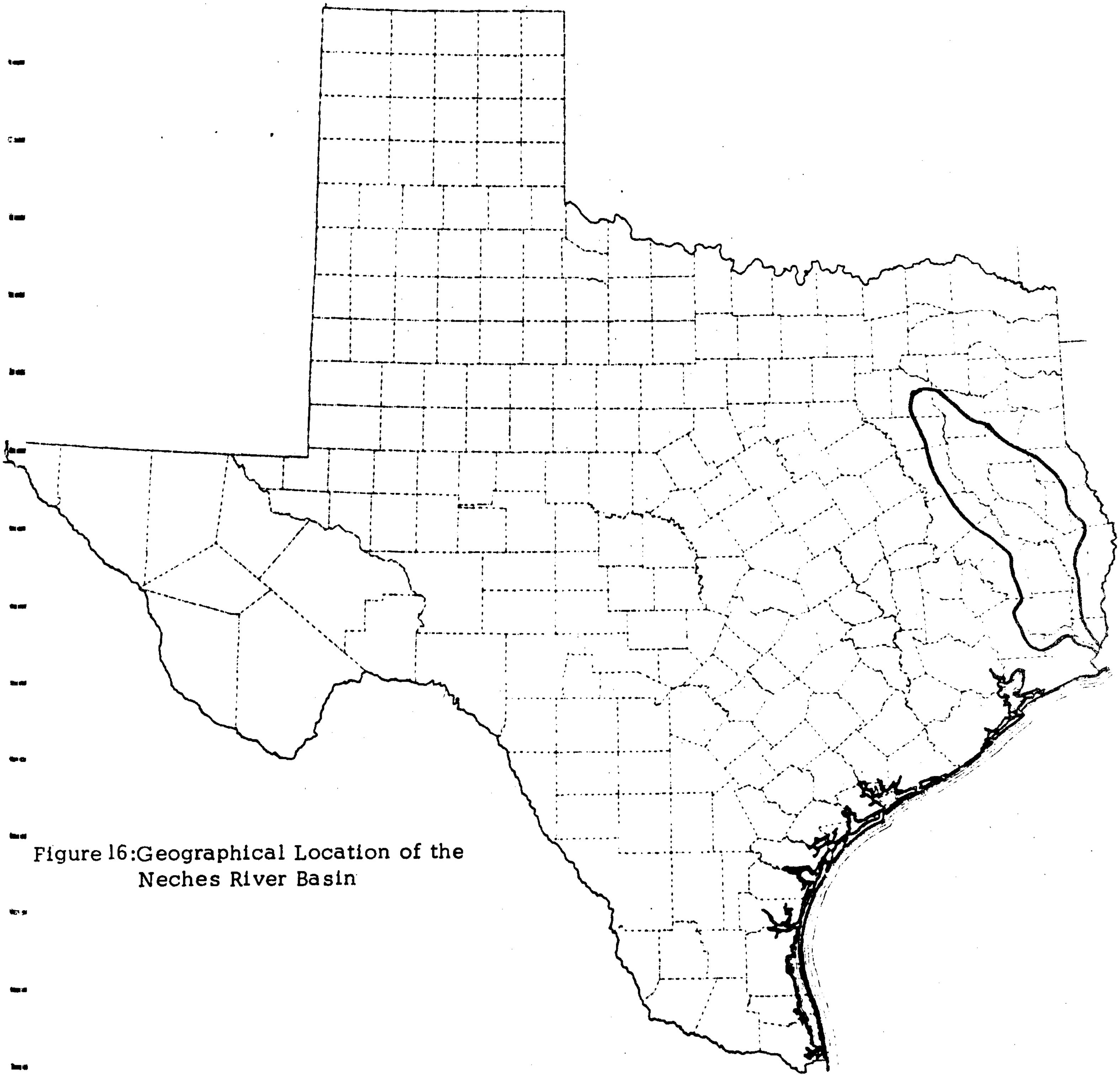

Figure 16:Geographical Location of the Neches River Basin

for industry in 1970 included a surface water use of approximately 196.9 billion gallons and a ground water use of approximately 26.0 billion gallons for a total use of approximately 222.9 billion gallons.

Projected water requirements for production are based on the Governor's Office of Information Services (OIS) projected oil production levels and indicate a demand of approximately 5.4 billion gallons per year for 1985 and an approximate 4.9 billion gallons per year for 2000.

Water use by the steam electric power industry is not expected to increase by 1985, as no additional electric power generation facilities are planned for the basin at this time. Projected use for the year 2000 is approximately 82.1 billion gallons per year utilizing recent generating capability projections developed from information furnished by regional electric reliability councils (40). The growth rate was applied to the estimated water consumption for 1985 (equal to the present consumption of 1.0 billion gallons per year) on the premise that future generating schemes will adhere to Federal guidelines calling for closed-cycle cooling systems. The projected value for the year 2000 was obtained by adding this increase in consumption for new facilities to the projected 1985 water use, assuming that once-through cooling systems already in existence will continue to operate as such to obtain the total projected.

Projected industrial water demands were calculated for TWDB Series A for industry using state-wide water demand growth rate predictions. Industry will require approximately 309.9 billion gallons per year in 1985 and approximately 432.5 billion gallons per year in the year 2000.

Municipal projections, using TWDB growth rates for the Neches Basin, indicate a 1985 demand of approximately 37.2 billion gallons per year and approximately 53.7 billion gallons per year in 2000.

The total surface water use projections for the Neches River Basin, including demands for production, the steam electric power industry, industries and municipalities amount to approximately 431 billion gallons per year in 1985 and approximately 573 billion gallons per year by 2000. It should be kept in mind that these numbers express total use requirements only, ignoring the large quantity of return flow restored to the system. The fresh water intake requirements in the Neches River Basin for 1970 and projections for 1985 and 2000 are given in Table 24.

Table 24: FRESH WATER INTAKE REQUIREMENTS
(Neches River Basin)

	Billions of Gallons		
	1970	1985	2000
PRODUCTION	4.1	5.36	4.86
STEAM ELECTRIC POWER INDUSTRY	78.8	78.8	83.1
INDUSTRY	222.9	309.9	432.5
MUNICIPALITIES	24.5	37.23	53.7
	293.7	431.29	573.16

Consumptive Use of Water

Consumptive use refers to that quantity of water that is not immediately available as a return flow. In 1970, the total consumptive use of fresh water in the Neches River Basin excluding irrigation amounted to approximately 52 billion gallons. In 1985, the consumptive use is projected to be approximately 73 billion gallons and approximately 100 billion gallons by 2000.

Production: The consumptive use of fresh water for secondary recovery techniques of petroleum production is taken as 100 per cent of the fresh water intake requirements.

Steam Electric Power Industry: In 1970, the consumptive use was approximately 1.0 billion gallons which is about 1.2 per cent of the intake requirements. Water consumption by the steam electric power industry is not expected to increase by 1985, as no additional electric power generation facilities are planned for the basin. A projected water intake increase of approximately 3.3 billion gallons per year by 2000 will not significantly increase the water consumption over 1985.

Industry: In 1970, the consumptive use of fresh water by industry in the basin was about 42.37 billion gallons or approximately 19 per cent of the fresh water intake requirements which is lower than the statewide average of 31 per cent. The difference is probably due to a lower reuse of industrial effluents for irrigation in this region of the state. Projected industrial water consumption, based on a consumption of 19 per cent of fresh water intake, will be approximately 58.0 billion gallons per year by 1985 and approximately 82.5 billion gallons by 2000.

Municipalities: The consumptive use of fresh water by municipalities for 1970 in this river basin was approximately 4.7 billion gallons or 21 per cent of the fresh water intake. Projected municipal water consumption, based on a consumption of 21 per cent of fresh water intake, will be approximately 7.23 billion gallons in 1985 and 11.4 billion gallons in 2000.

Table 25 summarizes the 1970 and projected 1985 and 2000 fresh water consumption for the Neches River Basin.

Table 25: CONSUMPTIVE USE OF WATER

(Neches River Basin)

	Billions of Gallons		
	1970	1985	2000
PRODUCTION	4.1	5.36	4.86
STEAM ELECTRIC POWER INDUSTRY	1.0	1.0	1.0
INDUSTRIAL	42.37	58.0	82.5
MUNICIPALITIES	4.7	7.23	11.4
	52.17	71.59	99.76

Waste Flows

Calculations for combined industrial wastewater flows including cooling waters were based on the water demand projections in Table 24 and applying a return flow-to-water use ratio of 0.81, which characterizes the current industrial situation. The 1970 industrial wastewater flow was approximately 175.9 billion gallons and is projected to be approximately 213.5 billion gallons in 1977, approximately 251.0 billion gallons in 1985, and approximately 350.0 billion gallons in 2000. The 1970 municipal wastewater flow was approximately 19.3 billion gallons and is projected to be approximately 24.1 billion gallons in 1977, approximately 30.0 billion gallons in 1985, and approximately 42.3 billion gallons in 2000.

An industrial waste load of 29.2×10^6 lbs/yr BOD and 84.8×10^6 lbs/yr TSS for 175.9 billion gallons per year of wastewater flow along with a municipal discharge of 19.3 billion gallons per year containing 2.82×10^6 lbs/yr BOD and 3.4×10^6 lbs/yr TSS were used as the base 1970 values. Of the combined industrial wastewater flow, the chemical and allied industry is accountable for 72 per cent, pulp and paper 15 per cent, petroleum refining 9 per cent, and other industries 4 per cent of the total. The chemical and allied industry also contributed 58 per cent of the total BOD and 83 per cent of the total TSS. Taken together, the three major industrial categories of petroleum refining, chemicals, and pulp and paper account for 96 per cent of the wastewater flow, 96 per cent of the BOD, and 99 per cent of the TSS in the industrial totals for the Neches River Basin. The large return flow from the steam electric power industry should be noted, which consists mainly of cooling water plus a small quantity of blowdown and imposes a negligible BOD and TSS load upon the system. A significant portion of the return flow from steam electric generating facilities is reintroduced into private cooling impoundments.

Future industrial wastewater loads for petroleum refining, chemical and allied industries, and pulp and paper operations were projected using presently reported water use, TWDB (22) growth predictions for the specific industrial categories, and wastewater-flow-to-water use return ratios reported by Malina and Burleson (41). These BOD and TSS parameters were calculated using effluent guidelines from the Environmental Protection Agency (27) (26) (25) which specify permissible BOD and TSS loadings for 1977 and 1985 on a pound per unit of production basis. This method necessitated the determination of a current wastewater-flow-to-production ratio for the industrial categories in question. For the Neches River Basin, these ratios were found to be 77.4 gal/bbl for petroleum refining, 20,155 gal/ton for chemical and allied industries, and 28,746 gal/ton for pulp and paper refining. These values, being somewhat higher than the statewide ratios, reflect the water-rich aspects of the basin. Current production estimates were extracted from data compiled by Prengle (21).

Considering the three major industrial categories, BOD loadings of 9.1×10^6, 4.4×10^6, and 5.6×10^6 lbs/year for 1977, 1985, and 2000, respectively, would be allowable as would TSS loadings of 15.6×10^6, 5.9×10^6, and 7.7×10^6 lbs/year for those years. Loadings for the year 2000 were based on the proposed 1983 guidelines (BATEA).

Municipal waste loadings were projected for 1977 secondary treatment, 1983 BPT, 1985 BTF, and 2000 BTF. Projected loadings after secondary treatment of 4.02×10^6 lb/year BOD and 4.02×10^6 lb/year TSS in 1977 could be reduced through BTF technology to 1.97×10^6 lb/year BOD and 0.99×10^6 lb/year TSS in 1985. BOD and TSS loadings were determined from target levels for secondary treatment (20 mg/l BOD, 20 mg/l TSS), and BTF (8 mg/l BOD, 4 mg/l TSS). Municipal discharges will continue to account for only a small portion of the total waste load in the basin. A summary of waste flows and waste loads for 1970 and projections for 1977, 1985, and 2000 are given in Table 26.

<u>Cost for Industrial Waste Treatment</u>

Waste treatment cost projections were calculated for industry as a whole assuming BPCTCA level processes applied in 1977, BATEA level processes applied for 1983 and ZDP level processes applied for 1985 and 2000. All cost projections were made on the basis of additional expenditures required for expansion and additions to present technology employed in the basin, assumed to be secondary treatment in general and the activated sludge process for computational purposes.

Table 26: WASTE FLOWS AND WASTE LOADS FROM POINT SOURCES
(Neches River Basin)

	1970	1977	1985	2000
WASTE WATER FLOWS (Billions of Gallons)				
INDUSTRY				
Process Water + Cooling	175.9	213.5	251.0	350.0
Process Water	52.8	64	75	105
MUNICIPALITIES	19.3	24.1	30.0	42.3
BIOCHEMICAL OXYGEN* DEMAND (Millions of Pounds)				
INDUSTRY	29.1	9.1	4.4	5.6
MUNICIPALITIES	2.8	4.02	1.97	2.8
SUSPENDED SOLIDS* (Millions of Pounds)				
INDUSTRY	84.8	15.6	5.9	7.7
MUNICIPALITIES	3.4	4.02	0.99	1.4

* 1970 values include BOD and Suspended Solids in both cooling water and treated process water.
Projections for 1977, 1985, and 2000 are waste loads to receiving water bodies from treated process wastewaters.

Costs per million gallons treated, taken from Smith (31) on the basis of a 2 MGD design flow, include $450,000 capital and $70 operation and maintenance for activated sludge, $70,000 capital and $47 operation and maintenance for filtration, and $290,000 capital and $80 operation and maintenance for granular carbon adsorption. All costs are in June, 1967 dollars. Costs for flash evaporation were taken from a publication by the National Council of the Paper Industry for Air and Stream Improvement, Inc. (30), and include $1,645,000/MGD capital and $1000/MGD operation and maintenance in 1972 dollars. Adjustment of the flash evaporation costs to June, 1967 dollars using the ENR construction cost index results in $1,000,000/MGD capital and $610/MGD operation and maintenance.

The implication of BPCTCA in 1977 will demand improvements to present systems resulting in an additional capital cost of approximately $24.6 million and an additional operating and maintenance cost of approximately $3.7 million per year. Attainment of BATEA in 1983 will require an additional capital expenditure of approximately $88.4 million and an additional operating and maintenance cost of approximately $8.0 million per year over present technology. Additional costs of approximately $235.2 million capital and approximately $48 million per year operation and maintenance are necessary to meet ZDP standards for 1985. An additional capital cost of approximately $152.7 million dollars and an additional operation and maintenance cost of approximately $23.5 million will be required to meet ZDP in 2000.

Cost for Municipal Waste Treatment

Waste treatment cost projections were calculated for municipalities assuming secondary treatment applies in 1977, BPT applies in 1983 and BTF applies in 1985 and 2000. Attainment of secondary treatment for 1977 will demand improvements to present systems resulting in an additional capital cost of about $5.9 million and an additional operation and maintenance cost of about $0.3 million per year. Attainment of BPT in 1983 will require an additional capital expenditure of about $16.4 million and an additional operation and maintenance cost of about $1.6 million per year. An additional capital cost of about $18.3

million and an additional operation and maintenance cost of about \$2.1 million per year will be necessary to meet BTF standards for 1985. An additional capital cost of about \$32.5 million and an additional operation and maintenance cost of about \$2.6 million per year will be necessary to meet the 1985 standards of BTF in 2000.

Energy Requirements

Computations for projected power consumption for industrial and municipal wastewater treatment were made on the basis of process power consumptions reported by Smith (32): 1000 kwh/MGD for activated sludge, 100 kwh/MGD for filtration, and 391 kwh/MGD for granular carbon adsorption and regeneration. A power consumption of 1330 kwh/MGD and a fuel consumption of 954 million BTU/MGD are reported for flash evaporation (30). Industrial waste treatment to attain BPCTCA in 1977 is estimated to demand approximately 0.7×10^{12} BTU/year and treatment to attain BATEA in 1983 will require approximately 1.1×10^{12} BTU/year. The addition of the flash evaporation process to meet ZDP will result in a substantial increase in power consumption to about 74×10^{12} BTU/year in 1985 and about 103×10^{12} BTU/year in 2000. Power consumption required to operate municipal waste treatment facilities is estimated to be approximately 0.241×10^{12} BTU/year to meet the 1977 standards of secondary treatment, approximately 0.316×10^{12} BTU/year to meet 1983 standards of BPT, approximately 0.326×10^{12} BTU/year to meet 1985 standards of BTF and approximately 0.465×10^{12} BTU/year to meet 1985 standards of BTF in 2000.

WATER DEMANDS FOR FUTURE ENERGY SOURCES

Increasing energy demands and diminishing oil and gas reserves have encouraged investigations into other possible sources of energy which have, until recently, received little attention. Future potential energy sources include geothermal, solar, wind, tidal and wood (4).

Water needs for development of geothermal resources are minimal and are usually available. Water production, however, presents varied problems depending upon the type of geothermal system. Vapor-dominated fluids are sulfur rich and require protection against corrosion. Hot brines found in liquid-dominated systems are chlorine rich and require protection from scaling and corrosion. Potable water for irrigation may become an important by-product of geothermal energy in both liquid-dominated systems and geopressured sands (42). The conversion of geothermal energy into usable power will require a substantial quantity of water for cooling due to the relatively low thermal efficiency of about 15 per cent (9).

The wide variety of solar power plants being considered imply a wide variation in the water requirements for these systems. The water requirements for solar thermal plants is critical and is dependent on the thermodynamic efficiency expected (5 - 55%). A 1,000 megawatt solar pond power plant operating at 7.5 per cent thermal efficiency would require about 80,000 gallons of water per minute of withdrawal to makeup for evaporative cooling consumption in a wet cooling tower. A 1,000 megawatt central receiver solar thermal plant using advanced combined cycles has a thermal efficiency of approximately 50 per cent and would similarly require a withdrawal of 6,800 gallons per minute to makeup for evaporative cooling consumption in a wet cooling tower. Photovoltaic power plants are not expected to require any water resources (43).

Water demands for power generation using windmills and tidal driven turbines are nominal as cooling water is not required. The water demands for space heating with firewood are essentially non-existent.

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APPENDIX A

COMPARISONS OF SCENARIOS I AND II

Introduction

In comparing Scenarios I and II, in this section, the assessment of the impact of alternate strategies for production, distribution, and utilization of energy in Texas on water resources and water quality has been made using information and data obtained from several sources. Basic data on fuel sources, energy consumption, and population were provided by the Governor's Office of Information Services, and are given in Tables I and II. These analyses include details as to fresh water requirements and availability, consumptive use, and return flows and their characteristics. This information has been used to establish baseline conditions as of the year 1970 from which projections have been made for the years 1985 and 2000. In the analyses, consideration has been given to the following major sectors: production of energy, municipalities, industries, and irrigation. For the industrial sector, separate analyses have been made for steam electric power, and for manufacturing industries including pulp and paper, chemicals, petroleum refining and primary metals. In 1970, the four latter industries accounted for more than 80 per cent of the manufacturing industrial water demand of the State. For this reason all other manufacturing industries have been included in a single category.

For both industries and municipalities, consideration has been given to the requirements stipulated in the Federal Water Quality Act--Amendments of 1972 (PL 92-500) to determine the treatment needed, waste loads, power requirement, and costs that would result in meeting the requirements of the Act.

Four case studies have been performed in order to evaluate the effects of the Federal Water Quality Act on Scenarios I and II.

Case A evaluates Scenario I, the baseline scenario with the 1970 environmental criteria of secondary treatment for both municipalities and industries applied.

Case B evaluates Scenario II, the market forces scenario with the same 1970 environmental criteria applied.

Case C evaluates Scenario II, the market forces scenario with the requirements stipulated in PL 92-500 applied. The environmental criteria considered in evaluating PL 92-500 are outlined in Table III.

Case D also evaluates Scenario II, the market forces scenario with the requirements stipulated in PL 92-500 applied. In addition, the effect of water conservation was evaluated by assuming that the municipal use of water would remain at the 1970 level of approximately 147 gallons/capita/day during the period 1970-2000, and that industry would be able to realize a water conservation of approximately 50 per cent during the period 1985-2000.

The results of the four case studies are summarized in Tables V through VIII and shown in Figures 1 through 7.

Consumptive Use of Water

Consumptive use refers to that quantity of water that is not immediately available as a return flow. Consumptive use includes evaporation, incorporation in products, and other losses. Consumptive use of fresh water for Scenarios I and II is given in Table IV and shown in Figure 1. Consumptive use for production increases by about 4 per cent from 1970 to 1985 for Scenario I and by about 20 per cent for the same years for Scenario II. Decreases in consumptive use for production occur at the year 2000 because of the decrease in oil production predicted.

Consumptive use in the steam electric power industry increases between the years 1970 and 1985 by about 48 per cent for Scenario I, and by about 36 per cent for Scenario II. The increase in the year 2000 over 1970 is about 109 per cent for Scenario I and 116 per cent for Scenario II.

Although coal, lignite and nuclear fuel have been introduced in Scenario II as partial substitutes for gas and oil in the generation of electric power, only nuclear fuel has a significantly higher consumptive use of water than gas and oil. However, the projected power generation of Scenario II is less than Scenario I with the result that the estimated consumptive use for the two scenarios is about the same.

The overall consumptive use in the state for all purposes excluding irrigation shows a 50 per cent increase between 1970 and 1985 for Scenario I and 40 per cent increase for these years for Scenario II. In the year 2000 for Scenario I the increase over 1970 is 92 per cent, and for Scenario II, 80 per cent.

Waste Loads from Point Sources

Steam Electric Power Industry: The principal waste loads from the steam electric power industry are the discharge of heat in condenser cooling water return and materials contained in blowdown water.

The principal source of heat discharge is from once-through cooling systems. The heat discharge by the steam electric power industry increases between the years 1970 and 1985 by about 34 per cent for Case A, and by about 25 per cent for Case B. The increase in the year 2000 over 1970 is about 81 per cent for Case A and 76 per cent for Case B. In Cases C and D, assuming that all new installations either cooling ponds or cooling towers will be used, no additional heat will be discharged to receiving streams and the waste heat load to the streams of the state will remain at approximately the 1970 level of 125×10^{12} BTU's per year.

Industries and Municipalities: The waste loads from industries and municipalities are essentially independent of the fuel mix and are a reflection of the predetermined requirements of the U. S. Environmental Protection Agency as set forth in PL 92-500.

Estimates have been made for the waste loads based on population predictions for municipalities and predictions of industry expansion as related to increased energy usage in the following industries; pulp and paper, petrochemical, petroleum refining and primary metals. All other industries are included in a separate category. The waste loads of biochemical oxygen demand and suspended solids for Case C as summarized in Table VII reflect the imposition of the more stringent standards of PL 92-500.

The biochemical oxygen demand discharges decrease by about 39 per cent in 1977 and by about 59 per cent in 1985 assuming the imposition of the 1983 environmental criteria. The decrease from 1970 to 1985 is about 80 per cent assuming the imposition of the 1985 environmental goal of Zero Discharge of Pollutants by industry and Best Treatment Feasible by municipalities. The assumption for zero discharge of pollutants by industry is that any water discharged would be of a quality equal to the intake water. Under these circumstances it is assumed that there would be complete recycle of the treated wastewater by industry. The biochemical oxygen demand discharges in the year 2000 will increase by about 36 per cent over 1985.

Similarly, the suspended solids discharges will be reduced by about 63 per cent in 1977 and by about 82 per cent in 1985 assuming the imposition of the 1983 environmental criteria. The reduction from 1970 to 1985 is about 95 per cent assuming the imposition of the 1985 environmental goal of Zero Discharge of Pollutants by industry and Best Treatment Feasible by municipalities. The suspended solids discharges in the year 2000 will increase by about 35 per cent over 1985.

The increased waste loads for the year 2000 over 1985 reflect the growth of municipalities and are not due to relaxation of environmental criteria.

Costs for Treatment

Because of variations in operating conditions amongst different industries and even for industries within the same category, cost estimates are only rough approximations. Nevertheless, the estimates indicate that capital costs by industries and municipalities to meet the 1977 environmental criteria for Case C will amount to about 227 million dollars. In order to meet the 1983 criteria additional capital costs of about 535 million dollars will be required. However, to meet the zero discharge of pollutants goal by 1985, capital expenditures as an incremental cost over 1977 will approach 1.2 billion dollars. During the period 1985 to 2000 an additional capital cost of approximately 709 million dollars will be required.

Energy Requirements for Treatment

Energy requirements by industries and municipalities to meet the 1977 environmental criteria for Case C will increase by approximately 33 per cent. The increase in the year 1985 over 1970 to meet the 1983 criteria is about 83 per cent. However, to meet the zero discharge of pollutants goal by 1985 energy required as an increment over 1977 will approach 312×10^{12} BTUs. During the period 1985 to 2000 additional energy of 94×10^{12} BTUs will be required by industries and municipalities in the treatment of wastewaters.

Table I : DATA OBTAINED FROM GOVERNOR'S OFFICE OF INFORMATION SERVICES FOR SCENARIOS I AND II

		1970	1985		2000	
		I and II	I	II	I	II
Population - Heads of Household		3.36×10^6	4.41×10^6	4.46×10^6	5.07×10^6	5.14×10^6
Total Texas Crude Oil Production	BBL	1.25×10^9	1.03×10^9	1.16×10^9	0.56×10^9	0.83×10^9
Total Texas Crude Oil Production	BTU	7.02×10^{15}	5.78×10^{15}	6.52×10^9	3.15×10^{15}	4.46×10^{15}
Total Texas Natural Gas Production	MCF	8.36×10^9	6.67×10^9	8.13×10^9	4.91×10^9	5.50×10^9
Total Texas Natural Gas Production	BTU	8.63×10^{15}	6.88×10^{15}	8.39×10^{15}	5.07×10^{15}	5.68×10^5
Oil Imports	BTU	1.70×10^{15}	6.18×10^{15}	8.24×10^{15}	11.58×10^{15}	15.47×10^{15}
Gas Imports	BTU	$.38 \times 10^{15}$	6.60×10^{15}	4.03×10^{15}	12.53×10^{15}	10.63×10^{15}
Coal Imports	BTU	-	-	0.52×10^{15}	-	0.67×10^{15}
Coal (Lignite) Production in Texas	BTU	-	-	0.38×10^{15}	-	0.61×10^{15}
Total Coal and Lignite Use in Texas	BTU	-	-	0.94×10^{15}	-	1.28×10^{15}
Crude Oil Exports	BBL	$.47 \times 10^9$	$.77 \times 10^9$	0.77×10^9	1.22×10^9	1.08×10^9
Crude Oil Exports	BTU	2.64×10^{15}	4.33×10^{15}	4.35×10^{15}	6.86×10^{15}	6.07×10^{15}
Natural Gas Exports	MCF	4.06×10^9	6.70×10^9	6.77×10^9	9.15×10^9	9.35×10^9
Natural Gas Exports	BTU	4.19×10^{15}	6.91×10^{15}	6.92×10^{15}	9.44×10^{15}	9.65×10^{15}
Total Texas Energy Consumption	BTU	5.76×10^{15}	9.09×10^{15}	7.63×10^{15}	12.05×10^{15}	10.24×10^{15}

Table II : SCENARIOS I AND II: ENERGY USES IN TEXAS 1970-2000
(All Values in BTU x 10^{12})

	1970	1985		2000	
	I & II	I	II	I	II
STEAM ELECTRIC POWER INDUSTRY (TOTAL)	877	1440	1255.8	1994	1697.2
Natural Gas	874	1435	490.6	1987	663
Refined Products	3	5	65.4	7	88
Coal	--	--	533.6	--	225
Nuclear	--	--	166.2	--	721
PULP & PAPER (TOTAL)	28.0	45	36	62	47.6
Natural Gas	18.0	29.1	15.9	40	20.8
Natural Gas Liquids	0.3	0.4	.5	0.6	.6
Refined Products	5.4	8.7	12.0	12	15.9
Electrical Generation	4.3	6.8	7.8	9.4	10.3
PETROCHEMICAL INDUSTRY (TOTAL)	1765	29.5	2131	4063	2963
Natural Gas	1015	1675	570	2334	793
Natural Gas Liquids	352	582	617	811	858
Refined Products	342	565	627	788	871
Electrical Generation	56	93	71	130	99
Coal/Lignite	--	--	246	--	342
PETROLEUM REFINING INDUSTRY (TOTAL)	1554	2526	1477	3487	2033
Natural Gas	603	980		1352	317
Natural Gas Liquids	564	918		1266	999
Refined Products	370	602		830	136
Electrical Generation	17	28		39	26
PRIMARY METALS INDUSTRY (TOTAL)	192	307	247	420	331
Natural Gas	164	262	89	359	119
Refined Products	10	16	54	22	73
Electrical Generation	18	29	24	40	32
Coal/Lignite	--	--	80	--	107
OTHER INDUSTRIES (TOTAL)	263	411	307	554	406
Natural Gas	197	309	171	417	226
Natural Gas Liquids	6	8	8	11	11
Refined Products	42	67	95	90	125
Electrical Generation	18	27	33	36	44

Table III: Pl 92-500 Environmental Criteria

Industries:

1977 - Best Practicable Control Technology Currently Available

1985 (1983 Criteria) - Best Available Technology Economically Achievable

(1985 Criteria) - Zero Discharge of Pollutants

2000 - Zero Discharge of Pollutants

Municipalities:

1977 - Secondary Treatment BOD = 20 mg/l
SS = 20 mg/l

1985 (1983 Criteria) - Best Practicable Treatment
BOD = 12 mg/l
SS = 9 mg/l

(1985 Criteria) - Best Treatment Feasible
BOD = 8 mg/l
SS = 4 mg/l

2000 - Best Treatment Feasible
BOD = 8 mg/l
SS = 4 mg/l

Table IV: COMPARISON OF FRESH WATER CONSUMPTION FOR SCENARIOS I AND II.

	BILLIONS OF GALLONS				
	1970	1985		2000	
		I	II	I	II
PRODUCTION					
Oil	66	77	87	54	80
Coal (Lignite)		--	0.2	--	0.3
Nuclear (Uranium)		--	0.2	--	0.7
Natural Gas Processing	35	28	34	20	23
STEAM ELECTRIC POWER INDUSTRY	44	65	60	92	95
INDUSTRY	161	261	188	359	255
MUNICIPALITIES	240	390	395	522	529
TOTAL	546	821	764	1047	983
% Increase over 1970		50	40	92	80

Table V

CASE A: SCENARIO I (BASELINE)

WATER QUANTITY & QUALITY

(1970 ENVIRONMENTAL CRITERIA)

	1970	1977	1985	2000
Water Consumption[1*] (Gallons x 10^9)	546	674	821	1047
Heat Discharge[2] to Receiving Streams from Steam Electric Power Industry (BTU x 10^{12})	125	145	168	226
Biochemical[3] Oxygen Demand Discharges (lb x 10^6)	196	250	311	420
Suspended Solids[4] Discharges (lb x 10^6)	384	490	610	827
Capital Costs[5] to Achieve Standards (\$ x 10^6)	--	201	430	820
Yearly Operating[6] Costs (\$ x 10^6)	--	11	25	47
Energy Requirements[7] (BTU x 10^{12})	6	8	10	13
Manpower Required For Surveillance	150	171	195	255

* See explanatory notes for Tables V - VIII.

Table VI

CASE B: SCENARIO II (MARKET FORCES)

WATER QUANTITY & QUALITY

(1970 ENVIRONMENTAL CRITERIA)

	1970	1977	1985	2000
Water Consumption[1*] (Gallons x 10^9)	546	647	764	983
Heat Discharge to[2] Receiving Streams from Steam Electric Power Industry (BTU x 10^{12})	125	139	156	220
Biochemical Oxygen[3] Demand Discharges (lbs x 10^6)	196	229	268	358
Suspended Solids[4] Discharges (lbs x 10^6)	384	437	499	672
Capital Costs[5] to Achieve Standards ($ x 10^6)	--	174	372	737
Yearly Operating[6] Costs ($ x 10^6)	--	10	21	42
Energy Requirements[7] (BTU x 10^{12})	6	7	9	12
Manpower Required For Surveillance	150	171	195	255

* See explanatory notes for Tables V - VIII.

Table VII

CASE C: SCENARIO II (MARKET FORCES)

WATER QUANTITY & QUALITY
(PL 92-500 ENVIRONMENTAL CRITERIA)

	1970	1977	1985		2000
			1983 Criteria	1985 Criteria	
Water Consumption[1*] (Gallons x 10^9)	546	647	764	764	983
Heat Discharged to[2] Receiving Streams from Steam Electric Power Ind. (BTU x 10^{12})	125	125	125	125	125
Biochemical Oxygen[3] Demand Discharges (lbs x 10^6)	196	120	80	39	53
Suspended Solids[4] Discharges (lbs x 10^6)	384	142	68	20	27
Capital Cost to[5] Achieve Standards (\$ x 10^6)	--	227	762	1416	2125
Yearly Operating[6] Cost (\$ x 10^6)	--	24	81	258	346
Energy Requirements[7] (BTU x 10^{12})	6	8	11	320	414
Manpower Required for Surveillance	150	171	195	195	255

* See explanatory notes for Tables V - VIII.

Table VIII

CASE D: SCENARIO II (MARKET FORCES + WATER CONSERVATION)

WATER QUANTITY & QUALITY

(PL 92-500 ENVIRONMENTAL CRITERIA)

	1970	1977	1985		2000
			1983 Criteria	1985 Criteria	
Water Consumption[1*] (Gallons x 10^9)	546	611	686	592	693
Heat Discharged[2] to Receiving Streams from Steam Electric Power Ind. (BTU x 10^{12})	125	125	125	125	125
Biochemical Oxygen[3] Demand Discharges (lbs x 10^6)	196	111	68	32	36
Suspended Solids[4] Discharges (lbs x 10^6)	384	133	60	16	18
Capital Cost to[5] Achieve Standards ($ x 10^6)	--	158	597	760	992
Yearly Operating[6] Costs ($ x 10^6)	--	20	69	143	181
Energy Requirements[7] (BTU x 10^{12})	6	7	10	164	210
Manpower Required for Surveillance	150	171	195	195	255

* See explanatory notes for Tables V - VIII.

EXPLANATORY NOTES FOR TABLES V - VIII

(1) Water Consumption includes requirements for oil, lignite, and uranium production, industries and municipalities. Irrigation is excluded.

(2) Heat Discharges include only those steam electric power plants using once-through cooling.

(3) Biochemical Oxygen Demand Discharges include both municipalities and industries.

(4) Suspended Solids Discharges include both municipalities and industries.

(5) Capital Costs as reported are estimates for both municipalities and industries and are increases over 1970.

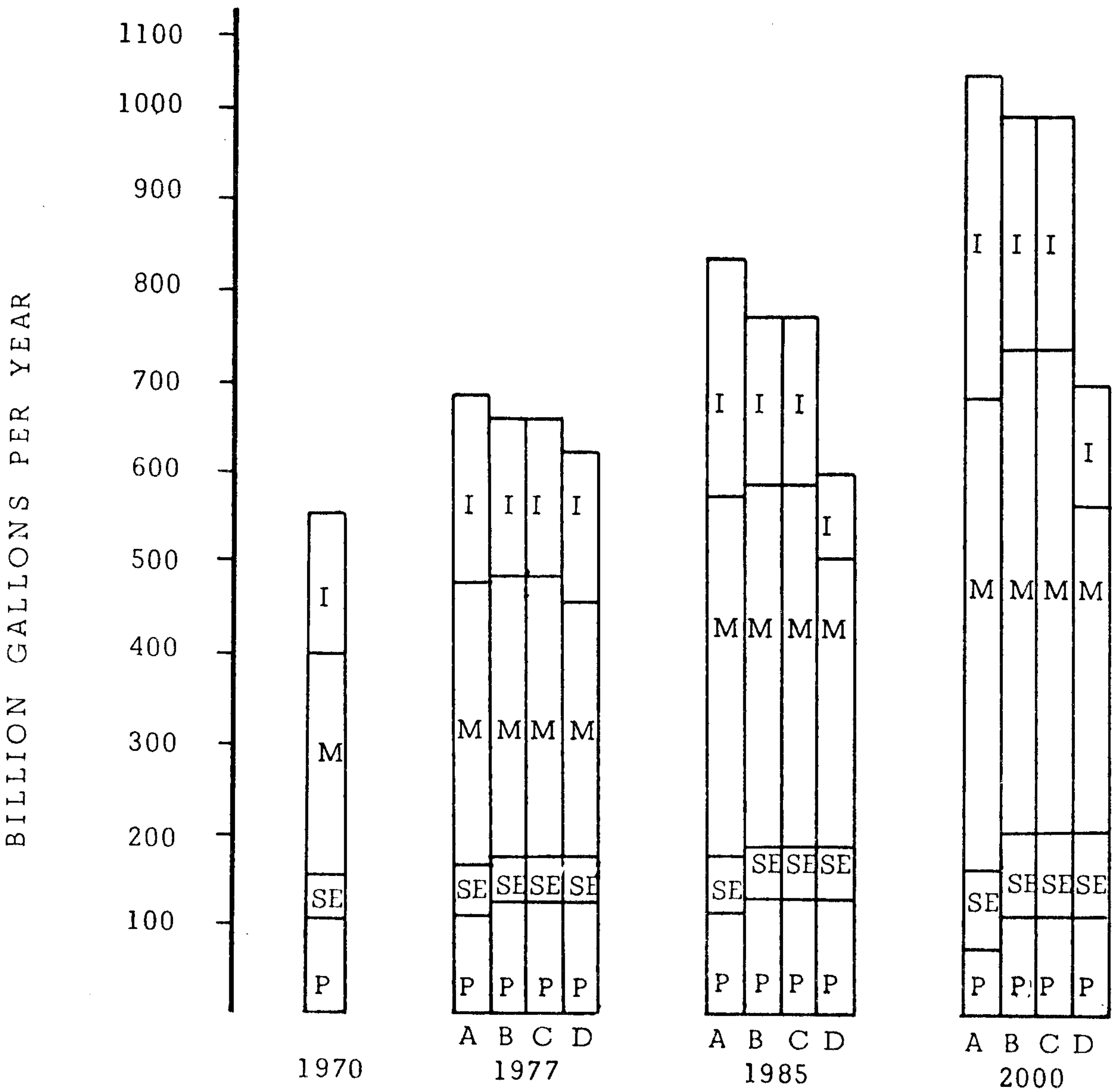
(6) Operating and Maintenance Costs as reported are yearly estimates for both municipalities and industries and are increases over 1970.

(7) Energy Requirements as reported are yearly estimates for both municipalities and industries and are not increases over 1970.

Estimated Energy Requirements in KWH/yr were converted to BTU/yr using a value of 10,000 BTU/KWH.

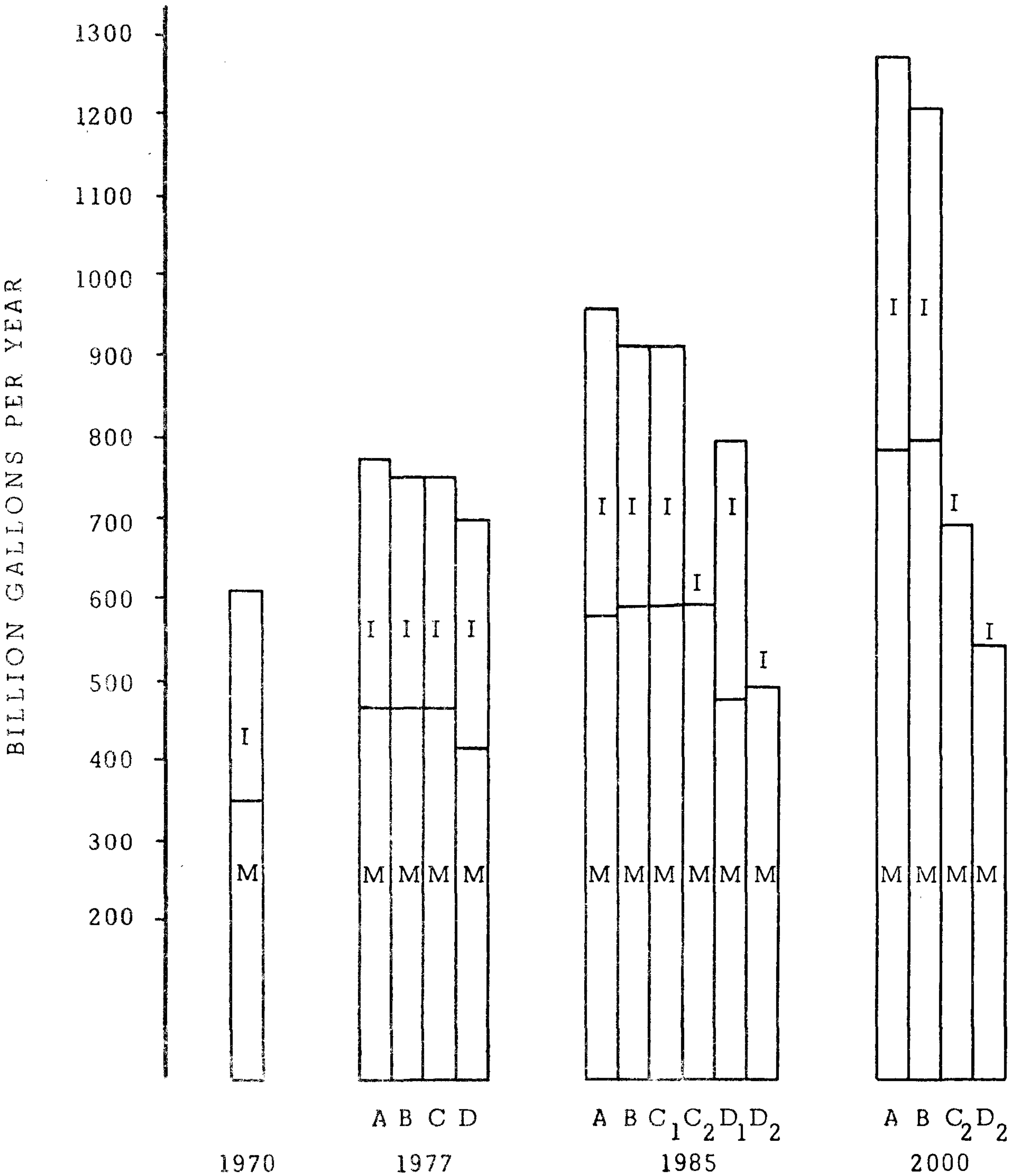
NOTE: CAPITAL AND OPERATING COSTS ARE IN 1967 DOLLARS.

FIGURE I: FRESH WATER CONSUMPTION



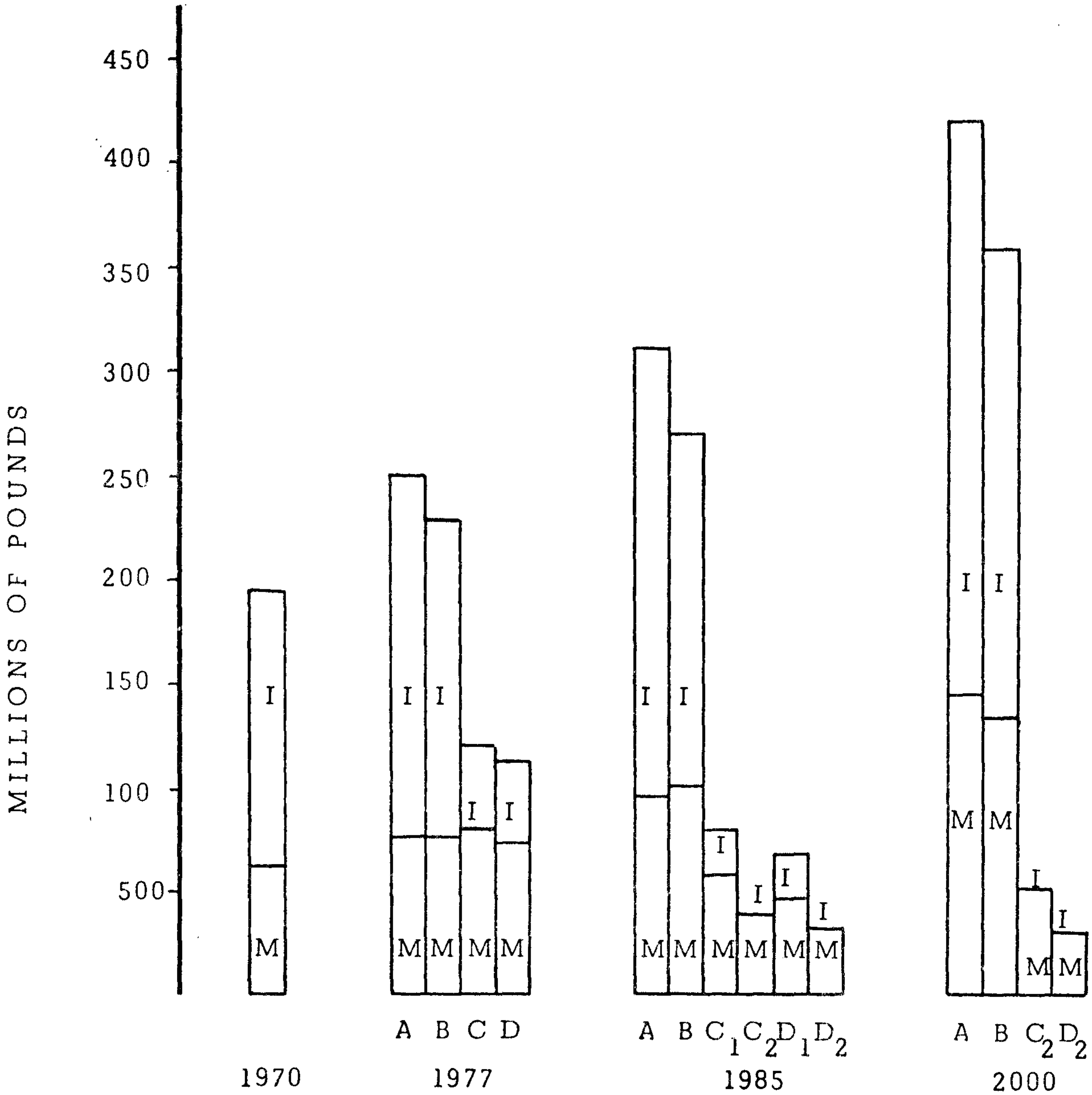
* See legend for explanation of symbols

Figure II WASTE FLOWS FROM INDUSTRIES AND MUNICIPALITIES



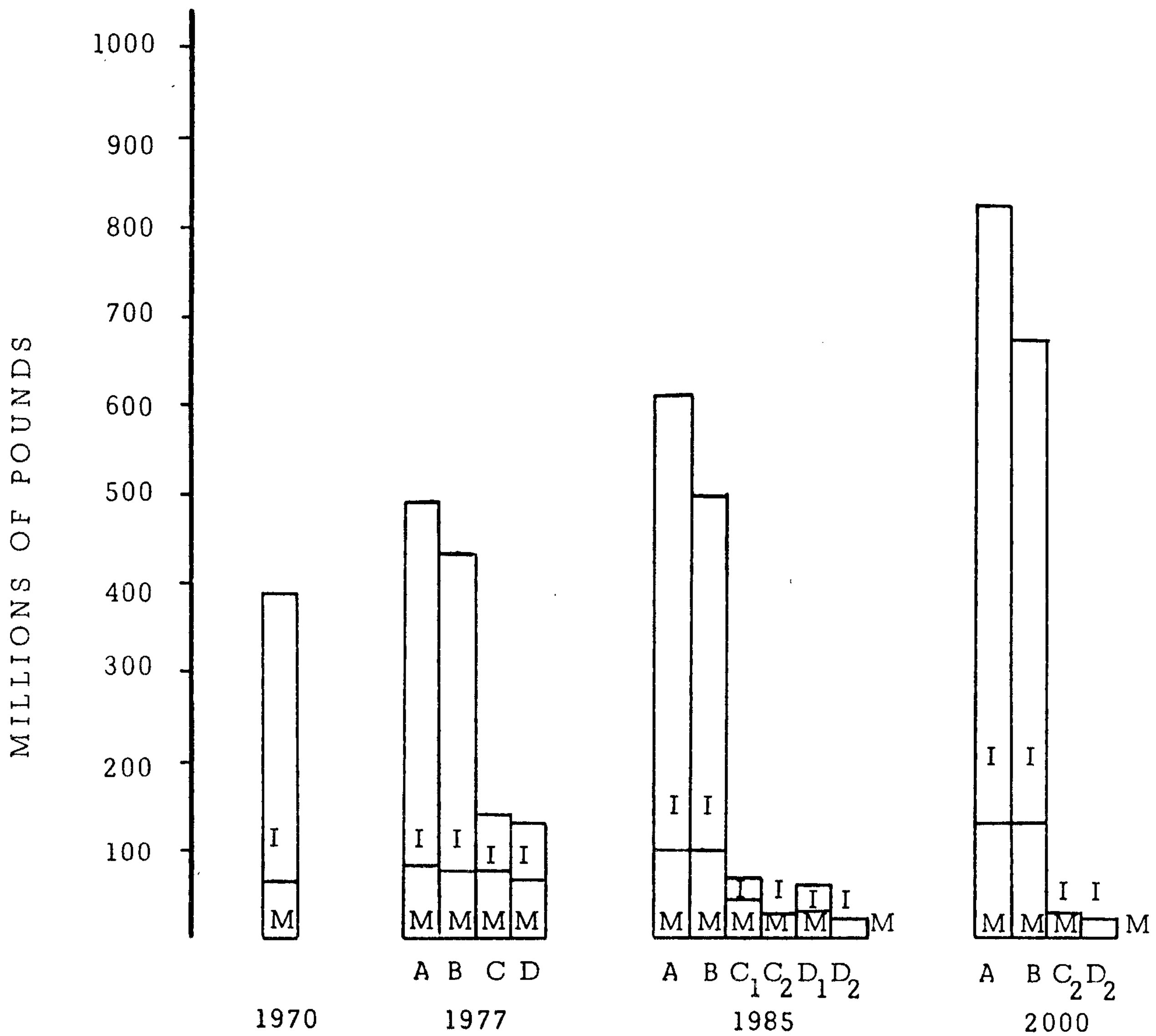
* See legend for explanation of symbols

Figure III BIOCHEMICAL OXYGEN DEMAND FROM INDUSTRIES AND MUNICIPALITIES



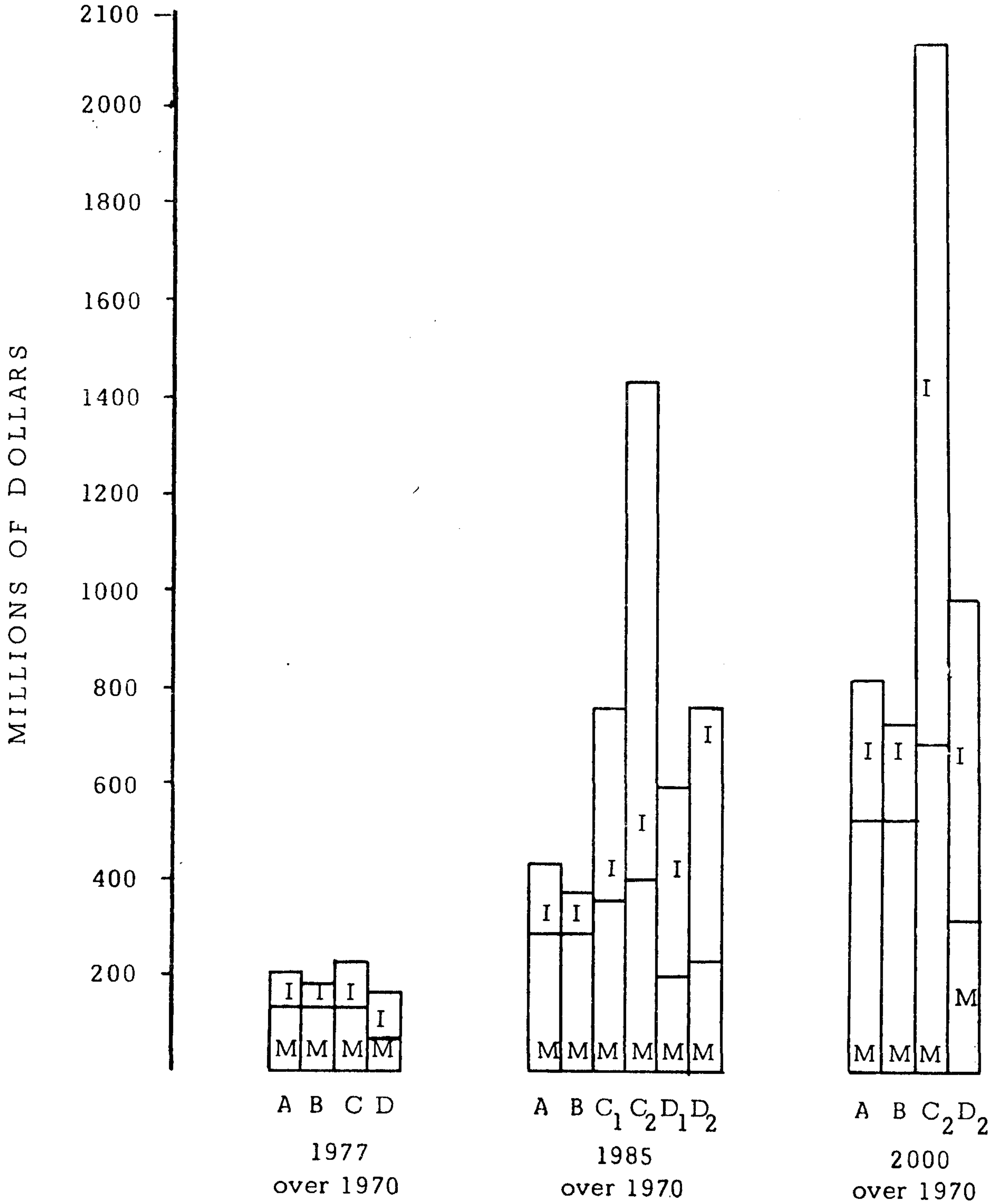
* See legend for explanation of symbols

Figure IV SUSPENDED SOLIDS FROM INDUSTRIES AND MUNICIPALITIES



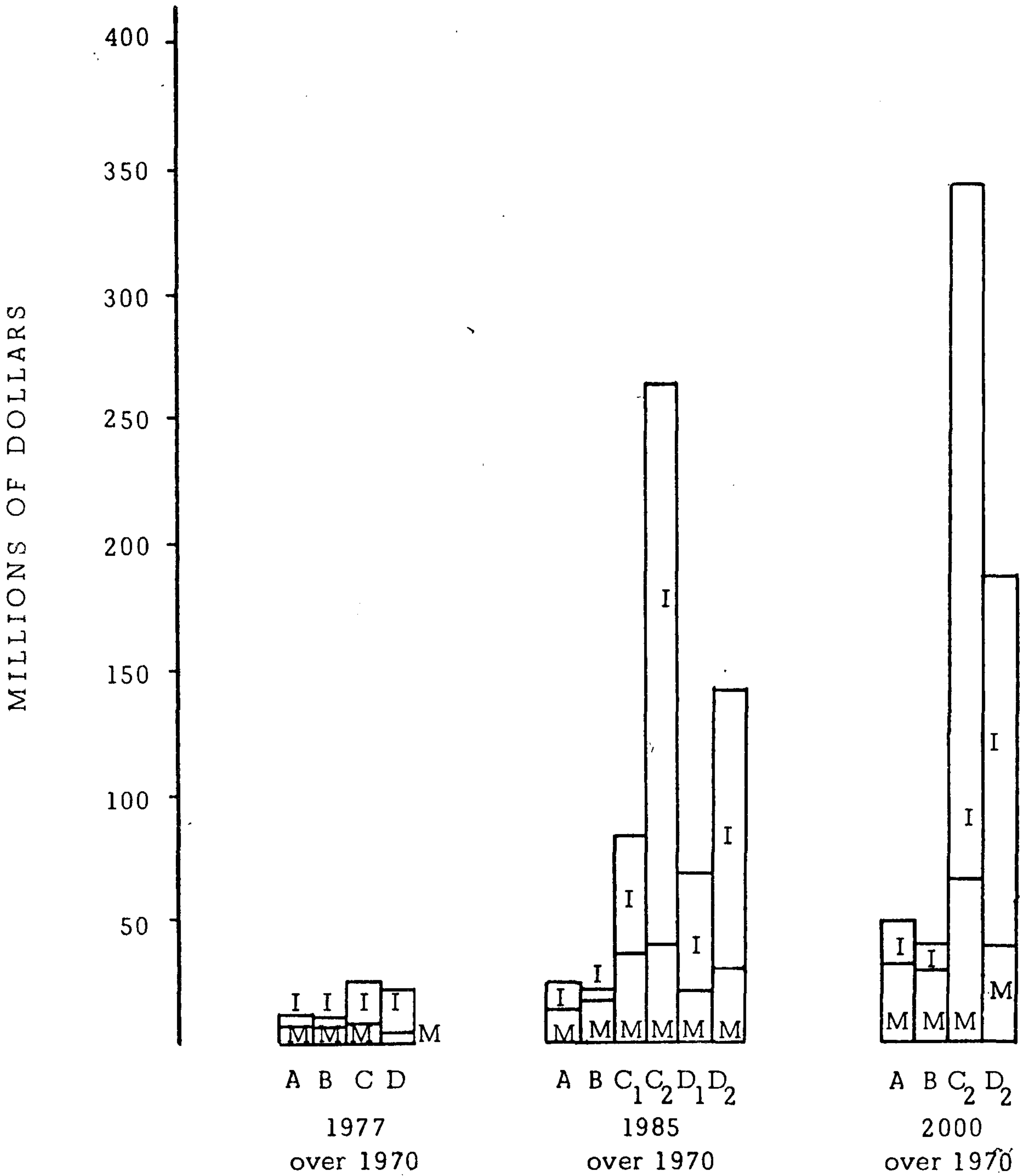
* See legend for explanation of symbols

Figure V CAPITAL COST FOR ENVIRONMENTAL CONTROL FACILITIES FOR INDUSTRIES AND MUNICIPALITIES



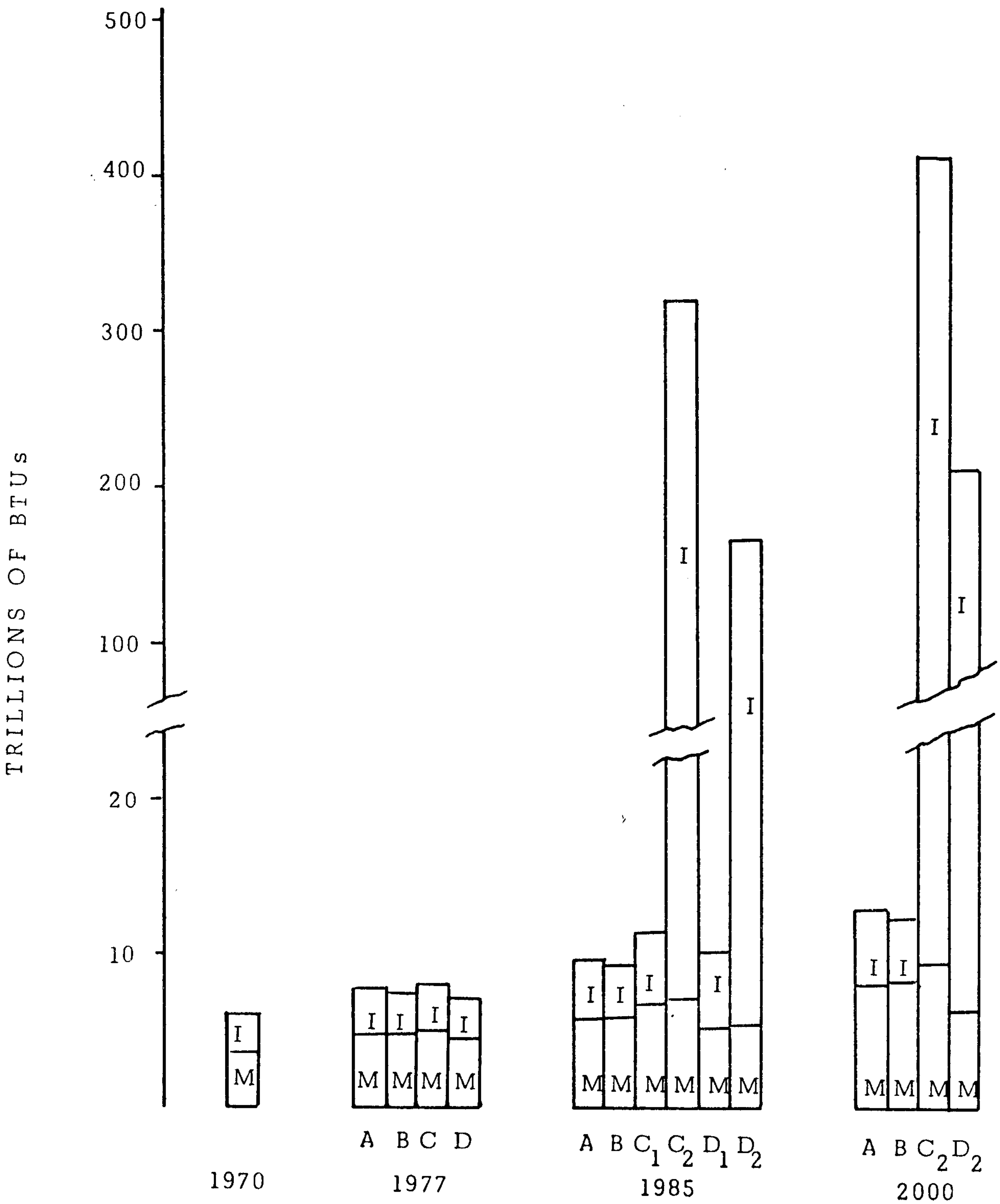
* See legend for explanation of symbols

Figure VI OPERATION AND MAINTENANCE COST OF ENVIRONMENTAL CONTROL FACILITIES FOR INDUSTRIES AND MUNICIPALITIES



* See legend for explanation of symbols

Figure VII ENERGY REQUIREMENTS FOR OPERATION OF ENVIRONMENTAL CONTROL FACILITIES FOR INDUSTRIES AND MUNICIPALITIES



* See legend for explanation of symbols

LEGEND FOR FIGURES 1 - 7

P - PRODUCTION
SE - STEAM ELECTRIC POWER INDUSTRY
I - INDUSTRY
M - MUNICIPAL

Cases:

A Scenario I - Baseline Case,

1970 Environmental Criteria, Secondary Treatment for both Municipalities and Industries for Period 1970-2000.

B Scenario II - Market Forces Case,

1970 Environmental Criteria, Secondary Treatment for both Municipalities and Industries for Period 1970-2000.

C Scenario II - Market Forces Case,

PL 92-500 Environmental Criteria

C : 1977 Industry: Best Practicable Control Technology Currently Available

Municipal: Secondary Treatment BOD = 20 mg/l
SS = 20 mg/l

C_1: 1985 Industry: Best Available Technology Economically Achievable

Municipal: Best Practicable Treatment BOD = 12 mg/l
SS = 9 mg/l

C_2: 1985 Industry: Zero Discharge of Pollutants

Municipal: Best Treatment Feasible BOD = 8 mg/l
SS = 4 mg/l

C_2: 2000 Industry: Zero Discharge of Pollutants

Municipal: Best Treatment Feasible BOD = 8 mg/l
SS = 4 mg/l

D Scenario II - Market Forces Case + Water Conservation

PL 92-500 Environmental Criteria, This case assumes that municipalities will use water at the 1970 per capita rate for the period 1970-2000 while industry will achieve a conservation of 50 per cent for the period 1985-2000.

D : 1977 Industry: Best Practicable Control Technology Currently Available

Municipal: Secondary Treatment BOD = 20 mg/l
SS = 20 mg/l

D_1: 1985 Industry: Best Available Technology Economically Achievable

Municipal: Best Practicable Treatment BOD = 12 mg/l
SS = 9 mg/l

D_2: 1985 Industry: Zero Discharge of Pollutants

Municipal: Best Treatment Feasible BOD = 8 mg/l
SS = 4 mg/l

D_2: 2000 Industry: Zero Discharge of Pollutants

Municipal: Best Treatment Feasible BOD = 8 mg/l
SS = 4 mg/l

ENVIRONMENTAL CRITERIA

A Scenario I (Baseline, 1970 Environmental Criteria):

The environmental criteria considered assumed that only secondary treatment of both municipal and industrial wastewaters would be required during the period 1970 - 2000.

B Scenario II (Market Forces - 1970 Environmental Criteria):

The environmental criteria considered assumed that only secondary treatment of both municipal and industrial wastewaters would be required during the period 1970 - 2000.

C Scenario II (Market Forces, PL 92-500 Environmental Criteria):

The environmental criteria considered assumed the following for industries and municipalities:

Industries:

1977 - Best Practicable Control Technology Currently Available

1985 (1983 Criteria) - Best Available Technology Economically Achievable

(1985 Criteria) - Zero Discharge of Pollutants

2000 - Zero Discharge of Pollutants

Municipalities:

1977 - Secondary Treatment BOD = 20 mg/l
SS = 20 mg/l

1985 (1983 Criteria) - Best Practicable Treatment
BOD = 12 mg/l
SS = 9 mg/l

(1985 Criteria) - Best Treatment Feasible
BOD = 8 mg/l
SS = 4 mg/l

2000 – Best Treatment Feasible
BOD = 8 mg/l
SS = 4 mg/l

ENVIRONMENTAL CRITERIA (cont.)

D Scenario II (Market Forces + Water Conservation, PL 92-500 Environmental Criteria):

The same environmental criteria as stated in "C" were used to evaluate this case. Case "D" assumes that municipalities will use water at the 1970 per capita rate for the period 1970 - 2000 while industry will achieve a conservation of 50 per cent for the period 1985 -2000.