Nuclear Operating Company

South Texas Project Electric Generating Station P.O. Box 289 Wadsworth, Texas 77483

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U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2746

South Texas Project
Units 1 and 2
Docket Nos. STN 50-498, STN 50-499
Transmittal of Document to Support Review of the
South Texas Project License Renewal Application (TAC Nos. ME4938 and ME5122)

References:
1. STPNOC Letter dated October 25, 2010, from G. T. Powell to NRC Document Control Desk, "License Renewal Application," (NOC-AE-10002607) (ML103010257)
2. NRC letter dated August 4, 2011, "Requests for Additional Information for the Review of the South Texas Project License Renewal Application" (ML11201A062)
3. NRC letter dated August 31, 2011, "Transmittal of Documents to Support Review of the South Texas Project License Renewal Application"

By Reference 1, STP Nuclear Operating Company (STPNOC) submitted a License Renewal Application (LRA) for South Texas Project (STP) Units 1 and 2. By Reference 2, the NRC staff requested the transmittal of a number of documents needed to complete the review of the STP LRA. By Reference 3, STPNOC transmitted the requested documents with the exception of the document designated AQ-6, "South Texas Project, Units 1 and 2, Environmental Report," Docket Nos. 50-498 and 50-499, July 1, 1974, and Subsequent Amendments". By an electronic mail received from the NRC on September 7, 2011, the NRC agreed that only Sections 2.5, 5.1.2, 5.1.3, 5.1.4, 5.7.2, 6.1.1 and 6.1.2 of the subject report are required to be submitted. This letter transmits the agreed upon sections of the 1974 Environmental Report.

There are no regulatory commitments in this letter.

Should you have any questions regarding this letter, please contact either Arden Aldridge, STP License Renewal Project Lead, at (361) 972-8243 or Ken Taplett, STP License Renewal Project regulatory point-of-contact, at (361) 972-8416.

G. T. Powell
Vice President,
Technical Support & Oversight

KJT

Enclosure: South Texas Project, Units 1 and 2, Environmental Report, Docket Nos. 50-498 and 50-499, July 1, 1974, Sections 2.5, 5.1.2, 5.1.3, 5.1.4, 5.7.2, 6.1.1 and 6.1.2

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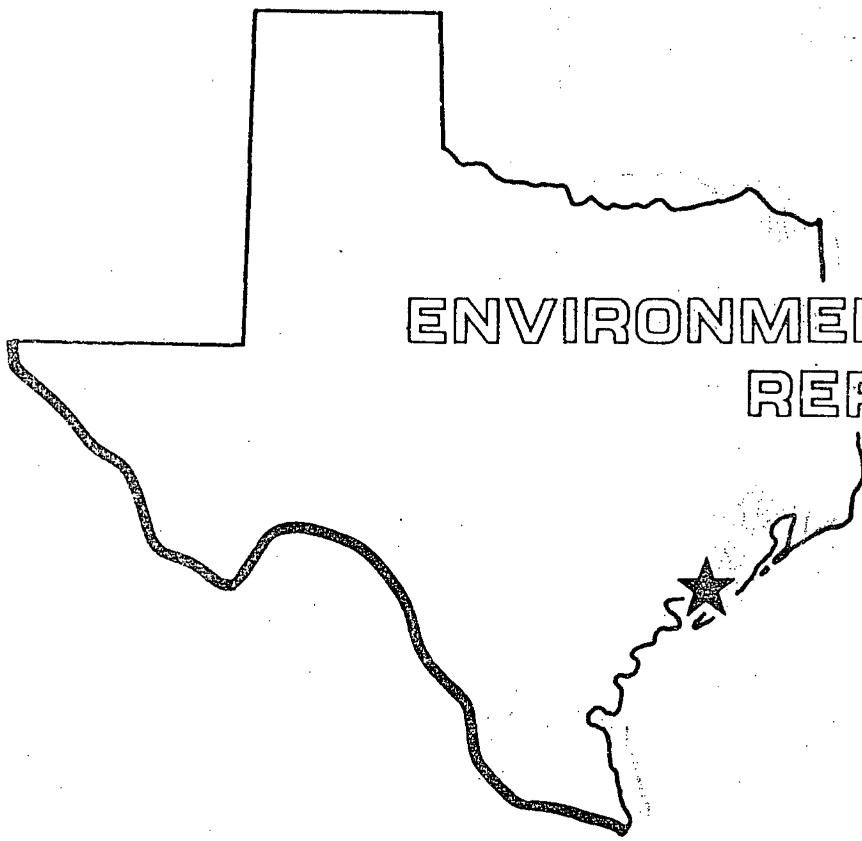
SOUTH TEXAS PROJECT

UNITS 1 & 2



ENVIRONMENTAL REPORT

VOLUME 1

2.5 HYDROLOGY

The proposed generating facility and associated cooling reservoir for South Texas Project (STP) is located near the west bank of the Colorado River in Matagorda County, Texas. The site is 12 miles south-southwest of Bay City, Texas, and 8 miles north-northwest of Matagorda, Texas. The site is located 10 miles north of Matagorda Bay and 15 miles north of the Gulf of Mexico.

Major surface water features of the STP site area are discussed in Section 2.5.1. A general description of the groundwater conditions is presented in Section 2.5.2. Water quality standards as established by the Texas Water Quality Board are set forth in Section 2.5.3.

2.5.1. SURFACE WATER

Ground slopes and general topographic relief in the immediate area of the STP site are minimal. Surface elevations range from approximately elevation 30 Mean Sea Level (MSL) at the north end of the site to elevation 15 MSL at the southwest end of the site, approximately 4.5 miles distant. Several irrigation canals are present throughout the site but are not interconnected with the natural drainage features.

The westerly divide of the Colorado River Basin passes through approximately the center of the site in a northwest to southeast direction. To the west of this divide is Little Robbins Slough.

The Colorado River flows along the easterly side of the STP site and is a navigable channel from its mouth at the Gulf to about 23 river miles upstream. The river intersects the Gulf Intracoastal Waterway (GIWW) approximately 5.6 river miles above the Gulf. To the east and west of the Colorado River between the GIWW and the Gulf are East Matagorda Bay and Matagorda Bay, respectively.

Features of the Colorado River Basin and the coastal area near the STP site are shown in Figures 2.5-1, 2.5-2, and 2.5-3. Figure 2.1-4 shows the major features of the STP site.

2.5.1.1 Colorado River

The main stem of the Colorado River meanders a distance of approximately 890 river miles from its upper reaches in New Mexico to its mouth at the Gulf of Mexico as shown in Figure 2.5-1. Along the main stem are a number of dams, including Mansfield Dam which retains Lake Travis and is located approximately 28 river miles upstream from Austin, Texas. This structure is the most downstream point of major control of flood flow in the Colorado River. All the principal tributaries of the Colorado River are upstream of Lake Travis. Normal and flood flows in these streams are regulated by reservoirs. Downstream from Austin, only a few minor tributaries are to be found. Below Columbus, Texas, definable tributaries are almost nonexistent. Other impoundments on the Colorado River below Mansfield Dam, but of a lesser significance on the control of the river flow, are Tom Miller Dam and Austin Dam, both above the USGS gage at Austin, and the Fabridam, an inflatable rubber dam located at river mile 32.5, approximately 1,000 feet upstream from the USGS gage near Bay City, Texas. Physical data pertinent to the river characteristics are shown in Table 2.5-1.

The Colorado River Basin, flow rates, tidal influence, river chemical characteristics, and river water temperatures are discussed in the following subsections.

2.5.1.1.1 The Colorado River Basin

The Colorado River Basin is oriented generally along a northwest to southeast direction and contains approximately 41,800 square miles, of which approximately 12,880 square miles are noncontributing (see Figure 2.5-1). The 600-mile length of the basin extends from the southeastern portion of New Mexico to Matagorda Bay which is located in southeast Texas at the Gulf of Mexico. The width of the basin increases from 85 miles in the upper portion to about 170 miles in the area of Stacy, Texas, narrowing to about 30 miles near Austin, Texas. From Austin, it gradually continues to narrow to about 4 miles wide near Matagorda, Texas.[1] Average annual rainfall in the basin varies from approximately 15 inches in the upper portion to 40 inches in the lower portion.[2] The average annual gross natural evaporation varies from 73 inches in the upper portion to 53 inches in the lower portion. Average annual runoff ranges from 50 acre-feet per square mile in the upper reaches to about 350 acre-feet per square mile in the lower reaches. Floods occur in the basin on an average of every 4 to 5 years.[3]

Near the STP site area, the average annual rainfall is 42.11 inches. The Probable Maximum Precipitation (PMP), which is defined as the theoretically greatest depth of precipitation for a given duration that is meteorologically possible over the applicable drainage area that would produce flood flows of which there is virtually no risk of being exceeded,[4] at the site is 45.82 inches based on a duration of 48 hours.[5] The
Standard Project Storm (SPS), which is defined as the most 1
severe flood-producing rainfall depth-area-duration relationship and isohetal pattern of any storm that is considered reasonably characteristic of the region in which the drainage basin is located, given consideration to the runoff characteristics and existence of water regulation structures in the basin, for the site area is 25.28 inches for a 48-hour rainfall duration.[6]

Although the Colorado River has undergone changes in course along portions of its path over recent history, it is anticipated that the probability of a change in course is not a significant consideration for that area near the site. This conclusion is based on the following facts:

1. it is concluded that floods are the most probable cause of channel realignment in the area, and the result of upstream control has been to reduce these floods; and,

2. the Corps of Engineers maintains the channel of the Colorado River opposite and north of the site as a navigable channel through frequent dredging.

2.5.1.1.2 Flow Rates

The Colorado River historically has demonstrated a wide range of flow rates. At the Bay City gage, located approximately 16 river miles upstream from the site, the average flow is 2,353 cfs based on records from 1948 through 1970.[7] The maximum discharge recorded at the Bay City gage is 84,100 cfs which occurred on June 26, 1960. The 7-day, 10-year low flow for this gage is 1.0 cfs. The mean monthly flows for the Bay City gage are shown in Figure 2.5-4. A frequency curve for mean daily discharge is presented in Figure 2.5-5. This mean daily frequency curve reflects upstream reservoir control. The discharge-frequency curve shown in Figure 2.5-6 was developed by the Corps of Engineers and reflects the existing conditions of all upstream diversions and reservoir control. Pertinent stream flow gage data including maximum, minimum, and mean values for the five active gages and two abandoned gages below Mansfield Dam are shown in Table 2.5-2.

Continuous long term discharge data for the Colorado River
below the Bay City gage (river mile 32.5) are not available.
At the point of diversion (river mile 14.6). Discharges in
the river are under tidal influence, which would tend to
lessen the accuracy of any discharge measurements made at that
point. The uncontrolled drainage area at the proposed diver- 1
sion point is estimated to be 3,600 square miles compared to
3,520 square miles at the Bay City gage, an increase of about
2 percent. In view of the foregoing it is expected that the
average annual discharge for the Colorado River at the pro-
posed diversion point, for all practical purposes, is the same
as that for the Bay City gage, or 1,658,600 acre-feet per year.

2.5.1.1.3 Tidal Influence

The lower portion of the Colorado River is under the tidal influence of the Gulf of Mexico for a maximum distance of approximately 32 miles upstream from the Gulf. The extent of tidal influence at any time is dependent on both the tidal conditions at the mouth of the Colorado River and the freshwater flow rate of the river.

The range of tides in the Gulf of Mexico is small. Along the Texas coast, the mean diurnal tidal range varies from 0.3 to 2.8 feet. At Port O'Connor on Matagorda Bay, approximately 30 miles southwest of the mouth of the Colorado River, the mean diurnal tidal range is 0.5 feet.[8] However, the type of tide differs considerably depending on the location as shown in Figure 2.5-7. At Key West, near the entrance to the Gulf of Mexico, the tide is semi-diurnal. At Pensacola, the tide is usually diurnal. At Galveston, the tide is mixed; it is semi-diurnal around the times the moon is on the equator but becomes diurnal around the times of maximum north or south declination of the moon. Tidal elevations are influenced by wind conditions. In general, the heights of both high and low waters are increased by onshore winds and decreased by offshore winds.

The tide at the mouth of the Colorado River was assumed to be similar to that observed at Port O'Connor. The tide at Port O'Connor is mixed as can be seen in Figure 2.5-8. The hydrodynamic response along the length of the Colorado River under varying tidal conditions and river inflows was calculated using a numerical two-dimensional (area-wise) tidal model designated HYDTID as presented in Appendix 2.5-A. The tidal data presented in Appendix 2.5-A was derived utilizing the data shown in Figure 2.5-8 and forms the basis of analyses shown in Section 5.1. Included in the Appendix is a "Typical Model of Exciting Tides," (see Figure A2.5-1), the calculated tidal flows (see Figures A2.5-2 through A2.5-6), the maximum flood and ebb flows (see Figures A2.5-7 through A2.5-11), and the 1974 predicted sequence of semi-diurnal and diurnal tides (see Figure A2.5-12).

2.5.1.1.4 River Chemical Characteristics

The U. S. Geological Survey (USGS), in cooperation with the Texas Water Development Board (TWDB), began a water resources investigation of estuaries in Texas in September, 1967.[10] Properties or constituents measured in the field are dissolved oxygen, specific conductance, temperature, pH, and turbidity. Laboratory analysis included the principal inorganic ions, biochemical oxygen demand, ammonia nitrate, nitrite, ortho and total phosphate, and several other selected ions such as bromide, iodide, strontium, lithium, and iron. The sampling stations are shown on Figure 2.5-9. Data collected by the USGS[10,11] are shown in Tables 2.5-3 through 2.5-9. Inspection of these tables reveals that there is a saltwater wedge existing in the Colorado River. The stratification is identified by an increase of total dissolved solids (TDS) concentration values from water surface to the river bottom for those sampling stations located near the mouth of the Colorado River.

As part of the South Texas Project, a biological and water sampling program was initiated in June, 1973. Methodology is discussed in Section 6.1.1 and sampling station locations are shown in Figure 6.1-1. All biological and water resources (quality) data generated from the sampling program have been tabulated and are presented in Reference 2.5-28. Biological data collected during the ongoing investigation are summarized in Section 2.7. The water quality data collected during the STP study and those collected by USGS in the water resources investigation of estuaries in Texas are discussed briefly in the following subsections.

2.5.1.1.4.1 Specific Conductivity, Salinity, Chlorides, Dissolved Oxygen, and pH

Parker and Blanton[12] reported that salt water traverses the Colorado River bottom for a distance of 24 miles upstream at times, but may be absent from the river during floods. Similar fluctuation was observed in the STP investigation (June through October, 1973), with maximum salt water intrusion being observed at station 3 (see Figure 2.7-5) in July, 1973 (see Table 2.5-10).

At river mile 14, bottom salinities[13] ranged from 4 to 6 percent from March, 1968 through March, 1969. During 1973, salinity values at mile 14 did not exceed 0.4 percent due to unusually high river flow.

Chloride values for June and August, 1973 show a general increase in chloride ion concentration downstream.

Parker, et al.,[13] report an average dissolved oxygen (DO) concentration in the Colorado River of 7.5 to 8.5 ppm. Data collected during the 1973 study show a slight decrease in mean DO, with an observed range of 4.2 to 10.4 ppm (see Table 2.5-11). Percent saturation ranged between 52 and 115 percent. The pH ranged from 7.7 to 8.7 throughout the study area during June through October 1973.

2.5.1.1.4.2 Alkalinity, Bicarbonates, Carbonates, Hydroxide, and Acidity

During the 1973 study, total alkalinity values in the Colorado River ranged from 94 to 233 ppm as calcium carbonate ($CaCO_3$), with an average surface value of 152 ppm and an average bottom value of 150 ppm. Generally higher total alkalinity values occurred in surface waters at upstream stations.

Generally, bicarbonate values were low, and within 40 to 180 ppm, the range for most fish-producing waters in the United States.[14] This range provides for an efficient buffering effect, thereby precluding hydroxide formation.

Total acidity values ranged from 0 to 7 ppm during the 5-month period.

2.5.1.1.4.3 Total Hardness, Calcium, and Magnesium

USGS total hardness data at Wharton, Texas during 1969, provide the means to establish a basis for classifying Colorado River water as hard (150-300 ppm $CaCO_3$).[15] STP hardness values meet these criteria at freshwater stations (see Table 2.5-12). Saltwater intrusion produced a general increase in hardness at downriver stations with bottom waters being of consistently higher hardness than surface waters.

STP data on calcium and magnesium concentrations are greater than those of the USGS (1969)[16] for samples collected at Wharton, Texas, because of saltwater intrusion in the study area. Bottom water calcium and magnesium concentrations were greater than corresponding surface samples, particularly when a saltwater wedge was observed. Calcium values ranged from 40 to 402 ppm (see Table 2.5-13) and magnesium from 1 to 1,346 ppm (see Table 2.5-14).

2.5.1.1.4.4 Sodium and Potassium

Data accumulated during the 1973 study for sodium and potassium levels at freshwater stations on the Colorado River are consistent with those reported by the USGS[16] at Wharton, Texas. Sodium and potassium values increased substantially with salinity as would be expected at downstream stations (see Tables 2.5-15 and 2.5-16).

2.5.1.1.4.5 Nutrients: Phosphate and Nitrogen

Mean total phosphate values at STP freshwater stations 1, 2 and 3 declined from June through August, 0.47 to 0.39 ppm PO_4, respectively, and increased in September to 0.47 ppm (see Table 2.5-17). Total phosphate values increased at down-river stations in both surface and bottom waters. Biologically utilizable orthophosphate concentrations generally decreased at all stations throughout the sampling period.

Nitrate (NO_3) concentrations fluctuated erratically during the sampling period, June through October, 1973. Mean values at freshwater stations ranged from 3.0 (September) to 8.6 ppm (October). Saline water stations generally had higher nitrate levels (see Table 2.5-18).

Nitrite (NO_2) values were generally less than 0.05 ppm and showed no appreciable fluctuation during the study period. Kjeldahl nitrogen (total organic nitrogen plus ammonia) concentrations tended to be higher in surface waters at freshwater stations and showed an increase during the October flood.

2.5.1.1.4.6 Sulfate and Sulfide

Sulfate concentrations (measured during June and August, 1973) displayed a general increasing trend toward down-stream stations, ranging from 29.0 ppm at station 1 (August) to 1947.0 ppm at station 15 (August). Bottom waters contained higher average concentrations of sulfate than surface waters.

Sulfide concentrations were uniformly low throughout the study area.

2.5.1.1.4.7 Total and Soluble Iron

Total iron concentrations varied from less than the detection threshold (0.01 ppm) to 21.0 ppm. Total iron concentrations increased sharply during October following heavy river discharge. Soluble iron concentrations were generally below detection limits (less than 0.02) in all samples.

2.5.1.1.4.8 Total Silica

STP data on total silica values at Colorado River upriver freshwater stations were generally higher than those reported by the USGS[16] at Wharton, Texas and were slightly less than STP values at downriver stations, except for station 15 located in the Gulf of Mexico (see Table 2.5-19). October values were an order of magnitude greater than those of previous months, a result of the heavy silt load produced by flooding which occurred prior to the sampling.

2.5.1.1.4.9 Oily Matter, Surfactants, Phenol, and Heavy Metals

With the exception of copper and manganese, all analytical values for oil matter, surfactants, phenol, and heavy metals listed in Reference 2.5-28 were below analytical detection limits during June-October, 1973. Copper concentrations existed in measurable quantities only during October. Manganese existed in measurable quantities during June and August, 1973.

2.5.1.1.4.10 Total, Suspended, and Dissolved Matter

Dissolved matter concentrations in the freshwater portion of the Colorado River ranged from 350 to 625 ppm in June, 1973; 347 to 3,597 ppm in July; 346 to 357 ppm in August; 348 to 429 ppm in September; and 255 to 273 ppm in October. Saltwater intrusion at downstream stations resulted in high values. The October flood decreased the total dissolved solid concentration at nearly every station and resulted in a simultaneous increase in suspended matter (see Tables 2.5-20 and 2.5-21).

2.5.1.1.4.11 Turbidity and Color

Turbidity values for Colorado River stations were generally less than 50 Jackson Turbidity Units (JTU) during June through September. Stations located in the GIWW exhibited consistently higher values during the same period. Turbidity values at all river stations exceeded 1,000 JTU following the October flood.

Color values ranged from 8 to greater than 70 color units, with lowest values occurring in August.

2.5.1.1.4.12 Biochemical Oxygen Demand (BOD_5)

The highest BOD_5 value recorded in the study area was 3 ppm at station 6 in July. BOD_5 values were low and indicate good water quality in this regard.

2.5.1.1.4.13 Chemical Oxygen Demand (COD)

Freshwater stations averaged less than 10 ppm COD with the exception of station 2 surface waters in June. Saltwater intrusion into the study area produced increased COD values with highest values occurring in bottom samples (see Table 2.5-22).

2.5.1.1.4.14 Total, Inorganic, and Organic Carbon

Total carbon concentrations in the Colorado River remained relatively stable at 29 to 61 ppm during June through

October, 1973, with a slight seasonal decrease noted from June through September. A slight increase occurred following the October flood.

2.5.1.1.5 River Water Temperature

Since there is no continuous historical river water temperature record other than a few miscellaneous data[17] shown in Table 2.5-23 taken at the Colorado River at Bay City gage, variations in river water temperature opposite the plant site are calculated utilizing the theory and method developed by Edinger and Geyer.[18]

The hourly wind speed, air temperature, and relative humidity data collected at the Victoria, Texas weather station over a period from July 1, 1961 through December 31, 1970 and the solar radiation data collected at the San Antonio weather station over the same period were utilized to calculate natural river water temperature variations. The Victoria weather station was chosen because of its proximity to the STP site area. The data used[19] consisted of hourly data from 1961 to 1964, and 3-hourly data from 1965 to 1970.

River water temperatures were calculated utilizing the following assumptions:

1. The response of river water to the changing of ambient weather condition was assumed to be slow.

2. The weather data for Victoria are applicable to the STP site.

3. The effect of Gulf tidal variation resulting in a saltwater wedge moving upstream from Colorado River mouth was considered to have an insignificant effect on surface temperatures since the salt water is heavier and stays near the river bottom.

The validity of these assumptions were verified by the close agreement between the calculated river water temperature and the water temperatures taken near the site during the field trip on the sixteenth and seventeenth of July, 1973, as shown in Figure 2.5-10. The daily Colorado River water temperatures near the site were then calculated for the period from July 1, 1961, through December 31, 1970. The calculated daily river water temperature was further averaged to derive mean monthly river water temperatures which are shown in Figure 2.5-11.

Surface water temperature values measured during the biological and water sampling program (Section 2.5.1.1.4) during August, September, and October, 1973 averaged 86°F, 84°F, and 73°F, respectively (see Table 2.5-11). This corresponds favorably to the seasonal pattern presented by Parker et al.[13]

2.5.1.2 Little Robbins Slough

The total acreage of open-water marsh within a 10-mile radius of the site is approximately 10,577. The acreage of open-water marsh fed by Little Robbins Slough is approximately 1
4,343 and includes the area of Crab Lake (199 acres) and Runnells Reservoir (143 acres).

The principal drainage feature other than the Colorado River in the STP site area is Little Robbins Slough. This drainage course becomes definable just south of road FM 521 and flows directly south to a coastal marsh area north of the GIWW (see Figure 2.1.4). The total drainage area of the Little Robbins Slough, East Fork of the Little Robbins Slough, and the Little Robbins Slough-Marsh Complex north of the GIWW is estimated to 7
be approximately 23,480 acres.

Approximately eight miles northeast of the Little Robbins Slough basin is the basin of Big Boggy Creek. This basin contains 10.3 square miles, compared to 9.33 square miles in the basin of the main fork of Little Robbins Slough. See Figure 2.5-2a. In June of 1970 the USGS installed a stream-flow gaging station and rainfall recording station on Big Boggy Creek, where it passes under FM 521. Table 2.5-2A shows a comparison of the hydrologic characteristics of Big Boggy and Little Robbins Basins. It can be seen that the two basins are hydrologically homogeneous, permitting the application of the hydrologic regime of the gaged basin to the ungaged basin. In order to estimate historic responses in the Little Robbins Slough drainage area, a rainfall-runoff correlation by multiple regression analysis was made for the 41 months of gage data available for the Big Boggy Creek basin. The correlation coefficients thus derived were applied to rainfall records for the USWB stations at Matagorda and Bay City for the period 1949 thru 1970 in order to generate synthetic runoff data for Little Robbins Slough. This cor- 1
relation was made on a monthly basis and an accounting was made for return flows from rice crop irrigation. The difference in rice crop acreage in the two basins also were taken into account. Based on the results of the correlation analysis, Table 2.5-2b presents acreages and estimated average annual discharge for Little Robbins Slough and its East Fork. 7
These flows apply at the point where each of these streams crosses the east-west irrigation canal on the south side of the STP site.

Physical and chemical parameters investigated in Little Robbins Slough are presented in Reference 2.5-28, Tables 2-1 through 2-22, and indicate values obtained from sample station 16. The results of all chemical parameters evaluated show a marked similarity to those obtained for freshwater samples in the Colorado

River. This is to be expected on the basis that the water in Little Robbins Slough is surface drainage. The results of microbiological analyses run on samples from Little Robbins Slough indicate high total plate counts (2,160/ml), total coliforms (870/100 ml) compared to other freshwater samples taken in the STP site area. These high counts are likely related to the fact that cattle graze in the drainage area of Little Robbins Slough.

2.5.1.3 Irrigation Canals

Several irrigation canals exist in the area to be encompassed by the STP. Irrigation canals supplying water to areas outside the site boundary are independent irrigation systems. Most of them derive their makeup from above the Fabridam impoundment above the Bay City gage.

2.5.1.4 Gulf Intracoastal Waterway

The GIWW, as shown on Figure 2.5-3, is a shallow draft channel approximately 12 feet deep and 125 feet wide, extending along the Gulf Coast from Apalachee Bay, Florida to Brownsville, Texas. The waterway crosses the Colorado River at a point 6.5 miles above the river mouth near the town of Matagorda, Texas. Locks are provided in the main channel of the waterway on the east and west sides of the Colorado River to facilitate navigation crossing during floods on the river and to prevent excessive currents and sedimentation in the waterway.

The GIWW at the Colorado River crossing is also under the tidal influence of Gulf of Mexico. Water level at the crossing is regulated by locks as mentioned above. A stage-duration analysis performed by the Galveston Office of the Corps of Engineers utilizing hourly water stage data collected at the north side of the west lock at the GIWW for a period from 1957 to 1972 (see Figure 2.5-12) indicated that for 98 percent of time the water level at the Colorado River crossing was at, or above, elevation 0.0 MSL and 0.015 percent of time the water level at the same location was below elevation (-) 1 MSL. The physical and chemical parameters of the GIWW are similar to those for Matagorda Bay (see Section 2.5.1.5).

2.5.1.5 Matagorda Bay

The Colorado River divides the bay system into two distinct parts: on the west, Matagorda Bay and on the east, East Matagorda Bay. Matagorda Bay, including the small adjoining Bays, covers more than 300 square miles (see Figure 2.5-3). Pass Cavallo, the natural entrance to the Bay, is located in the southwest end of the Bay about 29 miles southwest of the mouth of the Colorado River. The deep-draft Matagorda Ship Channel crosses the Matagorda Peninsula at a point 24 miles southwest of the mouth of the Colorado River and 5 miles northeast of Pass Cavallo (see Figure 2.5-3). Matagorda Bay is separated from the Gulf of Mexico by the long narrow barrier island known as Matagorda Peninsula.

Natural depths of 11 to 12 feet occur over a large portion of Matagorda Bay. The mean diurnal tidal range in Matagorda Bay is about 0.7 feet. Lavaca Bay has average depths of 6 to 7 feet. East Matagorda Bay, the severed portion of the Bay northeast of the Colorado River mouth, has average depths of 4 to 5 feet. No information is available on the tidal range in East Matagorda Bay. The only opening from this bay to the Gulf of Mexico is Brown Cedar Cut located 21 miles northeast of the mouth of the Colorado River. This small cut fosters intermittent flows and has a very small tidal provision and at present is practically closed.

Physical and chemical parameters investigated for STP in the GIWW and Matagorda Bay are presented in Reference 2.5-28, Tables 2-1 through 2-22, and indicate values obtained from sample stations 6, 7, 8, 9, 11, 12, and 13 (see Figure 6.1-1). The results of chemical analyses performed on samples from the GIWW indicate very little influence or mixing of brackish water with fresh water from the river during normal flow periods when locks on the GIWW remain open. The physical and chemical characteristics of the GIWW are included with those of Matagorda Bay because of their similarity. Specific conductance and chloride values as well as calcium, magnesium, sodium, alkalinities, etc., determined on GIWW and Bay waters during periods of normal rainfall and Colorado River flow, are 40 to 60 percent of the concentrations measured at sample station 15, which reflects the Gulf of Mexico water quality (3,000 to 12,000 ppm TDS as opposed to 30,000 to 35,000 ppm).

All of the water-related parameters in the GIWW and Matagorda Bay are, however, subject to large variations depending on weather and rainfall. Significant dilution of these bodies of water occurs as a result of heavy rains. This effect is demonstrated by the results of analyses performed on samples taken after the October, 1973 flood. An approximate tenfold dilution occurred at this time which is typical of estuarine bodies of water along the Texas coast confined behind sand bar peninsulas.

2.5.1.6 Gulf of Mexico

The Gulf of Mexico is a large ocean basin that covers nearly 700,000 square miles and is almost surrounded by the United States and Mexico (see Figure 2.5-13).[20] It is approximately 500 miles long (north to south) and 1,100 miles wide. The coastline of the Gulf is about 3,000 miles long and contains hundreds of lagoons and many salt marshes bordered by sand bars. The water of the Gulf is deepest (12,700)feet) near the coast of Mexico. The greatest depth in other areas is about 10,000 feet. The Gulf contains many shallow areas with gently sloping beds, formed by the silt deposits of rivers emptying into it.

The Gulf immediately off the coastline around the mouth of the Colorado River is rather shallow, ranging from elevation 0 to (-) 30 feet Mean Low Water (MLW) within 2.9 nautical miles of the coast. The distance from the coast to the edge of the Continental Shelf opposite of Colorado River mouth is approximately 57.5 nautical miles. The datum for MLW at the Colorado River mouth is (-) 1.43 MSL.[7]

In the Gulf of Mexico, the principal variation of tide along the Texas coast is due to the declination of the moon. The tide changes from semidiurnal during times when the moon is on the Equator to diurnal during times of maximum north or south declination of the moon. The range of tide in the Gulf of Mexico is small. The mean diurnal tidal range varies from 0.3 to 2.8 feet at different locations along the Texas coast with 0.7 feet of tidal range at Matagorda Bay. The mean tide level at Matagorda Bay is +0.3 MLW based on the daily tide predictions of Gulf of Mexico at the Galveston gage, Galveston, Texas by National Oceanic and Atmospheric Administration.[8] The maximum normal high tide would be at elevation +1.9 MLW and the minimum normal low tide would be at elevation (-) 0.8 MLW. Several sets of field measurements of temperature and specific conductance were taken from Gulf of Mexico at various estuary sampling stations along Texas coast, as shown on Figure 2.5-13, by the USGS in their water resources investigation of estuaries in Texas. The data collected are shown in Table 2.5-24.

The Gulf of Mexico is subject to hurricanes. A study performed by Bordine[21] in 1969 indicates a frequency of occurrence of a hurricane once every 3 years. The abnormal rise of sea surface caused by a single hurricane can flood vast areas of land. In 1961, Hurricane "Carla" produced a maximum surge elevation of 15.2 MSL at Matagorda, Texas[22] and flooded more than 1.5 million acres of low lying coastal area.

Physical and chemical parameters investigated in the Gulf of Mexico are tabulated in Reference 2.5-28, Tables 2-1 through 2-22 under sample station 15 which is located approximately 2 miles offshore. The physical and chemical results obtained from samples at this station are not completely typical of waters in the open Gulf of Mexico; however, under normal flow conditions the station reflects a reasonable representation because freshwater influence from the river is insignificant. The results of samples taken after the October, 1973 flood are of particular interest because specific conductance measurements on surface samples were considerably less than normal (24,000 μmhos as opposed to 36,000 μmhos). Bottom samples at this time, however, were essentially the same as normally measured (33,000 μmhos). These results indicate that at times of high flow in the Colorado River, fresh water is carried well offshore before complete mixing occurs.

2.5.1.7 West Branch of Colorado River

Under existing conditions, water flowing within the West Branch of the Colorado River originates north of the STP site as well as above Kelly Lake and flows in a path which is west of, and parallel to, the Colorado River, continuing until it reaches the GIWW. No discharge measurements have been made in the West Branch onsite other than a random observation made during a field trip on February 6, 1975, in which the flow that day was estimated to be approximately 5 cfs.

Historically, the West Branch was once the main branch of the Colorado River, diverting from the existing alignment at a point just west of the northern tip of Exotic Isle. Circa 1936 (See Appendix 2.3-A, pages 8 and 9) a log jam below that point was removed, and since then the river as it exists today has been the primary channel. This has been encouraged by dredging operations by the Corps to maintain it as a navigable channel. Early dredge deposits were apparently spoiled in the mouth of the West Branch opposite Exotic Isle, thus cutting off direct access to the Colorado River. Also, a short distance downstream from that point, an earthen embankment completely plugs the former river course, with no provision for allowing low flows to pass downstream. 5

2.5.2 GROUNDWATER

2.5.2.1 Regional Occurrence of Groundwater

In Matagorda County, groundwater exists in several formations of different ages but similar lithology. At the plant site, the shallow aquifer zone lies within the Beaumont Formation. However, the various waterbearing sand units do not necessarily correspond to geological units. Therefore, all usable, water-bearing strata within the county are collectively termed the Gulf Coast aquifer.[23]

Two different and distinct hydrologic units can be defined within the Gulf Coast aquifer. These units, termed the shallow aquifer zone, and the deep aquifer zone, are separated by an impervious confining zone of thickness approximately 200 feet near the proposed plant. Furthermore, hydraulic separation of these units is suggested by differences in water quality, differences in water level elevations and fluctuations, and differences in direction of groundwater flow.

Because the sands of the deep aquifer zone are capable of yielding larger amounts and higher quality water, the deep aquifer zone has been more extensively developed in preference to the shallow aquifer zone. This deep zone has been termed the "heavily pumped zone" by Hammond.[23] According to Hammond, the potential yield of the deep aquifer zone of Matagorda County far exceeds the present pumpage in that zone. Aquifers below a depth of 250 to 300 feet are the primary source of production and are under artesian pressure. Water quality is acceptable for irrigation and for domestic use and most industrial uses; however, below a depth of approximately 900 feet these aquifers contain saline water. Overlying the deep aquifer zone is a thick confining zone of predominantly clay materials which extends beyond the site boundary. Above this confining zone is a shallow aquifer zone, occuring above depths of 90 to 150 feet, which provides minor amounts of water for stock and for a few domestic wells. Water quality is marginal to poor in the shallow aquifer zone and deteriorates progressively southward toward Matagorda Bay.

It can be assumed that prior to 1900, before development of the groundwater supplies of Matagorda County had begun, groundwater conditions were in a state of equilibrium. Some of the very shallow isolated water sands near the coast contained salt water which had been entrapped when the sands were deposited.

Water levels have declined in the county as a result of increasing groundwater development for industrial, public supply, and domestic and livestock uses. Intensive pumping at Old Gulf has lowered water levels to approximately 100 feet below sea level resulting in a reversal of the hydraulic gradient on the coastal

side of this depression cone and causing the salt water - fresh
water interface to shift to an inland direction. Hammond[23]
notes that at the present time, salt-water encroachment does
not appear to be a serious problem in Matagorda County with
the possible exception of the Old Gulf area.

2.5.2.2 Hydrogeology

2.5.2.2.1 Lithology

In general the subsurface materials composing the Gulf Coast
aquifer in Matagorda County were deposited by a complex series
of coalescing alluvial and deltaic plains. Except for modern
river channel and coastal sands, the surface lithology is
mainly silt and clay. Deposits of various mixtures of clay,
silt, and sand grade vertically downward to slightly coarser
deposits of the same overall gross lithology. There are re-
latively more deposits of coarse sand and gravel in the lower 8
portions of the Gulf Coast aquifer.

Generalized cross sections of the subsoil stratification across
the project site are shown in Figures 2.5-14 and 2.5-15. An
impervious zone, composed mainly of silty clay, extends down
to about 5 to 10 feet below the surface and acts as a confin-
ing layer. Below this zone is a semipervious zone of sandy
silt with an average thickness of approximately 17 feet. Un-
derlying this zone is a fine sand layer of high permeability
and approximately 20 feet thick. This is underlain by another
impervious silty clay zone from about 35 to 60 feet thick,
which in turn is underlain by a pervious zone of fine sand
varying from 60 to 140 feet in thickness. In some places,
this fine sand is interbedded with clay and silt layers of
varying thickness. The three pervious layers constitute the
shallow aquifer zone. Acting as a confining layer below the
shallow aquifer zone, is a continuous zone of impervious silt
and clay, approximately 90 to 180 feet thick. Under this im- 8
pervious zone are the relatively fine sands, interbedded
with the silts and clays of the deep aquifer zone. At the
plant site, the deep aquifer zone begins at approximately 275
feet and extends to approximately 900 feet below the ground
surface with brackish water appearing at 750 ft. 8

2.5.2.2.2 Aquifer Characteristics

All original aquifer characteristics are based on aquifer
pumping tests performed by the Texas Water Development Board.
Four aquifer pump tests within the shallow aquifer zone and one
aquifer pump test in the deep aquifer have been performed to 8
supplement this information as a part of the site evaluation
studies for STP. The locations of these pump tests are shown in
Figure 6.1-3, "Pump Test and Piezometer Location Map." Analyses
of these tests confirm the confinement of the shallow aquifer
zone and the deep aquifer zone. 8

Representative values for the coefficient of permeability for the sand at depths of 60 to 140 feet range from 410 to 600 gallons per day per square foot (gpd/ft^2) or 1.94×10^{-2} cm/sec. Representative values for the coefficient of storage range from 0.0004 to 0.0007, typical for artesian aquifers. The coefficient of permeability of the sandy silt layers near the top of the shallow aquifer zone is much lower at about 65 gpd/ft^2 or 3.07×10^{-3} cm/sec. This layer has a coefficient of storage of about 0.002. The fine sand layer between 6 and 23 feet from the surface, has a coefficient of permeability of 3×10^{-3} cm/sec. Representative values for the coefficient of permeability for the sands within the deep aquifer zone range from 200 to 330 gallons per day per square foot or 1.55×10^{-2} cm/sec. Representative values for the coefficient of storage range from 0.0002 to 0.0007 which are typical for artesian aquifers. 8

2.5.2.2.3 Groundwater Flow

Contour maps of the piezometric surface of the deep aquifer zone and the shallow aquifer zone are presented in Figures 2.5-16, 2.5-17, and Figure 2.5-18. The contours show that the two zones have entirely different flow patterns and directions of flow based on evaluation of equipotential lines for piezometric contours. Water in the shallow zone flows to the southeast with a gradient of approximately 3 feet per mile and a rate of approximately 15 feet per year. Flow in the deep aquifer zone near the site is to the west with a gradient of about 6 feet per mile and a rate of approximately 45 feet per year.

2.5.2.2.4 Artesian Pressure

The deep aquifer zone has a lower artesian pressure than the shallow zone as verified by the piezometers. The elevation of water in the deep aquifer zone is approximately (-)20 feet MSL; beneath the plant site, the water level in the shallow aquifer zone varies from approximately +17 to +20 feet MSL.

2.5.2.2.5 Areas of Recharge

The deep artesian zone is recharged from infiltration of precipitation and stream percolation at higher elevations north of the project site area where aquifers outcrop and are unconfined. Considering the formation dip, the southerly extent of the deep zone recharge area should be a minimum of 8 to 10 miles distant and extends beyond the northern boundaries of Matagorda County.

Shallow zone replenishment does not originate within the project site, except where the upper portion may be locally unconfined. On the basis of present data, it appears that there is no significant shallow recharge from sources within or to the south of the proposed site.

2.5.2.3 Groundwater Elevations

2.5.2.3.1 Water Fluctuations

A water level monitoring program at the site was initiated in mid-July, 1973. Fluctuations of water in piezometers set in various sand layers are shown in Figure 2.5-19. Locations of the piezometers are shown in Figure 6.1-3 "Pump Test and Piezometer Location Map," and depths are shown in Figure 6.1-4, "Borehole Depth Chart." A maximum rise of about 4 to 6 feet occurred in the water level of the very shallow pervious zone (20 to 40 feet deep) between mid-July, 1973 and mid-January, 1974. The water level fluctuations in the 60- to 140-foot-deep pervious zone were measureably less, rising about 2 feet maximum. According to available data, seasonal fluctuations in the deep zone also are very minor (less than 2 feet total) near the proposed power plant.[23]

Long-term water level observations for the deep aquifer zone near the site are shown in Figure 2.5-20. The well showing the maximum decline is situated approximately 7 miles to the southwest of the plant site and reflects the results from heavy pumpage for rice irrigation in western Matagorda County. While there is potential for future industrial development along the Colorado River to the east of the proposed plant site, it is anticipated that resulting groundwater withdrawals will be localized within the deep aquifer zone. No sustained pumping will be permitted within at least 4,000 feet of the proposed power plant structures.

All land within 4,000 feet surrounding the power station will be owned by and under full control of the South Texas Project
utility companies. The minimum distance to the site boundary 7
from the power station is in excess of 4,000 feet.

The law of percolating groundwater rights in Texas upholds the principle that the person who owns the ground surface may use any and all the groundwater he can capture for any reasonable use. Furthermore, "a landowner is entitled to protection against an appropriation of the percolating water in his land by one who goes on the land, digs a well thereon, and takes the water away without his permission."[29]

Sustained pumping due to future groundwater development in the area outside the STP site boundary could remotely affect the power station site through regional groundwater drawdown. Localized drawdown effects would tend to dissipate laterally with proximity to the power station. Therefore, the resulting piezometric decline beneath the power station will be uniform and regional in nature.

If the piezometric decline were permanent and of sufficient magnitude, regional ground surface subsidence throughout the area would occur.

On the basis of observation and analysis of information concerning
subsidence in the Houston-Galveston area and on the basis of
soil consolidation tests from boreholes beneath the proposed STP
power station, estimates of the ratio of subsidence to piezo-
metric head decline have been derived. For an estimated
future artesian pressure decline of 87 feet in the area, future
regional land surface subsidence will not exceed 3.0 feet 7
over the design life of the South Texas Project. Regional sub-
sidence such as that observed in the Houston-Galveston area
with the magnitude estimated for the South Texas Project area
will have no effect on the safe operation of the facility.

Differential subsidence such as has been observed in the
vicinity of preexisting shallow growth "faults" within the
zone of groundwater decline in the Houston-Galveston area if
it occured at the site would have an effect on the safe operation 1
of the South Texas Project structures. However, subsurface
geologic investigations in the project area indicate that growth
"faults" are present only at great depth below the deep aquifer
zone of pumping. Reflection geophysical surveys completed to
date indicate that the shallowest of these growth "faults" is
a depth of at least 6,000 feet below the ground surface at the
site, well below the deep aquifer zone, which is between 250
and 900 feet for the area. Therefore differential ground
surface subsidence across shallow growth "faults" is not
conceivable at the site of the South Texas Project structures.

Another potential source of differential ground surface sub-
sidence, sharp lateral changes in sand-slit-clay ratios in
aquifer zones, is not present at the site. Subsurface invest-
igations completed to the present time indicate that the deep
aquifer geometry and composition throughout the project area
are relatively uniform. Consequently differential ground
surface subsidence from sharp lateral compositional changes
in the deep aquifer will have no effect on the South Texas
Project structures.

The shallow-aquifer zone beneath the site extends from near
the surface to a depth of approximately 100 to 150 feet; its
peizometric level is generally between 2 and 15 feet below ground
surface. Because of the poor quality and low volume of ground
water in the shallow-aquifer zone, there has been very little
exploitation of the ground-water contained therein. Conse-
quently, there has been no historical decline of the piezometric 7
level in the shallow-aquifer zone, and none is expected in the
future because of constraints on the use of the water because
of its poor chemical quality. Because of the geohydrologic
separation of the shallow-aquifer zone from the deep-aquifer
zone and because piezometric levels in this zone are expected to
be static, throughout plant operation, this shallow-aquifer sys-
tem will not participate or contribute significatnly to ground
surface subsidence at the STP.

2.5.2.3.2 Regional Depression Cones

Concentrated groundwater withdrawals and sulfur mining near the Old Gulf (Big Hill Dome) Salt Dome, located approximately 10 miles southeast of the site, had previously created a local cone of depression as shown in Figure 2.5-16. However, this condition has become less severe since the termination of sulfur mining operations subsequent to 1967. There are no localized or regional cones of depression that affect the plant site.

2.5.2.4 Groundwater Quality

Groundwater samples for water quality analyses were collected from three wells (Wells 114-A, 2, and 115-D) located on the STP reactor site (Figure 6.1-3). The objectives of the sampling program were to provide baseline data and to determine any short- or long-term variability in groundwater quality. Sampling was conducted in two phases. Phase I consisted of a short-interval sampling program commencing on December 11, 1973, and terminating on January 10, 1974. Phase II involved a long-interval sampling program commencing in late January 1974 and terminating in early September 1974. The results of these investigations are presented in Tables 2.5-25, 2.5-26, and 2.5-27. The concentration ranges discussed below represent mean values from these tables.

Groundwaters of Matagorda County are almost entirely alkaline, with reported pH values ranging from 6.7 to 8.5.[23] During the current study, pH values ranged from 7.2 to 7.6 at Well 115-D, from 7.5 to 9.6 at Well 2, and from 7.9 to 9.2 at Well 114-A. These ranges, although slightly higher, are generally consistent with values previously reported.[23] Throughout the sampling program, pH values tended to be highest from Well 114-A, the deepest zone sampled.

Phenolphthalein alkalinity (a measure of caustic alkalinity, attributable primarily to hydroxides and carbonates) was zero in all samples collected at Well 115-D, ranged from 0 to 44 mg/l ($CaCO_3$) at Well 2 and from 0 to 28 mg/l ($CaCO_3$) at Well 114-A.

Methyl orange alkalinity (bicarbonate alkalinity) was highest in shallow groundwaters at Well 115-D and ranged from 271 to 405 mg/l ($CaCO_3$). Ranges of 148 to 380 mg/l ($CaCO_3$) and 129 to 249 mg/l ($CaCO_3$) were recorded at Wells 2 and 114-A, respectively. High bicarbonate alkalinities are common in groundwater where the principal cation is sodium.

Acidity, both free and total, of groundwaters was determined during the Phase I sampling. Free acidity values were zero for all wells on all collection dates. Total acidity was highest in the clay strata of Well 115-D and ranged from 8.1 to 37 mg/l. Ranges of 10 to 20 mg/l and 0 to 5.4 mg/l were reported for Wells 2 and 114-A, respectively.

Groundwaters of Matagorda County ranged from 13 to 1,820 ppm hardness, with 124 of the 177 wells sampled having hardness 5 values greater than 120 ppm.[23] Groundwaters of the STP site ranged from moderately hard to very hard, with a general decrease in hardness in deeper waterbearing strata. Reported hardness ranges were 570 to 780 mg/l ($CaCO_3$), 91 to 449 mg/l ($CaCO_3$), and 61 to 317 mg/l ($CaCO_3$) for Wells 115-D, 2, and 114-A, respectively.

Calcium and magnesium concentrations paralleled total hardness values ranging from 113 to 140 mg/l, 9.6 to 137 mg/l, and 7.5 to 58 mg/l for calcium, and 70 to 104 mg/l, 16 to 50 mg/l, and 9.6 to 42 mg/l for magnesium at Wells 115-D, 2, and 114-A, respectively.

Chloride is important in assessing the usability of a water supply for industrial purposes. The Federal Water Pollution Control Administration[24] (Table 2.5-28) recommends that water for use in steam generation and as a coolant in heat exchange applications not exceed 600 ppm chloride for once-through use and 500 ppm chloride for recirculation. Chloride levels in STP groundwaters ranged from 990 to 1,133 mg/l at Well 115-D, from 238 to 402 mg/l at Well 2, and from 160 to 384 mg/l at Well 114-A. Throughout the sampling program, chloride concentrations generally were higher at the shallower wells (115-D and 2) and lower at the deepest well (114-A).

Specific conductance decreased with well depth and ranged from 3,390 to 4,020 μmhos/cm at Well 115-D, 1,080 to 1,900 μmhos/cm at Well 2, and 845 to 1,363 μmhos/cm at Well 114-A. 5

Hammond[23] reported silica concentrations in Matagorda County groundwaters ranging from 7 to 35 ppm, with most values between 12 and 22 ppm. Silica concentrations during the current study ranged from 6.9 to 136 mg/l at Well 115-D, to 0.58 to 20 mg/l at Well 2, and 6.2 to 28 mg/l at Well 114-A.

Total and inorganic carbon concentrations were lowest at Well 114-A and ranged from 38 to 66.6 mg/l and from 27.9 to 59 mg/l, respectively. Well 2 exhibited ranges of 31 to 90 mg/l for total carbon and 28.6 to 87 mg/l for inorganic carbon. Water from the most shallow well, 115-D, generally had highest levels for these constituents. Ranges were from 69 to 100.3 mg/l and 53.6 to 97.6 mg/l for total and inorganic carbon, respectively. Organic carbon levels ranged from <1.0 to 15.4 mg/l at Well 115-D, 1.3 to 8.9 mg/l at Well 2, and <1.0 to 10.4 mg/l at Well 114-A.

Concentrations of phenolic compounds ranged from below the detection limit (0.001 mg/l) for all wells to 0.012, 0.016, and 0.018 mg/l at Wells 115-D, 2, and 114-A, respectively.

Chemical oxygen demand, a measure of the oxygen equivalent required for complete chemical oxidation of reduced organic components in water, was highest at Wells 115-D and 114-A. Reported values in these wells ranged from 6.3 to 44 mg/l and 5.3 to 36 mg/l, respectively. Much lower oxygen requirements, ranging from <5 to 17.3 mg/l, were recorded for Well 2.

Nitrate concentrations ranged from 0.2 to 1.5 mg/l at Well 115-D, <0.2 to 0.6 mg/l at Well 2, and <0.2 to 1.4 mg/l at Well 114-A. Nitrite concentrations ranged from <0.1 mg/l at all three wells to 0.3 mg/l at Wells 115-D and 114-A, and to 0.4 mg/l at Well 2.

Highest concentration of ammonia occurred at Well 2, where a maximum value of 1.03 mg/l was reported on June 27, 1974. Minimum reported concentration for this well was below analytical sensitivity (0.07 mg/l). Ammonia concentrations for other wells were lower, ranging from <0.07 to 0.73 mg/l at Well 115-D, and 0.10 to 0.68 mg/l at Well 114-A.

Total phosphorus ranged from 0.09 to 0.43 mg/l at Well 115-D, 0.04 to 0.54 mg/l at Well 2, and <0.01 to 0.74 mg/l at Well 114-A. Orthophosphate exhibited a similar trend toward increased concentrations in deeper aquifer zones; values ranged from 0.01 to 0.24 mg/l at Well 115-D, 0.01 to 0.37 mg/l at Well 2, and <0.01 to 0.6 mg/l at Well 114-A.

Sulfate concentrations were highest in near-surface wells and decreased in deeper zones of the aquifer. Ranges were 25 to 34.1 mg/l (Well 115-D), <1.0 to 13.3 mg/l (Well 2), and 4.4 to 8.7 mg/l (Well 114-A). Concentrations of sulfide ranged from <0.02 mg/l at all wells to 0.12, 0.95, and 3.29 mg/l at Wells 115-D, 2, and 114-A, respectively. 5

Cyanide concentrations were consistently below detection limit (0.01 mg/l).

Fluoride concentrations ranged from 0.6 to 1.4 mg/l at Well 115-D, 0.6 to 1.3 mg/l at Well 2, and 0.6 to 1.4 mg/l at Well 114-A.

Sodium concentration decreased with aquifer depth with values ranging from 557 to 615 mg/l at Well 115-D, 196 to 280 mg/l at Well 2, and 175 to 203 mg/l at Well 114-A.

Similarly, highest concentrations of potassium were present in near-surface groundwaters, with values ranging from 4.7 to 8 mg/l at Well 115-D. Somewhat higher levels were reported for Well 114-A (range - 2.9 to 9.9 mg/l) than for Well 2 (range - 3.0 to 4.5 mg/l).

Iron concentrations ranged from 1.8 to 7.4 mg/l, 0.02 to 28 mg/l, and 0.03 to 4.4 mg/l at Wells 115-D, 2 and 114-A, respectively. The extremely high levels recorded for Well 2 may have resulted from the steel casing used to line the well (other wells sampled had PVC liners).

Manganese concentrations were highest in Well 115-D and ranged from 0.41 to 1.01 mg/l. Deeper wells exhibited lower concentrations, ranging from <0.02 to 0.35 mg/l and from <0.02 to 0.22 mg/l in Wells 2 and 114-A respectively.

Aluminum concentrations ranged from 0.2 to 5.4 mg/l at Well 115-D, <0.1 to 0.43 mg/l at Well 2, and <0.1 to 0.9 mg/l at Well 114-A.

Highest zinc levels were in samples from Well 2 (equipped with steel casing), where a range of 0.05 to 4.7 mg/l was recorded. Wells 115-D and 114-A exhibited ranges of 0.04 to 0.97 mg/l and <0.02 to 0.34 mg/l, respectively.

Arsenic concentrations were generally less than 0.01 mg/l and exceeded this level on only one occasion, on January 10, 1974, at Well 2.

Copper concentrations were highest in near-surface aquifer zones. Reported values ranged from <0.02 to 0.06 mg/l at Well 115-D, and <0.02 to 0.03 mg/l at Well 2, and were consistently below detection limits (0.02 mg/l) at Well 114-A.

Concentrations of mercury ranged from less than analytical detection limit (0.2 μg/l) at all wells to 0.5, 1.6, and 0.6 μg/l at Wells 115-D, 2, and 114-A, respectively.

Boron concentrations ranged from 0.1 to 1.1 mg/l at Well 115-D, 0.1 to 0.4 mg/l at Well 2, and <0.1 to 0.6 mg/l at Well 114-A.

Cadmium levels were generally less than minimum detection limits (0.01 mg/l), but ranged as high as 0.03 mg/l at Well 115-D and 5
Well 114-A.

Consistently below minimum analytical detection limits at all three wells were barium (0.2 mg/l), lead (0.5 mg/l), selenium (0.01 mg/l), silver (0.02 mg/l), and the hexavalent form of chromium (0.002 mg/l).

Total dissolved solids concentrations ranged from 2,337 to 2,730 mg/l (Well 115-D), 590 to 1,107 mg/l (Well 2), and 525 to 949 mg/l (Well 114-A).

Bacteriological analyses showed groundwaters (Tables 2.5-25 through 2.5-27) to be of generally good sanitary quality. Incidence of fecal bacteria was low and generally confined to groundwaters located near the surface. Total bacterial counts were highest at Well 115-D.

United States Public Health Service[25] drinking water standards, Environmental Protection Agency (EPA)[30] proposed drinking water criteria, and EPA[30] proposed criteria for preservation of aquatic life are compared to the grand mean and maximum value reported for each parameter investigated during the current study (Table 2.5-29).

Dewatering during plant construction will be from the shallow aquifer zone and will extend to a depth of 80 ft below the

surface. Effluents from site dewatering operations will be
released to the Colorado River at rates up to 5.6 cfs
(Section 4.1.2.5). A comparison of EPA proposed criteria
for the preservation of aquatic biota and the grand means of
chemical constituents of groundwater indicate that no toxic
effects are to be expected as a result of dewatering opera- 5
tions. All reported concentrations for heavy metals also
comply with regulatory standards promulgated by Texas Water
Quality Board Order No. 70-0828-5, which establishes effluent
limitations for certain hazardous metals including arsenic,
barium, boron, cadium, copper, chromium, lead, maganese,
mercury, selenium, silver, and zinc.[31]

2.5.3 WATER QUALITY STANDARDS

The Texas Water Quality Board has set the following specific water quality criteria for the Colorado River in the site vicinity:

1. Dissolved oxygen (not less than 5.0 mg/l).

2. pH range (6.7 to 8.5).

3. Fecal coliform (logarithmic average not more than 200 per 100 milliliters).

4. Temperature, maximum upper limit 95°F and 1.5°F above natural condition during summer season and 4°F above natural condition for spring, fall, and winter.

5. Mixing Zones

   "Where mixing zones are specifically defined in a valid waste control order issued by the Texas Water Quality Board or a National Pollutant Discharge Elimination System permit, the defined zone shall apply.

   "Where the mixing zone is not so defined, a reasonable zone shall be allowed. Because of varying local physical, chemical, and biological conditions, no single criterion is applicable in all cases. In no case, however, where fishery resources are considered significant, shall the mixing zone allowed preclude the passage of free-swimming and drifting aquatic organisms to the extent of significantly affecting their populations. Normally mixing zones should be limited to no more than 25 percent of the cross-sectional area and/or volume of flow of the stream or estuary, leaving at least 75 percent free as a zone of passage unless otherwise defined by a specific Board Order or permit."

The above water quality standards are presented in Texas Water Quality Standards[26] and are currently in effect in Texas. A complete text of Texas Water Quality Standards is presented in Appendix 2.5-B.

REFERENCES

2.5-1 U.S. Army, Corps of Engineers, January, 1971; "Water Resources Development."

2.5-2 Texas Water Development Board Report 52, July, 1967; "The Climate and Physiography of Texas."

2.5-3 Texas Water Development Board, 1968; "The Texas Water Plan."

2.5-4 Regulatory Guide 1.59, Design Basis Floods for Nuclear Power Plants, Appendix A, U.S. Atomic Energy Commission, Regulatory Guide, Directorate of Regulatory Standards, August, 1973. 1

2.5-5 Riedel, J.T., J.F. Appleby, and R.W. Schloemer, April 1956; "Seasonal Variation of the Probable Maximum Precipitation East of the 105th Meridian for Areas from 10 to 1000 Square Miles and Durations of 6, 12, 24 and 48 Hours," Hydrometeorological Report No. 33, Hydrologic Service Division, Hydrometeorological Section, U.S. Department of Commerce, Weather Bureau.

2.5-6 U.S. Army Corps of Engineers, March, 1952; "Standard Project Flood Determinations," Civil Engineering Bulletin No. 52-8.

2.5-7 U.S. Geological Survey, 1970; "Water Resources Data for Texas, Part 1, Surface Water Records."

2.5-8 National Oceanic and Atmospheric Administration, 1974; "Tide Tables, High and Low Water Predictions, 1974. East Coast of North and South America Including Greenland."

2.5-9 Texas Water Development Board, April 1972; "Chemical and Physical Characteristics of Water in Estuaries of Texas, October, 1968 - September, 1969," Report 144.

2.5-10 Texas Water Development Board, May 1970; "Chemical and Physical Characteristics of Water in Estuaries in Texas, September, 1967 - September, 1968," Report 117.

2.5-11 Texas Water Development Board, June, 1973; "Chemical and Physical Characteristics of Water in Estuaries of Texas, October, 1969 - September, 1970," Report 171.

2.5-12 Parker, R. H. and W. G. Glanton, 1970; "Environmental Factors Affecting Bay and Estuarine Ecosystems of the Texas Coast," Coastal Ecoysytems Management, Inc., Fort Worth, Texas.

2.5-13 Parker, R. H., W. G. Blanton, J. F. Slowey, and T. H. Baker, 1969; "Comparative Study of Two Estuarine Ecosystems: the Brazos and Colorado River Estuaries," Report No. 1, TCU Research Foundation, Texas Christian University.

2.5-14 Meller, J. E. and Wolf, H. W., 1963; "Water Quality Criteria;" Research Agency California Water Quality Control Board, 1963.

2.5-15 Sawyer, C. L., and McCarty, P. L., 1967; "Chemistry for Sanitary Engineers," McGraw-Hill Book Company, New York.

2.5-16 U. S. Geological Survey, 1969; "Water Resources Data for Texas, Part 1, Surface Water Records."

2.5-17 Texas Water Development Board, November, 1967; "Temperature of Texas Streams;" Report 65.

2.5-18 Edinger and Geyer, June 1, 1965; "Heat Exchange in the Environment;" The John Hopkins University, RP-49.

2.5-19 Data Tape from Texas Water Development Board, Data Bank.

2.5-20 Defense Mapping Agency Hydrographic Center, April 1949; "Gulf of Mexico and Caribbean Sea Including The West Indies," N. O. 410; 108th Ed., Revised September 24, 1973.

2.5-21 B. R. Bodine, February 1969; "Hurricane Surge Frequency Estimated for the Gulf Coast of Texas," TM No. 26, U. S. Army, Corps of Engineers, Coastal Engineering Research Center.

2.5-22 National Oceanic and Atmospheric Administration, Environmental Data Service, June, 1972; "Tropical Storm and Atlantic Hurricane Articles from the Monthly Weather Review," U. S. Department of Commerce.

2.5-23 W. W. Hammond, 1969; "Groundwater Resources of Matagorda County, Texas," Texas Water Development Board Report 91.

2.5-24 Federal Water Pollution Control Administration; "Water Quality Criteria."

2.5-25 American Public Health Association, 1971; "Standard Method for the Examination of Water and Wastewater," 13th edition.

2.5-26 Texas Water Quality Board, October, 1973; "Texas Water Quality Standards."

2.5-27 U. S. Geological Survey, 1971; "Water Resources Data for Texas, Part 1, Surface Water Records."

2.5-28 Groover, R.D., Sharik, T.L. and Morgan, P.V. "An Ecological Study of the Lower Colorado River - Matagorda Bay Area of Texas," R-24-05-04-606, NUS Corp. Rockville, Md. (1973). 3

2.5-29 Hutchins, Wells A., 1961, The Texas law of water rights; State of Texas, Board of Water Engineers, pp. 557-600. 1

2.5-30 U. S. Environmental Protection Agency, 1973; "Proposed Criteria for Water Quality. Volume 1."

2.5-31 Texas Water Quality Board, August 1970; Board Order No. 80-0828-5, "Hazardous Metals"; TWQB, Austin, Texas. 5

TABLE 2.5-1

PHYSICAL DATA FOR LOWER COLORADO RIVER

Gauge Location	Distance from Gulf (River Miles)	Avg. Bottom Slope (ft/1,000 ft)	Avg. Bottom Width (ft)	Avg. Top Width (ft)	Avg. Elev. Low Bank (ft MSL)	Bankfull Capacity (cfs)	Bankfull Capacity Return Interval (Years)
Austin	290.3		420	740	427	91,000	21.3
		0.347					
Bastrop*	236.8		450	680	339	80,000	10.0
		0.340					
Smithville	212.0		400	680	299	83,000	7.5
		0.304					
LaGrange**	174.0		500	700	251	136,000	16.0
		0.252					
Columbus	135.1		400	600	209	73,000	5.7
		0.247					
Wharton	66.6		240	370	98	89,000	9.5
		0.279					
Bay City	32.5		250	400	50	100,000	10.5

*Discontinued in 1973.
**Discontinued in 1955.

TABLE 2.5-1

PHYSICAL DATA FOR LOWER COLORADO RIVER

Gauge Location	Distance from Gulf (River Miles)	Avg. Bottom Slope (ft/1,000 ft)	Avg. Bottom Width (ft)	Avg. Top Width (ft)	Avg. Elev. Low Bank (ft MSL)	Bankfull Capacity (cfs)	Bankfull Capacity Return Interval (Years)
Austin	290.3		420	740	427	91,000	21.3
		0.347					
Bastrop*	236.8		450	680	339	80,000	10.0
		0.340					
Smithville	212.0		400	680	299	83,000	7.5
		0.304					
LaGrange**	174.0		500	700	251	136,000	16.0
		0.252					
Columbus	135.1		400	600	209	73,000	5.7
		0.247					
Wharton	66.6		240	370	98	89,000	9.5
		0.279					
Bay City	32.5		250	400	50	100,000	10.5

*Discontinued in 1973.
**Discontinued in 1955.

TABLE 2.5-2

GAGE DATA FOR THE LOWER COLORADO RIVER

Gauge Location	River Mile From Gulf	Period of Record: No. of Years	Period of Record: From	Period of Record: To	Drainage Area (mi^2)	Historical Daily Flow (cfs): Max.	Historical Daily Flow (cfs): Min.	Historical Daily Flow (cfs): Avg.
Austin	290.3	75	1898	1972	38,400	481,000	13	2,394
Bastrop**	236.8	13	1960	1972	39,400	79,600	75	2,040
Smithville	212.0	43	1930	1972	39,880	305,000	76	2,701
LaGrange***	174.0	17	1939	1955	40,430	200,000	210	2,372
Columbus	135.1	57	1916	1972	41,070	190,000	93	2,245
Wharton	66.6	35	1938	1972	41,380	159,000	0	2,799
Bay City	32.5	25	1948	1972	41,650	84,100	0	2,291

*Data based on Reference 2.5-27. Data for periods beyond 1972 are available in uncompiled format. Drainage area includes 12,880 square miles of noncontributing area.

**Discontinued in 1973.

***Discontinued in 1955.

TABLE 2.5-2a

HYDROLOGIC CHARACTERISTICS

LITTLE ROBBINS SLOUGH AND BIG BOGGY CREEK

Parameter	Little Robbins Slough*	Big Boggy Creek
Drainage Area	9.33 Square Miles	10.28 Square Miles
Length of Stream	6.87 Miles	9.11 Miles
Overall Slope of Stream Bottom	0.00061 ft/ft	0.00033 ft/ft
Distance Along Stream From Gage (or Canal) to Centroid of Basin	3.12 Miles	4.88 Miles
Vegetation Cover	Grains (maze, rice) and Pasturage	Grains (maze, rice) and Pasturage
Forest Cover	None except fringe along stream	None except fringe along stream
Soil Types	Clay	Clay
Average Annual Rice Acreage	1,990 Acres	1,100 Acres
Average Overland Slope Normal to Stream	2.4%	3.9%

1

*This data applies only to the drainage area north of the southernmost boundary of the site (that area directly affected by plant construction).

TABLE 2.5-2b

LITTLE ROBBINS SLOUGH

CHANGES IN DRAINAGE CHARACTERISTICS

DUE TO RESERVOIR CONSTRUCTION

	Little Robbins Slough	East Fork	Total*	
Existing drainage area (miles^2)	9.33	4.43	13.76	
Drainage area after reservoir construction (miles^2)	4.57	0.23	4.80	
Percent reduction	51	95	65	
Estimated 22 year average annual discharge in ac-ft from rainfall	6,300	3,000	9,300	
Estimated 22 year average annual discharge in ac-ft from irrigation return flow	1,300	640	1,940	
Estimated 22 year average annual total discharge in ac-ft	7,600	3,640	11,240	1
Estimated average annual discharge in ac-ft after reservoir construction	3,760	190	3,950	

*This data applies only to the drainage area north of the southernmost boundary of the site (that area directly affected by plant construction).

TABLE 2.5-3

NUTRIENT AND OTHER ENVIRONMENTAL CHARACTERISTICS OF WATER IN THE COLORADO ESTUARY, 1968*

Date of Collection	Time (24 hr)	Site	Depth Below Water Surface (ft)	Specific Conductance (micromhos at 25°C)**	pH**	Temperature (°C)**	Turbidity by Sacchi Disk (cm)**	Dissolved Oxygen: Concentration**	Dissolved Oxygen: Percent Saturation	Biochemical Oxygen Demand (BOD)	Silica (SiO_2)	Nitrate (NO_3)	Ammonium (NH_4)	Nitrate (NO_2)	Phosphate (PO_4): Ortho	Phosphate (PO_4): Total
							Line 5. Colorado River									
May 9	1220	2	1	360	7.9	22.9	--	9.1	105	--	--	--	--	--	--	--
			16	360	8.3	23.0		9.4	108	--	--	--	--	--	--	--
							Line 6. Colorado River									
May 9	1240	2	1	350	7.6	23.2	--	8.8	101	--	--	--	--	--	--	--
			15.5	340	7.7	23.2		8.3	95	--	--	--	--	--	--	--
							Line 8. Colorado River									
May 9	1322	2	1	350	7.8	23.5	--	9.1	107	--	--	--	--	--	--	--
			31	360	7.7	23.6		9.7	114	--	--	--	--	--	--	--
							Line 9. Colorado River									
May 9	1340	2	1	1,000	--	23.6	--	8.7	102	--	--	--	--	--	--	--
			10	1,300	--	23.6		9.0	106	--	--	--	--	--	--	--
			16	2,000	--	23.6		8.6	102	--	--	--	--	--	--	--
							Line 10. Colorado River									
May 9	1403	2	1	990	8.0	23.5	--	8.7	102	--	--	--	--	--	--	--
			10	1,500	7.9	23.5		9.2	108	--	--	--	--	--	--	--
			15	1,700	7.9	23.4		9.8	113	--	--	--	--	--	--	--
							Line 11. Colorado River									
May 9	1412	2	1	1,500	7.6	23.4	--	8.8	101	--	--	--	--	--	--	--
			10	1,500	7.6	23.4		9.2	106	--	--	--	--	--	--	--
			17	1,700	7.7	23.4		9.3	107	--	--	--	--	--	--	--
							Line 13. Colorado River									
May 9	1427	2	1	3,100	8.0	23.4	--	8.0	93	--	--	--	--	--	--	--
			5	17,000	8.1	23.4		8.3	98	--	--	--	--	--	--	--
			6	31,000	8.1	23.7		8.5	108	--	--	--	--	--	--	--
			7	35,000	8.1	23.7		7.8	104	--	--	--	--	--	--	--
			10	38,000	8.1	23.8		7.5	100	--	--	--	--	--	--	--
			14.5	38,000	8.1	23.9		8.9	119	--	--	--	--	--	--	--
							Line 14. Colorado River									
May 9	1508	2	1	37,000	7.8	23.9	--	7.4	99	--	--	--	--	--	--	--
			7	37,000	7.8	23.9		7.8	104	--	--	--	--	--	--	--

*Data from Reference 2.5-9. Results in milligrams per liter, except as indicated.
**Determined at data-collection site.

TABLE 2.5-4

NUTRIENTS AND OTHER ENVIRONMENTAL CHARACTERISTICS OF WATER IN THE COLORADO ESTUARY, 1969 WATER YEAR*

Date of Collection	Time (24 hr)	Site	Depth Below Water Surface (ft)	Specific Conductance (micromhos at 25°C)	pH**	Temperature (°C)	Secchi Disk transparency (cm)**	Dissolved Oxygen: Concentration**	Dissolved Oxygen: Percent Saturation	Biochemical Oxygen Demand (BOD)	Chemical Oxygen Demand (COD)	Silica (SiO_2)	Nitrate Nitrogen (N)	Ammonia Nitrogen (N)	Nitrate Nitrogen (N)	Orthophosphate as phosphorus (P)	Total Phosphorus (P)
								Line 1. Colorado River									
May 7	1530	2	1	180	7.7	24.0	4	7.2	85	1.8	20	9.4	0.3	QN***	QN	0.15	0.33
			5	180	7.7	24.0		7.1	84	--	--	--	--	--	--	--	--
			10	180	7.6	23.5		6.6	78	2.0	16	9.6	0.6	QN	QN	0.16	0.36
June 11	1530	1	1	600	8.4	30.3	--	9.2	121	3.1	--	8.5	0.0	QN	QN	0.08	0.11
	1510	2	1	580	8.3	29.7	20	9.2	121	3.4	0.8	9.0	0.0	QN	QN	0.08	0.11
			[illegible]	560	8.1	29.8		9.2	121	3.5	2.2	8.8	0.0	QN	QN	0.08	0.16
	1535	3	1	560	8.4	30.3	--	9.0	115	3.3	--	9.1	0.0	QN	QN	0.08	0.08
								Line 2. Colorado River									
May 7	1545	2	1	290	7.6	24.6	9	6.8	80	1.9	12	9.7	0.2	QN	QN	0.03	0.21
			5	290	7.6	24.0		6.6	78	--	--	--	--	--	--	--	--
			10	260	7.5	23.5		6.6	78	--	--	--	--	--	--	--	--
			17.5	280	7.4	23.6		6.2	73	2.3	17	9.9	0.7	QN	QN	0.12	0.14
June 11	1540	2	1	520	8.3	28.8	--	12.2	156	4.5	1.8	10	0.0	QN	QN	0.05	0.08
			5	520	8.4	28.4		10.6	134	--	--	--	--	--	--	--	--
			7.5	[illegible]	[illegible]	27.[illegible]		[illegible]	[illegible]	--	--	--	--	--	--	--	--
			8.5	520	7.9	26.9		5.0	62	--	--	--	--	--	--	--	--
			11	600	8.2	24.9		0.2	24	2.2	4.6	11	0.1	QN	QN	0.11	0.12
								Line 2b. Colorado River									
May 7	1600	2	0.2	3,800	10.6	26.9	--	6.6	83	4.8	201	18	1.8	4.7	0.55	0.22	0.29
			3	2,200	9.8	25.5		6.7	83	6.9	140	14	1.4	3.2	0.30	0.25	0.33
								Line 3. Colorado River									
Jan 29	1315	2	1	700	8.0	19.9	18	8.2	89	1.0	--	6.4	0.0	0.00	0.00	--	0.11
			13	1,000	7.9	20.0		8.8	96	1.6	--	6.2	0.0	0.00	0.00	--	0.12
Jan 31	0955	2	10	23,000	7.2	16.5		0.0	0	--	--	--	--	--	--	--	--
			13	23,000	7.1	16.4		0.0	0	--	--	--	--	--	--	--	--
June 11	1500	1	1	560	7.5	29.3	27	9.0	115	3.1	--	8.5	0.0	QN	QN	0.07	0.12
	1452	2	1	560	[illegible]	[illegible]	27	[illegible]	[illegible]	3.[illegible]	--	8.5	0.2	QN	QN	0.08	0.14
			5	560	7.4	29.0		9.0	115	--	--	--	--	--	--	--	--
			11	560	[illegible]	[illegible]		9.5	[illegible]	[illegible]	--	8.4	0.0	QN	QN	0.11	0.12
	1455	3	1	560	7.5	29.2	27	9.0	115	3.3	--	8.8	0.0	QN	QN	0.07	0.09
								Line 4. Colorado River									
Jan 29	1300	2	1	1,000	8.1	19.6	--	9.2	99	1.0	--	6.4	0.0	0.00	0.00	--	0.11
			5	1,000	8.1	19.4		8.9	96	--	--	--	--	--	--	--	--
			10	2,200	8.1	19.1		7.6	81	--	--	--	--	--	--	--	--
			12.5	24,000	7.2	16.7		0.0	0	2.1	--	4.7	0.0	0.12	0.00	--	0.22
June 11	1435	2	1	560	8.3	28.4	24	9.2	116	--	--	--	--	--	--	--	--
			5	560	7.9	28.2		8.6	109	--	--	--	--	--	--	--	--
			15	560	7.8	27.9		7.4	94	--	--	--	--	--	--	--	--
								Line 5. Colorado River									
Jan 29	1230	2	1	1,800	8.1	19.2	20	9.0	96	1.4	--	6.4	0.0	0.00	0.00	--	0.09
			5	2,000	8.2	19.3		8.9	96	--	--	--	--	--	--	--	--
			7.5	2,000	8.1	19.4		8.9	96	--	--	--	--	--	--	--	--
			10	23,000	7.4	17.3		1.5	15	--	--	--	--	--	--	--	--
			13.5	32,000	7.4	17.5		0.8	8	1.9	--	3.0	0.0	0.20	0.00	--	0.10
June 11	1425	2	1	560	7.7	29.8	--	8.7	114	--	--	--	--	--	--	--	--
			5	560	7.7	29.7		8.6	113	--	--	--	--	--	--	--	--
			14	560	7.6	29.4		7.7	99	--	--	--	--	--	--	--	--
								Line 6. Colorado River									
Jan 29	1353	2	1	3,700	8.1	18.7	--	9.6	102	2.2	--	7.0	0.0	0.00	0.00	--	0.08
			5	4,200	8.1	18.6		9.4	100	--	--	--	--	--	--	--	--
			7.5	4,600	8.0	18.4		9.0	95	--	--	--	--	--	--	--	--
			10	37,000	7.7	15.9		3.1	31	--	--	--	--	--	--	--	--
			15	37,000	7.8	15.5		4.1	41	2.3	--	1.4	0.0	0.00	0.00	--	0.10
June 11	1410	2	1	520	8.4	28.4	34	7.5	95	--	--	--	--	--	--	--	--
			5	480	8.4	28.4		7.4	94	--	--	--	--	--	--	--	--
			10	520	8.3	28.1		7.0	89	--	--	--	--	--	--	--	--
			16	640	8.1	28.0		6.8	86	--	--	--	--	--	--	--	--

TABLE 2.5-4 (Continued)

NUTRIENTS AND OTHER ENVIRONMENTAL CHARACTERISTICS OF WATER IN THE COLORADO ESTUARY, 1969 WATER YEAR*

Date of Collection	Time (24 hr)	Site	Depth Below Water Surface (ft)	Specific Conductance (micromhos at 25°C)**	pH**	Temperature (°C)**	Secchi Disk Transparency (cm)**	Dissolved Oxygen Concentration**	Dissolved Oxygen Percent Saturation	Biochemical Oxygen Demand (BOD)	Chemical Oxygen Demand (COD)	Silica (SiO_2)	Nitrate Nitrogen (N)	Ammonia Nitrogen (N)	Nitrate Nitrogen (N)	Orthophosphate as Phosphorus (P)	Total Phosphorus (P)
								Line 7. Colorado River									
Jan 29	1415	2	1	5,000	8.1	18.5	20	9.6	102	1.4	--	6.7	0.0	0.00	0.00	--	0.08
			5	5,300	8.1	18.5		9.6	102	--	--	--	--	--	--	--	--
			7.5	5,500	8.2	18.2		9.4	99	--	--	--	--	--	--	--	--
			10	40,000	7.9	14.7		5.4	52	--	--	--	--	--	--	--	--
			20	42,000	7.8	14.6		4.7	46	2.2	--	1.7	0.0	0.00	0.00	--	0.10
June 11	1350	2	1	450	8.1	29.8	28	8.2	108	--	--	--	--	--	--	--	--
			5	450	8.2	28.6		7.2	92	--	--	--	--	--	--	--	--
			10	640	8.2	28.1		6.8	86	--	--	--	--	--	--	--	--
			13	450	8.3	28.0		6.8	86	--	--	--	--	--	--	--	--
			15	600	8.5	28.0		6.7	85	--	--	--	--	--	--	--	--
			16	750	8.4	28.0		6.7	85	--	--	--	--	--	--	--	--
			19	7,000	8.2	27.4		4.0	51	--	--	--	--	--	--	--	--
								Line 8. Colorado River									
Jan 29	1435	2	1	7,700	8.2	18.4	56	10.2	107	1.4	--	5.7	0.0	0.00	0.01	--	0.08
			5	11,000	8.2	18.3		10.4	110	--	--	--	--	--	--	--	--
			7.5	31,000	7.8	16.5		7.8	79	--	--	--	--	--	--	--	--
			10	37,000	8.0	16.0		7.8	78	--	--	--	--	--	--	--	--
			20	42,000	8.0	14.4		5.8	56	--	--	--	--	--	--	--	--
			26	42,000	7.9	14.6		5.5	53	2.5	--	0.4	0.0	0.00	0.00	--	0.05
May 7	1440	2	1	290	7.5	23.6	5	7.0	82	2.6	--	9.7	0.7	QN***	QN	0.18	0.22
			10	290	7.5	23.5		7.0	82	--	--	--	--	--	--	--	--
			20	310	7.5	23.5		6.8	80	--	--	--	--	--	--	--	--
			39	290	7.5	23.5		6.9	81	3.1	--	10	0.4	QN	QN	0.16	0.28
June 11	1335	2	1	650	7.1	28.5	29	7.8	99	--	--	--	--	--	--	--	--
			7.5	900	7.2	28.0		7.3	92	--	--	--	--	--	--	--	--
			10	1,400	7.3	27.8		7.1	90	--	--	--	--	--	--	--	--
			12.5	8,800	6.9	27.3		4.5	57	--	--	--	--	--	--	--	--
			15	20,000	7.4	27.0		2.4	32	--	--	--	--	--	--	--	--
			20	23,000	7.4	27.2		1.8	24	--	--	--	--	--	--	--	--
								[illegible]									
May 7	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	--	[illegible]	[illegible]	[illegible]	--	9.5	0.4	QN	QN	0.18	0.32
			5	310	7.4	23.5		[illegible]	[illegible]	--	--	--	--	--	--	--	--
			10	310	7.4	23.5		6.8	80	--	--	--	--	--	--	--	--
			15	310	7.4	23.5		6.6	78	--	--	--	--	--	--	--	--
			20	310	7.5	23.6		6.7	79	2.6	--	9.5	0.6	QN	QN	0.14	0.33
June 11	1255	2	1	2,200	6.9	28.2	41	8.0	103	0.9	0.0	10	0.4	QN	QN	0.07	0.12
			3	2,800	6.6	28.3		8.2	105	--	--	--	--	--	--	--	--
			5	8,800	6.7	27.8		7.2	94	--	--	--	--	--	--	--	--
			7.5	10.000	6.7	27.8		6.9	90	--	--	--	--	--	--	--	--
			10	31,000	7.0	27.7		6.0	86	--	--	--	--	--	--	--	--
			18	40,000	7.1	27.6		6.2	91	1.5	--	1.8	0.0	QN	QN	0.05	0.06
								Line 10. Colorado River									
Jan 29	1515	2	1	23,000	8.1	17.9	102	9.5	100	2.4	--	3.8	0.0	QN	QN	--	0.06
			5	37,000	8.1	16.4		8.3	84	--	--	--	--	--	--	--	--
			10	44,000	8.1	16.4		8.2	83	--	--	--	--	--	--	--	--
			13	42,000	8.0	16.6		8.3	85	1.7	--	0.8	0.0	QN	QN	--	0.04
May 7	1405	2	1	410	7.4	23.5	5	6.9	81	--	--	--	--	--	--	--	--
			5	410	7.4	23.5		6.9	81	--	--	--	--	--	--	--	--
			10	380	7.4	23.5		6.9	81	--	--	--	--	--	--	--	--
			15	390	7.4	23.5		6.8	80	--	--	--	--	--	--	--	--
			20	400	7.4	23.6		6.2	73	--	--	--	--	--	--	--	--
			24	410	7.3	23.6		6.6	78	--	--	--	--	--	--	--	--
June 11	1235	2	1	8,600	7.7	28.3	44	8.1	105	--	--	--	--	--	--	--	--
			3	8,800	7.7	28.1		8.1	105	--	--	--	--	--	--	--	--
			5	13,000	7.9	27.4		7.2	92	--	--	--	--	--	--	--	--
			7.5	17,000	7.9	27.5		[illegible]	97	--	--	--	--	--	--	--	--
			10	42,000	8.0	27.7		[illegible]	93	--	--	--	--	--	--	--	--
			16	42,000	7.9	27.7		[illegible]	93	--	--	--	--	--	--	--	--

TABLE 2.5-4 (Continued)

NUTRIENT AND OTHER ENVIRONMENTAL CHARACTERISTICS OF WATER IN THE COLORADO ESTUARY, 1969 WATER YEAR

Date of Collection	Time (24 hr)	Site	Depth Below Water Surface (ft)	Specific Conductance (micromhos at 25° C)	pH**	Temperature (°C)	Secchi Disk transparency (cm)**	Dissolved Oxygen Concentration**	Dissolved Oxygen Percent Saturation	Biochemical Oxygen Demand (BOD)	Chemical Oxygen Demand (COD)	Silica (SiO_2)	Nitrate Nitrogen (N)	Ammonia Nitrogen (N)	Nitrite Nitrogen (N)	Orthophosphate as phosphorus (P)	Total Phosphorus (P)
								Line 11. Colorado River									
May 7	1345	2	1	560	7.6	23.9	--	6.2	73	2.8	--	9.5	0.6	QN***	QN	0.13	0.29
			5	580	7.6	23.8		6.2	73	--	--	--	--	--	--	--	--
			10	580	7.6	23.8		6.2	73	--	--	--	--	--	--	--	--
			18	580	7.5	23.8		6.0	71	3.3	--	9.6	0.5	QN	QN	0.13	0.30
June 11	1225	2	1	21,000	7.8	27.9	65	7.7	105	--	--	--	--	--	--	--	--
			5	21,000	7.9	27.8		7.4	101	--	--	--	--	--	--	--	--
			7.3	34,000	8.0	27.7		6.5	94	--	--	--	--	--	--	--	--
			10	42,000	8.1	27.4		6.5	96	--	--	--	--	--	--	--	--
			16	42,000	8.0	27.7		6.2	93	--	--	--	--	--	--	--	--
								Line 12. Colorado River									
Jan. 29	1535	2	1	29,000	8.2	17.6	107	9.0	94	2.3	--	3.4	0.0	0.00	0.00	--	0.05
			5	44,000	8.2	16.2		8.0	80	--	--	--	--	--	--	--	--
			10	44,000	8.2	15.9		7.9	79	--	--	--	--	--	--	--	--
			16.5	44,000	8.2	16.0		7.4	74	1.7	--	0.4	0.0	0.00	0.00	--	0.05
May 7	1330	2	1	340	7.5	23.7	6	6.6	78	--	--	--	--	--	--	--	--
			5	360	7.5	23.6		6.6	78	--	--	--	--	--	--	--	--
			10	380	7.5	23.6		6.6	78	--	--	--	--	--	--	--	--
			15	400	7.6	23.6		6.4	75	--	--	--	--	--	--	--	--
			22	2,100	7.6	23.6		5.9	79	--	--	--	--	--	--	--	--
June 11	1215	2	1	34,000	7.8	27.9	62	7.5	109	--	--	--	--	--	--	--	--
			5	38,000	7.8	27.7		7.5	110	--	--	--	--	--	--	--	--
			10	40,000	7.9	27.6		7.4	109	--	--	--	--	--	--	--	--
			17	40,000	8.0	27.3		6.5	94	--	--	--	--	--	--	--	--
								Parkers Cut									
May 7	1725	-	1	410	7.7	23.8	4	6.3	74	--	--	--	--	--	--	--	--
			5.5	520	7.7	24.0		6.2	73	--	--	--	--	--	--	--	--
June 11	1200	-	1	34,000	7.9	28.0	25	7.7	112	--	--	--	--	--	--	--	--
			5	36,000	7.8	28.4		7.4	107	--	--	--	--	--	--	--	--
								Line 13. Colorado River									
Jan. 29	1555	2	1	46,000	8.3	15.9	--	8.3	83	2.0	--	0.2	0.0	0.00	0.00	--	0.05
			5	46,000	8.3	15.9		8.3	83	--	--	--	--	--	--	--	--
			11.5	46,000	8.3	15.8		8.5	85	1.4	--	0.0	0.0	0.00	0.00	--	0.19
May 7	1305	2	1	1.700	7.6	23.6	8	7.0	82	2.2	--	8.9	0.5	QN	QN	0.10	0.18
			5	6.000	7.7	23.6		7.0	84	--	--	--	--	--	--	--	--
			7	6,200	7.7	23.6		7.0	84	--	--	--	--	--	--	--	--
			10	17,000	7.9	23.5		7.1	89	--	--	--	--	--	--	--	--
			17	30,000	8.0	23.7		7.0	92	2.4	--	2.3	0.2	QN	QN	0.05	0.08
	1700	2	1	490	7.7	24.0	--	6.4	75	--	--	--	--	--	--	--	--
			5	450	7.7	24.0		6.4	75	--	--	--	--	--	--	--	--
			10	470	7.8	24.0		6.4	75	--	--	--	--	--	--	--	--
			17.5	520	8.0	24.4		5.0	59	--	--	--	--	--	--	--	--
June 11	1115	2	1	36,000	8.3	27.4	35	7.3	103	1.5	--	2.7	0.1	QN	QN	0.04	0.06
			5	38,000	8.3	27.4		7.0	100	--	--	--	--	--	--	--	--
			10	40,000	8.4	27.3		6.8	99	--	--	--	--	--	--	--	--
			15	40,000	8.4	27.3		6.7	97	--	--	--	--	--	--	--	--
			18	42,000	8.4	27.4		6.5	96	1.6	--	1.6	0.1	QN	QN	0.02	0.04
								Line 14. Colorado River									
May 7	1235	1	1	2,400	7.8	24.0	8	7.1	85	--	--	--	--	--	--	--	--
			3	8,000	7.8	23.6		7.0	84	--	--	--	--	--	--	--	--
			5	22,000	8.0	23.9		7.2	91	--	--	--	--	--	--	--	--
			10.5	30,000	8.1	24.0		7.0	92	--	--	--	--	--	--	--	--
	1225	2	1	2,000	7.8	24.0	8	7.0	83	--	--	--	--	--	--	--	--
			3	6,200	7.7	23.8		7.1	86	--	--	--	--	--	--	--	--
			5	20,000	8.0	23.9		7.1	90	--	--	--	--	--	--	--	--
			6.5	26,000	8.0	23.9		6.9	85	--	--	--	--	--	--	--	--
	1710	2	1	1,200	7.7	23.9	--	6.6	78	--	--	--	--	--	--	--	--
			3	1,200	7.7	23.9		6.6	78	--	--	--	--	--	--	--	--
			6	1,300	7.7	24.0		6.4	75	--	--	--	--	--	--	--	--
June 11	1050	2	1	35,000	8.3	27.5	43	7.6	110	--	--	--	--	--	--	--	--
			5	36,000	8.3	27.4		7.6	107	--	--	--	--	--	--	--	--

*Data from Reference 2.5-10. Results in milligrams per liter, except as indicated.
**Determined at data-collection site.
***QN = qualitative test negative

TABLE 2.5-5

CHEMICAL ANALYSES OF WATER FROM THE COLORADO ESTUARY, 1969 WATER YEAR*

Date of Collection	Time (24 hr)	Site	Depth Below Water Surface (ft)	Specific Conductance (micromhos at 25°C)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)**	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Dissolved Solids (Calculated)	Hardness $CaCO_3$: Calcium, Magnesium	Hardness $CaCO_3$: Noncarbonate	Density (g/ml at 20°C)
Line 1. Colorado River															
May 7	1530	2	10	212	27	60	9.1		97	10	13	126	92	12	--
June 11	1510	2	4	549	54	19	34		200	36	59	310	212	48	--
Line 2. Colorado River															
May 7	1545	2	17.5	291	34	7.3	14		118	17	19	163	115	18	--
Line 2b. Colorado River															
May 7	1600	2	3	1,880	54	14	367		135	646	150	1,320	192	82	--
Line 3. Colorado River															
Jan. 29	1315	2	1	680	53	19	65		200	56	91	389	212	48	--
Line 8. Colorado River															
May 7	1440	2	39	311	36	8.3	15		125	20	22	175	124	22	--
Line 9. Colorado River															
May 7	1425	2	20	319	36	9.0	17		128	20	24	182	127	22	--
June 11	1255	2	1	2,180	58	50	351		161	114	610	1,270	352	220	--
			18	35,100	278	998	6,910		136	1,860	12,600	22,700	4,800	4,690	1.015
Line 11. Colorado River															
May 7	1345	2	1	518	38	14	49		128	28	86	291	154	49	--
Line 13. Colorado River															
Jan. 29	1600	2	11.5	46,500	345	1,160	8,770		142	2,490	15,600	28,400	5,650	5,530	1.018
May 7	1305	2	1	1,570	42	32	212		120	68	372	797	238	140	--
			17	29,200	210	670	5,730		125	1,480	10,000	18,200	3,280	3,180	--
June 11	1115	2	1	32,500	270	828	6,670		140	1,760	11,800	21,400	4,080	3,970	1.013
			18	35,000	272	992	6,680		136	1,880	12,200	22,100	4,750	4,640	1.014

* Data from Reference 2.5-10. Results in milligrams per liter, except as indicated.

** Included in sodium-ion concentration.

TABLE 2.5-6

ANALYSES FOR SELECTED IONS IN WATER FROM THE COLORADO ESTUARY, 1969 WATER YEAR*

Date of Collection	Time (24 hr)	Site	Depth Below Water Surface (ft)	Specific Conductance (micromhos at 25°C)	Iron (Fe)	Manganese (Mn)	Lithium (Li)	Fluoride (F) (mg/l)	Boron (B)	Chromium VI (Cr)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Arsenic (As)	Selenium (Se)	Cadmium (Cd)	Bromide (Br) (mg/l)	Iodide (I) (mg/l)	Strontium (Sr)
								Line 1. Colorado River											
May 7	1530	2	10	212	--	--	--	0.2	--	--	--	--	--			--	--	--	--
June 11	1510	2	4	549	--	--	--	0.3	--	--	--	--	--			--	--	--	--
								Line 2. Colorado River											
May 7	1545	2	17.5	291	--	--	--	0.2	--	--	--	--	--			--	--	--	--
								Line 2b. Colorado River											
May 7	1600	2	3	1,880	--	--	--	0.3	--	--	--	--	--			--	--	--	--
								Line 3. Colorado River											
Jan. 29	1315	2	1	680	--	--	--	0.2	--	--	--	--	--			--	0.62	0.052	--
								Line 8. Colorado River											
May 7	1440	2	39	311	--	--	--	0.2	--	--	--	--	--			--	--	--	--
								Line 9. Colorado River											
May 7	1425	2	20	319	--	--	--	0.2	--	--	--	--	--			--	--	--	--
June 11	1255	2	1	2,180	--	--	--	0.3	--	--	--	--	--			--	--	--	--
			18	35,100	--	--	--	0.7	--	--	--	--	--			--	--	--	--
								Line 11. Colorado River											
May 7	1345	2	1	518	--	--	--	0.2	--	--	--	--	--			--	--	--	--
								Line 13. Colorado River											
Jan. 29	1600	2	11.5	46,500	--	--	--	0.9	--	--	--	--	--			--	62	0.035	--
May 7	1305	2	1	1,570	--	--	--	0.2	--	--	--	--	--			--	--	--	--
			17	29,200	--	--	--	0.6	--	--	--	--	--			--	--	--	--
June 11	1115	2	1	32,500	--	--	--	0.7	--	--	--	--	--			--	--	--	--
			18	35,000	--	--	--	0.7	--	--	--	--	--			--	--	--	--

*Data from Reference 2.5-10. Results in micrograms per liter, except as indicated.

TABLE 2.5-6

ANALYSES FOR SELECTED IONS IN WATER FROM THE COLORADO ESTUARY, 1969 WATER YEAR*

Date of Collection	Time (24 hr)	Site	Depth Below Water Surface (ft)	Specific Conductance (micromhos at 25°C)	Iron (Fe)	Manganese (Mn)	Lithium (Li)	Fluoride (F) (mg/l)	Boron (B)	Chromium VI (Cr)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Arsenic (As)	Selenium (Se)	Cadmium (Cd)	Bromide (Br) (mg/l)	Iodide (I) (mg/l)	Strontium (Sr)
								Line 1. Colorado River											
May 7	1530	2	10	212	--	--	--	0.2	--	--	--	--	--			--	--	--	--
June 11	1510	2	4	549	--	--	--	0.3	--	--	--	--	--			--	--	--	--
								Line 2. Colorado River											
May 7	1545	2	17.5	291	--	--	--	0.2	--	--	--	--	--			--	--	--	--
								Line 2b. Colorado River											
May 7	1600	2	3	1,880	--	--	--	0.3	--	--	--	--	--			--	--	--	--
								Line 3. Colorado River											
Jan. 29	1315	2	1	680	--	--	--	0.2	--	--	--	--	--			--	0.62	0.052	--
								Line 8. Colorado River											
May 7	1440	2	39	311	--	--	--	0.2	--	--	--	--	--			--	--	--	--
								Line 9. Colorado River											
May 7	1425	2	20	319	--	--	--	0.2	--	--	--	--	--			--	--	--	--
June 11	1255	2	1	2,180	--	--	--	0.3	--	--	--	--	--			--	--	--	--
			18	35,100	--	--	--	0.7	--	--	--	--	--			--	--	--	--
								Line 11. Colorado River											
May 7	1345	2	1	518	--	--	--	0.2	--	--	--	--	--			--	--	--	--
								Line 13. Colorado River											
Jan. 29	1600	2	11.5	46,500	--	--	--	0.9	--	--	--	--	--			--	62	0.035	--
May 7	1305	2	1	1,570	--	--	--	0.2	--	--	--	--	--			--	--	--	--
			17	29,200	--	--	--	0.6	--	--	--	--	--			--	--	--	--
June 11	1115	2	1	32,500	--	--	--	0.7	--	--	--	--	--			--	--	--	--
			18	35,000	--	--	--	0.7	--	--	--	--	--			--	--	--	--

*Data from Reference 2.5-10. Results in micrograms per liter, except as indicated.

TABLE 2.5-7

QUALITY OF WATER IN THE COLORADO ESTUARY, 1970 WATER YEAR NUTRIENT AND OHTER ENVIRONMENTAL CHARACTERISTICS*

Date of Collection	Time (24 hr)	Site	Depth Below Water Surface (ft)	Specific Conductance (micromhos at 25°C)**	pH**	Temperature (°C)**	Secchi Disk Transparency (cm)**	Dissolved Oxygen Concentration**	Dissolved Oxygen Percent Saturation	Biochemical Oxygen Demand (BOD)	Chemical Oxygen Demand (COD)	Silica (SiO_2)	Nitrate Nitrogen (N)	Ammonia Nitrogen (N)	Nitrite Nitrogen (N)	Orthophosphate as Phosphorus (P)	Total Phosphorus (P)
Line 1. Colorado River																	
Feb. 25	1110	2	1	560	8.3	15.1	41	10.3	101	3.8	11	10	0.1	0.05	0.08	0.07	0.16
			10	590	8.3	15.1		10.3	101	--	--	--	--	--	--	--	--
			17	600	8.4	15.0		10.4	102	5.9	--	11	0.4	0.00	0.06	0.06	0.14
Apr. 20	1610	2	1	360	8.2	23.5	25	9.2	107	--	--	--	--	--	--	--	--
			5	360	8.2	23.5		9.0	105	--	--	--	--	--	--	--	--
			17	370	8.1	23.6		9.0	105	0.8	5.0	7.2	0.4	0.00	0.00	0.08	0.12
Line 2. Colorado River																	
Feb. 25	1130	2	1	540	8.3	15.0	--	9.9	97	3.4	--	9.4	0.3	0.00	0.13	0.03	0.20
			5	540	8.3	15.1		9.8	96	--	--	--	--	--	--	--	--
			16	550	8.3	15.1		9.6	94	6.9	--	9.5	0.2	0.06	0.02	0.11	0.34
Apr. 20	1630	2	1	370	8.1	23.8	37	8.6	101	--	--	--	--	--	--	--	--
			15	390	8.1	23.9		8.0	94	0.8	6.4	7.4	0.2	0.05	0.01	0.05	0.04
Line 3. Colorado River																	
Feb. 25	1145	2	1	570	8.3	15.0	52	9.8	96	--	--	--	--	--	--	--	--
			5	570	8.3	15.0		9.8	97	--	--	--	--	--	--	--	--
			15	570	8.3	15.0		10.2	100	--	--	--	--	--	--	--	--
Line 4. Colorado River																	
Feb. 25	1300	2	1	560	8.3	15.4	51	9.9	98	--	--	--	--	--	--	--	--
			5	560	8.3	15.4		10.0	99	--	--	--	--	--	--	--	--
			16	560	8.3	15.4		9.8	97	--	--	--	--	--	--	--	--
Line 5. Colorado River																	
Feb. 25	1320	2	1	560	8.4	15.7	--	10.9	108	--	--	--	--	--	--	--	--
			5	560	8.4	15.7		10.8	107	--	--	--	--	--	--	--	--
			13	560	8.4	15.8		10.6	106	--	--	--	--	--	--	--	--
Line 6. Colorado River																	
Feb. 25	1340	2	1	980	8.4	15.5	--	10.9	108	3.7	6.7	9.0	0.2	0.00	0.11	0.06	0.16
			3	1,000	8.4	15.5		10.8	107	--	--	--	--	--	--	--	--
			5	11,000	8.4	15.4		10.5	107	--	--	--	--	--	--	--	--
			10	16,000	8.1	15.1		7.8	81	--	--	--	--	--	--	--	--
			12	33,000	7.9	14.8		5.0	56	1.7	42	3.5	0.1	0.35	0.10	0.07	0.13
Line 7. Colorado River																	
Feb. 25	1400	2	1	1,600	8.5	15.7	61	11.7	116	--	--	--	--	--	--	--	--
			5	2,200	8.4	15.4		10.7	107	--	--	--	--	--	--	--	--
			8	11,000	8.3	15.2		9.5	96	--	--	--	--	--	--	--	--
			9	30,000	8.0	14.8		6.4	71	--	--	--	--	--	--	--	--
			10	34,000	8.0	14.7		6.0	67	--	--	--	--	--	--	--	--
			12	34,000	8.0	14.6		5.5	62	--	--	--	--	--	--	--	--
			15	34,000	7.9	14.9		5.4	61	--	--	--	--	--	--	--	--
Line 8. Colorado River																	
Feb. 25	1420	2	1	2,400	8.5	15.6	64	11.6	116	4.6	--	9.0	0.1	0.00	0.06	0.05	0.15
			5	2,600	8.5	15.5		11.5	115	--	--	--	--	--	--	--	--
			8	2,700	8.5	15.5		11.4	114	--	--	--	--	--	--	--	--
			10	32,000	8.0	14.8		7.1	79	--	--	--	--	--	--	--	--
			15	37,000	8.0	14.6		5.7	64	--	--	--	--	--	--	--	--
			20	41,000	8.0	14.5		5.2	60	--	--	--	--	--	--	--	--
			27	42,000	8.0	14.6		5.1	59	1.5	--	1.6	0.1	0.44	0.07	0.06	0.14
Apr. 20	1530	2	1	370	8.3	23.8	41	9.0	106	--	--	--	--	--	--	--	--
			5	370	8.2	23.9		9.3	109	--	--	--	--	--	--	--	--
			15	370	8.2	24.0		9.8	115	--	--	--	--	--	--	--	--
			22	390	8.2	24.1		9.9	116	0.9	--	7.7	0.3	0.01	0.01	0.06	0.12
May 21	0905	2	1	440	7.6	23.5	--	8.0	93	3.3	--	9.4	1.1	0.12	0.02	0.17	0.44
			5	440	7.6	23.5		8.0	93	--	--	--	--	--	--	--	--
			10	450	7.6	23.5		8.0	93	--	--	--	--	--	--	--	--
			15	460	7.6	23.5		8.1	94	--	--	--	--	--	--	--	--
			20	485	7.6	23.5		8.1	94	--	--	--	--	--	--	--	--
			23	850	7.7	23.5		8.2	95	2.5	--	9.2	1.1	0.05	0.02	0.18	0.52
June 9	1310	2	1	550	7.9	26.1	23	5.3	101	2.1	--	9.0	0.5	0.03	0.00	0.04	0.14
			5	550	7.9	26.1		8.2	100	--	--	--	--	--	--	--	--
			10	550	7.9	26.2		8.3	101	--	--	--	--	--	--	--	--
			15	655	7.9	26.2		8.2	100	--	--	--	--	--	--	--	--
			22	750	7.9	26.2		8.2	100	1.9	--	9.6	0.6	0.12	0.02	0.04	0.15

TABLE 2.5-7 (Continued)

QUALITY OF WATER IN THE COLORADO ESTUARY, 1970 WATER YEAR NUTRIENT AND OTHER ENVIRONMENTAL CHARACTERISTICS*

Date of Collection	Time (24 hr)	Site	Depth Below Water Surface (ft)	Specific Conductance (micromhos at 25°C)**	pH**	Temperature (°C)**	Secchi Disk Transparency (cm)**	Dissolved Oxygen Concentration**	Dissolved Oxygen Percent Saturation	Biochemical Oxygen Demand (BOD)	Chemical Oxygen Demand (COD)	Silica (SiO_2)	Nitrate Nitrogen (N)	Ammonia Nitrogen (N)	Nitrite Nitrogen (N)	Orthophosphate as Phosphorus (P)	Total Phosphorus (P)
							Line 8a. Intracoastal Waterway										
Apr. 20	1515	2	1	2,400	8.3	24.8	46	9.2	111	--	--	--	--	--	--	--	--
			5	3,400	8.2	24.7		9.2	111	--	--	--	--	--	--	--	--
			9	6,500	8.0	24.3		7.8	94	--	--	--	--	--	--	--	--
May 21	1025	2	1	20,000	7.7	24.2	56	6.6	84	--	--	--	--	--	--	--	--
			3	25,000	7.7	24.1		6.3	81	--	--	--	--	--	--	--	--
			5	33,000	7.7	24.2		6.0	80	--	--	--	--	--	--	--	--
			10	40,000	7.7	24.4		5.7	78	--	--	--	--	--	--	--	--
			17	40,000	7.7	24.6		6.2	86	--	--	--	--	--	--	--	--
June 9	1510	2	1	3,600	8.0	26.5	36	8.2	102	2.0	--	8.5	0.5	0.05	0.01	0.04	0.10
			5	5,200	8.0	26.5		7.8	98	--	--	--	--	--	--	--	--
			10	7,000	7.8	26.4		7.4	92	--	--	--	--	--	--	--	--
			16	11,000	7.8	26.6		7.0	89	2.5	--	7.4	0.3	0.06	0.01	0.03	0.11
							Line 9. Colorado River										
Feb. 25	1450	2	1	11,000	8.3	15.6	76	10.9	111	3.0	--	6.8	0.2	0.00	0.06	0.05	0.10
			5	16,000	8.2	15.3		9.7	102	--	--	--	--	--	--	--	--
			8	28,000	8.1	15.1		8.0	88	--	--	--	--	--	--	--	--
			11	30,000	8.0	15.1		7.4	82	3.8	--	4.0	0.1	0.14	0.08	0.06	0.12
Apr. 20	1425	2	1	340	8.3	24.0	39	8.9	105	--	--	--	--	--	--	--	--
			5	370	8.2	23.8		8.8	104	--	--	--	--	--	--	--	--
			11.5	390	8.2	23.9		8.6	101	1.4	6.4	7.5	0.4	0.03	0.01	0.07	0.12
May 21	0930	2	1	400	7.5	23.5	8	8.0	93	2.4	--	9.5	1.1	0.06	0.10	0.18	0.33
			5	440	7.5	23.5		8.0	93	--	--	--	--	--	--	--	--
			10	720	7.6	23.5		8.0	93	--	--	--	--	--	--	--	--
			14	5,900	7.5	23.5		8.0	95	3.1	--	8.2	1.0	0.11	0.05	0.07	0.64
June 9	1330	2	1	460	8.0	26.4	30	8.6	105	2.4	0.6	9.8	0.6	0.10	0.00	0.04	0.10
			5	550	8.0	26.4		8.4	102	--	--	--	--	--	--	--	--
			10	850	8.0	26.3		8.2	100	--	--	--	--	--	--	--	--
			13	2,600	7.9	26.3		7.7	95	--	--	--	--	--	--	--	--
			16.5	7,500	7.7	27.0		6.8	86	1.9	19	7.4	0.2	0.07	0.01	0.04	0.09
	1600	2	1	550	7.9	26.3	28	8.4	102	--	--	--	--	--	--	--	--
			5	590	7.9	26.3		8.4	102	--	--	--	--	--	--	--	--
			8	650	7.9	26.3		8.2	100	--	--	--	--	--	--	--	--
			10	2,500	7.8	26.3		7.8	96	--	--	--	--	--	--	--	--
			12	11,500	7.7	27.1		6.3	81	--	--	--	--	--	--	--	--
							Line 10. Colorado River										
Apr. 20	1415	2	1	360	8.2	23.6	--	8.7	101	--	--	--	--	--	--	--	--
			5	360	8.2	23.6		8.8	102	--	--	--	--	--	--	--	--
			10	360	8.2	23.7		9.5	110	--	--	--	--	--	--	--	--
			17	370	7.9	23.7		9.6	112	--	--	--	--	--	--	--	--
May 21	0945	2	1	560	7.6	23.5	8	8.0	93	--	--	--	--	--	--	--	--
			5	650	7.6	23.5		8.0	93	--	--	--	--	--	--	--	--
			10	950	7.6	23.5		8.0	93	--	--	--	--	--	--	--	--
			14.5	2,300	7.5	23.5		8.1	95	--	--	--	--	--	--	--	--
							Line 11. Colorado River										
Feb. 25	1515	2	1	11,000	8.3	15.7	77	11.5	117	--	--	--	--	--	--	--	--
			5	12,000	8.3	15.6		11.3	116	--	--	--	--	--	--	--	--
			8	19,000	3.2	15.2		9.6	100	--	--	--	--	--	--	--	--
			10	31,000	8.0	15.0		8.0	89	--	--	--	--	--	--	--	--
			14	44,000	8.0	15.0		6.5	76	--	--	--	--	--	--	--	--
Apr. 20	1355	2	1	370	8.3	23.9	46	9.8	115	--	--	--	--	--	--	--	--
			5	430	8.3	23.8		9.8	115	--	--	--	--	--	--	--	--
			10	790	8.3	23.7		9.5	110	--	--	--	--	--	--	--	--
			12	1,200	8.2	23.7		9.5	110	--	--	--	--	--	--	--	--
			14	10,000	8.2	23.0		9.3	109	--	--	--	--	--	--	--	--
			15.5	41,000	8.0	21.6		7.5	99	--	--	--	--	--	--	--	--
	1730	2	1	560	7.9	23.5	--	--	--	--	--	--	--	--	--	--	--
			15.5	6,000	7.8	23.3		--	--	--	--	--	--	--	--	--	--
May 21	0955	2	1	800	7.5	23.5	8	8.0	93	--	--	--	--	--	--	--	--
			5	1,000	7.5	23.5		8.0	92	--	--	--	--	--	--	--	--
			10	1,400	7.6	23.5		8.0	93	--	--	--	--	--	--	--	--
			15	6,500	7.6	23.5		8.0	95	--	--	--	--	--	--	--	--

TABLE 2.5-7 (Continued)

QUALITY OF WATER IN THE COLORADO ESTUARY, 1970 WATER YEAR NUTRIENT AND OTHER ENVIRONMENTAL CHARACTERISTICS*

Date of Collection	Time (24 hr)	Site	Depth Below Water Surface (ft)	Specific Conductance (micromhos at 25°C)**	pH**	Temperature (°C)**	Secchi Disk Transparency (cm)**	Dissolved Oxygen Concentration**	Dissolved Oxygen Percent Saturation	Biochemical Oxygen Demand (BOD)	Chemical Oxygen Demand (COD)	Silica (SiO_2)	Nitrate Nitrogen (N)	Ammonia Nitrogen (N)	Nitrite Nitrogen (N)	Orthophosphate as Phosphorus (P)	Total Phosphorus (P)
Line 12. Colorado River																	
Apr. 20	1330	2	1	590	8.3	24.0	57	8.7	102	--	--	--	--	--	--	--	--
			5	920	8.4	24.0		8.3	104	--	--	--	--	--	--	--	--
			10	1,000	8.5	23.7		8.7	101	--	--	--	--	--	--	--	--
			12.5	1,200	8.2	23.8		8.6	101	--	--	--	--	--	--	--	--
			14	9,500	8.1	23.5		7.9	94	--	--	--	--	--	--	--	--
			15	35,000	8.0	22.0		6.5	83	--	--	--	--	--	--	--	--
			15.5	40,000	8.0	21.6		6.0	79	--	--	--	--	--	--	--	--
	1740	2	1	560	7.9	23.5	43	--	--	--	--	--	--	--	--	--	--
			14	4,000	7.8	23.0		--	--	--	--	--	--	--	--	--	--
			16	44,000	7.6	20.5		--	--	1.1	37	1.6	0.1	0.08	0.00	0.01	0.05
May 21	1000	2	1	1,400	7.6	23.0	18	8.0	92	--	--	--	--	--	--	--	--
			5	1,600	7.6	23.0		8.0	92	--	--	--	--	--	--	--	--
			10	2,200	7.7	23.0		7.7	90	--	--	--	--	--	--	--	--
			15	28,000	7.9	25.0		7.2	95	--	--	--	--	--	--	--	--
			20	28,000	7.9	25.0		7.2	95	--	--	--	--	--	--	--	--
June 9	1405	2	1	2,400	8.2	25.4	39	8.6	106	--	--	--	--	--	--	--	--
			5	3,500	8.1	26.4		7.9	98	--	--	--	--	--	--	--	--
			7	10,000	7.9	26.1		7.5	91	--	--	--	--	--	--	--	--
			8	32,000	7.9	25.8		7.2	99	--	--	--	--	--	--	--	--
			10	36,000	8.0	25.7		7.1	99	--	--	--	--	--	--	--	--
			15	39,000	8.0	25.7		7.3	101	--	--	--	--	--	--	--	--
			20	38,000	8.0	25.7		7.3	101	--	--	--	--	--	--	--	--
Parkers Cut																	
Feb. 25	1615	--	1	13,000	8.3	15.5	76	--	--	--	--	--	--	--	--	--	--
			5	16,000	8.2	15.3		--	--	--	--	--	--	--	--	--	--
			10	32,000	8.0	14.9		--	--	--	--	--	--	--	--	--	--
June 9	1440	-	1	6,500	7.4	27	46	7.9	100	--	--	--	--	--	--	--	--
			3	12,000	7.4	27		7.7	99	--	--	--	--	--	--	--	--
			5	16,000	7.3	27.5		7.3	96	--	--	--	--	--	--	--	--
			7	24,000	7.3	28		6.8	93	--	--	--	--	--	--	--	--
	1445	-	1	5,000	8.0	26.8	36	8.6	109	--	--	--	--	--	--	--	--
			3	13,000	8.0	26.6		8.5	109	--	--	--	--	--	--	--	--
			6	15,000	7.9	26.5		8.2	105	--	--	--	--	--	--	--	--
	1605	-	1	4,800	--	27.5	--	8.0	101	--	--	--	--	--	--	--	--
			3	6,500	--	27.5		8.0	103	--	--	--	--	--	--	--	--
			4	19,000	--	27.5		7.6	101	--	--	--	--	--	--	--	--
			5	26,000	--	27		7.4	100	--	--	--	--	--	--	--	--
			12	22,000	--	27		7.5	100	--	--	--	--	--	--	--	--
	1630	-	1	12,000	7.4	27.5	--	8.9	116	--	--	--	--	--	--	--	--
			5	14,000	7.3	27		8.1	105	--	--	--	--	--	--	--	--
			7	20,000	7.3	27		7.4	99	--	--	--	--	--	--	--	--
			10	41,000	7.3	26		6.3	90	--	--	--	--	--	--	--	--
			12	42,000	7.3	26		6.2	90	--	--	--	--	--	--	--	--
Line 13. Colorado River																	
Feb. 25	1540	2	1	12,000	8.3	15.6	64	--	--	3.0	14	7.0	0.2	0.06	0.06	0.06	0.17
			3	13,000	8.3	15.6		--	--	--	--	--	--	--	--	--	--
			5	23,000	8.3	15.3		--	--	--	--	--	--	--	--	--	--
			8	23,000	8.2	15.1		--	--	--	--	--	--	--	--	--	--
			11	31,000	8.0	15.0		--	--	2.7	--	3.8	0.2	0.06	0.00	0.04	0.08
Apr. 20	1300	2	1	980	8.3	24.2	41	8.6	101	1.0	--	6.9	0.8	0.00	0.01	0.06	0.10
			3	2,600	8.2	24.0		8.6	102	--	--	--	--	--	--	--	--
			5	3,700	8.2	23.8		8.2	98	--	--	--	--	--	--	--	--
			6.5	4,000	8.1	23.8		8.2	98	--	--	--	--	--	--	--	--
			8.5	6,500	8.1	23.8		8.1	98	1.2	--	6.7	1.7	0.03	0.01	0.07	0.07
May 21	1015	2	1	6,000	7.6	24.0	15	7.8	94	1.6	--	7.8	1.6	0.09	0.04	0.05	0.16
			5	9,500	7.9	24.0		7.8	94	--	--	--	--	--	--	--	--
			11.5	30,000	7.9	25.0		7.3	97	2.0	--	[illegible]	0.3	0.33	0.03	0.03	0.16
June 9	1340	2	1	4,700	7.2	27	--	8.0	100	2.0	--	5.2	0.5	0.47	0.01	0.04	0.08
			3	5,000	7.1	27		7.9	99	--	--	--	--	--	--	--	--
			4	11,000	7.1	27		7.7	97	--	--	--	--	--	--	--	--
			5	25,000	7.2	27		7.5	101	--	--	--	--	--	--	--	--
			12	44,000	7.1	26.5		6.7	99	2.4	--	[illegible]	0.1	0.11	0.00	0.03	0.08

TABLE 2.5-7 (Continued)

QUALITY OF WATER IN THE COLORADO ESTUARY, 1970 WATER YEAR NUTRIENT AND OTHER ENVIRONMENTAL CHARACTERISTICS*

Date of Collection	Time (24 hr)	Site	Depth Below Water Surface (ft)	Specific Conductance (micromhos at 25°C)**	pH**	Temperature (°C)**	Secchi Disk Transparency (cm)**	Dissolved Oxygen Concentration**	Dissolved Oxygen Percent Saturation	Biochemical Oxygen Demand (BOD)	Chemical Oxygen Demand (COD)	Silica (SiO_2)	Nitrate Nitrogen (N)	Ammonia Nitrogen (N)	Nitrite Nitrogen (N)	Orthophosphate as Phosphorus (P)	Total Phosphorus (P)
								Line 13a. Colorado River									
Apr. 20	1315	2	1	4,300	8.2	24.3	41	8.4	100	--	--	--	--	--	--	--	--
			2.5	8,500	8.1	24.3		8.0	96	--	--	--	--	--	--	--	--
			4	12,000	8.1	24.2		7.7	94	--	--	--	--	--	--	--	--
			6.5	22,000	7.9	24.0		6.2	78	--	--	--	--	--	--	--	--
May 21	1030	2	1	12,000	7.8	24.5	19	7.7	94	1.3	--	7.3	1.0	0.12	0.05	0.07	0.07
			5	14,000	7.8	25.0		7.6	95	--	--	--	--	--	--	--	--
			10	16,000	7.8	25.0		7.5	95	1.7	--	6.0	0.7	0.20	0.05	0.05	0.14
								Line 14. Colorado River									
Feb. 25	1600	2	1	14,000	8.2	15.7	76	--	--	--	--	--	--	--	--	--	--
			3	14,000	8.3	15.8		--	--	--	--	--	--	--	--	--	--
Apr. 20	1240	2	1	7,500	8.1	23.9	42	8.3	100	--	--	--	--	--	--	--	--
			3.5	12,000	8.0	23.7		8.1	98	--	--	--	--	--	--	--	--
May 21	1040	2	1	32,000	8.0	26.0	19	7.7	105	--	--	--	--	--	--	--	--
			4	30,000	8.0	26.0		7.8	107	--	--	--	--	--	--	--	--
June 9	1320	2	1	47,000	7.4	26.5	30	7.2	106	2.6	--	0.3	0.0	0.11	0.00	0.01	0.07
			7	44,000	7.4	27		7.4	110	3.1	--	0.8	0.0	0.11	0.00	0.07	0.11

*Data from Reference 2.5-11. Results in milligrams per liter, except as indicated.
**Determined at data-collection site.

TABLE 2.5-8

QUALITY OF WATER IN THE COLORADO ESTUARY, 1970 WATER YEAR CHEMICAL ANALYSES*

Date of Collection	Time (24 hr)	Site	Depth Below Water Surface (ft)	Specific Conductance (micromhos at 25° C)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)**	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Disolved solids (calculated)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Density (g/ml at 20°C)
Line 1. Colorado River															
Feb. 25	1110	2	17	647	71	19	42		253	41	66	376	256	48	
Apr. 20	1615	2	17	506	38	17	34		126	32	54	261	166	39	
Line 6. Colorado River															
Feb. 25	1340	2	12	30,400	260	815	5,950		175	1,510	10,800	19,400	4,000	3,860	
Line 8. Colorado River															
Feb. 25	1420	2	1	2,810	80	68	424		246	133	750	1,590	480	278	
		2	27	41,200	330	1,170	7,910		170	2,030	14,600	26,100	5,650	5,510	
Line 9. Colorado River															
Apr. 20	1425	2	11.5	526	--	--	--		--	32	56	--	--	--	
May 21	0930	2	1	--	--	--	--		--	28	20	--	--	--	
			14	5,920	80	127	981		92	284	1,740	3,290	720	618	
June 9	1330	2	1	624	44	16	52		168	35	75	322	174	30	
			16.5	11,100	107	227	1,990		149	480	3,480	6,370	1,200	1,080	
Line 12. Colorado River															
Apr. 20	1740	2	16	45,100	350	1,200	8,460		141	2,280	15,400	27,800	5,800	5,680	
Line 13. Colorado River															
Feb. 25	1540	2	1	11,700	145	272	1,990		220	522	3,600	6,650	1,480	1,300	
			11	28,600	235	781	5,050		181	1,320	9,400	16,900	3,800	3,650	
Apr. 20	1300	2	8.5	6,990	82	163	1,070		161	320	1,930	3,660	875	736	
May 21	1015	2	11.5	30,800	253	942	5,740		136	1,580	10,800	19,400	4,520	4,410	
June 9	1340	2	1	4,600	71	89	753		171	440	1,110	2,570	544	388	
Line 14. Colorado River															
June 9	1320	2	7	48,400	378	1,550	9,190		156	2,400	17,500	31,100	7,300	7,170	

*Data from Reference 2.5-11. Results in milligrams per liter, except as indicated.
**Included in sodium-ion concentration.

TABLE 2.5-9

QUALITY OF WATER IN THE COLORADO ESTUARY, 1970 WATER YEAR ANALYSES FOR SELECTED IONS*

Date of Collection	Time (24 hr)	Site	Depth Below Water Surface (ft)	Specific Conductance (micromhos at 25°C)	Iron (Fe)	Manganese (Mn)	Lithium (Li)	Fluoride (F) (mg/l)	Boron (B)	Chromium VI (Cr)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Arsenic (As)	Mercury (Hg)	Cadmium (Cd)	Bromide (Br) (mg/l)	Iodide (I) (mg/l)	Strontium (Sr)
								Line 1. Colorado River											
Feb. 25	1110	2	17	647	--	--	--	0.2	100	--	--	--	--	--	--	--	0.8	0.035	--
Apr. 20	1615	2	17	506	--	--	--	0.2	80	--	--	--	--	--	--	--	1.0	0.018	--
								Line 6. Colorado River											
Feb. 25	1340	2	12	30,400	--	--	--	0.6	2,700	--	--	--	--	--	--	--	19	0.037	--
								Line 8. Colorado River											
Feb. 25	1420	2	1	2,810	--	--	--	0.7	250	--	--	--	--	--	--	--	2.9	0.034	--
			27	41,200	--	--	--	0.3	3,500	--	--	--	--	--	--	--	38	0.037	--
								Line 9. Colorado River											
Apr. 20	1425	2	11.5	526	--	--	--	0.2	120	--	--	--	--	--	--	--	0.9	0.014	--
May 21	0930	2	1	--	--	--	--	0.3	80	--	--	--	--	--	--	--	1.3	0.013	--
			14	5,920	--	--	--	0.4	500	--	--	--	--	--	--	--	7.1	0.017	--
June 9	1330	2	1	624	--	--	--	0.2	80	--	--	--	--	--	--	--	2.9	0.018	--
			16.5	11,100	--	--	--	0.3	850	--	--	--	--	--	--	--	14	0.026	--
								Line 12. Colorado River											
Apr. 20	1740	2	16	45,100	--	--	--	0.7	1,500	--	--	--	--	--	--	--	60	0.029	--
								Line 13. Colorado River											
Feb. 25	1540	2	1	11,700	--	--	--	0.4	880	--	--	--	--	--	--	--	14	0.033	--
			11	28,600	--	--	--	0.6	2,200	--	--	--	--	--	--	--	32	0.028	--
Apr. 20	1300	2	8.5	6,990	--	--	--	0.3	610	--	--	--	--	--	--	--	7.6	0.018	--
May 21	1015	2	11.5	30,800	--	--	--	0.7	1,700	--	--	--	--	--	--	--	37	0.026	--
June 9	1340	2	1	4,600	--	--	--	0.2	380	--	--	--	--	--	--	--	8.6	0.021	--
								Line 14. Colorado River											
June 9	1320	2	7	48,400	--	--	--	0.7	4,600	--	--	--	--	--	--	--	55	0.020	--

*Data from Reference 2.5-11. Results in micrograms per liter, except as indicated.

TABLE 2.5-10

SOUTH TEXAS PROJECT, 1973, SALINITY* CALCULATED FROM FIELD MEASUREMENTS OF SPECIFIC CONDUCTANCE AND TEMPERATURE

Station (Figure 2.7-5)	June		July		August		September		October		November		December	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
1	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.2	0.2	0.1	0.1
2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.2	0.2	0.1	0.1
3	0.2	0.7	0.3	7.8	0.3	0.3	0.3	0.5	0.4	0.4	0.2	0.6	0.1	0.1
4	0.7	15.2	0.3	7.0	0.3	0.3	0.7	0.7	0.4	0.4	0.2	0.3	0.1	0.2
5	3.6	15.2	0.7	16.7	0.5	16.8	2.0	2.6	0.4	0.4	0.7	8.7	0.5	9.6
6	11.0	11.2	1.2	11.5	--**	--	1.1	3.2	1.4	1.4	5.8	16.3	7.2	7.2
7	--	--	4.5	7.2	8.4	8.6	2.2	2.6	--	--	--	--	--	--
8	--	--	6.2	7.8	10.2	10.2	2.6	2.8	4.4	5.2	--	--	8.9	11.7
9	11.2	11.2	10.7	10.7	9.0	9.6	3.3	3.4	9.1	9.2	--	--	11.8	12.1
10	11.2	11.2	1.6	--	2.8	9.8	0.8	2.8	1.4	8.9	1.8	9.1	0.9	21.5
11	--	--	4.8	8.4	6.2	20.4	2.8	2.9	1.3	6.3	6.3	12.3	4.3	12.4
12	14.4	14.4	7.8	7.9	8.0	7.8	3.8	--	0.5	0.8	7.8	13.2	8.6	11.6
13	--	--	--	--	--	--	3.6	--	1.8	--	12.9	--	--	--
14	--	--	--	--	--	--	--	--	6.7	25.8	16.8	21.8	4.0	22.2
15	--	--	--	--	--	--	--	--	16.3	32.2	20.6	27.8	31.8	31.8
16	--	--	--	--	--	--	--	--	--	--	0.8	--	--	--

* Parts per thousand.
** Not sampled.

TABLE 2.5-11

SOUTH TEXAS PROJECT, 1973, DISSOLVED OXYGEN (ppm DO)
TEMPERATURE (T, °C) AND PERCENT SATURATION (Sat.)*

Station (Figure 2.7-5)		August			September			October			November			December		
		DO	T	Sat.	DO	T	Sat.	DO	T	Sat.	DO	T	Sat.	DO	T	Sat.
1	Surface	7.8	29	100	8.3	29	105	7.8	22	88	9.2	18	95	8.2	13	77
	Bottom	7.3	28	93	7.9	29	100	8.0	22	91	9.1	17	94	8.1	13	76
2	Surface	8.0	30	104	8.1	29	104	7.9	22	90	9.3	18	97	8.2	13	77
	Bottom	7.7	29	98	7.4	29	94	7.9	22	90	9.2	18	95	8.1	13	76
3	Surface	8.4	31	110	8.1	29	104	7.8	22	88	9.2	19	97	8.0	14	76
	Bottom	7.7	29	98	6.8	29	87	8.0	22	91	9.1	18	94	8.0	13	75
4	Surface	8.2	31	108	8.0	29	103	7.8	22	88	9.0	19	95	7.8	14	75
	Bottom	8.0	29	103	6.0	29	77	7.2	22	81	9.0	18	94	7.3	13	68
5	Surface	8.6	30	112	7.8	29	100	8.0	22	91	9.2	19	97	7.8	15	76
	Bottom	8.0	29	103	6.2	29	78	8.0	22	91	8.7	18	91	8.0	15	78
6	Surface	7.8	29	100	--**	--	--	7.7	22	87	8.6	19	92	9.4	15	93
	Bottom	6.5	29	82	--	--	--	7.7	22	87	9.0	17	93	9.6	15	94
7	Surface	6.8	30	88	--	--	--	--	--	--	8.7	18	91	--	--	--
	Bottom	5.8	29	72	--	--	--	--	--	--	9.3	17	95	--	--	--
8	Surface	6.9	30	90	4.5	29	57	7.9	23	90	9.1	17	94	8.8	14	84
	Bottom	6.3	29	80	4.4	29	55	7.6	22	86	9.1	17	94	8.8	14	84
9	Surface	7.2	30	93	4.7	28	58	8.2	23	95	9.2	20	95	7.8	16	78
	Bottom	7.4	29	95	4.6	28	57	8.2	23	95	9.1	19	96	7.7	16	77

TABLE 2.5-11 (Continued)

SOUTH TEXAS PROJECT, 1973, DISSOLVED OXYGEN (ppm Do) TEMPERATURE (T, °C) AND PERCENT SATURATION (SAT.)*

Station (Figure 2.7-5)		August			September			October			November			December		
		DO	T	Sat.	DO	T	Sat.	DO	T	Sat.	DO	T	Sat.	DO	T	Sat.
10	Surface	8.6	30	112	5.2	29	66	8.2	20	88	7.7	20	83	8.6	15	84
	Bottom	6.2	29	78	5.0	29	64	7.2	19	76	8.1	19	86	--	16	--
11	Surface	8.4	31	110	4.6	28	57	7.6	19	81	8.2	20	89	10.3	16	103
	Bottom	7.1	29	90	4.4	28	55	7.6	17	78	7.9	19	84	10.0	16	100
12	Surface	7.8	31	104	4.6	28	57	9.0	25	108	10.4	22	115	9.3	17	95
	Bottom	--	--	--	--	--	--	7.6	24	88	--	--	--	9.3	16	95
13	Surface	--	--	--	4.2	28	52	7.9	23	90	--	--	--	--	--	--
	Bottom	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
14	Surface	--	--	--	--	--	--	8.8	23	100	8.0	21	88	10.4	16	104
	Bottom	--	--	--	--	--	--	6.4	26	78	7.8	21	85	8.8	15	86
15	Surface	--	--	--	--	--	--	8.1	25	96	8.4	21	84	8.1	16	82
	Bottom	--	--	--	--	--	--	8.0	26	97	7.8	20	84	8.8	16	89
16		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

*August and November data from Water Quality Monitor; September, October and December data from field measurements.
**Not sampled.

TABLE 2.5-12

SOUTH TEXAS PROJECT, 1973, MEAN VALUE OF TRIPLICATE SAMPLES FOR TOTAL HARDNESS*

Station (Figures 2.7-5)	June Surface	June Bottom	July Surface	July Bottom	August Surface	August Bottom	September Surface	September Bottom	October Surface	October Bottom
1	222	213	197	210	211	211	196	193	290	293
2	219	211	206	211	211	215	183	187	294	299
3	229	288	206	747	212	215	191	195	295	301
4	247	1,814	217	1,358	215	218	212	254	298	305
5	224	2,055	278	1,320	281	351	528	658	293	293
6	300	2,131	429	2,197	761	1,837	647	778	749	300
7	384	2,184	802	2,174	2,110	2,447	617	775	219	222
8	1,658	2,578	1,818	2,180	1,930	2,383	822	847	228	233
9	2,072	2,389	2,058	1,913	2,127	2,237	1,158	1,204	793	487
10	458	817	381	3,120	523	2,570	687	746	262	291
11	2,512	5,224	1,017	2,603	1,193	3,187	748	--	208	209
12	3,900	3,968	1,527	1,549	1,370	1,450	1,113	--	180	203
13	1,931	1,883	--**	--	1,740	--	1,100	--	293	--
14	--	--	2,169	--	2,363	--	--	--	204	208
15	--	--	6,519	--	4,523	5,303	--	--	3,033	4,250
16	--	--	--	--	161	--	--	--	--	--

*In ppm $CaCo_3$
**Not measured

TABLE 2.5-13

SOUTH TEXAS PROJECT, 1973, MEAN VALUE OF TRIPLICATE SAMPLES FOR CALCIUM*

Station (Figure 2.7-5)	June Surface	June Bottom	July Surface	July Bottom	August Surface	August Bottom	September Surface	September Bottom	October Surface	October Bottom
1	54	52	52	57	55	55	49	48	80	81
2	55	51	54	56	55	55	47	48	82	82
3	52	55	54	84	55	55	46	47	82	83
4	53	158	55	125	55	56	46	49	82	84
5	40	170	57	121	58	63	59	61	80	81
6	62	173	65	173	91	143	62	65	81	83
7	63	169	88	131	117	180	61	64	58	58
8	132	191	145	132	150	177	66	71	54	55
9	165	178	153	127	150	160	81	82	74	110
10	57	89	63	216	76	180	62	63	73	81
11	192	354	65	150	110	220	59	--	70	70
12	258	280	83	89	120	120	84	--	60	70
13	152	181	--	--	140	--	80	--	81	--
14	--	--	127	--	160	--	--	--	67	68
15	--	--	402	--	293	343	--	--	180	240
16	--	--	--	--	43	--	--	--	--	--

*In ppm Ca
**Not measured

TABLE 2.5-14

SOUTH TEXAS PROJECT, 1973, MEAN VALUE OF TRIPLICATE SAMPLES FOR MAGNESIUM*

Station (Figure 2.7-5)	June Surface	June Bottom	July Surface	July Bottom	August Surface	August Bottom	September Surface	September Bottom	October Surface	October Bottom
1	21	20	16	16	18	18	18	17	14	14
2	20	17	17	17	18	19	16	16	14	14
3	23	36	17	131	18	19	18	19	14	14
4	28	346	19	225	19	19	23	32	14	14
5	30	404	33	248	33	48	93	123	14	13
6	35	412	65	430	130	360	120	150	14	13
7	55	573	141	450	447	487	113	150	15	15
8	323	512	355	453	380	473	160	163	20	23
9	397	473	408	389	427	447	233	243	148	52
10	60	145	54	629	81	516	130	143	13	13
11	497	1,058	208	543	223	643	147	**	1	1
12	793	797	322	323	260	280	220	--	2	6
13	377	435	--	--	340	--	220	--	13	--
14	--	--	452	--	473	--	--	--	1	1
15	--	--	1345	--	920	432	--	--	630	890
16	--	--	--	--	13	--	--	--	--	--

*In ppm Mg
**Not measured.

TABLE 2.5-15

SOUTH TEXAS PROJECT, 1973, MEAN VALUE OF TRIPLICATE SAMPLES FOR SODIUM*

Station (Figure 2.7-5)	June Surface	June Bottom	August Surface	August Bottom
1	52	43	44	41
2	46	44	45	42
3	67	114	46	45
4	38	3,300	43	45
5	587	4,233	180	377
6	1,193	4,450	1,000	3,967
7	1,227	4,167	2,800	5,467
8	4,067	5,450	3,633	5,467
9	5,367	5,533	4,433	4,400
10	1,053	1,230	720	4,933
11	5,333	10,933	2,233	6,467
12	7,217	8,533	2,633	2,700
13	4,400	4,350	3,400	--
14	--**	--	4,700	--
15	--	--	9,500	10,833
16	--	--	42	--

*Sodium measured during major surveys only, values in ppm Na.
**Not measured

TABLE 2.5-16

SOUTH TEXAS PROJECT, 1973, MEAN VALUE OF TRIPLICATE SAMPLES FOR POTASSIUM*

Station (Figure 2.7-5)	June Surface	June Bottom	August Surface	August Bottom
1	4.7	4.6	4.4	4.5
2	4.9	4.6	4.4	4.4
3	5.5	7.3	4.4	4.5
4	6.1	130.7	4.4	4.5
5	22.0	165.0	1.1	1.6
6	44.7	157.0	51.0	140.0
7	45.7	151.3	86.7	196.7
8	158.7	180.7	143.3	190.0
9	204.7	185.0	170.7	180.0
10	58.0	60.0	27.0	193.0
11	209.0	405.0	93.0	257.0
12	298.0	285.0	110.0	130.0
13	166.0	167.0	130.0	--
14	--	--	190.0	--
15	--	--	347.0	417.0
16	--	--	4.8	--

*Potassium measured during major surveys only, values in ppm K
** Not measured

TABLE 2.5-17

SOUTH TEXAS, 1973, MEAN VALUE OF TRIPLICATE SAMPLES FOR TOTAL PHOSPHATE*

Station (Figure 2.7-5)	June		July		August		September		October	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
1	0.44	0.53	0.38	0.42	0.43	0.39	0.46	0.45	0.62	0.74
2	0.36	0.52	0.38	0.38	0.37	0.39	0.50	0.47	0.96	0.82
3	0.46	0.53	0.34	0.38	0.34	0.42	0.46	0.46	0.85	0.84
4	0.50	0.49	0.33	0.36	0.34	0.37	0.49	0.52	0.84	0.79
5	0.45	0.47	0.30	0.30	0.40	0.35	0.42	0.43	0.49	0.67
6	0.43	0.52	0.25	0.25	0.41	0.39	0.39	0.39	0.82	0.68
7	0.44	0.39	0.33	0.29	0.38	0.51	0.38	0.41	0.37	0.50
8	0.33	0.44	0.27	0.37	0.33	0.45	0.38	0.44	0.48	0.43
9	0.51	0.49	0.28	0.34	0.33	0.49	0.39	0.42	0.34	0.26
10	0.42	0.40	0.31	0.22	0.35	0.18	0.37	0.38	0.59	0.89
11	0.26	0.20	0.24	0.21	0.33	0.28	0.34	--**	0.49	0.66
12	0.30	0.42	0.31	0.27	0.39	0.35	0.54	--	0.66	0.71
13	0.61	0.78	--	--	0.29	--	0.40	--	0.80	--
14	--	--	0.19	--	0.35	--	--	--	0.81	0.74
15	--	--	0.06	--	0.22	0.11	--	--	0.27	0.23
16	--	--	--	--	0.18	--	--	--	--	--

*In ppm PO_4
**Not measured

TABLE 2.5-18

SOUTH TEXAS PROJECT, 1973, MEAN VALUE OF TRIPLICATE SAMPLES FOR NITRATE*

Station (Figure 2.7-5)	June		July		August		September		October	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
1	3.7	3.5	2.8	3.6	8.1	6.4	3.2	2.1	9.3	7.9
2	2.3	4.2	3.3	2.9	7.0	5.2	2.9	2.9	8.7	7.0
3	3.4	4.2	3.0	2.2	3.3	9.0	2.6	2.9	11.1	7.3
4	3.9	6.0	1.7	2.1	5.1	7.5	2.0	3.3	9.1	11.9
5	6.2	5.7	1.6	2.5	0.7	9.4	1.2	1.9	10.9	11.5
6	6.6	6.3	1.8	0.9	8.4	7.2	2.9	2.7	10.5	11.5
7	3.3	4.3	2.2	0.3	15.9	25.0	2.2	1.9	6.5	6.7
8	3.5	0.9	0.9	0.2	26.0	26.3	2.3	1.7	4.9	5.5
9	8.0	4.8	0.2	0.3	26.7	25.9	1.7	1.2	5.9	2.4
10	3.9	3.1	0.9	1.9	5.4	21.8	2.6	1.8	9.0	8.8
11	0.3	0.5	0.2	0.3	10.9	1.2	0.8	--**	9.3	8.8
12	1.3	1.6	0.7	0.5	19.1	12.0	1.5	--	7.0	17.2
13	9.2	7.4	--	--	22.8	--	1.0	--	11.4	--
14	--	--	0.37	--	0.03	--	--	--	8.6	9.[illegible]
15	--	--	0.2	--	3.0	18.8	--	--	3.5	2.7
16	--	--	--	[illegible]	6.7	--	--	--	--	--

*In ppm NO_3

**Not measured

TABLE 2.5-19

SOUTH TEXAS PROJECT, 1973, MEAN VALUE OF TRIPLICATE SAMPLES FOR TOTAL SILICA*

Station (Figure 2.7-5)	June		July		August		September		October	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
1	16.2	20.8	21.9	38.3	19.0	20.2	21.0	21.3	148.0	142.0
2	17.5	21.2	18.3	26.9	18.3	17.9	24.7	25.0	158.7	132.0
3	16.1	27.3	16.9	19.3	15.9	17.2	20.3	23.3	148.0	152.0
4	15.1	25.0	17.1	13.5	16.9	26.0	24.3	28.3	167.0	105.0
5	11.9	12.7	16.9	12.4	14.2	24.0	19.7	22.3	127.7	103.7
6	15.8	34.2	19.1	12.6	17.3	60.0	21.7	33.7	146.7	90.7
7	12.7	20.1	16.9	11.0	29.7	44.7	22.7	31.0	60.7	34.3
8	10.7	32.5	14.3	19.3	23.7	27.7	32.3	31.7	41.0	25.3
9	58.2	40.8	22.0	23.7	27.7	47.3	36.3	59.0	25.3	11.0
10	18.7	11.8	15.3	10.5	21.0	32.0	23.0	29.0	111.0	134.0
11	14.5	5.2	12.1	11.8	15.7	14.7	21.0	--**	100.0	59.0
12	26.3	18.0	15.0	15.0	28.0	32.0	46.0	--	45.0	56.0
13	58.2	87.8	--	--	22.0	0.0	30.0	--	94.0	--
14	--	--	18.4	--	14.0	--	--	--	60.0	135.0
15	--	--	3.1	--	6.4	8.7	--	--	9.0	3.8
16	--	--	--	--	36.7	--	--	--	--	--

*In ppm SiO_2
**Not measured

TABLE 2.5-20

SOUTH TEXAS PROJECT, 1973, MEAN VALUE OF TRIPLICATE SAMPLES FOR TOTAL DISSOLVED SOLIDS*

Station	June		July		August		September		October		
(Figure 2.7-5)	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	
1	421	350	347	485	346	349	372	372	273	267	
2	447	359	351	427	351	348	349	348	262	261	
3	476	625	377	3,597	357	353	425	429	255	267	
4	540	10,860	457	9,974	360	356	556	916	269	279	
5	2,049	13,017	792	7,703	759	1,240	2,697	3,575	257	305	5
6	4,430	13,491	1,668	13,510	4,074	11,424	3,482	4,391	244	301	
7	4,413	13,994	4,154	14,184	6,828	18,229	3,207	4,523	366	430	
8	11,979	16,336	10,923	15,140	12,537	15,123	4,961	4,874	571	708	
9	15,901	14,951	12,717	13,834	13,999	15,872	7,256	7,490	4,680	10,197	
10	3,219	4,563	1,317	20,073	2,230	18,273	3,846	4,290	263	275	
11	24,066	34,485	6,300	17,086	7,300	19,842	4,377	--**	303	273	
12	23,291	36,960	9,895	9,981	8,326	8,302	6,307	--	498	1,497	
13	14,698	16,596	--	--	10,598	--	6,397	--	252	--	
14	--	--	19,090	--	14,590	--	--	--	240	283	
15	--	--	43,683	--	29,138	34,881	--	--	18,956	36,003	
16	--	--	--	--	390	--	--	--	--	--	5

* In ppm
** Not measured

TABLE 2.5-21

SOUTH TEXAS PROJECT, 1973, MEAN VALUE OF TRIPLICATE SAMPLES FOR SUSPENDED MATTER*

Station (Figure 2.7-5)	June Surface	June Bottom	July Surface	July Bottom	August Surface	August Bottom	September Surface	September Bottom	October Surface	October Bottom
1	46	41	32	74	39	50	26	25	454	456
2	42	44	24	39	32	36	28	27	493	462
3	38	36	22	32	24	31	22	22	460	539
4	28	52	22	36	21	29	21	30	529	517
5	20	65	19	29	19	20	21	27	485	597
6	24	125	24	44	33	103	32	47	505	554
7	24	34	25	44	46	182	19	32	175	142
8	18	59	53	74	37	54	29	38	111	120
9	267	171	79	99	51	213	58	99	54	33
10	16	21	19	26	20	54	25	28	358	460
11	19	23	24	53	21	29	31	--**	703	391
12	41	76	50	57	49	68	89	--	251	337
13	217	227	--	--	27	--	43	--	437	--
14	--	--	65	--	25	--	--	--	388	437
15	--	--	39	--	17	16	--	--	32	10
16	--	--	--	--	35	--	--	--	--	--

*In ppm
**Not measured

TABLE 2.5-22

SOUTH TEXAS PROJECT, 1973, MEAN VALUE OF TRIPLICATE SAMPLES FOR CHEMICAL OXYGEN DEMAND*

Station	June Surface	June Bottom	August Surface	August Bottom
1	10.7	8.0	5.1	5.5
2	36.8	7.8	5.3	5.9
3	8.5	9.0	9.9	6.5
4	7.9	13.7	10.0	6.1
5	14.3	17.0	11.8	11.9
6	24.4	21.6	23.5	57.5
7	21.3	17.8	32.8	65.8
8	13.4	16.7	50.2	65.3
9	21.9	19.2	65.1	64.1
10	16.5	7.3	14.0	67.7
11	17.0	25.0	44.5	80.2
12	20.3	22.3	43.7	33.5
13	22.6	24.0	50.0	--
14	--**	--	68.0	--
15	--	--	78.2	77.0
16	--	--	21.2	--

*In ppm
**Not measured

TABLE 2.5-23

RIVER WATER TEMPERATURE
USGS GAGE NO. 8-1625 COLORADO RIVER NEAR BAY CITY, TEXAS*

Date	Temperature (°F)	Date	Temperature (°F)	Date	Temperature (°F)
Apr. 28, 1949	71	May 31, 1952	75	June 27, 1957	82
May 16	82	June 7	82	July 17	86
July 21	88	July 1	85	Jan. 8, 1958	50
Aug. 27	85	July 30	87	Oct. 21	76
Sept. 1	89	July 31	84	Dec. 17	50
Sept. 19	82	Aug. 31	84	May 12, 1959	79
Oct. 31	62	Aug. 31	84	May 14	78
Nov. 29	70	Sept. 30	81	July 31	84
Jan. 4, 1950	59	Nov. 7	65	Feb. 8, 1960	57
Feb. 7	60	Dec. 2	47	Mar. 16	56
Mar. 7	66	Jan. 7, 1953	65	Apr. 20	72
Apr. 10	74	Feb. 1	62	May 26	83
May 10	81	Feb. 28	62	June 21	87
May 31	86	Mar. 29	71	Sept. 20	84
June 3	79	Apr. 25	78	Nov. 2	67
June 4	77	Apr. 30	76	Nov. 3	70
June 14	83	May 1	74	Dec. 19	50
July 18	90	June 2	88	Apr. 10, 1961	63
July 20	88	Aug. 5	87	May 11	75
Aug. 8	88	Aug. 14	88	Aug. 9	85
Sept. 19	81	Aug. 17	87	Jan. 10, 1962	42
Oct. 17	75	Aug. 27	84	Mar. 27	72
Nov. 16	70	Oct. 2	85	May 9	81
Dec. 12	55	Oct. 16	76	June 12	88
Jan. 4, 1951	57	Oct. 27	72	July 18	88
Feb. 7	51	Oct. 28	73	Oct. 26	70
Feb. 27	72	Nov. 8, 1954	64	Nov. 21, 1963	72
Mar. 9	75	Nov. 18	71	Dec. 18	48
Mar. 17	69	Dec. 7	56	Jan. 29, 1964	59
Apr. 11	65	Jan. 6, 1955	59	Mar. 10	62
Apr. 12	67	Feb. 3	68	Apr. 8	71

TABLE 2.5-23 (Continued)

RIVER WATER TEMPERATURE
USGS GAGE NO. 8-1625 COLORADO RIVER NEAR BAY CITY, TEXAS*

Date	Temperature (°F)	Date	Temperature (°F)	Date	Temperature (°F)
May 11	80	Mar. 3	56	May 20	86
May 23	84	Mar. 31	66	Aug. 24	84
May 29	87	Apr. 7	71	Sept. 28	78
May 31	87	May 4	80	Oct. 8	72
June 7	78	May 31	80	Nov. 4	74
June 11	86	July 7	84	Dec. 9	52
July 2	87	Aug. 5	85	Jan. 13, 1965	56
July 9	93	Oct. 5	79	Mar. 24	63
Aug. 2	87	Dec. 13	58	Apr. 28	70
Aug. 10	88	Jan. 17, 1956	56	Aug. 10	87
Sept. 6	88	Feb. 22	67	Sept. 14	86
Sept. 13	80	Mar. 28	73	Nov. 23	74
Oct. 3	85	May 10	80	Jan. 7, 1966	56
Nov. 8	59	June 12	84	Feb. 3	47
Dec. 5	70	July 18	90	Mar. 10	62
Jan. 8, 1952	59	Aug. 21	86	Apr. 19	71
Feb. 6	57	Sept. 25	83	June 28	87
Mar. 5	61	Jan. 11, 1957	53	July 29	88
Apr. 8	76	Feb. 15	66	Sept. 1	89
May 4	81	May 1	72	Sept. 12	82
May 30	75	May 2	72		

*Data from Reference 2.5-17

TABLE 2.5-24

GULF OF MEXICO, TEXAS COAST, SPECIFIC CONDUCTANCE AND TEMPERATURE

Location	Date of Collection	Time (24 hr)	Depth of Water (ft)	Specific Conductance (mhos)	Temp (°C)
Sabine	May 2, 1968	1557	1	35,000	25.6
Neches			30	48,000	22.5
			47.5	50,000	22.5
	Dec. 2, 1970	1145	1	50,000	15.5
			10	50,000	16.0
			20	50,000	16.0
			32	50,000	16.5
Nueces	Dec. 8, 1967	0900	0.2	48,000	-
	Mar. 26, 1969	1045	1	44,000	15.4
			3	45,000	15.0
	Sept. 17, 1969	1225	1	45,000	30.1
			5	45,000	29.7
			10	45,000	29.4
			20	47,000	29.2
			30	49,000	29.2
			36	59,000	29.2
Lagune Madre	April 21, 1968	1420	1	55,000	26.4
			10	56,000	26.0
			20	56,000	25.3
			34	56,000	24.5
	Sept. 9, 1969	0935	1	56,000	29.6
			5	56,000	29.5
			10	56,000	29.5
			20	56,000	29.5
			30	56,000	29.5
			48	56,000	29.4

*Data from References 2.5-9, 2.5-10, and 2.5-11.

TABLE 2.5-25

MEAN VALUE OF TRIPLICATE SAMPLES DURING GROUNDWATER QUALITY STUDIES, WELL 115-D (STP, 1973-1974)

Parameters (mg/l, except as noted)	1973 Dec 11	1973 Dec 18	1974 Jan 02	1974 Jan 10	1974 Jan 24	1974 April 25	1974 May 23	1974 June 27	1974 July 30	1974 Sept 06
Acidity, free ($CaCO_3$)	0	0	0	0	-*	-	-	-	-	-
Acidity, total ($CaCO_3$)	8.1	37	29	25	-	-	-	-	-	-
M.O. Alkalinity ($CaCO_3$)	271	405	381	380	377	364	362	366	370	363
Pht. Alkalinity ($CaCO_3$)	0	0	0	0	0	0	0	0	0	0
Aluminum (Al)	3.4	0.5	1.4	1	1.3	0.8	1.2	5.4	3.2	0.2
Ammonia (N)	0.73	0.10	<0.07	<0.07	<0.07	0.09	0.07	0.13	0.30	0.14
Arsenic (As)	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium (Cd)	0.03	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Calcium (Ca)	113	140	137	140	136	140	137	140	140	137
Carbon, inorganic (C)	53.6	87.4	95.7	89.4	81.4	97.6	92	93	93	95
Carbon, organic (C)	15.4	6.3	2.9	6.1	10.9	<1	5	5.3	3.3	5.3
Carbon, total (C)	69	93.7	98.7	95.5	92.3	98.3	97	98.3	94.6	100.3
Chem. Oxygen Demand (O_2)	44	12	8	10	8	40	9	7.6	6.3	7.6
Chloride (Cl)	***	990	1012	1023	1083	1100	1100	1120	1133	1100
Chromium (Cr^{+6})	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Copper (Cu)	0.03	<0.02	0.02	0.06	<0.02	<0.02	<0.02	0.023	0.023	0.023
Cyanide, total (CN)	0.01	0.01	<0.01	<0.01	<0.01	<0.01 **	<0.01	<0.01	<0.01	<0.01
Fluoride (F)	0.65	0.62	0.78	0.93	1.4	0.9	0.9	0.7	0.7	0.6

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TABLE 2.5-25 (Continued)

MEAN VALUE OF TRIPLICATE SAMPLES DURING GROUNDWATER QUALITY STUDIES, WELL 115-D (STP, 1973-1974)

Parameters (mg/l, except as noted)	1973 Dec 11	1973 Dec 18	1974 Jan 02	1974 Jan 10	1974 Jan 24	1974 April 25	1974 May 23	1974 June 27	1974 July 30	1974 Sept 06
Hardness ($CaCO_3$)	570	703	704	726	733	763	757	780	770	760
Iron, total (Fe)	7.4	2.6	4.1	4.7	2.3	3.6	1.8	5.4	3.3	2.4
Lead (Pb)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Magnesium (Mg)	70	86	88	92	99.3	100	100	104	101	100
Manganese (Mn)	1.01	0.82	0.63	0.63	0.61	0.61	0.51	0.48	0.52	0.41
Mercury (Hg), μg/l	<0.2	0.4	0.4	***	0.5	0.5	<0.2	0.4	0.23	<0.2
Nitrate (N)	1.5	1.4	1	1.3	0.4	0.4	0.2	0.4	0.3	0.4
Nitrite (N)	<0.01	<0.01	<0.01	<0.01	0.02	0.03	<0.01	<0.01	<0.01	<0.01
pH, units	7.8	7.2	7.2	7.4	7.6	7.3	7.4	7.4	7.4	7.3
Phenolic Cpds (Phenol)	0.007	0.007	0.009	0.002	<0.001	0.006	0.012	<0.001	0.009	0.001
Phosphorus, ortho (P)	0.01	0.02	0.01	0.01	0.03	0.09	0.07	0.03	0.24	0.08
Phosphorus, total (P)	0.17	0.18	0.09	0.15	0.18	0.43	0.29	0.43	0.26	0.17
Potassium (K)	7.9	6.4	7.5	8	6.8	4.7	5.2	7.5	5.2	6.3
Silica, total (Si)	6.9	57	35	136	69	49.3	28.6	67.3	33.3	33.3
Sodium (Na)	***	613	610	590	573	588	615	560	557	578
Solids, dissolved	***	2360	2371	2337	2630	2523	2547	2503	2730	2450
Sp. Conductance, 25°C, μmhos/cm	***	3390	3417	3600	3800	3947	3890	3913	4020	3950
Sulfate (S)	25	27	29	29	30.7	32.1	30.4	30	34.1	30.8

TABLE 2.5-25 (Continued)

MEAN VALUE OF TRIPLICATE SAMPLES DURING GROUNDWATER QUALITY STUDIES, WELL 115-D (STP, 1973-1974)

Parameters (mg/l, except as noted)	1973 Dec 11	1973 Dec 18	1974 Jan 02	1974 Jan 10	1974 Jan 24	1974 April 25	1974 May 23	1974 June 27	1974 July 30	1974 Sept 06
Sulfide (S)	0.03	<0.02	<0.02	<0.02	<0.02	0.04	0.05	0.12	0.06	<0.1
Zinc (Zn)	0.97	0.50	0.07	0.09	0.73	0.04	0.07	0.12	0.076	0.11
Barium (Ba)	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	<0.2	<0.2	<0.2	0.2
Boron (B)	0.2	0.2	0.6	0.6	1.1	0.4	0.1	0.5	0.2	0.7
Selenium (Se)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (Ag)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Bacteria										
Std. Plate Count, No./ml	88,200	19,800	12,800	17,600	>30,000	48,600	4333	12,633	6500	21,000
Coliforms, No./100 ml	13	17	100	3	67	6233	563	4033	2300	4167
Fecal Coliforms, No./100 ml	0	0	0	0	0	0	0	0	0	0
Fecal Streptococci, No./100 ml	3	7	112	0	0	90	35	1.3	1	0

* Parameter not measured.
** Only two replicates.
*** Data considered erroneous; therefore, not reported.

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TABLE 2.5-26

MEAN VALUE OF TRIPLICATE SAMPLES DURING GROUNDWATER QUALITY STUDIES, WELL 2 (STP, 1973-1974)

Parameters (mg/l, except as noted)	1973 Dec 11	1973 Dec 18	1974 Jan 02	1974 Jan 10	1974 Jan 24	1974 April 25	1974 May 23	1974 June 27	1974 July 30	1974 Sept 06
Acidity, free ($CaCO_3$)	0	0	*	0	-**	-	-	-	-	-
Acidity, total ($CaCO_3$)	18	20		0	-	-	-	-	-	-
M.O. Alkalinity ($CaCO_3$)	380	376		201	361	337	221	148	149	302
Pht. Alkalinity ($CaCO_3$)	0	0		44	0	0	17	35	32	2.6
Aluminum (Al)	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	0.43	0.4	<0.1
Ammonia (N)	0.11	0.07		<0.07	0.39	<0.07	0.07	1.03	0.91	<0.07
Arsenic (As)	<0.01	<0.01		0.013	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium (Cd)	<.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Calcium (Ca)	66	65		137	70	58	22	10	9.6	31.6
Carbon, inorganic (C)	82.7	81.5		34	81.1	87	48	28.6	29.6	72
Carbon, organic (C)	2.96	5.8		2.2	8.9	1.3	4	4.6	2.6	7.6
Carbon, total (C)	85.7	87.3		36.2	90	87.6	52	33.3	31	79.6
Chem. Oxygen Demand (O_2)	<5	<5		<5	<5	8	17.3	<5	5.6	<5
Chloride (Cl)	238	238		238	402	363	300	255	256	300
Chromium (Cr^{+6})	<0.002	<0.002		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Copper (Cu)	<0.02	<0.02		<0.02	<0.02	0.03	0.03	<0.02	<0.02	<0.02
Cyanide, total (CN)	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fluoride (F)	1.13	1.1		1	1	1.3	0.9	0.8	0.7	0.6

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TABLE 2.5-26 (Continued)

MEAN VALUE OF TRIPLICATE SAMPLES DURING GROUNDWATER QUALITY STUDIES, WELL 2 (STP, 1973-1974)

Parameters (mg/l, except as noted)	1973 Dec 11	1973 Dec 18	1974 Jan 02	1974 Jan 10	1974 Jan 24	1974 April 25	1974 May 23	1974 June 27	1974 July 30	1974 Sept 06
Hardness ($CaCO_3$)	308.3	307	*	449	377	329	190	91.6	91	240
Iron, total (Fe)	0.17	0.13		<0.02	11	28	1.6	1	0.79	3.8
Lead (Pb)	<0.05	<0.05		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Magnesium (Mg)	35	35		26	50	45	33	16	16	39.3
Manganese (Mn)	0.16	0.16		<0.02	0.35	0.29	0.10	0.04	0.03	0.16
Mercury (Hg), μg/l	<0.2	<0.2		1.6	0.4	<0.2	<0.2	0.33	0.4	<0.2
Nitrate (N)	<0.2	0.6		<0.2	0.4	0.4	0.2	<0.2	<0.2	0.3
Nitrite (N)	<0.01	<0.01		<0.01	0.04	0.02	0.01	<0.01	<0.01	<0.01
pH, units	7.5	7.5		9.6	7.5	7.5	8.9	9.3	9.4	8.3
Phenolic Cpds (Phenol)	0.005	<0.001		0.008	<.001	0.009	0.016	0.009	0.003	0.007
Phosphorus, ortho (P)	0.03	0.02		0.01	0.08	0.02	0.37	0.053	0.06	0.09
Phosphorus, total (P)	0.05	0.04		0.13	0.30	0.54	0.45	0.066	0.12	0.11
Potassium (K)	4.3	4		3.9	4.5	3	3.2	3.9	3.1	3.6
Silica, total (Si)	10.3	13.7		1.8	10.5	20	0.60	1.46	0.58	10.6
Sodium (Na)	227	230		220	280	250	217	196	209	226
Solids, dissolved	844	857		632	1107	975	745	590	598	748
Sp. Conductance, 25°C, μmhos/cm	1187	1187		1080	1900	1710	1173	1123	1160	1490
Sulfate (S)	11.3	12		11	13.3	7.9	6.7	10	9.3	<1

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TABLE 2.5-26 (Continued)

MEAN VALUE OF TRIPLICATE SAMPLES DURING GROUNDWATER QUALITY STUDIES, WELL 2 (STP, 1973-1974)

Parameters (mg/l, except as noted)	1973 Dec 11	1973 Dec 18	1974 Jan 02	1974 Jan 10	1974 Jan 24	1974 April 25	1974 May 23	1974 June 27	1974 July 30	1974 Sept 06
Sulfide (S)	<0.02	<0.02	*	<0.02	0.95	<0.02	0.04	0.04	0.03	0.1
Zinc (Zn)	0.05	0.07		4.7	2.4	0.15	0.23	0.32	0.13	0.43
Barium (Ba)	<0.2	<0.2		<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Boron (B)	0.3	0.3		0.3	0.4	0.2	0.1	0.2	0.1	0.4
Selenium (Se)	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (Ag)	<0.02	<0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Bacteria										
Std. Plate Count, No./ml	37,307	837		8000	1990	1187	4300	16,333	4300	3200
Coliforms, No./100 ml	33	3.3		3	0.7	0	0	0	0	4.3
Fecal Coliforms, No./100 ml	0	0		0	0	0	0	0	0	0
Fecal Streptococci, No./100 ml	0	0		0	0.3	0	0	0	0.3	9.3

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* Well 2 not sampled this date.
** Parameter not measured.

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TABLE 2.5-27

MEAN VALUE OF TRIPLICATE SAMPLES DURING GROUNDWATER QUALITY STUDIES, WELL 114-A (STP, 1973-1974)

Parameters (mg/l, except as noted)	1973 Dec 11	1973 Dec 18	1974 Jan 02	1974 Jan 10	1974 Jan 24	1974 April 25	1974 May 23	1974 June 27	1974 July 30	1974 Sept 06
Acidity, free ($CaCO_3$)	0	0	0	0	-*	-	-	-	-	-
Acidity, total ($CaCO_3$)	5.4	0	0	0	-	-	-	-	-	-
M.O. Alkalinity ($CaCO_3$)	193	129	136	206	240	200	219	218	234	249
Pht. Alkalinity ($CaCO_3$)	0	6.8	8.2	17.7	17.3	26.3	12.6	17.3	28	7.3
Aluminum (Al)	<0.1	0.5	<0.1	<0.1	0.3	0.7	0.3	0.9	0.5	0.1
Ammonia (N)	0.18	0.27	0.31	0.10	0.20	0.50	0.55	0.63	0.68	0.49
Arsenic (As)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium (Cd)	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Calcium (Ca)	58	16	20	8	8.8	8.5	7.5	8	8.8	9.6
Carbon, inorganic (C)	41.5	27.9	30	41	50.4	43.6	48	49	50.6	59
Carbon, organic (C)	8.2	10.4	8	3.7	7.8	10	<1.0	6	4.6	7.6
Carbon, total (C)	49.7	38.3	38	44.7	58	53.6	48.3	55	55.3	66.6
Chem. Oxygen Demand (O_2)	14	36	16	6	6.1	13.3	12.6	8.3	5.3	5.3
Chloride (Cl)	384	279	264	168	168	180	170	172	167	160
Chromium (Cr^{+6})	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Copper (Cu)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cyanide, total (CN)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fluoride (F)	0.68	0.60	0.64	0.99	1.4	1.2	1.0	0.9	0.93	0.7

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TABLE 2.5-27 (Continued)

MEAN VALUE OF TRIPLICATE SAMPLES DURING GROUNDWATER QUALITY STUDIES, WELL 114-A (STP, 1973-1974)

Parameters (mg/l, except as noted)	1973 Dec 11	1973 Dec 18	1974 Jan 02	1974 Jan 10	1974 Jan 24	1974 April 25	1974 May 23	1974 June 27	1974 July 30	1974 Sept 06
Hardness ($CaCO_3$)	317	116	127	70	81	61	62	67	64.3	74.6
Iron, total (Fe)	1.9	4.4	0.04	0.03	0.22	0.36	0.12	0.24	0.27	0.22
Lead (Pb)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Magnesium (Mg)	42	18	19	12	14	9.6	10.6	11	10	12
Manganese (Mn)	0.22	0.07	<0.02	<0.02	<0.02	0.03	<0.02	<0.02	0.03	<0.02
Mercury (Hg), μg/l	<0.2	<0.2	0.23	0.27	0.6	<0.2	<0.2	<0.2	0.33	<0.2
Nitrate (N)	0.4	1.4	0.67	0.2	0.4	0.4	0.53	0.43	<0.2	<0.2
Nitrite (N)	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.01	<0.01	<0.01	<0.01
pH, units	7.9	8.6	8.7	9.1	9	9.2	8.9	8.7	9	8.6
Phenolic Cpds (Phenol)	0.018	0.009	0.006	0.004	<0.001	0.011	0.017	0.008	0.003	0.009
Phosphorus, ortho (P)	<0.01	0.01	0.06	0.01	<0.01	<0.01	0.1	0.16	0.6	0.08
Phosphorus, total (P)	0.03	0.03	0.08	0.03	<0.01	0.24	0.14	0.20	0.74	0.09
Potassium (K)	9.9	6.3	6.6	4.6	3.8	3.2	3.5	4.2	2.9	3.4
Silica, total (Si)	6.2	8.7	8.2	10.5	10.6	25	15.6	20	20.3	28
Sodium (Na)	203	200	200	190	200	182	183	175	199	193
Solids, dissolved	949	644	609	530	577	557	543	527	538	525
Sp. Conductance, 25°C, μmhos/cm	1363	1083	1048	885	937	920	845	961	987	990

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TABLE 2.5-27 (Continued)

MEAN VALUE OF TRIPLICATE SAMPLES DURING GROUNDWATER QUALITY STUDIES, WELL 114-A (STP, 1973-1974)

Parameters (mg/l, except as noted)	1973 Dec 11	1973 Dec 18	1974 Jan 02	1974 Jan 10	1974 Jan 24	1974 April 25	1974 May 23	1974 June 27	1974 July 30	1974 Sept 06
Sulfate (S)	8.7	6.7	6.9	5.3	5.8	5.3	4.7	4.4	5.3	5.1
Sulfide (S)	<0.02	0.04	<0.02	<0.02	0.04	0.49	<0.02	3.29	2.19	0.8
Zinc (Zn)	0.31	0.34	<0.02	<0.02	<0.02	0.06	0.05	0.14	0.06	0.07
Barium (Ba)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2
Boron (B)	0.3	0.3	0.3	0.5	0.6	0.3	0.1	0.2	<0.1	0.4
Selenium (Se)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (Ag)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Bacteria										
Std. Plate Count, No./ml	19,460	16,600	17,400	29,200	>30,000	13,500	12,067	3500	14,067	8000
Coliforms, No./100 mg	47	17	3	47	7	0	273	143	990	0.6
Fecal Coliforms, No./100 ml	3	0	0	0	0	0	0	0	0	0
Fecal Streptococci, No./100 ml	0	1	15	0	0	0	5	0	7.7	0

* Parameter not measured.

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TABLE 2.5-28

QUALITY REQUIREMENTS OF WATER AT POINT OF USE FOR STEAM GENERATION AND COOLING IN HEAT EXCHANGES*

	Boiler feed water: Quality of water prior to the addition of substances used for internal conditioning				Cooling water			
	Industrial			Electric utilities	Once through		Makeup for recirculation	
Characteristic	Low pressure 0 to 150 psig	Intermediate pressure 150 to 700 psig	High pressure 700 to 1,500 psig	1,500 to 5,000 psig	Fresh	Brackish**	Fresh	Brackish**
Silica (SiO_2)	30	10	0.7	0.01	50	25	50	25
Aluminum (Al)	5	0.1	0.01	0.01	***	***	0.1	0.1
Iron (Fe)	1	0.3	0.05	0.01	***	***	0.5	0.5
Manganese (Mn)	0.3	0.1	0.01	††	***	***	0.5	0.02
Calcium (Ca)	***	†	†	††	200	420	50	420
Magnesium (Mg)	***	†	†	††	***	***	***	***
Ammonia (NH_4)	0.1	0.1	0.1	0.7	***	***	***	***
Bicarbonate (HCO_3)	170	120	48	††	600	140	24	140
Sulfate (SO_4)	***	†	***	††	680	2,700	200	2,700
Chloride (Cl)	***	†	***	††	600	19,000	500	19,000
Dissolved solids	700	500	200	0.5	1,000	35,000	500	35,000
Copper (Cu)	0.5	0.05	0.05	0.01		***	***	***
Zinc (Zn)	***	†	†	††		***	***	***
Hardness ($CaCO_3$)	20	†	†	†	850	6,250	130	6,250
Free mineral acidity ($CaCO_3$)	†	†	†	†	†	†	†	†
Alkalinity ($CaCO_2$)	140	100	40	†	500	115	20	115
pH	8.0-10.0	8.2-10.0	8.2-9.0	8.8-9.2	5.0-8.3	6.0-8.3	**	***
Color, units	***	***	***	***	***	***	***	***
Organics:				†				
Methylene blue active substances.	1	1	0.5			***	1	1
Carbon tetrachloride extract	1	1	0.5	†	†††	†††	1	2
Chemical oxygen demand (O_2)	5	5	0.5	†	75	75	75	75
Dissolved oxygen (O_2)	2.5	0.007	0.007	0.007	***	***	***	***
Temperature, °F	***	***	***	***	***	***	***	***
Suspended solids	10	5	†	†	5,000	2,500	100	100

*Unless otherwise indicated, units are mg/l and values that normally should not be exceeded. No water will have all the maximum values shown. Data from Reference 2.5-25.

**Brackish water--dissolved solids more than 1,000 mg/l by definition 1963 census of manufacturers.

***Accepted as received (if meeting total solids or other limiting values); has never been a problem at concentrations encountered.

†Zero, not detectable by test.

††Controlled by treatment for other constituents.

†††No floating oil.

NOTE: Application of the above values should be based on Part 23, ASTM book of standards or APHA Standard methods for the examination of water and wastewater.

TABLE 2.5-29

COMPARISON OF GROUNDWATER QUALITY TO DRINKING WATER STANDARDS AND PROPOSED CRITERIA FOR PRESERVATION OF AQUATIC LIFE

Parameter (mg/l, except as noted)	U.S. Public Health Service Drinking Water Standards*	EPA Proposed Drinking Water Criteria**	EPA Proposed Criteria for Preservation of Aquatic life**	Grand Mean, STP Groundwater	Maximum Value Reported During Current Study
Acidity, free ($CaCO_3$)				0	0 (all)***
Acidity, total ($CaCO_3$)				13.0	37 (115-D)
M.O. Alkalinity ($CaCO_3$)				281	405 (115-D)
Pht. Alkalinity ($CaCO_3$)				19.4	44 (2)
Aluminum (Al)			1.5	0.81	5.4 (115-D)
Ammonia (N)		0.5	0.4	0.29	1.03 (2)
Arsenic (As)	0.05	0.1	0.05	<0.01	0.013 (2)
Cadmium (Cd)	0.01	0.01	0.01	0.01	0.03 (115-D, 114-A)
Calcium (Ca				68.4	140 (115-D)
Carbon, inorganic (C)				64.3	97.6 (115-D)
Carbon, organic (C)	0.2(CCE)†	0.3 (CCE)†		5.8	15.4 (115-D)
Carbon, total (C)				69.9	100.3 (115-D)
Chem. Oxygen Demand (O_2)				11.6	44 (115-D)
Chloride (Cl)	250	250		513	1133 (115-D)
Chromium (Cr^{+6})	0.05	0.05	0.1	<0.002	<0.002 (all)
Copper (Cu)	1.0	1.0	0.05	<0.024	0.06 (115-D)
Cyanide, total (CN)	0.2	0.2	0.01	<0.01	0.01 (115-D)
Fluoride (F)	1.4-2.4††		1.5	0.89	1.4 (115-D, 114-A)

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TABLE 2.5-29 (Continued)

COMPARISON OF GROUNDWATER QUALITY TO DRINKING WATER STANDARDS AND PROPOSED CRITERIA FOR PRESERVATION OF AQUATIC LIFE

Parameter (mg/l, except as noted)	U.S. Public Health Service Drinking Water Standards*	EPA Proposed Drinking Water Criteria**	EPA Proposed Criteria for Preservation of Aquatic life**	Grand Mean, STP Groundwater	Maximum Value Reported During Current Study
Hardness ($CaCO_3$)				369	780 (115-D)***
Iron, total (Fe)	0.3†††	0.3†††	0.3†††	<3.2	28 (2)
Lead (Pb)	0.05	0.05	0.05	<0.05	<0.05 (all)
Magnesium (Mg)				48.1	104 (115-D)
Manganese (Mn)	0.05	0.05	0.1	<0.3	1.01 (115-D)
Mercury (Hg)		0.002	1.0 μg/l	<0.3 μg/l	1.6 μg/l (2)
Nitrate (N)	45	10		<0.5	1.5 (115-D)
Nitrite (N)		1.0		<0.01	0.04 (2)
pH, units		5.0 to 9.0, units	6.5 to 8.5, units	7.2-9.6	9.6 (2)
Phenolic Cpds (Phenol)	0.001	1.0 μg/l		<0.006	0.018 (114-A)
Phosphorus, ortho (P)				<0.08	0.6 (114-A)
Phosphorus, total (P)			0.1 μg/l	<0.20	0.74 (114-A)
Potassium (K)				5.1	9.9 (114-A)
Silica, total (Si)				25.5	136 (115-D)
Sodium (Na)				331	615 (115-D)
Solids, dissolved	500			1270	2730 (115-D)
Sp. Conductance, 25°C, μmhos/cm				1998	4020 (115-D)
Sulfate (S)	250	250		<15.1	34.1 (115-D)

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TABLE 2.5-29 (Continued)

COMPARISON OF GROUNDWATER QUALITY TO DRINKING WATER STANDARDS AND PROPOSED CRITERIA FOR PRESERVATION OF AQUATIC LIFE

Parameter (mg/l, except as noted)	U.S. Public Health Service Drinking Water Standards*	EPA Proposed Drinking Water Criteria**	EPA Proposed Criteria for Preservation of Aquatic life**	Grand Mean, STP Groundwater	Maximum Value Reported During Current Study
Sulfide (S)				<0.30	3.29 (114-A)***
Zinc (An)	5.0	5.0	0.1	<0.43	4.7 (2)
Barium (Ba)	1.0	1.0	1.0	<0.2	0.3 (115-D)
Boron (B)		1.0	0.1	<0.3	1.1 (115-D)
Selenium (Se)	0.01	0.01	0.01	<0.01	<0.01 (all)
Silver (Ag)	0.05	0.05	0.5 μg/l	<0.02	<0.02 (all)
Bacteria					
Std. Plate Count, No./ml				>17353	88,200 (115-D)
Coliforms, No./100 ml		10,000/100 ml		658	6233 (115-D)
Fecal Coliforms, No./100 ml		2,000/100 ml		<1	3 (114-A)
Fecal Streptococci, No./100 ml				10	112 (115-D)

* From Reference 2.5-25.
** From Reference 2.5-30.
*** Well number given in parentheses.
† Organic contaminants determined by carbon-chloroform extraction.
†† The concentration of fluoride may be between 0.6 and 1.7 mg/l, depending on annual average maximum daily air temperature.
††† Criteria given in terms of soluble iron and therefore may not be used to directly evaluate reported iron concentration.

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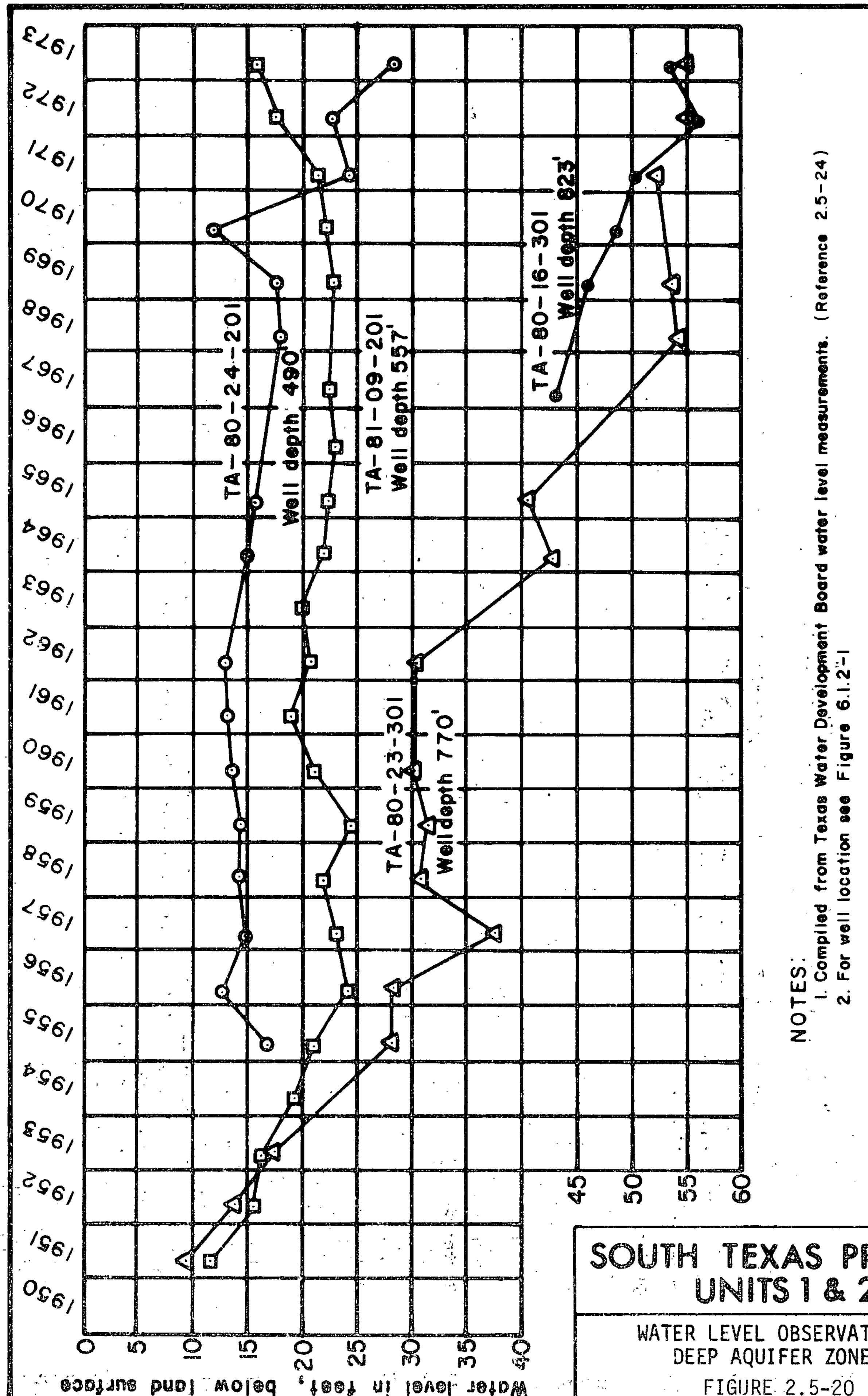
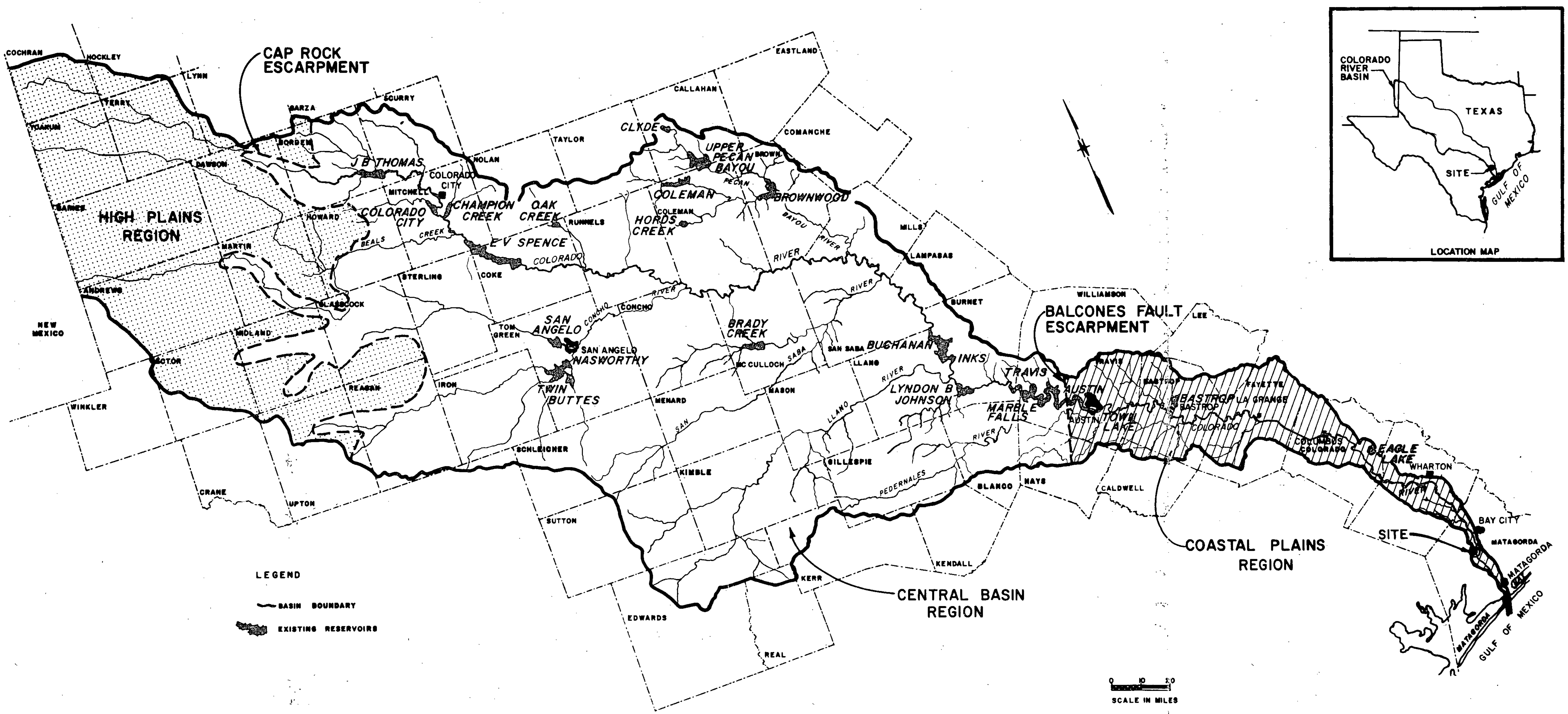


SOUTH TEXAS PROJECT
UNITS 1 & 2

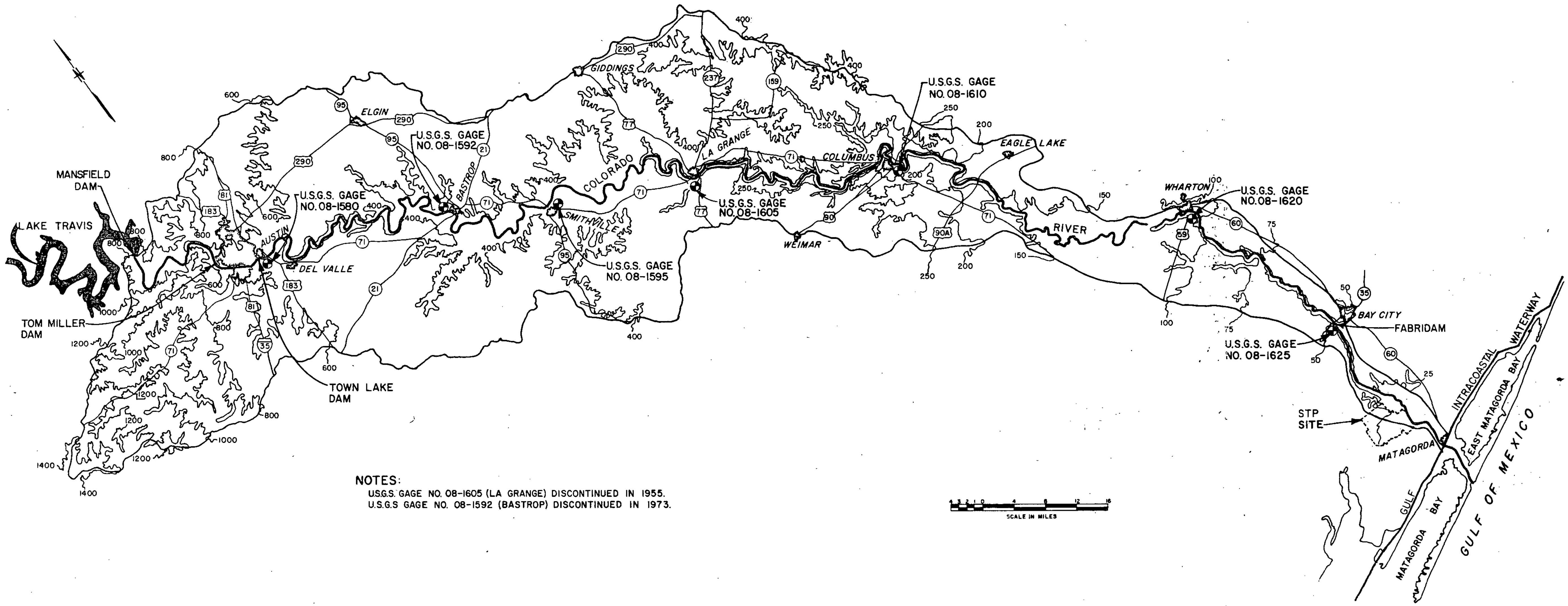
WATER LEVEL OBSERVATIONS
DEEP AQUIFER ZONE
FIGURE 2.5-20



SOUTH TEXAS PROJECT
UNITS 1 & 2

COLORADO RIVER BASIN
RESERVOIRS AND HYDROLOGIC REGIONS

FIGURE 2.5-1

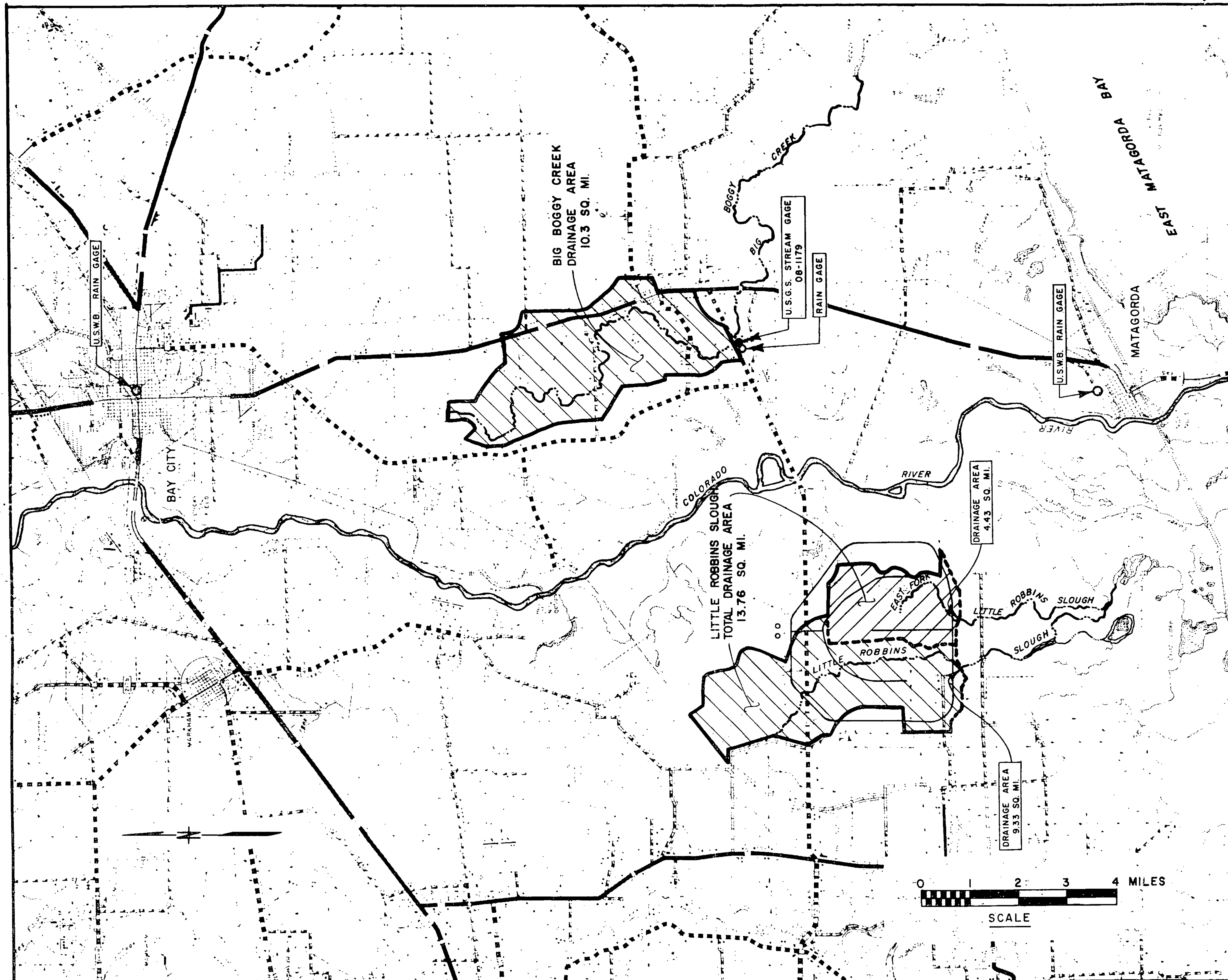


NOTES:
U.S.G.S. GAGE NO. 08-1605 (LA GRANGE) DISCONTINUED IN 1955.
U.S.G.S GAGE NO. 08-1592 (BASTROP) DISCONTINUED IN 1973.

SOUTH TEXAS PROJECT
UNITS 1 & 2

TOPOGRAPHY OF COLORADO RIVER BASIN
BELOW LAKE TRAVIS

FIGURE 2.5-2

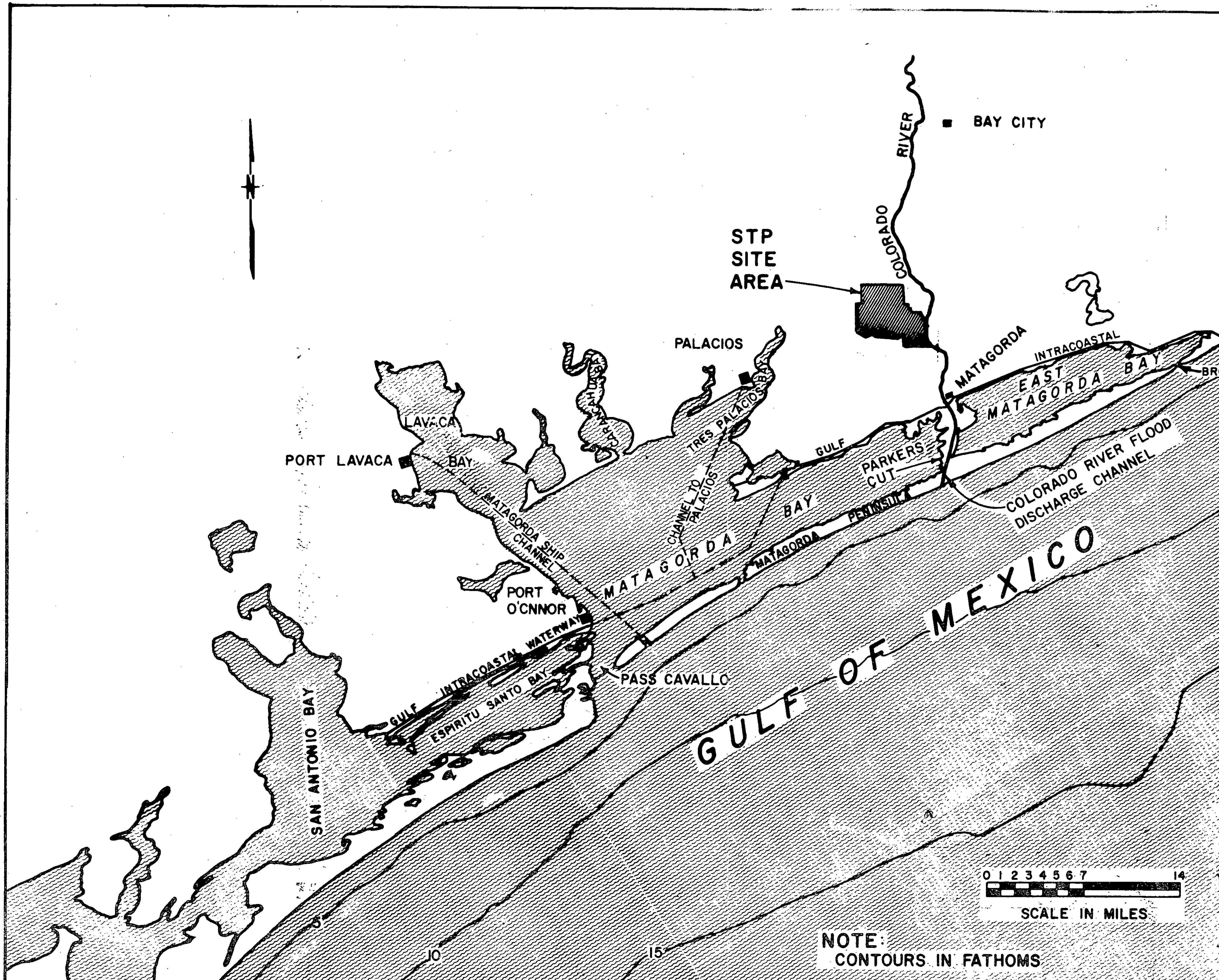


Amendment 1, August 2, 1974

SOUTH TEXAS PROJECT UNITS 1 & 2

BIG BOGGY CREEK AND LITTLE ROBBINS SLOUGH DRAINAGE AREAS

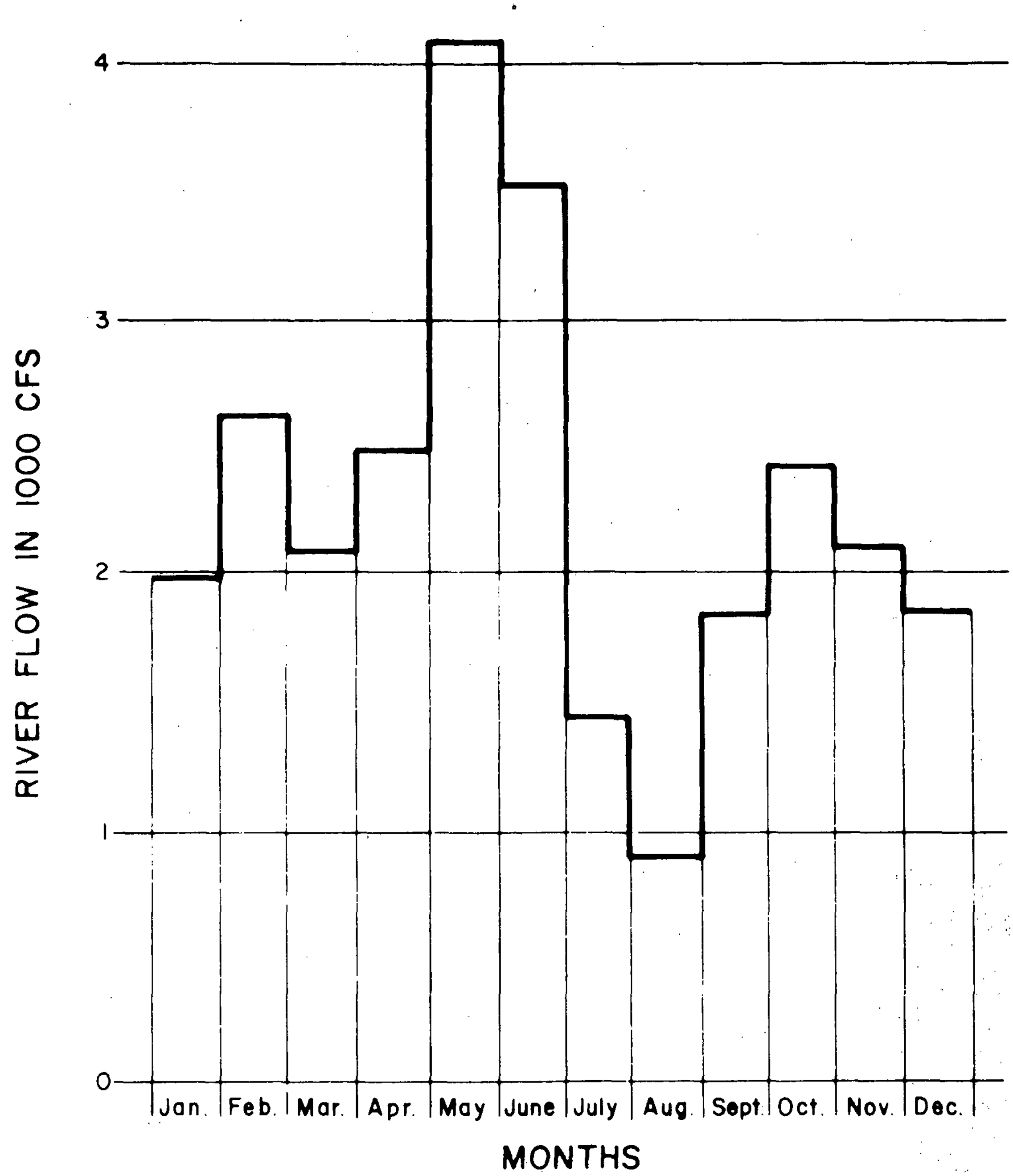
FIGURE 2.5-2a



SOUTH TEXAS PROJECT UNITS 1 & 2

COASTAL FEATURES NEAR STP SITE

FIGURE 2.5-3

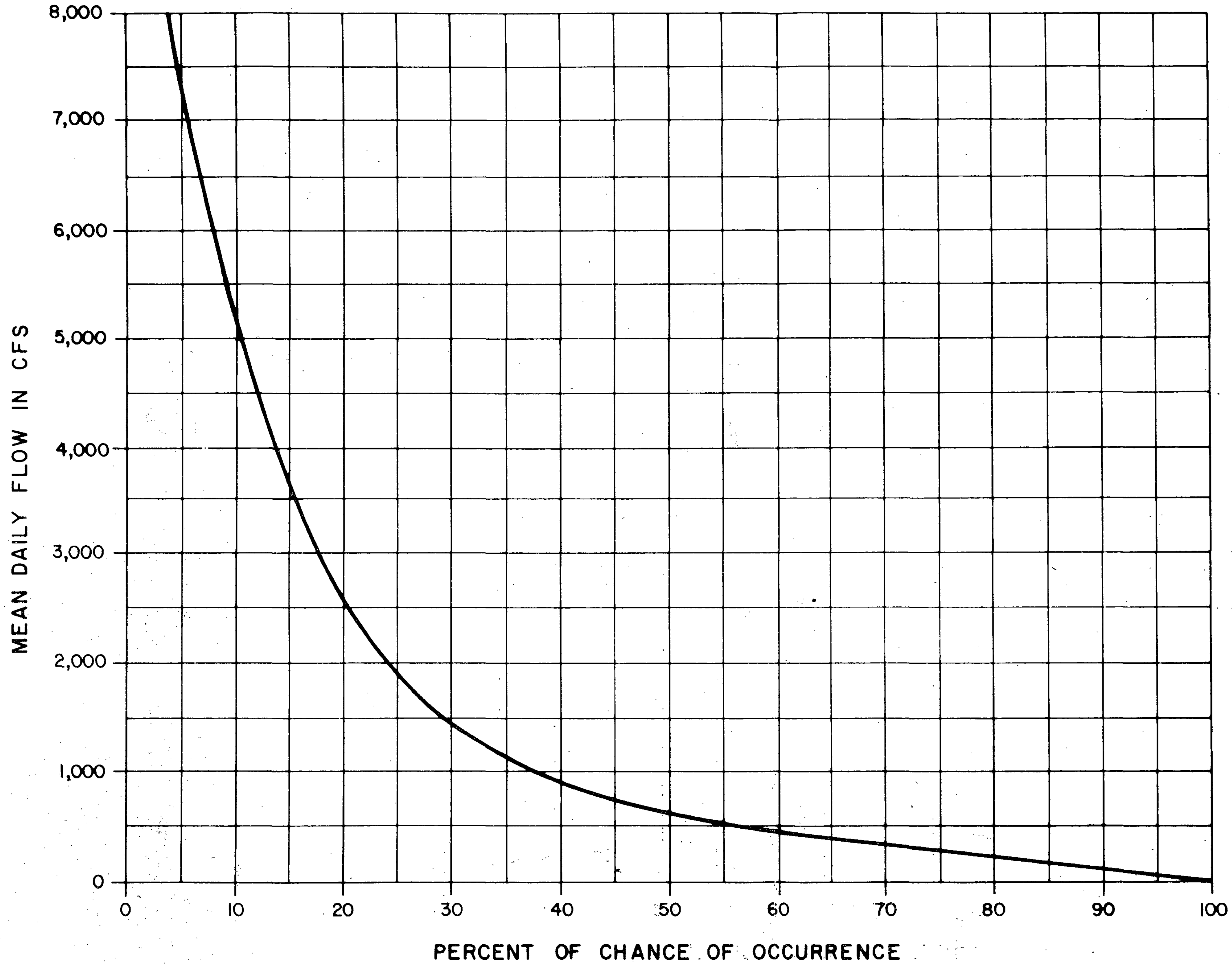


NOTE:
BASED ON USGS GAGE
08-1625, COLORADO RIVER
NEAR BAY CITY, TEXAS.
PERIOD OF RECORD 1948-1970
(REFERENCE 2.5-7)

SOUTH TEXAS PROJECT
UNITS 1 & 2

MEAN MONTHLY
HISTORICAL RIVER FLOWS
USGS GAGE AT BAY CITY

FIGURE 2.5-4

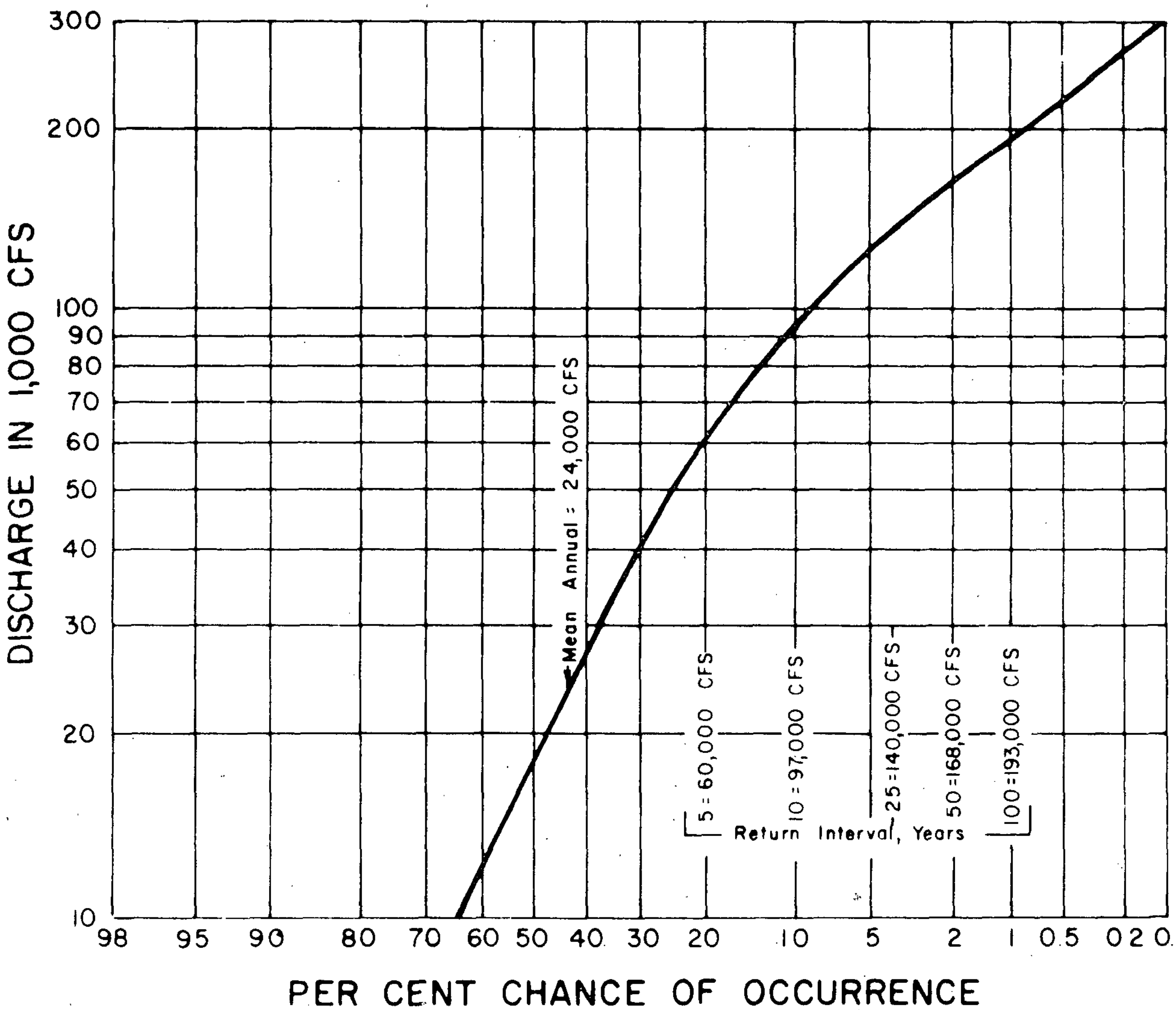


NOTE:
BASED ON USGS GAGE 08-1625, COLORADO RIVER NEAR BAY CITY, TEXAS. PERIOD OF RECORD 1948-1970 (REFERENCE 2.5-7)

SOUTH TEXAS PROJECT UNITS 1 & 2

DAILY FLOW - FREQUENCY USGS GAGE AT BAY CITY

FIGURE 2.5-5

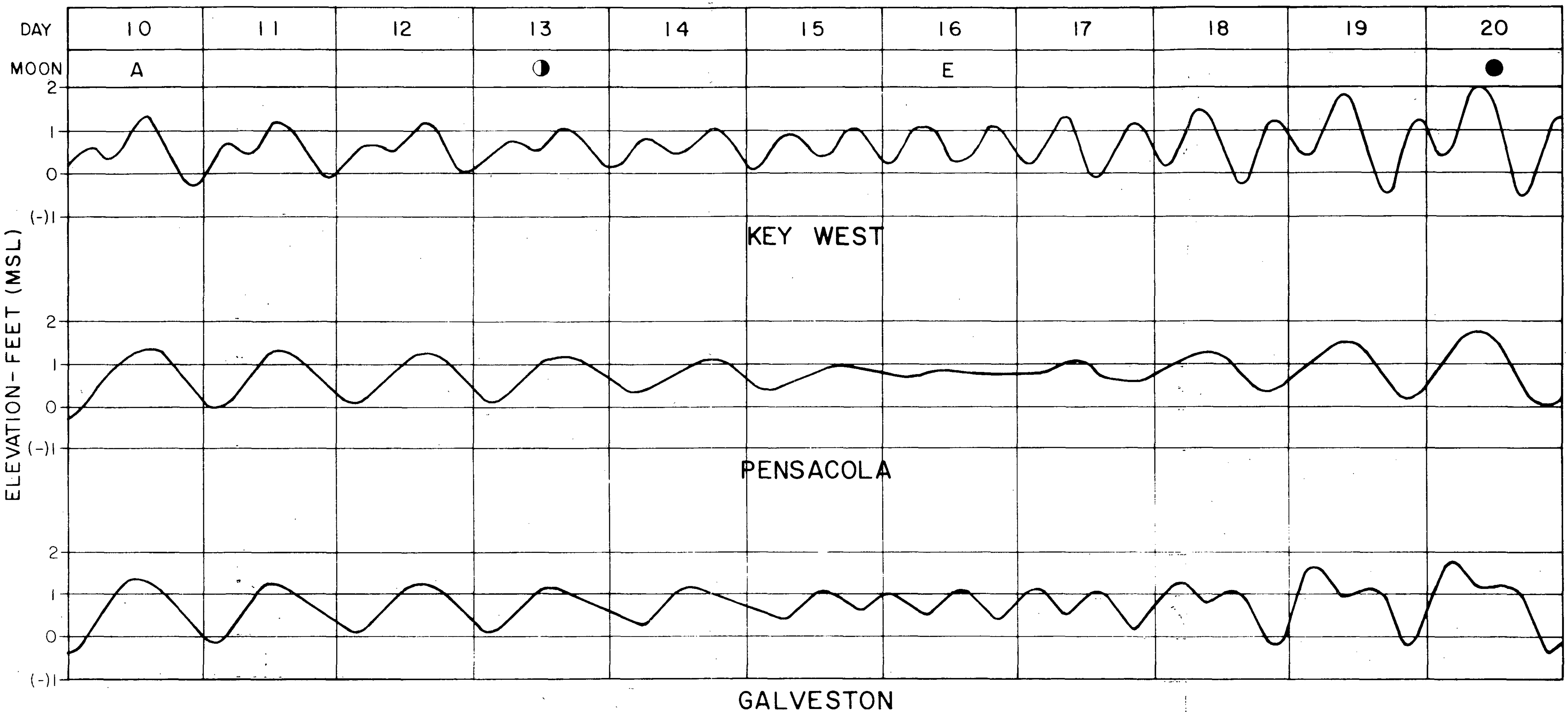


NOTE:
BASED ON USGS GAGE
08-1625, COLORADO RIVER
NEAR BAY CITY, TEXAS.
PERIOD OF RECORD 1948-1970
(REFERENCE 2.5-7)

SOUTH TEXAS PROJECT UNITS 1 & 2

DISCHARGE - FREQUENCY CURVE
USGS GAGE AT BAY CITY

FIGURE 2.5-6



LUNAR DATA:

A - MOON IN APOGEE
◑ - LAST QUARTER
E - MOON ON EQUATOR
● - NEW MOON

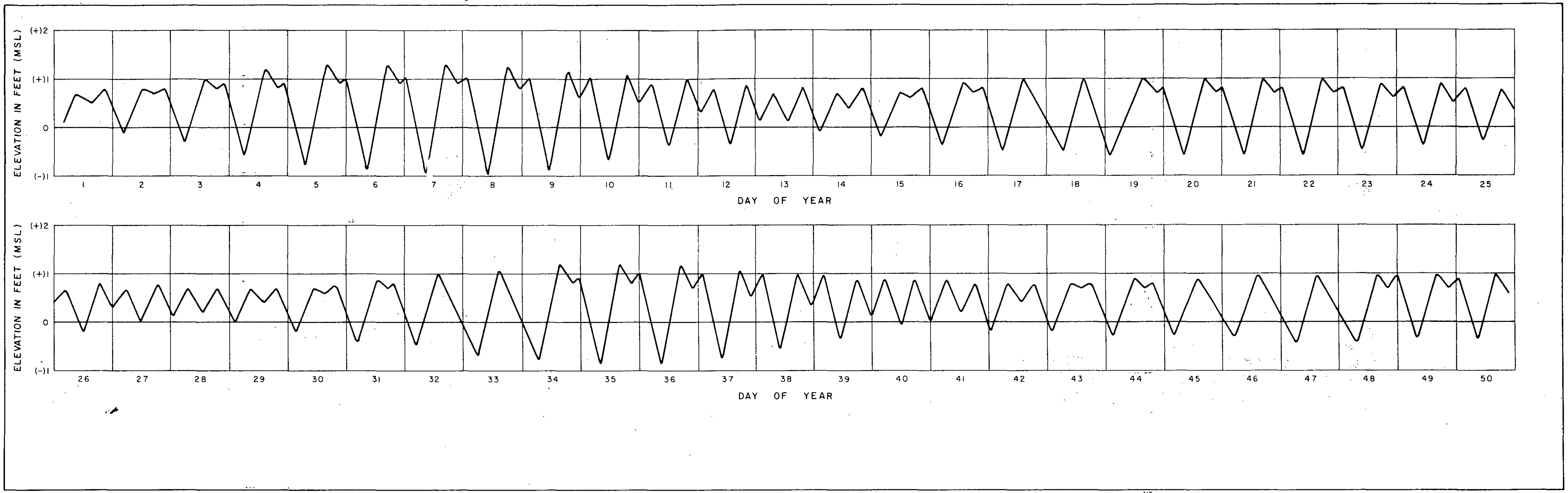
NOTE:

TIDE TABLES BASED ON "1973 TIDE TABLES FOR EAST COAST OF NORTH AND SOUTH AMERICA" BY U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION.

SOUTH TEXAS PROJECT
UNITS 1 & 2

TYPICAL TIDE CURVES
FOR
UNITED STATES PORTS

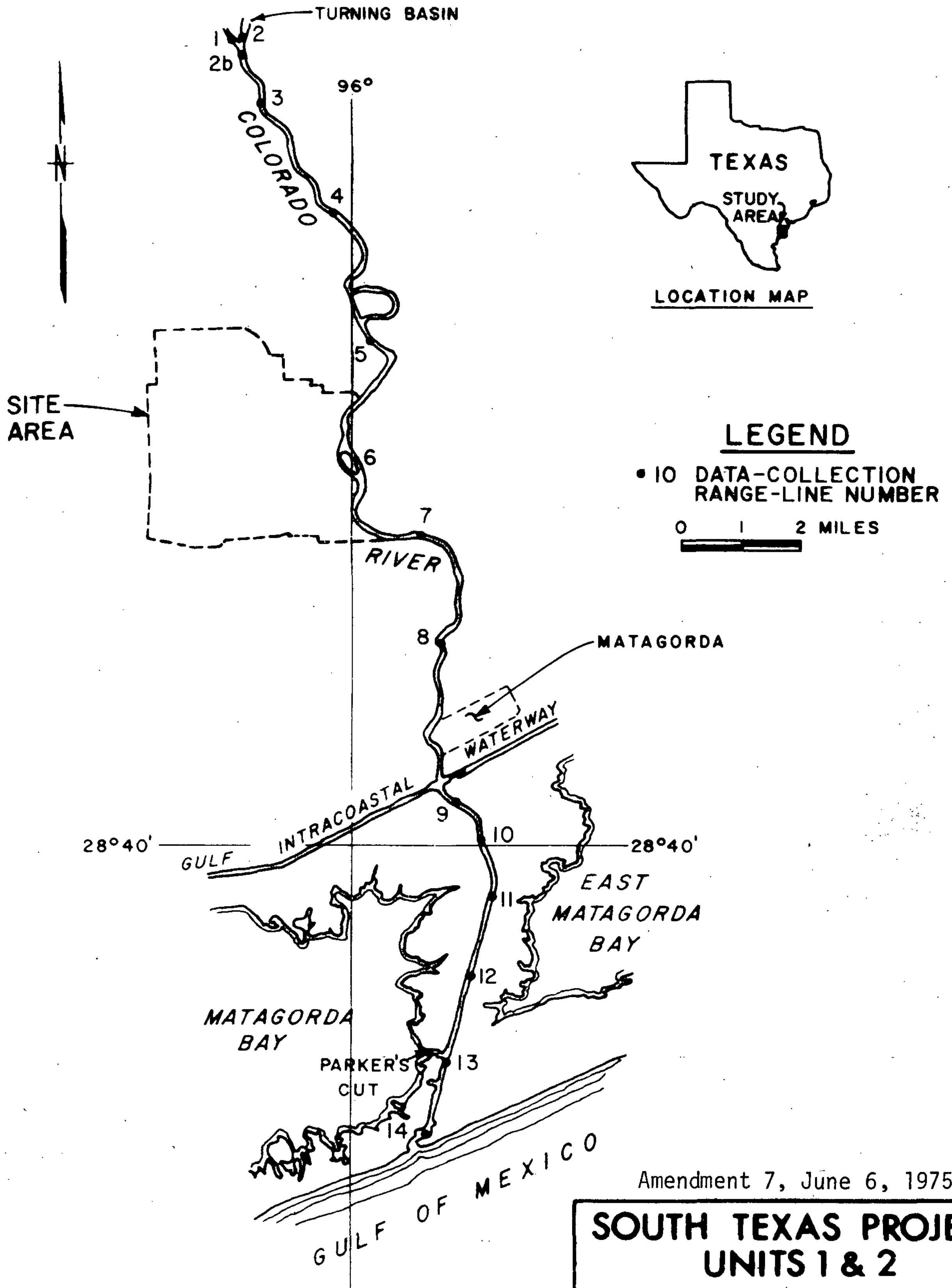
FIGURE 2.5-7



SOUTH TEXAS PROJECT
UNITS 1 & 2

PREDICTED TIDES FOR PORT O'CONNOR
FIRST 50 DAYS OF 1974

FIGURE 2.5-8



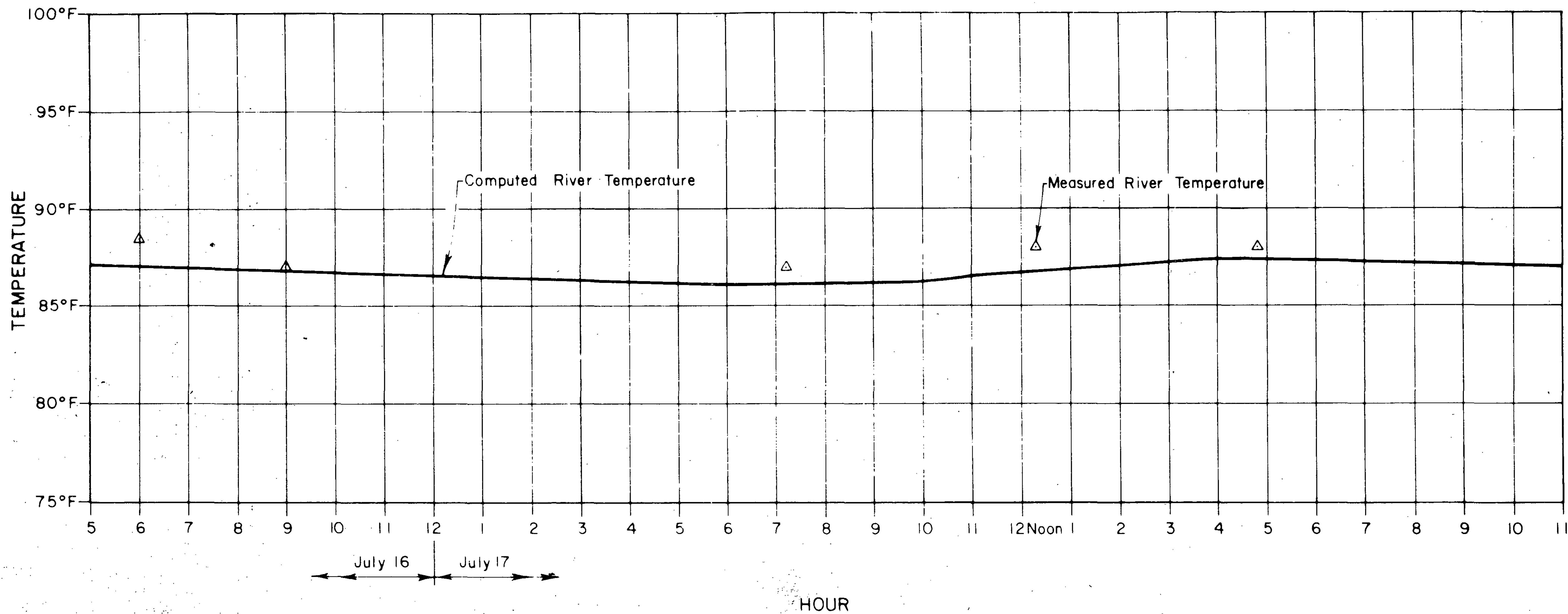
NOTE:
BASED ON SAMPLING STATIONS OUTLINED IN REFERENCE 2.5-9

Amendment 7, June 6, 1975

SOUTH TEXAS PROJECT UNITS 1 & 2

USGS DATA COLLECTION SITES IN THE COLORADO ESTUARY

FIGURE 2.5-9

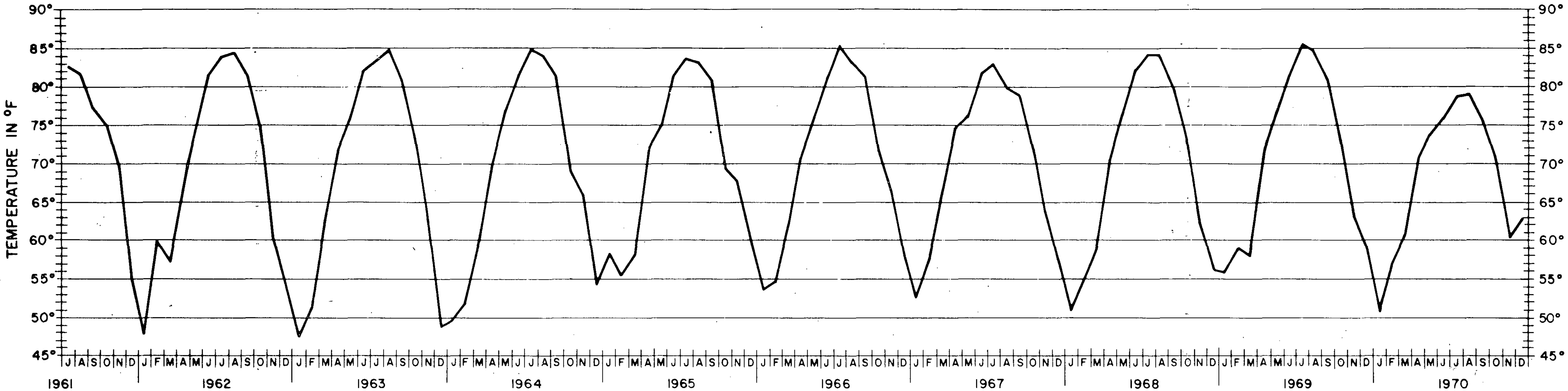


NOTE:
OBSERVED RIVER TEMPERATURES TAKEN ON
JULY 16-17, 1973 AT RIVER MILE 12.6.

SOUTH TEXAS PROJECT
UNITS 1 & 2

COMPARISON BETWEEN COMPUTED
& MEASURED RIVER WATER TEMPERATURE

FIGURE 2.5-10

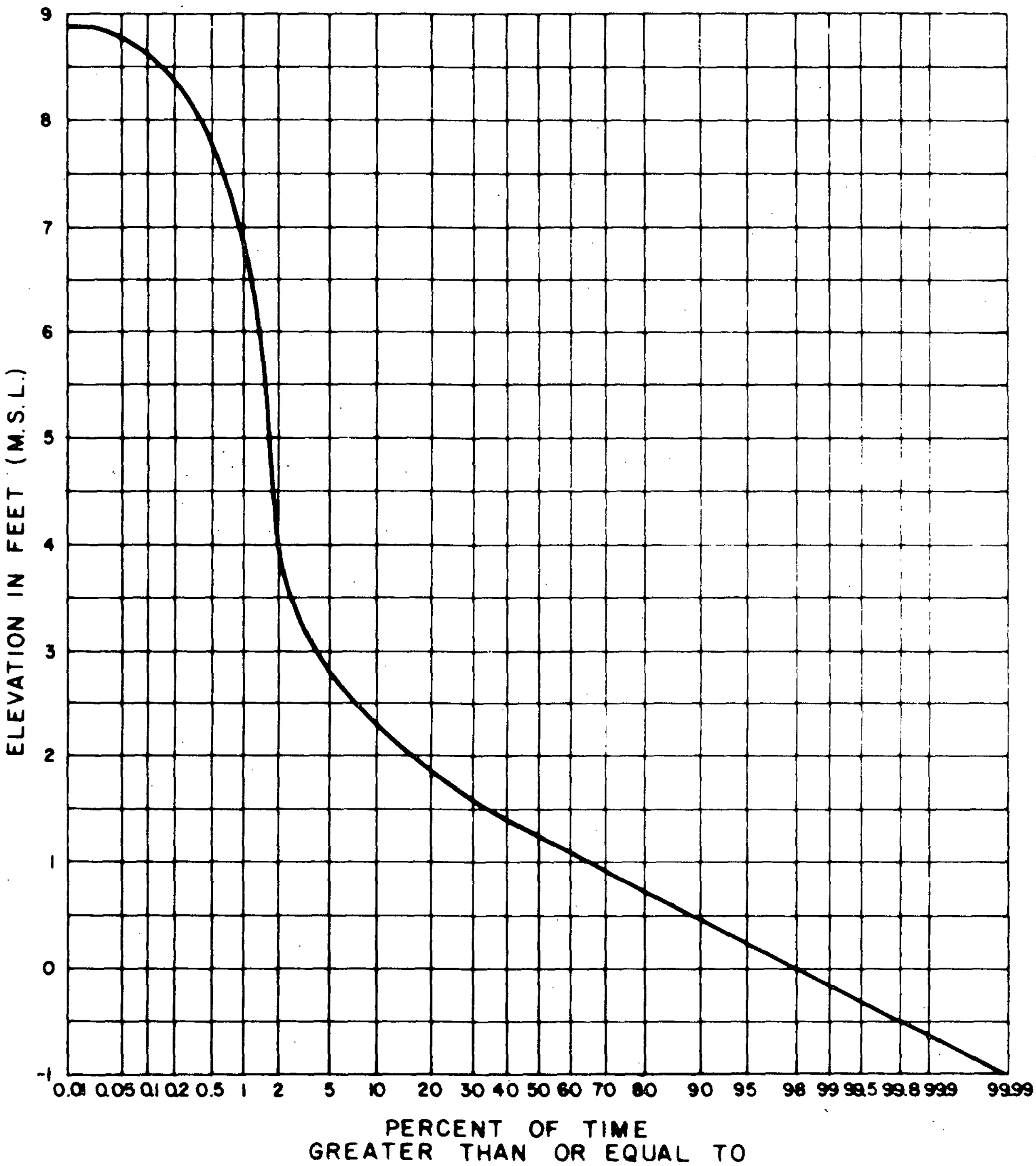


NOTE:
Weather data based on data from Victoria, Texas weather station.

SOUTH TEXAS PROJECT
UNITS 1 & 2

MONTHLY RIVER WATER TEMPERATURE

FIGURE 2.5-11

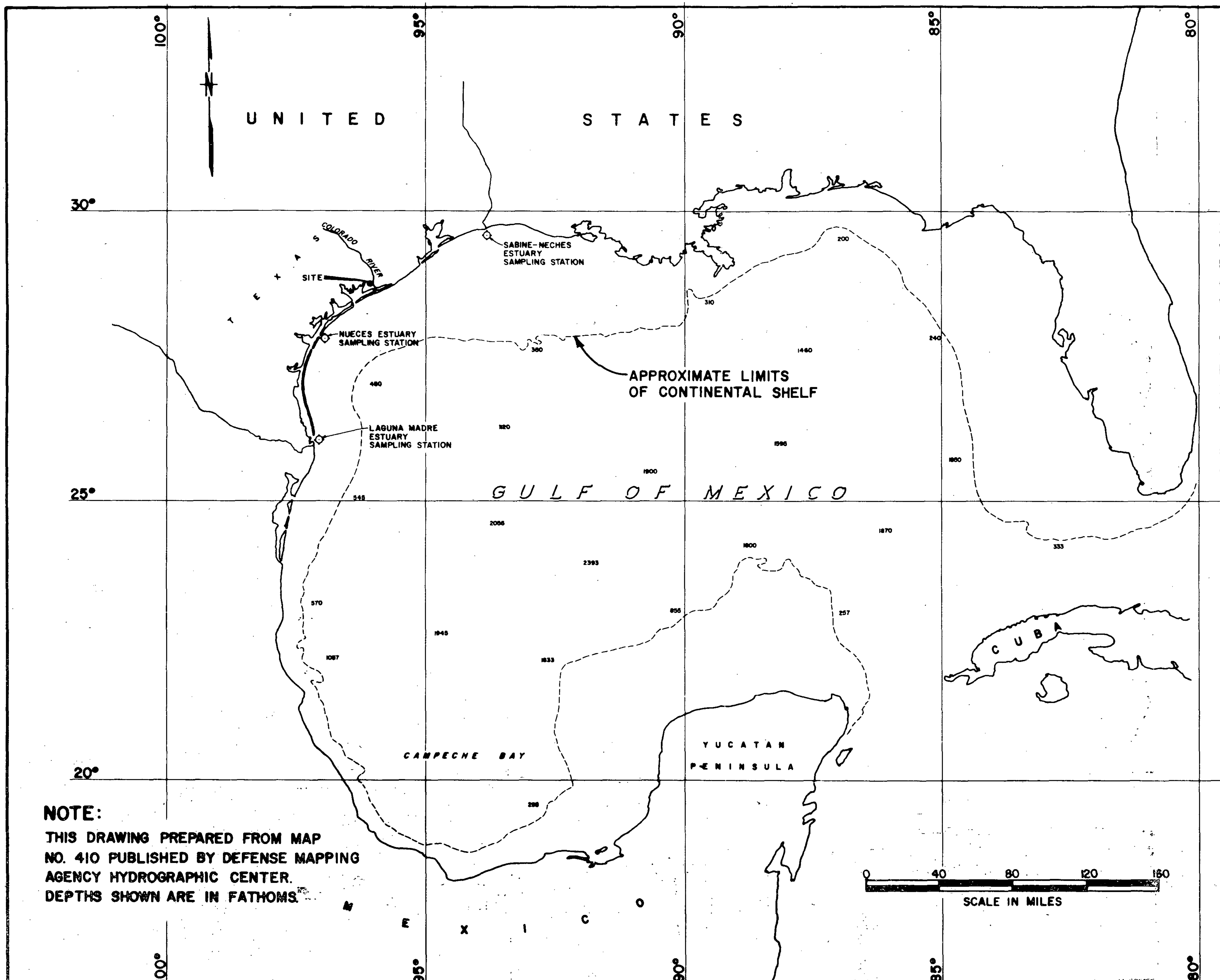


NOTE: DATA BASED ON WEST LOCK ON COLORADO RIVER AT G I W W AND TIME PERIOD 1957-1972

SOUTH TEXAS PROJECT
UNITS 1 & 2

COLORADO RIVER LOCKS
RIVER ELEVATION VS. PERCENT OF TIME
GREATER THAN OR EQUAL TO

FIGURE 2.5-12

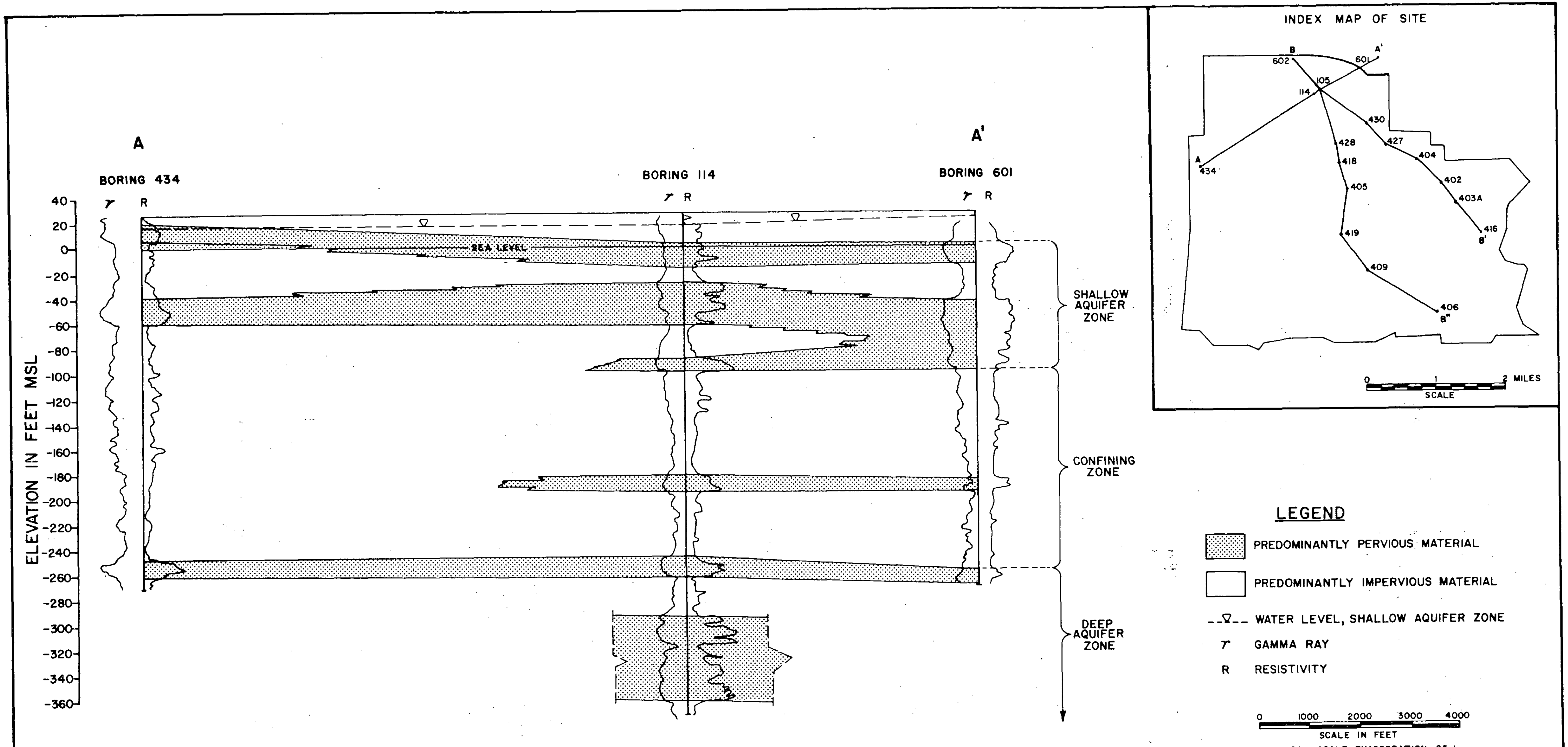


NOTE:
THIS DRAWING PREPARED FROM MAP NO. 410 PUBLISHED BY DEFENSE MAPPING AGENCY HYDROGRAPHIC CENTER. DEPTHS SHOWN ARE IN FATHOMS.

SOUTH TEXAS PROJECT
UNITS 1 & 2

GULF OF MEXICO

FIGURE 2.5-13

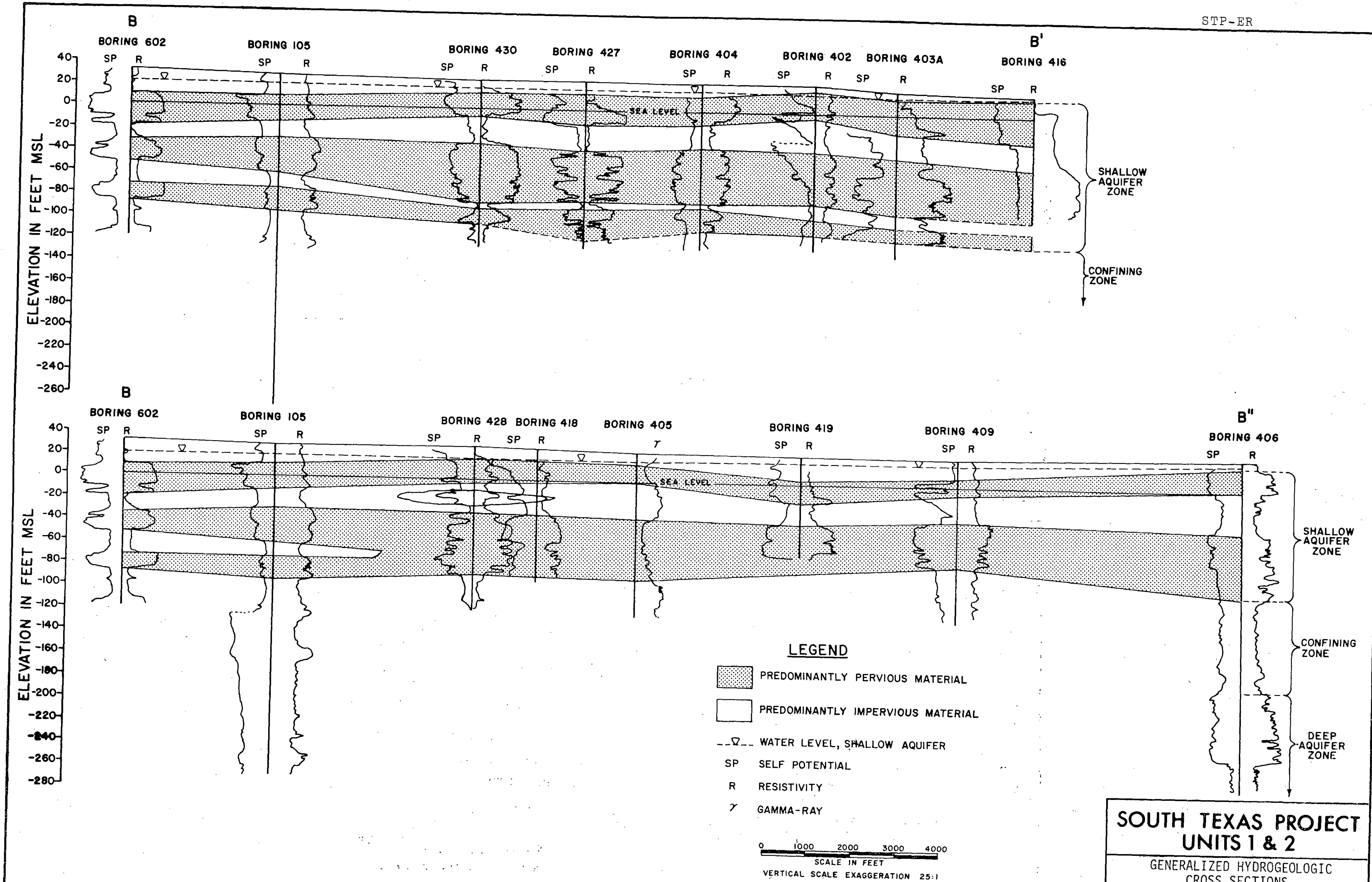


Amendment 8, September 22, 1975

SOUTH TEXAS PROJECT
UNITS 1 & 2

GENERALIZED HYDROGEOLOGIC CROSS SECTIONS

FIGURE 2.5-14



SOUTH TEXAS PROJECT
UNITS 1 & 2

GENERALIZED HYDROGEOLOGIC CROSS SECTIONS

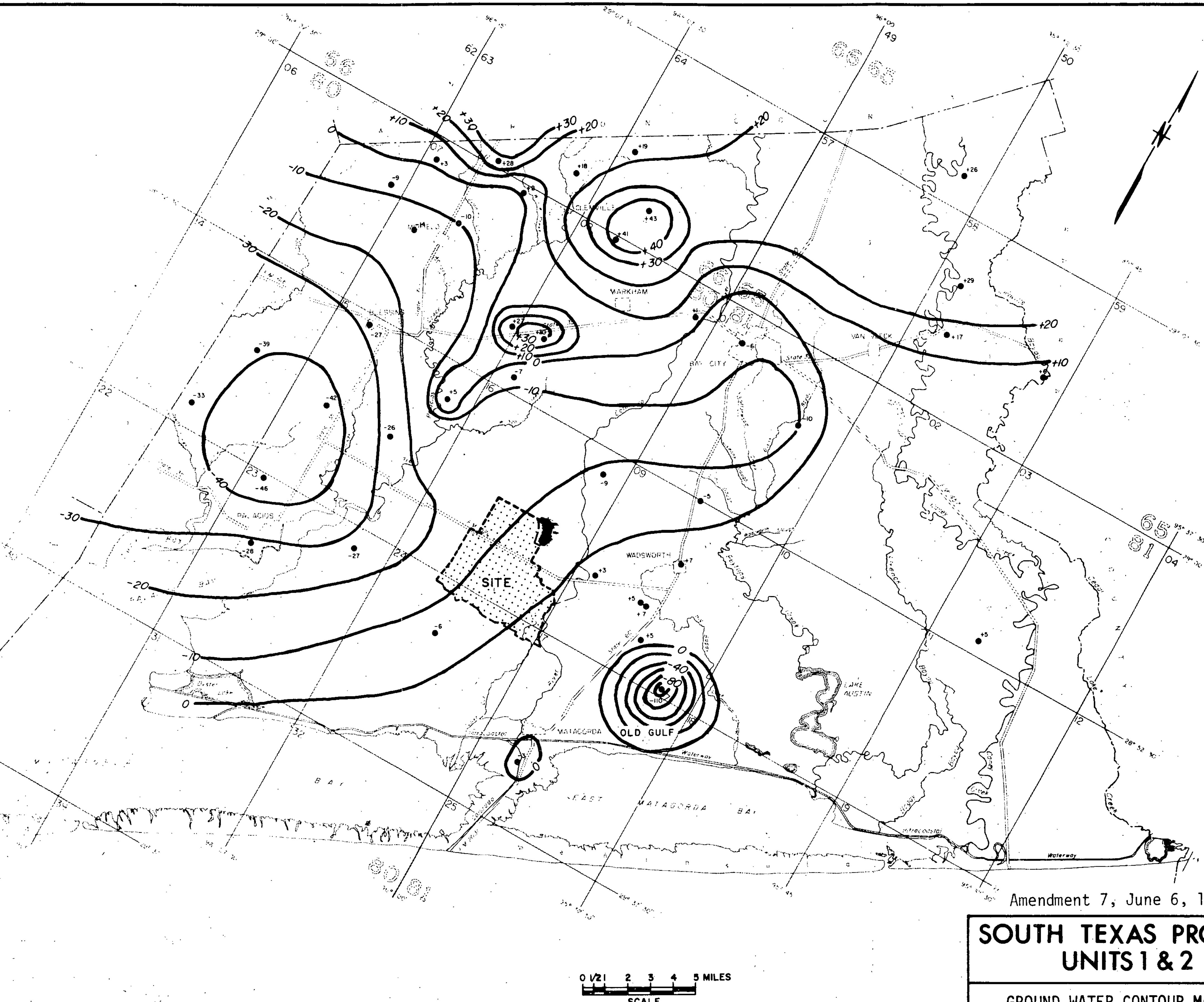
FIGURE 2.5-15

EXPLANATION

●+5 Well used for control. Number indicates altitude of water level in feet above (+) or below (-) sea level.

—-10— Elevation contours of piezometric levels in the deep aquifer zone, February, 1967. Contour interval 10 feet; contour interval 20 feet where gradient is steep near Old Gulf. Datum is mean sea level.

REFERENCE: 2.5-24 Figure 7.



Amendment 7, June 6, 1975

SOUTH TEXAS PROJECT UNITS 1 & 2

GROUND WATER CONTOUR MAP OF DEEP AQUIFER ZONE FEBRUARY, 1967

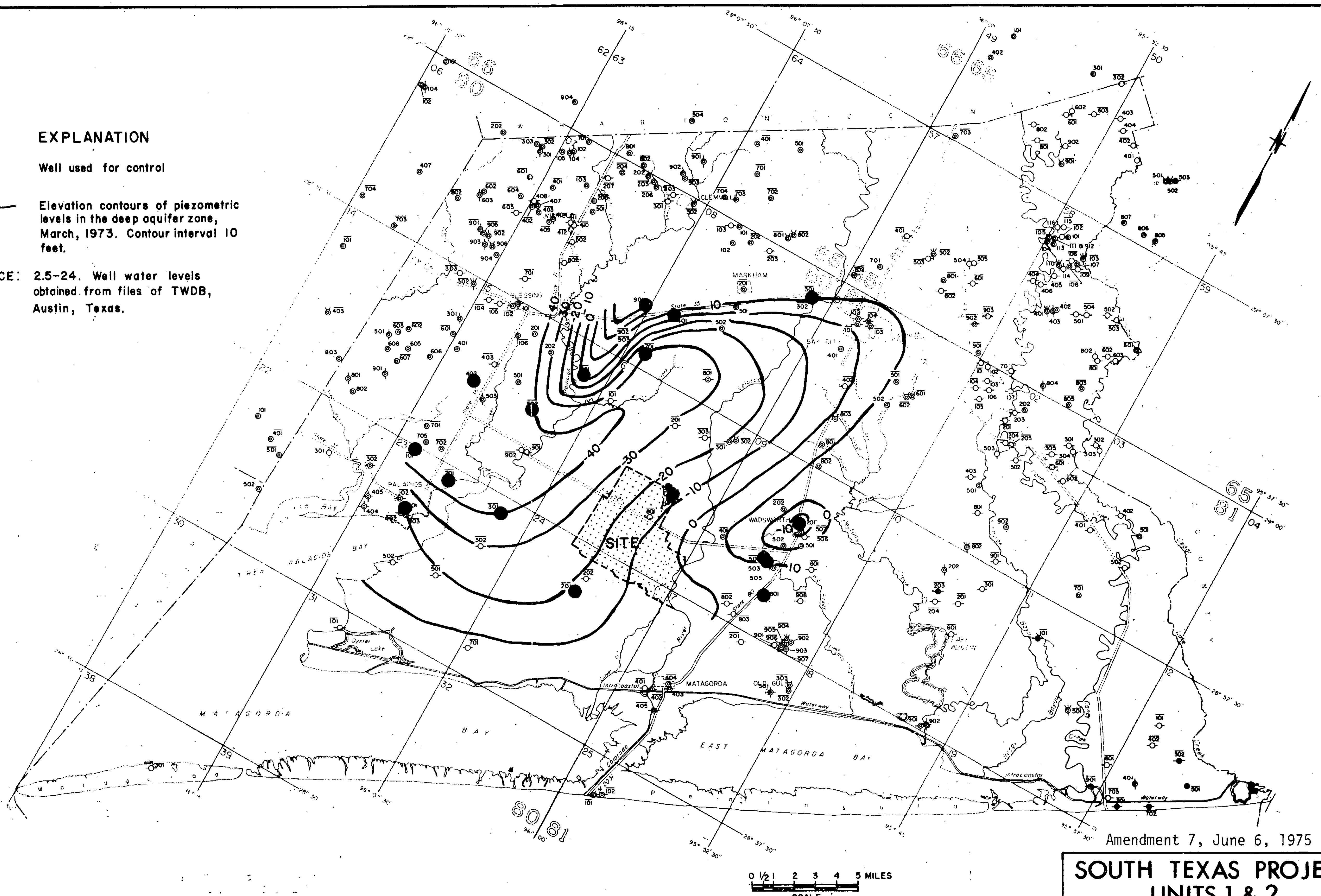
FIGURE 2.5-16

EXPLANATION

● Well used for control

—-10— Elevation contours of piezometric levels in the deep aquifer zone, March, 1973. Contour interval 10 feet.

REFERENCE: 2.5-24. Well water levels obtained from files of TWDB, Austin, Texas.

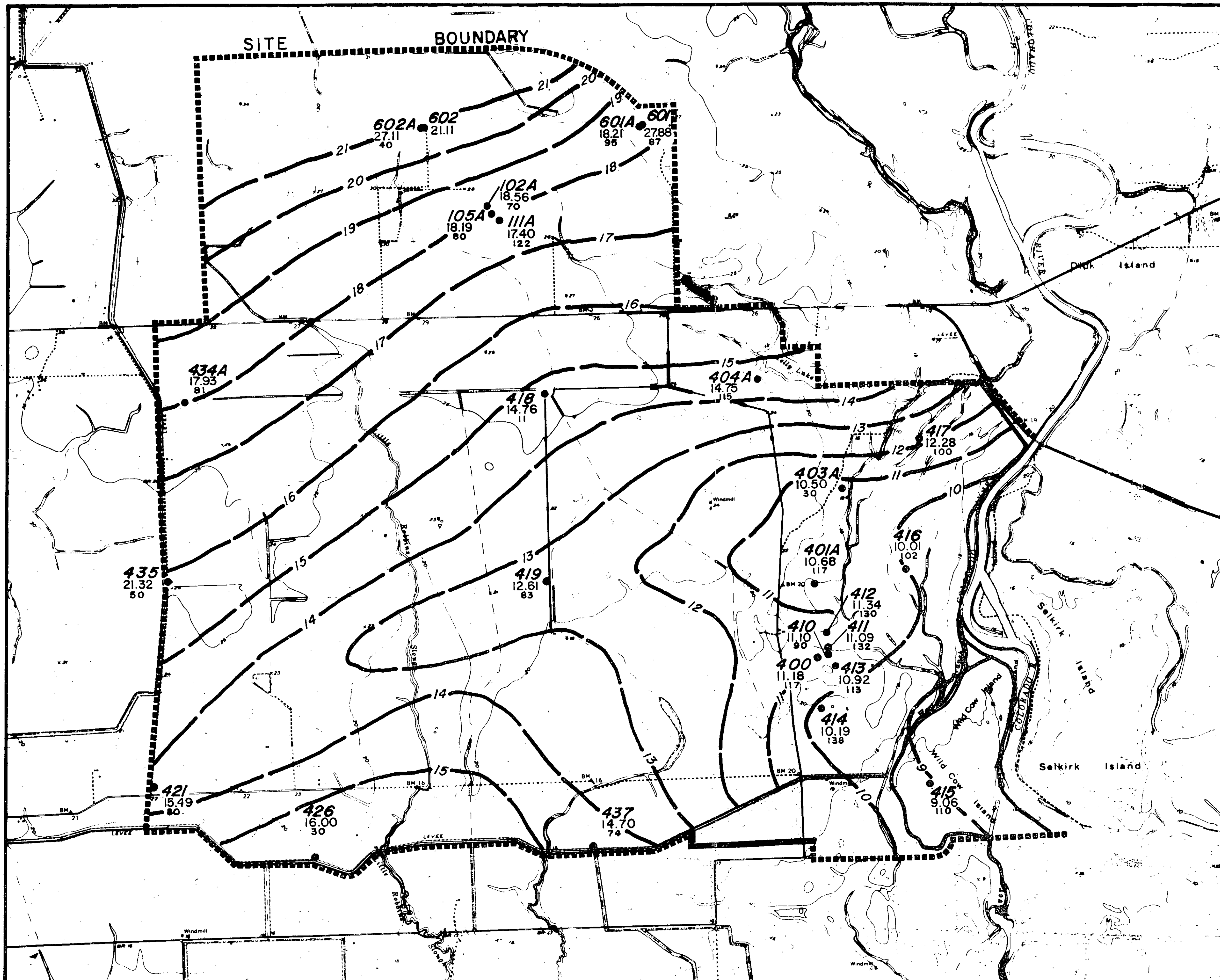


Amendment 7, June 6, 1975

SOUTH TEXAS PROJECT UNITS 1 & 2

GROUND WATER CONTOUR MAP
OF DEEP AQUIFER ZONE
MARCH, 1973

FIGURE 2.5-17



LEGEND

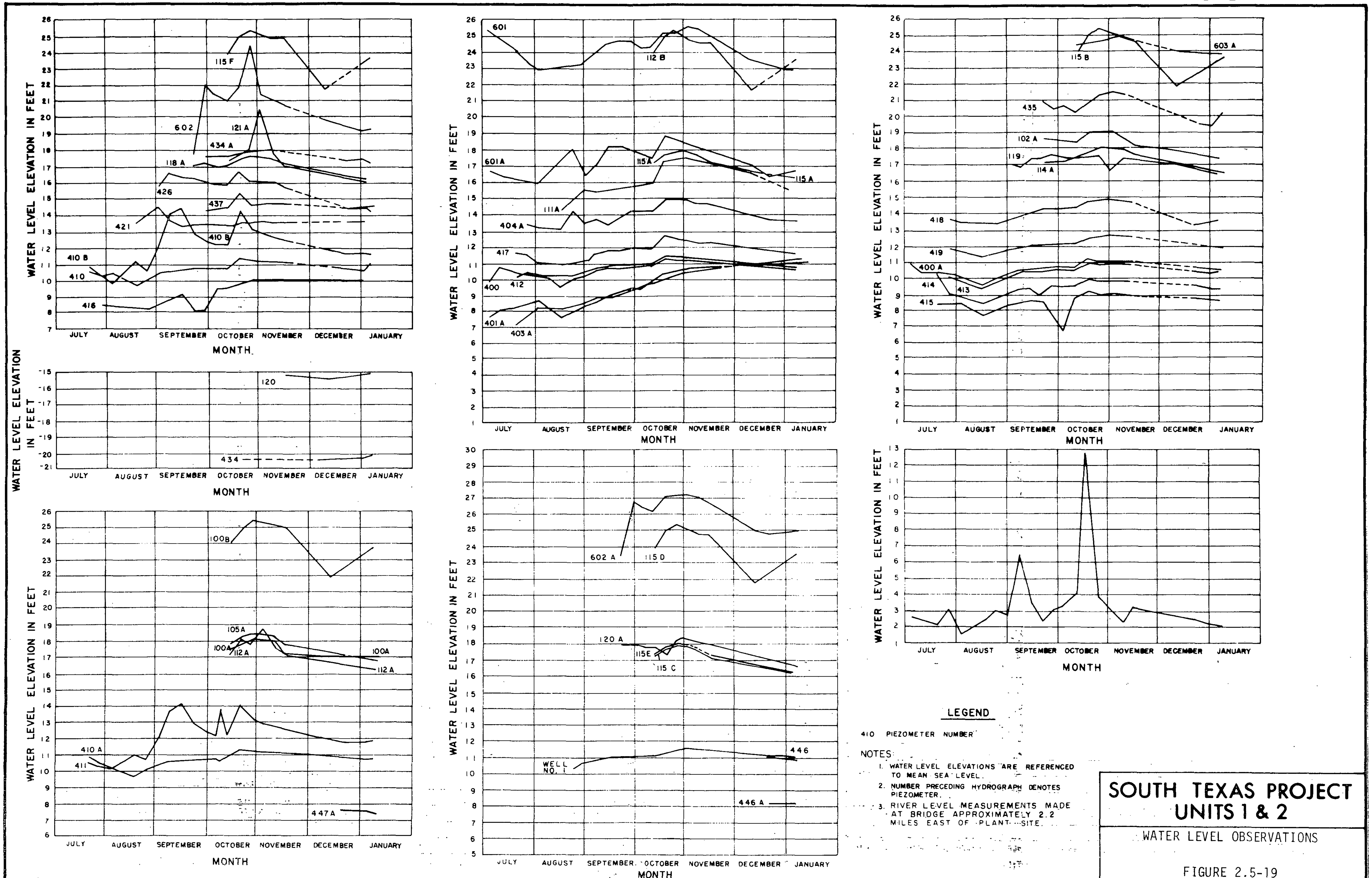
- 201 — Location and number of piezometer
- 16.89 — Elevation of water above sea level. in feet.
- 131 — Depth of piezometer.
- 15 — Elevation contours of piezometric levels in the lower portion of the shallow aquifer zone, November 8, 1973. Contour interval 1 foot.
- 30 — Ground surface contours.

Amendment 7, June 6, 1975

SOUTH TEXAS PROJECT UNITS 1 & 2

GROUNDWATER CONTOUR MAP OF SHALLOW AQUIFER ZONE

FIGURE 2.5-18



SOUTH TEXAS PROJECT
UNITS 1 & 2

WATER LEVEL OBSERVATIONS

FIGURE 2.5-19

APPENDIX 2.5-A

TIDAL PREDICTIONS
FOR THE ESTUARIAL
REGIONS OF THE
COLORADO RIVER

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TIDAL PREDICTIONS FOR THE ESTUARIAL REGIONS OF THE COLORADO RIVER

Tidal predictions for the estuarial regions of the Colorado River were calculated for the STP site based on the data presented in Figure 2.5-8 of the STP Enviromental Report and the mathematical model and computer code as presented in Reference A2.5-1. This model solves explicitly the basic unsteady equations of motion in two orthogonal directions coupled with the unsteady flow continuity equation. A basic assumption of this model is that vertical velocity distributions are uniform and hence, computed flows are integrated over the depth. Since application of HYDTID to the Colorado River involved flow in only one direction (longitudinal), the computer code was restructured to more efficiently solve this one-dimensional problem.

The HYDTID model uses a series of interconnected square elements to describe to physiography of a prototype system with the basic equations applied and solved over this grid arrangement. The model was adapted to handle rectangular elements to more effectively describe the river system. The length of these elements was specified as one-half mile (2,640 feet) and the width was varied between 150 and 185 feet as a function of river inflow. Average mean sea level bottom depths were assigned to each element based on profile data.

The mean sea level bottom depths assigned to each element in the model are given in Table A2.5-1. The index J refers to the element number starting with J-1 at the river's mouth; Element "1" is defined as the first element immediately offshore of River Mile (RM) 0.0 and Element "2" lies between RM 0.0 and RM 0.5.

TABLE A2.5-1

ELEMENT ASSIGNED MEAN SEA LEVEL BOTTOM DEPTHS

Element Number, J	Average Bottom Elevation MSL feet
1	-15.00
2	-15.10
3	-15.20
4	-15.30
5	-15.40
6	-15.40
7	-15.50
8	-15.60
9	-15.60
10	-15.70
11	-15.80
12	-15.90
13	-15.90
14	-16.00
15	-16.10
16	-16.20
17	-16.20
18	-16.30
19	-16.20
20	-16.20
21	-16.10
22	-15.20
23	-14.60

TABLE A2.5-1 (Continued)

ELEMENT ASSIGNED MEAN SEA LEVEL BOTTOM DEPTHS

Element Number, J	Average Bottom Elevation MSL feet
24	-13.80
25	-13.00
26	-12.40
27	-12.60
28	-12.80
29	-13.00
30	-13.20
31	-13.40
32	-13.60
33	-12.00
34	-11.60
35	-12.40
36	-12.90
37	-13.20
38	-13.60
39	-13.60
40	-13.40
41	-13.30
42	-11.60
43	-13.00
44	-16.00
45	-12.40
46	-12.50

TABLE A2.5-1 (Continued)

ELEMENT ASSIGNED MEAN SEA LEVEL BOTTOM DEPTHS

Element Number, J	Average Bottom Elevation MSL feet
47	-12.60
48	-15.00
49	-13.80
50	-12.50
51	-11.30
52	-10.00
53	- 8.75
54	- 7.50
55	- 6.25
56	- 5.00
57	- 3.75
58	- 2.50
59	- 1.25
60	0.00
61	1.30
62	2.50
63	3.80
64	5.00
65	6.30
66	7.50

To adjust the mean level of the downstream exciting tides for the effect of increased river inflow, a stage-discharge correlation was established using the available tide records at the GIWW. These data were initially screened to eliminate those where wind effects were dominant. The following relation was used to adjust the mean tidal elevations for the effect of river inflow.

$$\Delta h = 0.530\ Q_R^{0.178} - 0.750$$

A constant channel width was specified in the model for the entire length of the estuary for each river inflow considered. The following values were used as determined from available data.

Q_R	Width, feet
800	150
1,500	155
2,500	170
3,500	185

A Manning's "n" bottom roughness of 0.027 was used for Manning's "n" for all simulations.

The calculations were performed with five model exciting tides and with four freshwater inflows. The exciting tides, shown in Figure A2.5-1, were identified from an analysis of tidal records at Port O'Connor:

1. average semidiurnal,
2. average diurnal,
3. low range diurnal,
4. high range diurnal with a south wind, and
5. high range diurnal with a north wind.

The calculated tidal flows at the plant site (River Mile 12.5) are shown in Figures A2.5-2, A2.5-3, A2.5-4, A2.5-5 and A2.5-6. The maximum flood and ebb flows for the first 32 miles of the Colorado River are shown in Figures A2.5-7, A2.5-8, A2.5-9, A2.5-10, and A2.5-11.

The five model exciting tides were combined to form a synthetic annual tidal cycle. The 1974 predicted sequence of semidiurnal and diurnal tides[2] shown in Figure A2.5-12, was the basis for developing the synthetic annual tidal cycle. The model average semidiurnal tide was used when a predicted semidiurnal tide occurred. The model diurnal tides were distributed as listed in Table A2.5-2.

TABLE A2.5-2

PREDICTED DIURNAL TIDE

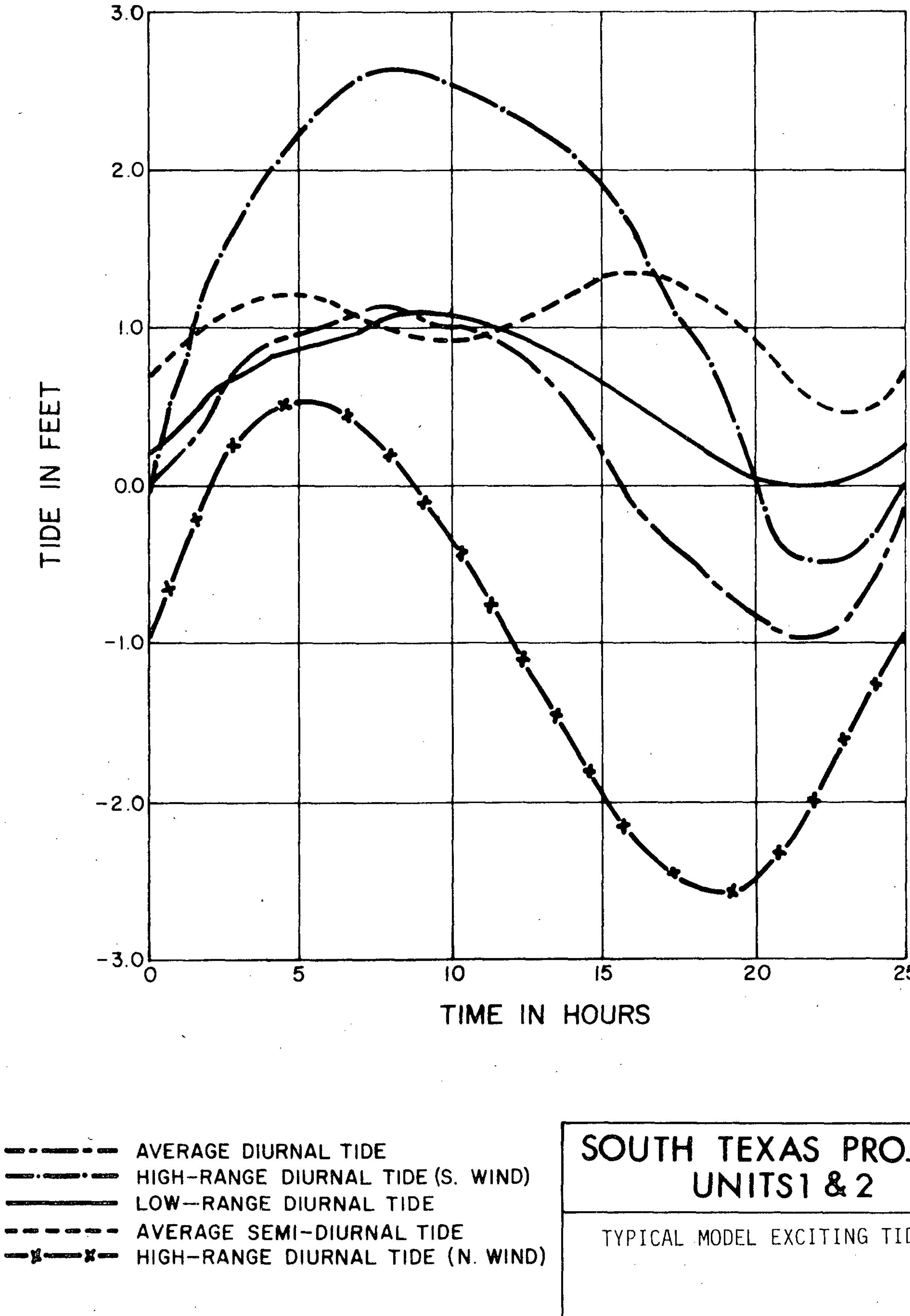
Height (feet)	Number of Occurrences	Model Diurnal Tide Selected
0.9	1	High Range with North Wind
1.0	7	
1.1	3	Low Range
1.2	2	
1.3	6	Average
1.4	13	
1.5	12	
1.6	10	
1.7	7	High Range
1.8	4	

The high range diurnal tide with a north wind occurs in the winter while the high range diurnal tide with a south wind occurs in the summer.

REFERENCES

A2.5-1. Masch, F.D., and Brandes, R.J., August 1971; Tidal Hydrodynamic Simulation in Shallow Estuaries; Hydraulic Engineering Laboratory, The University of Texas at Austin, Tech. Rep. HYD 12-7102.

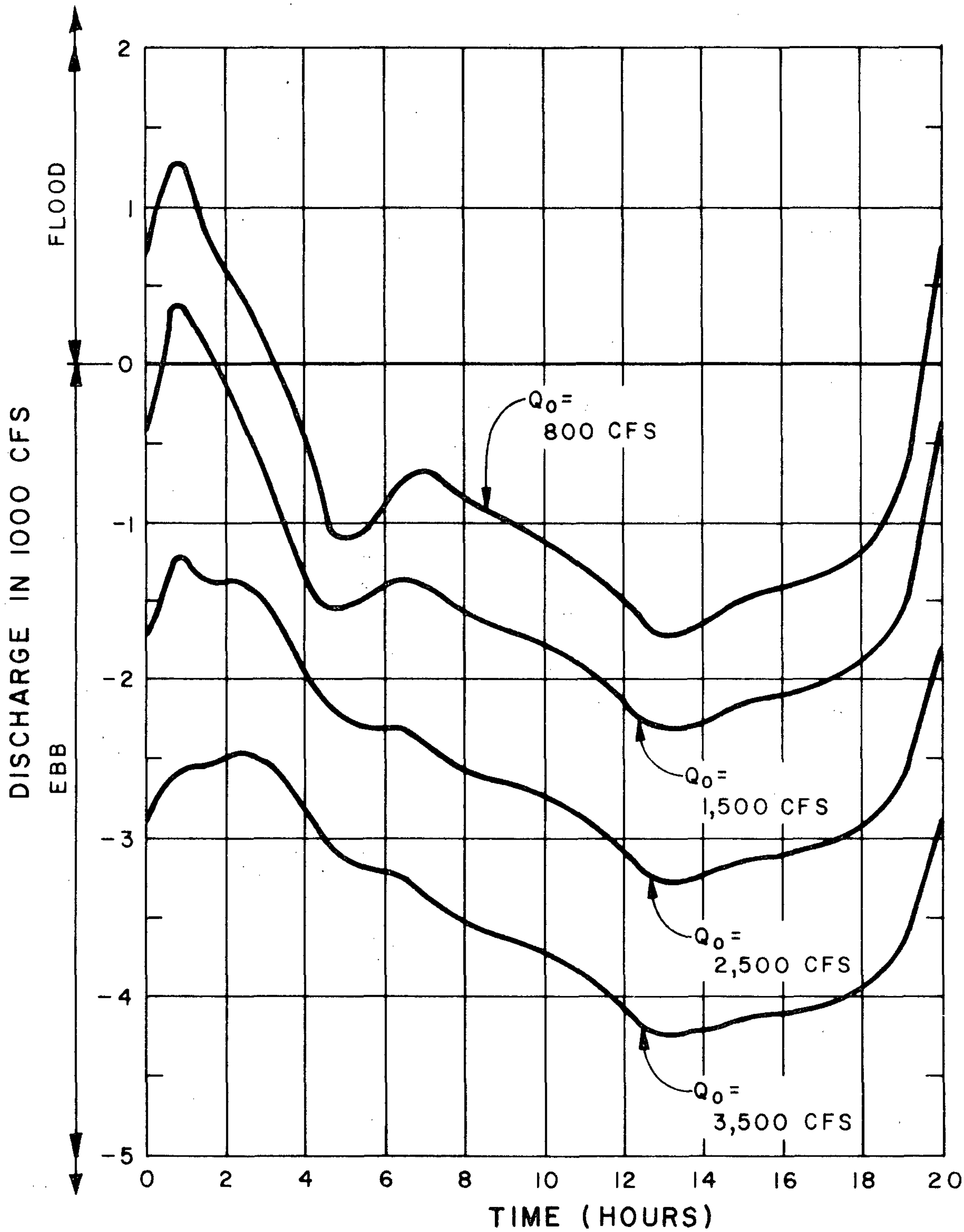
A2.5-2. National Oceanic and Atmospheric Administration, 1974; "Tide Tables, High and Low Water Predictions, 1974. East Coast of North and South America including Greenland."



SOUTH TEXAS PROJECT
UNITS 1 & 2

TYPICAL MODEL EXCITING TIDES

FIGURE 1

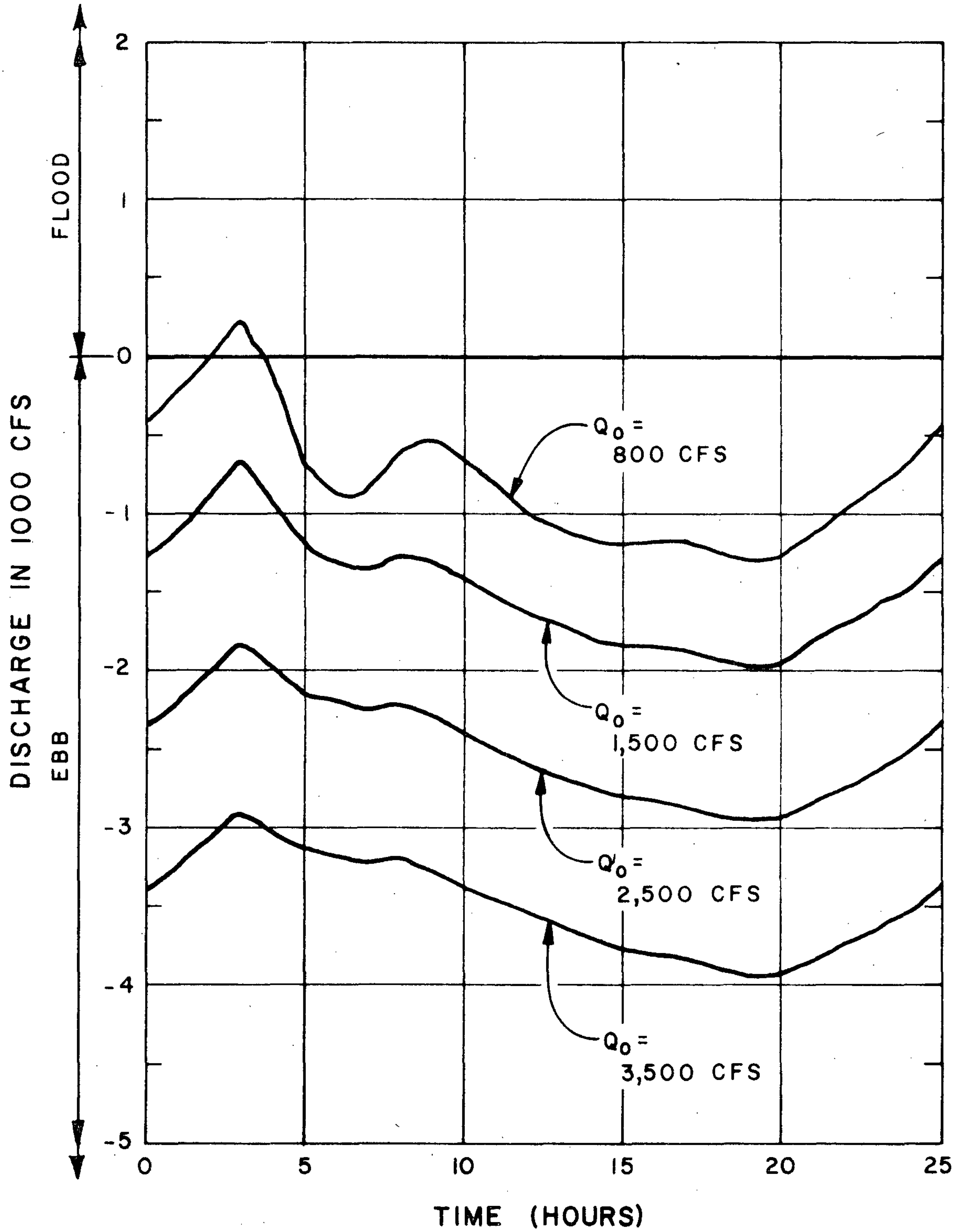


NOTE:
Q_o = FRESH WATER INFLOW

SOUTH TEXAS PROJECT
UNITS 1 & 2

TIDAL FLOW OPPOSITE PLANT SITE
WITH
AVERAGE DIURNAL EXCITING TIDE

FIGURE 2

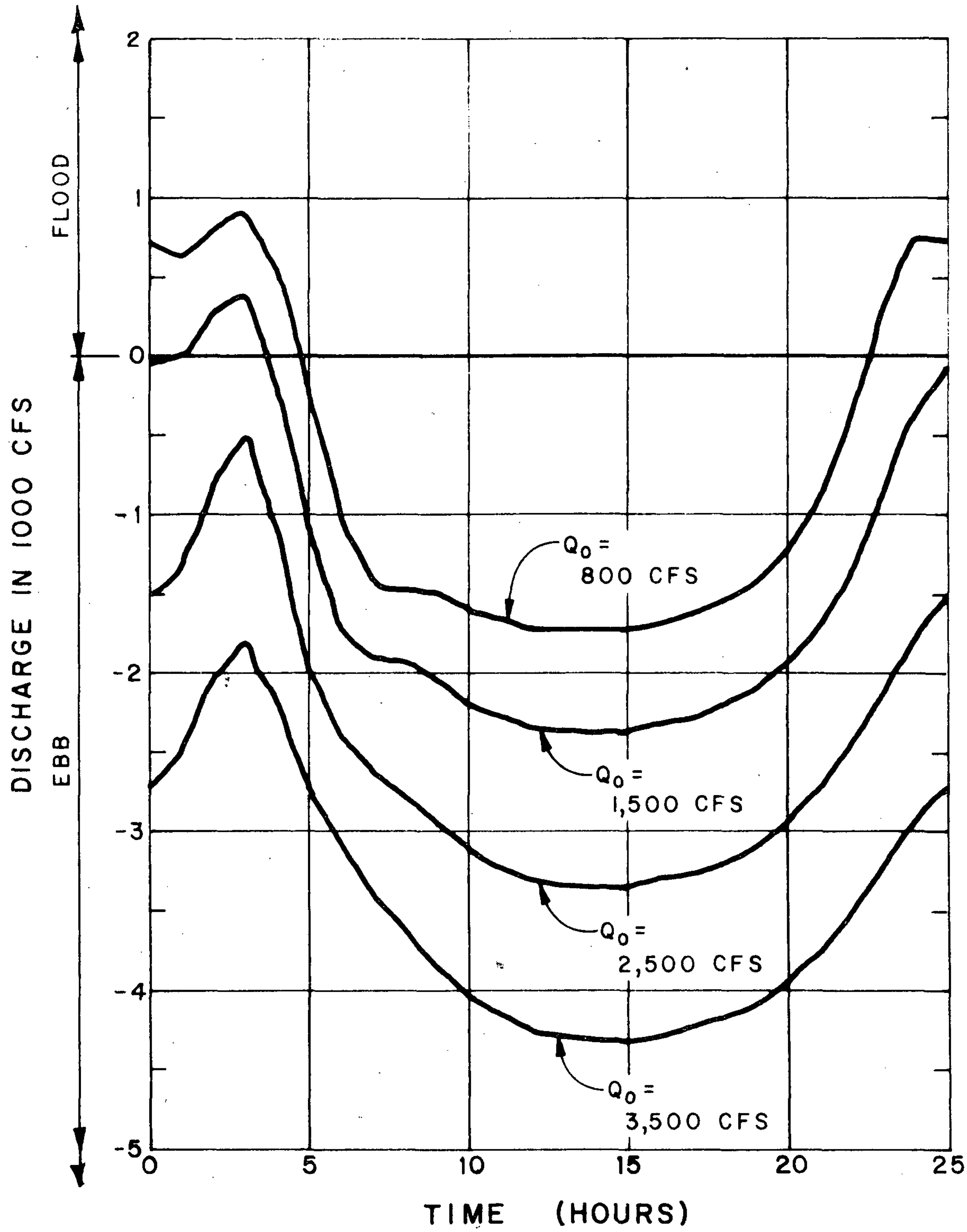


NOTE:
Q_o = FRESH WATER INFLOW

SOUTH TEXAS PROJECT
UNITS 1 & 2

TIDAL FLOW OPPOSITE PLANT SITE
WITH
LOW RANGE DIURNAL EXCITING TIDE

FIGURE 3

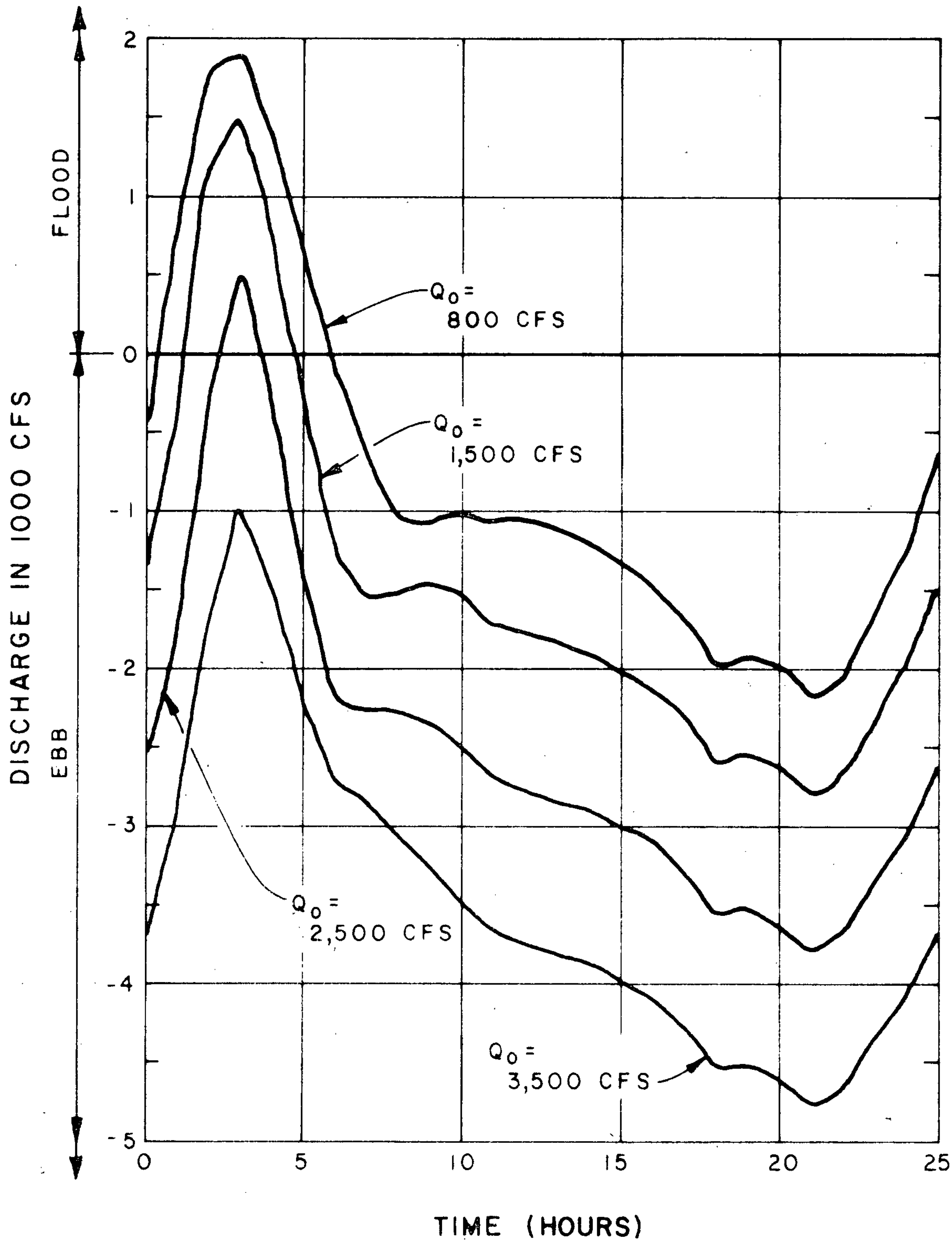


NOTE:
Q_0 = FRESH WATER INFLOW

SOUTH TEXAS PROJECT
UNITS 1 & 2

TIDAL FLOW OPPOSITE PLANT SITE
WITH
HIGH RANGE DIURNAL EXCITING TIDE
(NORTH WIND)

FIGURE 4

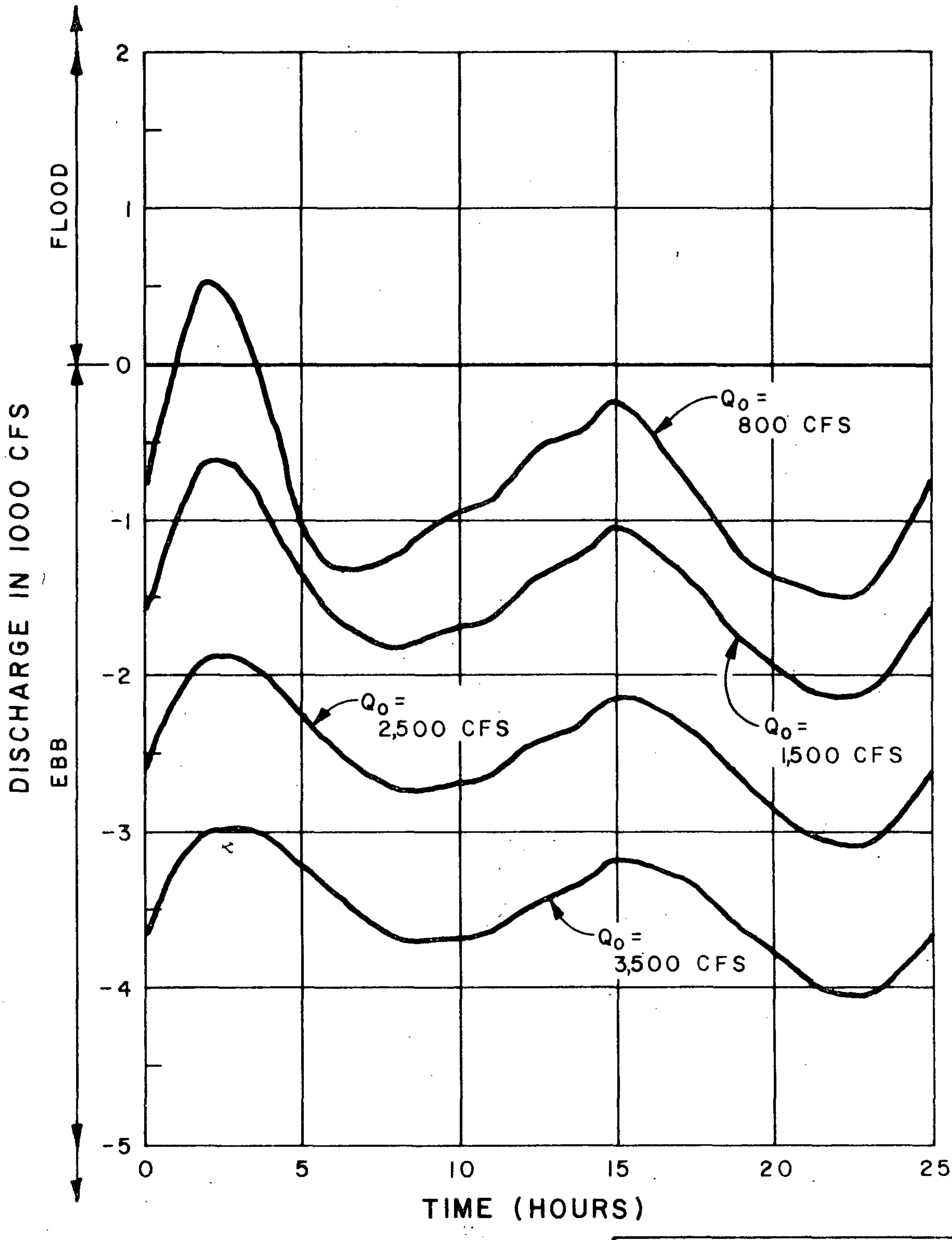


NOTE:
Q_0 = FRESH WATER INFLOW

SOUTH TEXAS PROJECT
UNITS 1 & 2

TIDAL FLOW OPPOSITE PLANT SITE
WITH
HIGH RANGE DIURNAL EXCITING TIDE
(SOUTH WIND)

FIGURE 5

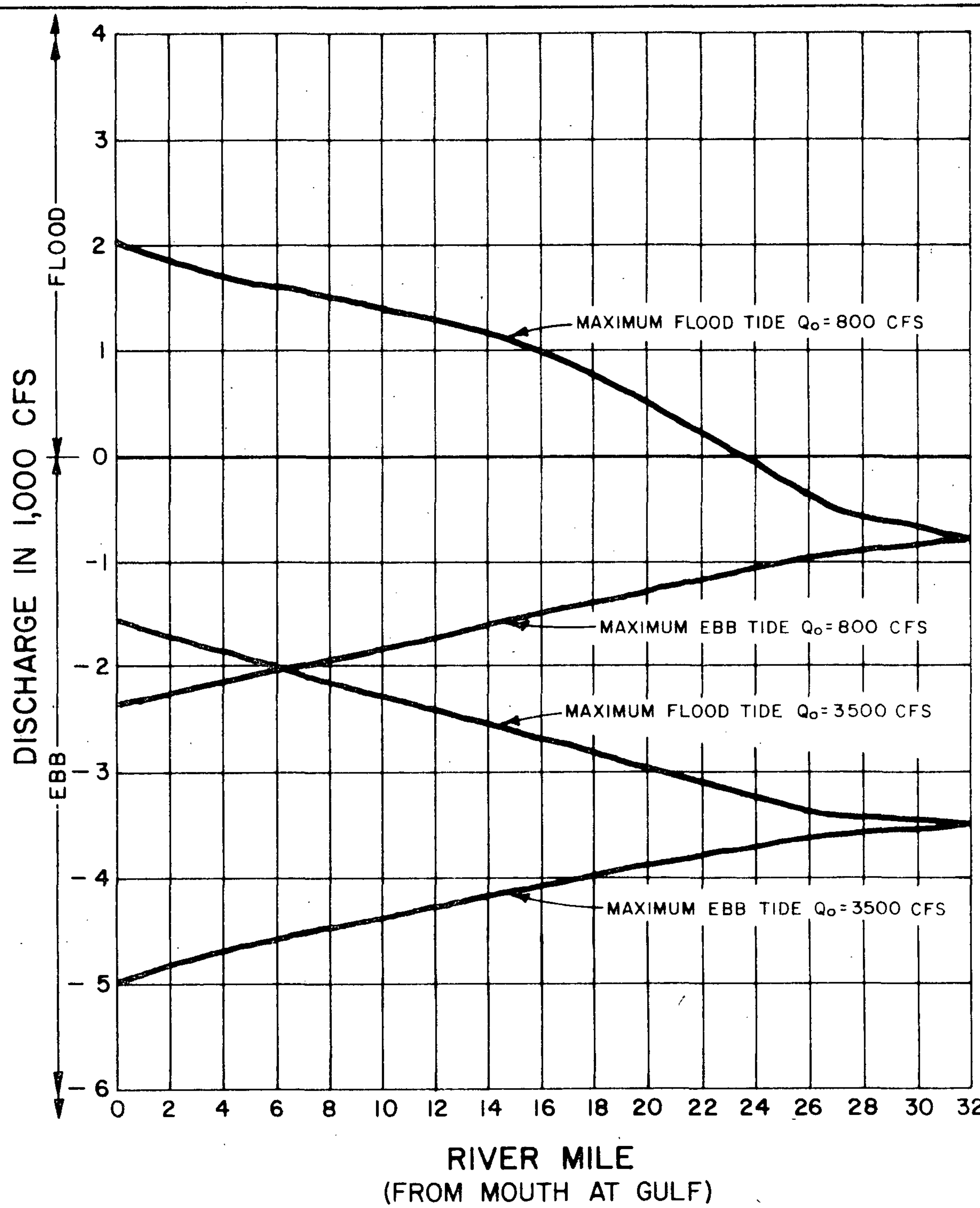


NOTE:
Q_0 = FRESH WATER INFLOW

SOUTH TEXAS PROJECT
UNITS 1 & 2

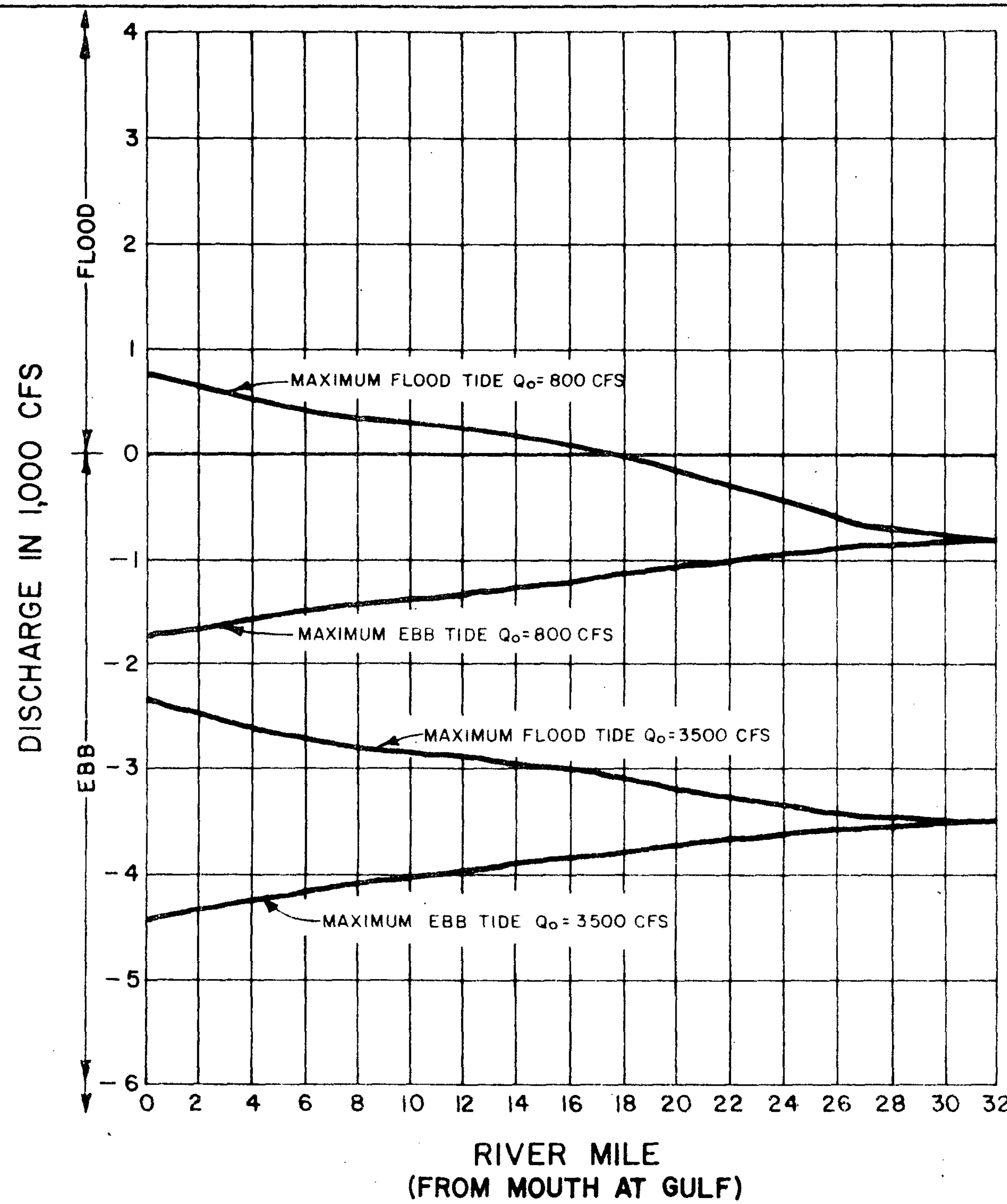
TIDAL FLOW OPPOSITE PLANT SITE
WITH
AVERAGE SEMIDIURNAL EXCITING TIDE

FIGURE 6



NOTE:
Q_0= FRESH WATER INFLOW

SOUTH TEXAS PROJECT UNITS 1 & 2
TIDAL FLOW RANGE ALONG COLORADO RIVER FOR AVERAGE DIURNAL EXCITING TIDE
FIGURE 7

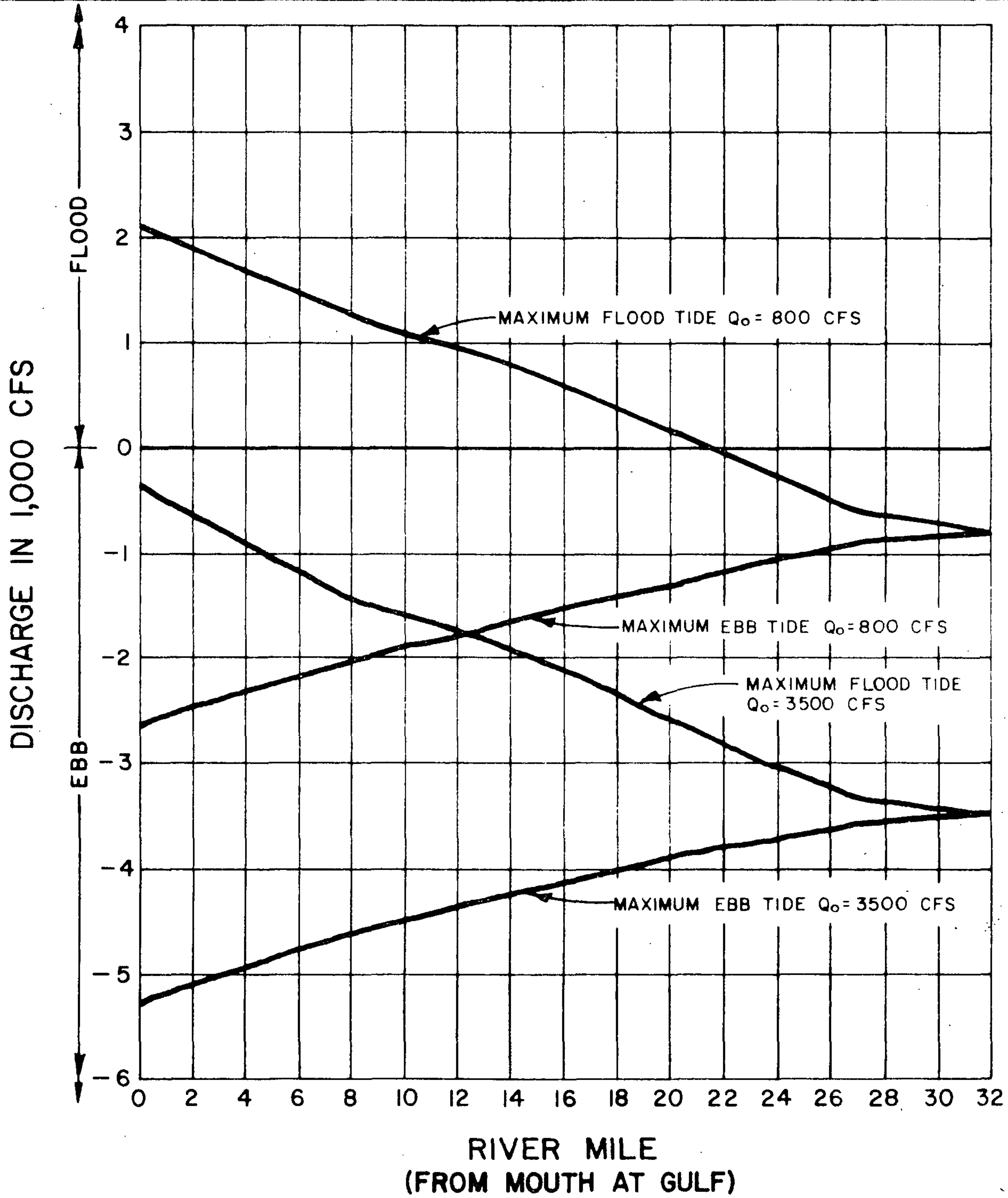


NOTE:
Q_o = FRESH WATER INFLOW

SOUTH TEXAS PROJECT
UNITS 1 & 2

TIDAL FLOW RANGE
ALONG COLORADO RIVER
FOR
LOW RANGE DIURNAL EXCITING TIDE

FIGURE 8

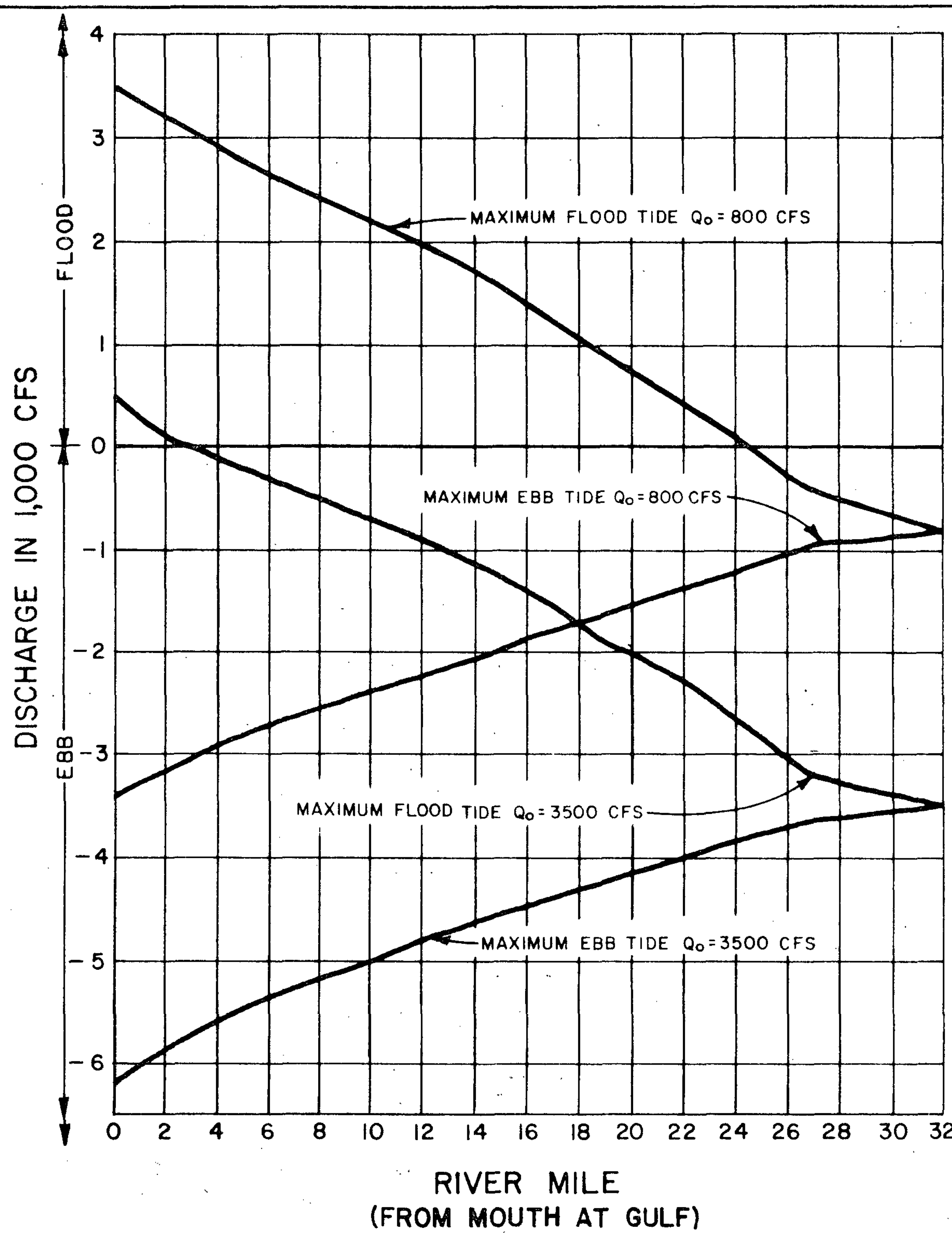


NOTE:
Q_0 = FRESH WATER INFLOW

SOUTH TEXAS PROJECT
UNITS 1 & 2

TIDAL FLOW RANGE
ALONG COLORADO RIVER
FOR
HIGH RANGE DIURNAL EXCITING TIDE
(NORTH WIND)

FIGURE 9

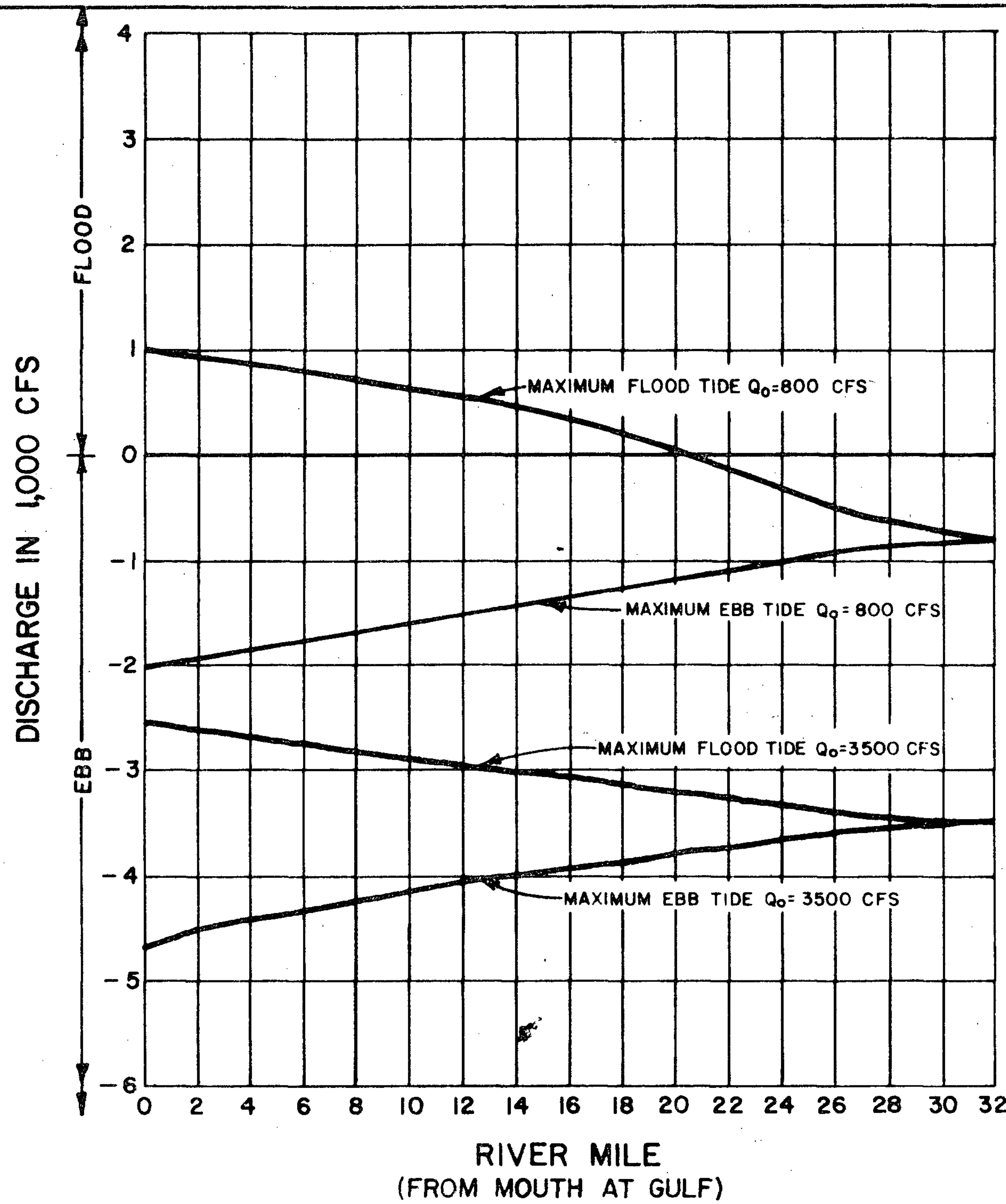


NOTE:
Q_0 = FRESH WATER INFLOW

SOUTH TEXAS PROJECT
UNITS 1 & 2

TIDAL FLOW RANGE
ALONG COLORADO RIVER
FOR
HIGH RANGE DIURNAL EXCITING TIDE
(SOUTH WIND)

FIGURE 10

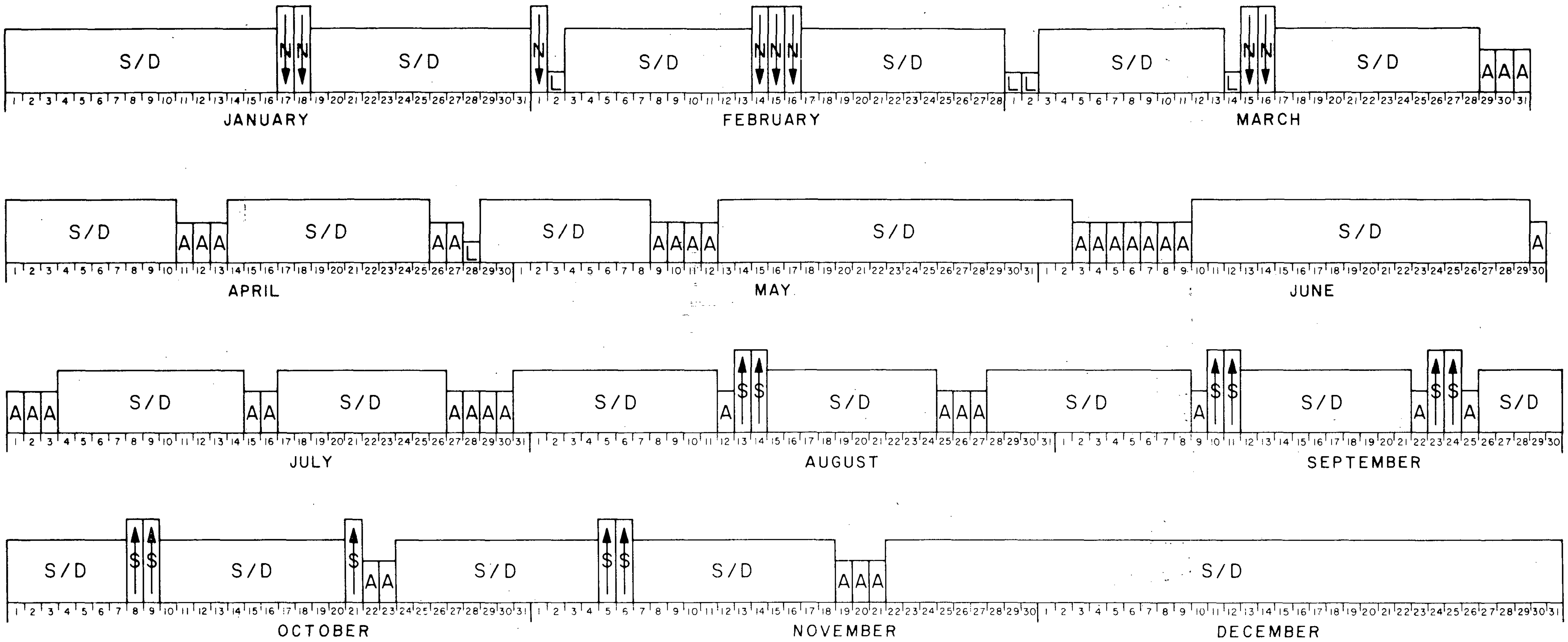


NOTE:
Q_o = FRESH WATER INFLOW

SOUTH TEXAS PROJECT
UNITS 1 & 2

TIDAL FLOW RANGE
ALONG COLORADO RIVER
FOR
AVERAGE SEMIDIURNAL EXCITING TIDE

FIGURE 11



LEGEND

N – HIGH RANGE DIURNAL TIDE (NORTH WIND)

$ – HIGH RANGE DIURNAL TIDE (SOUTH WIND)

A – AVERAGE DIURNAL TIDE

L – LOW RANGE DIURNAL TIDE

S/D–SEMIDIURNAL TIDE

SOUTH TEXAS PROJECT UNITS 1 & 2

PREDICTED DIURNAL TIDAL PATTERNS FOR 1974 AT PORT O'CONNOR

FIGURE 12

APPENDIX 2.5-B

TEXAS WATER QUALITY STANDARDS

TEXAS WATER QUALITY BOARD
P.O. BOX 13246, CAPITOL STATION
AUSTIN, TEXAS 78711

OCTOBER, 1973

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PREFACE

Following the passage of the Federal Water Pollution Control Act Amendments of 1972, the Texas Water Quality Board submitted the State's water quality standards to the Environmental Protection Agency Region VI office in Dallas, Texas, for their review and approval. Subsequently, revision of the water quality standards became necessary within a deadline date of April 18, 1973.

A public hearing was held on April 6, 1973 to adopt the proposed water quality standards prepared by the staff of the Texas Water Quality Board. Presentations and testimonies submitted during and immediately following this public hearing resulted in amendments to the proposed water quality standards. The standards were then adopted for the State of Texas by the Texas Water Quality Board on April 12, 1973. They were then submitted to the Environmental Protection Agency Region VI office in Dallas, Texas, by the Governor's office on April 18, 1973.

Following review by the Environmental Protection Agency staff, recommended changes were made during a series of meetings and conferences with the Texas Water Quality Board staff. Another public hearing was held on September 10, 1973. Some changes suggested by participants at the hearing were incorporated into the standards. The proposed standards were adopted by the Texas Water Quality Board on September 25, 1973 and forwarded to the Environmental Protection Agency on October 11, 1973. The Texas Water Quality Standards were approved by the Environmental Protection Agency on October 25, 1973 as shown on the following pages.

These water quality standards are subject to review at any time and are required to be reviewed every three years. As appropriate, changes will be made and adopted by the Texas Water Quality Board.

GENERAL STATEMENT

I. Authority

Pursuant to the authority contained in Sections 21.075 through 21.078 of the Texas Water Code (60th Legislature, Chapter 313, Sections 3.14 through 3.17, as amended by House Bill 343 during the regular session of the 62nd Legislature in 1971), the Texas Water Quality Board adopts the following stream standards.

II. Policy Statement

It is the policy of this state and the purpose of this chapter to maintain the quality of water in the State consistent with the public health and enjoyment, the propagation and protection of terrestrial and aquatic life, the operation of existing industries, and the economic development of the State; to encourage and promote the development and use of regional and area-wide waste collection, treatment, and disposal systems to serve the waste disposal needs of the citizens of the State; and to require the use of all reasonable methods to implement this policy. (Texas Water Code Chapter 21, Section 21.002, 60th Legislature, Chapter 313, Section 1.02, as amended).

III. Antidegradation Statement

In implementing the legislative policy expressed in the Texas Water Quality Act, it is the policy of the Texas Water Quality Board that the waters in the State whose existing quality is better than the applicable water quality standards described herein as of the date when these standards become effective will as provided hereafter be maintained at their high quality, and no waste discharges may be made which will result in the lowering of the quality of these waters unless and until it has been demonstrated to the Texas Water Quality Board that the change is justifiable as a result of desirable economic or social development. Therefore, the Board will not authorize or approve any waste discharge which will result in the quality of any of the waters in the State being reduced below the water quality standards without complying with the Federal and State laws applicable to the amendment of water quality standards. Anyone making a waste discharge from any industrial, public or private project or development which would constitute a new source of pollution or an increased source of pollution to any of the waters in the State will be required, as part of the initial project design to provide the highest and best degree of waste treatment available under existing technology consistent with the best practice in the particular field affected under the conditions applicable to the project or development. The Board will keep the Environmental Protection Agency informed of its activities and will furnish to the agency such reports in such form, and containing such information as the Administrator of the Environmental Protection Agency may from time to time reasonably require to carry out his functions under the Water Pollution Control Act Amendments of 1972. Additionally, the Board will consult and cooperate with the Environmental Protection Agency on all matters affecting the federal interest.

IV. Classification of Surface Waters

The surface waters of the State have been divided into the following categories for ease of classification.

1. River Basin Waters - those surface inland waters comprising the major rivers and their tributaries, including listed impounded waters, and including the tidal portion of the river to the extent that it is confined in a channel.

2. Coastal Basin Waters - those surface inland waters, including listed impounded waters, exclusive of 1 above discharging or flowing or otherwise communicating with bays or the gulf including the tidal portion of streams to the extent that they are confined in channels.

3. Bay Waters - all tidal waters exclusive of those included in river basin waters, coastal basin waters, and gulf waters.

4. Gulf Waters - those waters which are not included in or form a part of any bay or estuary but which are a part of the open waters of the Gulf of Mexico to the limit of Texas' jurisdiction.

V. Description of Standards

The General Statement is an integral part of the standards and the standards shall be interpreted in accord with the General Statement.

These standards consist of three parts:

1. General Criteria applicable to all surface waters of the State at all times to the maximum extent feasible

2. Numerical Criteria applicable to specific surface waters designated in the standards

3. Water Uses

   In determining the suitability of waters of the State for various uses, the following water quality criteria were used as guidelines. Nothing in these water quality standards limits the authority of the Commissioner of Health of the State of Texas to take such public health protective measures as he may deem necessary.

   a. Contact recreation waters

      Surface waters suitable for contact recreation shall not exceed a logarithmic mean (geometric mean) fecal coliform content from a representative sampling of not less than 5 samples collected over not more than 30 days, as determined by either multiple-tube fermentation or membrane filter techniques, of 200/100 ml, nor shall more than 10 percent of total samples during any 30-day period exceed 400/100 ml.

      Simple compliance with bacteriological standards does not insure that waters are safe for primary contact recreation, such as swimming. Long-standing public health principles mandate that watershed sanitary surveys be conducted in order to adequately evaluate the sanitary hazards potentially present on any natural watercourse.

   b. Noncontact recreation waters

      Surface waters for general or noncontact recreation should with specific and limited exceptions, be suitable for human use in recreation activities not involving significant risks of ingestion. These waters shall not exceed a logarithmic mean (geometric mean) fecal coliform content of 2,000/100 ml and a maximum of 4,000/100 ml, except in specified mixing zones adjacent to outfalls.

These waters should not exceed a logarithmic mean (geometric mean) fecal coliform content of 1,000/100 ml, nor equal or exceed 2,000/100 ml in more than 10 percent of the samples, except in specified mixing zones adjacent to outfalls.

c. Domestic raw water supply

It is the goal that the chemical quality of all surface waters used for domestic raw water supply conform to the U. S. Public Health Service, Drinking Water Standards, revised 1962, or latest revision. However, it must be realized that some surface waters are being used that cannot meet these standards. Since in these cases it is the only source available, these surface waters may be deemed suitable for use as a domestic raw water supply, where the chemical constituents do not pose a potential health hazard.

It is desirable that the total coliform content should not exceed 100/100 ml and the fecal coliform content 20/100 ml. The monthly arithmetic averages should not exceed 10,000/100 ml total coliforms or 2,000/100 ml fecal coliforms.

The evaluation of raw water cannot be reduced to simply counting bacteria of any kind and the foregoing must be used with judgment and discretion and this paragraph is not intended to limit the responsibilities and authorities of responsible local governments or local health agencies.

d. Irrigation waters

The suitability of water for use as irrigation water is influenced by:

(1) the total salt concentration or salinity hazards;

(2) the amount of sodium and its relation to other cations;

(3) the concentration of boron and other constituents that may be toxic; and

(4) the bicarbonate content in relation to calcium and magnesium.

The suitability of water for irrigation will be based on the irrigation water classification system prepared by the USDA salinity laboratory. The various salinity classes are:

<u>Class #1</u> - low-salinity water can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop.

<u>Class #2</u> - medium-salinity water can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

<u>Class #3</u> - high-salinity water cannot be used on soil with restricted drainage.

<u>Class #4</u> - very high-salinity water is not suitable for irrigation under ordinary conditions but may be used occasionally under special circumstances. The soil must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching and highly salt-tolerant crops must be selected.

The SAR (sodium adsorption ratio) should not exceed 8 for waters safe for irrigation. Sampling and analytical procedures and schedules are not specified but would be as appropriate for adequate protection of irrigation waters.

e. Shellfish waters

In shellfish areas in the bays and outside the buffer zones, the coliform criteria shall be limited and guided by the U. S. Public Health Service Manual, "Sanitation of Shellfish Growing Areas," 1965 revision, or latest revision.

VI. General Criteria

The general criteria enumerated below are applicable to all surface waters of the State at all times and specifically apply with respect to substances attributed to waste discharges or the activities of man as opposed to natural phenomena. Natural waters may, on occasion, have characteristics outside the limits established by these criteria; in which these criteria do not apply. The criteria adopted herein relate to the condition of waters as affected by waste discharges or man's activities. The criteria listed following do not override a specific exception to any one or more of the following if the exception is specifically stated in a specific water quality standard.

1. Taste and odor producing substances shall be limited to concentrations in the waters of the State that will not interfere with the production of potable water by reasonable water treatment methods, or impart unpalatable flavor to food fish, including shellfish, or result in offensive odors arising from the waters, or otherwise interfere with the reasonable use of the waters.

2. Essentially free of floating debris and settleable suspended solids conducive to the production of putrescible sludge deposits or sediment layers which would adversely affect benthic biota or other lawful uses.

3. Essentially free of settleable suspended solids conducive to changes in the flow characteristics of stream channels, to the untimely filling of reservoirs and lakes, and which might result in unnecessary dredging costs.

4. The surface waters in the State shall be maintained in an aesthetically attractive condition.

5. There shall be no substantial change in turbidity from ambient conditions due to waste discharges.

6. There shall be no foaming or frothing of a persistent nature.

7. There shall be no discharge of radioactive materials in excess of that amount regulated by the Texas Radiation Control Act, Article 4590(f), Revised Civil Statutes, State of Texas and Texas Regulation for Control of Radiation.

Radioactivity levels in the surface waters of Texas, including the radioactivity levels in both suspended and dissolved solids for the years 1958 through 1960, were measured and evaluated by the Environmental Sanitation Services Section of the Texas State Department of Health in a report prepared for and at the direction of the Health Department by the Sanitary Engineering Research Laboratory at the University of Texas. The document is entitled, "Report on Radioactivity -- Levels in Surface Waters -- 1958-1960" pursuant to contract No. 4413-407 and is dated June 30, 1960. This document comprises an authoritative report on background radioactivity levels in the surface waters in the State and quite importantly sets out the locations where natural radioactive deposits have influenced surface water radioactivity. The impact of radioactive discharges that may be made into the surface waters of Texas will be evaluated and judgments made on the basis of the information in the report which was at the time made, and may still be the only comprehensive report of its kind in the nation.

Radioactivity in fresh waters associated with the dissolved minerals (measurements made on filtered samples) shall not exceed those enumerated in U. S. Public Health Service, Drinking Water Standards, revised 1962, or latest revision, unless such conditions are of natural origin.

8. The surface waters of the State shall be maintained so that they will not be toxic to man, fish and wildlife, and other terrestrial and aquatic life.

With specific reference to public drinking water supplies, toxic materials not removable by ordinary water treatment techniques shall not exceed those enumerated in U. S. Public Health Service, Drinking Water Standards, 1962 edition, or later revision.

For a general guide, with respect to fish toxicity, receiving waters outside mixing zones should not have a concentration of nonpersistent toxic materials exceeding 1/10 of the 96-hour TLm, where the bioassay is made using fish indigenous to the receiving waters. Similarly, for persistent toxicants, the concentrations should not exceed 1/20 of the 96-hour TLm.

In general, for evaluations of toxicity, bioassay techniques will be selected as suited to the purpose at hand. However, bioassays will be conducted under water quality conditions (temperature, hardness, pH, salinity, dissolved oxygen, etc.) which approximate those of the receiving stream as closely as practical.

9. As detailed studies are completed, limiting nutrients identified, and the feasibility of controlling excessive standing crops of phytoplankton or other aquatic growths by nutrient limitations is determined, it is anticipated that nutrient standards will be established on the surface waters of the State. Such decisions will be made on a case-by-case basis by the Board after proper hearing and public participation. The establishment of a schedule for decisions as to the need for nutrient standards for specific waters and what standards should be adopted is not feasible at this time.

10. The surface waters of the State shall be maintained so that no oil, grease, or related residue will produce a visible film of oil or globules of grease on the surface, or coat the banks and bottoms of the watercourse.

VII. Numerical Criteria

The numerical criteria apply to the specific waters identified. Stream standards apply only to waters where standards are established and specifically apply with respect to substances attributed to waste discharges or the activities of man as opposed to natural phenomena.

Chemical concentration parameters, with the exception of dissolved oxygen and pH, apply to the approximate midpoint of the segment with reasonable gradients applying toward segment boundaries. The numerical values shown represent arithmetic average conditions over a period of one year. Whenever an unusual chemical concentration is found, an investigation of its origin will be made and such action as is warranted initiated. Salinity levels in estuarine areas are discussed in Section X, 3, Estuarine Salinity.

The dissolved oxygen values are minimum values which are applicable except as qualified in Section VIII. For short periods of time, diurnal variations of 1.0 mg/l below the standard specified in the table shall be allowed for not more than 8 hours during any 24-hour period.

The pH range represents maximum and minimum conditions throughout the segment except as qualified in Section VIII.

The temperature limitations are intended to be applied with judgment and are applicable to the waters specifically identified herein with the qualifications enumerated in Section VIII. Temperature standards are composed of two parts, a maximum temperature and a maximum temperature differential attributable to heated effluents.

Natural high temperatures, in excess of 96°F, occur regularly in Texas waters during the summer months. For example, 2.3% of United States Geological Survey measurements made during the summer months on the Double Mountain Fork of the Brazos River near Aspermont, Texas, during the period 1958 through 1971 exceeded 96°F. It is consequently concluded that the 90°F maximum temperature suggested by the National Technical Advisory Committee is not applicable to Texas conditions.

Fresh Water Streams:

Maximum Temperature	See Table for Specific Waters
Maximum Temp. Diff.	5°F rise over ambient

Fresh Water Impoundments:

Maximum Temperature	See Table for Specific Waters
Maximum Temp. Diff.	3°F rise over ambient

Tidal River Reaches, Bay and Gulf Waters:

	Fall, Winter, Spring	Summer
Maximum Temp. Diff.	4°F	1.5°F
Maximum Temperature	95°F	95°F

The temperature requirements shall not apply to off-stream or privately owned reservoirs, constructed principally for industrial cooling purposes and financed in whole or in part by the entity or successor entity using, or proposing to use, the lake for cooling purposes.

Heated wastes will not be discharged into the waters listed in Table 1, pages 11 and 12, without individual evaluation by the Texas Water Quality Board. These waters are construed to be cool waters and thereby potentially or presently suitable for cool water fisheries.

In effluent dominated streams, the specified temperature differentials shall not apply where the temperature increase is due to the discharge of a treated domestic (sanitary) sewage effluent.

Bacteriological water quality standards consist of two parts: (1) a measure of general quality, and (2) a limit on variations from the general quality.

For all waters except gulf and bay waters, the measure of general quality is the logarithmic mean (geometric mean) of fecal coliform determinations. The number specified in the tables applies to the logarithmic mean (geometric mean) of data from a representative sampling of not less than 5 samples collected over not more then 30 days. All aspects of the sampling shall be such that a truly representative result is obtained. For routine observation and evaluation of water quality, lesser numbers of samples collected over longer periods will be used. In bay waters (exclusive of bay waters in the buffer zone), the number specified in the tables applies to the median total coliform density as specified in the "National Shellfish Sanitation Program Manual of Operation, Part 1, Sanitation of Shellfish Growing Areas," 1965 Revision, or latest revision.

The limit on variations from the general bacteriological quality on all waters except gulf and bay waters is a fecal coliform density which shall not be equaled or exceeded in more than 10% of the samples. This density is twice the numerical criteria specified in the table. In the instance of gulf and bay waters (exclusive of the buffer zone), the criteria for shellfish growing water shall apply.

TABLE 1

San Marcos River	Headwaters to confluence at Blanco River
Blanco River	Headwaters to Halifax Creek
Guadalupe River	Headwaters to Ingram
Guadalupe River	Canyon Dam to Mountain Creek confluence
Llano River	Headwaters to SH 16 bridge in Llano
Nueces River	Headwaters to Northern Uvalde County Line
Brazos River	Below Possum Kingdom Dam for approximately ten miles
Frio River including Leona River	Headwaters to IH 35 bridge crossing
Sabinal River	Headwaters to southern Bandera County Line
Medina River	Headwaters to southern Bandera County Line
Lampasas River	Headwaters to Stillhouse Hollow Dam
Canyon Reservoir	Comal County
Lake Meredith	Hutchinson County
Greenbelt Lake	Donley County
Somerville Reservoir	Burleson County
Belton Reservoir	Bell County
Medina Reservoir	Medina County

TABLE 1
(continued)

Lake Lewisville	Denton County
Diversion Reservoir	Archer County
San Angelo Reservoir	Tom Green County
Twin Buttes Reservoir	Tom Green County
Lake Conroe	Montgomery County
Tule Canyon Lake	Swisher County
Lake J. B. Thomas	Scurry County
Lake Cypress Springs	Franklin County

VIII. Application of Standards

1. Flow Conditions

The flow conditions specified herein apply to river and coastal basin waters. They do not apply to bay and gulf waters, or lakes and reservoirs.

a. Chemical parameters: The water quality standards for chemical parameters, including chlorides, sulfates and total dissolved solids, exclusive of dissolved oxygen and pH, represent annual arithmetic mean concentrations which will not be exceeded for any year where the sampling median flow for the year under consideration equals or exceeds 50% of the median flow for the period of record for the existing hydrological conditions.

The sampling median flow for the year under consideration is defined for the purposes of this section to be the median of the flow measurements made on the days samples were collected. The "median flow for the period of record" is defined as the 50% value secured from a flow probability graph constructed from available data. Existing hydrologic conditions means, for the purpose of this section, the existing major physical features of the watershed, i.e., dams, diversion structures, etc.; the existing consumptive water uses; or any other factor which would significantly affect the hydraulic regime of the flow measuring station or other point under consideration.

When the flow is zero, no data will be collected and the annual arithmetic mean concentration is defined as the mean of the data collected when a flow exists.

b. The dissolved oxygen concentrations represent minimum values and shall apply at all times that the daily flow exceeds the 7-day minimum average flow for the existing hydrologic conditions with a recurrence interval of two years, except where this flow is zero. When the flow is zero, the dissolved oxygen standards shall not apply.

c. Temperature: Same as dissolved oxygen

d. Other Parameters and General Criteria: The general criteria and the numerical criteria not specifically discussed above shall apply at all times regardless of flow unless specifically excepted under Section VIII - 2, 3, and 4.

2. Mixing Zones

Where mixing zones are specifically defined in a valid waste control order issued by the Texas Water Quality Board or a National Pollutant Discharge Elimination System permit, the defined zone shall apply.

Where the mixing zone is not so defined, a reasonable zone shall be allowed. Because of varying local physical, chemical, and biological conditions, no single criterion is applicable in all cases. In no case, however, where fishery resources are considered significant, shall the mixing zone allowed preclude the passage of free-swimming and drifting aquatic organisms to the extent of significantly affecting their populations. Normally mixing zones should be limited to no more than 25 percent of the cross-sectional area and/or volume of flow of the stream or estuary,leaving at least 75 percent free as a zone of passage unless otherwise defined by a specific Board Order or permit.

3. Buffer Zones in Bay and Gulf Waters

For all bay and gulf waters, exclusive of those contained in river or coastal basins as defined in Section IV, a buffer zone of 1,000 feet measured from the shoreline at ordinary high tide is hereby established. In this zone, the bacteriological requirements enumerated in other sections of these standards shall not apply. In these zones, the logarithmic mean (geometric mean) density of fecal coliform organisms shall not exceed 200/100 ml, nor shall more than 10% of the total samples exceed 400/100 ml. The foregoing percentages are applicable when examining data from not less than 5 samples collected over not more than 30 days. For routine observation and evaluation of water quality, lesser numbers of samples collected over longer periods will be used.

4. Exceptions

The water quality standards will not apply to treated effluents.

The Water Quality Standards, except General Criteria, will not apply to:

a. water in mixing zones as defined in this section or in a valid waste control order issued by the Texas Water Quality Board or a National Pollutant Discharge Elimination System permit, or

b. inland effluent dominated streams during periods when the daily flow is totally composed of effluent excluding minor amounts of bank seepage, or

c. dead-end barge and dead-end ship channels constructed for navigation purposes unless specifically designated in the tables.

In cases where the exceptions enumerated in VIII - 4.b. and VIII - 4.c. are applicable, such waste treatment as is required to maintain a minimum of 2.0 mg/l of dissolved oxygen in the receiving stream will be required, taking full recognition of other provisions of the General Statement. Nothing in this statement precludes requiring waste treatment over and above that required to meet a 2 mg/l dissolved oxygen standard.

IX. Determination of Compliance

In making any tests or analytical determination on classified surface waters to determine compliance or noncompliance with water quality standards, representative samples shall be collected at locations approved by the Texas Water Quality Board.

1. Collection and Preservation of Samples

Samples for determining compliance with the standards, excepting temperature as explained below, will be collected one foot below the water surface unless the water depth is less than 1.5 feet, in which case the collection depth shall be one-third of the water depth measured from the water surface.

For impoundments, the temperature standards enumerated shall apply to the representative temperature of the receiving water outside the mixing zone measured by averaging temperature measurements made at equal and appropriate intervals from the surface to the bottom except where the impoundment is stratified. In these cases, the bottom is defined as the thermocline and the temperature measurements for determining compliance shall be confined to the epilimnion. The thermocline shall be that point of rapid temperature change with vertical depth as defined in standard textbooks on the subject. (The thermocline as defined in A Treatise on Limnology, Volume I, page 428, by G. Evelyn Hutchinson is the plane of maximum rate of decrease in temperature.)

In tidal river reaches, the temperature standards apply to the fresh water layer in stratified situations similar to impoundments above.

Samples will be collected from the present established sampling stations to insure continuance in monitoring with that done in the past. In those cases where there are not sufficient established points, it may be necessary to establish additional stations. This statement does not preclude sampling at other points in the conduct of field investigations.

Collection and preservation of samples will be in accordance with accepted procedures to assure representative samples of the water and to minimize alterations prior to analysis.

2. Analysis of samples

Numerical values in the water quality standards will be determined by analytical procedures outlined in the latest edition of "Standard Methods for the Examination of Water and Wastewater" as prepared and published jointly by the American Public Health Association, the American Waterworks Association, and the Water Pollution Control Federation. Also, tests may be in accordance with other acceptable methods which have proven to yield reliable data to the satisfaction of the Texas Water Quality Board.

X. Comments

1. Inadequate Data

In accord with the Environmental Protection Agency's letter of January 18, 1973, addressed to the Honorable Dolph Briscoe, Governor of Texas, we have identified streams and other waters which were not covered by previous stream standards. For some of these waters, adequate water quality and flow data to establish standards were not available. In these instances, standards were established based upon the best information available, however inadequate. In these instances, the Board reserves the right to amend these standards when data becomes available.

The Board also reserves the right to amend these standards following the completion of extensive studies presently under way or being planned in the near future on some of the major river basins.

2. Errors in these water quality standards resulting from clerical or human errors, or erroneous data, will be subject to correction by the Texas Water Quality Board; and the discovery of such errors does not render the remaining or unaffected standards invalid.

3. Estuarine Salinity

It is recognized that the maintenance of proper salinity gradients during various periods of the year within estuarine waters is very important to the continuation of balanced and desirable populations of estuarine dependent marine life. The dominant force in determining salinity gradients is weather -- although gradients can be affected by waste discharges; modifications in the flow regime of in-flow rivers and streams, by the construction of impoundments, water diversions, etc.; and by physical alterations of gulf passes and other interconnections between estuarine and gulf waters. Since the dominant force controlling salinity gradients is beyond control, meaningful salinity standards cannot be enforced. Careful consideration, however, should always be given to all activities of any nature which can or might detrimentally affect salinity gradients in estuarine waters.

All phases of the natural mineral composition of estuarine and marine waters commonly known as salinity or salinity gradient are outside the scope of these standards, but are not outside the scope of the interest, responsibility, and authority of the several State agencies concerned with water quality, quantity, development, regulation, and administration. For the State's purposes, using both existing data and data yet to be collected, the State proposes to adopt carefully considered estuarine salinity criteria upon which future State evaluations and regulatory actions might be based. Each action requiring approval by any State agency or subject to the control of any State agency shall be evaluated by that State agency or any other State agency having an interest, responsibility, and authority, on the basis of biological, economic, water rights, and property rights impacts in order that the agencies might be fully guided in their actions. Such evaluations shall not be precluded because of the absence of established salinity standards.

TEXAS WATER QUALITY STANDARDS
FRESH AND TIDAL WATERS

COLORADO RIVER BASIN*		WATER USES QUALITY DEEMED SUITABLE/ KNOWN USES				CRITERIA						
SEGMENT NUMBER	SEGMENT DESCRIPTION	CONTACT RECREATION	NONCONTACT RECREATION	PROPAGATION OF FISH & WILDLIFE	DOMESTIC RAW WATER SUPPLY	CHLORIDE (mg/1) avg. not to exceed	SULFATE (mg/1) avg. not to exceed	TOTAL DISSOLVED SOLIDS (mg/1) avg. not to exceed	DISSOLVED OXYGEN (mg/1) not less than	pH RANGE	COLIFORM FECAL/(100ml) - log. avg. not more than (see Gen. Statement)	TEMPERATURE °F (see Gen. Statement)
1401	Colorado River Tidal	s/k	s/k	s/k					5.0	6.7-8.5	200	95
1402	Colorado River - above tidal to Tom Miller Dam, including Town Lake	s/	s/k	s/k	s/k	100	75	500	5.0	6.7-8.5	200	95
1403	Lake Austin	s/k	s/k	s/k	s/k	100	75	400	5.0	6.5-8.5	200	90
1404	Lake Travis	s/k	s/k	s/k	s/k	100	75	400	5.0	6.5-8.5	200	90
1405	Lake Marble Falls	s/k	s/k	s/k	s/k	100	75	400	5.0	6.5-8.5	200	94
1406	Lake Lyndon B. Johnson	s/k	s/k	s/k	s/k	100	75	400	5.0	6.5-8.5	200	94
1407	Inks Lake	s/k	s/k	s/k	s/k	100	75	400	5.0	6.5-8.5	200	90
1408	Lake Buchanan	s/k	s/k	s/k	s/k	100	75	400	5.0	6.5-8.5	200	90
1409	Colorado River - Lake Buchanan headwater to San Saba River confluence	s/k	s/k	s/k	s/k	200	200	500	5.0	6.5-8.5	200	91

* Standards to be reviewed upon completion of Corps of Engineers Colorado River Study, if necessary

TEXAS WATER QUALITY STANDARDS
FRESH AND TIDAL WATERS

COLORADO RIVER BASIN*

SEGMENT NUMBER	SEGMENT DESCRIPTION	WATER USES (QUALITY DEEMED SUITABLE/KNOWN USES): CONTACT RECREATION	NONCONTACT RECREATION	PROPAGATION OF FISH & WILDLIFE	DOMESTIC RAW WATER SUPPLY	CRITERIA: CHLORIDE (mg/l) avg. not to exceed	SULFATE (mg/l) avg. not to exceed	TOTAL DISSOLVED SOLIDS (mg/l) avg. not to exceed	DISSOLVED OXYGEN (mg/l) not less than	pH RANGE	COLIFORM: FECAL/(100ml) - log. avg. not more than (see Gen. Statement)	TEMPERATURE °F (see Gen. Statement)
1410	Colorado River - San Saba River confluence to E. V. Spence Reservoir (Robert Lee Dam)	s/k	s/k	s/k	s/k	400	300	1,250	5.5	6.5-8.5	200	91
1411	E. V. Spence Reservoir	s/k	s/k	s/k	s/k	500	500	1,500	5.0	6.5-8.5	200	93
1412	Colorado River - FM 2059 near Silver to Lake J. B. Thomas (Colorado River Dam)		s/k	s/k		8,000	2,500	20,000	5.0	6.5-8.5	1,000	93
1413	Lake J. B. Thomas	s/k	s/k	s/k	s/k	50	60	500	5.0	6.5-8.5	200	90
1414	Pedernales River		s/k	s/k	s/k	80	50	500	5.0	6.5-8.5	1,000	91
1415	Llano River		s/k	s/k	s/k	50	50	300	5.0	6.5-8.5	1,000	91
1416	San Saba River	s/k	s/k	s/k	s/k	80	50	500	5.0	6.5-8.5	200	90
1417	Pecan Bayou - Colorado River confluence to Lake Brownwood Dam		s/k	s/k	s/k	250	200	1,000	5.0	6.5-8.5	1,000	90

* Standards to be reviewed upon completion of Corps of Engineers Colorado River Study, if necessary

TEXAS WATER QUALITY STANDARDS
FRESH AND TIDAL WATERS

COLORADO RIVER BASIN*		WATER USES QUALITY DEEMED SUITABLE/ KNOWN USES				CRITERIA					COLIFORM	
SEGMENT												
NUMBER	DESCRIPTION	CONTACT RECREATION	NONCONTACT RECREATION	PROPAGATION OF FISH & WILDLIFE	DOMESTIC RAW WATER SUPPLY	CHLORIDE (mg/l) avg. not to exceed	SULFATE (mg/l) avg. not to exceed	TOTAL DISSOLVED SOLIDS (mg/l) avg. not to exceed	DISSOLVED OXYGEN (mg/l) not less than	pH RANGE	FECAL/(100ml) - log. avg. not more than (see Gen. Statement)	TEMPERATURE °F (see Gen. Statement)
1418	Lake Brownwood	s/k	s/k	s/k	s/k	100	100	500	5.0	6.5-8.5	200	90
1419	Lake Coleman	s/k	s/k	s/k	s/k	100	100	500	5.0	6.5-8.5	200	93
1420	Pecan Bayou - above Lake Brownwood	s/k	s/k	s/k		500	500	1,500	5.0	6.5-8.5	200	90
1421	Concho River - Colorado River confluence to Fork in San Angelo, including South Fork to Lake Nasworthy Dam and North Fork to San Angelo Reservoir Dam		s/k	s/k	s/k	600	500	2,000	5.0	6.5-8.5	1,000	90
1422	Lake Nasworthy	s/k	s/	s/k		450	400	1,500	5.0	6.5-8.5	200	93
1423	Twin Buttes Reservoir	s/k	s/k	s/k	s/k	150	150	700	5.0	6.5-8.5	200	90
1424	South and Middle Concho Rivers - above Twin Buttes Reservoir	s/k	s/k	s/k	s/k	150	150	700	5.0	6.5-8.5	200	90
1425	San Angelo Reservoir	s/k	s/k	s/k	s/k	150	150	700	5.0	6.5-8.5	200	90

* Standards to be reviewed upon completion of Corps of Engineers Colorado River Study, if necessary

COLORADO-LAVACA COASTAL BASIN

SEGMENT NUMBER	SEGMENT DESCRIPTION	WATER USES (QUALITY DEEMED SUITABLE/KNOWN USES): CONTACT RECREATION	NONCONTACT RECREATION	PROPAGATION OF FISH & WILDLIFE	DOMESTIC RAW WATER SUPPLY	CRITERIA: CHLORIDE (mg/l) avg. not to exceed	SULFATE (mg/l) avg. not to exceed	TOTAL DISSOLVED SOLIDS (mg/l) avg. not to exceed	DISSOLVED OXYGEN (mg/l) not less than	pH RANGE	COLIFORM: FECAL/(100ml) - log. avg. not more than (see Gen. Statement)	TEMPERATURE °F (see Gen. Statement)
1501	Tres Palacios Creek Tidal	s/k	s/k	s/k					5.0	7.0-9.0	200	95
1502	Tres Palacios Creek - above tidal	s/k	s/k	s/k		250	100	600	5.0	6.5-8.5	200	90

TEXAS WATER QUALITY STANDARDS
BAY & GULF WATERS

LAVACA-TRES PALACIOS ESTUARY*

SEGMENT NUMBER	SEGMENT DESCRIPTION	WATER USES QUALITY DEEMED SUITABLE/ KNOWN USES: CONTACT RECREATION	NONCONTACT RECREATION	PROPAGATION OF FISH & WILDLIFE	CRITERIA: DISSOLVED OXYGEN (mg/l) not less than	pH RANGE	COLIFORM: TOTAL/ (100ml) - median not more than (see Gen. Statement)	TEMP.: FALL, WINTER & SPRING not to exceed 4°F rise SUMMER not to exceed a 1.5°F rise
2451	Matagorda Bay - including Powderhorn Lake	s/k	s/k	s/k	5.0	7.0-9.0	70	95
2452	Tres Palacios Bay - including Turtle Bay	s/k	s/k	s/k	5.0	7.0-9.0	70	95
2453	Lavaca Bay - including Chocolate Bay	s/k	s/k	s/k	5.0	7.0-9.0	70	95
2454	Cox Bay	s/k	s/k	s/k	5.0	7.0-9.0	70	95
2455	Keller Bay	s/k	s/k	s/k	5.0	7.0-9.0	70	95
2456	Carancahua Bay	s/k	s/k	s/k	5.0	7.0-9.0	70	95

* (See Figure 1)

STP-ER

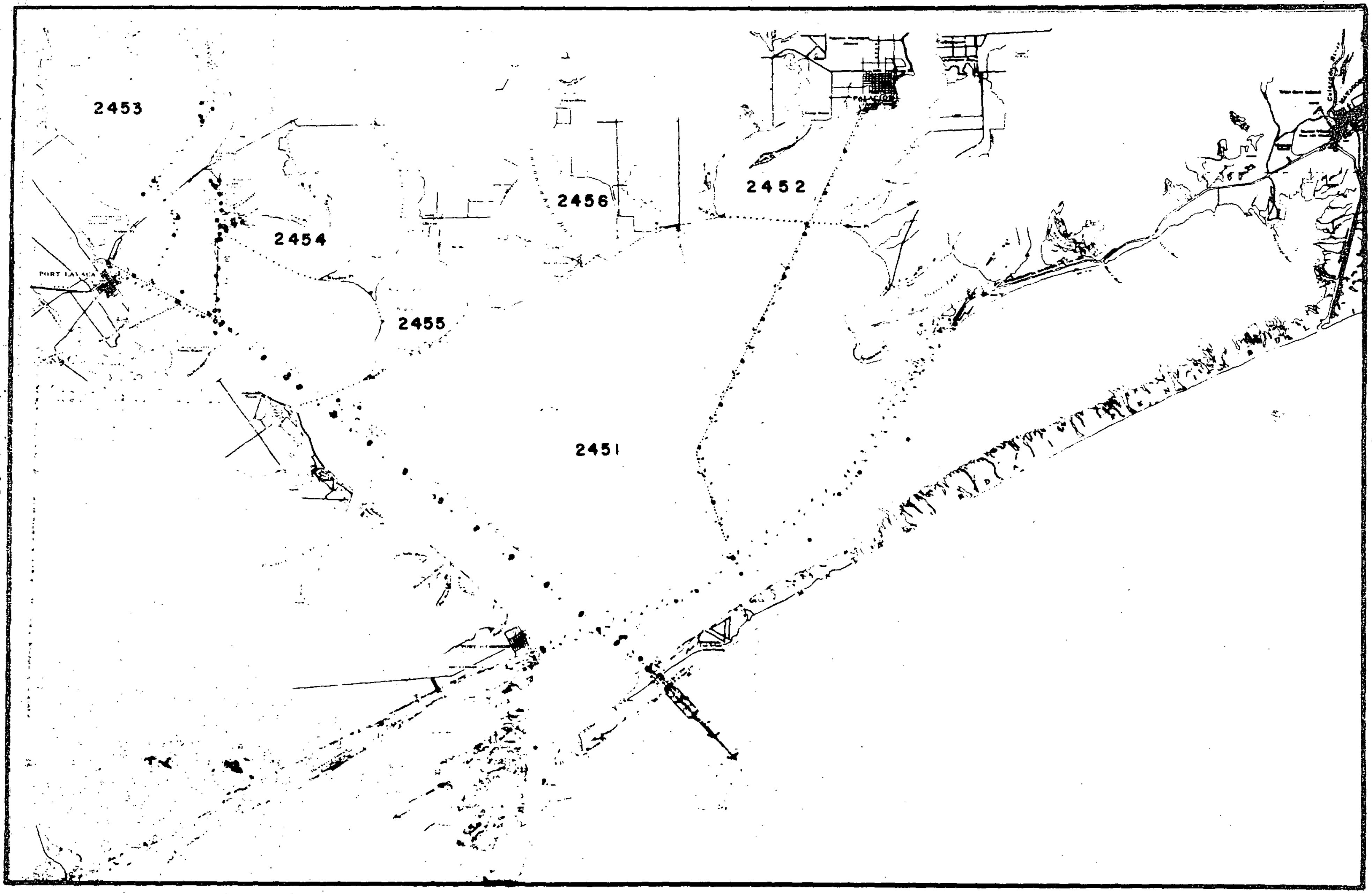
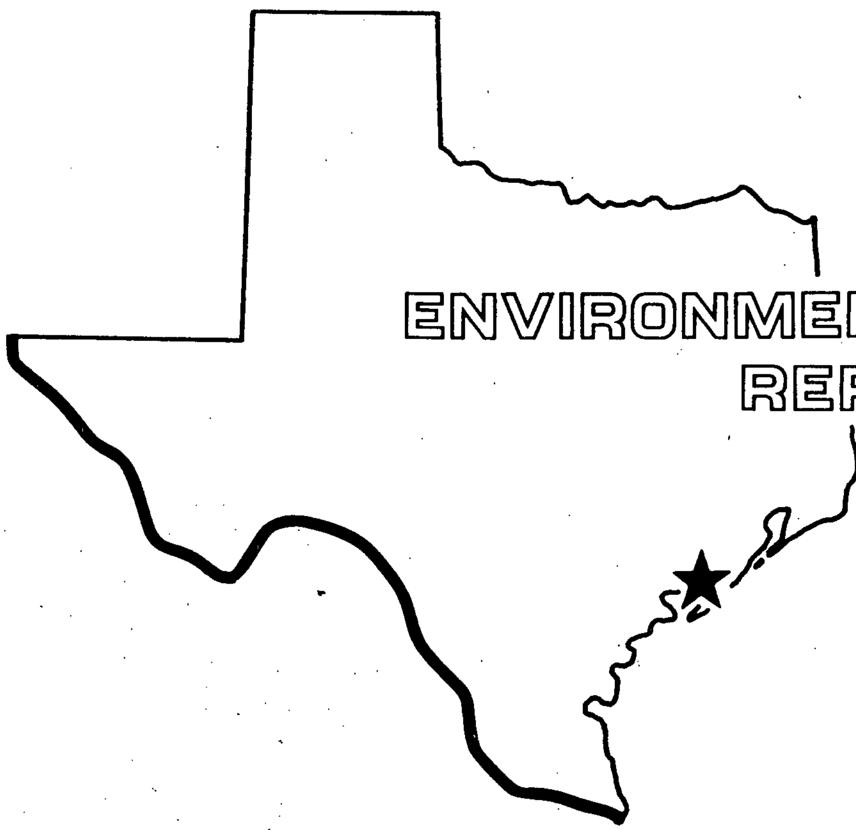


Figure 1. Lavaca-Tres Palacios Estuary

B2.5-29

SOUTH TEXAS PROJECT
UNITS 1 & 2



ENVIRONMENTAL REPORT

VOLUME 4

5.1.2 EFFECTS ON COLORADO RIVER WATER QUALITY

Blowdown water from the STP cooling reservoir will be discharged to the Colorado River at a point approximately 12.5 miles from the Gulf. The discharge structure consists of seven, 3-foot diameter discharge ports, spaced 250 feet apart, at a centerline depth of 5.5 feet below mean low water, and an angle of 45 degrees with the shore on the downstream side of each port. The ports will discharge water at velocities ranging from 4.14 fps to 6.22 fps. Detailed descriptions of the discharge structure and operation, and the temperature and total dissolved solids content of the blowdown are given in Section 3.4.

Makeup for the cooling reservoir will be taken at a point on the Colorado River approximately 15 miles from the Gulf. The maximum pumping rate is 1,200 cfs. This pumpage will indirectly affect the water quality of the river. The diversion of fresh water will lower the resistance to Gulf penetration upstream, thus raising the salinity at all points in the river below the intake.

Plant heat-dissipation-system operations and their environmental evaluation are based on adjusted, rather than actual, river flows as discussed in Section 5.1.1. This approach is more conservative, since the change in salinity due to plant operations is inversely proportional to fresh water flow rate (the lower the flow rate, the greater the change in salinity for a given deviation in plant operation).

5.1.2.1 Thermal Water Quality Standards

The thermal standards applicable to the Colorado River are given in the Texas Water Quality Standards as discussed in Section 2.5. These standards were approved by the Environmental Protection Agency on October 25, 1973 and provide for mixing zones as follows:

> "Because of varying local physical, chemical, and biological conditions, no single criterion is applicable in all cases. In no case, however, where fishery resources are considered significant, shall the mixing zone allowed preclude the passage of free-swimming and drifting aquatic organisms to the extent of significantly affecting their populations. Normally, mixing zones should be limited to no more than 25 percent of the cross-sectional area and/or volume of flow of the stream or estuary, leaving at least 75 percent free as a zone of passage unless otherwise defined by a specific Board Order or permit."[5]

Additionally, the maximum temperature difference outside of the mixing zone is limited to 4°F in the fall, winter, and spring and 1.5°F in the summer.[6]

5.1.2.2 Physical and Chemical Discharge/Intake Effects

Several major variables were considered in estimating the effects of thermal additions and water volume additions/withdrawals from the Colorado River, including:

1. the ambient thermal and flow history of the river in the vicinity of the site, including seasonal variations;

2. the volume and temperature of waters discharged from the reservoir into the river, including their seasonal variations;

3. the changes caused by thermal discharges on normal river temperatures;

4. the extent of the physical areas that are expected to be involved;

5. the rate of change of thermal additions;

6. the interactive effects of thermal additions on other physico-chemical parameters; and,

7. the volume of waters withdrawn from the river including their seasonal variations.

5.1.2.2.1 Near Field Thermal Effects

Near the discharge location, the discharge structure design determines the effect of the excess temperature and salinity of the blowdown water upon the receiving water body. This region is called the near field region. As explained in 5.1.1.2, the near field thermal model calculates the blockage temperature, ΔT_b, resulting from the discharge of blowdown water for each hour of the 40-year plant life. The blockage temperature is defined as the maximum temperature of all isotherms whose area, projected upon a vertical surface perpendicular to the shoreline, is greater than or equal to 25 percent of the river cross-sectional area. The river cross-sectional at the discharge location is assumed to be 12.4 feet by 150 feet, based on the tidal flow model described in Section 2.5. Figures 5.1-12 and 5.1-13 show the fraction of the time that the daily average blockage temperature is less than or equal to 1°F, and 0.5°F for each month over the 40-year period. The daily average blockage temperature is always less than 2°F. The maximum daily average blockage temperature occurring over the 40 years of plant life is 1.95°F during March of the twenty-second year of operation. The maximum daily average blockage temperature during the summer is 0.82°F, occurring in June of the twelfth and thirty-fifth years of operation.

Figures 5.1-14, 15, 16 and 17 show the fraction of the time that the daily maximum blockage temperature, as determined from the maximum of the daily hourly values, is less than or equal to 3°F, 2°F, 1°F and 0.5°F for each month over the 40-year period. The highest daily maximum blockage temperature occurs in March of the tenth year of plant operation, at which time the blockage temperature is 3.26°F, well under the criterion of 4°F. The highest daily maximum blockage temperature for the summer season is 1.10°F in September of the thirteenth year of plant operation, well under the criterion of 1.5°F.

Figures 5.1-18 and 5.1-19 show the monthly average blowdown flowrate, and the number of hours per day during which blowdown occurs for the 40-year period. These figures show that during approximately 60 percent of the 480 months of plant operation, no discharge will occur.

To better visualize the overall effect of the plant on water temperatures during its 40 years of operation, Figures 5.1-20 through 5.1-22 are presented. Figure 5.1-20 depicts the fraction of the time that the daily average blockage temperature is less than or equal to 1°F, and 0.5°F for an average year, as determined by the average of each month. Daily average blockage temperatures never exceed 2°F. The fractions of the 1°F and 0.5°F blockage temperatures range from 1.0 each for August to 0.775 and 0.718 respectively for the month of February. The average over the 40 years for 1°F is 0.924 and for 0.5°F is 0.891. This means that for 100 percent of the time the daily average blockage temperature is less than 2°F, and for 89.1 percent of the time it is less than 0.5°F.

Figure 5.1-21 depicts information similar to Figure 5.1-20, except that the daily maximum blockage temperatures are shown. These fractions range from 1.0 for each temperature during August to 0.996, 0.816, 0.762, and 0.701 during February for 3°F, 2°F, 1°F and 0.5°F. The averages over the 40 years for the four blockage temperatures are, in descending order, 0.999, 0.934, 0.916, and 0.884. This means that for 99.9 percent of the time the daily maximum blockage temperature is less than 3°F and for 88.4 percent of the time it is less than 0.5°F.

The discharge flow rates and the hours per day of discharge for the average year, assuming discharge during the total time period, are shown in Figure 5.1-22. The flow rates range from 53 cfs during February to 0 cfs during August. The corresponding hours per day of discharge operation are 5.7 for February and 0 for August. The months during which the maximum and minimum flow rates occur correspond to the months during which the frequency of occurrence of blockage temperatures is also a maximum and minimum. Over the 40 years, the average discharge flow rate is 18.5 cfs. The average hours per day of discharge is 2 (discharge occurs for approximately 8.4 percent of the time during 40 years of the plant life). The average discharge flow rate during actual discharge is 221 cfs.

To illustrate the variation within a single month, two sample months were chosen: March of year 21 and September of year 13. Figure 5.1-23 shows the daily variation of the daily average blockage temperature, the discharge flow rate during discharge operation, and the hours per day during which discharge occurred, for March of year 21. Daily average blockage temperatures ranged from 0.21°F to 1.87°F. Discharge occurred on every day but the thirteenth. The discharge flow rate ranged from 104 cfs to 308 cfs during the hours of operation, which ranged from 16 to 22. Figure 5.1-24 shows similar information for the daily maximum blockage temperature. These values ranged from 0.21°F to 2.94°F. Figure 5.1-25 shows the daily average blockage temperature, the discharge flow rate during discharge operation, and the hours per day during which discharge occurred for September of year 13. Daily average blockage temperatures ranged from 0.13°F to 1.80°F. Discharge occurred during each day of the month. Figure 5.1-26 shows similar information for the daily maximum blockage temperature. These values ranged from 0.13°F to 2.83°F. The maximum value for the summer part of the month was 1.10°F.

Figures 5.1-27 and 28 show the hourly values of the blockage temperature for the periods March 17 through 19 of year 10, and September 19 through 21 of year 13. As explained above, these periods contain the maximum blockage temperatures over the 40-year period for the fall, winter, spring, and summer seasons.

During March 17 through 19 of year 10, the discharge was operating at a flow rate of 308 cfs, 21 hours per day. Figure 5.1-27 shows that, although the maximum for this time period was 3.26°F, the values for most of the period were considerably less, reaching a minimum value of 0.89°F.

During September 19, 20, and 21 of year 13 the discharge was operating at a flow rate of 308 cfs during the hours of discharge operation. The discharge was operating for 24, 17 and 20 hours during the nineteenth, twentieth, and twenty first, respectively. Figure 5.1-28 shows that although the maximum blockage temperature for this time period was 1.10°F, the values for most of the period were considerably less, reaching a minimum value of 0.42°F.

Figures 5.1-29, 5.1-30, and 5.1-31 show the shape of the discharge plume. Figure 5.1-29 gives surface isotherms due to one port for the following discharge conditions:

$$T_a = 70°F$$

$$U_d = 4.14 \text{ fps}$$

$$\Delta T_o = 6.9°F$$

$$U_a = 1 \text{ fps}$$

Figure 5.1-30 gives surface isotherms for the same conditions, except that $U_d = 6.22$ fps. Background temperatures from previous heat discharges have not been considered, as these isotherms are simply for illustrative purposes. If a background temperature was present, the temperature of the indicated isotherms would be increased by the value of the background temperature. Figure 5.1-31 shows surface isotherms for all seven ports operating simultaneously.

Figures 5.1-32 and 5.1-33 show the isotherms for the above two cases projected on a vertical surface which is perpendicular to the shoreline. The temperature of the isotherm whose area is 25 percent of the river cross-section is the blockage temperature. From the equation developed in Section 5.1.1.2, the blockage temperatures predicted for these two cases are 0.50°F ($U_d = 4.20$ fps) and 0.92°F ($U_d = 6.22$ fps). These values agree well with those depicted in Figures 5.1-23 and 5.1-24.

The preceding analysis clearly shows that the blockage criteria will be met under all combinations of plant operating conditions and river conditions.

5.1.2.2.2 Far Field Thermal Effects

The effect of the discharge upon the river away from the immediate area of the discharge ports is governed by the discharge and ambient river characteristics. The effect in this region, called the far field region, is independent of the discharge structure design. In this region, the jet momentum has been dissipated, and therefore, no velocity effects are noticed.

Areas along the river corresponding to excess temperatures greater than or equal to a given temperature have been calculated (see Section 5.1.1.3) for the 40 years of plant operation. The river widths used to arrive at these results are those given in Section 2.5. Specifically, the widths corresponding to fresh water flow rates of 800, 1,500, 2,500 and 3,500 cfs are 150, 155, 170 and 185 feet, respectively. Widths at flow rates other than those that are given have been interpolated. For fresh water flow rates greater than 3,500 cfs, the river width was maintained at 185 feet. Areas given are exclusive of those of the near field discharge plume which are insignificant when compared with the area of the river downstream from the discharge port.

For the 40 years of plant operation, due to the minimum river flow required in order to blowdown, the discharge effects are always limited to locations less than 0.5 miles upstream from the discharge port closest to the intake. Therefore, the discharge never affects the intake which is located 2.5 miles upstream.

Figures 5.1-34 and 35 depict A(1.0) and A(1.5), those areas with excess temperatures greater than or equal to 1.0°F and 1.5°F for the 40 years of plant life. The three sets of data presented each month are the average for that month, the maximum of the daily averages for that month, and the hourly maximum for that month (defined as the area occurring when the daily maximum of the blockage temperature exists).

For A(1.0) and A(1.5) these areas are zero for approximately 80, and 98 percent of the months. The highest values of the daily and hourly maxima of A(1.0) correspond to those of approximately 9 and 15 percent of the river downstream from the discharge. For A(1.5) they correspond to those of approximately 2 and 3 percent of the downstream river area. For A(1.0) and A(1.5) the maximum monthly averages correspond to 3 and 0.06 percent of the downstream river area. Figures 5.1-34 and 35 indicate that the hourly maximum areas deviate little from the daily maximum areas during a month. This implies that the temporal variation of areas within the river subject to excess temperatures is slight.

Figures 5.1-36 and 37 show the same kind of information as Figures 5.1-34 and 35; however, the time period consists of an average year, determined by averaging the results from each month. For all curves except A(1.5), the largest area occurs in February. The maximum values of A(1.5) occur in November. Zero areas are found for each temperature in August, while A(1.5) occurs only during the months of February, March, April, November, and December.

5.1.2.2.3 Effects on River Hydraulics

Operations of the makeup and blowdown facilities will cause small changes in the flow pattern of the river in the immediate vicinity of discharge and withdrawal points. However, the operations will not create conditions that do not exist naturally but will simply change their frequency of occurrence slightly.

5.1.2.2.3.1 Discharge Flows

The selected operating scheme of the discharge facility restricts discharges to time periods when river velocity is approximately 0.4 fps or greater in the downstream direction. In addition, the discharge flow is equal to or less than 12.5 percent of the net river flow past the point of discharge.

The maximum discharge velocity of 6.22 fps will quickly dissipate as the plume entrains dilution water and is bent in a direction parallel to the shore. Directing the discharge ports at an angle of 45°F in the downstream direction limits the impingement of the plume on the river bank opposite the discharge port. Locating the port at a depth of 5.5 feet below mean low water (approximately 6 feet above the river bottom) eliminates the potential for significant bottom scour. The area of significant induced velocity will be limited to less than 25 percent of the river cross section.

5.1.2.2.3.2 Makeup Flows

Diversion of water from the river is limited to 55 percent of the river flow in excess of 300 cfs. The maximum diversion rate is 1,200 cfs at a river flow of 2,480 cfs or greater. The average river velocity is approximately 1.4 fps. Assuming isotropic flow into the intake structure, plant-induced velocity components in the direction of the intake would be approximately 0.3 fps which is small compared with the upstream river velocity. Since the river is essentially pooled (average water elevation at the intake similar to the elevation at the Gulf) there will be no measureable changes in water elevation due to intake facility operation.

5.1.2.2.4 Total Dissolved Solids Effects

Salinity is modified by power plant makeup and discharge operations. Modified salinities have been simulated using plant modified adjusted fresh water flow rates. These simulations are based on adjusted river flow, plant makeup flow, and plant discharge flow each day over the 40 years of the simulated operating scheme.

In the plant impact analysis, salinity changes attributed to intake operations are determined first. The simulation is used to calculate the ambient salinity over the top 4 feet of water at river mile 15 based on the adjusted fresh water flow rate. This is the salinity of the water that will be diverted. Since this water is not necessarily all fresh water, the volume of makeup must be corrected for the volume that is fresh water before this volume can be subtracted from the fresh water flow rate. The resultant net fresh water flow rate is then used to simulate the salinity distribution in the Colorado River. Any change of the salinity distribution from the ambient condition represents the impact from makeup operations alone.

Discharge impact is determined by a simple salt balance between the discharge and the previously determined river salinities (ambient or makeup induced). The monthly average blowdown salinities and volumes averaged over the period of plant life are presented in Table 5.1-5. The impact of discharge operation is limited to less than 13 miles upstream from the Gulf, or approximately 0.5 miles above the discharge.

Figures 5.1-38 through 5.1-40 show the change of salinity resulting from plant operation for each month averaged over the 40-year plant life. Data are given for river miles 1, 3, 6, 9, and 12 and for the depth/depth ranges of 0-4 feet, 8-16 feet, and 16 feet. The corresponding ambient salinities (those which would exist if the plant were not operating) have previously been presented in Figures 5.1-3 through 5.1-5. Figure 5.1-41 shows the monthly variation of ambient salinity, and change in salinity due to plant operation over a 23-year period at river mile 12. The greatest change in salinity due to plant operation occurs when ambient salinities are low; however, this change in salinity is always less than 2 $^{o}/oo$. These lower salinities occur during the higher flow months.

Plant induced temperature increases have been correlated with plant induced salinity changes. The frequency of occurrence of a given salinity and maximum temperature increase at specific locations in the Colorado River are tabulated in Tables 5.1-6 through 8. The salinities are taken from the above far field analyses. Temperature information is provided at each mile, daily, by application of the far field thermal distribution model (see Section 5.1.1.3). The general relationship between temperature increase and salinity depends primarily on flow rate. The higher the flow rate the lower the temperature change and the salinity at a given depth and distance.

5.1.2.2.5 Effects on Dissolved Oxygen

The concentrations of dissolved oxygen at the Gulf resulting from plant operations were calculcated for an average summer and winter month using reasonably conservative assumptions and the Streeter-Phelps equation. July and December are the representative months during which blowdown occurred when the river temperatures were the historical extremes, 89°F and 41°F (based on 10 years of river temperature measurements, see Section 2.5).

The maximum blowdown temperatures during these months were 4.3°F and 6.9°F above ambient, 93.3°F and 47.9°F (see Section 5.1.1.2). During the months of July and December the average blowdown flow rate was 180 cfs (see Table 5.1-5). The minimum summer and winter river flow rates into which this volume of water could be discharged are 800 cfs and 1440 cfs, respectively. Weighted averages of temperature, BOD, and dissolved oxygen, were calculated based on combined river and blowdown flows and concentrations.

The weighted average summer and winter river temperatures after blowdown are 89.4°F and 41.7°F, respectively.

The average dissolved oxygen concentration in the river (no blowdown) was 92 percent of saturation. Based on the above summer and winter river temperatures and chloride concentration of 5000 ppm, the 92 percent adjusted saturation values are 6.5 and 11.0 mg/l, respectively.

Blowdown dissolved oxygen is conservatively assumed to be zero at both times.

The river BOD is assumed to be 1.5 mg/l (see section 2.7). A BOD of 35 mg/l is conservatively assumed for the reservoir effluent based on a study by the EPA of lagoon performance.[68] This value represents the average effluent BOD from tertiary treatment lagoons. It represents algae and zooplankton growth in a lagoon. The cooling reservoir is not a tertiary treatment lagoon in the strict sense, hence the value of 35 mg/l is conservative.

Other parameters used in the analysis include deoxygenation coefficients, reoxygenation coefficients, and river velocities.

The deoxygenation coefficient, 0.17, usually associated with laboratory BOD analyses was adjusted for temperature differences in the field situation.

The reoxygenation coefficient was based on O'Connor's formula for natural rivers. This value depends on the diffusivity of oxygen in water, the river flow velocity, and the depth of flow. The river was assumed to be 12.4 feet deep and 150 feet wide. Using the average summer and winter river flow rates and the cross-sectional area, average velocities are determined.

The above information was used in the Streeter-Phelps equation to calculate the summer and winter dissolved oxygen concentrations at the Gulf (12.5 miles downstream from the point of discharge, the point of maximum oxygen depletion before entering the Gulf) for both power plant and natural conditions:

$$D = \frac{k_1' L_o}{k_2' - k_1'} \left(e^{-k_1' t} - e^{-k_2' t}\right) + D_o e^{-k_2' t}$$

where, k_1' = temperature-adjusted deoxygenation rate

k_2' = temperature-adjusted reoxygenation rate

L_o = initial weighted average BOD of river and blowdown

D_o = initial dissolved oxygen deficit

t = time for water to travel desired distance (12.5 miles).

Based on the above assumptions, values, and equations, the following values were calculated:

Summer:	D_o deficit due to plant discharge	= 0.95 mg/l
	D_o concentration in river	= 6.5 mg/l
	Net D_o concentration in river at Gulf	= 5.55 mg/l
Winter:	D_o deficit due to plant discharge	= 1.24 mg/l
	D_o concentration in river	= 11.0 mg/l
	Net D_o concentration in river at Gulf	= 9.76 mg/l.

These values do not reflect reoxygenation due to Gulf penetration and vertical mixing.

5.1.3 EFFECTS ON AQUATIC BIOTA

Environmental impact on aquatic organisms derived from operation of the heat dissipation system may be characterized by the following three catagories:

1. Effects associated with operation of the makeup water intake structure on the Colorado River.
2. Effects associated with the cooling water reservoir and the condensers.
3. Effects on the Colorado River due to blowdown operations.

The specific effects on aquatic organisms include:

1. Impingement and entrainment associated with the makeup water pump station located on the Colorado River and the cooling water intake structure located on the cooling water reservoir.
2. Thermal effects in condensers, the cooling water reservoir, and in the Colorado River due to blowdown of the cooling water reservoir.
3. Mechanical damage associated with any of the above structures.
4. Salinity effects in the Colorado River associated with the makeup and blowdown of the cooling water reservoir.

The expected effects of operation of the heat dissipation system on primary producers, zooplankton, benthos, ichthyoplankton, and larger fishes and invertebrates are discussed below.

5.1.3.1 Effects of Makeup Water Pumping on the Colorado River

5.1.3.1.1 Effects on Primary Producers

In general, the primary producer community near the selected intake is comprised primarily of diatoms and green algae, with other groups, notably blue-greens and dinoflagellates contributing only a small percentage to the total community. A review of phytoplankton community ecology is presented in Section 2.7. Aquatic macrophytes were noticeably absent in the STP study area, therefore, impacts of plant operation on primary producers will be limited to the phytoplankton.

The principal impact of operation of the makeup pumping station on primary producers is that phytoplankton entrained in the makeup water will experience some fractional mechanical disruption due to pump turbulence and physical abrasion. For conservatism in the evaluation of the potential impact of plant operation on the phytoplankton community of the Colorado River, it has been assumed that all plankton entrained are lost from the Colorado River. This provides an upper limit to the estimated impact of plant operation; during the warmer seasons it may be approached but will not be exceeded.

Based on standing crop data for all seasons at the STP site, the annual mean concentration of chlorophyll a is approximately 460 micrograms per cubic foot. This value may be multiplied by 60 to estimate the corresponding weight (as carbon) of phytoplankton[7]; therefore, 27,600 micrograms per cubic foot, or 6.07×10^{-5} pounds per cubic foot represent the mean weight. On this basis, the amount of phytoplankton as carbon removed from the Colorado River annually will be 1.9×10^{5} lb.

These data are taken largely from Strickland (1960), who gives the relationship:[70]

$$\text{mgC} = F \times \text{mg chlorophyll},$$

where C is organically combined carbon and chlorophyll is either chlorophyll a or a mixture of chlorophyll a and b. E-6

Table 5.1-8a shows values calculated for F, based on references listed within. Strickland points out that no value for F can be quoted which has significance less than a whole order of magnitude. Apparently the wide range of reported values for F depends mainly on the species, location, and state of nutrition of the phytoplankton organisms. 2

Strickland suggests a value of F = 30 for cultures or natural populations known to be without nutrient deficiencies and F = 60 for mixed natural populations subject to high light intensities or in warm, nutrient-deficient waters.

With respect to phytoplankton communities of the Colorado River, an intermediate value ($30<F<60$) is perhaps more appropriate than the value of 60 used, particularly since the river is not nutrient deficient. However, in the interest of conservatism in the estimation of standing crops, the larger value was used, and provides an upper-limit estimate of the mass of phytoplankton as organically combined carbon which will be removed from the Colorado River make-up water intake for the cooling reservoir.

Salinity changes in the Colorado River, attributable to make-up operations, are not expected to have an adverse effect on the phytoplankton community. Natural changes of greater magnitude occur within the area and result in temporary range extensions for some species.

5.1.3.1.2 Effects on Zooplankton

The zooplankton community of the Colorado River in the vicinity of the intake structure has been discussed in Section 2.7.

The STP nuclear power facility will entrain large numbers of zooplankton from the waters of the Colorado River. The principal impact being mechanical damage from pump turbulence and physical abrasion.

Less than 12 percent mortality among entrained zooplankton at the Waukegan Generating Station was reported[8], with mechanical damage as the primary source of zooplankton mortality. It was also found that mechanical damage was a linear function of organism size, with larger organisms such as *Limnocalanus macrurus* and *Daphnia retrocurva* experiencing higher mortality rates than smaller organisms such as copepod nauplii, *Bosmina longirostris*, and *Cyclops bicuspidatus.* These studies showed that entrainment had no lethal impact on zooplankton egg viability.

Zooplankton standing crop estimates, described in Section 2.7, predict a mean number of 3.0×10^4 organisms per cubic foot, therefore an estimated 7.0×10^{13} zooplankton organisms (based on projected makeup water requirements) will be removed from the Colorado River per year.

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5.1.3.1.3 Effects on Benthos

Quantitative benthic data collected in 1973 indicate very low species number and density per square meter of infaunal organisms in the Colorado River near the STP site, (stations 1-4). See Section 2.7 for discussion of the benthic fauna.

The observed sparsity of benthic organisms at upriver stations can be attributed in part to stressful conditions created by the fluctuating nature of the habitat from freshwater to estuarine and vice versa. In addition, substrates at midstream range from sandstone to hard clay or packed sand with occasional pockets of mud and shell. Substrates near the bank range from hard clay to sand or silty sand. With the exception of mud and silty sands, such substrates generally support few benthic organsims and are maintained by river flow. Softer sediments which are more productive build up through deposition during low flow conditions but are scoured during high flow.

The makeup pumping station on the Colorado River has been designed to minimize entrainment of benthos. Makeup water will be taken from the top four feet of the river, precluding entrainment of infaunal benthic organisms due to currents induced by the makeup station. There should be no scouring of the river bottom during pumping.

Entrainment of benthic macroinvertebrates will be greatest during periods of extremely high river flow. During floods, turbulence will displace and temporarily suspend sediments and associated organisms in the water column. This condition will result in a maximum concentration of drifting benthos in makeup water. Because of the continuing redistribution by natural phenomena, the relatively small populations potentially available for entrainment under these conditions and the short term duration of heavy flood conditions, the impact of benthic entrainment at the STP site will be negligible.

5.1.3.1.4 Ichthyoplankton

Ichthyoplankton (fish eggs and larvae) collected from the Colorado River near the STP site from June, 1973 to March, 1974 were examined to determine densities and species composition with the results being discussed in Section 2.7.

To predict the potential loss of ichthyoplankton per year at the STP makeup facility on the Colorado River, the following assumptions were made:

1. Ichthyoplankton densities are uniform throughout the sampling area in the vicinity of the site.

2. Species composition and species densities determined from the monthly samples are representative of the potential monthly entrainment.

3. Species composition and species densities for each month are constant throughout the pumping operations during that month.

4. The ichthyoplankton populations near the makeup are not being depleted but are constantly repopulated.

5. At makeup salinities between 0.0 and 1.5 °/oo, ichthyoplankton data from station 2 are representative of the species composition and species densities of the makeup water; at makeup salinities between 1.5 and 5.0 °/oo, from the closest downriver station having a bottom salinity above 1.5 °/oo were chosen.

6. The standing crop per cubic foot is equal to the number of fish eggs or larvae caught divided by the amount of water strained by the net.

7. All fish 4.0 inches total length (TL) or less are subject to entrainment.[9,10]

8. The numbers of fish eggs or larvae entrained is equal to the standing crop in number per cubic foot multiplied by the percent entrainable (percentage of larvae less than 4 inches). This figure was then multiplied by the intake volume in cubic feet.

Based on 10 months of data collected during the 1973-74 STP study, potential entrainment of ichthyoplankton by species is shown in Table 5.1-9. The two larval fish species most likely to be entrained are the Gulf menhaden, Brevoortia patronus, (1,200,000 per year) and the Atlantic croaker, Micropogon undulatus, (700,000). Of the remaining potential entrainable species, only cyprinids and gobies may be taken in appreciable numbers. The above estimates are somewhat low, since they were based on 10 months of data. Gulf menhaden, bay anchovies, and gobies may have higher yearly entrainment values by perhaps 10 percent. The relatively few eggs subject to entrainment indicates that little or no spawning occurs near the STP site.

To determine the total number of eggs and larvae that may be entrained per year, monthly standing crop estimates were made (see Table 5.1-10) and the mean of these monthly estimates was used to estimate entrainment values for April and May, the two months not sampled as yet during the STP study (see Table 5.1-10). It is estimated that over 2.6 million fish eggs and larvae may be entrained each year. Highest entrainment losses may occur during months of high pumping rates and high standing crop (November and February).

Calculations were also made of the number of adults that could have been produced from the entrained ichthyoplankton (see Table 5.1-11). These estimates were calculated by determing average female fecundity and mortality rates between the egg and adult stages.[11] Fecundity estimates were available for some taxa, and were extrapolated for others. Information on mortality rates between eggs and adult stages is scarce. It is reported[12] that mackerel had a daily loss of 5 percent at the egg stage, but a loss of 10 to 14 percent at the larval stage. Einsele[13] found that only 1 to 10 adults will result from 10,000 naturally spawned coregonid eggs, and that survival among larvae of many fishes is one in several thousand. It is postulated[14] that in the course of a fish's life it belongs to three or more populations (larval, young and adolescent, and adult), and that each population has its own mortality rate. Using this approach, mortality rates were estimated for the egg to larval stage, and for the larval to adult stage. For those species exhibiting little parental care and having a high fecundity, a 75 percent egg to larvae mortality was assigned. For those species exhibiting parental care and having a low fecundity, a mortality value of 25 percent was assigned. Mortality rates between larvae and adult were based on the fact that to maintain a stable population, one female must produce two fish. Accordingly, the number of surviving larvae was divided into two to obtain a percentage survival between larvae and adult stages. This figure was multiplied by the number of larvae entrained to obtain the number of adults that would have been produced from those larvae lost by entrainment.

It is estimated that over 1,900 adults of all species would have been produced from the estimated 2.6 million eggs and larvae lost annually by entrainment (see Table 5.1-12). Although the majority of the larvae expected to be entrained are of commercial importance, few commercially important adults would have been produced from the entrained ichthyoplankton. Over 85 percent of the adults would probably have been in the families Cyprinidae and Gobiidae. The estimated number of larvae entrained yearly may be high since lifetime fecundity values were not used. Lack of information on the age structure of important species makes using lifetime fecundity vales impractical at this time.

The entrainment of fish eggs and larvae at the STP site will probably not affect fish populations in the Colorado River significantly. The low number of eggs taken near the site indicate the lack of major spawning areas in that section of the river. Although the majority of the larval fish that might be subject to entrainement are of commercial importance, the adult stock should not be significantly affected since relatively few adults would have been produced from those larvae lost. Local populations of ichthyoplankton near the STP site may be depressed, however the effect on the Colorado River ecosystem should be slight.

5.1.3.1.5 Effects of Impingement on Juvenile and Adult Fish, Shrimp, Crabs and Other Invertebrates

Effects of operation of the STP makeup pumping facility on juvenile and adult fish, shrimp, crabs and other invertebrates in the Colorado River are discussed below. The most important design consideration for reducing fish impingement at makeup structures is velocity through the travelling screens. Intake velocities are usually measured in two ways; approach velocity and net screen velocity. Approach velocity is the most common measurement and is the velocity in the screen channel measured immediately upstream of the screen face. Net screen velocity is the velocity through the screen and is always higher than approach velocity.[15,16,17,18]

These reviews indicate that in the past, intake structures have usually been designed solely on debris removal considerations and with little regard for alleviating fish impingement. Typical net screen velocities have ranged from 2.0 to 3.0 fps which correlate to approach velocities of 0.8 to 1.1 fps or higher. As recently as 1971, many workers considered that an approach velocity of 1.5 fps would permit most fish to escape impingement.[17] However, a more recent theory of how to decrease fish impingement is to lower intake velocities to the point where all healthy fish can escape.[19]

Selection of intake velocities should be based on swimming speed data of fishes at each particular site in question.[20] Fish swimming ability is a function of species, age, size, temperature and dissolved oxygen. Swimming speeds were found[21] to double at temperature increases from 5 to 20°C. It is reported[9] that swimming speeds are generally directly proportional to body length with most fish having sustained speeds three to six times their body length. Swimming speed studies on fishes of the lower Colorado River Delta are rare. Indications are that most sunfish smaller than 4 inches cannot outswim a current of 0.55 fps.[10] The corresponding speed for 4 inch channel catfish is 1 fps. Channel catfish larger than 4 inches generally avoid or can outswim these currents.[10]

A summary of intake design specifications, which will minimize impingement hazards, aids in evaluating the impact of STP intake operation on the aquatic ecosystem. Based on results of field studies presented earlier, incorporation of a 0.55 fps approach velocity will reduce potential impingement effects considerably. Screens mounted flush with the shoreline and without protruding sidewalls will reduce entrapment and fish concentrations, lessen the impact of eddy currents on the downstream side of the makeup structure, and allow organisms free passageway. The trash racks also permit open passage to the river. Incorporated in the intake design is a fish handling and bypass system which will return impinged organisms to the river downstream of the intake structure. Reduced makeup water intake during late spring, summer, and early fall months will minimize impingement of young-of-the year freshwater species. The use of upper strata river water as makeup, will reduce the potential for entrapment of estuarine organisms found in the lower strata salt wedge.

Determination of the potential effects of the proposed STP makeup water intake design and operation on subadult and adult macrocrustaceans and fishes, is based on impingement estimates calculated from trawl data collected near the STP site during 1973 and 1974. Estimates of standing crop per cubic foot of water were extrapolated to yield annual number and weight of impinged organisms. The procedure and assumptions used in calculating impingement totals are as follows:

1. Species present in monthly trawl samples and estimates of standing crop by month at the STP intake site based on trawl data are representative of potential average monthly impingement. Estimates are based on June, August and October, 1973, data presented in Section 2.7 and on July, September and November, 1973, through March, 1974, data subsequently analyzed in part for the purpose of this Section.

2. No trawl catch data are available for estimation of standing crops in April or May. Estimated standing crops for these months are thus based on average values from the remaining 10 months (January through March 1974, and June through December 1973).

3. At intake salinities between 0.0 and 1.5 $^{o}/oo$, trawl catch data from station 2 are indicative of average standing crops of the intake water in terms of species present, numbers of individuals and biomass. At intake salinities ranging between 1.5 and 5.0 $^{o}/oo$, standing crop estimates for a given month are based on trawl catch data from the nearest downriver station (3, 4, 5 or 10) having a bottom salinity greater than 1.5 $^{o}/oo$.

4. Fish and crustacean species are equally distributed as to number and weight throughout the water column in the intake area.

5. Estimated standing crop and impingement for each month are constant throughout pumping operations during that

month, the area near the intake structure not being depleted but constantly repopulated.

6. Number or pounds of fish impinged is equal to the standing crop in number or pounds per cubic foot multiplied by the percent of the standing crop estimate that is available to impingement multiplied by the volume of intake in cubic feet.

7. Standing crop per cubic foot is equal to the number or pounds of fish in a trawl sample divided by the estimated average volume of water sampled by the trawl.

8. The percent of the standing crop susceptible of impingement is equal to the number or pounds of fish in the trawl sample susceptible to impingement divided by the total number or pounds of fish. All fish 4.0 inches in total length or less and all crustaceans present in standing crop estimates are subject to impingement.

9. The estimated average volume of water sampled by the trawl, during the collection of one sample, equals 87,280 cubic feet.

Monthly average intake volumes in cubic feet for projected salinity ranges of 0.0-1.5 °/oo are given in Table 5.1-13. Months with maximum and minimum impingement potentials (based on intake volume) are February (5.01×10^8 ft^3 at 0.0-1.5 °/oo and 1.98×10^7 ft^3 at 1.5-5.0 °/oo) and August (zero intake at both salinity ranges), respectively.

Species contributing to monthly standing crop estimates and the percent of standing crop subject to impingement based on trawl data are presented in Tables 5.1-14 and 5.1-15. Approximately 96 percent of the total number (i.e., fish 4.0 inches long or less) and 24 percent of the total weight of trawled organisms are considered susceptible to impingement. Table 5.1-16 presents an example for monthly estimates of standing crop and impingement totals (number and weight) of river shrimp. Similar estimates were prepared for those species of commercial and forage importance, and are summarized in Table 5.1-17. Combined species estimates indicated that 6.25 million crustaceans and fishes totalling about 16,100 pounds will be subject to impingement per year. These weight totals represent less than 0.03 percent of the annual harvestable fish and crustacean catch (70,091,000 pounds) estimated to be produced in the lower Colorado River and Matagorida Bay areas.[22]

Species of commercial and forage importance constitute 99.3 percent and 98.6 percent of the impinged number and weight totals, respectively. Species with highest annual impingement totals include the white shrimp (33,200 individuals weighing 77 pounds), river shrimp (2,916,000 individuals weighing 6,375 pounds), Gulf menhaden (261,260 individuals weighing 901 pounds), bay anchovy (207,680 individuals weighing 168 pounds), blue catfish (246,580 individuals weighing 6,890 pounds), and Atlantic croaker (2,508,000 individuals weighing 793 pounds). Impingement totals for commercial species near the STP site constitute less than 0.1 percent of the annual Texas commercial finfish and shellfish landings.

Since a majority of the individuals subject to impingement generally are considered too small for commercial harvest, the above comparisons may not present a true picture of the impact of STP impingement upon finfish and shellfish stocks of the lower Colorado River and Gulf of Mexico. However, comparison of these estimated impingement totals with the standing crops of zero-year-class and one-year-class fishes and crustaceans necessary to produce harvestable, adult populations indicates that potential impingement losses at the STP site will have no substantial effect on standing stocks of fishes and crustaceans in the Colorado River Delta. Therefore, the STP intake design and operation will produce negligible impact on the aquatic fauna of the Colorado River and Gulf of Mexico.

5.1.3.2 Effects of Blowdown Operations on the Colorado River

The STP discharge facility has been designed to preclude the existence of significant volumes of Colorado River receiving waters with elevated temperatures. Rapid dissipation of maximum ΔT during summer (6.1°F) and winter (6.9°F) will reduce the potential impact of blowdown upon the aquatic biota. Maximum impact from blowdown should be limited to receiving waters experiencing a ΔT above 2.0°F. However, temperatures greater than 2.0°F above ambient will exist only a relatively short distance downstream (<30 ft) from each diffuser and will not form an effective barrier to fish and crustacean migration.

5.1.3.2.1 Effects on Primary Producers

Some thermal stimulation of phytoplankton growth and reproduction in the area of the Colorado River affected by blowdown is expected during winter. Thermal depression of productivity rates in the Colorado River during summer may occur for short distances, but will be minimal. A shift in phytoplankton community structure due to thermal effects is not anticipated for the Colorado River.

5.1.3.2.2 Effects on Zooplankton

There will be a potential for increased productivity of zooplankton in the area of the Colorado River affected by blowdown due to thermal and nutrient enrichment. However, any increase in zooplankton productivity in the river is expected to be slight due to the intermittent nature of blowdown.

Blowdown-induced salinity changes in the Colorado River are not expected to produce a change in zooplankton community structure. A considerable variation in salinity occurs naturally, resulting only in temporary range extensions for a few species.

5.1.3.2.3 Effects on Benthos

A potential mode of impact on the benthic infaunal community involves the interaction between intermittent blowdown and Colorado River benthos in the vicinity of the discharge facility. Possible detrimental effects are related to increased temperatures and scouring as a result of the multiport diffuser. Maximum projected ΔT at the point of blowdown is 6.9°F and is not expected to affect benthic organisms. Rapid dispersion of blowdown water and loss of temperature will result in a low ΔT downstream from the blowdown facility. Effects of scouring due to blowdown is precluded by natural scouring as a result of river flow. Blowdown will not occur at river flows below 800 cfs, a level at which natural scouring will be in effect.

5.1.3.2.4 Ichthyoplankton

The STP blowdown should have little effect on the abundance or distribution of ichthyoplankton in the Colorado River. No eggs or yolk sac larvae were taken near the discharge site during field sampling, and apparently little or no spawning occurs in this section of the river. Larvae taken near the site were probably spawned above or below the site. These larvae are probably motile enough to avoid the higher ΔT's near the discharge, and the impact on larvae may be similar to that discussed for adult fish.

5.1.3.2.5 Effects on Fish and Crustaceans

Data on preferred, upper tolerance, lower lethal, and/or avoidance temperatures for some of the fishes and crustaceans known to occur in the lower Colorado River are found in Table 5.1-18. Low ΔT, infrequency of blowdown, relatively high preferred and avoidance temperatures exhibited by these organisms, and the ability of these motile organisms to avoid any potentially lethal temperature by going under or around the discharge plume indicates that STP discharge operations will have no significant impact on fishes and crustaceans during summer conditions. In addition, laboratory experiments and field observations have shown that sudden increases in temperature up to 10°C caused by intermittent discharge, similar to that designed for the STP site, are effective in driving fish away from thermal plumes.[23]

Some fishes and crustaceans will probably be attracted to the discharge plume, particularly during the colder months. However, the rapid deterioration of discharge temperatures, the intermittent nature of discharging, and the small area affected by temperatures greater than 2°F above ambient will prevent blowdown from having any significant, adverse impact on fishes and crustaceans. Generally, temperature differentials between discharge and Colorado River waters will not be high enough or sustained over long enough periods to cause these organisms to become acclimated, to become physiologically incapable of leaving the area for adjacent waters of cooler temperature, or to induce premature spawning. Most fish in the Colorado River receiving waters near the discharge will be subjected only to a 2°F or lower rise above ambient and should experience little or no increase in incidence of disease. Discharge velocity and the associated turbulence will not be sufficient to supersaturate the receiving waters to a point where gas bubble disease is induced. The majority of temperature differentials experienced in STP receiving waters will not be great enough to significantly alter metabolic rates of fishes and crustaceans and, in turn, should cause no significant weight loss or reduction in condition of or enhance the uptake of pollutants by these organisms.

5.1.3.3 Effects in Reservoir and Condensers

In Section 5.1.3.1 it was conservatively assumed that all entrained organisms are lost from the Colorado River biota. Actually, the entrained organisms will be passed to the 7,000-acre cooling water reservoir, which will provide a new habitat which should support abundant aquatic life. Fluctuating salinities will dictate whether freshwater and/or estuarine-dependent species inhabit the reservoir. Effects of the reservoir and passage of organisms through the plant condensers are discussed below.

5.1.3.3.1 Effects on Primary Producers

Phytoplankton entrained in the condenser intake will experience mechanical disruption from pump turbulence and physical abrasion when passing through the condenser system. At present the amount of mechanical damage is difficult to quantify, although smaller phytoplankton species are less likely to be injured. Losses due to mechanical damage have been estimated at 15 percent.[24]

Entrained phytoplankton will experience thermal damage in the condensers, particularly during the summer months. In general, lethal temperatures range from 91°F to 113°F for many species of algae.[25] Diatoms, which tend to be the most thermally sensitive group of algae and in general prefer cooler waters, can withstand only limited temperature increases up to approximately 18°F above ambient. Green algae, as a group, are somewhat more adaptable to thermal change and have tolerances covering a broad range of temperatures. The blue-green algae are the most tolerant to thermal change and to high ambient temperatures. Certain blue-green species have been observed in hot springs at temperatures up to 167°F.[26] Cairns[27] presented an idealized graph of the relative performances of these groups at different temperatures.

Thermal stimulation of growth and reproduction of algal cells may occur in the discharge plume within the cooling water reservoir. Increases in water temperature have the potential for increasing the rate of photosynthetic activity during cooler seasons of the year and inhibiting the photosynthetic rate during warmer seasons, especially summer. Warriner and Brehmer[28] studied the response of phytoplankton in the York River, Virginia, to passage through condensers. They determined that temperature rises increased the productivity of winter communities and increases of 6.3°F or more depressed the productivity of communities in July and August. Morgan and Stross[29] found similar results in the Patuxent estuary. Phytoplankton photosysthesis was stimulated by 14.4°F increases; when ambient temperatures exceeded 68°F, this temperature rise inhibited photosynthesis.

Principal factors expected to influence algal growth in the reservoir are temperature, nutrient availability, rate of light attenuation, and detention time of water within the reservoir.

Cairns[27] has presented an idealized representation of the response of algal populations to increased temperature. In E-12
general, diatoms are predominant in a community at temperatures below 85°F, green algae become most abundant in the range 85 to 95°F, and blue-green algae dominate a community at temperatures above 95°F. Table 5.1-18a presents predicted temperature means at the circulating water discharge. During the period 2
April through October, temperatures in the immediate vicinity of the circulating water discharge are expected to stimulate growth of blue-green algae.

Nutrient loading in the reservoir is expected from two primary sources: leaching from soils in the reservoir bed during filling, and nutrients present as dissolved minerals in makeup water. Additional in-plant sources of nutrients, principally phosphate, are described in Section 5.4.4 of the STP-ER. Concentration of ortho-phosphate, as P, based upon mean values determined for water samples collected at station 2 (located in the vicinity of the location of the intake structure), is 0.09 ppm. The concentration of nitrate plus nitrite, as N, based upon mean values determined for similar samples collected at station 2, is 1.06 ppm. Concentration effects within the cooling reservoir (Section 3.4) are expected to raise levels of soluble phosphorus and inorganic nitrogen to 0.27 and 3.18 ppm, respectively. Vollenweider[71], in a study of nutrient loadings of natural lakes, reported that nuisance growth of algae occurs at phosphorus concentrations greater than 0.2 ppm and nitrogen concentrations greater than 3.0 ppm.

The siltation basin incorporated into the proposed makeup water intake design will provide a quiescent area in which setteable sediments conveyed by the makeup water can settle E-12
out. Thus, the cooling reservoir may be less turbid than similar Texas impoundments. Decreased turbidity may result in increased algal productivity through extension of the euphotic zone.

Figure 3.4-14 shows that during summer months blowdown occurs 2
at reduced frequency with no blowdown during August. During such periods of reduced blowdown frequency, which coincides with maximum blue-green algae abundance, the reservoir may function as an effective nutrient trap. Figure 3.4-17 shows that under extreme drought conditions a period of several years may occur in which there is no blowdown discharge. The reservoir thus will operate as a closed-system with essentially little or no outflow for extended periods of time.

In summary, it is assumed that a probability exists that phytoplankton densities will occur in the cooling reservoir, and during the period of April through October, the dominant component of this community will be blue-green species. However, a plankton community of this type will not affect the performance capability of the reservoir as a heat-sink. Loss of aesthetic quality due to discoloration is of little consequence as no recreational usage is planned for this reservoir.

5.1.3.3.2 Effects on Zooplankton

Effects on zooplankton include the following:

1. thermal stress from rapid temperature increases during passage through the condenser;

2. the potential for increased productivity of zooplankton in the area of discharge into the cooling water reservoir.

Numerous references discuss the effects of entrainment on zooplankton communities, although few have been able to distinguish between mechanical, thermal, and chemical inhibitory effects. Whitehouse[30] studied a cooling pond used by a nuclear power plant and found no change in composition, abundance, or timing of periods of increase or decrease in zooplankton concentrations that could be attributed to thermal discharge. Youngs[31] found that 19 percent of the Cayuga Lake zooplankton were killed after passage through a cooling system that raised temperatures from 50°F up to 77°F. Zooplankton have been shown to adjust to temperature changes within their range of tolerance by altering various metabolic functions.[67] Similar studies[32,33,34] suggest that mortality rates may exceed 80 percent when ambient temperatures are elevated above 98.6°F (37°C). During warmer months (May through September), zooplankton mortality, attributable to thermal effects in the condenser system and the area of the cooling water reservoir affected by condenser discharge may approach 100 percent.

Studies of the Paradise Power Plant[35] indicate that accelerated rates of reproduction of zooplankton organisms occurred in areas marginally affected by heated effluents. Thermal acceleration of zooplankton reproductive rates may occur in a large portion of the cooling water reservoir.

5.1.3.3.3 Effects on Benthos

Effects of plant operation on benthic populations of the cooling water reservoir which become established during the three-year filling period are expected to be negligible. Expected ΔT values will not result in thermal stress of benthic organisms except in the immediate vicinity of condenser discharge outfall into the reservoir.

Similar effects were observed[36] in the 2,600-acre brackish water cooling pond of the Cedar Bayou Electric Power Station near Trinity Bay, Texas. Depressed diversity and abundance were noted[36] where the heated discharge entered the reservoir as compared to high diversity and abundance in other areas of the reservoir. The benthic fauna was found[36] to be dominated by polychaetes, molluscs, chironomids, and amphipods. Most forms observed[36] also occur in brackish water areas of the STP study area. These forms are tolerant of very low salinity waters as projected for the STP cooling water reservoir and are expected to contribute in large part to the benthic fauna during operation.

5.1.3.3.4 Effects on Fish and Crustaceans

The impact of condenser cooling water discharge upon fishes and crustaceans in the 7,000-acre reservoir will be minimal. As shown in Figure 3.4-18 thermal conditions in reservoir areas outside the immediate vicinity of condenser discharge are not greatly different from those in the Colorado River. The large area and depth of the reservoir should provide areas of refuge from most elevated temperatures during the summer, areas of more favorable, warmer temperatures in the winter, and areas for spawning of freshwater fishes and crustaceans in the spring. The similarity between temperatures in most parts of the reservoir and ambient river temperatures should negate any thermally induced effects of pollutants, increased incidence of disease, loss of weight or reduction in condition, or extensive, premature spawning by freshwater fishes and crustaceans.

5.1.3.4 Discussion of Effects on Aquatic Organisms

The effects on aquatic organisms resulting from operation of the heat dissipation system as described above are not of sufficient magnitude to produce discernible changes in populations in the Colorado River or adjacent waters. Impingement and entrainment associated with the STP makeup water pumping station located on the Colorado River will have the greatest impact of all potential sources. However, loss of organisms through impingement and entrainment has been minimized by intake design and plan of operation and will be of such low magnitude that the aquatic biota in the immediate area of the STP site will exhibit only negligible effects. This is because the Colorado River near the STP site is a transition zone, fluctuating between fresh and estuarine conditions. The zone is characterized by lower diversity and numbers of organisms than either freshwater or estuarine portions of the river.

The relative effect of entrainment and impingement at the STP site is difficult to quantify because populations of many species (estuarine-marine) occuring at the STP site are not confined to the Colorado River but occur throughout much of the Gulf of Mexico. Thus, estimation of total populations for comparison would be impossible. In general, estimates of impingement and entrainment presented above would have a minute relative effect, even when compared to total populations of the Colorado River-Matagorda Bay system.

Operation of the cooling water reservoir will have little impact on the aquatic biota of the Colorado River beyond the impact associated with the makeup-water pumping station. This is because organisms affected by pond operation were previously considered lost from river populations through entrainment and thus, are not additive.

Under the projected hydrological conditions for the cooling water reservoir, a large portion of the reservoir will be suitable for rapid growth and reproduction of aquatic organisms and will support large populations. Although the cooling water intake structure and condenser discharge will exert a continuous detrimental effect on aquatic life of the reservoir, reservoir populations will be sufficiently large enough to readily absorb these potential losses. The reservoir will be supplied with a constant source of nutrients and will probably act to some extent as a nursery area for many estuarine species, with emigration occurring during blowdown operations.

Release of reservoir water into the spillway will be infrequent. Based on operational constraints outlined in Section 3.4, spillway release during a 23-year period from 1949 through 1971 would have occurred 0.18% of the time or one day out of 560 days. Hence, subjecting of aquatic organisms to thermal shock or cold shock would occur infrequently.

The chance for development of a resident population of fishes or other motile aquatic organisms in the spillway and stilling basin is small. Normally there will be no Colorado River water in the
stilling basin. Water found in the stilling basin generally will E-1
be groundwater which has entered the basin through seepage and attained a level equal to that of the groundwater table. The infrequency of spillway release and those flood periods during
which Colorado River water may enter the stilling basin greatly 2
reduces the chances for resident aquatic populations to develop in the spillway and associated basins.

Entry of aquatic life from the Colorado River directly into the stilling basin can occur only during flood conditions. However, flooding of the Colorado River pushes the salt wedge and associated organisms from the area into the lower reaches of the estuary and into the Gulf of Mexico, and thereby reduces the probability that estuarine organisms enter the spillway basin. Freshwater organisms are discouraged from entering the stilling basin by the velocity of the flows associated with spillway release. Water being released from the reservoir will be travelling at 60 fps upon entry into the spillway channel, 6 fps upon entry into the stilling basin, and 2.5 fps upon entry into the discharge channel. The majority of organisms entering the spillway structure from the reservoir will be swept by these high-velocity flows into the Colorado River.

A survey by Tilton[72] of 210 Job Completion Reports entitled "Pollution studies in fish population determinations", authored
by Texas Parks and Wildlife Department aquatic biologists, has E-13
shown no increased incidence in noxious vegetation or algal growths resulting from thermal additions into 30 Texas reservoirs. These reports also show no reduction in fish condition,
angler use or aesthetic qualities due to algal blooms in Texas 2
reservoirs.

Fruh[73] has conducted extensive limnological research in Texas Lakes and reports that data on eutrophication experience do not exist for these impoundments. This pronounced lack of data would seem to support the fact that eutrophication does not present a problem in Texas impoundments.

Environmental effects in the Colorado River and adjacent waters resulting from blowdown will be negligible. The multiport blowdown design will affect rapid mixing of blowdown water with Colorado River water resulting in rapid heat loss and a small mixing zone. Generally, blowdown will result in a slight increase in ambient temperatures and salinity downstream, with the effect decreasing with distance (Section 5.1.1). Projected salinity and temperature changes due to blowdown are not expected to have significant effects on aquatic organisms either at the point of blowdown or in the Colorado River between the blowdown structure and Gulf of Mexico. Likewise, blowdown operations will have no effect on aquatic life in the adjacent bay systems or in the Gulf of Mexico.

Overall, detrimental effects on the aquatic ecology of the Colorado River due to operation of the STP heat-dissipation system with controlled makeup and blowdown of the cooling water reservoir will be negligible and restricted to the portion of the river near the STP site. There should be no effect on parent stocks or availability of harvestable size individuals of commercial or sport-fishery species. No effects are expected upstream from the plant site, in the lower Colorado River, in Matagorda or East Matagorda Bays, in the Gulf Intracoastal Waterway or in the Gulf of Mexico.

5.1.4 EFFECT ON GROUNDWATER

A description of the hydrogeology of the plant area is given in Section 2.5.2.2. In general, the groundwater regime consists of a deep aquifer zone located at a depth of approximately 275 feet and a shallow aquifer zone located above approximately 90 feet. The deep zone is confined under artesian pressure by a thick (more than 150 feet) confining or aquiclude zone of predominantly clay sediments. The aquifer recharge area is far removed, at higher elevations where the aquifers crop out at the surface. This artesian zone, the region's only important source of usable groundwater (see Section 2.2), is therefore sealed from surface or cooling-reservoir seepage in the site area. In view of these conditions, the deep-zone aquifers will not be affected by heat-dissipation-system operation.

Groundwater in the shallow zone flows southeasterly from the plant site, to the Colorado River and possibly to Matagorda Bay. Existing water quality is known to be marginal to poor in intervening areas (see Section 2.5.2). Test holes show that this condition prevails in the site area also. Shallow wells are rarely employed for any use except occasional domestic and stock watering anywhere in the region; only one shallow (107 feet deep with screens between 104 and 107 feet), low-production well is reported to be in present use downstream of the site. Considering water quality and quantity limitations of this zone, there is very low probability of any new use of shallow water in the general area and downstream from the site.

5.1.4.1 Modification of Water Table Position

Based on the following discussions, it is shown that the reservoir seepage will flow vertically in the shallow aquifer displacing, in a pistonlike fashion, the groundwater ahead and that no change will take place in the position of the water table except immediately under the reservoir.

The seepage of water from the cooling reservoir is estimated to be at about 2 cubic feet per second (1,448 acre-ft/yr) under steady-state condition.

Several models (see Appendix 6.1-C) designed to determine the type of flow emanating from the STP cooling reservoir, have indicated that such a flow is essentially vertical in the unsaturated zone and upper shallow aquifer zone. The seepage flow will first saturate the unsaturated four feet of formation before meeting the groundwater level. When this happens two possibilities must be considered: either the reservoir water will move laterally (parallel to water table) or it will flow vertically displacing the groundwater ahead of it. If the first alternative takes place, the reservoir water will move laterally for a certain distance before gravity pulls the flow vertically. Moreover, the permeability of the underlying sandy silt is 100 times greater than the permeability of the silty clay harboring the piezometric level. (See Section 2.5). Thus, in either case the flow would be vertical in these strata.

Other evidence to support the theory of vertical flow exists. Field tests conducted on wells bottomed in the upper aquifer reveal the existence of vertical fluid migration before the emplacement of the cooling reservoir. After juxtaposing the gradient of a head of water (equal to approximately 20 feet), the vertical flow would be more accentuated. A third reason supporting the theory of vertical flow may be that, if the flow is vertical, the displaced fluid will be channeled to the lower Colorado River via a 20-foot section of fine sand about 10,000 times more permeable than the bed of silty clay lying below the pond. If the flow were to be considered horizontal, a permeability of 10^{-7} cm/sec would have to be sufficient to channel the flow-which is obviously not the case.

Withdrawal of potable and service waters from the deep aquifer zone (see Section 5.7.2) will not affect the cooling-reservoir seepage nor the shallow aquifer water level because of the thick confining layer separating the shallow- and deep-aquifer zones.

5.1.4.2 Infiltration Into The Groundwater System

The results presented below indicate that reservoir water will invade the upper parts of the shallow aquifer before it is channeled to the Colorado River in a southeasterly direction. It should be noted that all water used for human consumption comes from the strata constituting the lower aquifer.

As described in Section 3.4, the water elevation in the reservoir will assume a different value during each month throughout the plant life. For any one year, it is found that the difference between the highest and the lowest elevations is of the order of 5 percent. Because of the slight effect of water elevation on the dispersion phenomenon, it was deemed advisable to use one value for the average water head for a full year. Using the value for the first year, the water encroachment into the dry soil was evaluated followed by the resulting dispersion after the front reached the groundwater system.

The advance of the water front in the unsaturated formation was determined by the following expression:

$$t = \frac{f}{K} \left[L_w - (H_w - P_w) \ln \left(\frac{H_w - P_w + L_w}{H_w - P_w} \right) \right] \quad (1)$$

where:

- t time
- f porosity
- K hydraulic conductivity
- L_w depth of water penetration at time t
- H_w depth of water in reservoir
- P_w capillary rise in silty clay layer

The derivation of this formula is given in Appendix 6.1-C. The first year of dispersion was determined by the following partial differential equation:

$$\frac{\partial C}{\partial t} + v \frac{\partial C}{\partial x} = D_x \frac{\partial^2 C}{\partial x^2} \quad (2)$$

The solution of this equation for a constant velocity v and a constant initial value C_o is:

$$C/C_o = 1/2 \text{ erfc} \left(\frac{x-vt}{2 (D\ t)^{1/2}} \right) + \frac{1}{2} \exp \frac{(vx)}{D} \text{ erfc} \left(\frac{X-vt}{2 (D\ t)^{1/2}} \right) \quad (3)$$

where:

- C_o = initial concentration
- C = concentration at time t
- x = is spatial coordinate
- v = the velocity of flow
- D = the dispersion coefficient
- t = time

Because this formula applies only when the velocity and the boundary condition are constant, it was used to calculate the concentration distribution of the total dissolved solids for the first year of operation. In Figure 5.1-42, which shows the contaminant concentration vs depth distribution, this curve is labeled H_w = 25.96, year 1.

Because of the constraints imposed in obtaining the solution of equation 2, equation 3 was not used to calculate any other concentration distribution. Instead, the partial differential equation was written in the following difference form:

$$\Delta C = \Delta t \left[- v\frac{\Delta C}{\Delta x} + D_x \frac{\Delta^2 C}{\Delta x^2} \right] \quad (4)$$

To calculate the concentration distribution at year two for H_w = 24.93, the average velocity was calculated for the depths 2, 3 and 4 feet. The concentration distribution at year one was used to evaluate the slope and the curvature: $\Delta C/\Delta x$ and $\Delta^2 C/^2x$. Replacing these and other terms by the appropriate values, ΔC was calculated for many of the points on the curve for year one (H_w = 25.96). In this manner, the entire concentration distribution corresponding to year two (H_w = 24.93) was obtained. This water head is the average of 12 monthly readings for the second year of operation.

All other concentration distributions corresponding to 60 years of dispersion have been calculated and shown in Figure 5.1-42. As can be seen on this graph, the intersection of these curves with the x-axis gives the positions of the dispersion front at various times. For example, a half-year after dilution begins, the dispersion front reaches a depth of two feet. After five years and for the conditions assumed in the solution of the problem, the dispersion front will have penetrated 7.5 feet. Between the depths of 2 and 19 feet below the piezometric level lies a stratum of sandy silt. Therefore, the dilution phenomenon will take place in the sandy silt stratum between the second and twenty-seventh years.

After 27 years of dilution, the dispersion front will reach the top of the fine sand located 23 feet below the ground surface. From this point on, the dispersion moves horizontally in the stratum of fine sand with a constant velocity of 5×10^{-6} ft/sec. The flow will occur in a southeasterly direction parallel to the regional migration in the upper aquifer.

The concentration of total dissolved solids in the fine sand will be approximately fifty percent of the original value 60 years after the seepage front meets the water table.

The increase in concentration in the layer of fine sand will occur very slowly beyond the median value of fifty percent. However, if the concentration of total dissolved solids is held constant at fifty percent of the original value and for a velocity of 5×10^{-6} ft/sec, it is estimated that the dilution front will reach well number 42 (see Section 2.2) 185 years after dispersion begins. Well 42 is located 3.5 miles from the geographic center of the pond measured in a direction parallel to the regional flow and is the closest existing groundwater use.

Flow from the reservoir will reach some parts of the Colorado River sooner than well number 42 (approximately 150 years), on account of the shorter distance to the river.

REFERENCES

5.1-1 Bryan, C.E., February 28, 1974; Texas Parks and Wildlife Department, letter to K.A. Wood.

5.1-2 Pritchard, D.W. and H.H. Carter, April 1972; Design and Siting Criteria for Once-Through Cooling Systems Based on A First Order Thermal Plume Model; AEC Document No. COO-3062-3, p. 6.

5.1-3 Pritchard, D.W. and H.H. Carter, April 1972; Design and Siting Criteria for Once-Through Cooling Systems Based on a First Order Thermal Plume Model; AEC Document No. COO-3062-3, p. 7.

5.1-4 National Oceanic and Atmospheric Administration, 1972; Local Climatological Data, Victoria, Texas, U.S. Department of Commerce.

5.1-5 Texas Water Quality Standards, October 1973, p. 14.

5.1-6 Texas Water Quality Standards, October 1973, p. 9.

5.1-7 Vollenveider, R.A., 1969; Primary Production in Aquatic Environments; Blackwell Scientific Publications, Edinburg, Scotland.

5.1-8 McNaught, D.C., 1972; The Potential Effects of Condenser Passage on the Entrained Zooplankton at Zion Station; Presented at Lake Michigan Enforcement Conference, Chicago, Illinois.

5.1-9 Bainbridge, R., 1958; "Speed and stamina in three fish"; J. Exp. Biol. 37(1): pp. 129-153.

5.1-10 King, L.R., 1969; "Swimming speed of the channel catfish, white crappie and other warm water fishes from Conowingo Reservoir, Susquehanna River, Pa."; Ichthyological Associates Bulletin 4: pp. 1-74.

5.1-11 Carlander, K.D., 1969; "Handbook of freshwater fishery biology"; The Iowa State Univ. Press, Ames, Iowa, p. 752.

5.1-12 Sette, O.E., 1943; "Biology of the Atlantic mackerel (Scomber scombrus) of North America, Part I, Early life history"; U.S. Fish Wildl. Serv., Fish. Full., 50(38): pp. 149-237.

REFERENCES (Continued)

5.1-13 Einsele, W., 1965; "Problems of fish-larvae survival in nature and the rearing of economically important middle European freshwater fishes"; Calif. Coop. Oceanic Fish. Invest., Rept. 10: pp. 24-30.

5.1-14 Hempel, G., 1965; "On the importance of larval survival for the population dynamics of marine food fish"; Calif. Coop. Oceanic Fish. Invest., Rept. 10: pp. 13-23.

5.1-15 Ebasco Services Incorporated, 1972; "Cedar Bayou Unit 3 intake design study"; Ebasco Services Incorporated for Houston Lighting and Power Company, p. 32.

5.1-16 Moore, R.E., 1972; "Survey of large volume intake system velocities and fish swimming speeds in the Great Lakes"; C.W. Rice Division, NUS Corporation, Pittsburgh, Pa., Submitted to the Cleveland Electric Illuminating Company, Cleveland, Ohio, Contract No. 2065, p. 27.

5.1-17 Maxwell, W.A., 1973; "Fish diversion for electrical generating station cooling systems - a state-of-the-art report for Florida Power and Light Company"; NUS Corporation, Southern Nuclear Department, Engineering Consulting Division, p. 78.

5.1-18 Sonnichsen, J.C., Jr., Bentley, B.W., Bailey, G.F., and Nakatani, R.E., 1973; "A review of thermal power plant intake structure designs and related environmental considerations"; Hanford Engineering Development Laboratory, Richland, Washington, Prepared for the U.S. Atomic Energy Commission, Contract No. AT(45-1)-2170, p. 93.

5.1-19 Quirk, Lawler and Matusky Engineers, 1973; "Astoria impingement study for Consolidated Edison Company of New York, Inc."; Q, L and M Project No. 115-16, Tappan, New York, p. 75.

5.1-20 U.S. Environmental Protection Agency, 1973; "Cooling Water Intake Structures"; Federal Register, Vol. 38, No. 239, Part II.

5.1-21 Clay, C.H., 1961; "Design of fishways and other fish facilities"; Dep. Fish. Canada, Ottawa, Canada, p. 301.

REFERENCES (Continued)

5.1-22 Krummes, W.T., 1967; Interim Report on Colorado River and Tributaries, Texas - Mouth of Colorado River; Appendix III, Dept. of the Army, Galveston District, Corps of Engineers, Galveston, Texas, p. 149.

5.1-23 Coutant, C.C., 1970; Biological Aspects of Thermal Pollution I. Entrainment and Discharge Canal Effects; CRC Critical Reviews in Environmental Control, 1(3): pp. 341-381.

5.1-24 Ayers, J.C., Anderson, R.F., O'Hara, N.W., and Kidd, C.C., 1970; "Benton Harbor Power Plant Limnological Studies"; Part IV, Cook Plant Preoperational Studies 1969, Special Report No. 44, Great Lakes Research Division.

5.1-25 Patrick, R., 1969; Some Effects of Temperature on Freshwater Algae; In, Biological Aspects of Thermal Pollution, Krenkel, P.A. and Parker, F.L. (Ed.), Vanderbilt Univ. Press.

5.1-26 Patrick, R., 1971; The Effects of Increasing Light and Temperature on the Structure of Diatom Communities; Limnology and Oceanography, Vol. 16, pp. 405-421.

5.1-27 Cairns, J., 1956; Effects of Increased Temperatures on Aquatic Organisms; Ind. Wastes, Vol. 1, pp. 150-152.

5.1-28 Warriner, J.E. and Brehmer, M.L., 1966; The Effects of Thermal Effluents on Marine Organisms; International Journal Air and Water Pollution, Vol. 10, No. 4, pp. 277-289.

5.1-29 Morgan, R.P. and Stross, R.G., 1969; Destruction of Phytoplankton in the Cooling Supply of a Steam Electric Station; Chesapeake Science, Vol. 10, pp. 165-172.

5.1-30 Whitehouse, J.W., 1971; Some Aspects of the Biology of Lake Trawsfynydd: A Power Station Cooling Pond; Hydrobiologia, Vol. 38, No. 2, pp. 253-288.

5.1-31 Youngs, W.D., 1969; Milliken Station Studies; In, Ecology of Cayuga Lake and the Proposed Bell Station (Nuclear Powered), Oglesby, R.T., and Allee, D.J. (Ed.), Publ. No. 27, Water Resources and Marine Sciences Center, Cornell Univ., Ithaca, N.Y., pp. 315-386.

REFERENCES (Continued)

5.1-32 Churchill, M.A. and Wojtalik, T.A., 1969; Effects of Heated Discharges: The T.V.A. Experience; Nuclear News, pp. 80-86.

5.1-33 Normandeau, D.A., 1970; The Effects of Thermal Releases on the Ecology of the Merrimack River; In, A Report to Public Service Company of New Hampshire, Institute Res. Services St. Auselin's College, New Hampshire, pp. 199-210.

5.1-34 Badger, R.G. and Roessler, M.A., 1971; Zooplankton, In, An Ecological Study of South Biscayne Bay and Card Sound; Progress Report to U.S. Atomic Energy Commission and Florida Power and Light Co., Univ. of Miami, pp. 1-29.

5.1-35 Welch, E.G., 1969; Ecological Changes from Waste Heat; In, Engineering Aspects of Thermal Pollution, Parker, F.L. and Krenkel, P.A. (Ed.), Vanderbilt Univ. Press, pp. 58-71.

5.1-36 Personal Communication from M.J. Poff to G.E. Williams, NUS Corp., 1974.

5.1-37 Baxter, J.L., 1967; Summary of biological information on the northern anchovy; Engraulis mordax Girard, Calif. Coop. Oceanic Fish. Invest., Rept. (11): pp. 110-116.

5.1-38 Hayasi, S., 1967; A note on the biology and fishery of the Japanese anchovy; Engraulis japonica (Houttuyn), Calif. Coop. Oceanic Fish. Invest., Rept. (11): pp. 44-57.

5.1-39 Dz de Ciechomski, J., 1967; Present state of the investigations on the Argentine anchovy; Engraulis anchoita (Hubbs, Marini), Calif. Coop. Oceanic Fish. Invest., Rept. (11): pp. 58-66.

5.1-40 Mansueti, A.J. and Hardy, J.D., 1967; Development of fishes of the Chesapeake Bay region, An atlas of egg, larvae, and juvenile stages; Part I, Port City Press, Baltimore, p. 202.

5.1-41 Hildebrand, S.F. and Schroeder, W.C., 1928; Fishes of Chesapeake Bay; U.S. Fish Wildl. Serv., Fish. Bull. 43, (1927), doc. 1024: 366 p.

REFERENCES (Continued)

5.1-42 Moe, M.A., Lewis, R.H., and Ingle, R.M., 1968; Pompano mariculture: preliminary data and basic considerations. Fla. State Board Conserv. Tech. Ser., 55: p. 65.

5.1-43 Breder, C.M., Jr. and Rosen, D.E., 1966; Modes of reproduction in fishes; American Museum of Natural History, Natural History Press, Garden City, N.Y., p. 941.

5.1-44 Hildebrand, S.F. and Cable, L.E., 1938; Further notes on the development and life history of some teleosts at Beaufort; N.C., U.S. Fish Wildl. Serv., Fish. Bull., 48(24): pp. 505-642.

5.1-45 Topp, R.W. and Hoff, F.H., Jr., 1972; Flatfishes (Pleuronectiformis), Memoirs of the Hourglass Cruises, Vol. IV, Pt. II, Fla. Dept. Nat. Resources Mar. Res. Lab., p. 135.

5.1-46 Meldrim, J.W. and Gift, J.J., 1971; Temperature preference, avoidance and shock experiments with estuarine fishes; Ichthyological Associates Bull., 7: pp. 1-75.

5.1-47 Gift, J.J. and Westman, J.R., 1971; Responses of some estuarine fishes to increasing thermal gradients; Ichthyological Associates Bull. p. 154.

5.1-48 Wiesepape, L.M. and Aldrich, D.V., 1970; Effects of temperature and salinity on thermal death in postlarval brown shrimp, *Penaeus aztecus*; Sea Grant Publication TAMU-SG-71-201, p. 70.

5.1-49 Zein-Eldin, Z.P. and Griffith, G.W., 1966; The effect of temperature upon the growth of laboratory-held postlarval *Penaeus aztecus*; Biol. Bull., 131: pp. 186-196.

5.1-50 Copeland, B.J. and Bechtel, T.J., 1971; Some environmental limits of six important Galveston Bay species; N.C. State Univ., Pamlico Mar. Lab., 20: pp. 1-108.

5.1-51 Chin, E., 1961; *A trawl study of an estuarine nursery area in Galveston Bay with particular reference to penaeid shrimp*; Ph.D. Dissertation, Univ. Washington, 113 pp.

REFERENCES (Continued)

5.1-52 Holland, J.S., Aldrich, D.V. and Strawn, K., 1971; Effects of temperature and salinity on growth, food conversion, survival and temperature resistance of juvenile blue crabs, Callinectes sapidus Rathbun; Sea Grant Publication TAMU-SG-71-222, 166 pp.

5.1-53 Tagatz, M.E., 1969; Some relations of temperature acclimation and salinity to thermal tolerance of the blue crab, Callinectes sapidus; Trans. Amer. Fish. Soc., 98(4): pp. 713-716.

5.1-54 Gallaway, B.J. and Strawn, K., 1973; Species diversity, seasonal abundance, and distribution of marine fishes at a hot water discharge in Galveston Bay, Texas; Manuscript submitted to Publ. Inst. Mar. Sci., Univ. Tex., p. 177.

5.1-55 Johnson, K.W., 1973; Occurrence and abundance of fishes in the intake and discharge areas of the Cedar Bayou Power Station before and during the first year of plant operation; Ph.D. Dissertation, Tex. A&M Univ., p. 348.

5.1-56 Jensen, L.D., Carpenter, J.H., Hargis, W.J., Odum, E.P., Patton, V.D., Samsell, T.R., Scott, D.H., Strawn, K. and Warriner, J.E., 1970; Environmental effects; p. 86-105, In, W.W. Eaton (Task Force Chairman), Nuclear Power in the South, A Report on the Southern Governor's Task Force for Nuclear Power Policy, Southern Interstate Nuclear Board, Atlanta, Georgia, p. 138.

5.1-57 Whitford, W.G., 1969; The effect of water quality and environmental factors on freshwater fish; New Mexico State Univ., p. 6.

5.1-58 Smith, H.M., 1907; The fishes of North Carolina; North Carolina Geological and Economic Survey, Vol. II, Raleigh, p. 453.

5.1-59 Suttkus, R.D. and Sundararaj, B.I., 1961; Fecundity and reproduction in the largescaled menhaden; Brevoortia patronus Goode, Tulane Studies Zool. 8(6): pp. 177-182.

5.1-60 Baxter, J.L., 1960; A study of the yellowtail; Seriola dorsalis (Gill), Calif. Dep. Fish Game, Fish Bull., 110: p. 96.

REFERENCES (Continued)

5.1-61 Petterssen, S., 1956; Weather Analysis and Forecasting, Volume II, McGraw-Hill, New York.

5.1-62 Hrischke, R.E., 1959; Glossary of Meteorology, American Meteorological Society, Boston, pp. 227-228.

5.1-63 National Oceanic and Atmospheric Administration, 1972; Local Climatological Data, Annual Summary with Comparative Data, U.S. Department of Commerce.

5.1-64 Traffic Map, Matagorda County, Texas State Highway Department, Planning Survey Division, 1970.

5.1-65 Personal communication from Charles Studzenbater (Texas Parks and Wildlife Department), and Gordon Folzenlogen (Bureau of Sport Fisheries and Wildlife) to Terry L. Sharik, NUS Corp., February, 1974.

5.1-66 Treshow, M., 1970; Environment and plant response; McGraw-Hill, New York, 422 p.

5.1-67 Warren, C. E., 1971; Biology and Water Pollution; W. B. Saunders Co., Philadelphia, Pa.; 434 pp.

5.1-68 Barsom, G., June 1973; Lagoon Performance and the State of Lagoon Technology; EPA-R2-73-144.

5.1-69 Chabrek, R.H., 1971; Ponds and Lakes of the Louisiana Coastal Marshes and Their Value to Fish and Wildlife, Proceedings of the Twenty-Fifth Annual Conference, Southeastern Association of Game and Fish Commissioners, October 17-20, 1971, Charleston, South Carolina.

5.1-70 Strickland, J.D.M., 1960; Measuring the Production of Marine Phytoplankton, Bull. Fisheries Research Boards of Canada, No. 122, pp. 1-172. 2

5.1-71 Vollenweider, R.A., 1968; Scientific fundamentals of eutrophication of lakes and flowing waters, with particular reference to nitrogen and phosphorus as factors of eutrophication. Directorate for Scientific Affairs, Organization for Economic Cooperation and Development, Paris.

REFERENCES (Continued)

5.1-72 John Tilton, Personal Communication, Texas Electric Service, Fort Worth, Texas, July 17, 1974. E-13

2

5.1-73 Dr. E. Gus Fruh, Personal Communication, Environmental Health Engineering Program, University of Texas, Austin, Texas, July 14, 1974.

5.1-74 Okubo, A. and Pritchard, D. W. "Summary of Our Present Knowledge of the Physical Processes of Mixing In the Ocean and Coastal Waters." Chesapeake Bay Institute, USAEC Report Number NYO-3109-40, September, 1969.

2

5.1-75 Koh, R.C.Y. and Fan, L. "Mathematical Models For The Prediction of Temperature Distributions Resulting From The Discharge of Heated Water Into Large Bodies of Water." Water Quality Office, Environmental Protection Agency, October, 1970.

TABLE 5.1-1

TEMPERATURE AND SALINITY DATA TAKEN IN THE GULF OF MEXICO NEAR THE LOWER COLORADO RIVER*

Date	Depth (Fathoms)	Location	Temperature C° Surface	Temperature C° Bottom	Salinity °/oo Surface	Salinity °/oo Bottom
6/67	8	5 Miles offshore	27.8	27.5	31.1	32.2
5/68	4	SE Brown Cedar Cut	26.7	23.6	20.7	22.7
5/68	10	SE Brown Cedar Cut	25.9	22.9	26.1	31.7
5/68	7	Between Colorado River and Pass Cavallo	28.0	24.0	22.8	29.5
5/68	10	Between Colorado River and Pass Cavallo	27.6	23.6	25.0	31.7
6/68	10	28°23'N-96°09'W	29.5	24.0	24.2	34.1
6/68	4	28°44'N-95°38'W	30.6	24.7	21.9	32.5
6/68	10	28°35'N-95°29'W	29.0	24.5	28.6	35.0
4/72	4	28°41'N-95°43'W	26.1	22.3	13.6	17.0
4/72	8	28°37'W-95°39'W	22.3	20.8	16.6	26.2

*See Reference 5.1-1

TABLE 5.1-2

AVERAGE MONTHLY MAKEUP SALINITIES AND PUMPING RATES
AVERAGED OVER PLANT LIFE

Month	Average Salinity (°/oo)	Average Pumping Rate (cfs)
January	0.46	398
February	0.46	467
March	0.59	288
April	0.46	445
May	0.49	448
June	0.35	745
July	0.96	200
August	0.0	0.0
September	0.46	428
October	0.48	452
November	0.60	286
December	0.60	340
Average Yearly	0.49	375

TABLE 5.1-3

SURFACE COOLING COEFFICIENTS*

The Surface Cooling Coefficient, mμ $\left(Btu \cdot ft^{-2} \cdot (°F)^{-1} \cdot hr^{-1}\right)$ as a Function of the Wind Speed, W (mph), the Natural Surface Water Temperature, T_α(°F), and the Excess Temperature, ΔT(°F)

Wind Speed (mph)	ΔT+ 2°	6°	10°	14°	18°
	For T_α = 40° F				
2	1.39	1.51	1.65	1.83	2.07
4	1.90	2.05	2.21	2.42	2.68
6	2.42	2.58	2.78	3.00	3.29
8	2.94	3.12	3.33	3.59	3.89
10	3.46	3.66	3.90	4.18	4.50
	For T_α = 60°F				
2	1.73	1.87	2.05	2.30	2.61
4	2.47	2.69	2.88	3.17	3.52
6	3.23	3.45	3.70	4.02	4.42
8	3.98	4.23	4.53	4.89	5.32
10	4.73	5.02	5.36	5.75	6.21
	For T_α = 80°F				
2	2.26	2.44	2.68	3.03	3.47
4	3.43	3.66	3.97	4.38	4.88
6	4.59	4.90	5.27	5.74	6.31
8	5.77	6.11	6.57	7.08	7.71
10	6.93	7.37	7.86	8.45	9.13

*see Reference 5.1-3

TABLE 5.1-4

MONTHLY AVERAGE WIND SPEED AT
VICTORIA, TEXAS

Month	Mean Speed (mph)
January	10.7
February	11.2
March	11.7
April	12.2
May	11.0
June	9.8
July	9.2
August	8.5
September	8.6
October	8.7
November	9.7
December	10.4

TABLE 5.1-5

MONTHLY AVERAGE BLOWDOWN SALINITIES AND DISCHARGE RATES AVERAGED OVER THE PERIOD OF PLANT LIFE

Month	Average Salinity ($^o/oo$)	Average Discharge Rate (cfs)
January	2.0	164
February	1.7	189
March	1.7	170
April	1.7	207
May	1.7	179
June	1.7	200
July	1.8	178
August	0.0	0
September	1.9	211
October	2.0	208
November	1.7	196
December	1.7	179
Yearly Average	1.63	173

TABLE 5.1-6

FREQUENCY OF OCCURRENCE OF PARTICULAR VALUES OF MAXIMUM ΔT AND SALINITY AT RIVER MILE 0.0 AVERAGE FREQUENCY OVER PERIOD OF RECORD FOR MONTH INDICATED

Month	Depth/Depth Range (ft)	ΔT (°F)	Salinity Range (°/oo) 0-0.8	0.8-1.5	1.5-3	3-5	5-8	8-12	12-16	16-20	20-24	24-27
January	0-4	0	0.006	0.000	0.000	0.001	0.003	0.012	0.025	0.056	0.013	0.605
		>0-0.25	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.007
		0.25-0.5	0.000	0.000	0.002	0.007	0.013	0.001	0.000	0.003	0.007	0.006
		0.5-1.0	0.000	0.000	0.000	0.000	0.002	0.012	0.031	0.061	0.027	0.028
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.002	0.007	0.002	0.002	0.000
January	16	0	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.024	0.690
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.007
		0.25-0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.025	0.014
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.096	0.066
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.003
January	8-16	0	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.048	0.664
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.007
		0.25-0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.022	0.004	0.013
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.094	0.065
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.003
February	0-4	0	0.004	0.000	0.000	0.004	0.007	0.018	0.043	0.026	0.040	0.540
		>0-0.25	0.012	0.000	0.003	0.002	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.002	0.000	0.000	0.006	0.014	0.001	0.001	0.005	0.004	0.005
		0.5-1.0	0.001	0.000	0.004	0.003	0.006	0.060	0.066	0.050	0.016	0.027
		1.0-1.5	0.000	0.000	0.000	0.002	0.000	0.011	0.008	0.002	0.000	0.000
February	16	0	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.040	0.637
		>0-0.25	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000
		0.25-0.5	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.022	0.014
		0.5-1.0	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.172	0.059
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.002
February	8-16	0	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.069	0.602
		>0-0.25	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000
		0.25-0.5	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.005	0.011
		0.5-1.0	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.166	0.055
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.019	0.002

TABLE 5.1-6 (Continued)

FREQUENCY OF OCCURRENCE OF PARTICULAR VALUES OF MAXIMUM ΔT AND SALINITY AT RIVER MILE 0.0
AVERAGE FREQUENCY OVER PERIOD OF RECORD FOR MONTH INDICATED

			Salinity Range (°/oo)									
Month	Depth/Depth Range (ft)	ΔT (°F)	0-0.8	0.8-1.5	1.5-3	3-5	5-8	8-12	12-16	16-20	20-24	24-27
March	0-4	0	0.000	0.000	0.000	0.000	0.003	0.006	0.005	0.019	0.012	0.721
		>0-0.25	0.001	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.020
		0.25-0.5	0.001	0.000	0.000	0.001	0.002	0.001	0.001	0.000	0.002	0.012
		0.5-1.0	0.000	0.000	0.000	0.000	0.002	0.018	0.062	0.014	0.018	0.040
		1.0-1.5	0.000	0.000	0.000	0.000	0.001	0.002	0.010	0.000	0.000	0.000
March	16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.754
		>0-0.25	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.020
		0.25-0.5	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.014
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.092	0.060
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.000
March	8-16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.019	0.748
		>0-0.25	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.020
		0.25-0.5	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.002	0.014
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.092	0.060
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.012	0.000
April	0-4	0	0.003	0.000	0.000	0.000	0.002	0.000	0.002	0.007	0.007	0.738
		>0-0.25	0.010	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.047
		0.25-0.5	0.007	0.000	0.000	0.006	0.009	0.000	0.000	0.001	0.000	0.011
		0.5-1.0	0.000	0.000	0.000	0.001	0.003	0.021	0.012	0.017	0.012	0.017
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
April	16	0	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.752
		>0-0.25	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.047
		0.25-0.5	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.015	0.012
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.050	0.034
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
April	8-16	0	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.752
		>0-0.25	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.047
		0.25-0.5	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.015	0.001	0.011
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.049	0.031
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000

TABLE 5.1-6 (Continued)

FREQUENCY OF OCCURRENCE OF PARTICULAR VALUES OF MAXIMUM ΔT AND SALINITY AT RIVER MILE 0.0 AVERAGE FREQUENCY OVER PERIOD OF RECORD FOR MONTH INDICATED

Month	Depth/Depth Range (ft)	ΔT (°F)	Salinity Range (°/oo) 0-0.8	0.8-1.5	1.5-3	3-5	5-8	8-12	12-16	16-20	20-24	24-27
May	0-4	0	0.000	0.000	0.000	0.002	0.005	0.003	0.006	0.008	0.009	0.766
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.049
		0.25-0.5	0.000	0.000	0.000	0.003	0.004	0.001	0.000	0.001	0.000	0.010
		0.5-1.0	0.000	0.000	0.000	0.000	0.001	0.008	0.013	0.011	0.006	0.012
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000	0.000
May	16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.790
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.049
		0.25-0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.010
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.031	0.020
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000
May	8-16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.017	0.782
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.049
		0.25-0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.002	0.010
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.031	0.019
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000
June	0-4	0	0.000	0.000	0.000	0.000	0.022	0.008	0.005	0.007	0.012	0.683
		>0-0.25	0.012	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.045
		0.25-0.5	0.002	0.000	0.000	0.001	0.003	0.010	0.009	0.001	0.000	0.008
		0.5-1.0	0.002	0.000	0.000	0.000	0.001	0.003	0.005	0.010	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
June	16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.032	0.705
		>0-0.25	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.045
		0.25-0.5	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.024	0.008
		0.5-1.0	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.001
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
June	8-16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.035	0.702
		>0-0.25	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.045
		0.25-0.5	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.020	0.008
		0.5-1.0	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.017	0.001
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 5.1-6 (Continued)

FREQUENCY OF OCCURRENCE OF PARTICULAR VALUES OF MAXIMUM ΔT AND SALINITY AT RIVER MILE 0.0
AVERAGE FREQUENCY OVER PERIOD OF RECORD FOR MONTH INDICATED

			Salinity Range (°/oo)									
Month	Depth/Depth Range (ft)	ΔT (°F)	0-0.8	0.8-1.5	1.5-3	3-5	5-8	8-12	12-16	16-20	20-24	24-27
July	0-4	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.696
		>0-0.25	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.002	0.054
		0.25-0.5	0.000	0.000	0.000	0.000	0.002	0.003	0.000	0.005	0.000	0.005
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
July	16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.699
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.056
		0.25-0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.006
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
July	8-16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.699
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.056
		0.25-0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.006	0.006
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
August	0-4	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.725
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
August	16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.725
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
August	8-16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.725
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 5.1-6 (Continued)

FREQUENCY OF OCCURRENCE OF PARTICULAR VALUES OF MAXIMUM ΔT AND SALINITY AT RIVER MILE 0.0 AVERAGE FREQUENCY OVER PERIOD OF RECORD FOR MONTH INDICATED

Month	Depth/Depth Range (ft)	ΔT (°F)	Salinity Range (°/oo) 0-0.8	0.8-1.5	1.5-3	3-5	5-8	8-12	12-16	16-20	20-24	24-27
September	0-4	0	0.000	0.000	0.000	0.003	0.000	0.002	0.007	0.007	0.002	0.687
		>0-0.25	0.007	0.000	0.000	0.002	0.002	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.002	0.000	0.000	0.000	0.003	0.005	0.014	0.001	0.000	0.000
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.003	0.007	0.002	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000
September	16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.702
		>0-0.25	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000
		0.25-0.5	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.023	0.000
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000
September	8-16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.009	0.696
		>0-0.25	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000
		0.25-0.5	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.020	0.000
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000
October	0-4	0	0.010	0.000	0.000	0.008	0.006	0.009	0.006	0.039	0.014	0.677
		>0-0.25	0.004	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.000
		0.25-0.5	0.004	0.000	0.000	0.006	0.006	0.000	0.000	0.002	0.000	0.003
		0.5-1.0	0.000	0.000	0.000	0.002	0.003	0.014	0.010	0.015	0.006	0.005
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000	0.000
October	16	0	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.022	0.738
		>0-0.25	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
		0.25-0.5	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.005
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.035	0.019
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000
October	8-16	0	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.022	0.730
		>0-0.25	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
		0.25-0.5	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.002	0.003
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.037	0.014
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000

TABLE 5.1-6 (Continued)

FREQUENCY OF OCCURRENCE OF PARTICULAR VALUES OF MAXIMUM ΔT AND SALINITY AT RIVER MILE 0.0
AVERAGE FREQUENCY OVER PERIOD OF RECORD FOR MONTH INDICATED

Month	Depth/Depth Range (ft)	ΔT (°F)	Salinity Range (°/oo) 0-0.8	0.8-1.5	1.5-3	3-5	5-8	8-12	12-16	16-20	20-24	24-27
November	0-4	0	0.000	0.000	0.000	0.000	0.005	0.019	0.062	0.051	0.057	0.640
		>0-0.25	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
		0.25-0.5	0.000	0.000	0.000	0.003	0.008	0.002	0.000	0.000	0.000	0.003
		0.5-1.0	0.000	0.000	0.002	0.000	0.002	0.035	0.030	0.031	0.012	0.007
		1.0-1.5	0.000	0.000	0.000	0.000	0.002	0.002	0.003	0.002	0.000	0.001
November	16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.814
		>0-0.25	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
		0.25-0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.003
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.094	0.024
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.001
November	8-16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.084	0.750
		>0-0.25	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
		0.25-0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.002	0.003
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.092	0.022
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.007	0.001
December	0-4	0	0.000	0.000	0.000	0.000	0.005	0.006	0.036	0.063	0.062	0.565
		>0-0.25	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.001	0.000	0.000	0.006	0.013	0.002	0.000	0.003	0.000	0.001
		0.5-1.0	0.000	0.000	0.000	0.000	0.006	0.029	0.052	0.033	0.032	0.018
		1.0-1.5	0.000	0.000	0.000	0.000	0.002	0.002	0.012	0.000	0.002	0.000
December	16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.015	0.722
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
		0.25-0.5	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.023	0.002
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.106	0.065
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.015	0.002
December	8-16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.042	0.695
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
		0.25-0.5	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.019	0.005	0.001
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.109	0.056
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.014	0.002

TABLE 5.1-7

FREQUENCY OF OCCURRENCE OF PARTICULAR VALUES OF MAXIMUM ΔT AND SALINITY AT RIVER MILE 6
AVERAGE FREQUENCY OVER PERIOD OF RECORD FOR MONTH INDICATED

			Salinity Range (°/oo)									
Month	Depth/ Depth Range (ft)	ΔT (°F)	0-0.8	0.8-1.5	1.5-3	3-5	5-8	8-12	12-16	16-20	20-24	24-27
January	0-4	0	0.014	0.009	0.007	0.015	0.044	0.069	0.070	0.148	0.282	0.069
		>0-0.25	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.000
		0.25-0.5	0.019	0.000	0.000	0.000	0.002	0.005	0.001	0.000	0.001	0.000
		0.5-1.0	0.007	0.004	0.007	0.029	0.052	0.043	0.001	0.000	0.001	0.000
		1.0-1.5	0.000	0.002	0.008	0.021	0.003	0.002	0.000	0.000	0.000	0.000
January	16	0	0.009	0.000	0.000	0.000	0.002	0.003	0.003	0.006	0.044	0.660
		>0-0.25	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008
		0.25-0.5	0.008	0.000	0.001	0.003	0.006	0.000	0.000	0.000	0.002	0.006
		0.5-1.0	0.000	0.001	0.000	0.001	0.001	0.005	0.004	0.000	0.084	0.049
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.005	0.027	0.004
January	8-16	0	0.009	0.002	0.002	0.002	0.002	0.006	0.002	0.009	0.054	0.641
		>0-0.25	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008
		0.25-0.5	0.009	0.003	0.006	0.000	0.000	0.000	0.000	0.002	0.000	0.006
		0.5-1.0	0.001	0.002	0.001	0.004	0.003	0.001	0.002	0.044	0.043	0.045
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.002	0.004	0.025	0.003	0.002
February	0-4	0	0.023	0.007	0.004	0.028	0.027	0.145	0.129	0.111	0.154	0.050
		>0-0.25	0.019	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
		0.25-0.5	0.020	0.000	0.000	0.001	0.004	0.004	0.000	0.000	0.000	0.000
		0.5-1.0	0.038	0.019	0.014	0.066	0.050	0.032	0.000	0.000	0.000	0.000
		1.0-1.5	0.004	0.006	0.019	0.015	0.004	0.000	0.000	0.000	0.000	0.000
February	16	0	0.009	0.000	0.002	0.002	0.002	0.007	0.005	0.004	0.041	0.608
		>0-0.25	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
		0.25-0.5	0.006	0.004	0.005	0.002	0.003	0.000	0.000	0.000	0.004	0.004
		0.5-1.0	0.007	0.000	0.000	0.002	0.006	0.019	0.020	0.005	0.121	0.039
		1.0-1.5	0.002	0.000	0.000	0.000	0.000	0.003	0.004	0.011	0.026	0.003
February	8-16	0	0.011	0.004	0.004	0.004	0.002	0.007	0.002	0.016	0.041	0.590
		>0-0.25	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
		0.25-0.5	0.014	0.005	0.001	0.000	0.000	0.000	0.000	0.003	0.002	0.004
		0.5-1.0	0.007	0.004	0.004	0.017	0.016	0.011	0.003	0.084	0.043	0.032
		1.0-1.5	0.002	0.000	0.000	0.003	0.002	0.004	0.013	0.021	0.003	0.000

TABLE 5.1-7 (Continued)

FREQUENCY OF OCCURRENCE OF PARTICULAR VALUES OF MAXIMUM ΔT AND SALINITY AT RIVER MILE 6
AVERAGE FREQUENCY OVER PERIOD OF RECORD FOR MONTH INDICATED

Month	Depth/ Depth Range (ft)	ΔT (°F)	0-0.8	0.8-15	1.5-3	3-5	5-8	8-12	12-16	16-20	20-24	24-27
March	0-4	0	0.008	0.002	0.000	0.005	0.013	0.081	0.057	0.125	0.119	0.373
		>0-0.25	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.019
		0.25-0.5	0.004	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.002	0.002
		0.5-1.0	0.005	0.008	0.015	0.037	0.019	0.026	0.006	0.002	0.002	0.002
		1.0-1.5	0.002	0.001	0.011	0.023	0.006	0.002	0.000	0.000	0.000	0.000
March	16	0	0.000	0.000	0.000	0.000	0.003	0.002	0.005	0.000	0.005	0.769
		>0-0.25	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020
		0.25-0.5	0.002	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.000	0.006
		0.5-1.0	0.000	0.000	0.000	0.000	0.002	0.002	0.006	0.004	0.069	0.036
		1.0-1.5	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.006	0.032	0.005
March	8-16	0	0.000	0.002	0.002	0.002	0.003	0.002	0.000	0.003	0.015	0.756
		>0-0.25	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020
		0.25-0.5	0.002	0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.006
		0.5-1.0	0.000	0.001	0.002	0.001	0.005	0.006	0.002	0.049	0.019	0.036
		1.0-1.5	0.001	0.000	0.000	0.001	0.000	0.001	0.007	0.027	0.005	0.002
April	0-4	0	0.005	0.000	0.000	0.000	0.005	0.014	0.028	0.025	0.052	0.632
		>0-0.25	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.047
		0.25-0.5	0.017	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.011
		0.5-1.0	0.015	0.005	0.005	0.012	0.021	0.013	0.002	0.000	0.000	0.005
		1.0-1.5	0.000	0.000	0.002	0.003	0.002	0.000	0.000	0.000	0.000	0.000
April	16	0	0.003	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.755
		>0-0.25	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.047
		0.25-0.5	0.008	0.003	0.002	0.001	0.002	0.000	0.000	0.000	0.000	0.012
		0.5-1.0	0.001	0.003	0.000	0.000	0.000	0.011	0.002	0.007	0.032	0.022
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.005	0.000
April	8-16	0	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.752
		>0-0.25	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.047
		0.25-0.5	0.013	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.012
		0.5-1.0	0.004	0.000	0.002	0.007	0.002	0.004	0.004	0.017	0.017	0.020
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.003	0.002	0.000

TABLE 5.1-7 (Continued)

FREQUENCY OF OCCURRENCE OF PARTICULAR VALUES OF MAXIMUM ΔT AND SALINITY AT RIVER MILE 6
AVERAGE FREQUENCY OVER PERIOD OF RECORD FOR MONTH INDICATED

			Salinity Range (°/oo)									
Month	Depth/ Depth Range (ft)	ΔT (°F)	0-0.8	0.8-1.5	1.5-3	3-5	5-8	8-12	12-16	16-20	20-24	24-27
May	0-4	0	0.006	0.000	0.006	0.002	0.005	0.031	0.040	0.007	0.003	0.652
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.076
		0.25-0.5	0.007	0.000	0.000	0.000	0.002	0.001	0.000	0.001	0.000	0.012
		0.5-1.0	0.005	0.002	0.003	0.010	0.011	0.013	0.002	0.000	0.000	0.002
		1.0-1.5	0.000	0.001	0.006	0.002	0.001	0.001	0.000	0.000	0.000	0.000
May	16	0	0.002	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.009	0.736
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.077
		0.25-0.5	0.004	0.002	0.000	0.001	0.001	0.000	0.000	0.000	0.002	0.014
		0.5-1.0	0.000	0.000	0.000	0.000	0.002	0.003	0.002	0.002	0.023	0.017
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.008	0.002
May	8-16	0	0.002	0.000	0.005	0.000	0.000	0.000	0.002	0.005	0.006	0.732
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.077
		0.25-0.5	0.006	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.002	0.014
		0.5-1.0	0.000	0.000	0.002	0.002	0.002	0.002	0.001	0.015	0.009	0.016
		1.0-1.5	0.000	0.000	0.000	0.000	0.001	0.000	0.002	0.006	0.001	0.001
June	0-4	0	0.030	0.000	0.002	0.002	0.005	0.045	0.013	0.013	0.000	0.575
		>0-0.25	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.046
		0.25-0.5	0.008	0.003	0.007	0.005	0.000	0.000	0.000	0.000	0.000	0.008
		0.5-1.0	0.004	0.001	0.006	0.008	0.005	0.000	0.000	0.000	0.000	0.003
		1.0-1.5	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
June	16	0	0.000	0.002	0.003	0.003	0.013	0.007	0.002	0.000	0.005	0.650
		>0-0.25	0.012	0.000	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.046
		0.25-0.5	0.004	0.000	0.000	0.001	0.002	0.002	0.002	0.004	0.008	0.008
		0.5-1.0	0.000	0.000	0.000	0.000	0.001	0.002	0.001	0.002	0.017	0.004
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
June	8-16	0	0.003	0.010	0.012	0.003	0.002	0.000	0.000	0.003	0.005	0.647
		>0-0.25	0.015	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.046
		0.25-0.5	0.004	0.001	0.002	0.002	0.001	0.002	0.003	0.008	0.000	0.008
		0.5-1.0	0.000	0.000	0.002	0.000	0.002	0.001	0.002	0.012	0.005	0.003
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000

TABLE 5.1-7

FREQUENCY OF OCCURRENCE OF PARTICULAR VALUES OF MAXIMUM ΔT AND SALINITY AT RIVER MILE 6
AVERAGE FREQUENCY OVER PERIOD OF RECORD FOR MONTH INDICATED

			Salinity Range (°/oo)									
Month	Depth/ Depth Range (ft)	ΔT (°F)	0-0.8	0.8-1.5	1.5-3	3-5	5-8	8-12	12-16	16-20	20-24	24-27
July	0-4	0	0.000	0.000	0.000	0.000	0.002	0.002	0.026	0.000	0.000	0.625
		>0-0.25	0.002	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000	0.046
		0.25-0.5	0.003	0.002	0.000	0.000	0.005	0.003	0.003	0.000	0.000	0.002
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
July	16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.652
		>0-0.25	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.049
		0.25-0.5	0.000	0.002	0.000	0.000	0.000	0.002	0.000	0.002	0.003	0.010
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
July	8-16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.652
		>0-0.25	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.049
		0.25-0.5	0.002	0.000	0.000	0.002	0.000	0.002	0.000	0.000	0.005	0.008
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
August	0-4	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.675
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
August	16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.675
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
August	8-16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.675
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 5.1-7 (Continued)

FREQUENCY OF OCCURRENCE OF PARTICULAR VALUES OF MAXIMUM ΔT AND SALINITY AT RIVER MILE 6
AVERAGE FREQUENCY OVER PERIOD OF RECORD FOR MONTH INDICATED

			Salinity Range (°/oo)									
Month	Depth/ Depth Range (ft)	ΔT (°F)	0-0.8	0.8-1.5	1.5-3	3-5	5-8	8-12	12-16	16-20	20-24	24-27
September	0-4	0	0.005	0.002	0.002	0.007	0.002	0.008	0.032	0.032	0.022	0.552
		>0-0.25	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.008	0.002	0.007	0.007	0.002	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.000	0.002	0.006	0.002	0.002	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
September	16	0	0.003	0.000	0.000	0.000	0.000	0.002	0.000	0.002	0.009	0.647
		>0-0.25	0.008	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.002	0.000	0.000	0.000	0.003	0.003	0.002	0.000	0.017	0.000
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.008	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000
September	8-16	0	0.003	0.000	0.000	0.002	0.000	0.000	0.004	0.002	0.007	0.646
		>0-0.25	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.002	0.002	0.002	0.003	0.002	0.000	0.002	0.013	0.002	0.000
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.007	0.002	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000
October	0-4	0	0.031	0.003	0.003	0.021	0.024	0.057	0.075	0.026	0.099	0.443
		>0-0.25	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.017	0.000	0.000	0.000	0.002	0.000	0.002	0.000	0.000	0.000
		0.5-1.0	0.009	0.003	0.002	0.006	0.015	0.010	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.010	0.004	0.000	0.000	0.000	0.000	0.000	0.000
October	16	0	0.019	0.000	0.002	0.003	0.003	0.003	0.002	0.002	0.031	0.717
		>0-0.25	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.010	0.000	0.002	0.003	0.002	0.000	0.000	0.000	0.002	0.002
		0.5-1.0	0.002	0.000	0.000	0.000	0.002	0.004	0.004	0.001	0.019	0.012
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.010	0.000
October	8-16	0	0.020	0.003	0.005	0.002	0.002	0.000	0.003	0.008	0.039	0.700
		>0-0.25	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.012	0.003	0.002	0.000	0.000	0.000	0.000	0.000	0.002	0.002
		0.5-1.0	0.002	0.000	0.003	0.002	0.003	0.002	0.000	0.009	0.013	0.010
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.006	0.000	0.000

TABLE 5.1-7 (Continued)

FREQUENCY OF OCCURRENCE OF PARTICULAR VALUES OF MAXIMUM ΔT AND SALINITY AT RIVER MILE 6
AVERAGE FREQUENCY OVER PERIOD OF RECORD FOR MONTH INDICATED

			Salinity Range (°/oo)									
Month	Depth/ Depth Range (ft)	ΔT (°F)	0-0.8	0.8-1.5	1.5-3	3-5	5-8	8-12	12-16	16-20	20-24	24-27
November	0-4	0	0.013	0.014	0.051	0.022	0.038	0.078	0.102	0.152	0.123	0.245
		>0-0.25	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.012	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.027	0.008	0.016	0.029	0.018	0.014	0.003	0.002	0.000	0.000
		1.0-1.5	0.000	0.000	0.006	0.003	0.002	0.001	0.000	0.000	0.000	0.000
November	16	0	0.000	0.002	0.000	0.000	0.005	0.003	0.008	0.011	0.078	0.733
		>0-0.25	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.003	0.000	0.002	0.002	0.005	0.000	0.000	0.000	0.002	0.000
		0.5-1.0	0.002	0.000	0.000	0.002	0.005	0.019	0.004	0.006	0.062	0.019
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.002
November	8-16	0	0.002	0.002	0.005	0.002	0.005	0.009	0.010	0.054	0.047	0.705
		>0-0.25	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.005	0.002	0.005	0.000	0.000	0.000	0.000	0.002	0.001	0.000
		0.5-1.0	0.002	0.003	0.006	0.010	0.009	0.006	0.003	0.048	0.012	0.019
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.004	0.002	0.001
December	0-4	0	0.010	0.002	0.007	0.053	0.039	0.164	0.130	0.117	0.136	0.084
		>0-0.25	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.019	0.000	0.000	0.000	0.002	0.001	0.000	0.000	0.000	0.000
		0.5-1.0	0.016	0.016	0.014	0.032	0.040	0.025	0.002	0.000	0.000	0.000
		1.0-1.5	0.000	0.001	0.016	0.021	0.002	0.005	0.000	0.000	0.000	0.000
December	16	0	0.000	0.000	0.002	0.000	0.003	0.005	0.002	0.000	0.070	0.660
		>0-0.25	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.006	0.002	0.002	0.005	0.005	0.000	0.000	0.000	0.002	0.001
		0.5-1.0	0.000	0.002	0.002	0.000	0.006	0.004	0.012	0.006	0.085	0.027
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.033	0.006
December	8-16	0	0.002	0.002	0.002	0.005	0.000	0.002	0.000	0.043	0.056	0.631
		>0-0.25	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.010	0.005	0.005	0.000	0.000	0.000	0.000	0.000	0.002	0.001
		0.5-1.0	0.003	0.000	0.006	0.002	0.009	0.011	0.000	0.047	0.039	0.027
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.001	0.009	0.028	0.001	0.006

TABLE 5.1-8

FREQUENCY OF OCCURRENCE OF PARTICULAR VLAUES OF MAXIMUM ΔT AND SALINITY AT RIVER MILE 12
AVERAGE FREQUENCY OVER PERIOD OF RECORD FOR MONTH INDICATED

Month	Depth/ Depth Range (ft)	ΔT (°F)	Salinity Range (°/oo) 0-0.8	0.8-1.5	1.5-3	3-5	5-8	8-12	12-16	16-20	20-24	24-27
January	0-4	0	0.044	0.031	0.077	0.051	0.152	0.175	0.159	0.032	0.029	0.055
		>0-0.25	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.019	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.010	0.044	0.031	0.010	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.052	0.016	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
January	16	0	0.023	0.006	0.002	0.002	0.003	0.008	0.003	0.003	0.059	0.697
		>0-0.25	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.001
		0.5-1.0	0.007	0.001	0.000	0.000	0.002	0.004	0.006	0.015	0.030	0.030
		1.0-1.5	0.010	0.006	0.013	0.015	0.003	0.010	0.005	0.000	0.006	0.002
January	8-16	0	0.023	0.001	0.006	0.002	0.005	0.010	0.006	0.072	0.098	0.585
		>0-0.25	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.000
		0.5-1.0	0.006	0.001	0.001	0.000	0.002	0.004	0.033	0.027	0.022	0.000
		1.0-1.5	0.007	0.002	0.010	0.020	0.007	0.015	0.006	0.002	0.000	0.000
February	0-4	0	0.060	0.007	0.122	0.118	0.145	0.120	0.074	0.023	0.021	0.003
		>0-0.25	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.029	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.050	0.030	0.021	0.008	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.095	0.035	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000
February	16	0	0.034	0.000	0.009	0.005	0.011	0.002	0.004	0.000	0.043	0.586
		>0-0.25	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.029	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004
		0.5-1.0	0.048	0.000	0.000	0.000	0.000	0.004	0.002	0.007	0.034	0.014
		1.0-1.5	0.027	0.008	0.017	0.027	0.017	0.012	0.009	0.003	0.020	0.002
February	8-16	0	0.032	0.000	0.004	0.012	0.011	0.004	0.002	0.063	0.229	0.338
		>0-0.25	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.029	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000
		0.5-1.0	0.046	0.002	0.000	0.000	0.001	0.004	0.014	0.029	0.012	0.000
		1.0-1.5	0.013	0.013	0.013	0.024	0.031	0.019	0.015	0.009	0.002	0.000

TABLE 5.1-8 (Continued)

FREQUENCY OF OCCURRENCE OF PARTICULAR VALUES OF MAXIMUM ΔT AND SALINITY AT RIVER MILE 12
AVERAGE FREQUENCY OVER PERIOD OF RECORD FOR MONTH INDICATED

			Salinity Range (°/oo)									
Month	Depth/ Depth Range (ft)	ΔT (°F)	0-0.8	0.8-1.5	1.5-3	3-5	5-8	8-12	12-16	16-20	20-24	24-27
March	0-4	0	0.013	0.005	0.084	0.044	0.121	0.138	0.075	0.048	0.057	0.267
		>0-0.25	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.005	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.014	0.009	0.015	0.010	0.000	0.000	0.001	0.000	0.000	0.000
		1.0-1.5	0.076	0.013	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000
March	16	0	0.010	0.000	0.002	0.002	0.000	0.000	0.002	0.000	0.037	0.799
		>0-0.25	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
		0.5-1.0	0.010	0.000	0.000	0.002	0.002	0.002	0.001	0.003	0.014	0.016
		1.0-1.5	0.016	0.010	0.026	0.020	0.003	0.002	0.002	0.003	0.005	0.003
March	8-16	0	0.010	0.000	0.002	0.002	0.000	0.002	0.000	0.059	0.089	0.689
		>0-0.25	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
		0.5-1.0	0.010	0.000	0.000	0.002	0.002	0.002	0.005	0.014	0.014	0.001
		1.0-1.5	0.010	0.006	0.018	0.035	0.007	0.005	0.008	0.000	0.003	0.000
April	0-4	0	0.005	0.002	0.016	0.024	0.030	0.036	0.031	0.000	0.000	0.675
		>0-0.25	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.046
		0.25-0.5	0.018	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.011
		0.5-1.0	0.014	0.009	0.011	0.001	0.000	0.000	0.000	0.000	0.000	0.004
		1.0-1.5	0.020	0.011	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
April	16	0	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.807
		>0-0.25	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.046
		0.25-0.5	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012
		0.5-1.0	0.012	0.000	0.000	0.000	0.002	0.000	0.003	0.001	0.010	0.011
		1.0-1.5	0.009	0.001	0.002	0.004	0.003	0.004	0.001	0.001	0.007	0.001
April	8-16	0	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.042	0.762
		>0-0.25	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.046
		0.25-0.5	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.011
		0.5-1.0	0.012	0.000	0.000	0.000	0.002	0.000	0.006	0.008	0.007	0.004
		1.0-1.5	0.005	0.004	0.002	0.003	0.005	0.005	0.006	0.002	0.001	0.000

TABLE 5.1-8 (Continued)

FREQUENCY OF OCCURRENCE OF PARTICULAR VALUES OF MAXIMUM ΔT AND SALINITY AT RIVER MILE 12
AVERAGE FREQUENCY OVER PERIOD OF RECORD FOR MONTH INDICATED

Month	Depth/ Depth Range (ft)	ΔT (°F)	Salinity Range (°/oo) 0-0.8	0.8-1.5	1.5-3	3-5	5-8	8-12	12-16	16-20	20-24	24-27
May	0-4	0	0.015	0.000	0.026	0.037	0.029	0.003	0.006	0.005	0.003	0.718
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.028
		0.25-0.5	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006
		0.5-1.0	0.007	0.006	0.006	0.005	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.016	0.008	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
May	16	0	0.010	0.003	0.000	0.000	0.002	0.000	0.000	0.000	0.008	0.819
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.028
		0.25-0.5	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006
		0.5-1.0	0.006	0.000	0.000	0.000	0.001	0.000	0.000	0.004	0.006	0.007
		1.0-1.5	0.004	0.005	0.002	0.003	0.002	0.002	0.002	0.001	0.005	0.000
May	8-16	0	0.006	0.003	0.003	0.000	0.002	0.000	0.000	0.016	0.060	0.751
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.028
		0.25-0.5	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006
		0.5-1.0	0.006	0.000	0.000	0.000	0.001	0.000	0.005	0.006	0.007	0.000
		1.0-1.5	0.002	0.002	0.006	0.003	0.002	0.004	0.005	0.001	0.000	0.000
June	0-4	0	0.033	0.003	0.043	0.012	0.017	0.000	0.000	0.000	0.000	0.675
		>0-0.25	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.029
		0.25-0.5	0.017	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007
		0.5-1.0	0.011	0.003	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.002
		1.0-1.5	0.006	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
June	16	0	0.032	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.008	0.743
		>0-0.25	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.029
		0.25-0.5	0.014	0.002	0.002	0.000	0.000	0.002	0.000	0.000	0.000	0.007
		0.5-1.0	0.007	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.005	0.002
		1.0-1.5	0.002	0.002	0.001	0.000	0.000	0.002	0.002	0.002	0.000	0.000
June	8-16	0	0.030	0.000	0.002	0.002	0.000	0.000	0.000	0.010	0.053	0.688
		>0-0.25	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.029
		0.25-0.5	0.011	0.003	0.003	0.000	0.000	0.002	0.000	0.000	0.000	0.007
		0.5-1.0	0.004	0.002	0.000	0.000	0.004	0.000	0.002	0.003	0.000	0.002
		1.0-1.5	0.001	0.001	0.002	0.001	0.000	0.002	0.003	0.000	0.000	0.000

TABLE 5.1-8 (Continued)

FREQUENCY OF OCCURRENCE OF PARTICULAR VALUES OF MAXIMUM ΔT AND SALINITY AT RIVER MILE 12 AVERAGE FREQUENCY OVER PERIOD OF REOCRD FOR MONTH INDICATED

Month	Depth/ Depth Range (ft)	ΔT (°F)	Salinity Range (°/oo) 0-0.8	0.8-1.5	1.5-3	3-5	5-8	8-12	12-16	16-20	20-24	24-27
July	0-4	0	0.000	0.000	0.003	0.023	0.008	0.000	0.000	0.000	0.000	0.750
		>0-0.25	0.003	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.030
		0.25-0.5	0.003	0.003	0.003	0.002	0.000	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
July	16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.784
		>0-0.25	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.030
		0.25-0.5	0.003	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.005	0.002
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
July	8-16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.031	0.750
		>0-0.25	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.030
		0.25-0.5	0.003	0.000	0.000	0.000	0.000	0.000	0.002	0.005	0.002	0.000
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
August	0-4	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.800
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
August	16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.800
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
August	8-16	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.800
		>0-0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 5.1-8 (Continued)

FREQUENCY OF OCCURRENCE OF PARTICULAR VALUES OF MAXIMUM ΔT AND SALINITY AT RIVER MILE 12
AVERAGE FREQUENCY OVER PERIOD OF RECORD FOR MONTH INDICATED

			Salinity Range (°/oo)									
Month	Depth/ Depth Range (ft)	ΔT(°F)	0-0.8	0.8-1.5	1.5-3	3-5	5-8	8-12	12-16	16-20	20-24	24-27
September	0-4	0	0.016	0.000	0.008	0.013	0.048	0.024	0.013	0.004	0.007	0.664
		>0-0.25	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.020	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.008	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
September	16	0	0.009	0.000	0.001	0.002	0.003	0.000	0.000	0.000	0.002	0.781
		>0-0.25	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.012	0.004	0.004	0.000	0.000	0.002	0.002	0.000	0.002	0.000
		0.5-1.0	0.002	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.001	0.000
		1.0-1.5	0.002	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.001	0.000
September	8-16	0	0.009	0.000	0.000	0.002	0.005	0.000	0.000	0.003	0.033	0.746
		>0-0.25	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.008	0.003	0.005	0.003	0.000	0.003	0.001	0.001	0.000	0.000
		0.5-1.0	0.002	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.000	0.000
		1.0-1.5	0.002	0.000	0.007	0.000	0.000	0.000	0.001	0.000	0.000	0.000
October	0-4	0	0.056	0.016	0.043	0.064	0.060	0.069	0.067	0.018	0.018	0.451
		>0-0.25	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.014	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.010	0.010	0.004	0.002	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.020	0.005	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000
October	16	0	0.035	0.002	0.003	0.008	0.006	0.002	0.003	0.006	0.022	0.775
		>0-0.25	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
		0.5-1.0	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.009	0.004
		1.0-1.5	0.011	0.001	0.004	0.000	0.004	0.000	0.000	0.000	0.005	0.002
October	8-16	0	0.034	0.002	0.002	0.006	0.011	0.005	0.006	0.026	0.123	0.648
		>0-0.25	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000
		0.5-1.0	0.010	0.000	0.000	0.000	0.000	0.000	0.009	0.004	0.003	0.000
		1.0-1.5	0.002	0.008	0.002	0.004	0.004	0.000	0.004	0.001	0.002	0.000

TABLE 5.1-8 (Continued)

FREQUENCY OF OCCURRENCE OF PARTICULAR VALUES OF MAXIMUM ΔT AND SALINITY AT RIVER MILE 12
AVERAGE FREQUENCY OVER PERIOD OF RECORD FOR MONTH INDICATED

Month	Depth/ Depth Range (ft)	ΔT (°F)	Salinity Range (°/oo) 0-0.8	0.8-1.5	1.5-3	3-5	5-8	8-12	12-16	16-20	20-24	24-27
November	0-4	0	0.099	0.024	0.072	0.072	0.188	0.121	0.044	0.055	0.122	0.058
		>0-0.25	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.015	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.028	0.011	0.008	0.002	0.002	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.038	0.026	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
November	16	0	0.044	0.034	0.007	0.005	0.003	0.006	0.007	0.003	0.037	0.708
		>0-0.25	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
		0.5-1.0	0.028	0.000	0.000	0.000	0.000	0.000	0.003	0.007	0.003	0.009
		1.0-1.5	0.012	0.008	0.007	0.002	0.005	0.017	0.002	0.002	0.008	0.000
November	8-16	0	0.032	0.005	0.042	0.008	0.005	0.007	0.008	0.052	0.137	0.556
		>0-0.25	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000
		0.5-1.0	0.027	0.002	0.000	0.000	0.000	0.002	0.008	0.007	0.006	0.000
		1.0-1.5	0.004	0.008	0.012	0.005	0.005	0.019	0.010	0.001	0.000	0.000
December	0-4	0	0.070	0.021	0.115	0.162	0.111	0.175	0.005	0.074	0.056	0.000
		>0-0.25	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.025	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000
		0.5-1.0	0.022	0.023	0.026	0.008	0.000	0.000	0.000	0.000	0.000	0.000
		1.0-1.5	0.073	0.026	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
December	16	0	0.012	0.010	0.025	0.007	0.007	0.009	0.005	0.002	0.040	0.673
		>0-0.25	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
		0.5-1.0	0.020	0.000	0.002	0.000	0.000	0.000	0.000	0.003	0.030	0.023
		1.0-1.5	0.017	0.017	0.026	0.007	0.005	0.004	0.010	0.000	0.015	0.000
December	8-16	0	0.011	0.000	0.012	0.029	0.007	0.015	0.002	0.065	0.258	0.391
		>0-0.25	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.25-0.5	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000
		0.5-1.0	0.020	0.000	0.002	0.000	0.000	0.000	0.008	0.027	0.022	0.000
		1.0-1.5	0.008	0.009	0.031	0.017	0.007	0.015	0.011	0.004	0.000	0.000

TABLE 5.1-8a

F VALUES, CALCULATED FROM EXPERIMENTAL DATA[70]

Nature of Plankton	Mean F Value	Key measurement	Reference to key[70]
<u>Dunaliella</u> <u>euchlora</u>	45	From mean chlorophyll: N ratio	Yentsch, private comm.
Mixed lake population	50	From HPPU and dry weight	Riley, 1938b
Mixed population	61	From HPPU and cell volume	Riley, 1941b
Mixed population	20	From HPPU and phosphorus	Harvey, 1950
<u>Chlorella</u> sp.	6	Pigment per cell volume	Atkins and Parke, 1951
<u>Coscinodiscus</u> <u>centralis</u>	4	Pigment per cell volume	Atkins and Parke, 1951
<u>Thalassiosira</u> <u>gravida</u>	70	Pigment per cell volume	Atkins and Parke, 1951
Diatoms	17	Pigment per cell volume	Gillbricht, 1952
<u>Gymnodinium</u> sp.	12	Pigment per cell volume	Atkins and Parke, 1951
Dinoflagellates	33	Pigment per cell volume	Gillbricht, 1952
<u>Chaetoceros</u> <u>gracilis</u>	11	Pigment per cell volume	Krey, 1939
<u>Chlorella</u> sp.	16	Pigment per unit dry weight	Data from Rabinowitch, 19
<u>Nitzschia</u> <u>closterium</u>	13	Pigment per unit dry weight	Pace, 1941
<u>Coscinodiscus</u> sp.	70	Pigment per unit dry weight	Riley <u>et</u> <u>al</u>., 1956
Mixed population	66	Pigment per unit dry weight	Riley, 1941b

E-6

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TABLE 5.1-9

NUMBERS AND KINDS OF LARVAL FISH THAT WOULD BE ENTRAINED AT THE STP SITE BASED ON MONTHLY STANDING CROP OF LARVAE AND PROJECTED AVERAGE MONTHLY INTAKE VOLUMES.

Species	Month and Salinity of Intake ($^{o}/oo$)	Standing Crop Per Cubic Foot (Number)	Intake volume In Cubic Feet	Entrainment (Number)
Ophichthidae (snake eels) *Myrophis punctatus*	January			
	0.0 - 1.5			
	1.5 - 5.0	0.0006	1.42×10^7	4,000
	TOTAL			4,000
Clupeidae (herrings) *Brevoortia patronus*	January			
	0.0 - 1.5			
	1.5 - 5.0	0.0036	1.42×10^7	51,000
	February			
	0.0 - 1.5	0.0016	5.01×10^8	800,000
	1.5 - 5.0	0.0047	1.98×10^7	93,000
	March			
	0.0 - 1.5	0.0016	1.57×10^8	250,000
	1.5 - 5.0	0.0002	1.35×10^7	3,000
	April - May*			
	December			
	0.0 - 1.5			
	1.5 - 5.0	0.0002	1.47×10^7	3,000
	TOTAL			1,200,000

* Collections not made in April or May; for other months not listed, no standing crop existed.

TABLE 5.1-9 (Continued)

NUMBERS AND KINDS OF LARVAL FISH THAT WOULD BE ENTRAINED AT THE STP SITE BASED ON MONTHLY STANDING CROP OF LARVAE AND PROJECTED AVERAGE MONTHLY INTAKE VOLUMES.

Species	Month and Salinity of Intake (°/oo)	Standing Crop Per Cubic Foot (Number)	Intake Volume In Cubic Feet	Entrainment (Number)
Engraulidae (anchovies) *Anchoa mitchilli*	January			
	0.0 - 1.5			
	1.5 - 5.0	0.0008	1.42×10^7	10,000
	February			
	0.0 - 1.5			
	1.5 - 5.0	0.0004	1.98×10^7	8,000
	April - May*			
	June			
	0.0 - 1.5			
	1.5 - 5.0	0.0014	2.20×10^6	3,100
	July			
	0.0 - 1.5			
	1.5 - 5.0	0.0001	2.20×10^6	200
	September			
	0.0 - 1.5			
	1.5 - 5.0	0.0003	4.20×10^7	10,000
	TOTAL			31,300
Cyprinidae (minnows and carps) Unidentified species	October			
	0.0 - 1.5			
	1.5 - 5.0	0.0006	1.92×10^8	100,000
	TOTAL			100,000

* Collections not made in April or May; for other months not listed, no standing crop existed.

TABLE 5.1-9 (Continued)

NUMBERS AND KINDS OF LARVAL FISH THAT WOULD BE ENTRAINED AT THE STP SITE BASED ON MONTHLY STANDING CROP OF LARVAE AND PROJECTED AVERAGE MONTHLY INTAKE VOLUMES.

Species	Month and Salinity of Intake (°/oo)	Standing Crop Per Cubic Foot (Number)	Intake Volume In Cubic Feet	Entrainment (Number)
Ictaluridae (freshwater catfishes) *Ictalurus punctatus*	September 0.0 - 1.5 1.5 - 5.0	0.0006	4.2×10^7	30,000
	TOTAL			30,000
Syngnathidae (pipefishes and seahorses) *Syngnathus* sp.	September 0.0 - 1.5 1.5 - 5.0	0.0003	2.75×10^6	800
	TOTAL			800
Carangidae (jacks and pompanos) *Caranx hippos*	June 0.0 - 1.5 1.5 - 5.0	0.0001	2.20×10^6	200
	TOTAL			200
Sciaenidae (drums) *Micropogon undulatus*	January 0.0 - 1.5 1.5 - 5.0	0.0035	1.42×10^7	50,000
	November 0.0 - 1.5 1.5 - 5.0	0.0283	2.31×10^7	654,000
	TOTAL			704,000

TABLE 5.1-9 (Continued)

NUMBERS AND KINDS OF LARVAL FISH THAT WOULD BE ENTRAINED AT THE STP SITE BASED ON MONTHLY STANDING CROP OF LARVAE AND PROJECTED AVERAGE MONTHLY INTAKE VOLUMES.

Species	Month and Salinity of Intake (°/oo)	Standing Crop Per Cubic Foot (Number)	Intake Volume In Cubic Feet	Entrainment (Number)
Gobiidae (gobies)	November			
Gobionellus	0.0 - 1.5			
boleosoma	1.5 - 5.0	0.0004	2.31×10^7	9,000
	December			
	0.0 - 1.5			
	1.5 - 5.0	0.0002	1.47×10^7	3,000
	TOTAL			12,000
	April - May*			
Gobiosoma bosci	June			
	0.0 - 1.5			
	1.5 - 5.0	0.0145	2.20×10^6	31,900
	July			
	0.0 - 1.5			
	1.5 - 5.0	0.0001	2.20×10^6	200
	September			
	0.0 - 1.5			
	1.5 - 5.0	0.0016	2.75×10^6	4,400
	October			
	0.0 - 1.5			
	1.5 - 5.0	0.0005	6.82×10^6	3,000
	TOTAL			39,500

* Collections not made in April or May; for other months not listed, no standing crop existed.

TABLE 5.1-9 (Continued)

NUMBERS AND KINDS OF LARVAL FISH THAT WOULD BE ENTRAINED AT THE STP SITE BASED ON MONTHLY STANDING CROP OF LARVAE AND PROJECTED AVERAGE MONTHLY INTAKE VOLUMES.

Species	Month and Salinity of Intake (°/oo)	Standing Crop Per Cubic Foot (Number)	Intake Volume In Cubic Feet	Entrainment (Number)
Gobiosoma robustum	October			
	0.0 - 1.5			
	1.5 - 5.0	0.0005	6.82×10^6	3,000
	TOTAL			3,000
Gobiidae (Type D)	November			
	0.0 - 1.5			
	1.5 - 5.0	0.0004	2.31×10^7	9,000
	TOTAL			9,000
Gobiidae (Type F)	February			
	0.0 - 1.5			
	1.5 - 5.0	0.0007	1.98×10^7	10,000
	TOTAL			10,000
Bothidae (lefteye flounders) Paralichthys lethostigma	December			
	0.0 - 1.5			
	1.5 - 5.0	0.0007	1.47×10^7	10,000
	TOTAL			10,000
Unidentified Eggs	June			
	0.0 - 1.5			
	1.5 - 5.0	0.0001	2.20×10^6	200
	TOTAL			200

TABLE 5.1-9 (Continued)

NUMBERS AND KINDS OF LARVAL FISH THAT WOULD BE ENTRAINED AT THE STP SITE BASED ON MONTHLY STANDING CROP OF LARVAE AND PROJECTED AVERAGE MONTHLY INTAKE VOLUMES.

Species	Month and Salinity of Intake (°/oo)	Standing Crop Per Cubic Foot (Number)	Intake Volume In Cubic Feet	Entrainment (Number)
Larvae	February			
	0.0 - 1.5			
	1.5 - 5.0	0.0002	5.01×10^8	100,000
	April - May*			
	June			
	0.0 - 1.5			
	1.5 - 5.0	0.0001	2.20×10^6	200
	September			
	0.0 - 1.5			
	1.5 - 5.0	0.0006	2.75×10^6	2,000
	October			
	0.0 - 1.5			
	1.5 - 5.0	0.0006	1.92×10^8	100,000
	December			
	0.0 - 1.5			
	1.5 - 5.0	0.0002	3.18×10^8	60,000
	TOTAL			262,200

* Collections not made in April or May; for other months not listed, no standing crop existed.

TABLE 5.1-10

NUMBER OF EGGS AND LARVAL FISH EXPECTED TO BE ENTRAINED BY MONTH AT THE STP SITE BASED ON MONTHLY STANDING CROP AND PROJECTED AVERAGE MONTHLY INTAKE VOLUMES

Month and Salinity of Intake °/oo	Standing Crop Per Cubic Foot (Number)	Intake Volume In Cubic Feet	Entrainment (Number)
January			
0.0-1.5	0.0000	3.68×10^8	120,000
1.5-5.0	0.0085	1.42×10^7	
TOTAL			120,000
February			
0.0-1.5	0.0018	5.01×10^8	900,000
1.5-5.0	0.0058	1.98×10^7	110,000
TOTAL			1,010,000
March			
0.0-1.5	0.0016	1.57×10^8	250,000
1.5-5.0	0.0002	1.35×10^7	3,000
TOTAL			253,000
April			
0.0-1.5	0.0006*	1.08×10^8	60,000
1.5-5.0	0.0065*	2.80×10^6	18,000
TOTAL			78,000
May			
0.0-1.5	0.0006*	1.32×10^8	80,000
1.5-5.0	0.0065*	5.53×10^6	36,000
TOTAL			116,000
June			
0.0-1.5	0.0000	1.61×10^8	
1.5-5.0	0.0162	2.20×10^6	35,000
TOTAL			35,000

TABLE 5.1-10 (Continued)

NUMBER OF EGGS AND LARVAL FISH EXPECTED TO BE ENTRAINED BY MONTH AT THE STP SITE BASED ON MONTHLY STANDING CROP AND PROJECTED AVERAGE MONTHLY INTAKE VOLUMES

Month and Salinity of Intake °/oo	Standing Crop Per Cubic Foot (Number)	Intake Volume In Cubic Feet	Entrainment (Number)
July			
0.0-1.5	0.0000	1.03×10^7	
1.5-5.0	0.0002	2.20×10^6	400
TOTAL			400
August			
0.0-1.5	0.0000	0	0
1.5-5.0	0.0000	0	0
TOTAL			0
September			
0.0-1.5	0.0009	4.20×10^7	40,000
1.5-5.0	0.0025	2.75×10^6	6,900
TOTAL			46,900
October			
0.0-1.5	0.0012	1.92×10^8	230,000
1.5-5.0	0.0010	6.82×10^6	6,800
TOTAL			236,800
November			
0.0-1.5	0.0000	2.56×10^8	
1.5-5.0	0.0291	2.31×10^7	672,000
TOTAL			672,000

TABLE 5.1-10 (Continued)

NUMBER OF EGGS AND LARVAL FISH EXPECTED TO BE ENTRAINED BY MONTH AT THE STP SITE BASED ON MONTHLY STANDING CROP AND PROJECTED AVERAGE MONTHLY INTAKE VOLUMES

Month and Salinity of Intake o/oo	Standing Crop Per Cubic Foot (Number)	Intake Volume In Cubic Feet	Entrainment (Number)
December			
0.0-1.5	0.0002	3.18×10^8	60,000
1.5-5.0	0.0011	1.47×10^7	16,000
TOTAL			76,000

Mean Density = $\frac{.0703}{12}$ = .0070 eggs and larvae/ft^3.

Yearly Total = 2,645,000 eggs and larvae.

*Mean Values

TABLE 5.1-11

CALCULATION OF THE NUMBER OF ADULTS THAT WOULD HAVE BEEN PRODUCED BY SPECIES OR FAMILY FROM THE ESTIMATED NUMBER OF LARVAE KILLED

A. Ophichthidae

Myrophis punctatus (Speckled worm eel):

1. Fecundity = 30,000 eggs (extrapolated from fecundity values of the Conger eel (*Conger oceanicus*).[58]

2. 25% survival to larvae stage = 30,000 x0.25 = 7,500 larvae survived.

3. $\frac{\text{2 adults}}{\text{7,500 larvae}}$ = 0.0002667 probability of survival to adult stage.

4. 4260.000 larvae lost by entrainment
   0.0002667 probability of survival to adult stage
   1 adult that would have been produced.

B. Clupeidae

Brevoortia patronus (Gulf menhaden):

1. Fecundity = 72,000 eggs.[59]

2. 25% survival to larvae stage = 72,000 x0.25 = 18,000 larvae survived

3. $\frac{\text{2 adults}}{\text{18,000}}$ = 0.0001111 probability of survival to adult stage.

4. 1,202,620 larvae lost by entrainment
   0.0001111 probability of survival to adult stage
   134 adults that would have been produced.

C. Engraulidae

Anchoa mitchilli (Bay anchovy):

1. Fecundity = 23,000 eggs (from other species of engraulids;[37,38,39]

2. 25% survival to larvae stage = 23,000 x 0.25 = 5,750 larvae survived.

TABLE 5.1-11 (Continued)

CALCULATION OF THE NUMBER OF ADULTS THAT WOULD HAVE BEEN PRODUCED BY SPECIES OR FAMILY FROM THE ESTIMATED NUMBER OF LARVAE KILLED

3. $\frac{2 \text{ adults}}{5,750}$ = 0.0003478 probability of survival to adult stage.

4. 35,180.00 larvae lost by entrainment
   0.0003478 probability of survival to adult stage
   12 adults that would have been produced.

D. Cyprinidae

Unidentified

1. Fecundity = 1,000 eggs (based on other *Notropis* species)[40]

2. 50% survival to larvae stage = 1,000 x0.50 = 500 larvae survived.

3. $\frac{2 \text{ adults}}{500}$ = 0.0040000 probability of survival to adult stage.

4. 115,200.0 larvae lost by entrainment
   0.0040000 probability of survival to adult stage
   461 adults that would have been produced.

E. Ictaluridae

Ictalurus punctatus (Channel catfish):

1. Fecundity = 36,000 eggs[40]

2. 75% survival to larvae stage = 36,000 x 0.75 = 27,000 larvae survived.

3. $\frac{2 \text{ adults}}{27,000}$ = 0.0000741 probability of survival to adult stage.

4. 25,000.00 larvae lost by entrainment
   0.0000741 probability of survival to adult stage
   2 adults that would have been produced.

TABLE 5.1-11 (Continued)

CALCULATION OF THE NUMBER OF ADULTS THAT WOULD HAVE BEEN PRODUCED BY SPECIES OR FAMILY FROM THE ESTIMATED NUMBER OF LARVAE KILLED

F. Syngnathidae

<u>Syngnathus</u> sp. (Pipefishes):

1. Fecundity = 300 eggs[41]

2. 75% survival to larvae stage = 300 x0.75 = 225 larvae survived.

$$\begin{array}{r} 300 \\ \times 0.75 \\ \hline 225 \end{array}$$

3. $\frac{2 \text{ adults}}{225}$ = 0.0088889 probability of survival to adult stage.

4. 825.0000 larvae lost by entrainment
0.0088889 probability survival to adult stage
7 adults that would have been produced.

G. Carangidae

<u>Caranx hippos</u> (Crevalle jack):

1. Fecundity = 1,400,000 eggs (extrapolated from other carangids;[60,42]

2. 25% survival to larvae stage = 1,400,000 x0.25 = 350,000 larvae survived.

$$\begin{array}{r} 1,400,000 \\ \times 0.25 \\ \hline 350,000 \end{array}$$

3. $\frac{2 \text{ adults}}{350,000}$ = 0.0000057 probability of survival to adult stage.

4. 220.0000 lost by entrainment
0.0000057 probability of survival to adult stage
1 adult would have been produced.

H. Sciaenidae

<u>Micropogon</u> <u>undulatus</u> (Atlantic croaker):

1. Fecundity = 180,000 eggs.[41]

2. 25% survival to larvae stage = 180,000 x0.25 = 45,000 larvae survived.

$$\begin{array}{r} 180,000 \\ \times 0.25 \\ \hline 45,000 \end{array}$$

TABLE 5.1-11 (Continued)

CALCULATION OF THE NUMBER OF ADULTS THAT WOULD HAVE BEEN PRODUCED BY SPECIES OR FAMILY FROM THE ESTIMATED NUMBER OF LARVAE KILLED

3. $\frac{2 \text{ adults}}{45,000}$ = 0.0000444 probability of survival to adult stage.

4. 703,430.0 lost by entrainment
   0.0000444 probability of survival to adult stage
   31 adults that would have been produced.

I. Gobiidae

a. Gobionellus boleosoma (Darter goby):

1. Fecundity = 200 eggs.[43]

2. 75% survival to larvae stage = 200 x0.75 = 150 larvae survived.

3. $\frac{2 \text{ adults}}{150}$ = 0.0133333 probability of survival to adult stage.

4. 12,180.00 larvae lost by entrainment
   0.0133333 probability of survival to adult stage
   162 adults that would have been produced.

b. Gobiosoma bosci (Naked goby):

1. Fecundity = 250 eggs.[44]

2. 75% survival to larvae stage = 250 x0.75 = 188 larvae survived.

3. $\frac{2 \text{ adults}}{188}$ = 0.0106667 probability of survival to adult stage.

4. 39,930.00 lost by entrainment
   0.0106667 probability of survival to adult stage
   426 adults that would have been produced.

c. Gobiosoma robustum (Code goby):

1. Fecundity = 250 eggs.[44]

2. 75% survival to larvae stage = 250 x0.75 = 188 larvae survived.

TABLE 5.1-11 (Continued)

CALCULATION OF THE NUMBER OF ADULTS THAT WOULD HAVE BEEN PRODUCED BY SPECIES OR FAMILY FROM THE ESTIMATED NUMBER OF LARVAE KILLED

3. $\frac{2 \text{ adults}}{188}$ = 0.0106667 probability of survival to adult stage.

4. 3410.000 lost by entrainment
0.0106667 probability survival to adult stage
36 adults that would have been produced.

d. Gobiidae (types D and F):

1. Fecundity = 200 eggs (mean value).[43,44]

2. 75% survival to larvae stage = 200 x0.75 = 150 larvae survived.

3. $\frac{2 \text{ adults}}{150}$ = 0.0133333 probability of survival to adult stage.

4. 23,100.00 lost by entrainment
0.0133333 probability of survival to adult stage
308 adults that would have been produced.

J. Bothidae

Paralichthys lethostigma (Southern flounder):

1. Fecundity = 123,000 eggs (extrapolated from other bothids).[45]

2. 25% survival to larvae stage = 123,000 x0.25 = 30,750 larvae survived.

3. $\frac{2 \text{ adults}}{30,750}$ = .0000650 probability of survival to adult stage.

4. 10,290.00 lost by entrainment
0.0000650 probability of survival to adult stage
1 adult would have been produced.

K. Others (unidentified):

1. Fecundity = 142,000 eggs (mean of fecundity for all taxa).

2. 50% survival to larvae stage = 142,000 x0.50 = 71,000 larvae survived.

TABLE 5.1-11 (Continued)

CALCULATION OF THE NUMBER OF ADULTS THAT WOULD HAVE BEEN PRODUCED BY SPECIES OR FAMILY FROM THE ESTIMATED NUMBER OF LARVAE KILLED

3. $\frac{2 \text{ adults}}{71{,}000}$ = 0.0000282 probability of survival to adult stage.

4. 280,870.0 lost by entrainment
<u>0.0000280</u> probability of survival to adult stage
8 adults would have been produced.

TABLE 5.1-12

CALCULATED NUMBER OF ADULTS THAT WOULD HAVE BEEN PRODUCED FROM THE ESTIMATED LARVAE LOST BY ENTRAINMENT

Species or Family	Estimated Number of Adults Lost Per 10 Months
Ophichthidae (snake eels)	
Myrophis punctatus	1
Clupeidae (herrings)	
Brevoortia patronus	134
Engraulidae (anchovies)	
Anchoa mitchilli	12
Cyprinidae (minnows and carps)	
Unidentified	461
Ictaluridae (freshwater catfishes)	
Ictalurus punctatus	2
Syngnathidae (pipefishes and seahorses)	
Syngnathus sp.	7
Carangidae (jacks and pompanos)	
Caranx hippos	<1
Sciaenidae (drums)	
Micropogon undulatus	31

TABLE 5.1-12 (Continued)

CALCULATED NUMBER OF ADULTS THAT WOULD HAVE BEEN PRODUCED FROM THE ESTIMATED LARVAE LOST BY ENTRAINMENT

Species or Family	Estimated Number of Adults Lost Per 10 Months
Gobiidae (gobies)	
Gobionellus boleosoma	162
Gobiosoma bosci	426
Gobiosoma robustum	36
Types D and F	308
Bothidae (lefteye flounders)	
Paralichthys lethostigma	1
Others	8
TOTAL (10 months)	1,590
Estimate for 12 months	1,908

TABLE 5.1-13

MONTHLY AVERAGE PROJECTED INTAKE VOLUME FROM THE COLORADO RIVER PER INTAKE SALINITY RANGE AT THE STP SITE

Intake Volume (Cubic Feet)

Month	At Salinities of 0.0 - 1.5 $^{o}/_{oo}$	At Salinities of 1.5 - 5.0 $^{o}/_{oo}$	Total Intake Volume (Cubic feet)
January	3.61×10^8	1.42×10^7	3.752×10^8
February	5.01×10^8	1.98×10^7	5.208×10^8
March	1.57×10^8	1.35×10^7	1.705×10^8
April	1.079×10^8	2.80×10^6	1.107×10^8
May	1.32×10^8	5.53×10^6	1.3753×10^8
June	1.611×10^8	2.20×10^6	1.633×10^8
July	1.03×10^7	2.20×10^6	1.25×10^7
August	0	0	0
September	4.20×10^7	2.75×10^6	4.475×10^7
October	1.92×10^8	6.82×10^6	1.9882×10^8
November	2.56×10^8	2.31×10^7	2.791×10^8
December	3.18×10^8	1.47×10^7	3.327×10^8

TABLE 5.1-14

ESTIMATED PERCENT OF STANDING CROP (NUMBER) SUBJECT TO IMPINGEMENT AT PROJECTED INTAKE SALINITY RANGES FOR THE STP SITE. DASH INDICATES SPECIES NOT CONTRIBUTING TO STANDING CROP ESTIMATE

Species	°/oo Range	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Shortfin squid	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
	1.5-5.0	-	-	-	100	100	-	-	-	-	-	100	-
Net-clinger shrimp	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
	1.5-5.0	-	-	-	100	100	-	-	100	-	-	100	-
River shrimp	0.0-1.5	100	100	-	100	100	-	-	-	100	100	100	100
	1.5-5.0	100	100	-	100	100	-	-	-	-	100	-	-
Brown shrimp	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
	1.5-5.0	-	-	-	100	100	100	-	100	100	-	-	-
White shrimp	0.0-1.5	-	-	-	100	100	-	-	100	-	-	-	-
	1.5-5.0	-	-	-	100	100	-	100	100	100	100	100	-
Blue crab	0.0-1.5	-	-	-	100	100	-	-	-	100	-	100	100
	1.5-5.0	100	-	-	100	100	-	-	-	100	-	100	-
Mud crab	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
	1.5-5.0	100	-	-	100	100	-	-	-	-	-	-	-
American eel	0.0-1.5	0	-	-	0	0	-	-	-	-	-	-	-
	1.5-5.0	-	-	-	-	-	-	-	-	-	-	-	-
Gulf menhaden	0.0-1.5	-	100	100	100	100	-	-	-	100	-	-	-
	1.5-5.0	100	100	100	100	100	98	100	70	100	-	100	-

TABLE 5.1-14 (Continued)

ESTIMATED PERCENT OF STANDING CROP (NUMBER) SUBJECT TO IMPINGEMENT AT PROJECTED INTAKE SALINITY RANGES FOR THE STP SITE. DASH INDICATES SPECIES NOT CONTRIBUTING TO STANDING CROP ESTIMATE

Species	°/oo Range	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Threadfin	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
shad	1.5-5.0	-	-	100	100	100	-	100	100	-	-	-	-
Bay	0.0-1.5	-	100	-	100	100	100	100	-	100	-	100	-
anchovy	1.5-5.0	100	100	100	100	100	100	100	100	100	100	100	100
Speckled	0.0-1.5	100	100	-	100	100	-	-	-	-	100	100	-
chub	1.5-5.0	-	-	-	-	-	-	-	-	-	-	-	-
Blue	0.0-1.5	0	16	-	100	100	-	100	100	18	-	3	14
catfish	1.5-5.0	0	0	-	100	100	-	-	-	-	0	0	-
Channel	0.0-1.5	-	-	-	100	100	-	-	-	100	43	100	-
catfish	1.5-5.0	-	-	-	-	-	-	-	-	-	-	-	-
Sea	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
catfish	1.5-5.0	-	-	-	0	100	-	-	0	0	13	10	-
Gafftop-													
sail	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
catfish	1.5-5.0	-	-	-	0	0	-	-	0	-	-	-	-
Bluefish	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
	1.5-5.0	-	-	-	100	100	-	-	100	-	-	-	-
Crevalle	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
jack	1.5-5.0	-	-	-	100	100	-	-	100	-	-	0	-

TABLE 5.1-14 (Continued)

ESTIMATED PERCENT OF STANDING CROP (NUMBER) SUBJECT TO IMPINGEMENT AT PROJECTED INTAKE SALINITY RANGES FOR THE STP SITE. DASH INDICATES SPECIES NOT CONTRIBUTING TO STANDING CROP ESTIMATE

Species	°/oo Range	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Sheeps head	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
	1.5-5.0	-	-	-	0	0	-	-	0	-	-	-	0
Silver perch	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
	1.5-5.0	-	0	0	0	0	-	-	-	-	-	25	-
Sand seatrout	0.0-1.5	-	-	-	100	100	100	-	-	-	-	-	-
	1.5-5.0	-	-	-	100	100	85	100	96	100	100	80	-
Spot	0.0-1.5	-	0	-	100	100	100	-	-	-	-	-	-
	1.5-5.0	0	-	0	100	100	96	-	100	-	-	-	-
Atlantic croaker	0.0-1.5	-	100	-	100	100	-	-	-	-	-	100	100
	1.5-5.0	91	100	-	100	100	-	-	-	100	0	100	100
Black drum	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
	1.5-5.0	-	-	-	0	0	-	-	-	-	-	-	0
Star drum	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
	1.5-5.0	-	-	-	100	100	-	-	-	-	100	50	-
Striped mullet	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
	1.5-5.0	-	0	-	0	0	-	-	100	100	-	0	-
Southern flounder	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
	1.5-5.0	0	-	-	0	0	-	-	-	-	-	-	-

TABLE 5.1-14 (Continued)

ESTIMATED PERCENT OF STANDING CROP (NUMBER) SUBJECT TO IMPINGEMENT AT PROJECTED INTAKE SALINITY RANGES FOR THE STP SITE. DASH INDICATES SPECIES NOT CONTRIBUTING TO STANDING CROP ESTIMATE

Species	°/oo Range	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Lined sole	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
	1.5-5.0	-	-	-	100	100	-	-	-	-	-	100	-
Hog-choker	0.0-1.5	-	-	-	100	100	-	-	-	-	-	-	100
	1.5-5.0	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 5.1-15

ESTIMATED PERCENT OF STANDING CROP (POUNDS) SUBJECT TO IMPINGEMENT AT PROJECTED INTAKE SALINITY RANGES FOR THE STP SITE. DASH INDICATES SPECIES NOT CONTRIBUTING TO STANDING CROP ESTIMATE.

Species	o/oo Range	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Shortfin	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
squid	1.5-5.0	-	-	-	100	100	-	-	-	-	-	100	-
Net-clinger	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
shrimp	1.5-5.0	-	-	-	100	100	-	-	100	-	-	100	-
River	0.0-1.5	100	100	-	100	100	-	-	-	100	100	100	100
shrimp	1.5-5.0	100	100	-	100	100	-	-	-	-	100	-	-
Brown	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
shrimp	1.5-5.0	-	-	-	100	100	100	-	100	100	-	-	-
White	0.0-1.5	-	-	-	100	100	-	-	100	-	-	-	-
shrimp	1.5-5.0	-	-	-	100	100	-	100	100	100	100	100	-
Blue	0.0-1.5	-	-	-	100	100	-	-	-	100	-	100	100
crab	1.5-5.0	100	-	-	100	100	-	-	-	100	-	100	-
Mud	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
crab	1.5-5.0	100	-	-	100	100	-	-	-	-	-	-	-
American	0.0-1.5	0	-	-	0	0	-	-	-	-	-	-	-
eel	1.5-5.0	-	-	-	-	-	-	-	-	-	-	-	-
Gulf	0.0-1.5	-	100	100	100	100	-	-	-	100	-	-	-
menhaden	1.5-5.0	100	100	100	100	100	79	100	22	100	-	100	-

TABLE 5.1-15 (Continued)

ESTIMATED PERCENT OF STANDING CROP (POUNDS) SUBJECT TO IMPINGEMENT AT PROJECTED INTAKE SALINITY RANGES FOR THE STP SITE. DASH INDICATES SPECIES NOT CONTRIBUTING TO STANDING CROP ESTIMATE.

Species	°/oo Range	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Threadfin	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
shad	1.5-5.0	-	-	100	100	100	-	100	100	-	-	-	-
Bay	0.0-1.5	-	100	-	100	100	100	100	-	100	-	100	-
anchovy	1.5-5.0	100	100	100	100	100	100	100	100	100	100	100	100
Speckled	0.0-1.5	100	100	-	100	100	-	-	-	-	100	100	-
chub	1.5-5.0	-	-	-	-	-	-	-	-	-	-	-	-
Blue	0.0-1.5	0	4	-	100	100	-	100	100	10	-	1	7
catfish	1.5-5.0	0	0	-	100	100	-	-	-	-	0	0	-
Channel	0.0-1.5	-	-	-	100	100	-	-	-	100	22	100	-
catfish	1.5-5.0	-	-	-	-	-	-	-	-	-	-	-	-
Sea	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
catfish	1.5-5.0	-	-	-	0	100	-	-	0	0	2	1	-
Gafftop-													
sail	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
catfish	1.5-5.0	-	-	-	0	0	-	-	0	-	-	-	-
Blue	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
fish	1.5-5.0	-	-	-	100	100	-	-	100	-	-	-	-
Crevalle	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
jack	1.5-5.0	-	-	-	100	100	-	-	100	-	-	0	-

TABLE 5.1-15 (Continued)

ESTIMATED PERCENT OF STANDING CROP (POUNDS) SUBJECT TO IMPINGEMENT AT PROJECTED INTAKE SALINITY RANGES FOR THE STP SITE. DASH INDICATES SPECIES NOT CONTRIBUTING TO STANDING CROP ESTIMATE.

Species	$^{o}/_{oo}$ Range	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Sheeps-	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
head	1.5-5.0	-	-	-	0	0	-	-	0	-	-	-	0
Silver	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
perch	1.5-5.0	-	0	0	0	0	-	-	-	-	-	9	-
Sand	0.0-1.5	-	-	-	100	100	100	-	-	-	-	-	-
seatrout	1.5-5.0	-	-	-	100	100	98	100	89	100	100	66	-
Spot	0.0-1.5	-	0	-	100	100	100	-	-	-	-	-	-
	1.5-5.0	0	-	0	100	100	67	-	100	-	-	-	-
Atlantic	0.0-1.5	-	100	-	100	100	-	-	-	-	-	100	100
croaker	1.5-5.0	1	100	-	100	100	-	-	-	100	0	100	100
Black	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
drum	1.5-5.0	-	-	-	0	0	-	-	-	-	-	-	0
Star	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
drum	1.5-5.0	-	-	-	100	100	-	-	-	-	100	18	-
Striped	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
mullet	1.5-5.0	-	0	-	0	0	-	-	100	100	-	0	-
Southern	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
flounder	1.5-5.0	0	-	-	0	0	-	-	-	-	-	-	-

TABLE 5.1-15 (Continued)

ESTIMATED PERCENT OF STANDING CROP (POUNDS) SUBJECT TO IMPINGEMENT AT PROJECTED INTAKE SALINITY RANGES FOR THE STP SITE. DASH INDICATES SPECIES NOT CONTRIBUTED TO STANDING CROP ESTIMATE.

Species	o/oo Range	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Lined	0.0-1.5	-	-	-	-	-	-	-	-	-	-	-	-
sole	1.5-5.0	-	-	-	100	100	-	-	-	-	-	100	-
Hog-	0.0-1.5	-	-	-	100	100	-	-	-	-	-	-	100
choker	1.5-5.0	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 5.1-16

MONTHLY ESTIMATES OF STANDING CROP AND IMPINGEMENT OF RIVER SHRIMP FOR PROJECTED INTAKE SALINITIES (ppt) AT THE STP SITE

Month and Salinity Range	Standing Crop Per Cubic Foot		Impingement	
	Number	Weight (lb)	Number	Weight (lb)
January				
0.0-1.5	1.60×10^{-4}	2.12×10^{-7}	58,000	90
1.5-5.0	1.15×10^{-5}	1.57×10^{-7}	163	2
Total			58,163	92
February				
0.0-1.5	1.31×10^{-3}	2.76×10^{-6}	654,000	1380
1.5-5.0	1.15×10^{-5}	8.00×10^{-9}	227	0.1
Total			654,227	1380
March				
0.0-1.5	0	0	0	0
1.5-5.0	0	0	0	0
Total			0	0
April				
0.0-1.5	9.38×10^{-4}	2.01×10^{-6}	101,000	217
1.5-5.0	6.87×10^{-6}	2.20×10^{-8}	19	0.1
Total			101,019	217
May				
0.0-1.5	9.38×10^{-4}	2.01×10^{-6}	124,000	266
1.5-5.0	6.87×10^{-6}	2.20×10^{-8}	38	0.1
Total			124,038	266

TABLE 5.1-16 (Continued)

MONTHLY ESTIMATES OF STANDING CROP AND IMPINGEMENT OF RIVER SHRIMP FOR PROJECTED INTAKE SALINITIES (ppt) AT THE STP SITE

Month and Salinity Range	Standing Crop Per Cubic Foot		Impingement	
	Number	Weight (lb)	Number	Weight (lb)
June				
0.0-1.5	0	0	0	0
1.5-5.0	0	0	0	0
Total			0	0
July				
0.0-1.5	0	0	0	0
1.5-5.0	0	0	0	0
Total			0	0
August				
0.0-1.5	0	0	0	0
1.5-5.0	0	0	0	0
Total			0	0
September				
0.0-1.5	2.29×10^{-5}	5.40×10^{-8}	962	2
1.5-5.0	0	0	0	0
Total			962	2
October				
0.0-1.5	2.02×10^{-3}	1.99×10^{-6}	387,000	382
1.5-5.0	1.15×10^{-5}	5.20×10^{-8}	78	0.3
Total			387,078	382

TABLE 5.1-16 (Continued)

MONTHLY ESTIMATES OF STANDING CROP AND IMPINGEMENT OF RIVER SHRIMP FOR PROJECTED INTAKE SALINITIES (ppt) AT THE STP SITE

	Standing Crop Per Cubic Foot		Impingement	
Month and Salinity Range	Number	Weight (lb)	Number	Weight (lb)
November				
0.0-1.5	4.49×10^{-3}	1.22×10^{-5}	1,150,000	3,130
1.5-5.0	0	0	0	0
Total			1,150,000	3,130
December				
0.0-1.5	1.39×10^{-3}	2.84×10^{-6}	441,000	902
1.5-5.0	0	0	0	0
Total			441,000	902
Annual Total			2,916,000	6,375.6

TABLE 5.1-17

ESTIMATES OF ANNUAL IMPINGEMENT OF SPECIES
OF COMMERCIAL AND FORAGE IMPORTANCE
AT THE STP SITE

Species	Number	Weight (lb)
River shrimp	2,916,000	6,375
Brown shrimp	216	<1
White shrimp	33,200	77
Blue crab	8,365	294
Gulf menhaden	261,260	901
Bay anchovies	207,680	168
Blue catfish	246,580	6,890
Channel catfish	12,480	206
Sea catfish	604	30
Sand seatrout	9,555	113
Spot	5,245	48
Atlantic croaker	2,508,000	793
Black drum	<1	<1
Striped mullet	32	5
Southern flounder	<1	<1
Total	6,210,000	15,900

TABLE 5.1-18
ACCLIMATION TEMPERATURE AND SALINITY (°/oo) AND UPPER TOLERANCE, PREFERRED, AVOIDANCE AND LD_{50} TEMPERATURES FOR CRUSTACEANS AND FISHES OCCURRING IN THE LOWER COLORADO RIVER.

	Acclimation		Temperature				
Species	Temp	Sal	Upper Tolerance	Preferred	Avoidance	LD_{50}	Reference
Grass shrimp (*Palaemonetes vulgaris*)	77°F	3.2	----	----	91.8°F	----	46
	68°F	----	----	----	90.0°F	101.89°F	47
	61°F	4.0	----	72.0°F	----	----	46
	74°F	1.0	----	83.0°F	----	----	46
Brown Shrimp (*Penaeus aztecus*)	24°C	5.0	36.6-36.8°C	----	----	----	48
	24°C	15.0	36.6-36.8°C	----	----	----	48
	24°C	25.0	36.6-36.8°C	----	----	----	48
	29°C	5.0	<38.0°C	----	----	----	48
	29°C	15.0	<38.0°C	----	----	----	48
	29°C	25.0	<38.0°C	----	----	----	48
	34°C	5.0	<38.6°C	----	----	----	48
	34°C	15.0	<38.6°C	----	----	----	48
	34°C	25.0	<38.6°C	----	----	----	48
	25°C	5.0	35.0°C	----	----	----	49
	25°C	25.0	35.0°C	----	----	----	49
	25°C	50.0	35.0°C	----	----	----	49
	----	----	----	20.0-35.0°C	>35.0°C	----	50
Pink Shrimp (*Penaeus duorarum*)	----	----	----	20.0-38.0°C	----	----	50
White shrimp (*Penaeus setiferus*)	----	----	30.0°C	----	----	----	51
	----	----	----	20.0-38.0°C	----	----	50
Blue crab (*Callinectes sapidus*)	30°C	----	39.4°C	----	----	----	52
	79°F	4.0	----	----	94.0°F	----	46
	57°F	4.5	----	77.0°F	----	----	46
	68°F	----	----	----	99.5°F	106.28°F	47
	30°C	34.0	38.7°C	----	----	----	53
	30°C	6.8	37.0°C	----	----	----	53
	22°C	34.0	36.9°C	----	----	----	53
	22°C	6.8	36.9°C	----	----	----	53
	30°C	34.0	39.0°C	----	----	----	53
	30°C	6.8	39.0°C	----	----	----	53
	22°C	34.0	37.2°C	----	----	----	53
	22°C	6.8	37.0°C	----	----	----	53
	----	----	----	10.0-35.0°C	----	----	50
Gulf menhaden (*Brevoortia patronus*)	----	----	----	12.0-30.0°C	30.0°C	----	54
	----	----	----	----	30.0°C	----	55
	----	----	----	25.0-35.0°C	>35.0°C	----	50
Gizzard shad (*Dorosoma cepedianum*)	----	----	97.5°F	73.0-74.5°F	----	----	56
Bay anchovy (*Anchoa mitchilli*)	----	----	----	23.0-30.0°C	----	----	55
	----	----	----	24.5-32.5°C	33.0°C	----	54
	59 F	4.0	----	60.0°F	----	----	46
	72°F	4.0	----	86.0°F	----	----	46
	61°F	4.5	----	65.0°F	----	----	46
	61°F	4.5	----	68.0°F	----	----	46
	64°F	4.0	----	----	80.0°F	----	46
	61°F	4.5	----	----	75.0°F	----	46
Sea catfish (*Arius felis*)	----	----	----	>21.0°C	----	----	55
	----	----	----	----	38.0°C	----	54
Sheepshead minnow (*Cyprinodon variegatus*)	68°F	----	----	----	102.5°F	109.45°F	47
Rough silverside (*Membras martinica*)	----	----	----	----	33.0°C	----	54
	68°F	4.0	----	----	84.0°F	----	46
	72°F	4.0	----	----	81.0°F	----	46
Tidewater silverside (*Menidia beryllina*)	----	----	----	----	39.0°C	----	54
	68°F	6.0	----	----	91.0°F	----	46
Green sunfish (*Lepomis cyanellus*)	20°C	----	35.0°C	----	----	----	57
	40°C	----	35.0°C	----	----	----	57
	10°C	----	31.0°C	----	----	----	57
Largemouth bass (*Micropterus salmoides*)	77°F	0.0	----	----	87.0°F	----	46
	77°F	0.0	----	----	91.0°F	----	46
	----	----	96.0°F	82.0-86.0°F	----	----	56
Bluefish (*Pomatomus saltatrix*)	72°F	4.0	----	----	89.0°F	----	46
	68°F	----	----	----	88.0°F	96.30°F	47
	65°F	6.0	----	72.0°F	----	----	46
	70°F	6.0	----	70.0°F	----	----	46
	75°F	4.0	----	83.0°F	----	----	46

TABLE 5.1-18 (Continued)

ACCLIMATION TEMPERATURE AND SALINITY (°/oo) AND UPPER TOLERANCE, PREFERRED, AVOIDANCE AND LD_{50} TEMPERATURE FOR CRUSTACEANS AND FISHES OCCURRING IN THE LOWER COLORADO RIVER.

	Acclimation		Temperature				
Species	Temp	Sal	Upper Tolerance	Preferred	Avoidance	LD_{50}	Reference
Crevalle jack (*Caranx hippos*)	68°F	----	----	----	89.0°F	99.74°F	47
Pinfish (*Lagodon rhombiodes*)	68°F	----	----	----	96.0°F	100.10°F	47
Silver perch (*Bairdiella chrysura*)	68°F	----	----	----	85.5°F	95.81°F	47
Sand seatrout (*Cynoscion arenarius*)	----	----	----	25.0-33.0°C	None at 40.0°C	----	54
	----	----	----	20.0-35.0°C	>35.0°C	----	50
Spotted seatrout (*Cynoscion nebulosus*)	----	----	----	15.0-34.9°C	35.0°C	----	50
Spot (*Leiostomus xanthurus*)	----	----	----	25.0-34.0°C	37.5°C	----	54
	----	----	----	>15.0°C	----	----	55
	68°F	4.5	----	65.0°F	78.0°F	----	46
Atlantic croaker (*Micropogon undulatus*)	----	----	----	----	38.0°C	----	54
Black drum (*Pogonias cromis*)	77°F	4.0	----	----	85.0°F	----	46
	65°F	4.5	----	----	79.0°F	----	46
	84°F	4.0	----	97.0°F	----	----	46
Red drum (*Sciaenops ocellata*)	----	----	----	15.0-29.9°C	>33.0°C	----	50
Atlantic threadfin (*Polydactylus octonemus*)	----	----	----	----	33.0°C	----	54
Hogchoker (*Trinectes maculatus*)	79°F	4.0	----	----	91.0°F	----	46
	63°F	4.0	----	----	68.0°F	----	46
	75°F	4.0	----	----	84.0°F	----	46

TABLE 5.1-18a

APPROXIMATE MONTHLY TEMPERATURE (°F)
AT CIRCULATING WATER DISCHARGE INTO RESERVOIR*

MONTH	TEMPERATURE
January	75.5
February	78.4
March	83.6
April	92.7
May	97.4
June	102.8
July	105.2
August	104.7
September	100.8
October	92.8
November	84.6
December	79.1

E-12

2

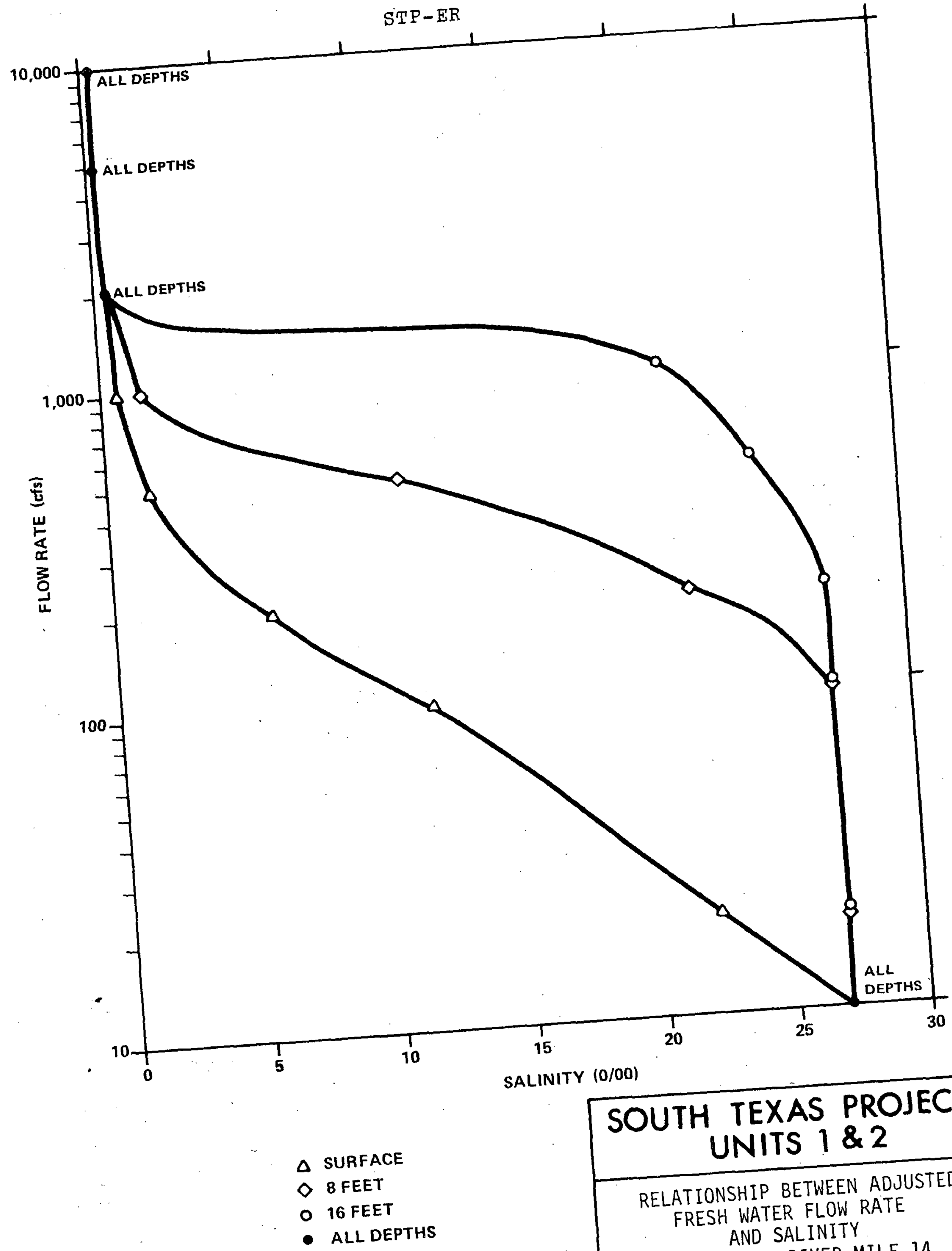
*Values were obtained by adding condenser ΔT to mean monthly plant intake temperature (Figure 3.4-20).

TABLE 5.1-19

SUMMARY OF REDUCED VISIBILITY OCCURRENCES AND ELEVATED VISIBLE PLUME OCCURRENCES AT SELECTED LOCATIONS AROUND THE STP SITE

Location	Frequency of Occurrence*, hour/year: Reduced Visibility (to less than 1,000 meters)	Elevated Visible Plumes
State Highway 60	1	4
State Highway 35	0	18
Farm to Market Road 1095	1	11
Farm to Market Road 521	34	197
Colorado River	4	16
Gulf Intracoastal Waterway	0	13
Matagorda Bay	0	13
Gulf of Mexico	0	12
Port of Bay City	0	1
Southern Pacific Railroad	0	9
Missouri Pacific Railroad	0	20
Atchison-Topeka and Santa Fe RR	0	4
Matagorda	0	4
Bay City	0	0
Palacios	0	4
Wadsworth	0	0
Blessing	0	4
Markham	0	1
Celanese Chemical Company	0	1

*Based on heat load from two 1,250 Mwe generating units operating at 100% load factor. For locations covering wide areas, maximum values are presented.



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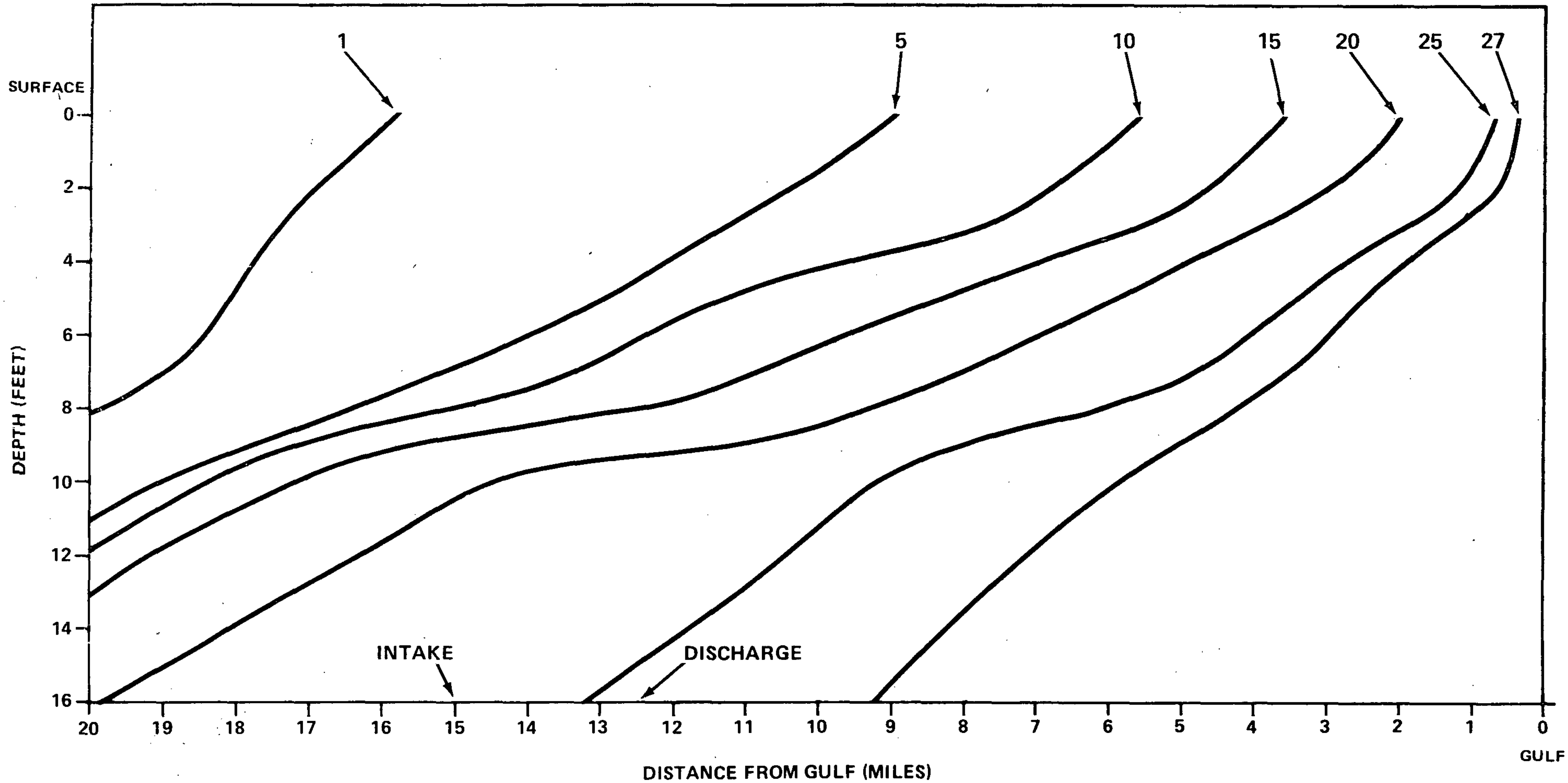
UNITS 1 & 2

RELATIONSHIP BETWEEN ADJUSTED FRESH WATER FLOW RATE AND SALINITY
LOCATION: RIVER MILE 14

FIGURE 5.1-1



FRESHWATER FLOW RATE = 500 cfs

STP-ER

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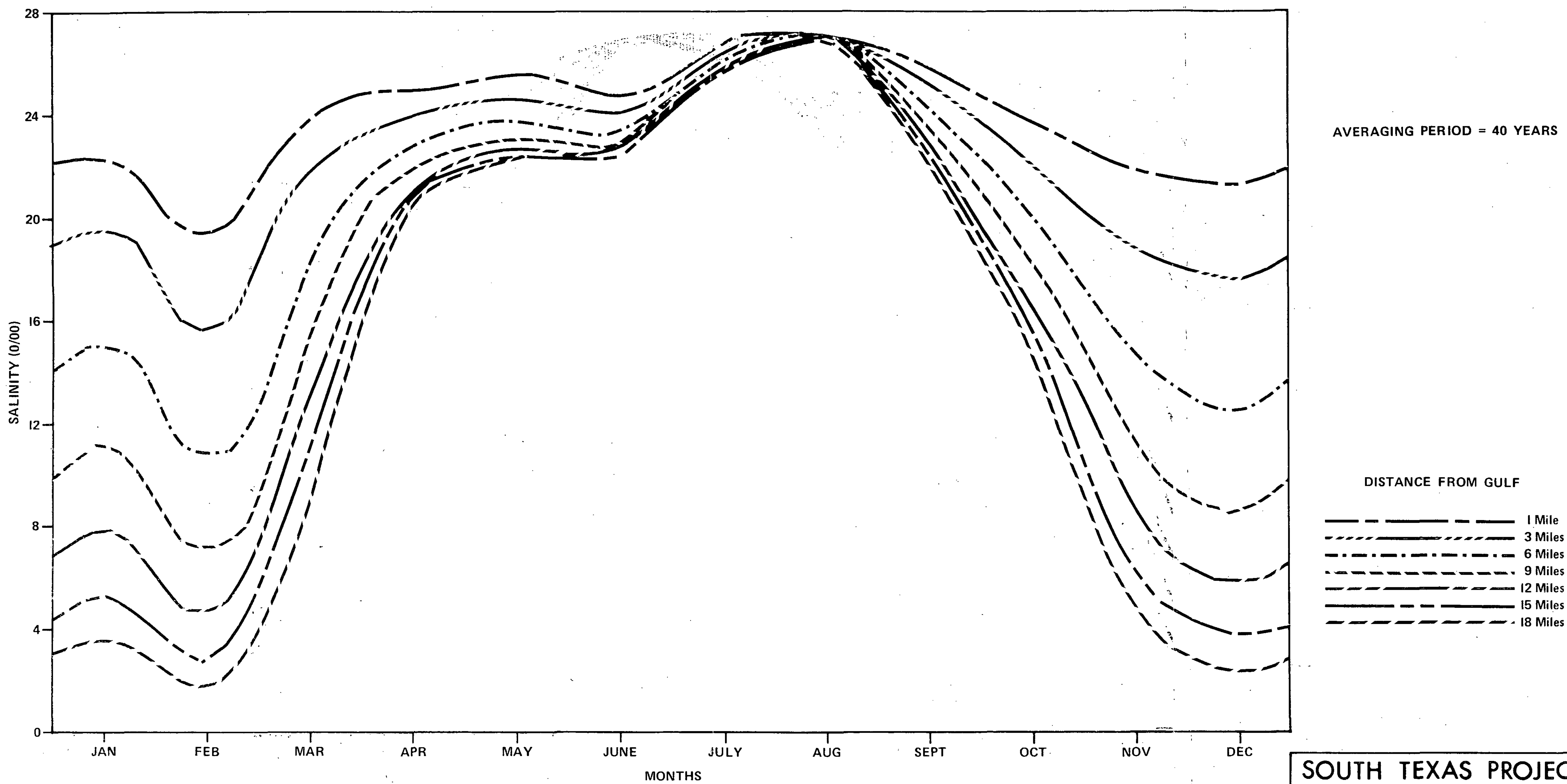
EXAMPLE

SIMULATED SALINITY ISOPLETHS (0/00) ON COLORADO RIVER

FIGURE 5.1-2



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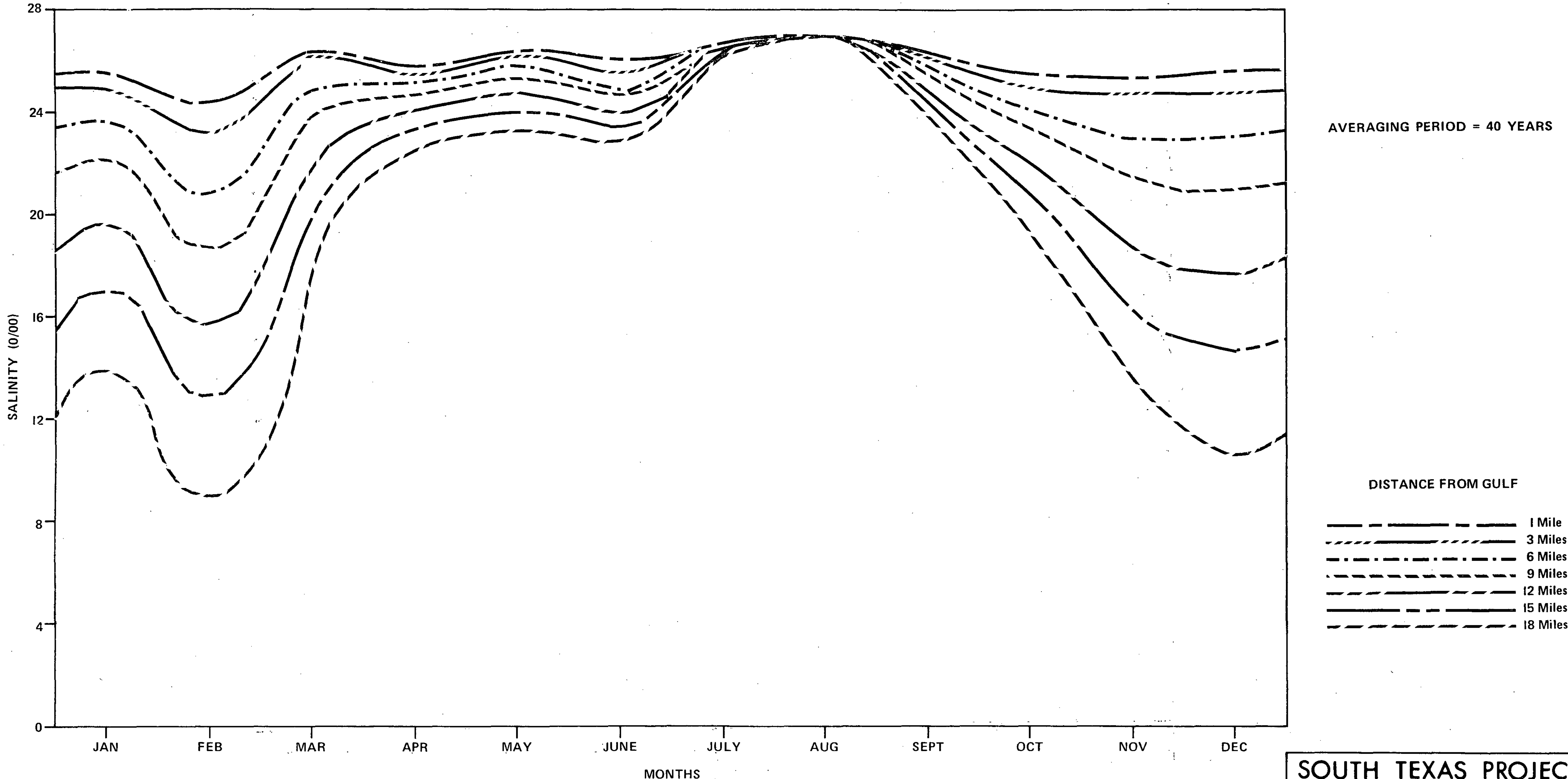
AVERAGE MONTHLY AMBIENT SALINITIES
DEPTH: 0-4 FEET

FIGURE 5.1-3



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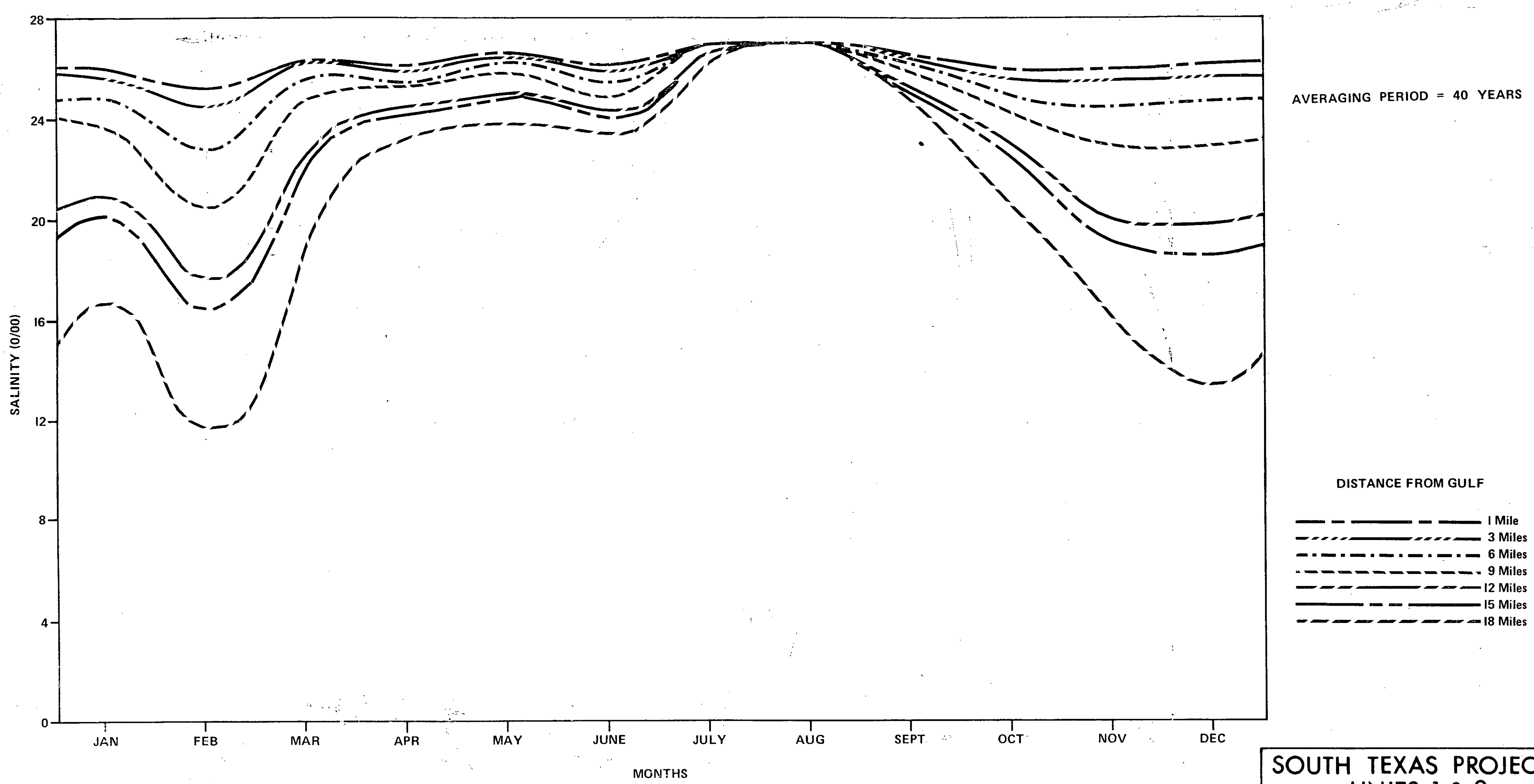
AVERAGE MONTHLY AMBIENT SALINITIES
DEPTH: 8-16 FEET

FIGURE 5.1-4



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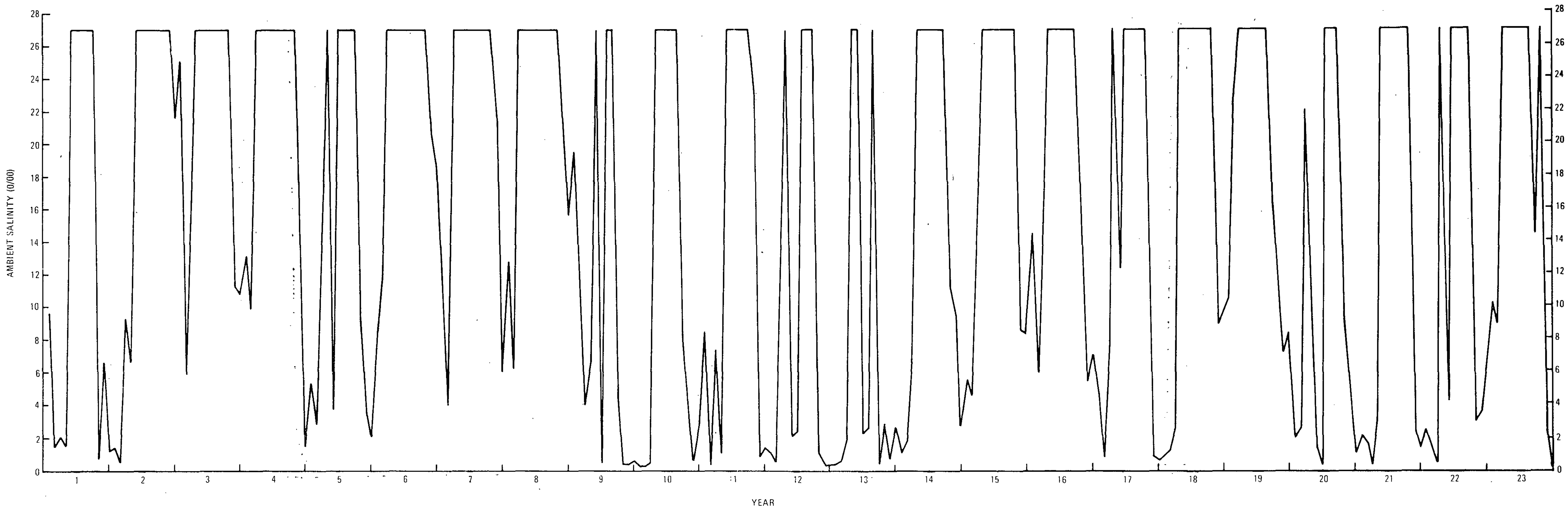
AVERAGE MONTHLY AMBIENT SALINITIES
DEPTH: 16 FEET

FIGURE 5.1-5



DEPTH: 0 — 4 FEET
LOCATION: RIVER MILE 12

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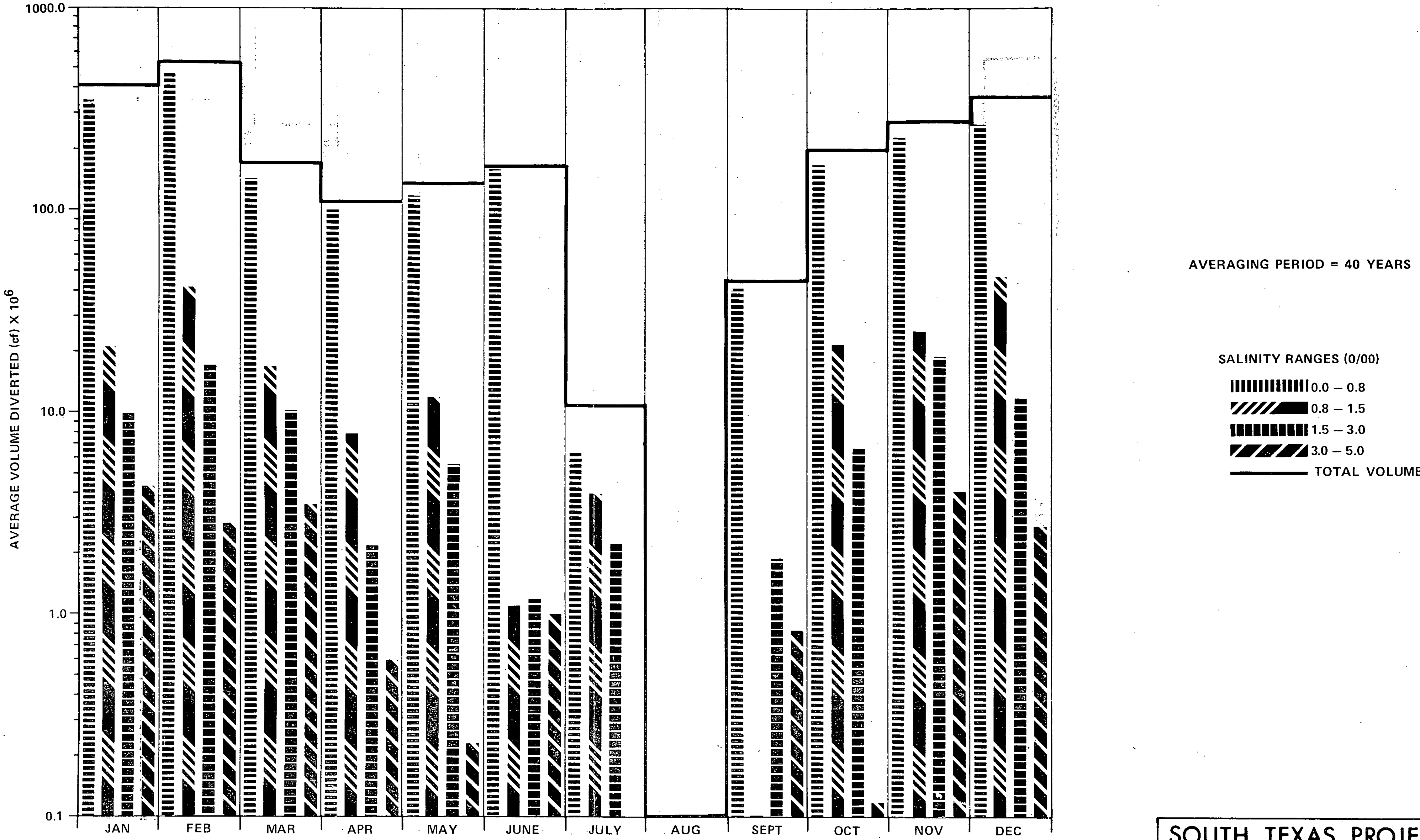
MONTHLY AVERAGE AMBIENT SALINITIES
OVER 23 YEARS

FIGURE 5.1-6



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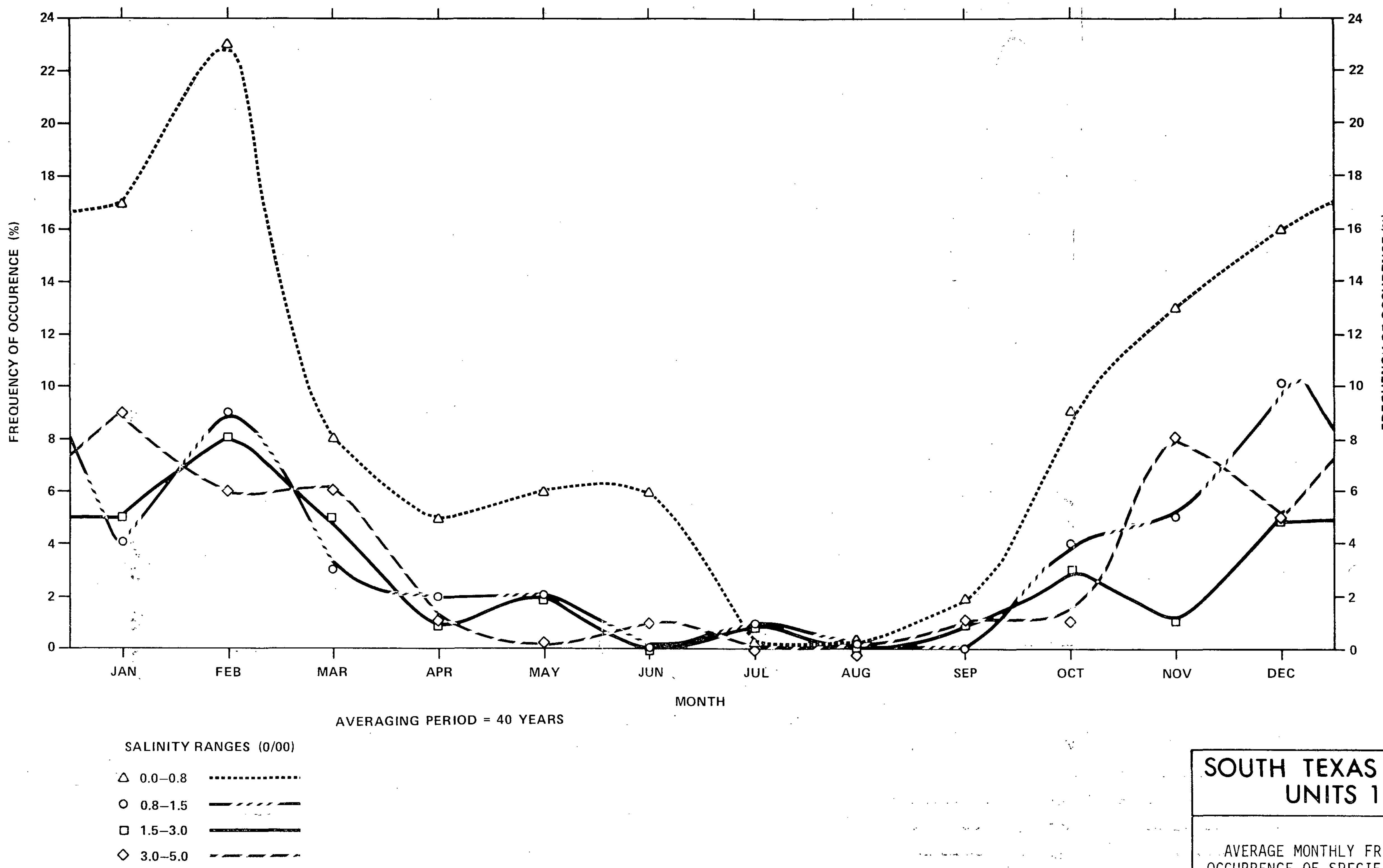
UNITS 1 & 2

AVERAGE MONTHLY VOLUMES DIVERTED IN SPECIFIC SALINITY RANGES

FIGURE 5.1-7



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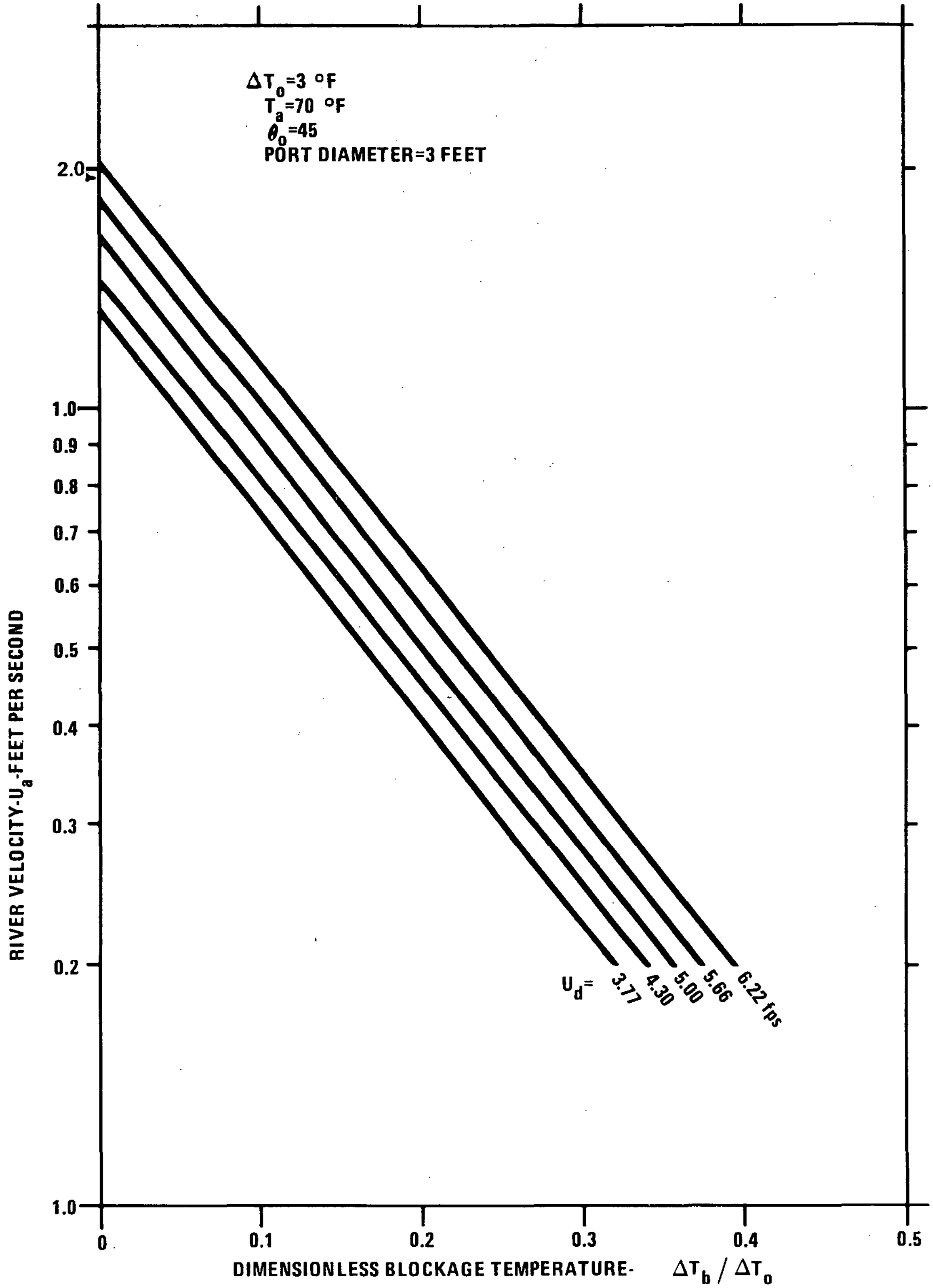
AVERAGE MONTHLY FREQUENCY OF OCCURRENCE OF SPECIFIC SALINITIES OF MAKEUP WATER

FIGURE 5.1-8



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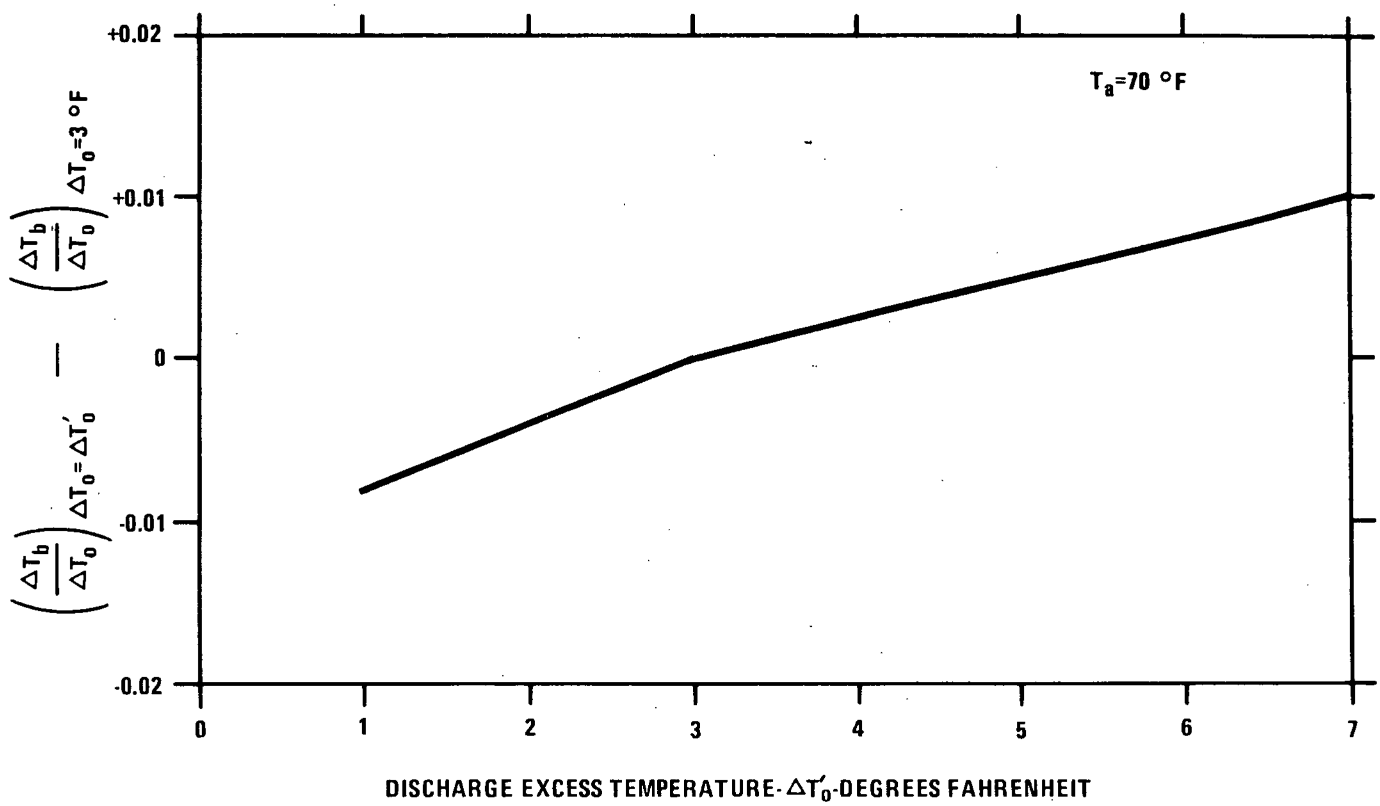
UNITS 1 & 2

RELATIONSHIP AMONG DIMENSIONLESS BLOCKAGE TEMPERATURE, RIVER VELOCITY AND DISCHARGE VELOCITY

FIGURE 5.1-9



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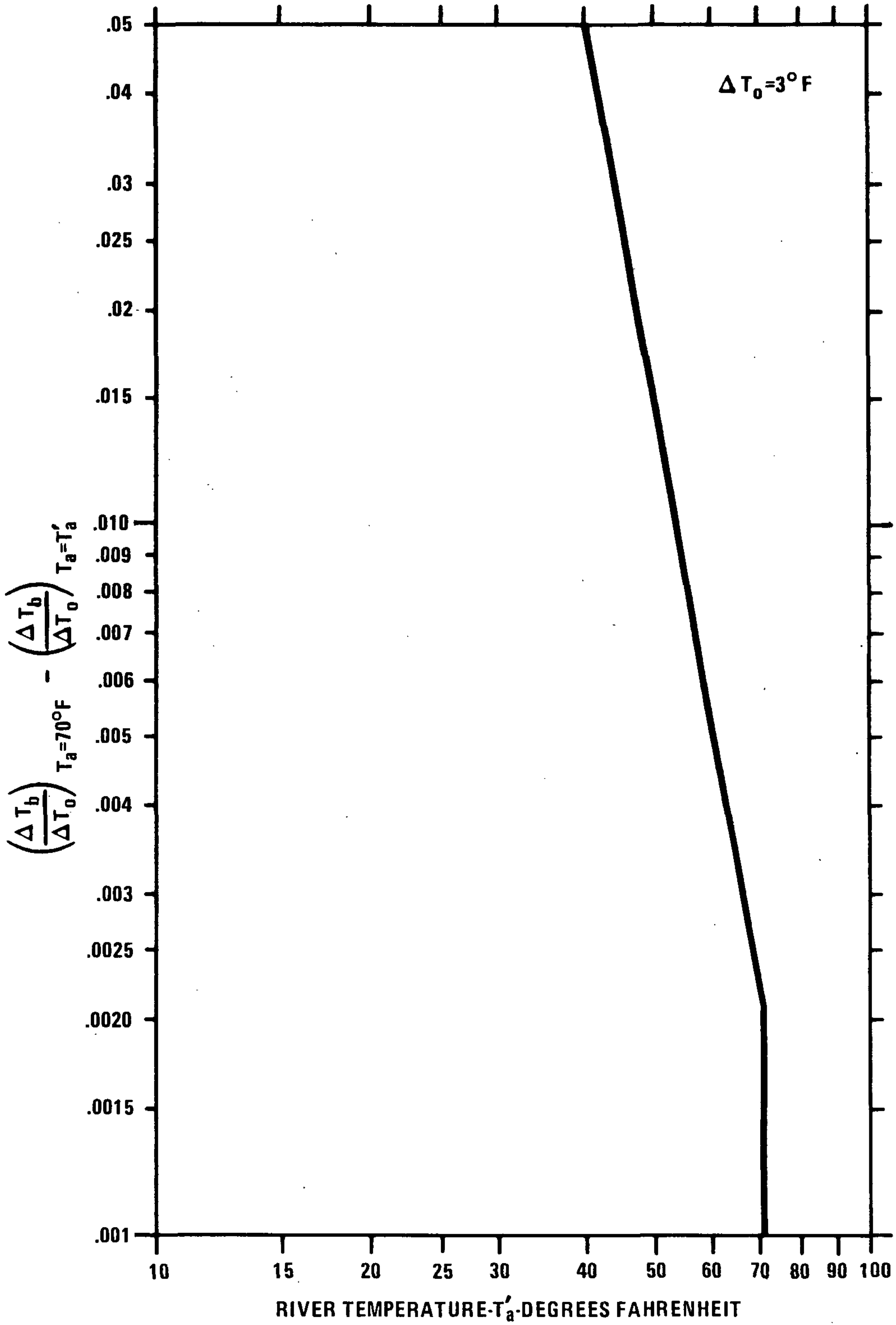
THE VARIATION OF DIMENSIONLESS BLOCKAGE TEMPERATURE WITH DISCHARGE EXCESS TEMPERATURE

FIGURE 5.1-10



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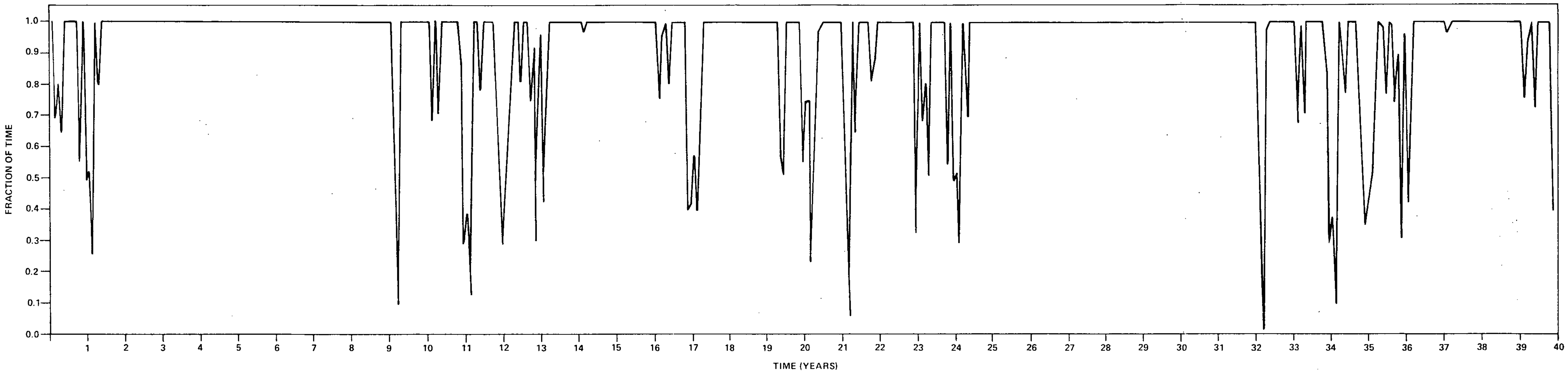
THE VARIATION OF DIMENSIONLESS BLOCKAGE TEMPERATURE WITH RIVER TEMPERATURE

FIGURE 5.1-11



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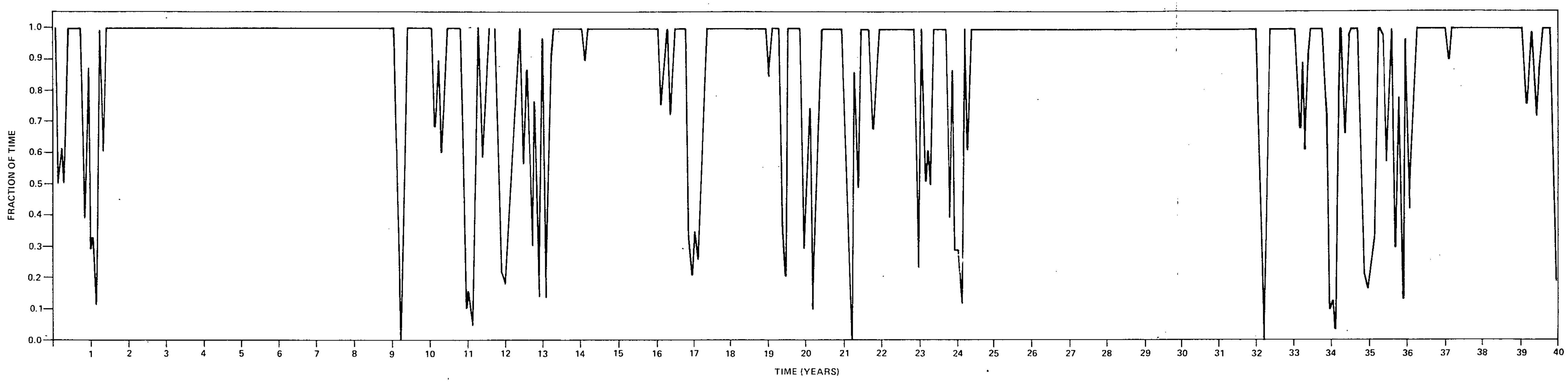
FRACTION OF TIME THAT THE DAILY AVERAGE BLOCKAGE TEMPERATURE IS LESS THAN OR EQUAL TO 1.0°F

FIGURE 5.1-12



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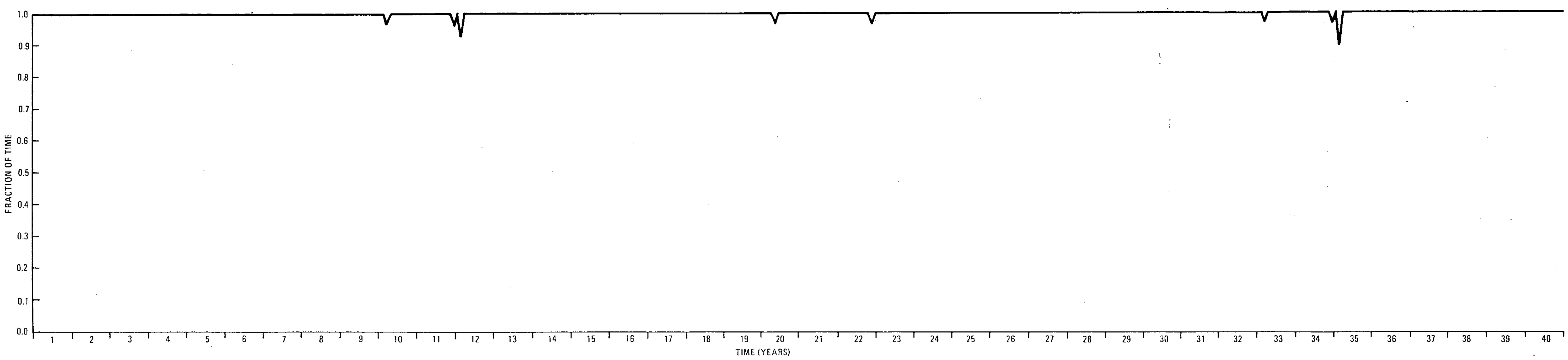
UNITS 1 & 2

FRACTION OF TIME THAT THE DAILY AVERAGE BLOCKAGE TEMPERATURE IS LESS THAN OR EQUAL TO 0.5°F

FIGURE 5.1-13



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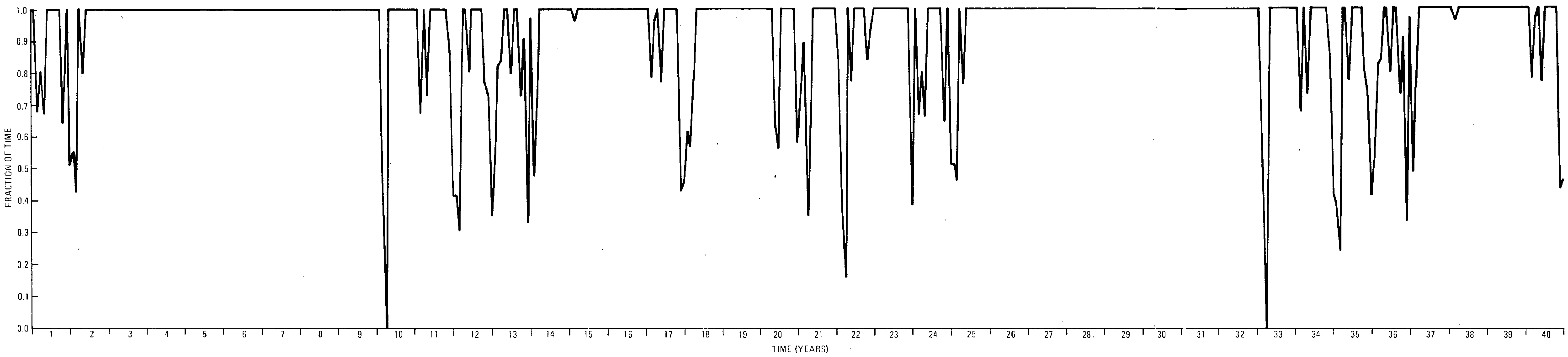
FRACTION OF TIME THAT THE DAILY MAXIMUM BLOCKAGE TEMPERATURE IS LESS THAN OR EQUAL TO 3^{O}F

FIGURE 5.1-14



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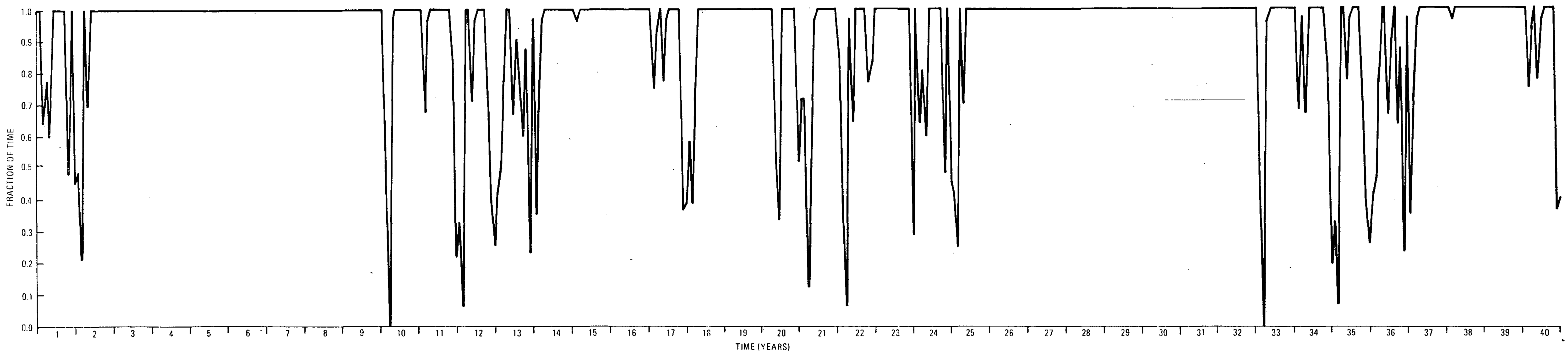
UNITS 1 & 2

FRACTION OF TIME THAT THE DAILY MAXIMUM BLOCKAGE TEMPERATURE IS LESS THAN OR EQUAL TO $2^{o}F$

FIGURE 5.1-15



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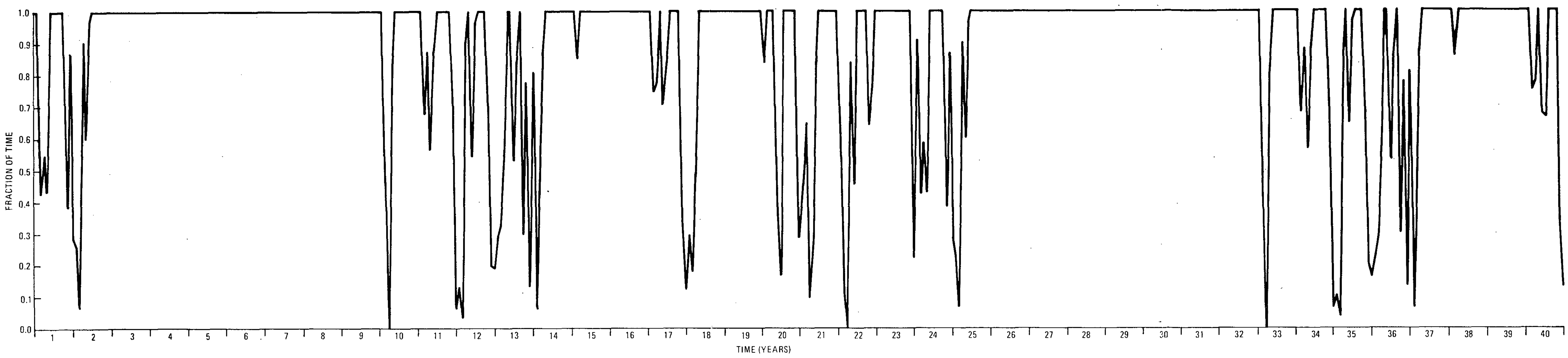
FRACTION OF TIME THAT THE DAILY MAXIMUM BLOCKAGE TEMPERATURE IS LESS THAN OR EQUAL TO 1°F

FIGURE 5.1-16



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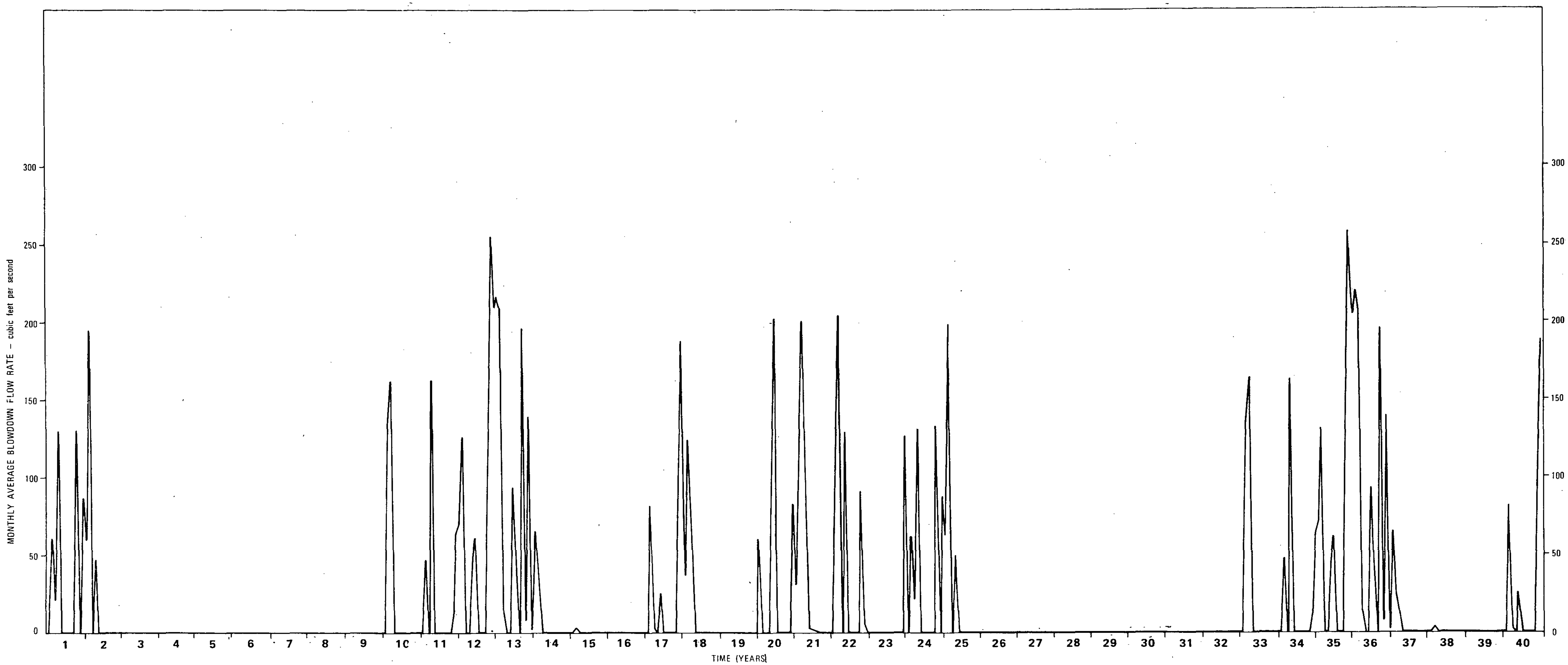
FRACTION OF TIME THAT THE DAILY MAXIMUM BLOCKAGE TEMPERATURE IS LESS THAN OR EQUAL TO 0.5°F

FIGURE 5.1-17



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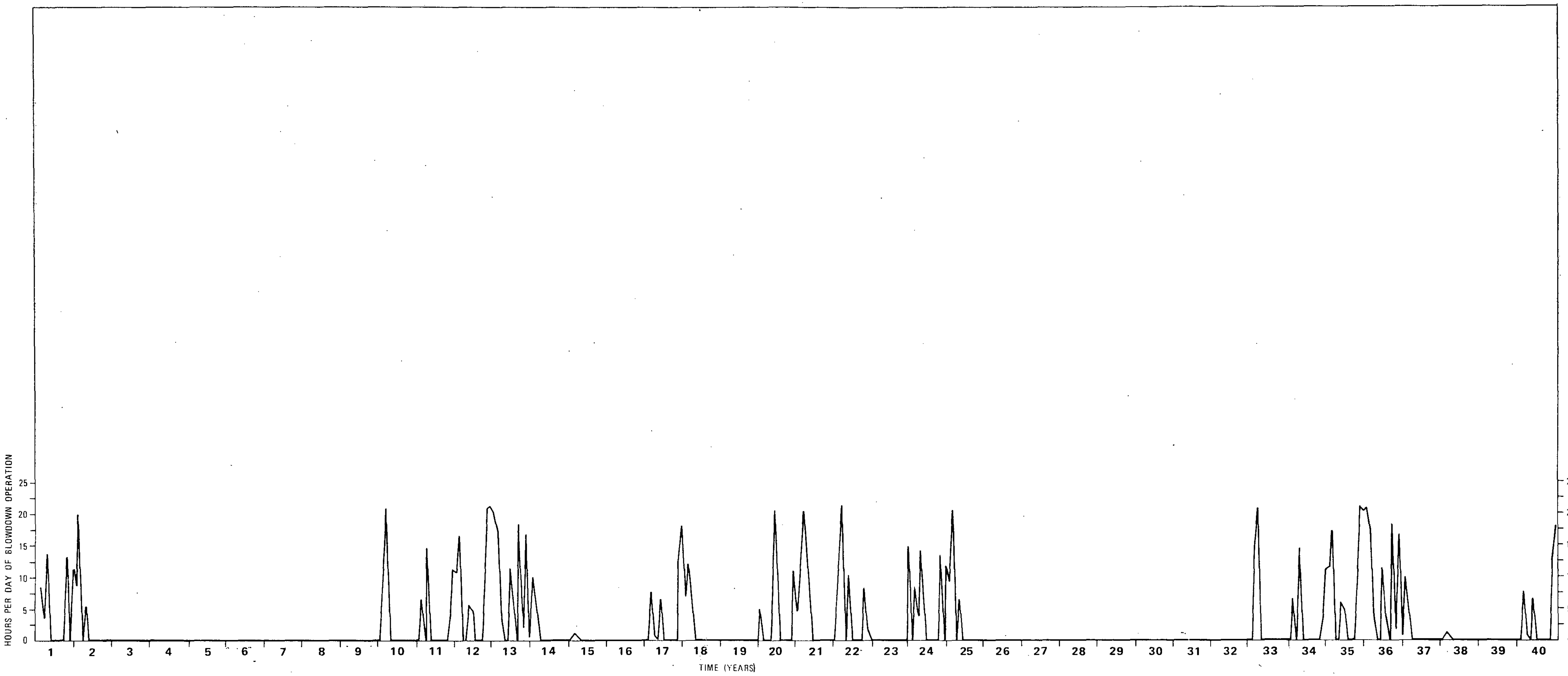
UNITS 1 & 2

MONTHLY AVERAGE BLOWDOWN FLOW RATE FOR THE FORTY YEARS OF PLANT OPERATION

FIGURE 5.1-18



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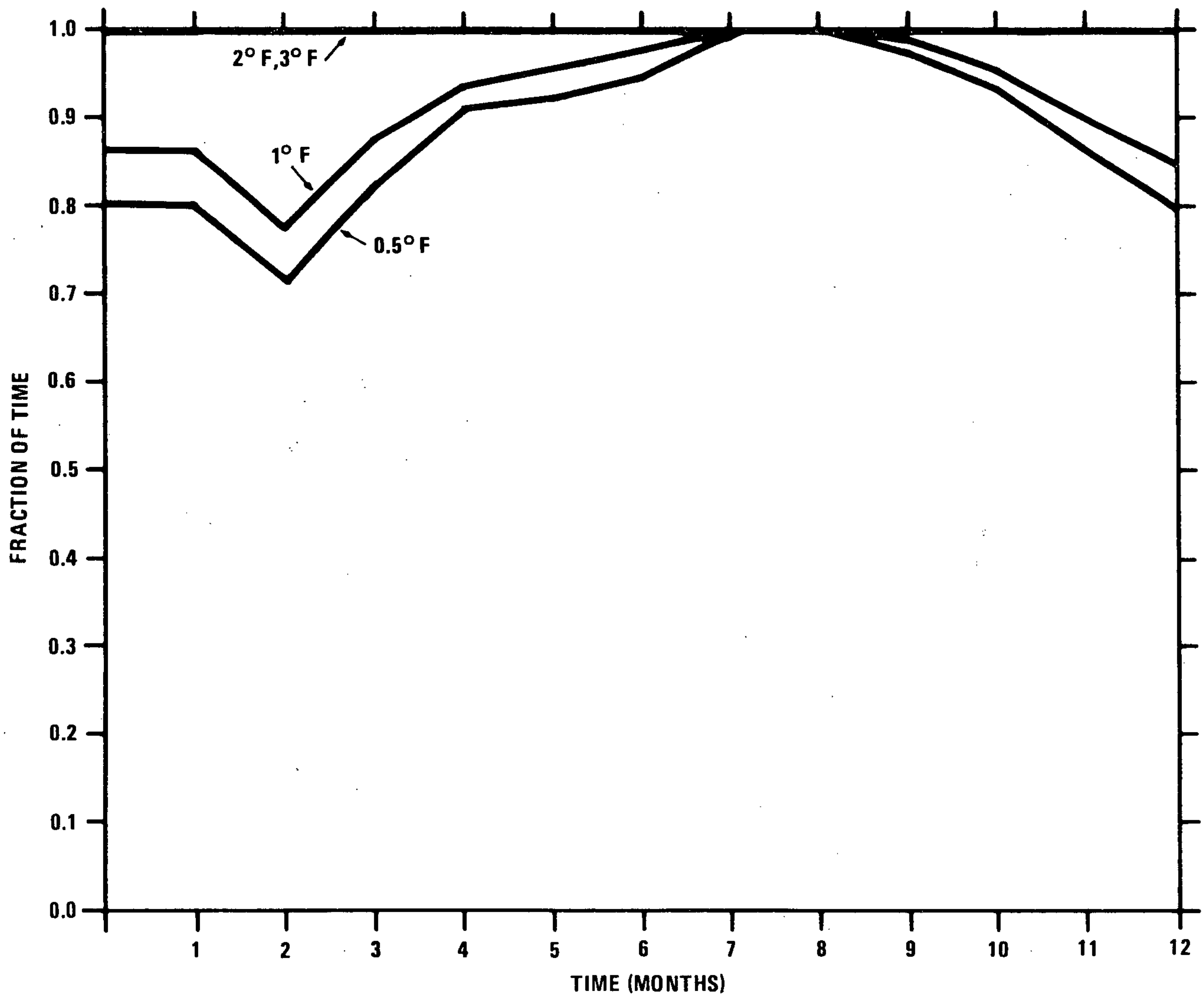
MONTHLY AVERAGE
NUMBER OF HOURS PER DAY OF BLOWDOWN OPERATION FOR THE FORTY YEARS OF PLANT OPERATION

FIGURE 5.1-19



AVERAGING PERIOD = 40 YEARS

SOUTH TEXAS PROJECT
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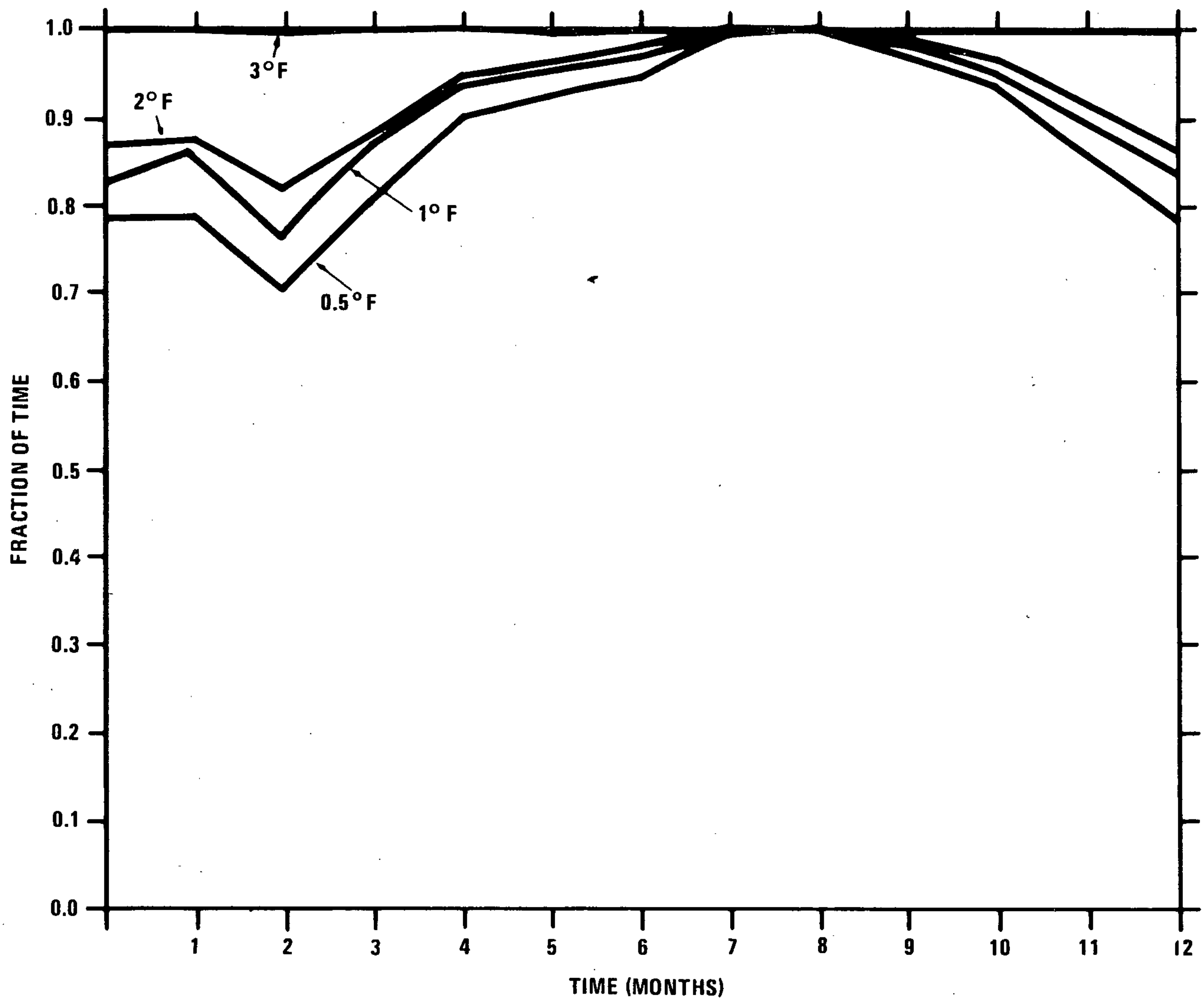
FRACTION OF THE TIME THAT THE DAILY AVERAGE BLOCKAGE TEMPERATURE IS LESS THAN OR EQUAL TO 3, 2, 1, AND 0.5°F FOR AN AVERAGE YEAR

FIGURE 5.1-20



AVERAGING PERIOD = 40 YEARS

SOUTH TEXAS PROJECT
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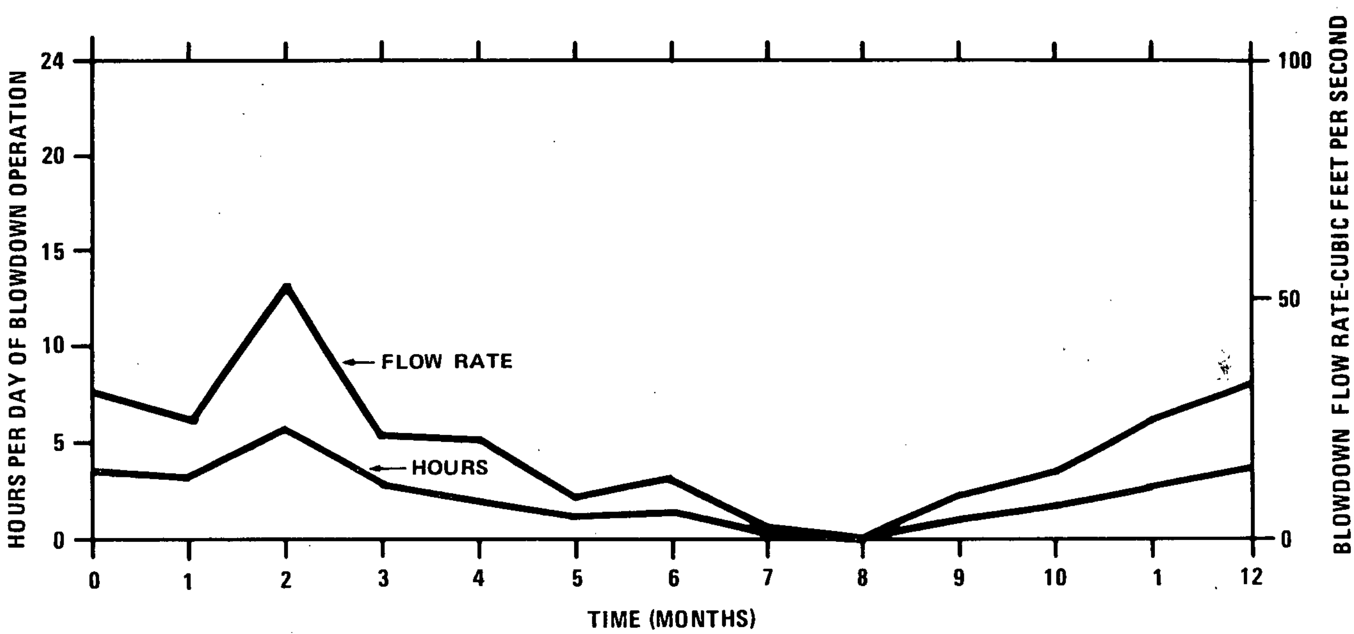
FRACTION OF TIME THAT THE DAILY MAXIMUM BLOCKAGE TEMPERATURE IS LESS THAN OR EQUAL TO 3, 2, 1, AND 0.5°F FOR AN AVERAGE YEAR

FIGURE 5.1-21

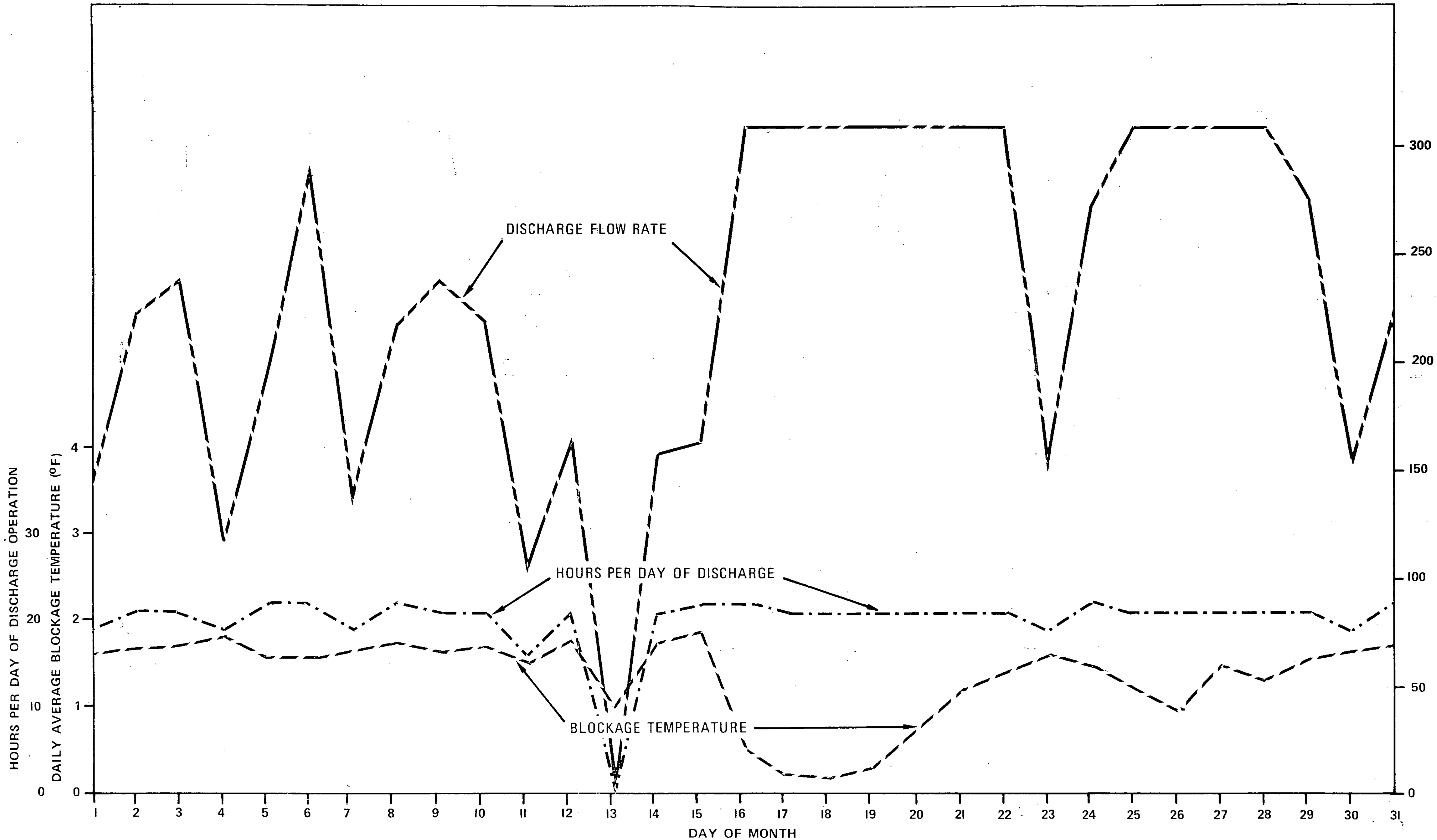


AVERAGING PERIOD = 40 YEARS

SOUTH TEXAS PROJECT UNITS 1 & 2

MONTHLY AVERAGE BLOWDOWN FLOW RATE AND NUMBER OF HOURS PER DAY OF BLOWDOWN OPERATION FOR AN AVERAGE YEAR

FIGURE 5.1-22



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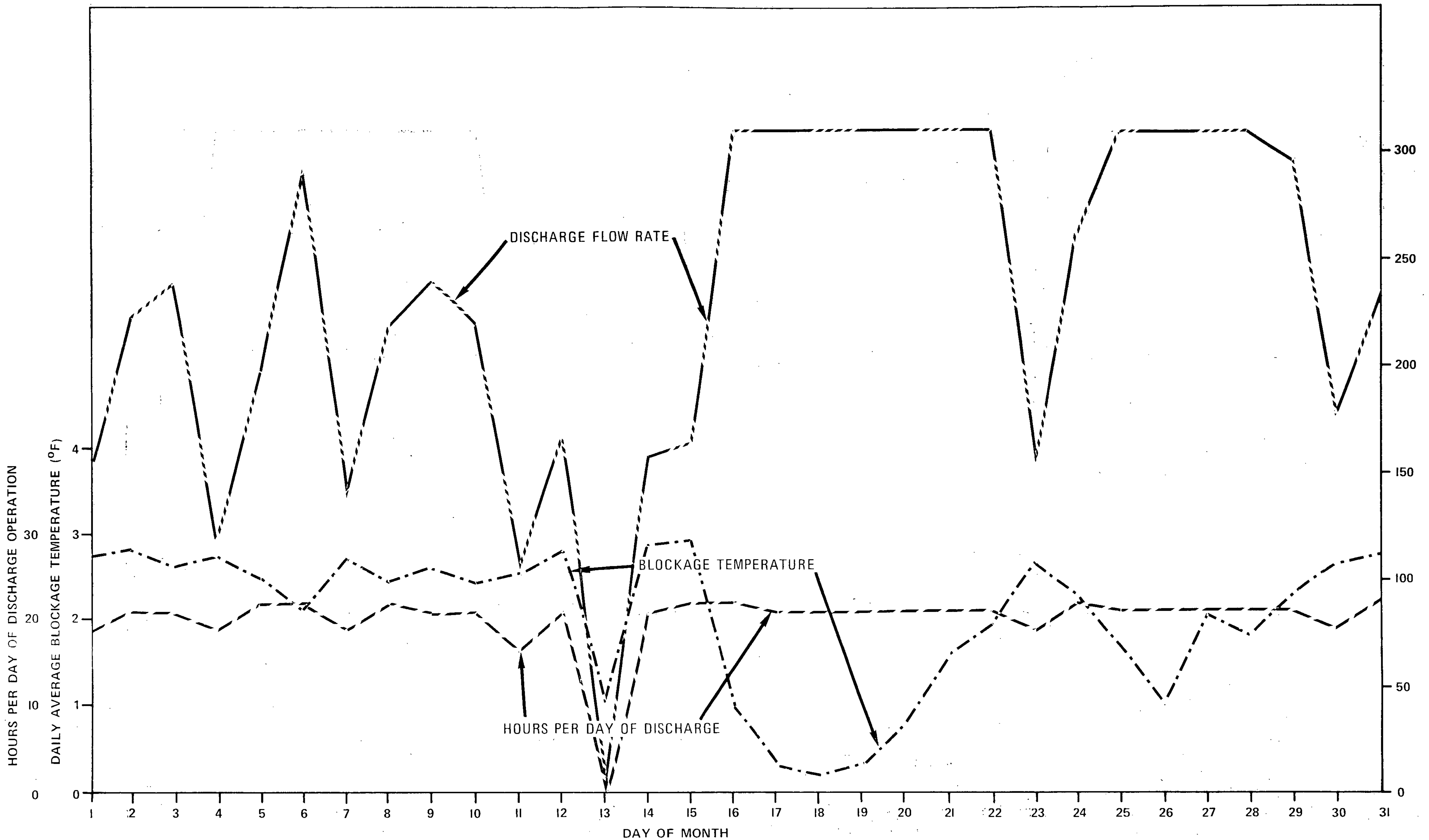
DAILY AVERAGE BLOCKAGE TEMPERATURE, HOURS PER DAY OF DISCHARGE, AND DISCHARGE FLOW RATE DURING THOSE HOURS FOR MARCH OF YEAR 21

FIGURE 5.1-23



SOUTH TEXAS PROJECT
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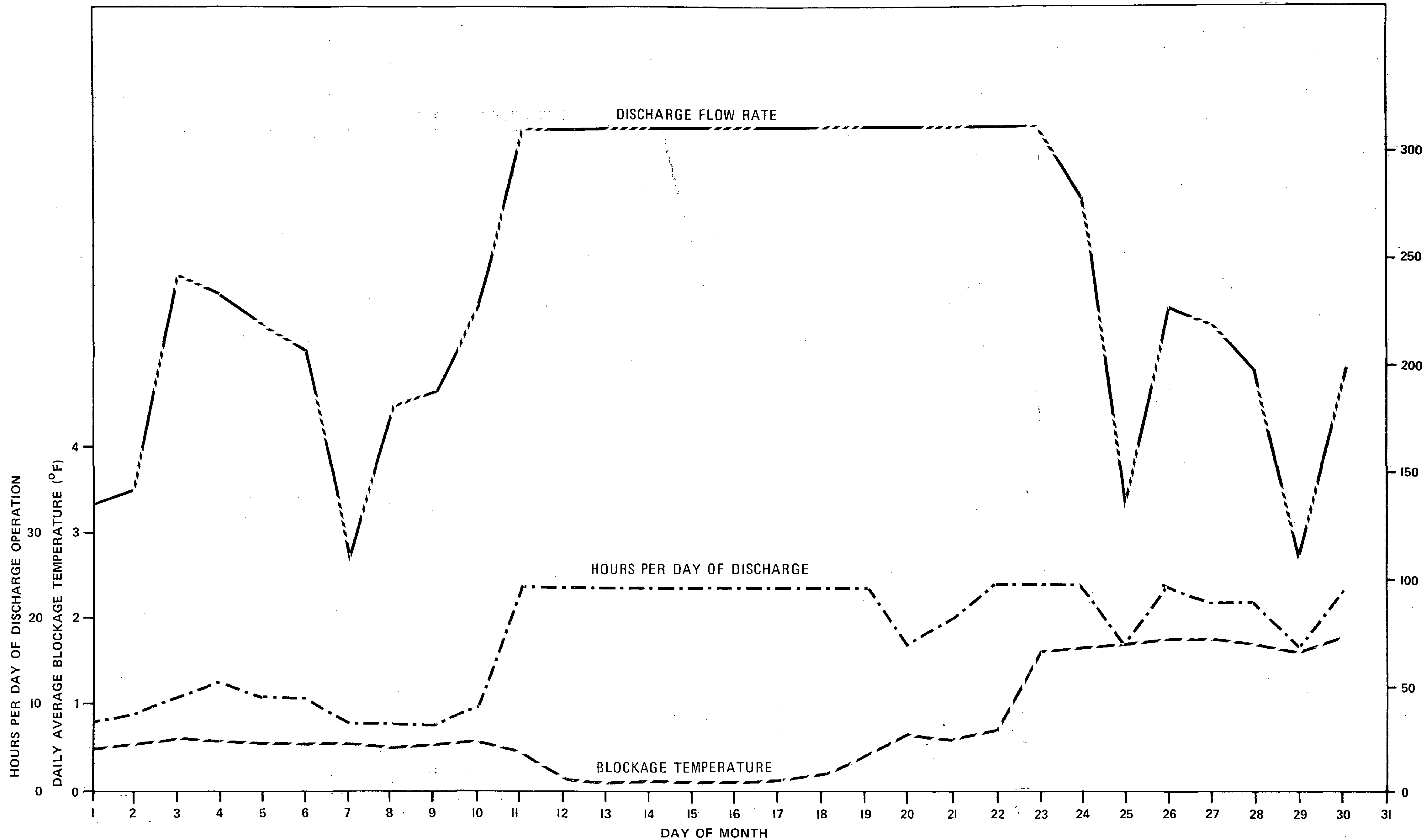
DAILY MAXIMUM BLOCKAGE TEMPERATURE, HOURS PER DAY OF DISCHARGE, AND DISCHARGE FLOW RATE DURING THOSE HOURS FOR MARCH OF YEAR 21

FIGURE 5.1-24



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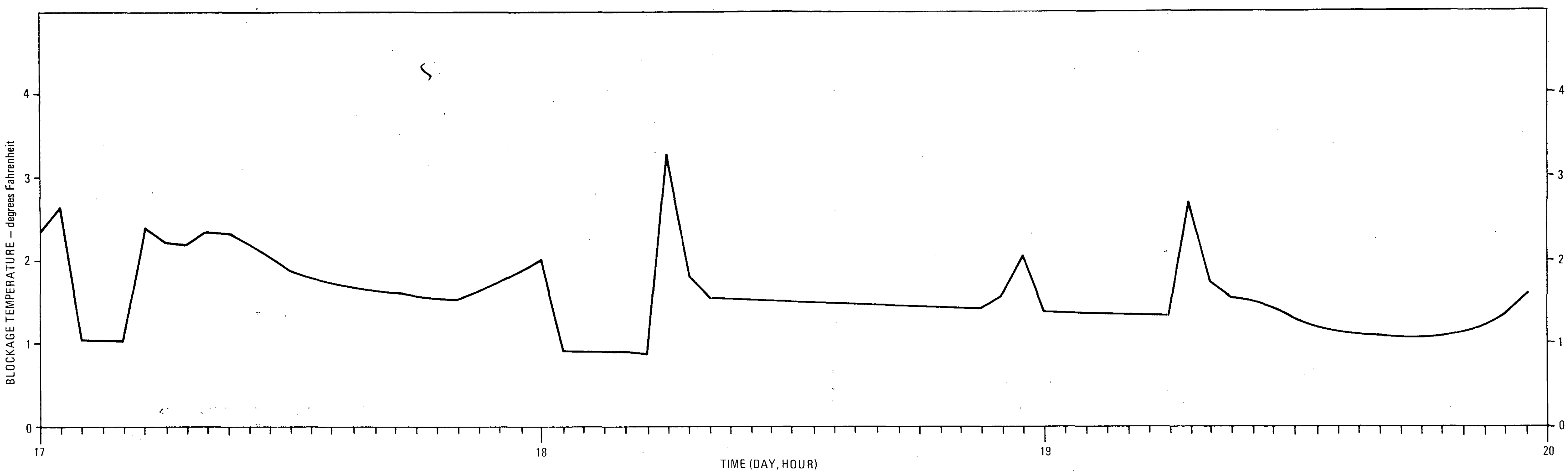
DAILY AVERAGE BLOCKAGE TEMPERATURE, HOURS PER DAY OF DISCHARGE, AND DISCHARGE FLOW RATE DURING THOSE HOURS FOR SEPTEMBER OF YEAR 13

FIGURE 5.1-25



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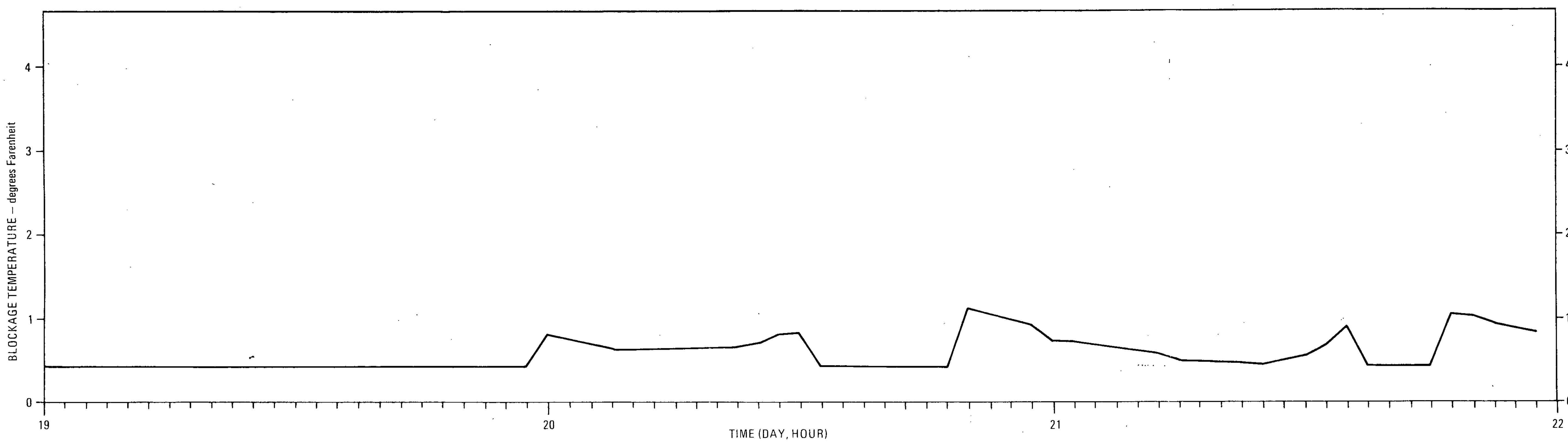
UNITS 1 & 2

HOURLY BLOCKAGE
TEMPERATURES FOR MARCH 17
THROUGH 19 OF YEAR 10

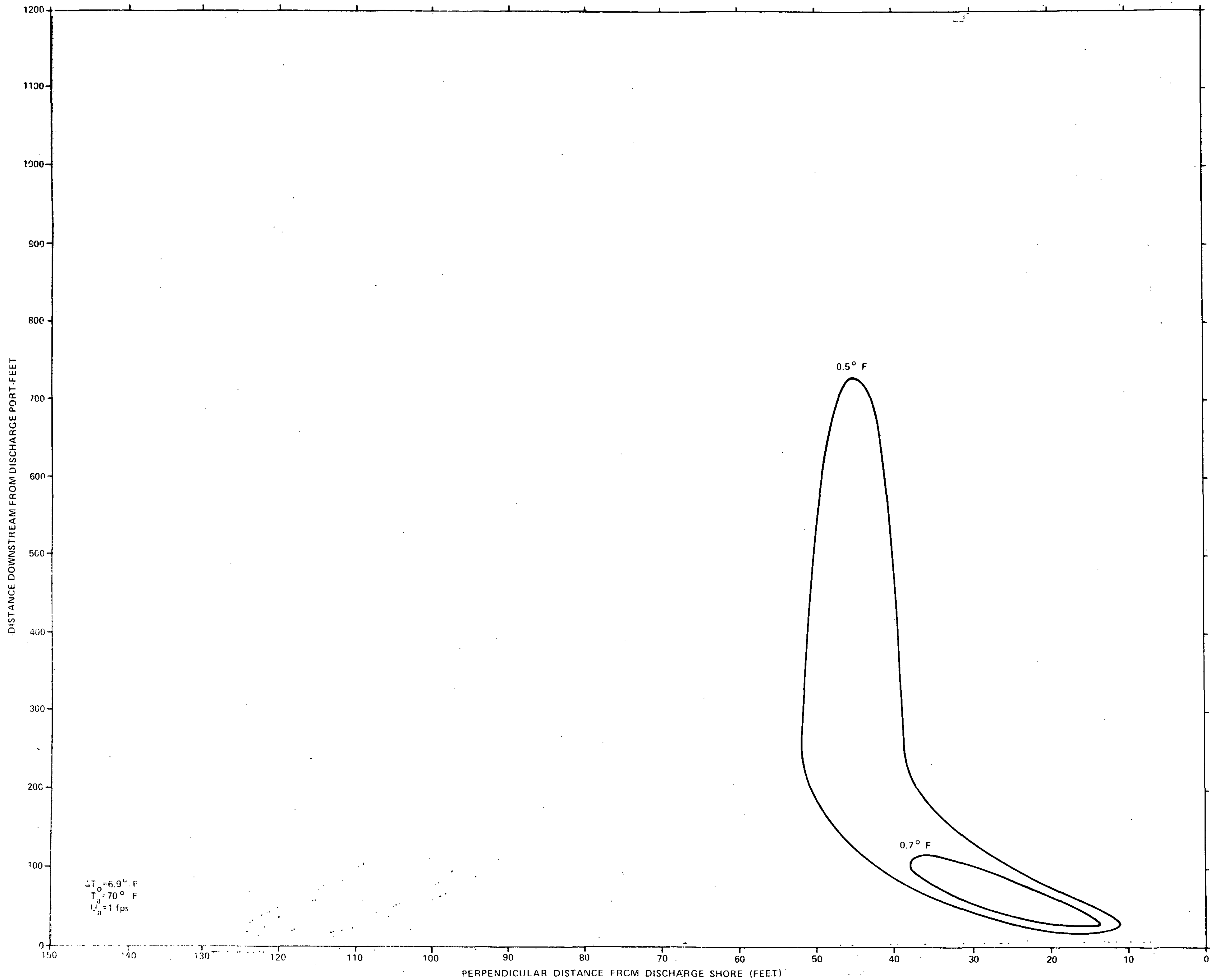
FIGURE 5.1-27



SOUTH TEXAS PROJECT
UNITS 1 & 2

HOURLY BLOCKAGE TEMPERATURES FOR SEPTEMBER 19 THROUGH 21 OF YEAR 13

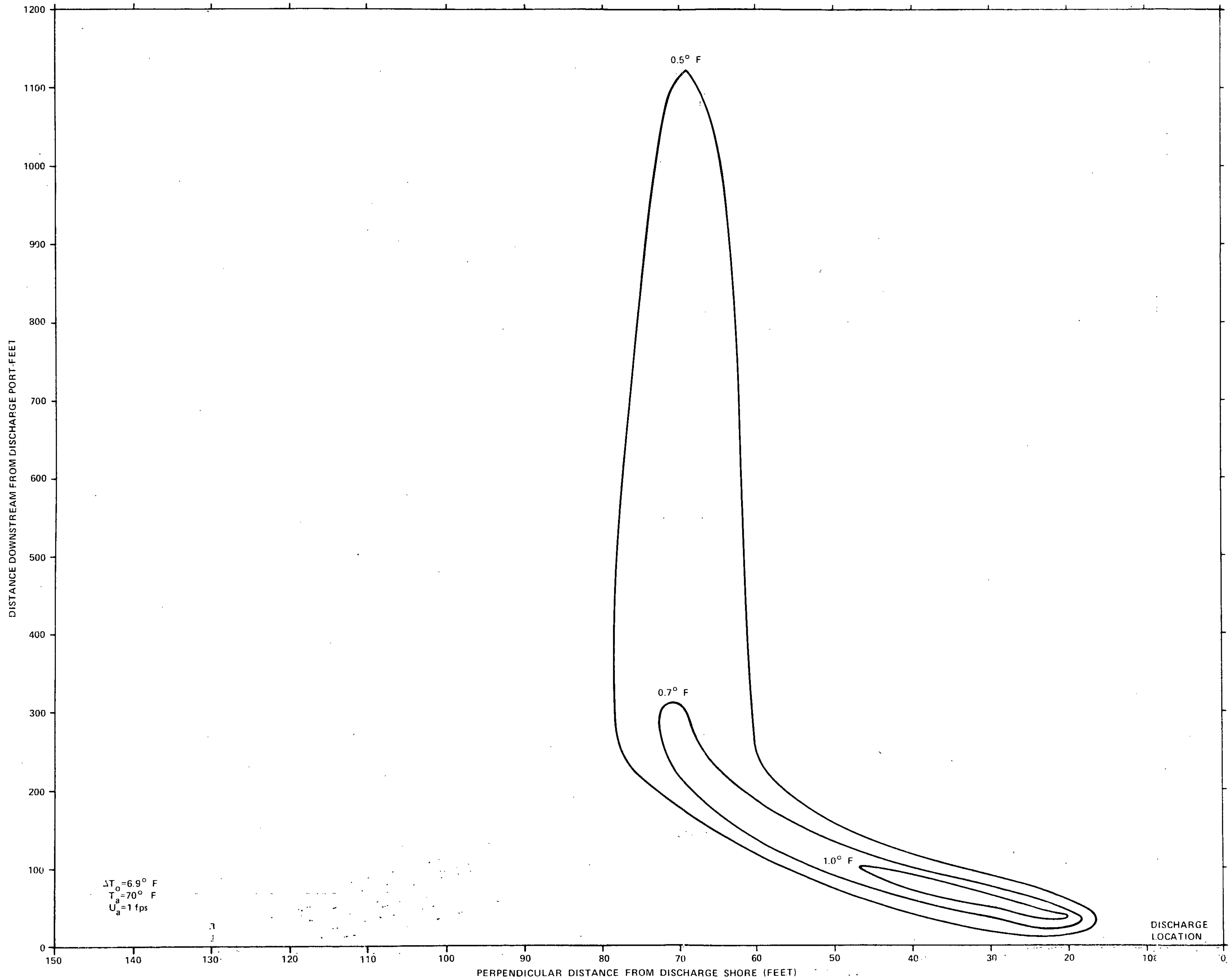
FIGURE 5.1-28



SOUTH TEXAS PROJECT
UNITS 1 & 2

ISOTHERMS ALONG THE RIVER SURFACE DUE TO A DISCHARGE VELOCITY OF 4.14 fps

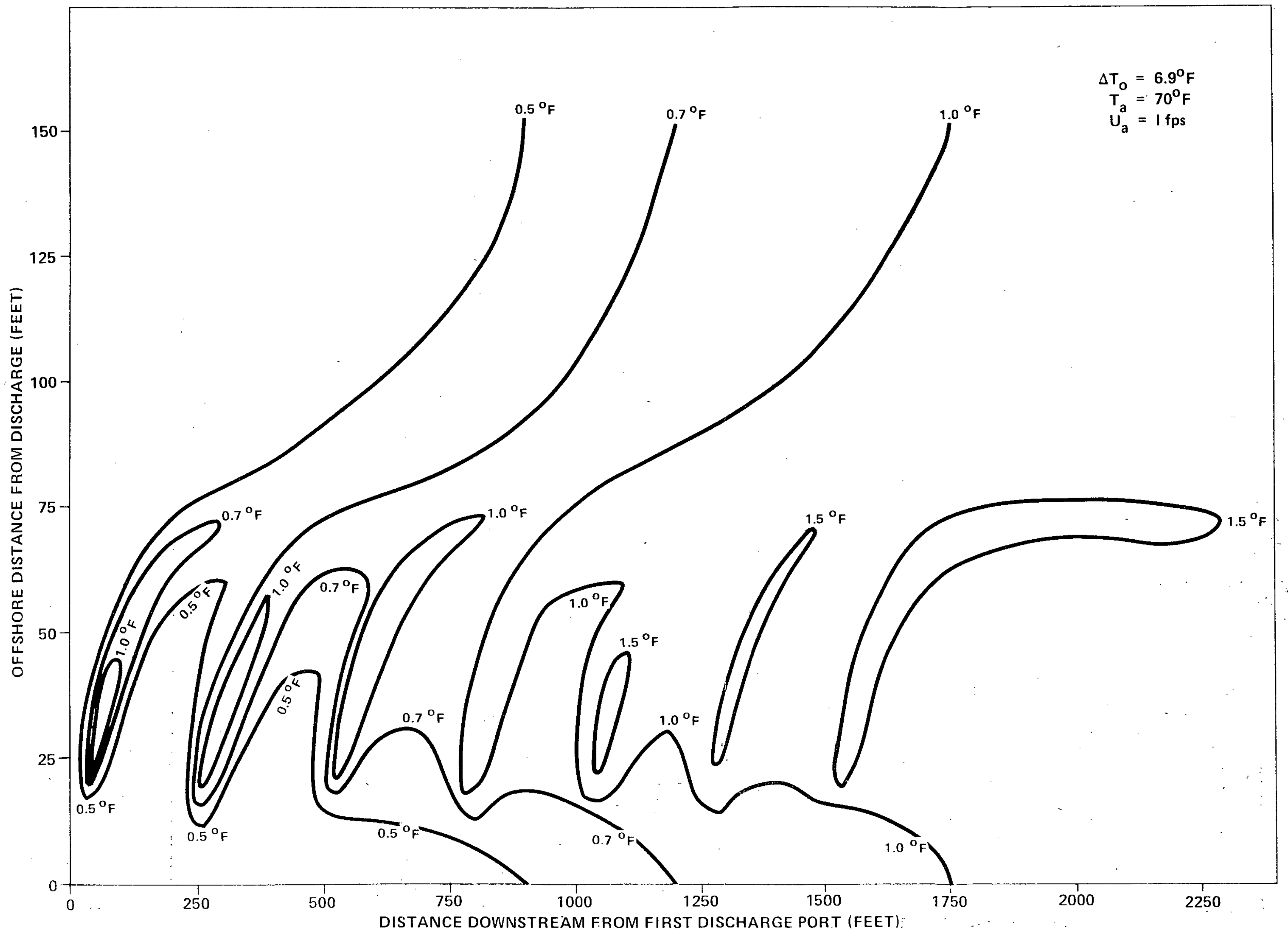
FIGURE 5.1-29



SOUTH TEXAS PROJECT UNITS 1 & 2

ISOTHERMS ALONG THE RIVER SURFACE DUE TO A DISCHARGE VELOCITY OF 6.22 fps

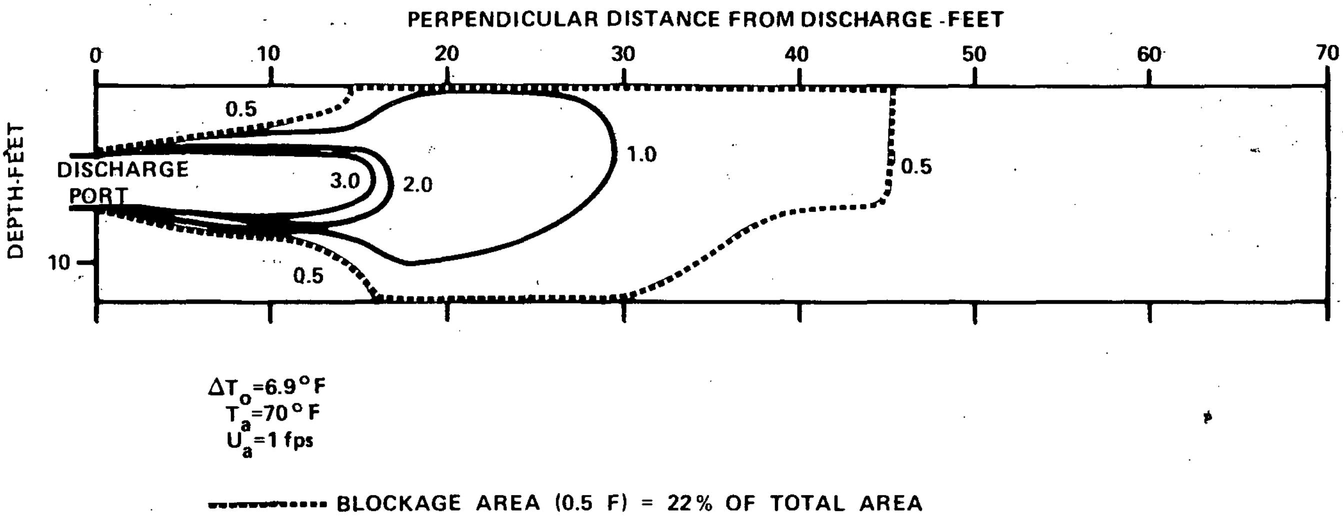
FIGURE 5.1-30



SOUTH TEXAS PROJECT UNITS 1 & 2

ISOTHERMS ALONG THE RIVER SURFACE DUE TO A DISCHARGE FLOW OF 308cfs (7 PORTS, 6.22fps DISCHARGE VELOCITY)

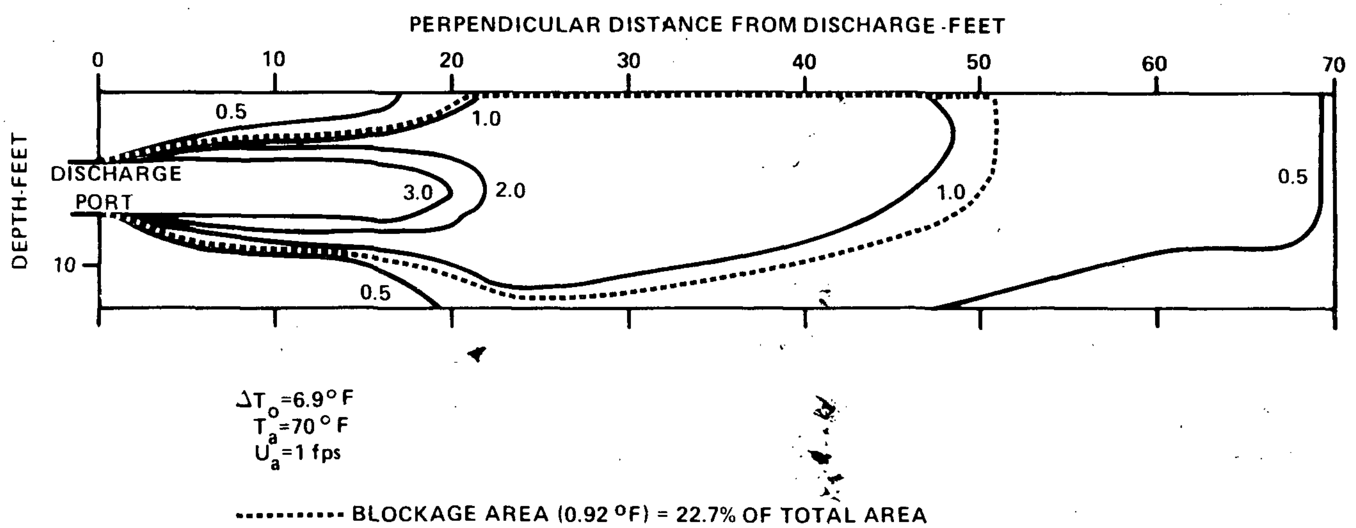
FIGURE 5.1-31



SOUTH TEXAS PROJECT
UNITS 1 & 2

VERTICAL ISOTHERMS DUE TO A DISCHARGE VELOCITY OF 4.20 fps

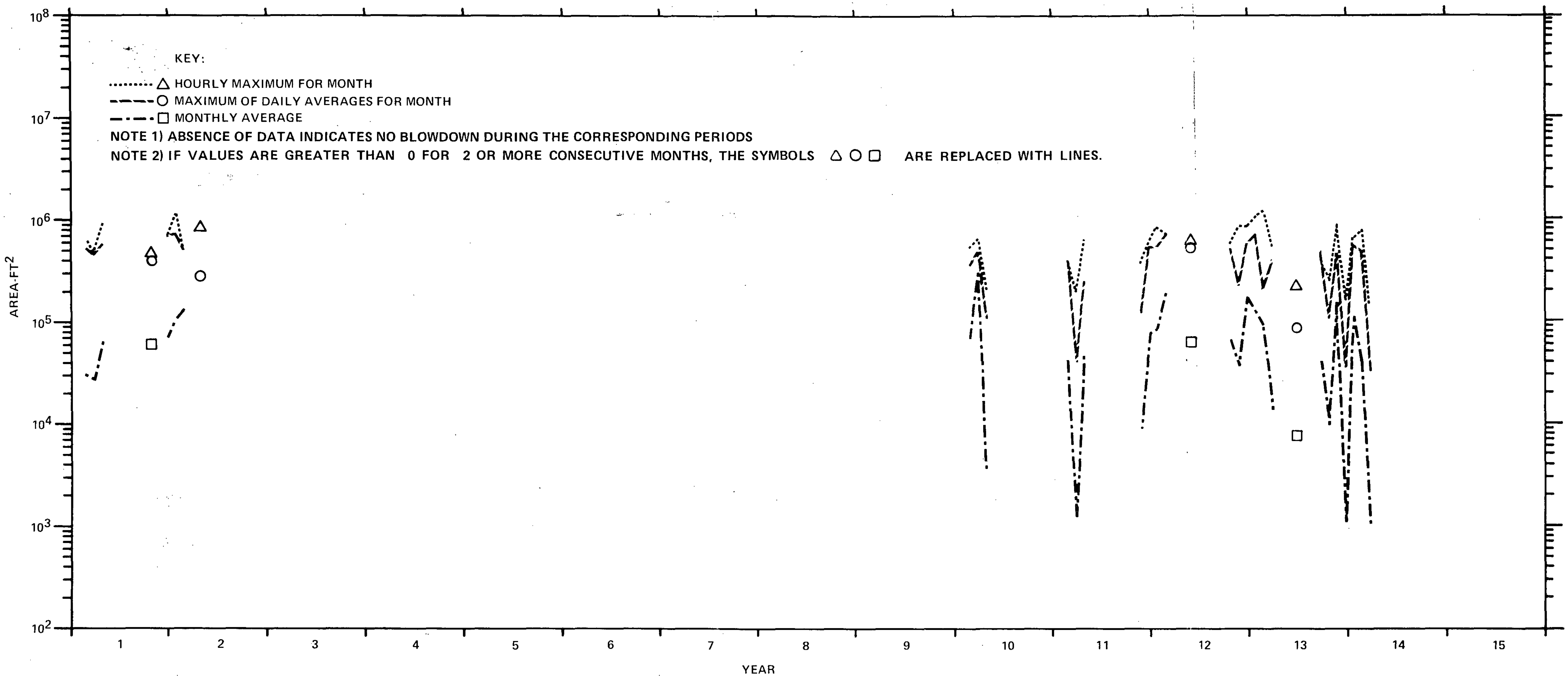
FIGURE 5.1-32



SOUTH TEXAS PROJECT UNITS 1 & 2

VERTICAL ISOTHERMS DUE TO A DISCHARGE VELOCITY OF 6.22 fps

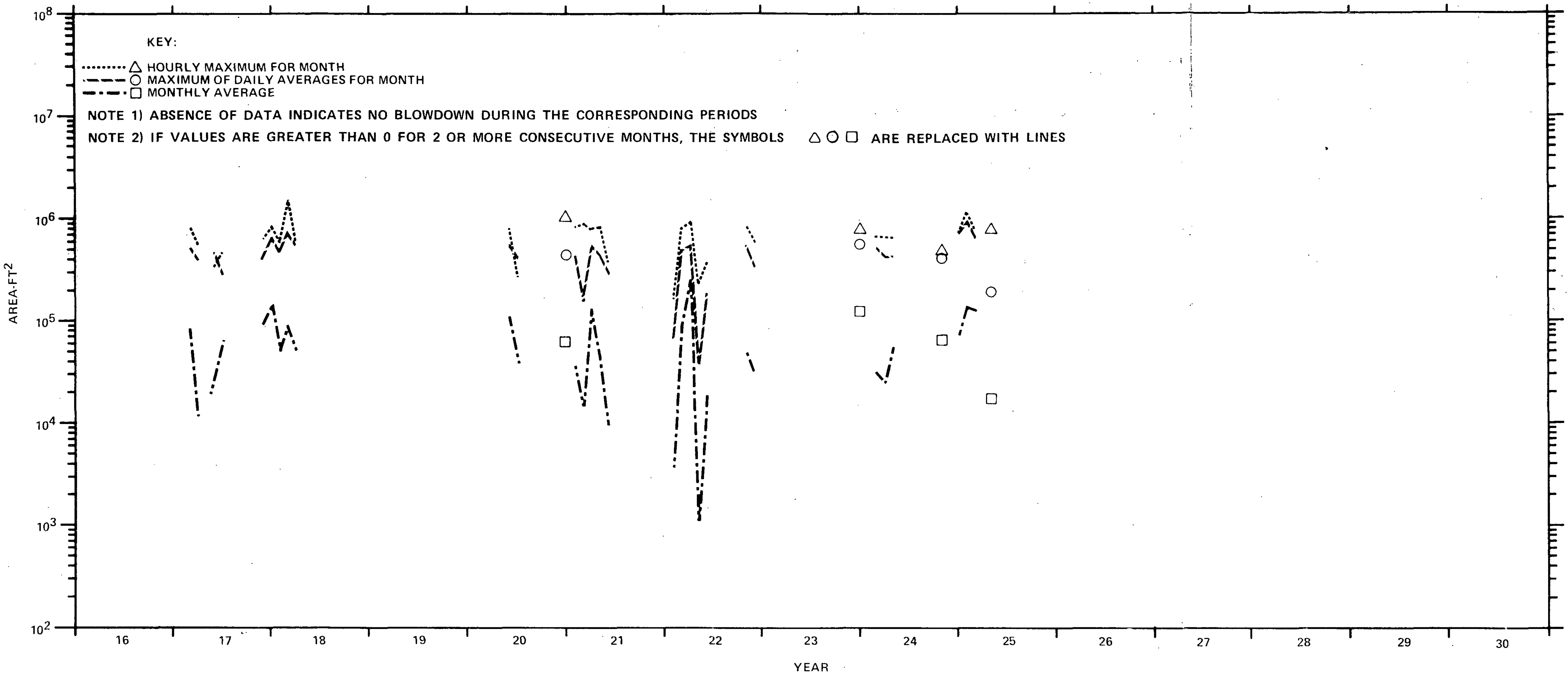
FIGURE 5.1-33



SOUTH TEXAS PROJECT
UNITS 1 & 2

RIVER AREAS WITH EXCESS TEMPERATURE $\geq 1.0^{\circ}F$
(SHEET 1 OF 3)

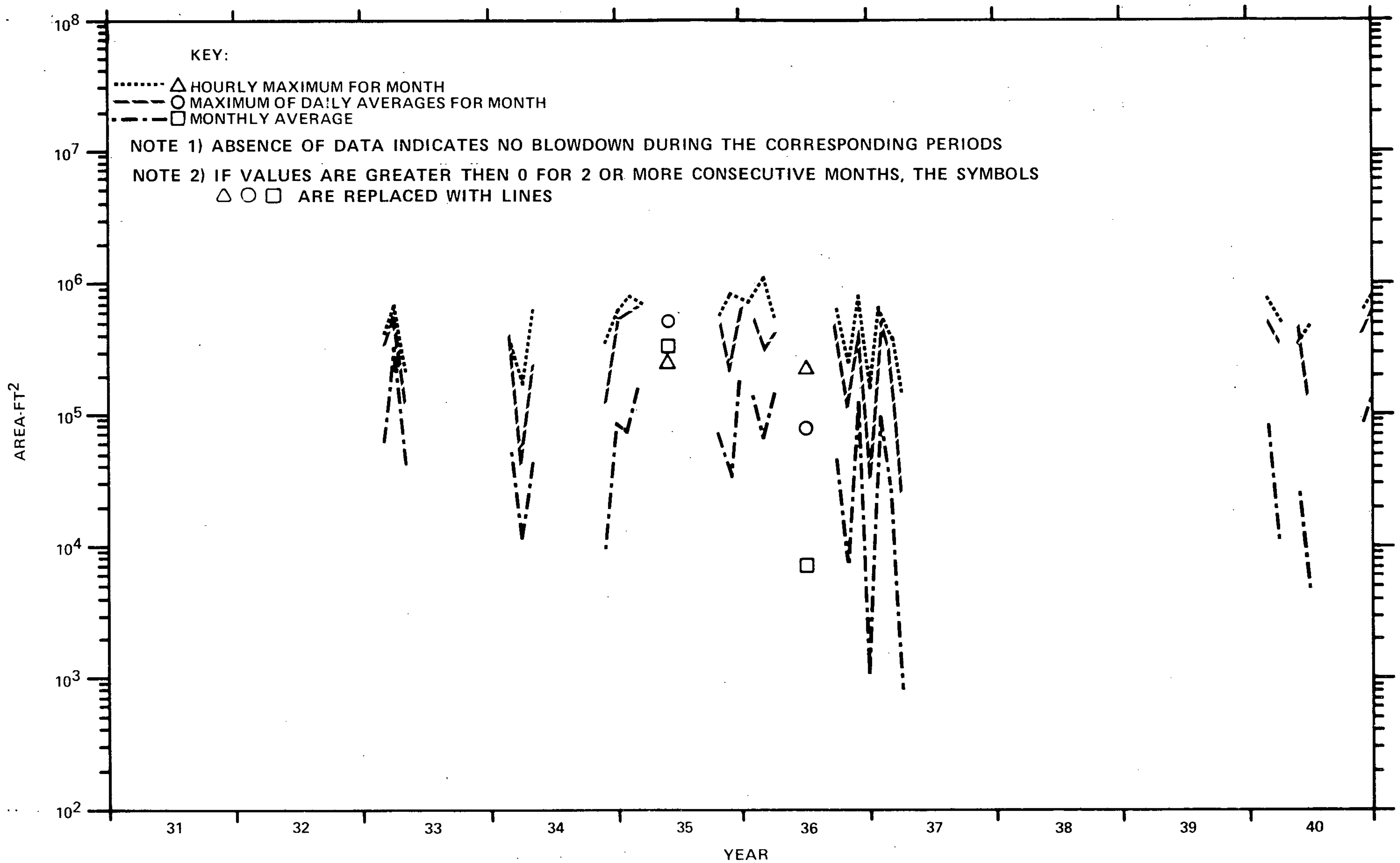
FIGURE 5.1-34



SOUTH TEXAS PROJECT
UNITS 1 & 2

RIVER AREAS WITH EXCESS TEMPERATURE ≥1.0°F
(SHEET 2 OF 3)

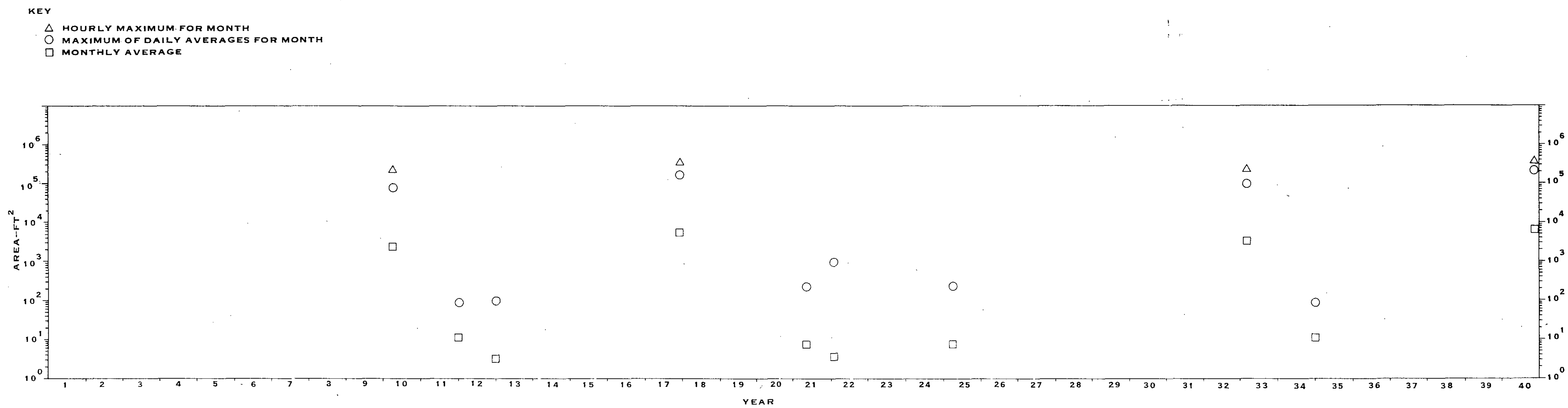
FIGURE 5.1-34



SOUTH TEXAS PROJECT
UNITS 1 & 2

RIVER AREAS WITH EXCESS TEMPERATURE ≥1.0°F
(SHEET 3 OF 3)

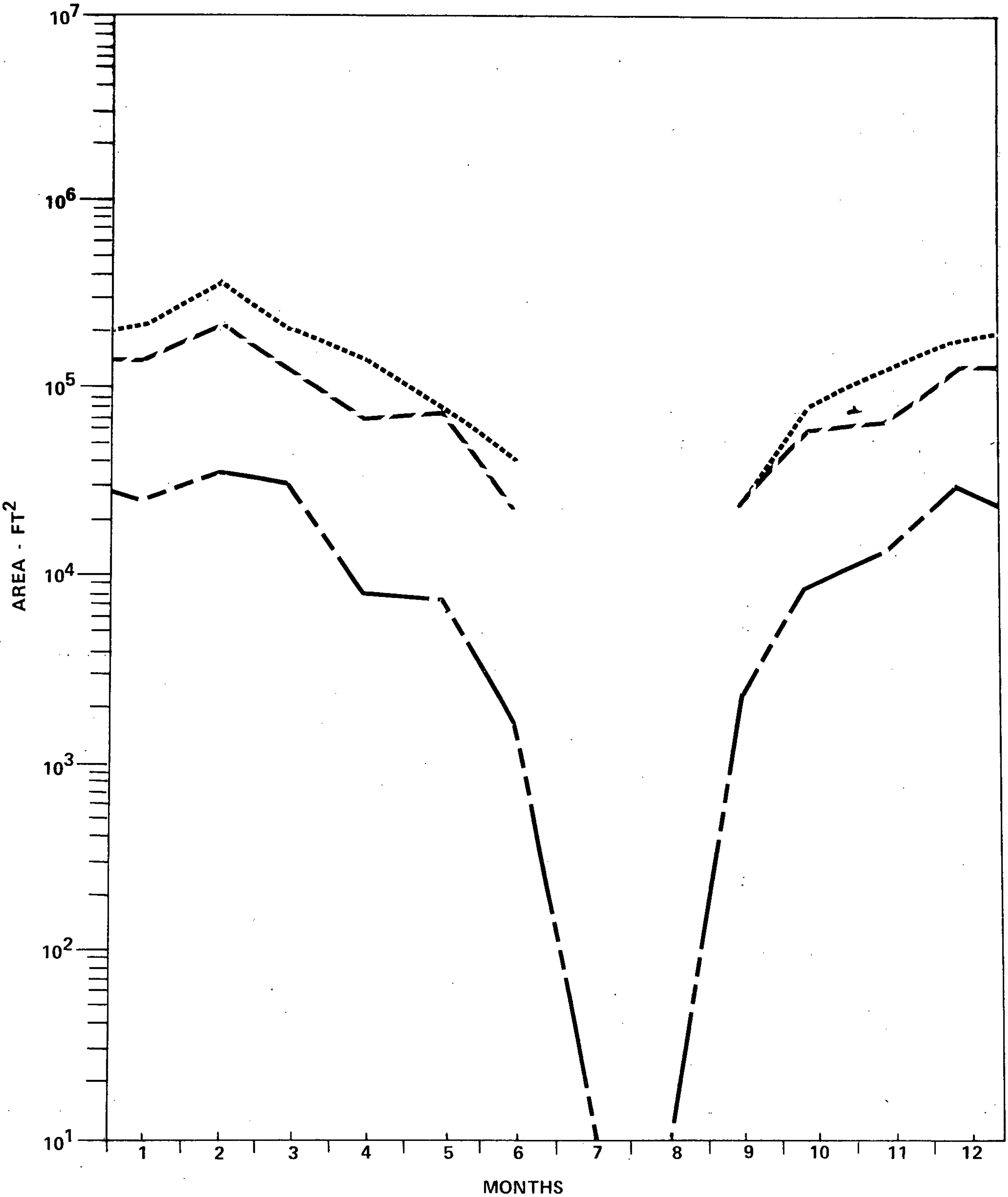
FIGURE 5.1-34



SOUTH TEXAS PROJECT
UNITS 1 & 2

AREAS OF RIVER WITH EXCESS TEMPERATURES GREATER THAN OR EQUAL TO 1.5°F, A(1.5), FOR THE FORTY YEARS OF PLANT OPERATION

FIGURE 5.1-35



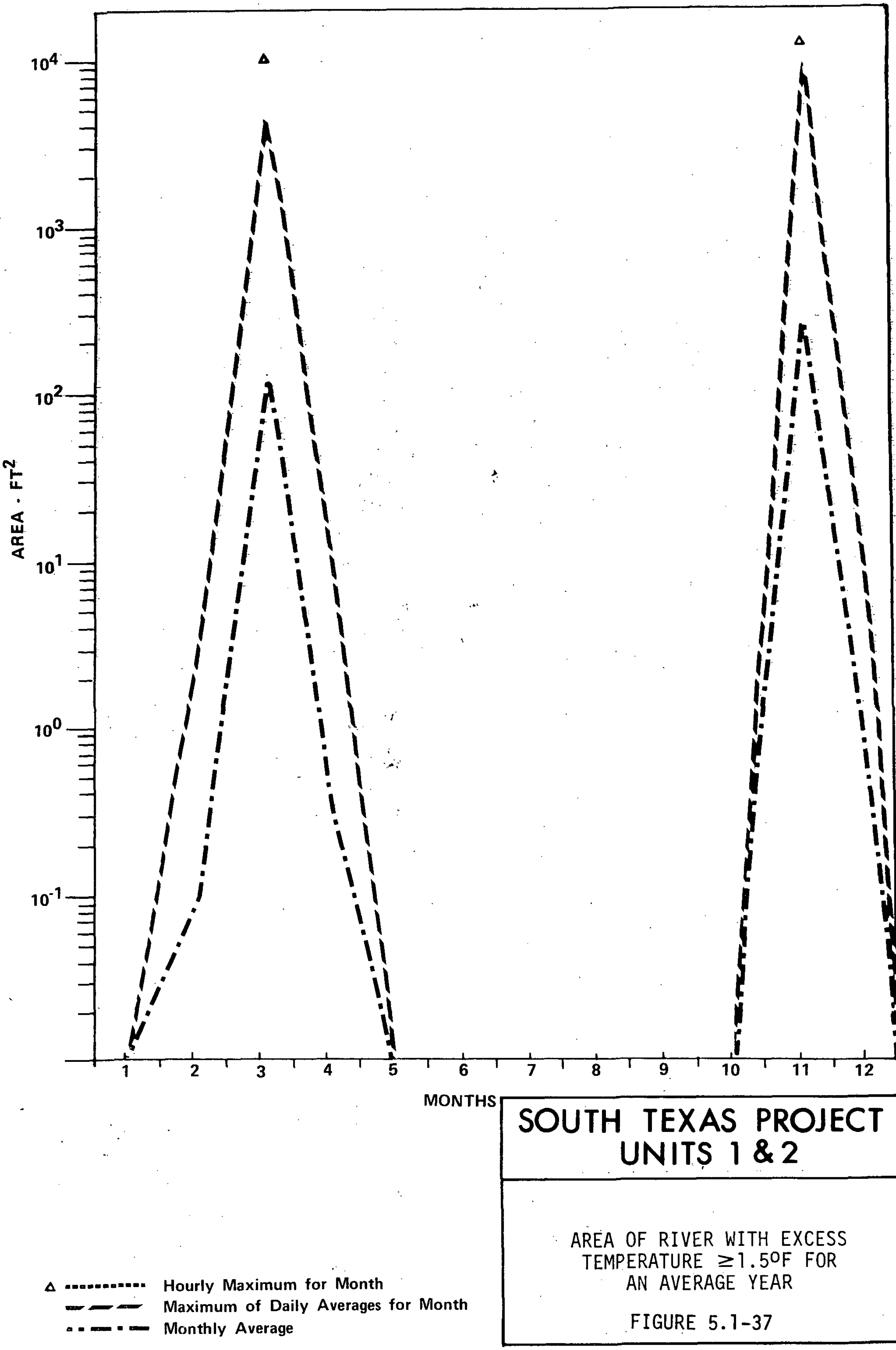
AVERAGING PERIOD = 40 YEARS

Hourly Maximum for Month
Maximum of Daily Averages for Month
Monthly Average

SOUTH TEXAS PROJECT UNITS 1 & 2

AREA OF RIVER WITH EXCESS TEMPERATURE ≥ 1°F FOR AN AVERAGE YEAR

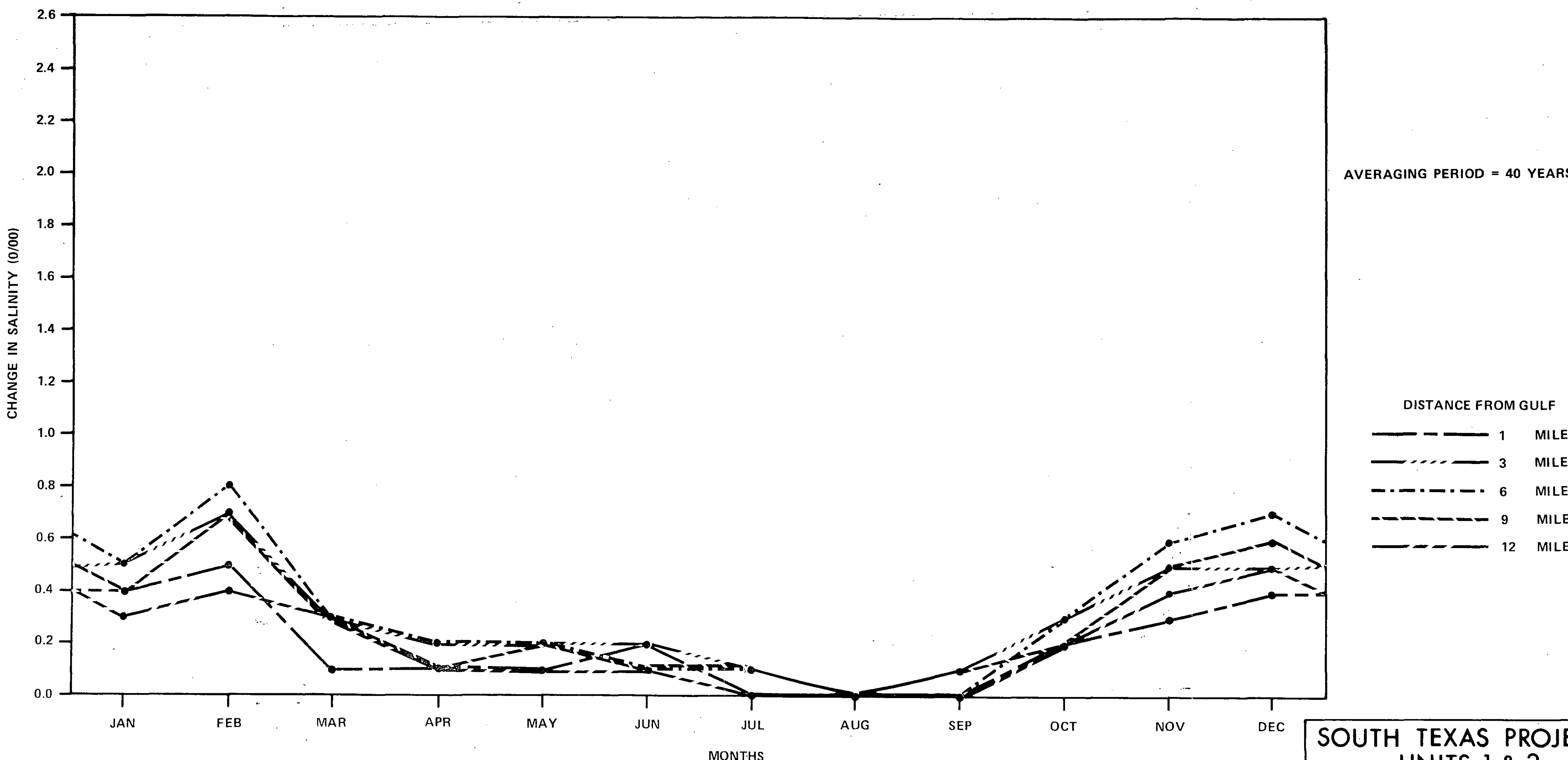
FIGURE 5.1-36



SOUTH TEXAS PROJECT
UNITS 1 & 2

AREA OF RIVER WITH EXCESS TEMPERATURE ≥1.5°F FOR AN AVERAGE YEAR

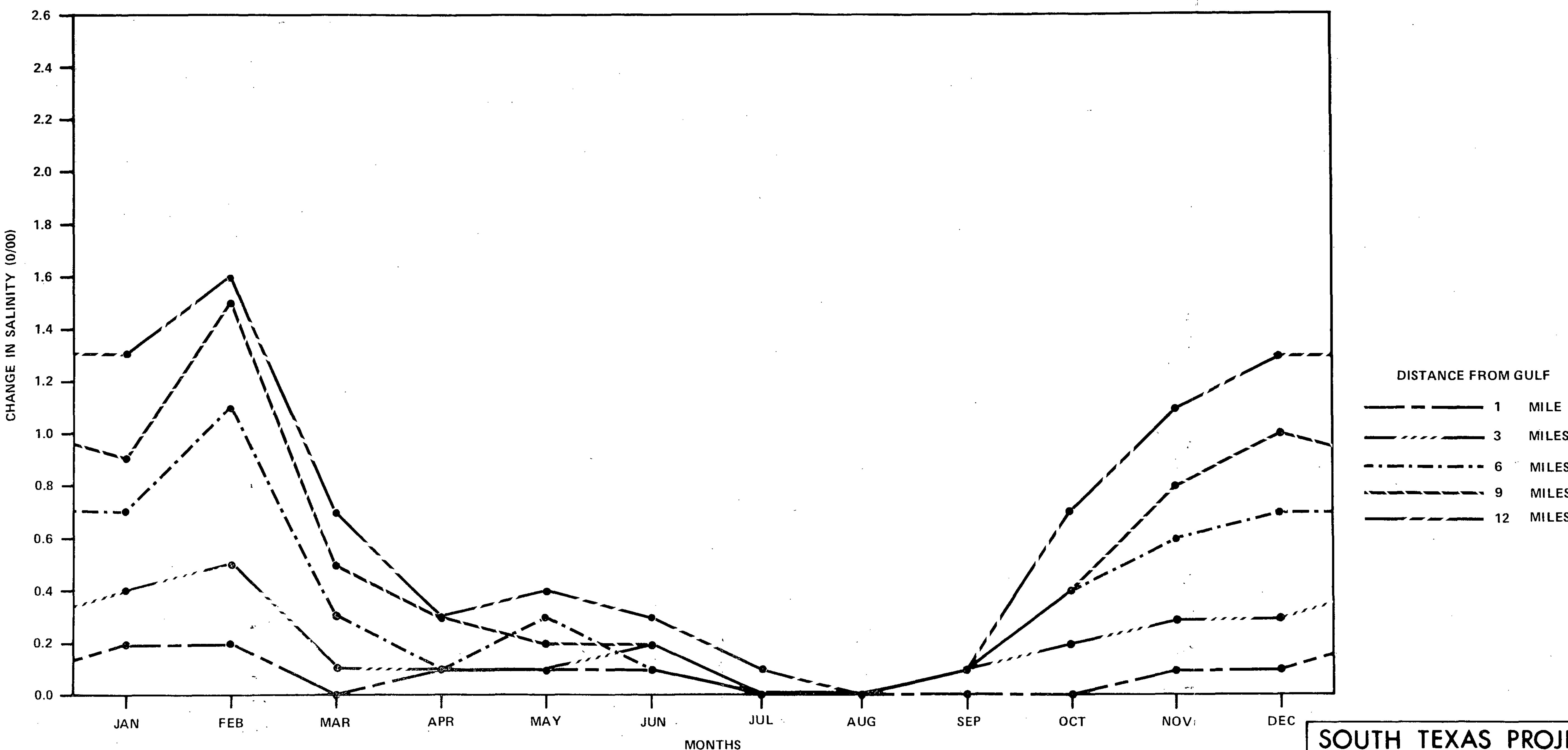
FIGURE 5.1-37



SOUTH TEXAS PROJECT
UNITS 1 & 2

AVERAGE MONTHLY CHANGE IN SALINITY RESULTING FROM PLANT OPERATIONS
DEPTH: 0-4 FEET

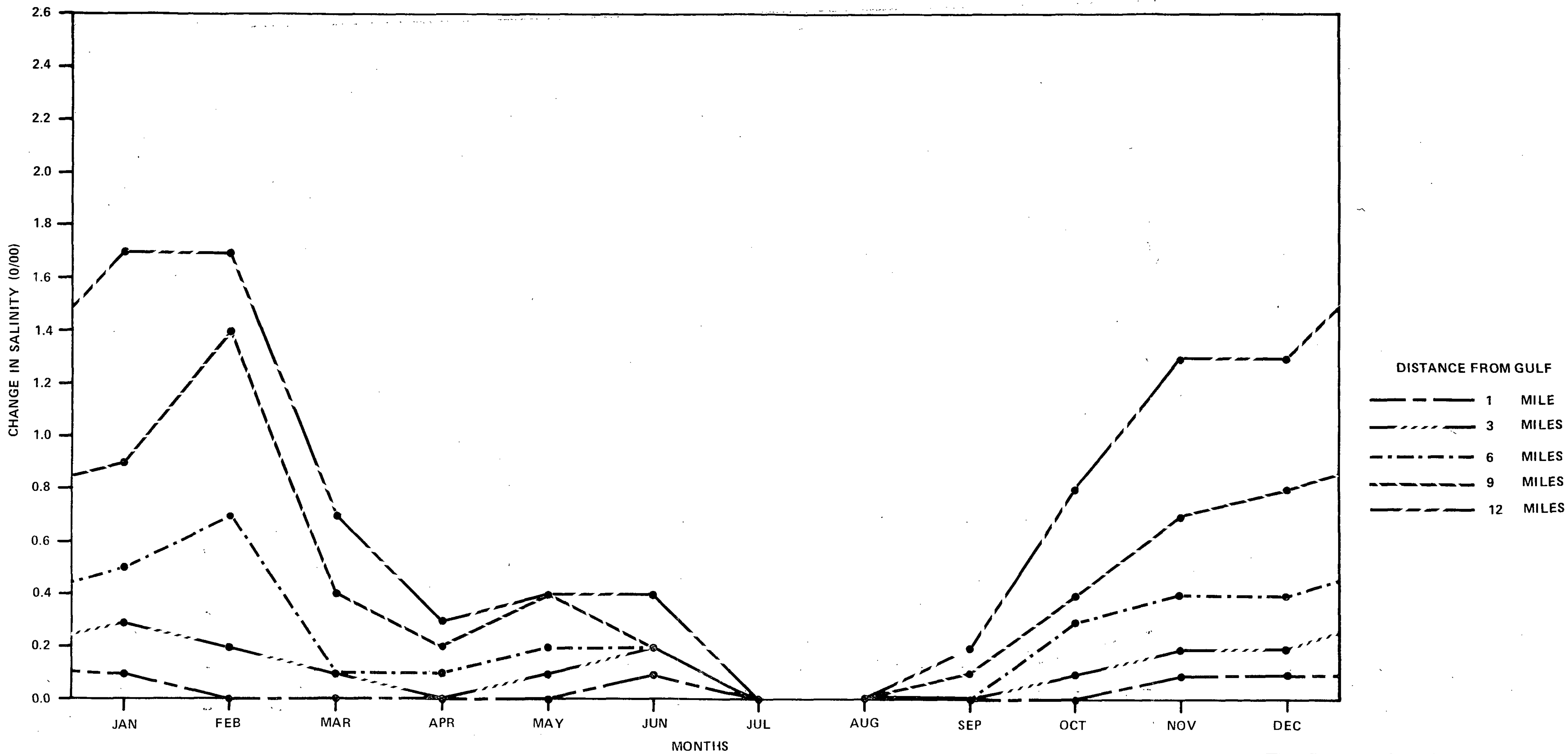
FIGURE 5.1-38



SOUTH TEXAS PROJECT UNITS 1 & 2

AVERAGE MONTHLY CHANGE IN SALINITY RESULTING FROM PLANT OPERATIONS
DEPTH: 8-16 FEET

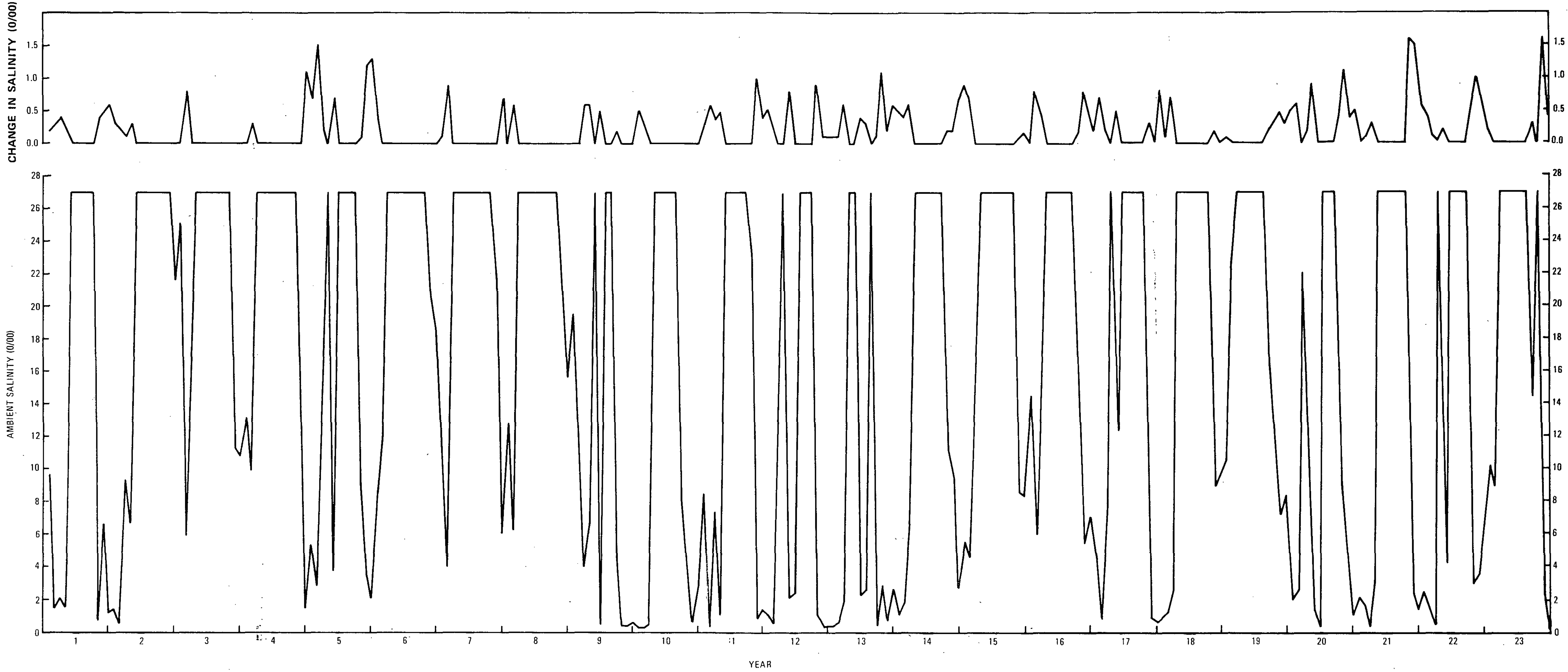
FIGURE 5.1-39



SOUTH TEXAS PROJECT
UNITS 1 & 2

AVERAGE MONTHLY CHANGE IN
SALINITY RESULTING FROM
PLANT OPERATIONS
DEPTH: 16 FEET

FIGURE 5.1-40

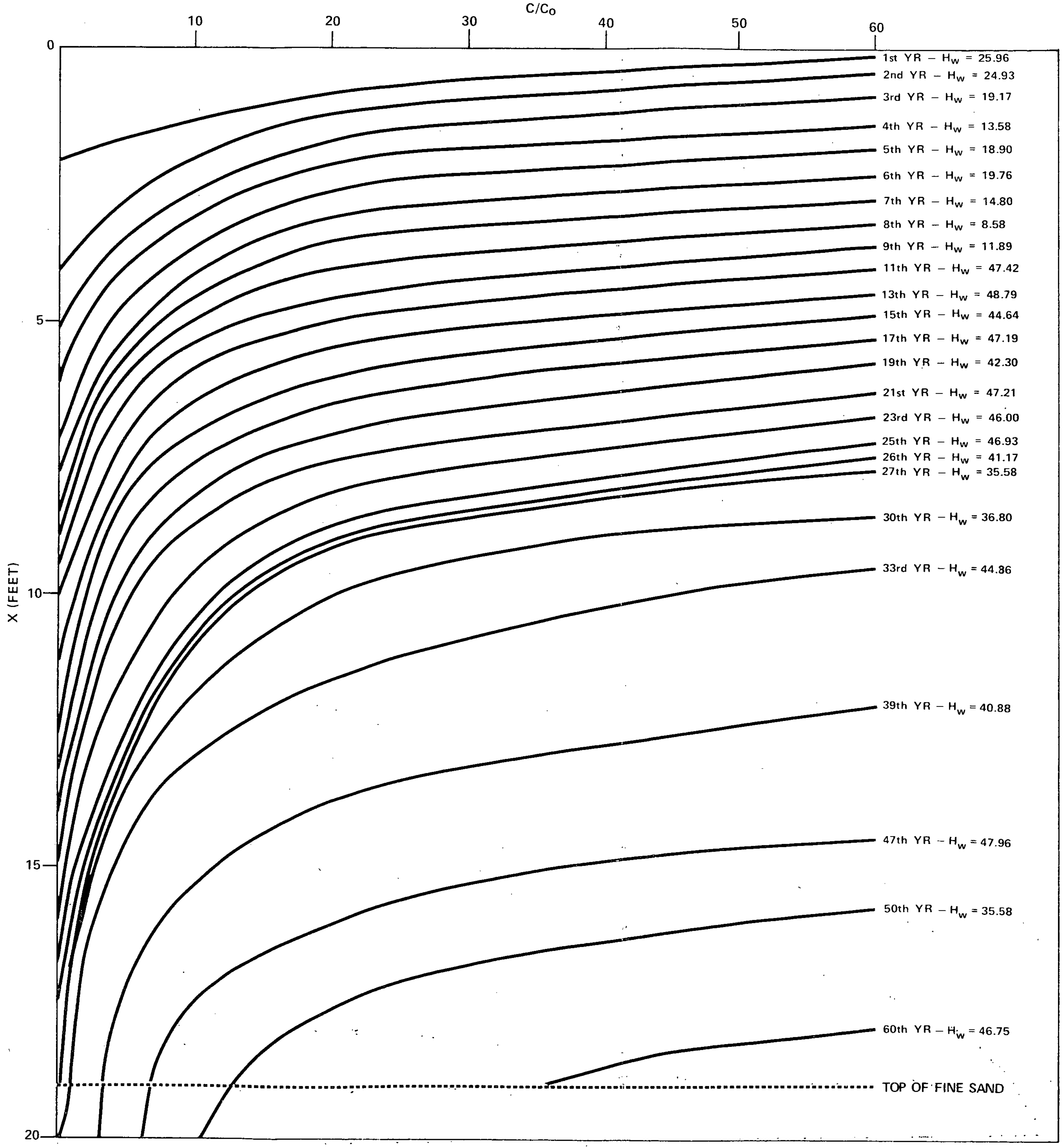


DEPTH: 0 – 4 FEET
LOCATION: RIVER MILE 12

SOUTH TEXAS PROJECT
UNITS 1 & 2

MONTHLY AVERAGE AMBIENT SALINITIES AND SALINITY CHANGES OVER 23 YEARS

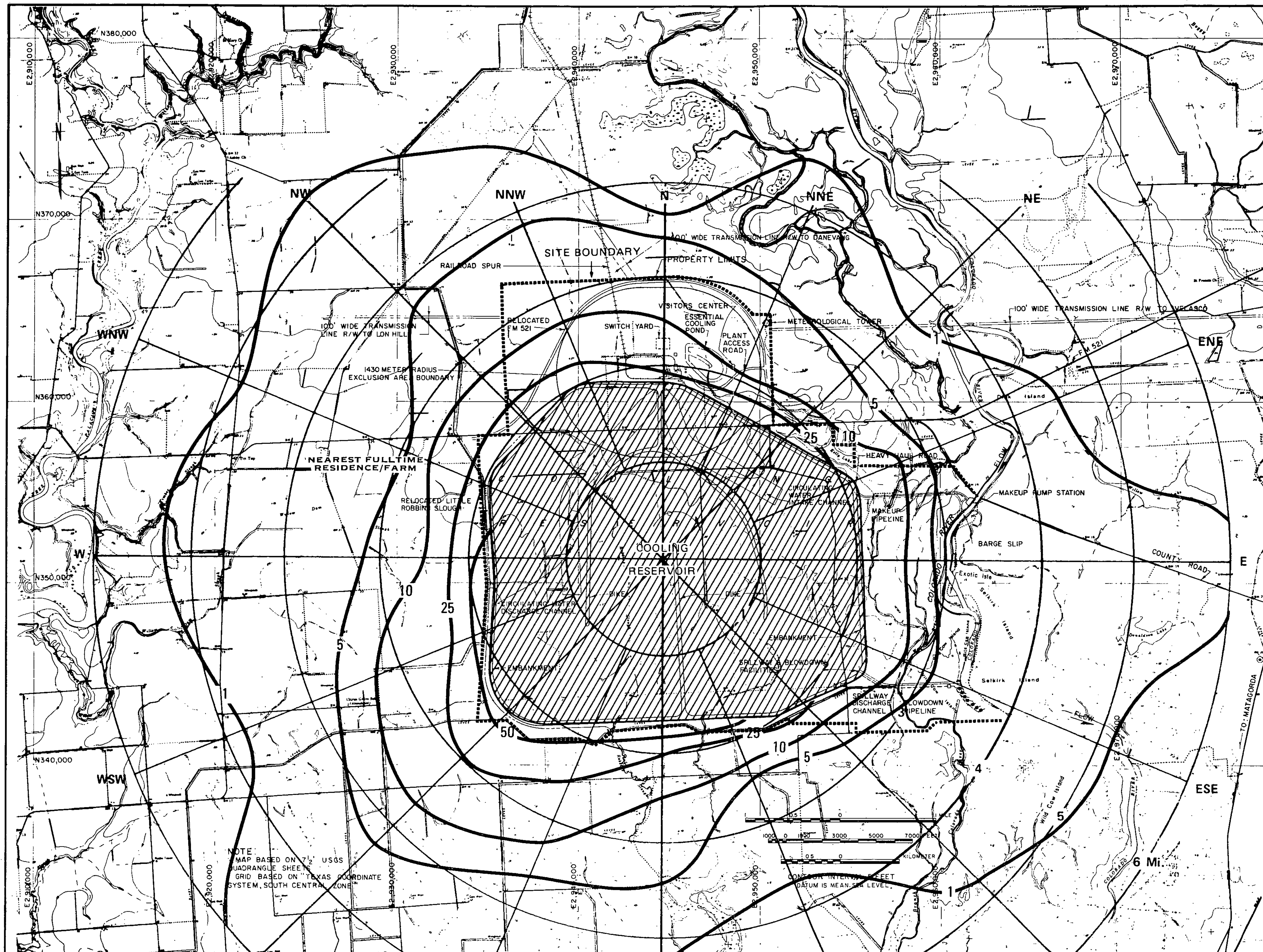
FIGURE 5.1-41



SOUTH TEXAS PROJECT
UNITS 1 & 2

GROUNDWATER CONTAMINATION AS A FUNCTION OF POSITION AND TIME

FIGURE 5.1-42

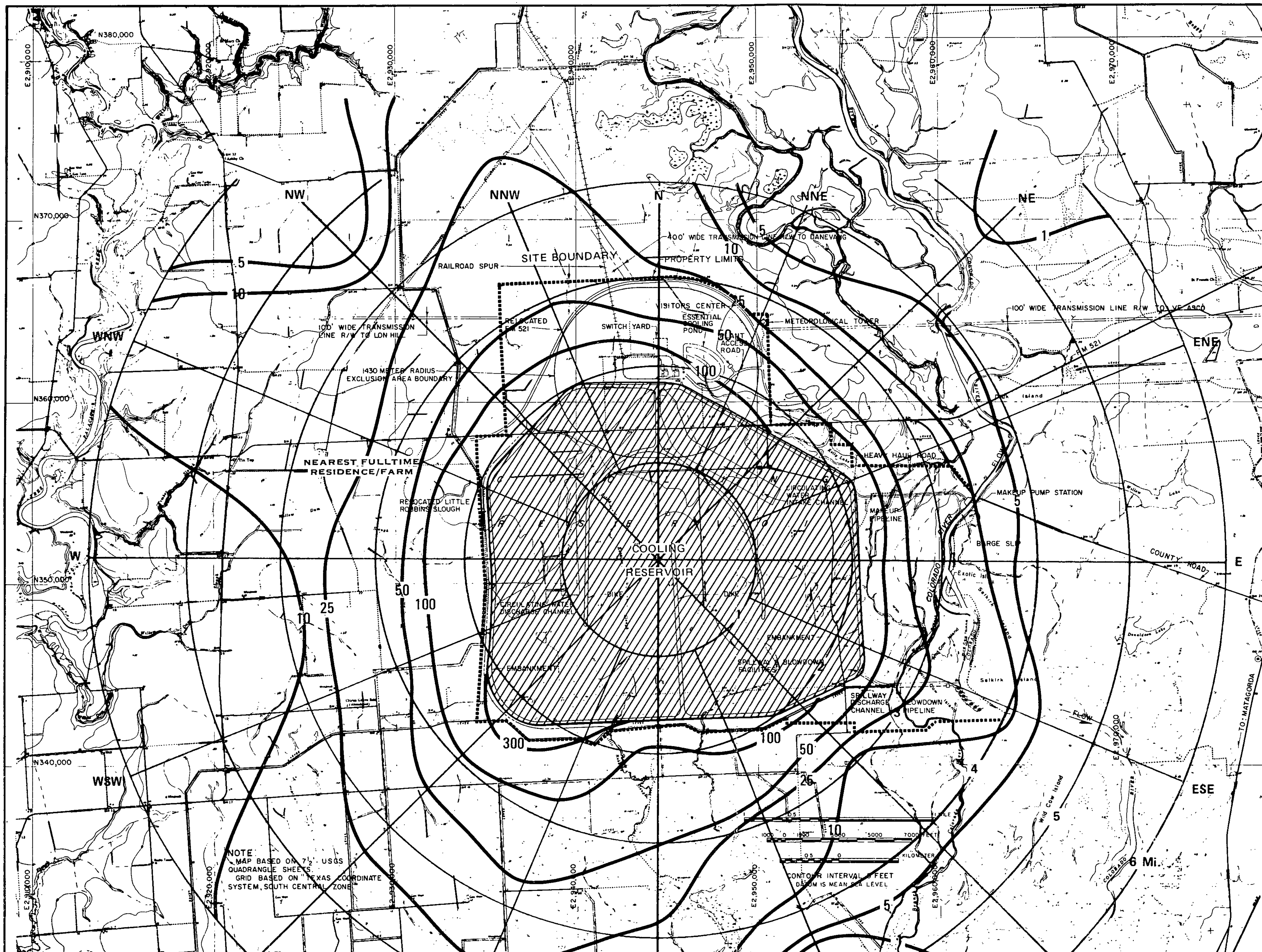


Amendment 7, June 6, 1975

SOUTH TEXAS PROJECT UNITS 1 & 2

OCCURRENCE OF GROUND-LEVEL REDUCED VISIBILITY (1000 METERS) HOURS/YEAR COOLING RESERVOIR

FIGURE 5.1-43



Amendment 7, June 6, 1975

SOUTH TEXAS PROJECT UNITS 1 & 2

OCCURRENCE OF ELEVATED VISIBLE PLUMES, HOURS/YEAR, COOLING RESERVOIR

FIGURE 5.1-44

5.7.2 CHANGES IN WATER USE

Water for consumption by STP is withdrawn from the excess unappropriated water in the estuarine portion of the Colorado River. At present, the Colorado River water below the Fabridam impoundment near Bay City, Texas (see Figure 2.5-2) in the area where the STP makeup will be withdrawn is used for some irrigation (see Section 2.2). The method of withdrawal is expected to result in a minimal change in water use by off-site Colorado River water users. This method removes water from the Colorado River only after all water users, both upstream and immediately across the river from the site, have had the opportunity to obtain their full water allotments.

Potable and service water will be drawn from wells as described in Section 3.3. The effect of continuous pumping of site wells on local offsite wells was investigated using the Theis equation[1] for pumping at a constant rate from an extensive confined aquifer. This aquifer is not hydraulically connected to the shallow aquifer zone as discussed in Section 2.5.2.1. The Theis equation is as follows:

$$s = \frac{114.6Q}{T} W(u)$$

Where

s = drawdown (feet)
Q = well discharge (gpm)
T = coefficient of transmissibility (gpd/ft)
$W(u)$ = well function 7

The argument of the well function[1] W(u) is as follows:

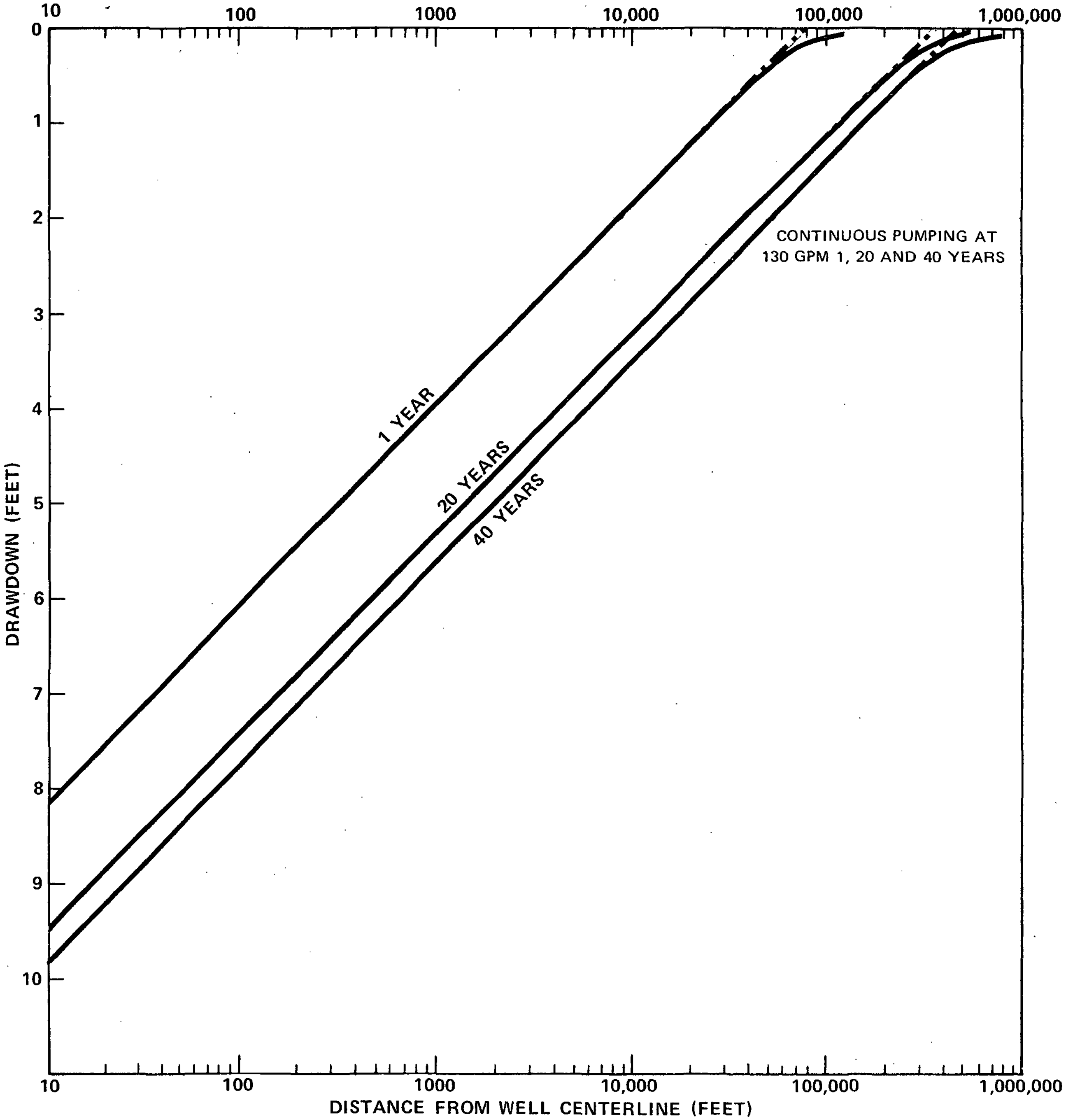
$$u = \frac{1.87r^2S}{Tt}$$

Where

r = distance from center line of well (ft) 7
S = storage coefficient
t = pumping time (days)

Calculations were made for pumping rates of 130 gpm and 560 gpm; 130 gpm represents the average pumping rate over the life of the plant and 560 gpm represents the peak pumping rate. The results are shown in Table 5.7-1 and in Figures 5.7-1 and 5.7-2. The radius of influence is obtained by extrapolating the linear portion of the curves to a drawdown of 0 feet. The results are shown in Table 5.7-2.

As discussed in Section 2.5, the deep-water aquifer at the site is located at approximately (-) 260 feet MSL and has a normal piezometric level of approximately (-) 20 feet MSL. The piezometric head is approximately 240 feet. As shown in Figure 5.7-2, the maximum drawdown at a distance of 7
10 feet from the site well is approximately 42 feet after 40 years of continuous pumping at the peak pumping rate of 560 gpm. Thus, the cone of depression does not intercept the aquifer. The drawdown at 0.5, 1, 2 and 5 miles from the site well will be approximately 21, 17, 15 and 12 feet, respectively. Thus, wells located at 0.5, 1, 2 and 5 miles from the site well will have a piezometric head of 219, 223, 225 and 228 feet, respectively, as compared to the original piezometric head of 240 feet. This small decrease in piezometric head will require additional energy to lift the water but will not decrease the yield of offsite wells. A more realistic estimate of drawdown over the plant life is to consider the average pumping rate of 130 gpm. The drawdown at 10 feet and at 0.5, 1 and 2 miles from the site well will be approximately 10, 5, 4 and 3 feet.

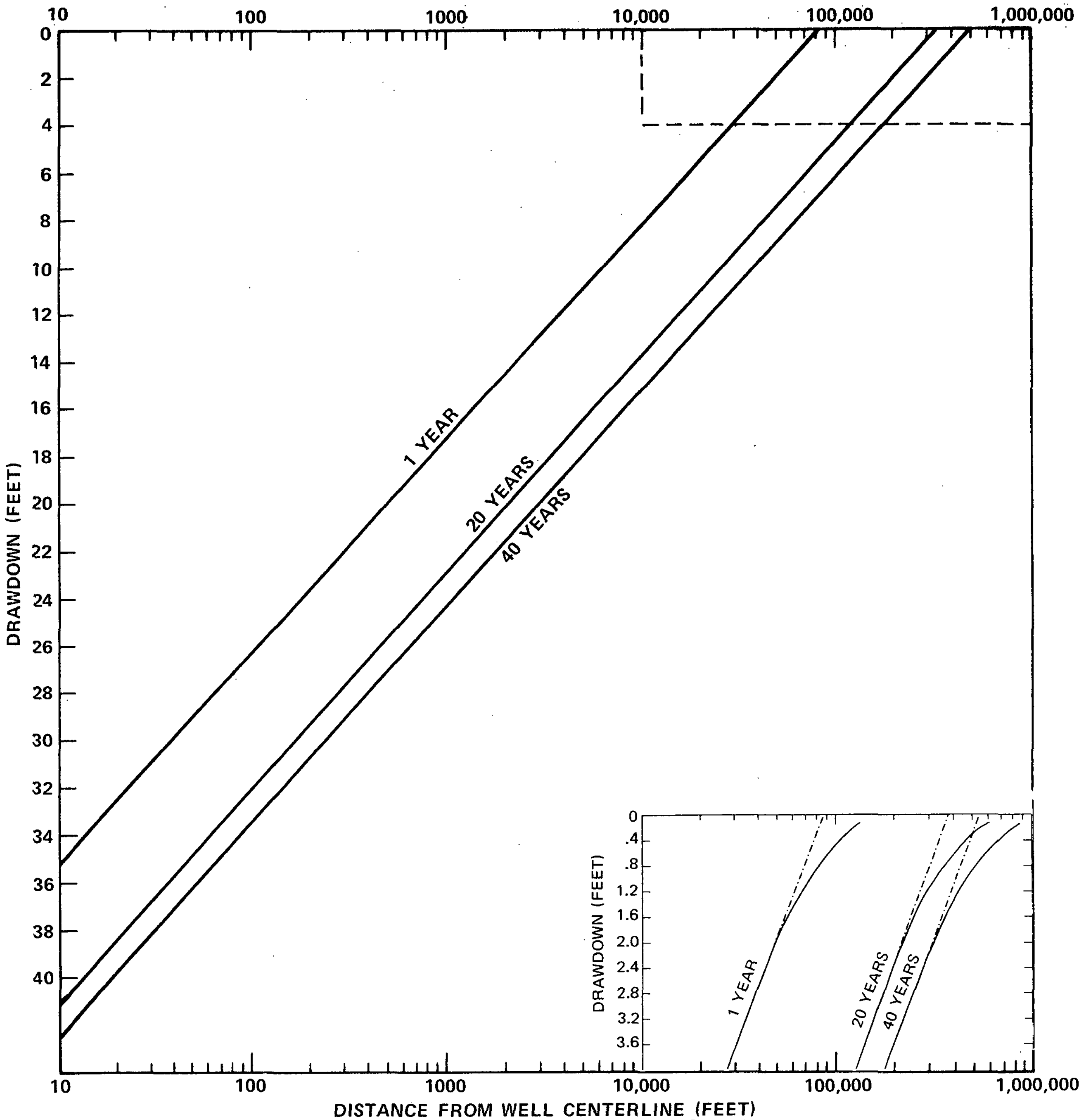


Amendment 7, June 6, 1975

SOUTH TEXAS PROJECT
UNITS 1 & 2

CONTINUOUS PUMPING AT 130 GPM
FOR 1, 20 AND 40 YEARS

FIGURE 5.7-1

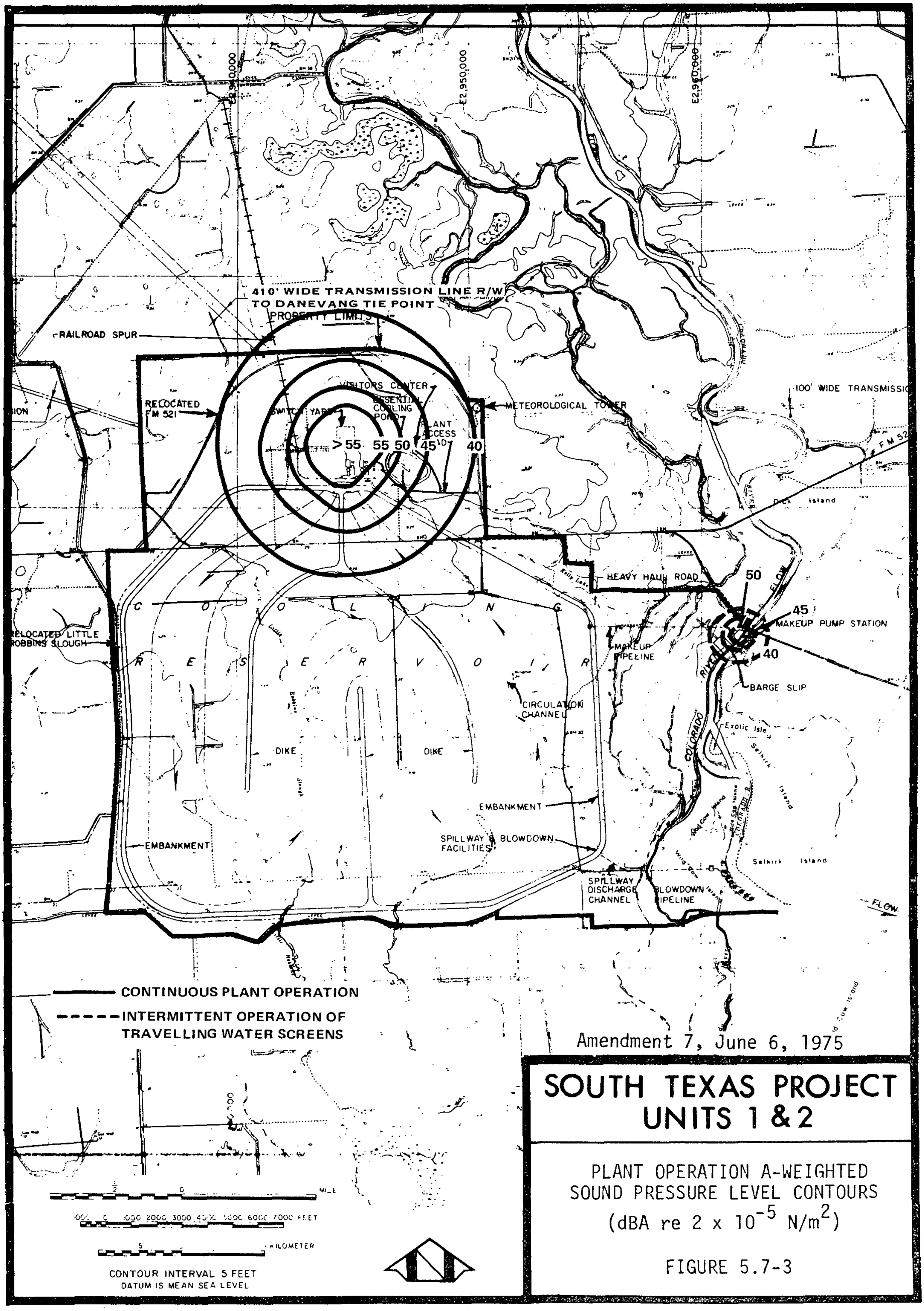


Amendment 7, June 6, 1975

SOUTH TEXAS PROJECT
UNITS 1 & 2

CONTINUOUS PUMPING AT 560 GPM
FOR 1, 20 AND 40 YEARS

FIGURE 5.7-2



Amendment 7, June 6, 1975

SOUTH TEXAS PROJECT
UNITS 1 & 2

PLANT OPERATION A-WEIGHTED
SOUND PRESSURE LEVEL CONTOURS
(dBA re 2×10^{-5} N/m^2)

FIGURE 5.7-3

SOUTH TEXAS PROJECT

UNITS 1 & 2

ENVIRONMENTAL REPORT

VOLUME 5

6.1 APPLICANTS PREOPERATIONAL ENVIRONMENTAL PROGRAMS

6.1.1 SURFACE WATERS

To adequately predict and evaluate the environmental impact of South Texas Project (STP) Units 1 and 2 on associated surface waters, a program designed to provide pertinent chemical, physical, and biological baseline data was initiated in June, 1973. This program involves an intensive effort to gather previously existing data and a field survey program to supplement existing data. Available information from various state and federal agencies and from scientific literature relative to the STP site and the surrounding region are reviewed in Sections 2.5 and 2.7.

Data gathered through this program provides the bases for estimating environmental impact of various plant systems, when operational, on ecological parameters of associated surface waters. Water temperature and salinity are the only parameters with potential lethality that could be modified by STP plant discharges. As the STP plant discharge will be the only discharge in the area which will affect these parameters, there will be no interactive effects of multiple discharges.

The following discussion addresses methods used in the field study program and procedures used in evaluating data obtained. 7

6.1.1.1 Physical and Chemical Characteristics

Water survey sampling is divided into two schedules. Major physical and chemical water quality characterization surveys (see Table 6.1-1) are conducted on a quarterly basis and minor physical and chemical water quality characterization surveys (see Table 6.1-2) at monthly intervals between major surveys. All stations shown on Figure 6.1-1 and discussed in Section 2.7 of this report are sampled during both major and minor surveys, with the exception of station 16 which is sampled only during major surveys. Two water quality parameters not listed in Tables 6.1-1 and 6.1-2, bacteria and chlorophyll a, are scheduled for major surveys only. However, during June-September, bacteria samples were taken on a monthly basis.

Although station 15 (open Gulf) is scheduled for monthly surveys, it was not possible to sample this station during June or September due to unfavorable weather conditions and/or interruption of boat traffic from the Colorado River to the Gulf by the buildup of sand bars at the mouth of the river and subsequent filling of the river channel.

6.1.1.1.1 Physical Parameters

Physical parameters measured during major and minor physical and chemical water quality characterization surveys include water temperature, specific conductance, pH, dissolved oxygen, turbidity, color, and odor.

Odor is measured only during major surveys; all other physical parameters are measured during both major and minor surveys. Color and odor are determined in the laboratory from water samples collected in the field. Turbidity is determined in the laboratory each month and also in the field during major aquatic surveys.

Specific conductance, salinity, pH, temperature, and dissolved oxygen are determined in the field at each sampling station at two depths (surface and bottom). Additional measurements of specific conductance and salinity, at vertical intervals of approximately 3 feet, are taken when the presence of a salt-water tidal wedge is noted. This is indicated by wide ranges in conductivity and salinity between surface and bottom measurements.

Specific conductance is measured with a Beckman Solu-Bridge conductivity meter, model RB3-334I (±2 percent). This instrument, equipped with conductivity probe, model CEL-VS02-2VH20-KP-X10, provides temperature-compensated (to 25°C) conductivity measurements over the range 40 to 400,000 micromhos/cm. The conductivity cell is calibrated with standard solutions before and after each field survey to determine drift.

Salinity is determined with a Beckman Electrodeless Induction Salinometer, model RS5-3. This instrument provides salinity measurements over the range 0-40 $^{o}/_{oo}$ (±0.3 $^{o}/_{oo}$); conductivity measurements over the range 0-60 millimhos/cm (±0.5 millimhos/cm); and temperature measurements over the range 0-40°C (±0.5°C).

Periodic checks on calibration of the instrument are made in the field with a fixed resistor. Before and after each field survey the instrument is calibrated against known standards.

The pH is determined using a Leeds & Northrup model 7417 pH/Specific Ion/mV meter (±0.1 units). This instrument is field calibrated daily with standard buffer solutions. Subsurface water samples are obtained using an all-plastic Kemmerer water sampler.

Dissolved oxygen is measured at the time of water chemistry sample collection using a YSI (model 51A) DO meter and probe (±0.2 ppm). This instrument is field calibrated daily using Hach chemistry for modified Winkler technique and a mercury thermometer.

In addition to the above instruments, a portable water quality monitor is used during major surveys. This instrument is a model RM925 Robot Monitor manufactured by the Schneider Instrument Company, Cincinnati, Ohio. This instrument is used to measure the following parameters on a continuous horizontal basis.

1. Temperature
2. DO
3. pH
4. Turbidity
5. Chloride
6. Conductivity

Water is pumped separately from two depths, surface then bottom, through the monitor to obtain measurements of the above parameters.

Additional measurements of surface and bottom water temperature, specific conductance and dissolved oxygen and surface pH are obtained monthly during the biological sampling at each station.

6.1.1.1.2 Chemical Parameters

Triplicate water samples for chemical analysis of parameters indicated in Table 6.1-3 acquired at each sampling station from two depths, surface and bottom, with a submersible pump. Exceptions exist at stations 12 and 13 where very shallow water (<4 feet) frequently dictates that only surface samples be taken. It is assumed that complete mixing of the water column occurs at these shallow water stations due to turbulence generated by tidal currents and wave action. Three 6.5-gallon plastic carboys are filled one at a time as the research vessel makes three consecutive passes along the transect.

All water chemistry samples were obtained on the same date during September, October, January, March, April and May. Two consecutive days were required during June, July, December and February, while three consecutive days were required in August and November. 2

Station 13 (Figure 2.7-5) is located in Matagorda Bay at the mouth of a narrow (30 ft.), shallow (1-4 ft.) outlet from Parker's Cut to Matagorda Bay. A small channel extends into the bay for a short distance before shallow water is reached. Samples are taken in the channel proper as low tides frequently F-15 2 result in complete drainage of the alluvial sand and mud flats around the channel. The channel itself is normally so shallow that, once instrument probes are situated for surface measurements, they are also situated for bottom measurements. Thus, only one measurement is taken. Deeper waters (3-4 ft.) exist in the channel only during periods of heavy runoff or high tides. During either condition, strong and turbulent flow has always been observed at this stationand it has been assumed that the water column is vertically mixed.

Station 12 is similar to station 13, but in a slightly wider and deeper channel at the mouth of Culver's Cut where it empties into Matagorda Bay. There is generally less turbulent flow at station 12 than at station 13. Some surface-bottom data do exist for station 12 which substantiate that the water column is vertically mixed (June, July, August, October) during
periods of flow, whether runoff or tidal induced. Thus, during F-15
both low and high water conditions, the water column is vertically mixed, if flow exists. There are similar data (November and December) which indicate that during slack water conditions, the water column is not vertically mixed. Measurements made under these conditions at both surface and bottom show that exceptions exist when the water is too shallow to allow adjustment of probe position as at station 13.

Available surface-bottom field measurements of temperature,
dissolved oxygen, salinity and conductivity for STP sampling 2
station 12 are given below.[66]

	Temp °C		D.O.		Sal.		Cond.	
Month	S	B	S	B	S	B	S	B
June	28 -	28			14.4 -	14.4	25,000 -	25,000
July	32 -	31			7.8 -	7.9	15,000 -	15,000
Aug	31 -	32			8.0 -	7.8	15,220 -	14,700
Oct	25 -	24	9.0 -	7.6	0.05 -	0.8	976 -	1,520
Nov	19 -	20			7.8 -	13.2	12,050 -	19,700
Dec	17 -	16	9.3 -	9.3	8.6 -	11.6	12,700 -	15,900

Contents of each carboy are mixed by agitation and transferred by means of a spigot to properly labeled sample bottles. Labels bear sufficient information to identify the sample as to location, replicate number, time and date of collection, and sample type. Perishable samples such as BOD and bacteria are immediately stored on ice and transported to a local analytical lab for processing. Other samples, containing appropriate stabilizing agents, are stored without refrigeration and shipped to an analytical laboratory. Preservatives, holding time, and analytical techniques for each parameter are as specified in the methods referenced in Table 6.1-3. Water samples are filtered (Millipore, 0.45 micron) in the field for chlorophyll a analysis.

6.1.1.1.3 Calculational Models

Three major calculational models have been used to assist in predicting the effect of plant operation upon the physical/chemical characteristics of the Colorado River.

The salinity distribution within the estuary portion of the river has been predicted for both ambient and plant operating conditions using an empirical model, designated "SALTY", which is based upon observed salinity distributions. The basis and complete description of the model are given in Appendix 6.1-A entitled "An Empirical Model for the Determination of Salinity Distributions in the Lower Colorado River."

The excess temperature distribution in the Colorado River resulting from the discharge of the reservoir blowdown is predicted using a model, designated MUDSUB, based on the work of Koh and Fan.[1] The model has been modified to adequately treat the water surface and river bottom boundary conditions which are present at the STP site. A detailed description of the model is given in Appendix 6.1-B, entitled "Mathematical Dispersion Models for Heated Discharges."

A mathematical model was used to estimate the tidal flow and stage variations in the Colorado River near the proposed discharge point of the reservoir blowdown. Specifically calculations have been carried out for one complete tidal cycle to determine the temporal variations of the longitudinal vertically integrated tidal/river flow at River Mile 12.5 (R.M. 12.5) for a range of gaged inflows up to 3,500 cubic feet per second (cfs).

To describe the hydrodynamic response along the length of the Colorado River under varying tidal inputs and river inflows, a numerical two-dimensional (area-wise) tidal hydrodynamic model (HYDTID[2]) has been employed. This model solves explicitly the basic unsteady equations of motion in two orthogonal directions coupled with the unsteady flow continuity equation. A basic assumption of this model is that vertical velocity distributions are uniform and hence, computed flows are integrated over the depth. Since application of HYDTID to the STP site involved flow in only one direction (longitudinal), the computer code was restructured to more efficiently solve this one-dimensional problem. The only modification to the HYDTID model as applied to the Colorado River was to input values for lateral parameters which would result in uniform conditions across the width of the river. 2

F-15

The HYDTID model has been verified using prototype data from the San Antonio-Espirito Santo Bays. A detailed description 2
of the verification is given in Chapter V (pages 40-53) of the referenced report. F-15

The HYDTID model uses a series of interconnected square elements to describe to physiography of a prototype system with the basic equations applied and solved over this grid arrangement. The model was adapted to handle rectangular elements to more effectively describe the river system. The length of these elements was specified as one-half mile (2,640 feet) and the width was varied between 150 and 185 feet as a function of river inflow. Average mean sea level bottom depths were assigned to each element based on profile data.

6.1.1.1.4 Continuous Measurement System

The conductivity of the Colorado River is expected to show both long term variations, dependent on the concentrations and nature of the chemicals present, and short term fluctuations due to the intrusion of saline water from the Gulf of Mexico. Short term fluctuations in temperature, flow, and current direction are also expected. To measure the rate and extent of fluctuations, a continuous measurement system to monitor conductivity, temperature, and stream flow direction and velocity has been installed in the Colorado River. Data from the continuous monitoring program, will be used in confirming predictions made with mathematical models of the mixed quality of intake water from the lower Colorado River and the consequent blowdown composition. The monitoring system will also verify predictions of dispersive characteristics near the discharge point of the STP plant and predictions of the dilution profiles of the near field discharge plume region and the farfield estuary.

The monitoring system consists of four stations, A, B, C, and D (see Figure 6.1-2). All stations are capable of continuously determining temperature and conductivity. Additionally, three of the four locations (stations A, C, and D) have the capability of recording river level and one station (station C) river flow. Temperature and conductivity are monitored at three water depths at stations B, C, and D. At station A they are monitored at only two depths because of the water shallowness.

The temperature sensors are the Thermistor-Sensitor, model RM-25, manufactured by the Scheider Instrument Company, Cincinnati, Ohio. These sensors measure over the range 0-50°C with an accuracy of ±0.5°C, full-scale:

Beckman direct reading electrodeless conductivity meters (Solu Meter), models SMS 905 and SMS 950, are used for conductivity measurements. Each element has automatic temperature compensation, a cell constant of 0.75/cm, and accuracy of ±3 percent, fullscale. Dual conductivity channels are used at each water depth for each station. The low-range channels (model SMS 905) a range of 0-5,000 micromhos/cm and the high-range channels (model SMS 950) a range of 0-40,000 micromhos/cm.

For flow measurements, the Marsh-McBirney Electromagnetic Water Current Meter (model 711) was selected. This instrument propagates an electromagnetic field which is sensed on dual flow-measuring axes and will measure water flow velocities up to 10 fps on each axis. The overall accuracy of the instrument is composed of four factors:

1.	Long term zero drift	Less than $\pm$ 0.07 fps
2.	Linearity of response	$\pm$ 2 percent of reading
3.	Wideband electronic noise	$0.03/\sqrt{T}$ rms fps Where T is the output time constant expressed in seconds (standard value is one second)
4.	Absolute calibration	$\pm$ 2 percent of reading.

The river level is monitored with a Water Level Parametric System, SIC model RM25, Scheider Instrument Company.

The subsurface sensors are cabled to wooden pilings anchored in the river, 20 feet below the river bed. Each piling is equipped with a U.S. Coast Guard (USCG) approved day marker. Prior to placement of the pilings, necessary permits were obtained from the Army Corps of Engineers and the USCG.

The sensors are hardwired to shore-based strip chart recorders by flexible shielded cabling. The cabling is enclosed in conduit which is anchored to the river bottom.

The chart recorders function as a back-up, with the primary data transfer system being a telemetry channel linked to a central data acquisition station in Pittsburgh. The shore-based chart recorders are housed in Cary-Way portable buildings equipped with air conditioning, heat, lighting and telephone.

The continuous monitor at station C became operational during the first week of January, 1974, and, at the remaining stations, during the first week of March. These monitors are expected to be in operation for a period of one to two years.

6.1.1.2 Ecological Parameters

A biological field study program is being conducted in parallel with the physical and chemical field program described in Section 6.1.1.1. This program is similarly divided into major and minor surveys. Major surveys (see Table 6.1-4) are conducted on a three-month basis and minor surveys (see Table 6.1-5) are made at monthly intervals between major surveys. All locations (see Figure 6.1-1) previously described in Section 2.7 are sampled. Just prior to plant operation aquatic sampling stations will be established in the cooling reservoir. Data collected will be used for later comparison with data collected during plant operation. The operational aquatic ecological monitoring program is discussed in Section 6.2.5.1. 8

The biological program is designed to assess the natural and seasonal variation in populations and interrelationships of fish, phytoplankton, zooplankton, ichthyoplankton and benthos by repetitive monthly sampling in several localities. Taxonomic identification of organisms are made by qualified biologists with specialties in the respective areas above, using standard and accepted local and regional taxonomic keys and other scientific literature. Bacterial populations are also being investigated using standard methods as referenced in Table 6.1-3. During each survey, visual observations were made for aquatic macrophytes. The contents of benthic and trawl samples were also observed for such plants. Since no aquatic macrophytes were observed, methodology for their study is omitted in the discussion below.

6.1.1.2.1 Plankton

Phytoplankton and zooplankton samples are obtained concurrently with the collection of water chemistry samples from two depths, surface and bottom, by use of a submersible pump. A 500-milliliter portion is refrigerated and shipped immediately to the laboratory for microscopic examination.

Three one-gallon replicate samples are fixed and preserved with acid Lugol's solution (approximately one percent final concentration). These samples are shipped to the laboratories for a detailed species composition analysis.

Additional zooplankton samples are collected using an Isaacs-Kidd high speed plankton sampler. This unit, equipped with a flowmeter is towed for 10 minutes at each station, and the sample obtained is preserved in 10 percent formalin. To further implement the sampling of planktonic organisms, a 10-inch, No. 20 mesh Wisconsin plankton net is towed for one minute at the surface to collect highly buoyant forms. This sample also is preserved in 10 percent formalin.

Ichthyoplankton and larval shrimp, crabs, and larger members of the macrozooplankton are taken with a plankton sled equipped with a half-meter, No.10 (0.5-millimeter) mesh, tapered net and an integral flowmeter which permits volumetric determinations.

The sled is towed by boat at each station at or near the bottom for five minutes, and again near the surface for five minutes. Each sample is preserved with 10 percent buffered formalin. Approximately one gram per liter of Rose Bengal is added to facilitate the sorting and identification of larval fish and eggs.

Cooled plankton samples are concentrated by centrifugation and examined at 200x and 400x for motile algae. A qualitative species list is prepared to aid in the subsequent identification of preserved phytoplankton. A similar qualitative examination is made for live zooplankton.

For quantitive enumeration of phytoplankton, a 50-milliter aliquot of the well-mixed preserved plankton sample is concentrated by centrifugation at 3,000 rpm for 10 minutes. The supernatant liquid is decanted and precipitated material is suspended in five milliliter of water. An aliquot of the concentrated sample is placed into the well of a Palmer counting chamber and all algal forms present are identified and enumerated. Hyrax mounts of cleaned diatoms are prepared to facilitate the identification to species level.

Samples collected with the Wisconsin plankton net are examined qualitatively to ascertain whether significant numbers of highly buoyant algal species were present at or near the surface.

Using a No. 20 mesh net, a 1.0-liter portion of the preserved plankton sample is filtered and allowed to settle. The zooplankers present are then identified and enumerated at 100x in a Sedgewick-Rafter cell. A 1.0-milliliter aliquot of the well-mixed sample obtained with the Isaacs-Kidd plankton sampler is examined at 100x in a Sedgewick-Rafter cell.

Samples collected with the plankton sled are hand sorted in the laboratory. Both larval fish and eggs are identified (when possible) and counted using a stereomicroscope. Following removal of larval fish and eggs, the samples are retained for the later examination for larval shrimp and crabs and other macrozooplankton. All specimens are stored in 10 percent formalin and deposited in a permanent collection of voucher specimens.

6.1.1.2.2 Benthos

Benthic macroinvertebrates were collected in June, 1973, with a Birge-Ekman dredge. All subsequent samples were taken with a Ponar dredge which is better suited for use on substrates common to the Colorado River and Matagorda Bay estuaries. Nine samples, three near each bank and three from mid channel, are taken at each station. Exceptions occur at stations 13, 15, and 16 which are sampled with three grabs, due to the open-water characteristics of these areas. After collection, benthic samples receive an initial separation from sediments by washing in a 0.595-millimeter mesh sieve-bottom bucket. Samples are preserved in 10 percent formalin and returned to the laboratories for further processing.

Emergent adult insects are collected with an insect light trap, preserved in 70 percent ethyl alcohol, and returned to the laboratories. These samples provide necessary data for estimating seasonal life-cycle variations of important fish food species. Also, adult specimens are used to verify identifications of larval forms collected in benthic samples during previous field studies.

Benthic samples are washed in U.S. Standard Series sieves in the laboratory and hand sorted. Organisms not requiring special preparation prior to identification, are classified and enumerated using approprate optical aids. These specimens are then placed in 70 percent ethyl alcohol and deposited in a permanent collection. Chironomid larvae are cleared by digestion of muscle tissue, in heated five percent potassium hydroxide solution. This process renders the taxonomic features more readily visible. Cleared specimens are then washed and mounted on glass slides for identification and enumeration. Oligochaete worms are mounted on glass slides in Ammans lactophenol solution and stored on trays for a period of 3 to 7 days. This procedure clears the specimen, rendering both internal and external characters visible under magnification, and facilitates identification and counting of individuals present. Both chironomid larvae and oligochaetes are placed in 70 percent ethyl alcohol, after identification and deposited in a permanent collection of voucher specimens.

6.1.1.2.3 Fish and Associated Organisms

Fish populations are sampled consistently with one or more types of collecting gear at each station (see Table 6.1-6). Experimental gill nets, consisting of five panels, each 25 feet wide and 6 feet deep, with an open mesh ranging from 1.5 to 3.5 inches, are set at selected stations for periods ranging from 12 to 24 hours. All fish and crabs collected by this method are identified, weighed and measured.

An otter trawl, with an aperture of 20 feet (headrope length), upper bag mesh of 0.75 inch and cod end mesh of 0.25 inch, is towed for 5 minutes at those stations (see Table 6.1-6) where water and bottom conditions permit its proper deployment and use. Upon retrieval of the catch, larger fish specimens are identified, weighed, measured and returned to the water; all smaller fish, shrimp, crabs, and other organisms are preserved in 10 percent formalin and returned to the laboratory. Additional estimates of the fish population are provided by the use of a two-man, 20-foot bag seine in shallow areas of Matagorda Bay and surrounding waters. Large specimens captured by this method are identified, weighed and measured in the field and released; smaller fish, crustaceans and other organisms are preserved as described above and returned to the laboratories.

Organisms collected by trawl or seine gear and returned to the laboratory are identified, enumerated and measurements of length and weight are obtained. These data are collected on a repetitive monthly basis, and yield valuable information on the following topics:

1. Seasonal variation in biomass
2. Growth rates of important estuarine-dependent species such as shrimp, crab, and many fish, and
3. Extent of utilization of the study areas by these organisms at various stages in their life-histories.
4. The type specimens for each species are preserved in 10 percent formalin and deposited in a permanent collection.

6.1.1.3 Special Studies

6.1.1.3.1 Little Robbins Slough Marsh Complex

Construction of the South Texas Project Reservoir will result in reduced freshwater flow and nutrient input into the Little Robbins Slough marsh complex. A possible result could include shifts in salinity gradients in the lower marsh and loss of an undetermined amount of freshwater marsh to brackish marsh and coastal prairie. Due to the possible change in salinity regimes, population sizes of freshwater fish, invertebrates and aquatic plants may be reduced.

To provide information regarding utilization of the Little Robbins Slough ecosystem as a nursery area by estuarine dependent organisms, baseline studies are being conducted to gather data on existing salinity regimes, temporal and spatial species distribution and species population sizes. The monitoring program includes sampling at two Matagorda Bay control stations to provide information on organism migration into and utilization of the eastern portion of the Matagorda Bay estuary. Station 99, originally located in Matagorda Bay, was to have monitored the movement of estuarine organisms through an unnamed barge canal. However, it was learned that this canal has been plugged, precluding any movement through it. Therefore, it was decided that a station in Crab Lake would be more meaningful to the program. Hence, Station 99 has been relocated to the middle of Crab Lake. Such data can be used on a comparative basis with lower open-marsh data to establish the slough's relative role as a nursery. 6

Salinity monitoring of Little Robbins Slough environs will be conducted concurrently with biological sampling to ensure detection of organism-salinity correlation.

Nutrient input studies will be conducted monthly at selected stations to assess potential impact of reduced freshwater inflow and associated nutrients on the lower marsh's role in meeting developmental needs of young estuarine dependent organisms.

Field studies began in April of 1975 and will continue for one year to document seasonal changes.

Thirteen stations will be sampled including 11 stations in the Little Robbins Slough marsh complex and two stations in Matagorda Bay (Figure 6.1-1a). Stations 12, 13 and 16 were sampled during the June, 1973 - May, 1974 baseline environmental survey.

Salinity, specific conductance, water temperature, pH and dissolved oxygen will be measured (in the field) concurrently with collection of biological samples at each station. Water level variation will also be observed at each station.

Water samples for nutrient levels including nitrates, orthophosphate, inorganic carbon, total organic carbon and total carbon will be taken monthly during collection of biological samples at eight stations (stations 16, 91, 92, 93, 94, 95, 96 and 97 - see Figure 6.1-1a).

Fish, ichthyoplankton, crustaceans and macrozooplankton will be sampled monthly at all stations with frequency increasing to once every two weeks at the station in Crab Bayou, (station 98) and stations 12, 13 and 99 during March through May and August through December. These periods of intensive sampling are representative of the expected highest influx of estuarine dependent organisms. Benthos, phytoplankton, periphyton, macrophyton and microzooplankton will be sampled quarterly at all stations in May, August, November and February. Macrophyton studies will include quarterly sampling of any forms present and qualitative estimates of dominant forms and relative abundance. Qualitative observations will be made during other trips. Emergent hydrophytes will be included in a terrestrial survey of the marsh ecosystem. 6

Duplicate water samples will be taken monthly and duplicate sediment samples will be taken quarterly during collection of biological samples at 12 stations. Water samples will be analyzed for dissolved nutrients and when applicable (i.e., high turbidity), suspended matter will be analyzed using procedures for analyses of sediment nutrients. Parameters will include nitrates, orthophosphate, inorganic carbon, total organic carbon and total carbon.

6.1.1.3.2 Entrainment Monitoring Program

The location of the STP makeup pump station on the Colorado River is such that a potential exists for entrainment of eggs, larvae, and/or juveniles of commercially and recreationally valuable fish, shrimp and crabs. Low river flow allows some salt water intrusion and associated migration of these organisms into the vicinity of and upstream from the intake. Under the proposed intermittent makeup water pumping scheme, the magnitude of any entrainment can be expected to vary with season and salinity regimes in the river. Although STP baseline data were gathered during an extremely wet year, density calculations for these organisms in the vicinity of the proposed intake were made in a conservative manner and are believed representative.

To confirm predicted entrainment under low flow conditions, an additional study will be conducted to determine the densities of planktonic organisms adjacent to the proposed makeup intake structure during low flow conditions.

The program will be divided into two phases: the first phase will be prior to actual pumping and the second phase will be during cooling lake filling operations. The first phase began during April, 1975 and will continue until such time that adequate data have been acquired during low river flow conditions to characterize the plankton populations under those low flow conditions. The second phase will begin upon initiation of cooling lake fill operations and continue for one year to assure that adequate data have been acquired to measure actual entrainment.

During phase one, four stations in the Colorado River will be
sampled (stations 1, 2, 3, 5 - Figure 6.1-1) to enable characteri-
zation of population densities in the Colorado River under various
flow conditions. Distance between stations 1 and 2 and 2 and 3 is 6
not considered sufficient for intermediate stations. During phase
two emphasis will be on documentation of actual entrainment under
various flow-salinity conditions and sampling will thus be limited
to station 2 and the siltation basin.

Salinity, specific conductance, water temperature, pH and dissolved oxygen will be measured in the field concurrently with collection of biological samples at each station.

Tidal excursion will be determined from the specific conductance data to indicate the presence of a salt wedge. Freshwater flow will be obtained from USGS records.

Fish, ichthyoplankton, crustaceans and macrozooplankton will be sampled at each station at least quarterly in May, August, November and February during the first phase. Additional samples will be taken when a salt-wedge is present in the vicinity of the makeup pump station as evidenced by a salinity of $3^{o}/_{oo}$ at a depth of 8 to 10 feet. Salinity will be checked daily at station 2 by on-site personnel to determine the need for intensive sampling. Intensive sampling will not exceed weekly intervals during March through May and August through December and will not exceed once every two weeks during January, February, June and July. An intensive sampling frequency will be followed only for the duration of low flow conditions (i.e., salinity at a depth of 8 to 10 feet is $3^{o}/_{oo}$ or greater). Bottom-fishing otter trawls and bag seines will be used to sample fish and crustaceans. One trawl and one seine sample will be taken per station. Single, oblique plankton tows (0.5 mm) near each shore and separate tows at the surface, middepth and bottom at midstream will be used to sample ichthyoplankton and macrozooplankton.

During cooling lake filling operations, sampling procedures and frequency will be as during the initial phase except for the following: (1) Sampling will be conducted only during periods of actual pumping during which the above salinity and sampling interval guidelines will be applicable; (2) Exact sampling procedures (i.e., use of trawls, seines, and ichthyoplankton nets) in the siltation basin will be adjusted as necessary to meet physical sampling restrictions. 6

Organisms collected by trawl or seine gear and returned to the laboratory are identified, enumerated and measurements of length and weight are obtained. These data are collected on a repetitive monthly basis, and yield valuable information on the following topics:

1. Seasonal variation in biomass
2. Growth rates of important estuarine-dependent species such as shrimp, crab, and many fish, and
3. Extent of utilization of the study areas by these organisms at various stages in their life-histories.
4. The type specimens for each species are preserved in 10 percent formalin and deposited in a permanent collection.

6.1.2 GROUNDWATER

The STP site is located in Matagorda County, Texas. In the site area, shallow and deep aquifer zones are separated by an impervious confining zone of considerable thickness. The known major differences in the water quality data and the direction of groundwater flow confirm the substantial thickness of the impervious zone. The deep aquifer zone is recharged from infiltration of precipitation and stream percolation outside the site area. The shallow aquifer zone is also replenished from outside the site area (see Section 2.5.2).

6.1.2.1 Physical and Chemical Parameters

6.1.2.1.1 Physical Parameters

A weekly water level monitoring program was initiated for the STP in July 1973. Piezometers were installed at various depths in each aquifer zone. In addition to these onsite water level measurements, previous Texas Water Development Board measurements for wells in the offsite area have been utilized.

Piezometer locations are shown in Figure 6.1-3, (Pump Test and Piezometer Location Map). Typical piezometer installation details are shown in Figure 6.1-5, (Typical Piezometer Installation). Locations and depths of piezometers are shown in Figures 6.1-6 (Borehole Location Map), and 6.1-4, (Borehole Depth Chart).

The onsite water level measurements were obtained using piezometers consisting of slotted plastic (PVC) screens 2 inches in diameter and 3 feet long with 0.010-inch slots connected to plastic (PVC) rise pipes. The pipes are either 0.75 or 2.0 inches in diameter. The top of the riser generally projects about 2.5 feet above ground surface and is protected with metal covers. Installation of piezometers followed drilling, surging, and electric logging of the holes.

Clean uniform sand was placed in the borehole around the screen and riser to near the top of the particular sand unit in which the water level was to be monitored. Bentonite seals were placed in specified wells. The remainder of the hole was grouted with cement up to the ground surface, providing an effective seal. Holes for the piezometers were drilled using the hydraulic rotary method using only the natural muds while drilling. Several days after the cement grout had set, each of the piezometers was checked to ensure that it was functioning properly. Each riser was filled to the top with fresh water, and the rate of fall was then observed. When the response was sluggish, the piezometer was flushed by pumping.

Measurements of water level were taken using an electric fluid conductivity probe. When the probe at the end of the cable on the instrument touched the top of the water in the piezometer, a red light flashed on. The depth to water was measured using an engineer's field scale with the probe which is accurate to ±.02 foot. The tops of the riser pipe and ground surface elevations were determined for all piezometers.

6.1.2.1.2 Chemical Parameters

The preoperational program of groundwater quality sampling is divided into two phases. Phase I consisted of a monitoring program in which the well samples were collected and analyzed at weekly intervals. Phase I was completed in December, 1973. The purpose of this program was to determine the short term variability of the ground water quality. The Phase II sampling began February 1974. During Phase II the sampling programs will be conducted at monthly intervals for a 6-month period.

Samples for groundwater quality analysis are secured from three separate test wells located on the plant site (see Figure 6.1-3). These wells provide water from three distinct zones of the Gulf Coast Aquifer. The wells and the zones sampled are identified below:

1. Well No. 115-D 39.5 ft clay

2. Well No. 2 60-80 ft sand

3. Well No. 114-A 125 ft sand

Triplicate water samples from each well for bacteriological and chemical analysis of parameters indicated in Table 6.1-7 are acquired with an aspirator sampling device. This apparatus consists of 0.5-inch I.D. polyvinyl chloride (PVC) pipe cut into 5-foot lengths for portability and handling ease and fitted with threaded couplings, a 5-gallon glass container for sample collection and connecting tubes of Tygon (flexible PVC). The required lifting force is supplied by a vacuum pump (Millipore Corporation) and power supply is from a gasoline-powered generator.

Each well is pumped prior to sample collection to ensure a fresh inflow of water from the aquifer being sampled. Sample bottles are filled by reversing the connecting tubes, thus pressurizing the collection vessel and forcing the water into the sample bottles.

Water samples collected as described above are stored on ice and shipped to analytical labs for processing. Analytical techniques used for each parameter are referenced in Table 6.1-7.

The proposed monitoring program will be extended into Phase III to determine the effect of plant construction on the ground water quality. Similarly, the effects of plant operation on the ground water quality will be monitored by the continuation of the surveillance program into the postoperational phase.

6.1.2.2 Models

Models may be used to predict effects such as changes in groundwater level, dispersion of contaminants, and eventual transport through aquifers to surface water bodies. Descriptions of basic subsurface and groundwater parameters and comments relating to their reliability are presented in this section. The parameters to be discussed are those determined by one of the following methods: analysis of pump test data, laboratory permeability testing procedure, or establishment of aquifer geometry.

6.1.2.2.1 Analysis of Pump Test Data

Theis[12] developed the nonequilibrium well formula, which takes into account the effect of pumping time. Theis's formula is based on the following assumptions:

1. The aquifer is uniform in character and permeability in both vertical and horizontal directions.

2. The formation has uniform thickness and the well penetrates the formation fully.

3. The formation is of infinite areal extent and has no recharging source.

4. The water removed from storage is discharged instantaneously with lowering of head.

In its simpliest form the Theis formula is

$$T = \frac{114.6QW(u)}{s}$$

where s = drawdown in feet

Q = pumping rate in gpm

T = coefficient of transmissibility

$W(u)$ = well function of (u)

and $$S = \frac{uTt}{1.87r^2}$$

where S = coefficient of storage

t = time in days

r = distance in feet from pumped test well to observation well

The Theis curve-matching technique is used to get T and S. This technique is very well explained by Todd.[13]

Jacob[14] modified the Theis formula for small values of u. If time is plotted on a log scale and drawdown on an arithmetical scale, then the curve becomes a straight line. The coefficient of transmissibility is

$$T = \frac{264Q}{\Delta s}$$

where T = coefficient of transmissibility in gpd/ft

Q = pumping rate in gpm

Δs = slope of time-drawdown curve

and $$S = \frac{0.3Tt_o}{r^2}$$

where t_o = intercept of straight line at zero drawdown in days

r = distance in feet from pumped well to observation well where drawdown measurements were made

Data from the test well sand piezometers were analyzed by this procedure. To provide a check of results the Theis method was also utilized and found to agree.

The Theis nonequilibrium equation is applicable for analysis of the recovery of a well pumped at a constant rate. If a well is pumped for a known period and then shut down, the drawdown thereafter will be the same as if the well were being pumped continuously and a recharging well of the same capacity were superimposed at the time the pumping was stopped

Calculated recovery can be computed and plotted against logged time since pumping stopped. The values of T and S are then

$$T = \frac{264Q}{\Delta(s-s')}$$

$$S = \frac{0.3Tt_o}{r^2}$$

where $\Delta(s-s')$ = change in water level recovery per log cycle due to the recharging well

A second method of plotting the data permits direct use of residual drawdown without calculating the recovery from any extension of time-drawdown curves. It can be shown that in this case the coefficient of permeability is given by the following relation:

$$T = \frac{264Q}{\Delta s'}$$

where $\Delta s'$ = the change in residual drawdown per logarithmic cycle of t/t' where t is the time since pumping began and t' is the time since it stopped

6.1.2.2.2 Laboratory Permeability Testing

Permeabilities have been obtained on representative clayey samples from various borings using falling-head permeability tests and consolidation tests. Because of in situ soil fabric (root holes, silt seams, desiccation cracks and so forth) the in situ permeability may be considerably larger than (ten to one hundred or more times) the laboratory permeability.

Deviations from Darcy's law are most severe at low gradients, and gradients in the field seldom are much greater than unity. On the other hand, the gradients used in laboratory permeability tests and developed during consolidation tests are usually very large (one hundred or more). Therefore, the applicability of laboratory test results for analysis of field behavior is subject to scrutiny. Estimates of seepage rates and consolidation rates may be considerably greater than those actually developed in the field, if true non-Darcy flow exists.

6.1.2.2.3 Establishment of Aquifer Geometry

The subsurface explorations were reviewed and interpreted by ground water hydrologists, who prepared generalized cross sections of the subsurface aquifer conditions. These evaluations are presented in Section 2.5 Hydrology and shown in Figures 2.5-14 and 2.5-15, Generalized Hydrogeologic Cross Sections.

The accuracy of these subsurface sections is known only at the actual locations of the subsurface borings. The interpolation between borings and the generalization of the figures represents the best professional interpretation.

The presence of an intervening confining clay layer, separating the shallow aquifer zone from the deep aquifer zone is strongly suggested by the following findings:

1. Drillers logs from water wells in the site vicinity indicate a highly consolidated clay at depths of approximately 120 to 200 feet.

2. Site exploration borings and electric logs indicate a clay zone at depths of approximately 120 to 200 feet.

3. Different hydrostatic heads exist in the deep and shallow aquifer zones.

4. Ground water gradients are oriented in almost opposite directions in the two primary aquifer zones.

5. Water quality in the two aquifers is noticeably different.

6. Onsite pump tests and previous offsite (water well) pump tests by others indicate confined conditions.

Present onsite information pertaining to the shallow aquifer zone, indicates that it consists of interbedded sand, silt, and clay layers which extend under much of the site. Between the surface and the 100-foot depth are a surface clay, a silty sand, a second sand, and a third clay. Although exploration borings and electric logs have not found these clays and sands to be perfectly uniform and continuous, they do indicate that the individual deposits are continuous under wide areas of the site. Relatively small, differing hydrostatic heads have been observed between some piezometers installed at different elevations within the upper aquifer zone. The first pump test near the southeast side of the cooling reservoir indicated that this layer is confined within the 5,800-foot radius of influence developed during the test.

Although the clay layers within the shallow aquifer zone have not been proven to be complete barriers to groundwater movement, present data indicates that vertical movement of groundwater must be retarded. Therefore, a generalized "layered" system of pervious and impervious zones may be inferred as shown in Figures 2.5-14 and 2.5-15.

6.1.2.2.4 Ground Water Infiltration Model

Quantification of the infiltration of water from the 7,000-acre cooling reservoir into the groundwater system of the site area is achieved by developing a mathematical model. Seepage source dilution characteristics are traced further into the local aquifer by another mathematical model of the contaminant dispersion in the aquifer zone. Environmental impacts of the cooling reservoir predicted by these mathematical models are presented in Chapter 5. The mathematical models used for these predictions are presented in this section.

6.1.2.2.4.1 Seepage Model

A closed-form approximate mathematical model was used to characterize the nature of the flowfield generated by the seepage from a 7,000-acre cooling reservoir. The selected mathematical analog movement of seepage through the unsaturated zone was used to define the time of arrival of the seepage at the saturated zone interface. The mathematical development of the seepage analysis is presented in Appendix 6.1-C. The predicted seepage characteristics are presented in Chapter 5.

6.1.2.2.5 Contaminant Dispersion Model

The transient two-dimensional dispersion of the seepage into the water table is predicted by a two-dimensional transport model. To solve the nonlinear partial differential time-dependent equations, a numerical scheme is developed. The method of developing a mathematical dispersion model is described in Appendix 6.1-B. The predicted spatial and temporal variation in contaminant buildup is presented in Chapter 5.

TABLE 6.1-1

WATER CHEMISTRY AND PHYSICAL PARAMETERS
MAJOR FIELD AND LABORATORY STUDIES

Physical Measurements

Temperature	Color
Specific Conductance	Turbidity
pH	Odor
Dissolved Oxygen	

Chemical Analyses

Alkalinity *	Organic carbon	Oily Matter
Acidity, total	Inorganic carbon	Aluminum
Bicarbonate	Silica, total	Chromium, total
Carbonate	Phosphate, total	Chromium, hexavalent
Hydroxide	Phosphate, ortho	Copper
Chloride	Nitrate	Manganese
Calcium	Nitrite	Cadmium
Magnesium	Sulfate	Nickel
Hardness, total	Sulfide	Zinc
Suspended matter	Sodium	Lead
Dissolved matter	Potassium	Tin
Total matter	Iron, total	Mercury
Surfactants	Iron, soluble	BOD_5
Phenol	Ammonia	COD
Total carbon	Kjeldahl nitrogen	Pesticides (selected)

* Phenolphthalein and methyl orange.

TABLE 6.1-2

WATER CHEMISTRY AND PHYSICAL PARAMETERS
MINOR FIELD AND LABORATORY STUDIES

Physical Measurements

Temperature
Specific conductance
pH
Dissolved oxygen
Color
Turbidity

Chemical Analyses

Alkalinity*
Acidity, Total
Bicarbonate
Carbonate
Hydroxide
Calcium
Magnesium
Hardness, total
Suspended matter
Dissolved matter
Total matter
Total carbon
Organic carbon
Inorganic carbon
Silica,total
Phosphate, total
Phosphate, ortho
Nitrate
Nitrite
Surfactants
Iron, total
Kjeldahl nitrogen
Copper
Mercury
BOD_5
Sulfate (begun in March)

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*Phenolphthalein and methyl orange

TABLE 6.1-3

WATER QUALITY PARAMETERS AND METHODS OF ANALYSIS

Parameter	Reference
Alkalinity, acidity	*APHA p. 54
Bicarbonate, carbonate, hydroxide	Calculated from acidity and alkalinity
Chloride	APHA p. 307 section 203C
Calcium	** AA - Instrumentation Laboratory
Magnesium	AA - Instrumentation Laboratory
Hardness	Calculated from Ca and Mg
Sodium	AA - Instrumentation Laboratory
Potassium	AA - Instrumentation Laboratory
Hexavalent chromium	APHA p. 157 section 117C
*Other metals	AA - Instrumentation Laboratory
Specific conductance	APHA p. 323 section 154
pH	Sargent - Welch NX pH meter
Color	APHA p. 160 section 118
Turbidity	Hach Photometric Turbidimeter Model 1860
Phosphate, total & ortho	*** EPA p. 235
Silica, total	APHA p. 306 except sulfuric acid is used instead of oxalic acid
Sulfate	APHA p. 331 section 156A
Sulfide	APHA p. 558 section 228C
Nitrate	APHA p. 461 section 213C
Nitrite	APHA p. 230 section 134
Ammonia	APHA p. 226 section 132B
Kjeldahl nitrogen	Total Kjeldahl APHA p. 469 section 216
Suspended matter	Membrane Filter
Dissolved matter	Evaporation
Total matter	Calculated - Dissolved + Suspended
Inorganic carbon	By IR with Beckman Model 915 Total Carbon Analyzer
Total carbon	By IR with Beckman Model 915
Total organic carbon	Calculated from IC&TC
Oily matter	†API Method 733-58
Odor	APHA p. 248 section 136

TABLE 6.1-3 (Continued)

WATER QUALITY PARAMETERS AND METHODS OF ANALYSIS

Parameter	Reference
Phenol	APHA p. 505, section 222C
Surfactant	APHA p. 339, section 159A
COD	APHA p. 495, section 220
BOD	APHA p. 489, section 219
Bacteria, plate count	APHA p. 660, section 406
Bacteria, coliform	APHA p. 679, section 408A
Bacteria, fecal streptococcus	APHA p. 690, section 409B
Chlorophyll a	†† Lorenzen (1967)

*See Reference 6.1-3.
**See Reference 6.1-4.
***As listed in Table 6.1-1.
†See Reference 6.1-5.
††See Reference 6.1-6.
†††See Reference 6.1-7.

TABLE 6.1-4

MAJOR ECOLOGICAL CHARACTERIZATION SURVEY MEASUREMENTS

Bacteria, total plate count

Bacteria, total coliform

Bacteria, fecal coliform

Bacteria, fecal streptococcus

Chlorophyll <u>a</u>

Phytoplankton

Zooplankton

Ichthyoplankton

Benthos

Fish and other nekton

Light trap (insects)

TABLE 6.1-5

MINOR ECOLOGICAL CHARACTERIZATION
SURVEY MEASUREMENTS

Phytoplankton

Zooplankton

Ichthyoplankton

Benthos

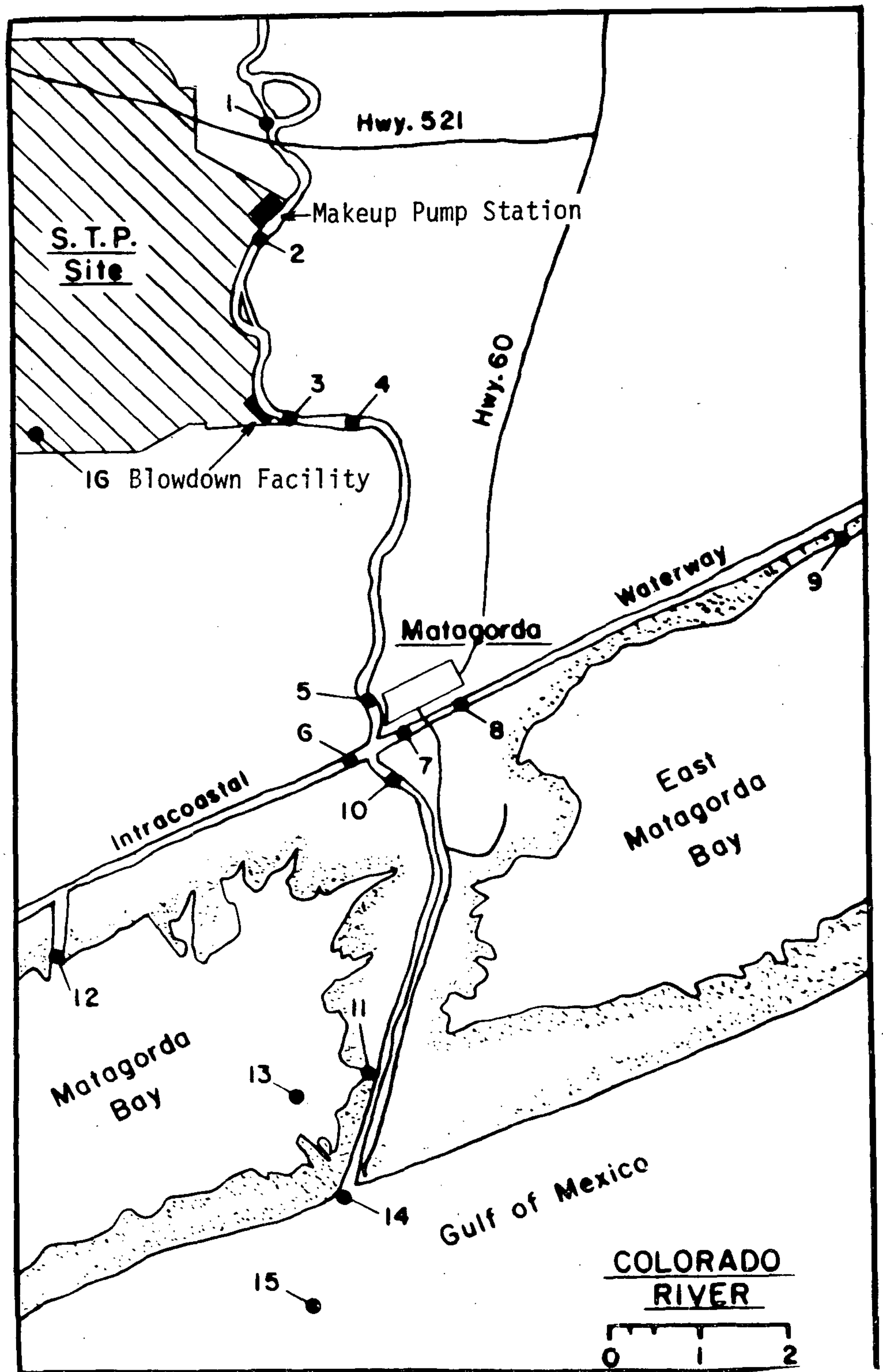
Fish and other nekton

TABLE 6.1-6

SCHEDULE OF GEAR UTILIZATION (X)
FOR SAMPLING OF FISH AND ASSOCIATED
ORGANISMS AT EACH SAMPLING STATION
(STP 1973 - 1974)

Station (Figure 6.1-1)	Trawl	Gill Net	Seine
1	X	X	
2	X	X	
2.5		X	
3	X		
4	X	X	
4.5		X	
5	X	X	
6	X	X	
7			
8	X	X	
9	X	X	X
10	X	X	
11	X		X
12	X		X
13			X
14	X		X
15	X		
16			X*

* Majors only

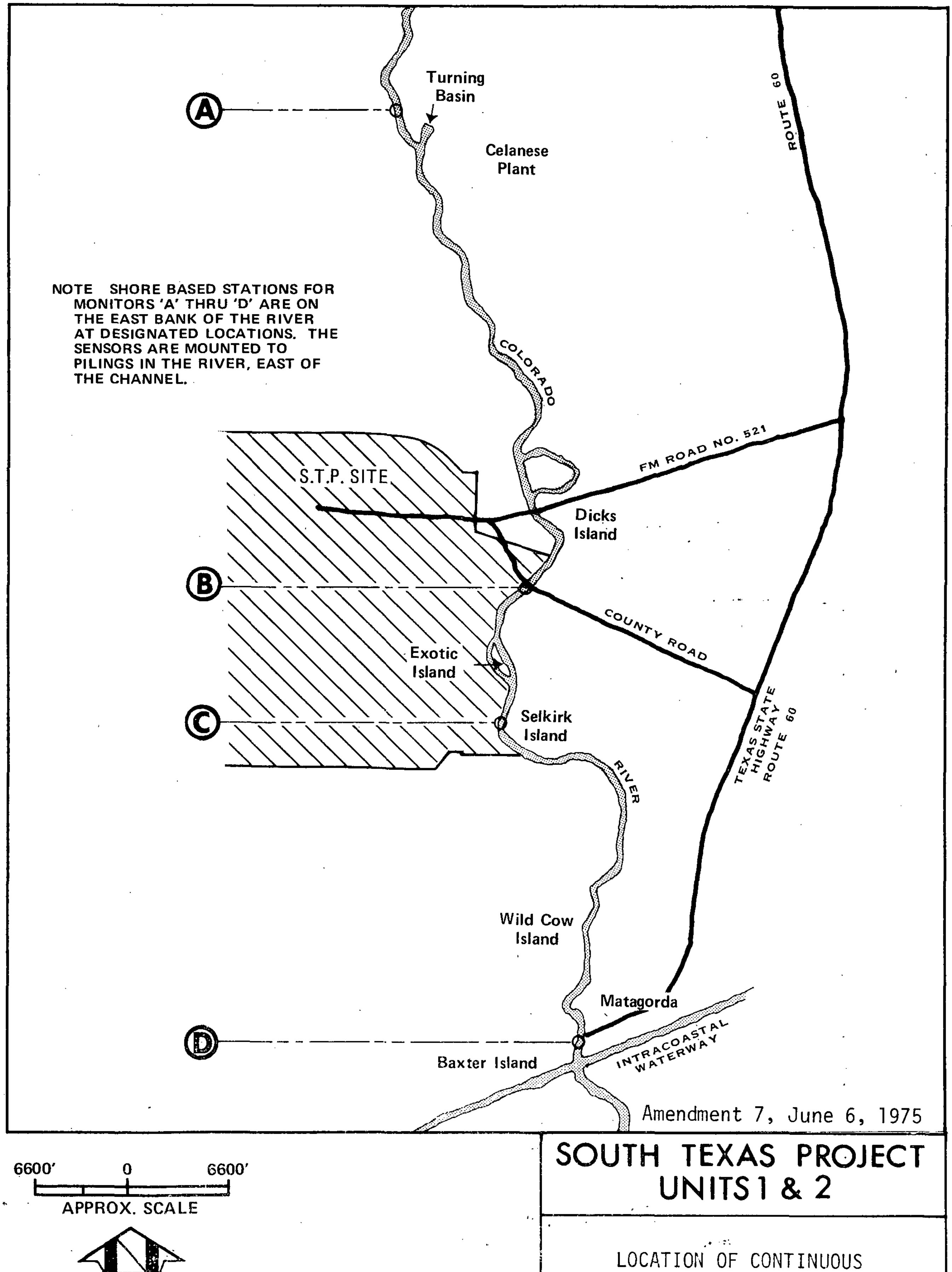


Amendment 7, June 6, 1975

SOUTH TEXAS PROJECT
UNITS 1 & 2

MAP OF THE LOWER COLORADO RIVER
SHOWING SAMPLING STATIONS

FIGURE 6.1-1

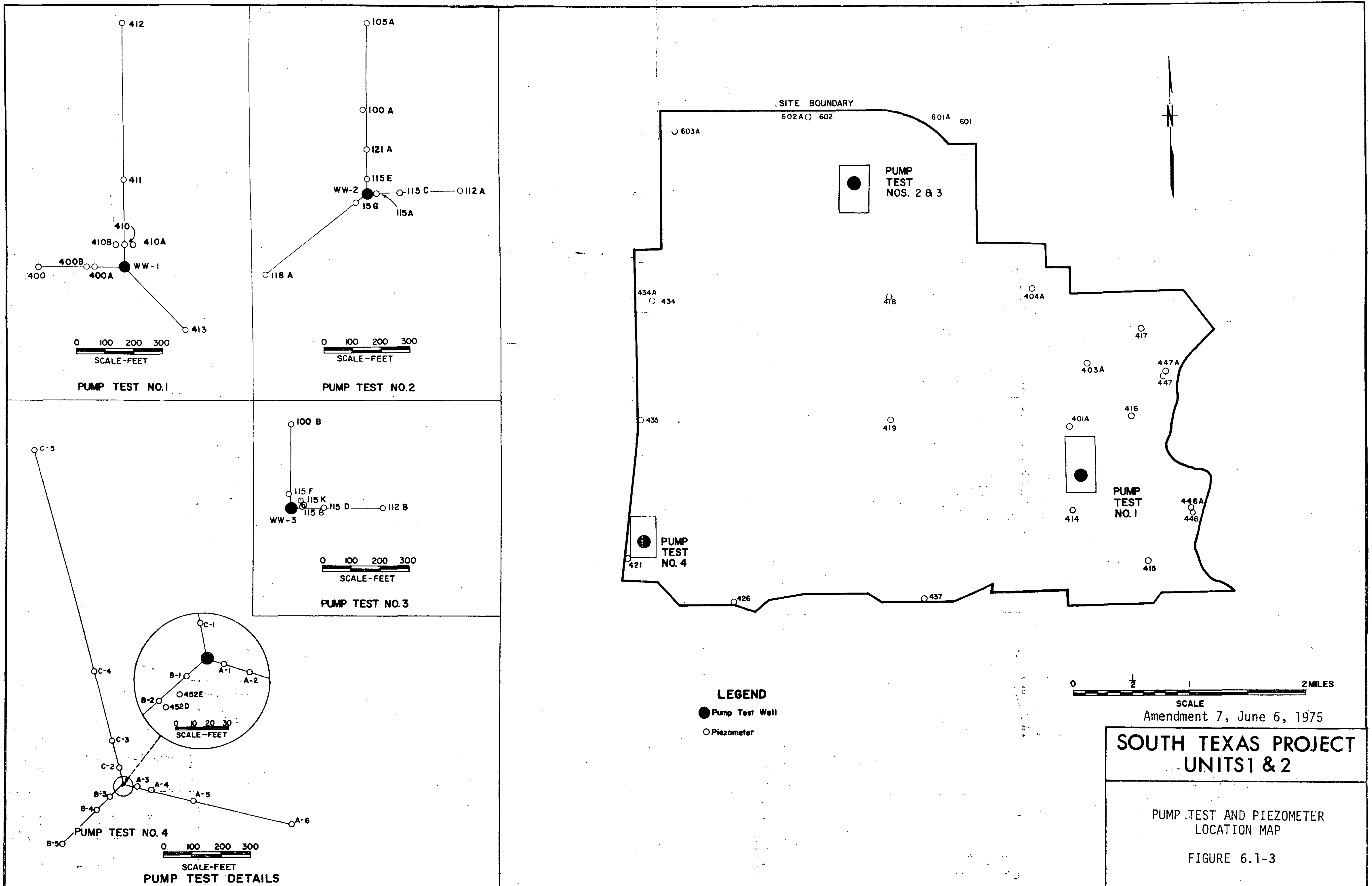


Amendment 7, June 6, 1975

SOUTH TEXAS PROJECT
UNITS 1 & 2

LOCATION OF CONTINUOUS MONITORING STATIONS

FIGURE 6.1-2

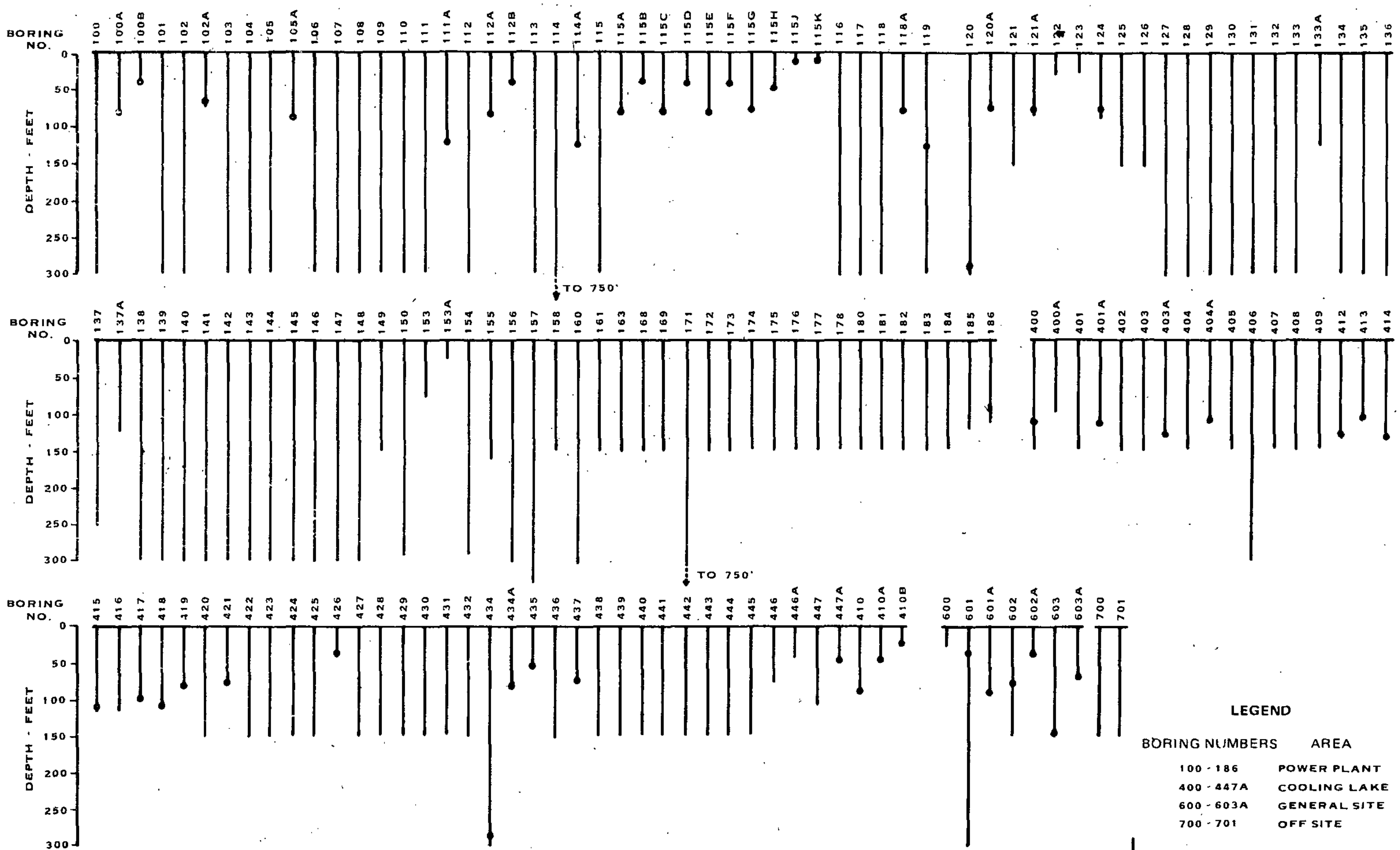


Amendment 7, June 6, 1975

SOUTH TEXAS PROJECT
UNITS 1 & 2

PUMP TEST AND PIEZOMETER
LOCATION MAP

FIGURE 6.1-3



NOTES:
1 VERTICAL SCALE AS SHOWN
2 NO HORIZONTAL SCALE IMPLIED
3 SITE INVESTIGATION IN PROGRESS AT THE TIME THIS DRAWING WAS PREPARED, JAN. 1974.

LEGEND

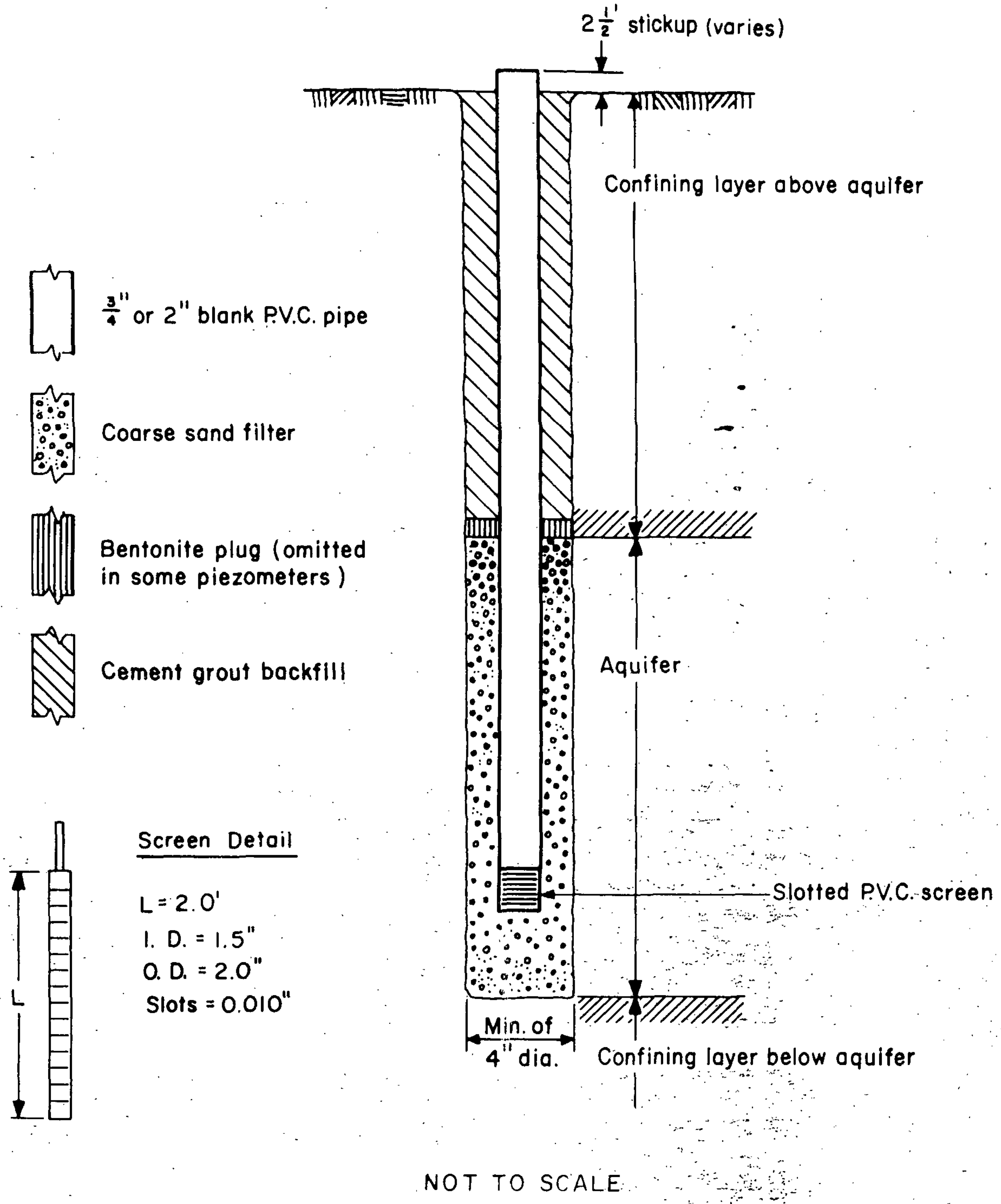
BORING NUMBERS	AREA
100 - 186	POWER PLANT
400 - 447A	COOLING LAKE
600 - 603A	GENERAL SITE
700 - 701	OFF SITE

BORINGS WITH PIEZOMETERS

SOUTH TEXAS PROJECT UNITS 1 & 2

BOREHOLE DEPTH CHART

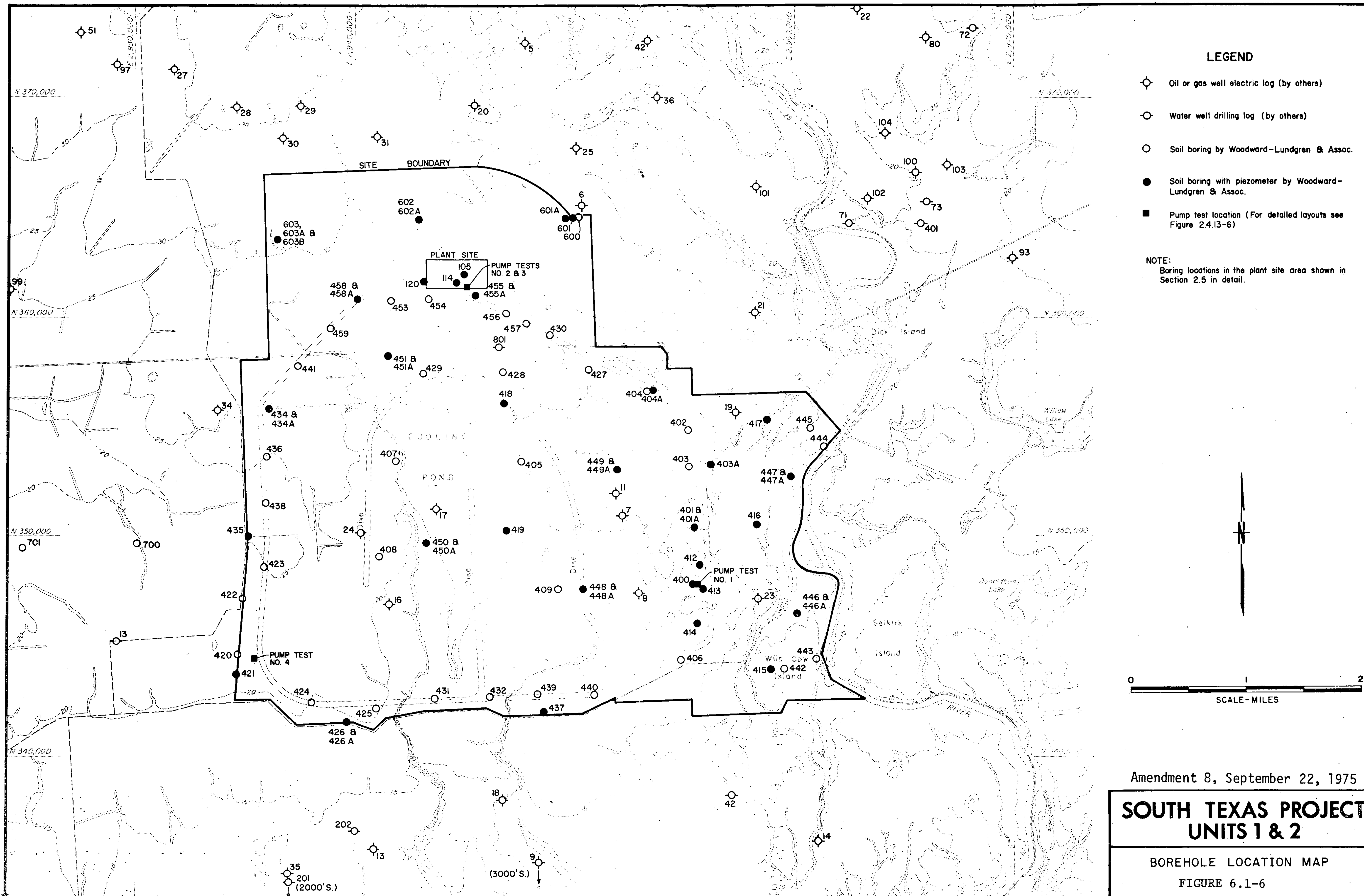
FIGURE 6.1-4



SOUTH TEXAS PROJECT
UNITS 1 & 2

TYPICAL PIEZOMETER INSTALLATION

FIGURE 6.1-5

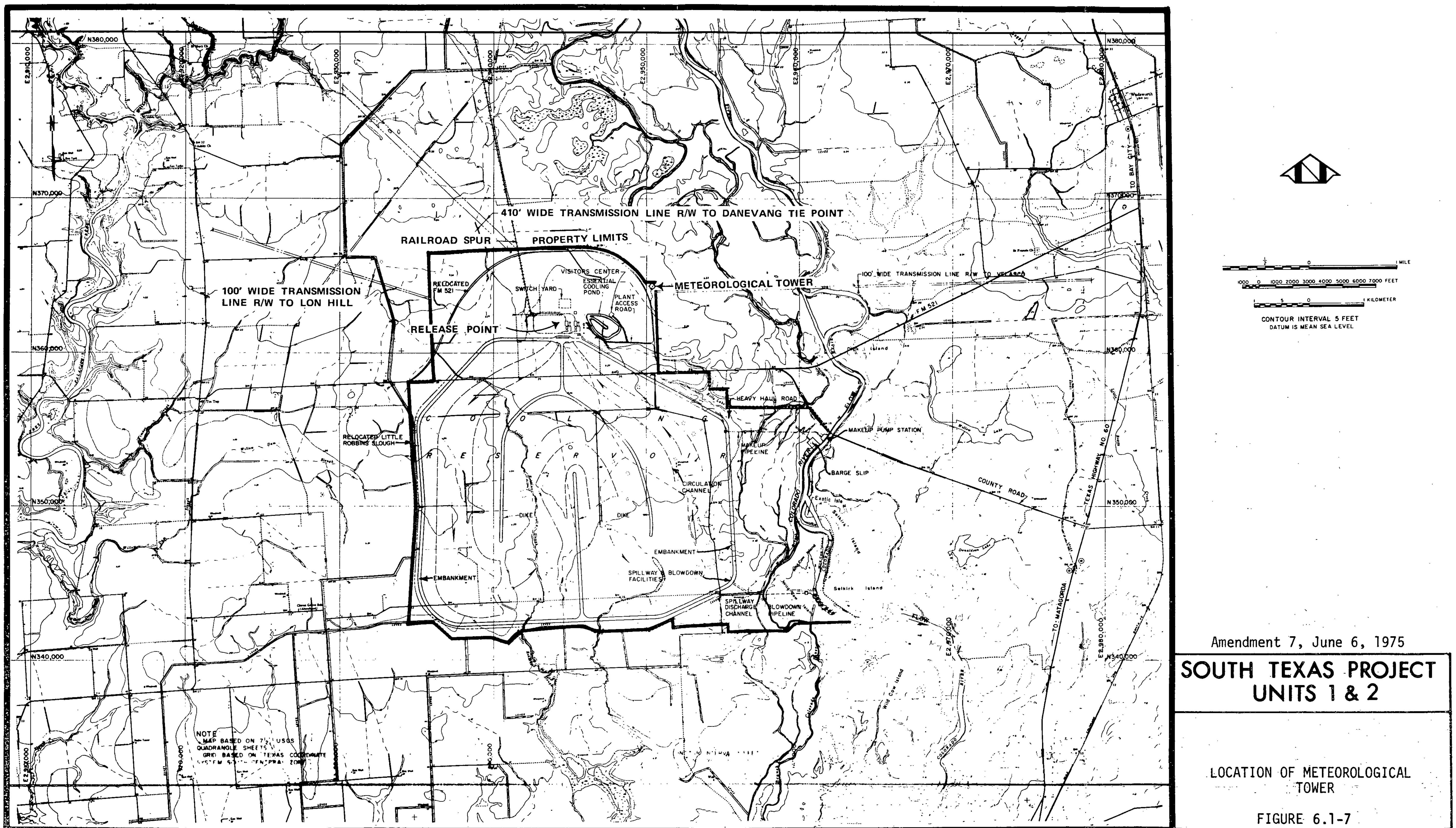


Amendment 8, September 22, 1975

SOUTH TEXAS PROJECT UNITS 1 & 2

BOREHOLE LOCATION MAP

FIGURE 6.1-6



Amendment 7, June 6, 1975

SOUTH TEXAS PROJECT UNITS 1 & 2

LOCATION OF METEOROLOGICAL TOWER

FIGURE 6.1-7

APPENDIX 6.1-B

MATHEMATICAL DISPERSION MODELS FOR HEATED DISCHARGES

by

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MATHEMATICAL DISPERSION MODELS FOR HEATED DISCHARGES

The performance evaluation of the discharge structures has been conducted using state-of-the-art mathematical models implemented on a high speed digital computer. A computer code has been developed. This code treats submerged discharges (slot, multiport, and single-port diffuser structures) and has been designated MUDSUB. The analytical formulation of this model is described in the following sections.

SUBSURFACE THERMAL DISPERSION MODEL

When hot cooling water is realeased from a power plant through a discharge structure, the effluent induces a strong momentum transfer resembling a jet. Since the heated effluent is usually warmer than the receiving water, there is a tendency for the effluent to float upward as it propagates in the direction of the release of the discharge. As the effluent travels in the direction of the release it begins to dissipate its forward thrust (due to momentum transfer) and buoyant thrust (due to mixing with colder ambient water). When the effluent has dissipated most of its momentum, it ceases to behave as a jet and continues to disperse as a passive layer of water where mixing is dominated by the ambient currents and turbulence of the receiving body of water. The passive flow region could begin either when the effluent field is trapped below the water surface or after it has reached the surface. It is possible that in the case of shallow freeboard (depth of the diffuser) the effluent may arrive at the surface of the water with a high horizontal velocity. The effluent may continue to travel as a surface jet until the momentum of the plume is comparable with the receiving body. The plume then continues to be dispersed by the ambient currents as a passive layer.

For the purpose of mathematical model development the effluent discharge is divided into regions comprising:

1. the dynamic jet discharge region

2. the passive diffusion region.

The entrainment contribution of this transition region will slightly increase the dilution of the effluent and somewhat decrease the surface temperatures beyond those predicted. Figure B6.1-1 shows the propagation and regions of interest of a submerged buoyant jet which arrives at the surface of the water and a buoyant jet which loses its buoyancy before it reaches the surface of the water. The following sections discuss the analytical models describing the effluent dispersion in a subsurface region of the jet and in a surface passive turbulent diffusion region.

I. SUBSURFACE JET DISPERSION ANALYSIS

A mathematical model has been developed to predict the temperature distribution due to a discharge of heated water into a stratified receiving water. The model, based on the approach of Koh and Fan,[1] is capable of analyzing a two-dimensional slot jet or an axisymmetric (round) jet discharge from a single-port or multiport diffuser system.

The mixing of a submerged buoyant jet discharge is assumed to be governed by the magnitudes of the discharge velocity, ambient velocity, and buoyant momenta and by the profiles of ambient temperature and density stratification. Significant discharge and ambient characteristics of a typical jet are presented in Figure B6.1-2, which illustrates the angle (θ_0) of the discharge direction to the horizontal, the assumed cross-sectional velocity (u^*) profiles, and the reference coordinates (x,y) and (s). The figure also shows typical ambient density $[\rho_a(y)]$ and temperature $[T_a(y)]$ stratification profiles.

The analytical approach for power plant waste water discharge is based on the generalized integral equations describing the transport characteristics of the jet as well as its interactions with the ambient water. Assuming Gaussian cross-sectional velocity, temperature and density profiles across the jet, which are superimposed upon the velocity, temperature, and density profiles of the ambient, the equations for momentum, density-difference field, and temperature-difference field can be expressed in terms of integrals of the cross-sectional variations of the Gaussian functions for ciruclar and rectangular jets. In any discharging jet there exists a zone of flow establishment extending a few diameters from the exit plane where the cross-sectional velocity profile changes from a rectangular profile (uniform velocity at the exit plane) to a Gaussian profile. Experimental investigations[1] show that the zone of flow establishment extends 6.2 port diameters from the exit point. This model, therefore, starts the calculations at 6.2 diameters away from the exit point. The cross-sectional variation is described as follows (All symbols are defined in the List of Symbols at the end of this appendix):

a. Circular Jet Cross-Sectional Variation

$$u^* (s,r) = u(s) \exp(-r^2/b^2) + U_a \cos\theta \cos\phi \tag{1}$$

$$\rho_a - \rho^* (s,r) = \left[\rho_a - \rho(s)\right] \exp(-r^2/\lambda_r^2 b^2) \tag{2}$$

$$T_a - T^* (s,r) = \left[T_a - T(s)\right] \exp\left(-r^2/\lambda_r^2 b^2\right) \tag{3}$$

b. Slot-Jet Cross-Sectional Variation

$$u^* (s,\eta) = u(s) \exp\left(-\eta^2/b^2\right) + U_a \cos\theta \cos\phi \tag{4}$$

$$\rho_a - \rho^* (s,\eta) = \left[\rho_a - \rho(s)\right] \exp\left(-\eta^2/\lambda_s^2 b^2\right) \tag{5}$$

$$T_a - T^* (s,\eta) = \left[T_a - T(s)\right] \exp\left(-\eta^2/\lambda_s^2 b^2\right) \tag{6}$$

Invoking the conservation of mass, momentum, density deficiency (the difference between the jet-water density and the ambient-water density) and temperature deficiency (difference in jet-water temperature and ambient-water temperature) a set of characteristic equations can be defined in terms of the Gaussian velocity profiles as illustrated by Equations (7) and (8) for each slot jet.

$$Q = \int_{Area} u^* (s,\eta) d\,Area = L \int_{-h_L}^{h_u} \left[u(s) \exp -\eta^2/b^2 + U_a \cos\theta\cos\phi\right] d\eta$$

$$= L\, u(s)\, b\sqrt{\frac{\pi}{2}} \left[\operatorname{erf}\left(h_u/b\right) + \operatorname{erf}\left(h_L/b\right)\right] + LU_a \cos\theta \cos\phi \left(h_u + h_L\right) \tag{7}$$

$$F = \int_{Area} \left[\rho_a - \rho^* (s,\eta)\right] u^* (s,\eta) \, d\,Area$$

$$= L\int_{-h_L}^{h_u} \left\{ \left[\rho_a - \rho(s)\right] \exp\left(-\eta^2/\lambda_s^2 b^2\right) u(s) \exp\left(-\eta^2/b^2\right)\right.$$

$$\left. + \left[\rho_a - \rho(s)\right] \exp\left(-\eta^2/\lambda_s^2 b^2\right) U_a \cos\theta \cos\phi \right\} d\eta$$

$$= L \left[\rho_a - \rho(s)\right] b\lambda_s \sqrt{\frac{\pi}{2}}$$

$$\cdot \left[\frac{u(s)}{\sqrt{\lambda_s^2 + 1}} \left\{ \text{erf}\left(h_u \sqrt{\lambda_s^2 + 1}/\lambda_s b\right) + \text{erf}\left(h_L \sqrt{\lambda_s^2 + 1}/\lambda_s b\right) \right\}\right.$$

$$\left. + U_a \cos\theta \cos\phi \left\{ \text{erf}\left(h_u/\lambda_s b\right) + \text{erf}\left(h_L/\lambda_s b\right) \right\} \right] \qquad (8)$$

The pertinent equations for round and slot jets are developed in a similar fashion and are summarized in Table B6.1-1.

The equations in Table B6.1-1 define all the quantities needed for either a round-jet or a slot-jet thermal analysis. However, a multiple-jet submerged discharge consists partly of distinct round jets and partly of merged jets which can be treated as slot jets. In order to compute the propagation variations of the properties of multiple-jet discharges it is necessary to identify the jet interference threshold and to switch the computational sequence from the round-jet equations to the slot-jet equations.

The transition from round jet to slot jet occurs when the entrainment as calculated by round-jet equations is equal to that calculated by slot-jet equations. The transition is defined by the following equations:

$$b_r = \frac{\alpha_s L}{\alpha_r \pi} \sqrt{\frac{u_s^2 + U_a^2\left(1-\cos^2\theta \cos^2\phi\right)}{u_r^2 + U_a^2\left(1-\cos^2\theta \cos^2\phi\right)}} \tag{9}$$

(From experimental results reported by Koh and Fan[1] $\alpha_s = 0.16$ and $\alpha_r = 0.082$, for $U_a = 0$)

The model equations use the distance(s) along the jet centerline as the independent variable. The variable of distance along the centerline is related to variations in the x,y,z coordinates by the following:

$$dx = ds \cos\theta \sin\phi \tag{10}$$

$$dy = ds \sin\theta \tag{11}$$

$$dz = ds \cos\theta \cos\phi \tag{12}$$

Starting with the initial jet conditions and invoking the conservation of mass, momentum, density deficiency and temperature deficiency, the conditions at the end of the zone of the established flow (6.2 port diameters from the exit plane) are calculated. The equations defining Q, M, θ, ϕ, F, G, x, y and z as functions of s are used to calculate the jet characteristics along the centerline.

$$\frac{dQ}{ds} = E \tag{13}$$

$$\frac{d(M' \cos\theta\sin\phi)}{ds} = - F_D \sin\theta \cos\phi \tag{14}$$

$$\frac{d(M' \cos\theta\cos\phi)}{ds} = \rho_a E U_a + F_D \sin\theta \sin\phi \tag{15}$$

$$\frac{d(M' \sin\theta)}{ds} = f + F_D \cos\theta \tag{16}$$

$$\frac{dF}{ds} = \frac{d\rho_a}{ds} Q \tag{17}$$

$$\frac{dG}{ds} = \frac{dT_a}{ds} Q \tag{18}$$

A computer program has been developed to solve these equations. The method of solution consists of calculating the initial conditions Q_1, M_1, F_1, G_1 from the given discharge characteristics.

Starting with these values the equations are integrated using the round-jet relations in Table B6.1-1. When transition, given by Equation (9), is reached the solution is continued but with the slot-jet equations for E and f as shown in Table B6.1-1. The results obtained are then converted from the variables Q, M, F, and G to the physical variables u, ρ, T and b. The conversion is determined from the relations in Table B6.1-1. The effects of surface and bottom boundaries on the diepersion of a subsurface discharge have been incorporated by checking at each step of the calculations for the wetted surface area of the plume. This modification accounts for the fact that those portions of the plume in contact with the surface and/or bottom of the receiving body cannot entrain new cooling water from their surroundings.

II. PASSIVE TURBULENT DIFFUSION ANALYSIS

When warm water effluent loses its discharge and buoyant momenta and spreads as a passive turbulent layer, the dispersion of the effluent is primarily governed by the ambient turbulence and natural currents.

A mathematical model has been developed to calculate the distribution of the excess temperature function (or dilution function) due to the effect of ambient turbulence, ambient currents, and the surface heat exchange.

It is assumed that the effluent discharges from a continuous source in a steady shear current and undergoes only passive turbulent diffusion. The continuous source can be either on the surface of the water or below the surface of the water. The case of a passive turbulent layer below the water surface arises due to a subsurface discharge being trapped by the ambient density stratification.

III. ANALYTICAL APPROACH

The basic equation governing the mode of effluent dispersion is the diffusion equation. The constant release of waste heat effluent into steady environment, where longitudinal transport by diffusion is small compared with transverse transport by diffusion, is defined by the following equation:

$$u \frac{\partial T}{\partial x} = \frac{\partial}{\partial y}\left(K_y \frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial T}{\partial z}\right) \tag{17}$$

where T is defined as the temperature excess above ambient assuming a constant specific heat.

The equation can be generalized to represent either an excess temperature field or a concentration field. The generalized governing equation may be expressed as:

$$u \frac{\partial c}{\partial x} = \frac{\partial}{\partial y}\left(K_y \frac{\partial c}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial c}{\partial z}\right) - K_d c \qquad (18)$$

The boundary conditions may now be developed as follows:

a. On the surface of the water the vertical transport of heat or molecular species is equal to transport due to exchange to the atmosphere.

$$K_y \frac{\partial c}{\partial y} = K_e c \qquad \text{at } y = 0 \qquad (19)$$

where K_e is the coefficient for exchange of heat or mass.

b. The rate of change of the field property normal to the propagation vanishes at the effluent and water body interface.

$$\frac{\partial c}{\partial y} = 0 \qquad \text{at } y = h_b \qquad (20)$$

The field source is assumed to be located at $x = 0$ and $y = y_o$. The thickness and the width of the source are defined in Figure B6.1-3 for the case of surface flow and in Figure B6.1-4 for the subsurface flow. Assuming the source field distribution in the y and z direction to be Gaussian, as it would be for a single subsurface jet discharge which has lost its momentum, the source field function can be expressed (in terms of the subsurface round-jet width characteristic σ_r) as:

$$c(0,y,z) = c_{max}(0,y_o) \exp\left\{ -\frac{(y-y_o)^2}{2\sigma_y^2} - \frac{(z-z_o)^2}{2\sigma_r^2} \right\} \qquad (21)$$

The source field for a slot jet which is initially directed along the direction of ambient flow can be expressed as:

$$c(0,y,z) = c_{max}(0,y_o) \exp\left\{ -\frac{(y-y_o)^2}{2\sigma_y^2} \right\} \quad \text{for } \frac{W_t}{2} > z > -\frac{W_t}{2} \qquad (22)$$

$$c(0,y,z) = c_{max}(0,y_o)\exp\left\{-\frac{(y-y_o)^2}{2\sigma_y^2} - \frac{(z-z_o)^2}{2\sigma_r^2}\right\} \qquad (23)$$

$$\text{for } |z| > \frac{W_t}{2}$$

The preceding equations are developed on the assumption that the end jets of a multiple-jet diffuser system are different from the other jets. The end jets are assumed to have a round configuration on one side and a slot configuration on the side adjacent to the intervening jet. In this way the increased entrainment of the end is accounted for in the temperature prediction calculation.

IV. METHOD OF SOLUTION

The equations developed for the passive turbulent effluent diffusion are complicated by the three independent variables and the complex coefficient functions. This difficulty is partially overcome by using the method of moments to reduce the number of independent variable.

The moments of the distribution may be defined as:

$$c_o(x,y) = \int_{-\infty}^{\infty} c(x,y,z)\,dz \qquad (24)$$

$$c_1(z,y) = \int_{-\infty}^{\infty} zc(x,y,z)\,dz \qquad (25)$$

$$c_2(x,y) = \int_{-\infty}^{\infty} z^2\,c(x,y,z)\,dz \qquad (26)$$

The zeroth moment c_o is the integrated amount of excess temperature transverse to the plume in the z-direction. The first moment c_1 is related to the z-coordinate of the centroid of the c-distribution. In the present model, it is zero because of the symmetry of the distribution in the z-direction. The second moment c_2 defines the spread in the z-direction. The width of the effluent field is usually taken to be $4\sigma_z$ where $\sigma_z^2 = c_2/c_o$.

The equations governing the moments are:

$$u\frac{\partial c_o}{\partial x} = \frac{\partial}{\partial y}\left(K_y\frac{\partial c_o}{\partial y}\right) - K_d c_o \qquad (27)$$

$$u \frac{\partial c_2}{\partial x} = \frac{\partial}{\partial y} \left(K_y \frac{\partial c_2}{\partial y}\right) - K_d c_2 + 2K_z c_o \qquad (28)$$

Using the relation $\sigma_z^2 = c_2/c_o$, an equation can be written in terms of σ_z as:

$$u \frac{\partial \sigma_z^2}{\partial x} = \frac{\partial}{\partial y} \left(K_y \frac{\partial \sigma_z^2}{\partial y}\right) + 2K_y \frac{1}{c_o} \frac{\partial c_o}{\partial y} \left(\frac{\partial \sigma_z^2}{\partial y}\right) + 2K_z \qquad (29)$$

The boundary conditions expressed in terms of the moments are:

$$\left.\begin{aligned} K_y \frac{\partial c_o}{\partial y} &= K_e c_o \\ K_y \frac{\partial c_2}{\partial y} &= K_e c_2 \end{aligned}\right\} \quad \text{at } y = 0 \qquad (30)$$

or

$$k_y \frac{\partial \sigma_z^2}{\partial y} = 0 \qquad \text{at } y = 0 \qquad (31)$$

and

$$\frac{\partial c_o}{\partial y} = \frac{\partial c_2}{\partial y} = \frac{\partial \sigma_z^2}{\partial y} = 0 \qquad \text{at } y = h_b \qquad (32)$$

The source condition for a single round-jet discharge expressed in terms of the moments is:

$$c_o (0,y) = c_o (0,y_o) \exp \left\{ - \frac{(y-y_o)^2}{2\sigma_y^2} \right\} \qquad (33)$$

where:

$$c_o (0,y_o) = c_{max} (0,y_o)\, \sigma_r \sqrt{2\pi}$$

and:

$$c_2 (0,y) = c_2 (0,y_o) \exp \left\{ - \frac{(y-y_o)^2}{2\sigma_y^2} \right\} \qquad (34)$$

where:

$$c_2\ (0,y_o) = c_{max}\ (0,y_o)\ \sigma_r^{\ 3}\ \sqrt{2\pi}$$

or alternately:

$$\sigma_z^{\ 2}\ (0,y) = \sigma_z^{\ 2}\ (0,y_o) = \sigma_r^{\ 2}$$

The source condition for a multiple-port discharge that results in a slot jet in terms of the moments is:

$$c_o\ (0,y) = c_o\ (0,y_o)\ \exp \left\{ - \frac{(y-y_o)^2}{2\sigma_y^{\ 2}} \right\} \tag{35}$$

where:

$$c_o\ (0,y_o) = c_{max}\ (0,y_o) \left[W_t + \sigma_r \sqrt{2\pi} \right]$$

and:

$$c_2\ (0,y) = c_2\ (0,y_o)\ \exp\ - \frac{(y-y_o)^2}{2\sigma_y^{\ 2}} \tag{36}$$

where:

$$c_2\ (0,y_o) = c_{max}\ (0,y_o) \left[\frac{W_t^{\ 3}}{12} + \sigma_r^{\ 3} + \sqrt{2\pi} + 2W_t\sigma_r^{\ 2} + \frac{W_t^{\ 2}}{4}\ \sigma_r \sqrt{2\pi} \right]$$

or alternatively:

$$\sigma_z^{\ 2}\ (0,y) = \sigma_z^{\ 2}\ (0,y_o) = \frac{\frac{W_t^{\ 3}}{12} + \sigma_r^{\ 3}\sqrt{2\pi} + 2W_t\sigma_r^{\ 2} + \frac{W_t^{\ 2}}{4}\ \sigma_r \sqrt{2\pi}}{W_t + \sigma_r \sqrt{2\pi}}$$

Thus, by the moment method, the number of independent variables is reduced by one. Since the c-distribution in the z-direction is usually found to be of Gaussian form from both field and laboratory experiments,[1] the diffusion process can be adequately described by knowing the zeroth moment and the second moment. In fact, if c is exactly Gaussian in the z-direction, then it is completely specified by its zeroth and second moments. Equations for higher moments can be formulated in a similar way. The higher moments are necessary if the c-distribution is distinctly non-Gaussian in the z-direction.

A computer code (MUDSUB) based on the models described above has been developed to calculate the thermal dispersion due to either a single or multiple subsurface discharge. Starting with the independent variables describing the jet characteristics such as port diameter, effluent flow rate, temperature at the port exit, spacing between the ports, the location of the diffuser in relation to the ambient water and the variables describing the ambient waters (ambient diffusion coefficients and velocity), the code generates the temperature profiles in the ambient receiving water when warm water is discharged from a subsurface diffuser assembly. The output of the computer program is suitable for plotting isotherms in horizontal planes at selected ambient depths and for vertical planes using the data of the isothermal contours. The program also calculates isothermal surface areas and isothermal volumes.

LIST OF SYMBOLS

A = dissipation parameter ($K_z = A\sigma_z^{4/3}$)

C_D = drag coefficient

D_o = jet diameter

E = entrainment function

F = density deficiency

F_D = drag force

F_w = fraction of the plume perimeter which is wetted

G = temperature deficiency

G_1 = initial value of temperature deficiency

K_e = kinematic surface heat exchange coefficient

K_d = decay coefficient

K_y = vertical diffusion coefficient

K_{y1} = vertical diffusion coefficient at the surface

K_{yo} = characteristic vertical diffusion coefficient

K_z = lateral diffusion coefficient (horizontal)

L = jet spacing

M = kinematic momentum

M' = momentum

M_1 = initial value of kinematic momentum

Q = volume flow

Q_1 = initial value of volume flow

T = temperature or temperature excess

T_a = ambient temperature

T^* = local temperature

U_a = ambient velocity

W_t = width of the region which may be considered a slot jet

b* = subsurface jet characteristic width in the unrestricted direction

b_r = jet characteristic width as defined by the round-jet equations

c = concentration or field strength function

c_o = zeroth moment of c

c_1 = first moment of c

c_2 = second moment of c

c_{max} = maximum value of c along z

d_j = jet discharge depth

f = buoyancy force

g = gravitational acceleration

h_o = source thickness of the passive region of a subsurface discharge

h_b = depth of water

h_L = minimum of y_L and $b\sqrt{2}$

h_u = minimum of y_u and $b\sqrt{2}$

r = coordinate normal to subsurface jet path

r_c = radius of circle whose area is equal to that portion of a subsurface round jet between the surface and bottom boundaries

s = coordinate along the subsurface jet path

t = time

u* = local velocity in the jet

u = velocity

u_r = velocity as calculated by the round-jet equations

u_s = velocity as calculated by the slot-jet equations

x = horizontal coordinate

y = vertical coordinate

y_L = distance between plume centerline and intersection of plume with the lower boundary

y_u = distance between plume centerline and intersection of plume with the upper boundary

z = lateral coordinate

α_r = entrainment coefficient for round jet

α_s = entrainment coefficient for slot jet

ΔT = temperature difference

η = coordinate normal to s in a slot jet

Θ = angle of jet trajectory to the horizontal in a subsurface jet

Θ_0 = initial angle of subsurface jet discharge

Θ_1 = angle formed by the radii subtending the chord which is defined by the intersection between a round jet and the lower boundary

Θ_2 = angle formed by the radii subtending the chord which is defined by the intersection between a round jet and the upper boundary.

λ_r = spreading ratio for round jet

λ_s = spreading ratio for slot jet

ρ = density

ρ_a = ambient density

ρ^* = local density

σ_o = source depth for passive region of subsurface discharge

σ_r = width characteristic of a round jet

σ_y = $\sigma_o/4$

REFERENCES

B6.1-1 Koh, R.C.Y. and L.N. Fan, Oct. 1970; Mathematical Models for Predicting Temperature Distributions Resulting from Discharge of Heated Water Into Large Bodies of Water. Water Pollution Research Series. 16130 DW 010/70 Environmental Protection Office, Water Quality Office, Washington, D.C.

TABLE B6.1-1

SUMMARY OF PERTINENT EQUATIONS FOR SUBSURFACE BUOYANT JETS

Quantity	For Round Jet	For Slot Jet of Length L
Volume flux, Q	$\pi ub^2\left[1-\exp\left(-r_c^2/b^2\right)\right] + \pi U_a \cos\Theta \cos\phi\, r_c^2$	$Lub\frac{\sqrt{\pi}}{2}\left[\mathrm{erf}\left(h_u/b\right) + \mathrm{erf}\left(h_L/b\right)\right]$ $+ LU_a \cos\theta \cos\phi \left(h_u + h_l\right)$
Momentum flux, $M = \frac{M'}{\rho_o}$	$\frac{\pi}{2}u^2b^2\left[1-\exp\left(-2r_c^2/b^2\right)\right]$ $+ 2\pi ub^2U_a\cos\theta\cos\phi\left[1-\exp\left(-r_c^2/b^2\right)\right]$ $+ \pi U_a^2\cos^2\theta\cos^2\phi\, r_c^2$	$\frac{Lu^2b\sqrt{\pi}}{2\sqrt{2}}\left[\mathrm{erf}\left(h_u\sqrt{2}/b\right) + \mathrm{erf}\left(h_L\sqrt{2}/b\right)\right]$ $+ LubU_a\cos\theta\cos\phi\sqrt{\pi}\left[\mathrm{erf}\left(h_u/b\right) + \mathrm{erf}\left(h_L/b\right)\right]$ $+ LU_a^2\cos^2\theta\cos^2\phi\left(h_u + h_L\right)$
Density deficiency flux, F	$\pi\left(\rho_a-\rho\right)\lambda_r^2b^2\left\{\frac{u}{\lambda_r^2+1}\left[1-\exp\left\{-r_c^2\left(\lambda_r^2+1\right)/\lambda_r^2b^2\right\}\right]\right.$ $\left. + U_a\cos\theta\cos\phi\left[1-\exp\left(-r_c^2/\lambda_r^2b^2\right)\right]\right\}$	$L\left(\rho_a-\rho\right)b\lambda_s\frac{\sqrt{\pi}}{2}\left[\frac{u}{\sqrt{\lambda_s^2+1}}\left\{\mathrm{erf}\left(h_u\sqrt{\lambda_s^2+1}/\lambda_s b\right)\right.\right.$ $\left. + \mathrm{erf}\left(h_L\sqrt{\lambda_s^2+1}/\lambda_s b\right)\right\} + U_a\cos\theta\cos\phi$ $\left.\left\{\mathrm{erf}\left(h_u/\lambda_s b\right) + \mathrm{erf}\left(h_L/\lambda_s b\right)\right\}\right]$

TABLE B6.1-1 (Continued)

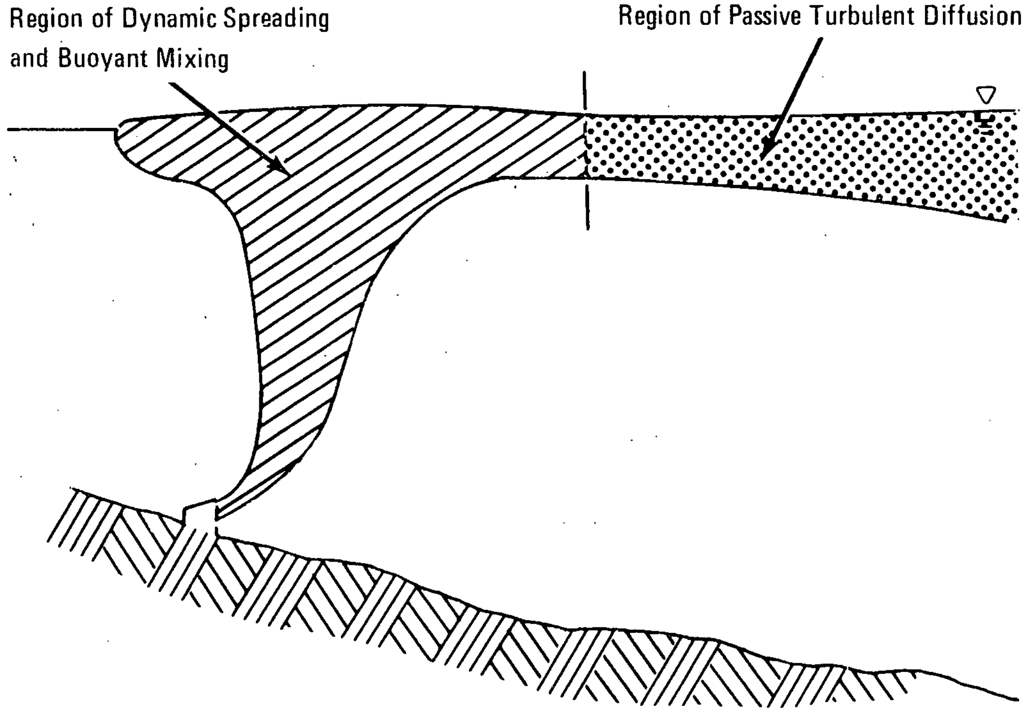
SUMMARY OF PERTINENT EQUATIONS FOR SUBSURFACE BUOYANT JETS

Quantity	For Round Jet	For Slot Jet of Length L
Temperature deficiency flux, G	$\pi\left(T_a-T\right)\lambda_r^2 b^2\left\{\frac{u}{\lambda_r^2+1}\left[1-\exp\left\{-r_c^2\left(\lambda_r^2+1\right)/\lambda_r^2 b^2\right\}\right] + U_a \cos\theta \cos\phi\left[1-\exp\left(-r_c^2/\lambda_r^2 b^2\right)\right]\right\}$	$L\left(T_a-T\right)b\lambda_s\sqrt{\frac{\pi}{2}}\left[\frac{u}{\sqrt{\lambda_s^2+1}}\left\{\mathrm{erf}\left(h_u\sqrt{\lambda_s^2+1}/\lambda_s b\right) + \mathrm{erf}\left(h_L\sqrt{\lambda_s^2+1}/\lambda_s b\right)\right\} + U_a\cos\theta\cos\phi\left\{\mathrm{erf}\left(h_u/\lambda_s b\right) + \mathrm{erf}\left(h_L/\lambda_s b\right)\right\}\right]$
Buoyancy force, f	$\pi g\left(\rho_a-\rho\right)\lambda_r^2 b^2\left[1-\exp\left(-r_c^2/\lambda_r^2 b^2\right)\right]$	$L\left(\rho_a-\rho\right)b\lambda_s g\frac{\sqrt{\pi}}{2}\left[\mathrm{erf}\left(h_u/\lambda_s b\right) + \mathrm{erf}\left(h_L/\lambda_s b\right)\right]$
Entrainment function, E	$2\pi\alpha_r b F_w\sqrt{u^2+U_a^2\left(1-\cos^2\theta\cos^2\phi\right)}$	$2\alpha_s L F_w\sqrt{u^2+U_a^2\left(1-\cos^2\theta\cos^2\phi\right)}$

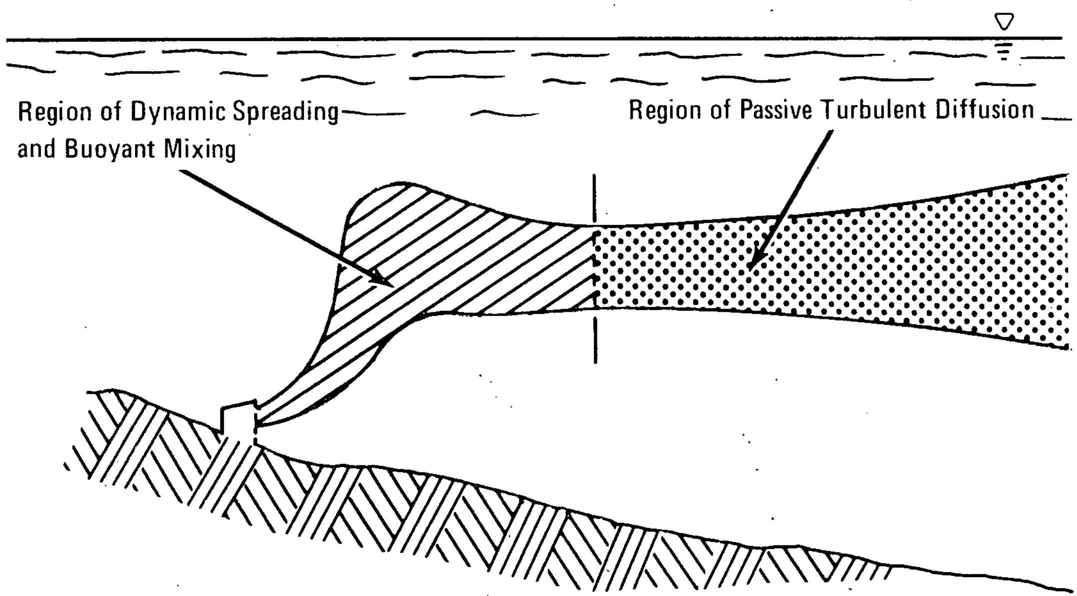
TABLE B6.1-1 (Continued)

SUMMARY OF PERTINENT EQUATIONS FOR SUBSURFACE BUOYANT JETS

Quantity	For Round Jet	For Slot Jet of Length L
Drag Force, F_D	$\sqrt{2}\, C_D b \rho_a U_a^2 \left(1-\cos^2\theta\cos^2\phi\right)$	$\sqrt{2}\, C_D b \rho_a U_a^2 \left(1-\cos^2\theta\cos^2\phi\right)$
	$r_c = \sqrt{\dfrac{b^2\left(2\pi-\theta_1-\theta_2\right) - \sqrt{2}b\left(h_L \sin\left[\theta_1/2\right] + h_u \sin\left[\theta_2/2\right]\right)}{\pi}}$	
	$\theta_1 = 2\cos^{-1}\left(h_L/\sqrt{2}b\right)$ $\theta_2 = 2\cos^{-1}\left(h_u/\sqrt{2}b\right)$	



(a) EFFLUENT FIELD ESTABLISHED AT WATER SURFACE



(b) EFFLUENT FIELD TRAPPED BELOW WATER SURFACE

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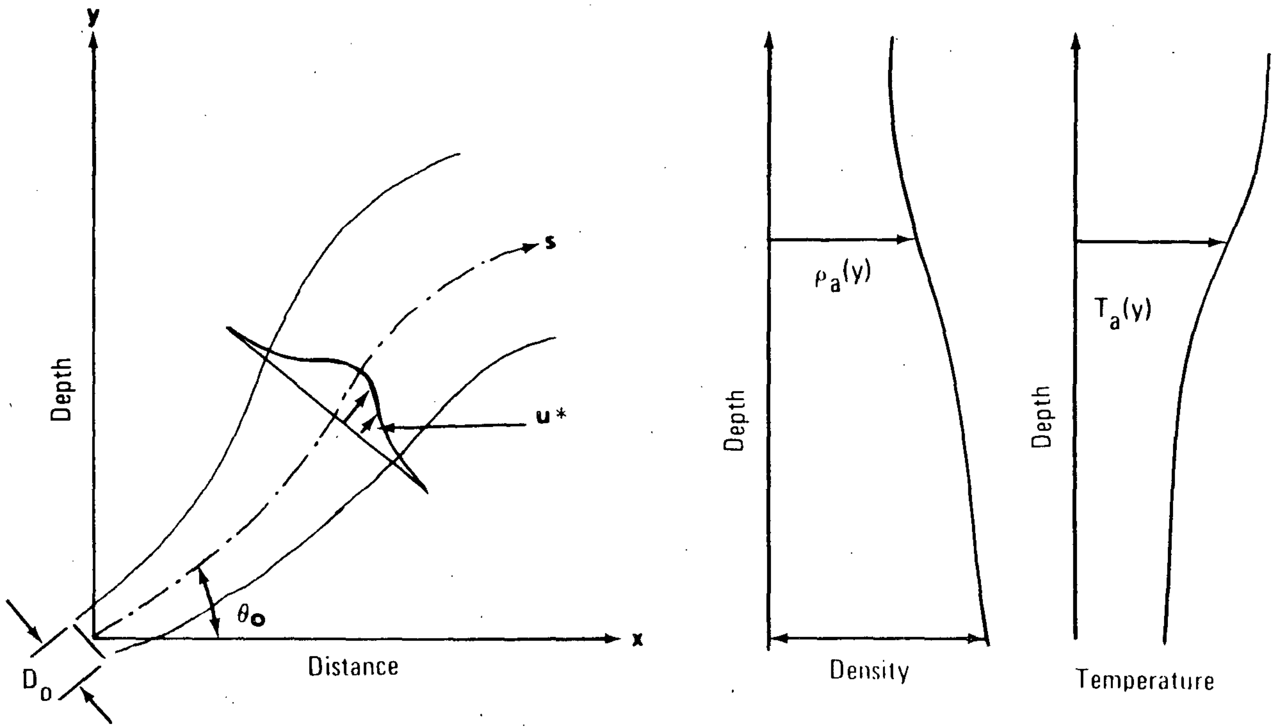
SUBMERGED COOLING WATER
DISCHARGE PLUME REGIONS

FIGURE B6.1-1



(a) Jet Definition (b) Ambient Density Profile (c) Ambient Temperature Profile

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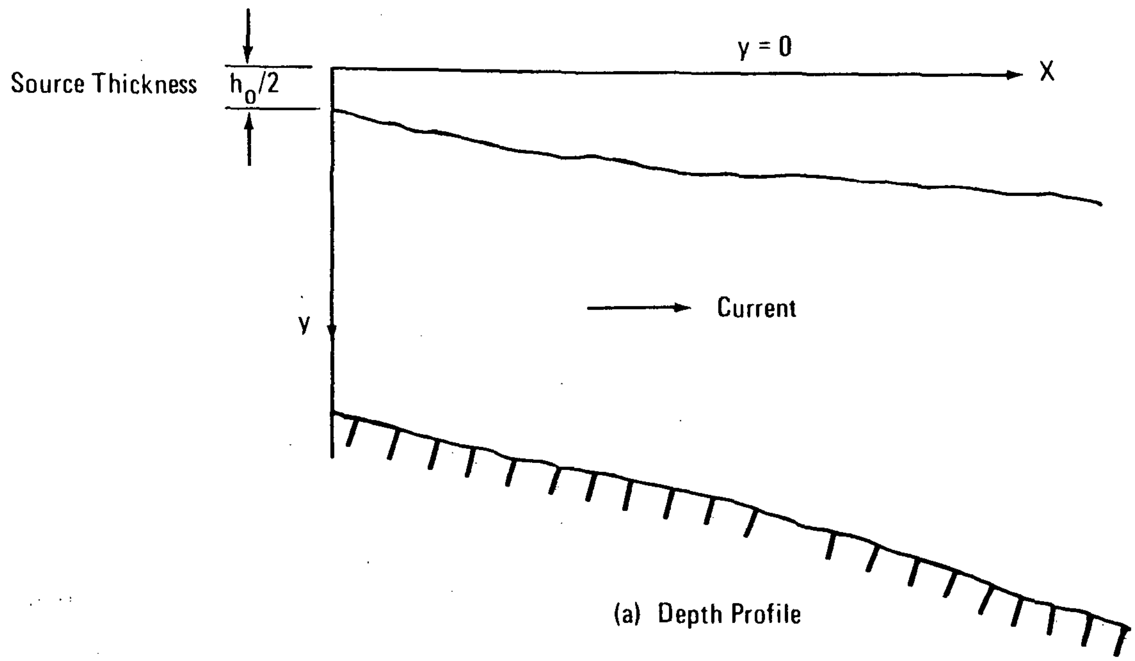
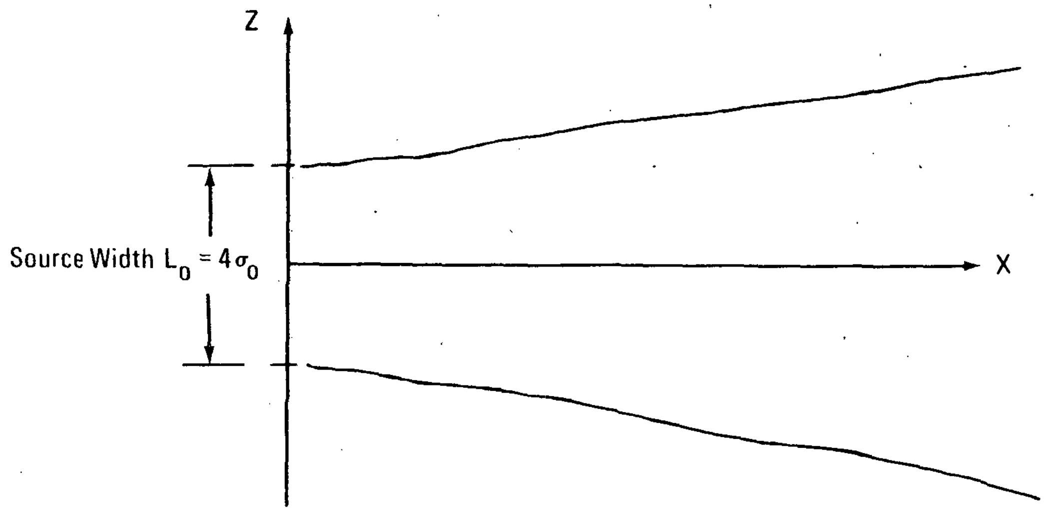
SUBMERGED JET DEFINITION SKETCH

FIGURE B6.1-2



(a) Depth Profile



(b) Surface Profile

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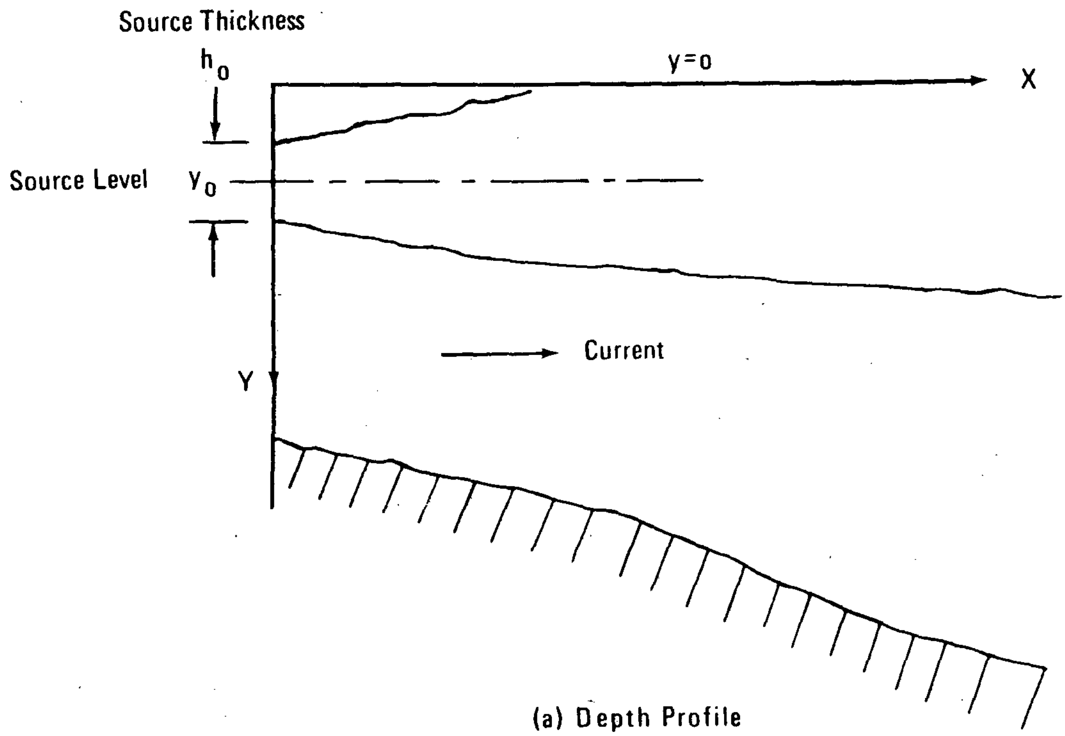
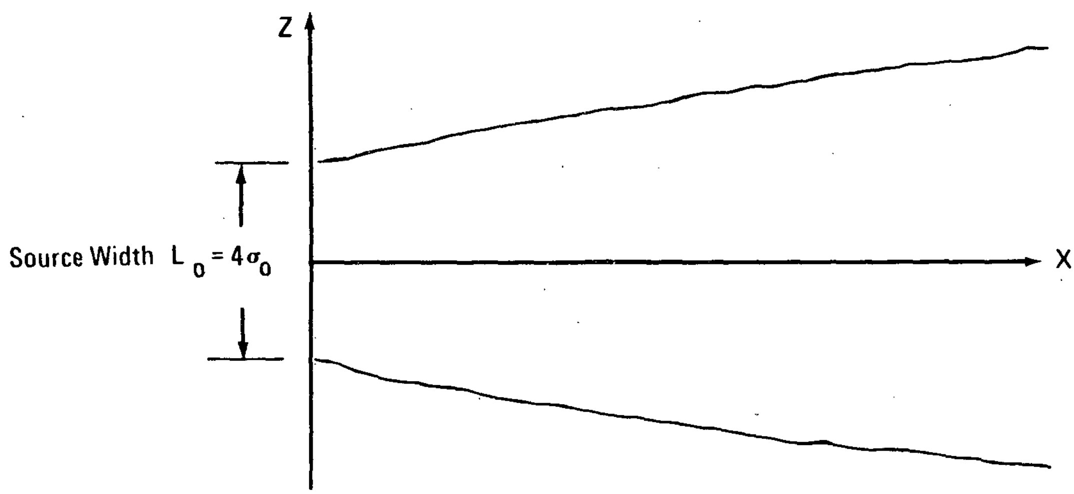
FLOW CONFIGURATIONS
FOR STEADY SURFACE FLOW

FIGURE B6.1-3



(a) Depth Profile



(b) Horizontal Profile

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FLOW CONFIGURATIONS
FOR STEADY SUBMERGED FLOW

FIGURE B6.1-4

APPENDIX 6.1-C

MATHEMATICAL MODELS TO PREDICT SEEPAGE FROM COOLING RESERVOIRS

MATHEMATICAL MODELS TO

PREDICT SEEPAGE FROM COOLING RESERVOIRS

APPENDIX 6.1-C

Prepared for

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APPENDIX 6.1-C

GROUND WATER MODELS

INTRODUCTION

The STP site is located in Matagorda County. Covering an area of approximately 7,000 acres, it is a small part of the Gulf Coastal Plain which is composed of thousands of feet of semiconsolidated to unconsolidated sediments sloping gulfward at a regional angle of three degrees. In the immediate vicinity of the site, the inclination is smaller and approximates one degree. Because the surface of the plant site is nearly flat, there is no unusual relief and no visible drainage.

Below the surface, an impervious zone about 6 feet thick is present. The permeability of this confining layer is 1.53×10^{-7} cm/sec.

A stratum of sandy silt 17 feet thick and slightly more permeable (10^{-5} cm/sec) underlies the top layer. The piezometric surface is located approximately 4 feet below the surface.

Several wells drilled in the area of the cooling reservoir indicate the presence of a permeable (3×10^{-3} cm/sec) strip of fine sand sloping gently toward the lower Colorado River. This layer tends to act as a fracture for fluids draining from the upper layers.

A detailed description of the geological cross section of the plant site is found in Section 2.5.2 of the South Texas Project Environmental Report. However, for the purpose of designing the seepage models a schematic diagram of the soil profile is shown in Figure C6.1-1.

PART I. APPROXIMATE TRANSIENT TWO-DIMENSIONAL MODEL

The flowfield under the STP cooling reservoir can be described by the mathematical techniques of potential theory. In the x,y plane, a complex potential ω may be defined by means of the following relation[1]:

$$z = H_w e^{-\pi\omega/Q} - i\omega + \frac{Q}{2} \tag{1}$$

(See Nomenclature for definition of terms.)

If Equation (1) is separated into real and imaginary parts, one obtains:

$$x = H_w e^{-\pi\phi/Q} \cos\frac{\pi\psi}{Q} + \psi + \frac{Q}{2}$$

and (2)

$$y = -H_w e^{-\pi\phi/Q} \sin\frac{\pi\psi}{Q} - \phi$$

The shape of the reservoir may be obtained by setting $\phi = 0$ in equations (2) and then eliminating ψ by appropriate manipulations. This gives:

$$\left(x - \frac{Q}{\pi}\cos^{-1}\frac{y}{H_w}\right)^2 + y^2 = H_w^{\ 2} \tag{3}$$

If the shape of the reservoir is given by (3), then steady-state seepage flux will be obtained by setting $y = 0$ and $x = B/2$. After performing these operations one obtains:

$$Q = B - 2H_w \tag{4}$$

The flux lines out of the reservoir are shown in Figure C6.1-2.

The stream functions passing through A and B are the free surfaces, $\psi = 0$, and $\psi = -Q$, bounding the flow.

If we use the steady-state distribution of velocities (u, v) obtained from this system and combine it with the Kelvin frontal-advance equation $DF'/Dt = 0$, we will have a formula with which it is possible to predict an approximate transient advance of a seepage front whose initial position is AOB in Figure C6.1-2. Expanding the Kelvin equation, it is possible to write:

$$\frac{DF'}{Dt} = \frac{\partial F'}{\partial t} + u\frac{\partial F'}{\partial x} + v\frac{\partial F'}{\partial y} = 0 \tag{5}$$

The functions F' (x,y,t) represents lines AOB, A'O'B' and A"O"B" at different times. At t = 0 F' (x,y,0) describes line AOB. Similarly F' (x,y,t_1) and F' (x,y,t_2) describe the frontal positions at time t_1 and t_2. Now if we change the x,y coordinates to the orthogonal system ϕ,ψ, Equation (5) may be written after incorporating the porosity f in the form:

$$\frac{\partial F}{\partial t} - \frac{1}{f}\left|\nabla\phi\right|^2 \frac{\partial F}{\partial \phi} = 0 \qquad (6)$$

The solution of (6) can be readily obtained as:

$$F(\phi,\psi) = t + f\int \frac{d\phi}{\left|\nabla\phi\right|^2} + g(\psi) = 0 \qquad (7)$$

where: $g(\psi)$ is a function dependent on ψ resulting from the integration, and

$$|\nabla\phi|^2 = \left|\frac{\partial\phi}{\partial z}\right|^2$$

which can be obtained by differentiating (1) with respect to z and then separating the real and imaginary parts.

Hence:

$$\left|\frac{\partial\phi}{\partial z}\right|^2 = \left[\text{Real}\left(\frac{\partial\phi}{\partial z}\right)\right]^2 + \left[\text{Imag}\left(\frac{\partial\phi}{\partial z}\right)\right]^2 \qquad (8)$$

If we replace $|\nabla\phi|^2$ by its value, perform the integration and apply the condition: for t = 0, $g(\psi) = F(0,\psi)$ we get:

$$\frac{t}{f} = -\phi - \frac{\pi H_w^2}{2Q}\left(1 - e^{-2\pi\phi/Q}\right) + 2H_w\left(1 - e^{-\pi\phi/Q}\right)\sin\frac{\pi\phi}{Q} \qquad (9)$$

For reservoirs as large as the one planned for STP, the rate of flux Q is much larger than the largest value of ϕ in the system. Several calculations carried out for a reservoir 20,000 feet wide have shown that $e^{-2\pi\phi/Q}$ and $e^{-\pi\phi/Q}$ are essentially equal to one. Under these conditions formula (9) reduces to the form:

$$t = -f\phi \qquad (10)$$

This indicates first, that the seepage from a large reservoir is essentially vertical and second that the transient flood front is parallel to the potential lines.

Although Equations (9) and (10) may be used to calculate the transient seepage flow from reservoirs, ditches or ponds, their use is limited to homogeneous formations. Because heterogeneity is more predominant in real formations, it was felt necessary to develop a two-dimensional numerical model which can be used for all types of underground strata. The development of Equation (9) was basically used to determine the type of flow from a reservoir into a homogeneous medium.

PART II. TWO-DIMENSIONAL NUMERICAL MODEL FOR UNSATURATED SOIL

A schematic diagram of the groundwater seepage model is shown in Figure C6.1-3.

The first 4 feet of formation lying below the bottom of the pond is initially dry. The seepage flow will have to saturate this layer of silty clay before it connects with the piezometric surface. If we assume that the properties of the contaminated water, such as viscosity, density, and surface tension, are identical to the properties of groundwater then it is possible to state that at the time the hydraulic connection occurs nearly steady-state conditions prevail.

Therefore, the first task to perform was to evaluate the two-dimensional case of transient flow occurring under a constant water head equal to H_w. This was accomplished by assuming that at a certain distance Δy below the bottom of the pond (origin of problem), a constant potential ϕ_1 exists and corresponds to an increment in time Δt_1. Both ϕ_1 and Δt_1 were found by solving Laplace's and Kelvin's equations simultaneously. This agreement preceded the second step which was calculated in a similar fashion. The position of the front at Δt_1 was used as the origin of the next time increment. The potential drop was calculated for an increment in time equal to Δt_2.

The major difficulty in a problem of this kind is to determine the position of the free surfaces. Even though these lines can be determined by a trial-and-error procedure in the $\phi(x,y)$, $\psi(x,y)$ system, R. Jeppson[2] showed that it is preferable to change the ϕ,ψ coordinates into $x(\phi,\psi)$ and $y(\phi,\psi)$ planes. In this manner, the free surfaces would be defined by definite values of ψ. The relations used for this conversion are:

$$\frac{\partial x}{\partial \phi} = \frac{1}{J}\frac{\partial \psi}{\partial y}; \quad \frac{\partial y}{\partial \phi} = -\frac{1}{J}\frac{\partial \psi}{\partial x};$$
$$\frac{\partial x}{\partial \psi} = -\frac{1}{J}\frac{\partial \phi}{\partial y}; \quad \frac{\partial y}{\partial \psi} = \frac{1}{J}\frac{\partial \phi}{\partial x} \tag{11}$$

$$J = \begin{bmatrix} \frac{\partial \phi}{\partial x} & \frac{\partial \phi}{\partial y} \\ \frac{\partial \psi}{\partial x} & \frac{\partial \psi}{\partial y} \end{bmatrix} = \begin{bmatrix} u & v \\ -v & u \end{bmatrix} \tag{12}$$

Relations (12) can be used to transform Equations (13)

$$\frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2} = 0 \text{ and } \frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} = 0 \qquad (13)$$

to Equations (14)

$$\frac{\partial^2 x}{\partial \phi^2} + \frac{\partial^2 x}{\partial \psi^2} = 0 \text{ and } \frac{\partial^2 y}{\partial \phi^2} + \frac{\partial^2 y}{\partial \psi^2} = 0 \qquad (14)$$

In the x,y plane the flow configuration for a time increment is shown in Figure C6.1-4. Because of symmetry, the following boundaries are sufficient:

Along OB_1B $\phi = 0$

Along the BD^1(free surface) $\psi = Q/2$

Along CD $\phi = \phi_1$

Along OC (axis of symmetry) $\frac{\partial\phi}{\partial x} = 0$ and $\psi = 0$

If we translate these boundaries to the ϕ,ψ plane we obtain the result shown in Figure C6.1-5.

After fixing the boundaries, the Laplace's equation in y must be solved, subject to the above conditions. The numerical procedure and the iterative steps are described in Jeppson's paper and need not be repeated here. It suffices, however, to say that the solution in the ϕ,ψ plane is considered final only after all calculated variables in the ϕ,ψ plane agree with the boundary conditions specified in the x,y plane.

The adjusted position of the water front at time Δt_1 would be used as the initial condition of the next step. The procedure is repeated until the summation of the Δy terms add to the total distance between the surface and the water table.

The technique described above was used to calculate stepwise the transient seepage from the STP cooling reservoir. The width of the reservoir was taken to be 20,000 feet. The calculations were made for homogeneous, heterogeneous, and anisotropic media. All these computations have shown that the lateral spread of the seepage beyond the vertical line is less than 7 feet per 10,000 feet width. Considering the flow to be vertical would be equivalent to committing an error of less than 0.07 percent. This conclusion coupled with the result we found using Equation (9) proved conclusively that the flow from the STP cooling reservoir is essentially one-dimensional and vertical in the layer underlying the cooling reservoir.

PART III. TRANSIENT LINEAR MODEL

The previous sections dealt in great detail with the type of flow which takes place when water seeps from a reservoir into the underlying unsaturated formation. The problem is essentially a water encroachment occurring under the driving force of a constant head H_w. To derive a relation giving the time as a function of water penetration the following balance should be made: (see Figure C6.1-6)

Let us suppose that at time t, the seepage front reaches a depth of L_w. The volume and rate of water at that instant can be written as:

$$V = AfL_w \tag{15}$$

and $$Q = Af\frac{dL_w}{dt} \tag{16}$$

The rate of linear flow can also be written as

$$Q = KA\left(\frac{H_w - P_w + L_w}{H_w - P_w}\right) \tag{17}$$

Equating (17) with (16) and integrating the resulting equation between the appropriate boundaries we obtain:

$$t = \frac{f}{K}\left[L_w - (H_w - P_w)\ \ln\left(\frac{H_w - P_w + L_w}{H_w - P_w}\right)\right] \tag{18}$$

This equation gives the time t required for the contaminated water to penetrate to a certain depth L_w in a soil whose permeability, porosity and capillary pressure are K, F, and P_w.

For $K = 1.53 \times 10^{-7}$ cm/sec, f = 0.25, P_w = 1 foot, the contaminated water will require 0.50 years to saturate 4 feet of formation underlying the reservoir area. This result applies only if H_w = 21.62 feet, which is the average head to be maintained in the reservoir.

PART IV. STEADY-STATE SEEPAGE MODEL

The geologic configuration for the steady-state model is shown in Figure C6.1-7.

As indicated in this sketch there is a layer of silty clay about 6 feet thick below the base of the reservoir. The permeability of this bed is 1.53×10^{-7} cm/sec. The piezometric surface is located 4 feet below the ground surface.

Models described in the previous pages prove beyond doubt that the flow from a large reservoir is vertical. This direction does not change until the vertical flow touches the groundwater table.

The groundwater steady state model may be obtained by solving Laplace's equation:

$$\nabla^2\phi = 0 \tag{19}$$

BOUNDARY CONDITIONS

The boundary conditions of the system are shown in Figure C6.1-7. As indicated on this diagram, along the base of the reservoir $\phi = \phi_1$ = constant. Because the flow is essentially vertical, the boundaries along $A_1A_2A_3$ and $B_1B_2B_3$ are:

$$\left.\frac{\partial\phi}{\partial x}\right|_{A_1A_2A_3} = \left.\frac{\partial\phi}{\partial x}\right|_{B_1B_2B_3} = 0 \tag{20}$$

where ϕ is equal to ϕ_1 in zone $A_1A_2B_2B_1$
and ϕ is equal to ϕ_2 in zone $A_2A_3B_3B_2$

At the junction A_2B_2 and A_3B_3 between two layers of differing permeability, the continuity of the flow dictates that

$$\frac{\partial \phi_1}{\partial y} = \frac{\partial \phi_2}{\partial y} \qquad (21)$$
$$\frac{\phi_1}{K_1} = \frac{\phi_2}{K_2}$$

Along segments CA_3, B_3E and DF, the confined nature of the aquifer suggests that the normal flow is negligible, therefore, a common condition here would be:

$$\frac{\partial \phi}{\partial m} = 0 \quad \text{(m is the normal to the direction considered)} \qquad (22)$$

The boundaries on faces CD and EF would be respectively equal to:

$$-T \frac{\partial \phi_3}{\partial x} = Q_2 \qquad (23)$$

and
$$-T \frac{\partial \phi_3}{\partial x} = Q_1 + Q_2 \qquad (24)$$

ϕ_3 is the potential distribution in zone CA_3B_3EFD. Q_2 is the rate of flow in the small aquifer located between CA_3B_3E and DF. This rate was calculated from piezometric readings and was verified by comparison with the regional migration of fluid in that area. Q_1 is the steady-state rate of flow out of the reservoir. An approximate value for this variable may be obtained by evaluating the velocity of the vertical flow at line A_3B_3 and then multiplying it by the cross-sectional area A_3B_3. If this calculation is made for one foot of width we would get a rate equal to 0.100×10^{-3} ft^3/sec-ft.

The rate of flow at face CD was calculated and found to be equal to 0.623×10^{-6} ft^3/sec-ft. Hence, the rate of flux at face EF must be equal to 0.1006×10^{-3} ft^3/sec-ft.

STEADY-STATE NUMERICAL MODEL

If we discretize Laplace's equation using an (i,j) grid system, we obtain:

$$\frac{\phi_{i+1,j} - 2\phi_{i,j} + \phi_{i-1,j}}{(\Delta x)^2} + \frac{\phi_{i,j+1} - 2\phi_{i,j} + \phi_{i,j-1}}{(\Delta y)^2} = 0 \qquad (19a)$$

In general Δx would be taken equal to Δy and Equation (19a) would be reduced to a much simpler form. However, in this problem the horizontal coordinate extends from 0 to 10,000 feet whereas the vertical demension varies from 0 to 43 feet. A grid based on $\Delta x = \Delta y$ is possible but would make the system too lengthy and too tedious to solve. A more efficient solution dictates that we take Δx much larger than Δy.

The conditions expressed in Equations (20), (21), (23), and (24) can be expressed numerically in the following way:

$$\left.\frac{\partial \phi}{\partial x}\right|_{B_1B_2B_3} = \left.\frac{\partial \phi}{\partial x}\right|_{A_1A_2A_3} = 0 \tag{20a}$$

$$\frac{\phi_{-n+1} - \phi_{-n-1}}{2\Delta x} = \frac{\phi_{n+1} - \phi_{n-1}}{2\Delta x} = 0$$

Where $\pm n$ represents the boundaries of the system.

Above line A_2B_2 continuity of the flow requires that Equations (21a) be verified:

$$\left.\frac{\partial \phi_1}{\partial y}\right|_{A_2B_2} = \left.\frac{\partial \phi_2}{\partial y}\right|_{A_2B_2}$$

$$= \frac{\phi_{1,i,j+1} - \phi_{1,i,j-1}}{2\Delta y} = \frac{\phi_{2,i,j+1} - \phi_{2,i,j-1}}{2\Delta y} \tag{21a}$$

$$\frac{\phi_{1,i,j}}{K_1} = \frac{\phi_{2,i,j}}{K_2}$$

On faces CD and EF the following numerical approximations must be verified:

$$-T\left(\frac{\phi_{3,i+1,j} - \phi_{3,i-1,j}}{2\Delta x}\right) = Q_2 \tag{23a}$$

$$-T\left(\frac{\phi_{3,i+1,j} - \phi_{3,i-1,j}}{2\Delta x}\right) = Q_1 + Q_2 \tag{24a}$$

The potential distribution of the system was obtained by solving Equation (19a) subject to all the boundary considerations of the system. The Gauss-Seidel method was used, except in cases when we were able to determine the over-relaxation coefficient. In most cases, the overrelaxation method was used, reducing the number of iterations necessary to obtain the solution from about 600 to 250.

PART V. DISPERSION MODEL

The seepage of contaminated water from the cooling reservoir will invade the first four feet of unsaturated soil. Assuming there is no exchange of salt concentration between the water and the soil the calculation of the transient water movement can be easily made by means of Equation (18). The time required by the contaminant to reach the piezometric surface depends on the properties of the fluid and formation as well as the head of water maintained in the reservoir. For the condition cited above, the concentration of contaminant above the water table would be equal to the original concentration existing in the reservoir.

Dispersion takes place when the contaminated water touches the piezometric surface and begins to displace the groundwater. In order to predict the movement and dispersion of the contaminant a predictive dispersion model was developed. The transport of contaminants can be described by means of the following equation:

$$\frac{\partial C}{\partial t} + u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = \frac{\partial}{\partial x}\left(D_x \frac{\partial C}{\partial x}\right) + \frac{\partial}{\partial y}\left(D_y \frac{\partial C}{\partial y}\right) \qquad (25)$$

The velocities u, v which appear in Equation (25) or their distribution throughout the system are given by the transient and steady-state models previously described. In the description of the present model, it is therefore implied that u and v are known at each grid point.

The hydrodynamic dispersion coefficients may be calculated as a function of the molecular diffusion and the Peclet number by these following formulas:

$$D_x = 0.7D_m + \beta_x PeD_m$$
$$D_y = 0.7D_m + \beta_y PeD_m \qquad (26)$$

where:

D_m is the molecular diffusion coefficient

Pe is the Peclet number. It is defined as

$$Pe = q(d_{50}/Dm)$$

q is the resultant velocity of flow

d_{50} is the median grain diameter of the porous material under study

β_x and β_y are empirical constants. For isotropic media $\beta_x = \beta_y = 1.8$.

Figure C6.1-8 is a schematic diagram of the model where dispersion will take place under prescribed conditions. The boundary conditions of the system are as follows:

Along A_2A_1 and B_2B_1: $\frac{\partial C}{\partial y} = 0$ for $t \geq 0$

Along A_2B_2: $C = C_o = 1.00$ for $t \geq 0$

On segments CA_3, B_3E and DF: $\frac{\partial C}{\partial y} = 0$ for $t \geq 0$

On EF, at a large distance from the reservoir, $C = 0$

METHOD OF ANALYSIS

Because of the complexity of the boundaries and for the benefit of using variable dispersion coefficients, a numerical scheme was sought. We considered first an explicit scheme. This procedure consists of calculating a variable at time $t + \Delta t$ as a function of others evaluated at time t. This technique is simpler to program and requires less core space than other methods and less computer time. However, the time step is constrained by stability considerations.

The implicit method is unconditionally stable but requires more space, more computer time and is generally more tedious because it involves the simultaneous solution of n equations with n unknowns.

A compromise was adopted by using the alternating-direction method. This consists of a three-point formula calculating three variables at time $t + \Delta t$ and taken along the x direction as a function of three known values taken along the y direction at time t.

This scheme combines the stability of the implicit method with the ease and speed of the explicit procedure. Under some conditions, this finite difference method produces mild oscillations and local numerical error which tends to dissipate quickly.

Of all the various versions of the A.D.I. scheme described in the literature, the Peaceman and Racheford procedure was selected because of its suitability to the conditions of the problem under consideration.

Following this scheme, the discretization of the partial differential equations give, for the first half time step:

$$2\left(\frac{C^{+}_{i,j} - C^{n}_{i,j}}{\Delta t}\right) + u_{i,j}\frac{C^{+}_{i+1,j} - C^{+}_{i-1,j}}{2\Delta x} + v_{i,j}\frac{C^{n}_{i,j+1} - C^{n}_{i,j-1}}{2\Delta y}$$

$$= \frac{D_{x,i+1,j}C_{i+1,j} - \left(D_{x,i+1,j} + D_{x,i,j}\right)C^{+}_{i,j} + D_{x,i-1,j}C^{+}_{i-1,j}}{(\Delta x)^2}$$

$$+ \frac{D_{y,i,j+1}C^{n}_{i,j+1} - \left(D_{y,i,j+1} + D_{y,i,j}\right)C^{n}_{i,j} + D_{y,i,j}C^{n}_{i,j-1}}{(\Delta y)^2} \quad (27)$$

For the second half time step:

$$2\left(\frac{C^{n+1}_{i,j} - C^{+}_{i,j}}{\Delta t}\right) + u_{i,j}\frac{C^{+}_{i+1,j} - C^{+}_{i-1,j}}{2\Delta x} + v_{i,j}\frac{C^{n+1}_{i,j+1} - C^{n+1}_{i,j-1}}{2\Delta y}$$

$$= \frac{D_{x,i+1,j}C^{+}_{i+1,j} - \left(D_{x,i+1,j} + D_{x,i,j}\right)C^{+}_{i,j} + D_{x,i-1,j}C^{+}_{i-1,j}}{(\Delta x)^2}$$

$$+ \frac{D_{y,i,j+1}C^{n+1}_{i,j+1} - \left(D_{y,i,j+1} + D_{y,i,j}\right)C^{n+1}_{i,j} + D_{y,i,j}C^{n+1}_{i,j-1}}{(\Delta y)^2} \quad (28)$$

The solution of these equations subject to the boundary conditions of the model would give the concentration distribution of the contaminant at various times. From these results, lines of equal concentrations can be drawn which show how the dispersion invades the system and the speed with which the increase in contaminant concentration occurs.

NOMENCLATURE

A	Cross sectional area of flow
B	Total width of the cooling reservoir measured at water level
C	Concentration of the contaminant
$C_{i,j}$	Concentration of nΔt, iΔx, jΔy
$C^{+}_{i,j}$	Concentration at (n+1/2)Δt, iΔx, jΔy
$D_{x,i,j}$ $D_{y,i,j}$	Dispersion coefficients in the x and y directions at iΔx, jΔy
D_m	Molecular diffusion coefficient
f	Porosity of the medium
F'(x,y,t)	Position of Seepage front at time t
pg-rho	Gravity force
H_w	Water height maintained in the cooling reservoir
K	Hydraulic conductivity
k	Coefficient of permeability
L_w	Water penetration
μ	Viscosity of the fluid
P_w	Capillary suction of the soil
Q, Q_1, Q_2, Q_3	Rate of flow, rates of flow in Regions 1, 2, 3.
$\phi, \phi_1, \phi_2, \phi_3$	Velocity potentials and velocity potentials in Zones 1, 2, 3.
ψ	Stream function
t	Time
T	Thickness of the aquifer
u,v	Velocity components in x,y directions
ω	Complex potential $\phi + i\psi$
z	Complex plane $x + iy$

REFERENCES

C6.1-1 Muskat, M., 1946; The Flow of Homogeneous Fluids Through Porous Media, J. W. Edwards, Ann Arbor, Mich.

C6.1-2 Jeppson, R. W., January 1968; "Seepage From Ditches: Solution by Finite Differences." Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers.

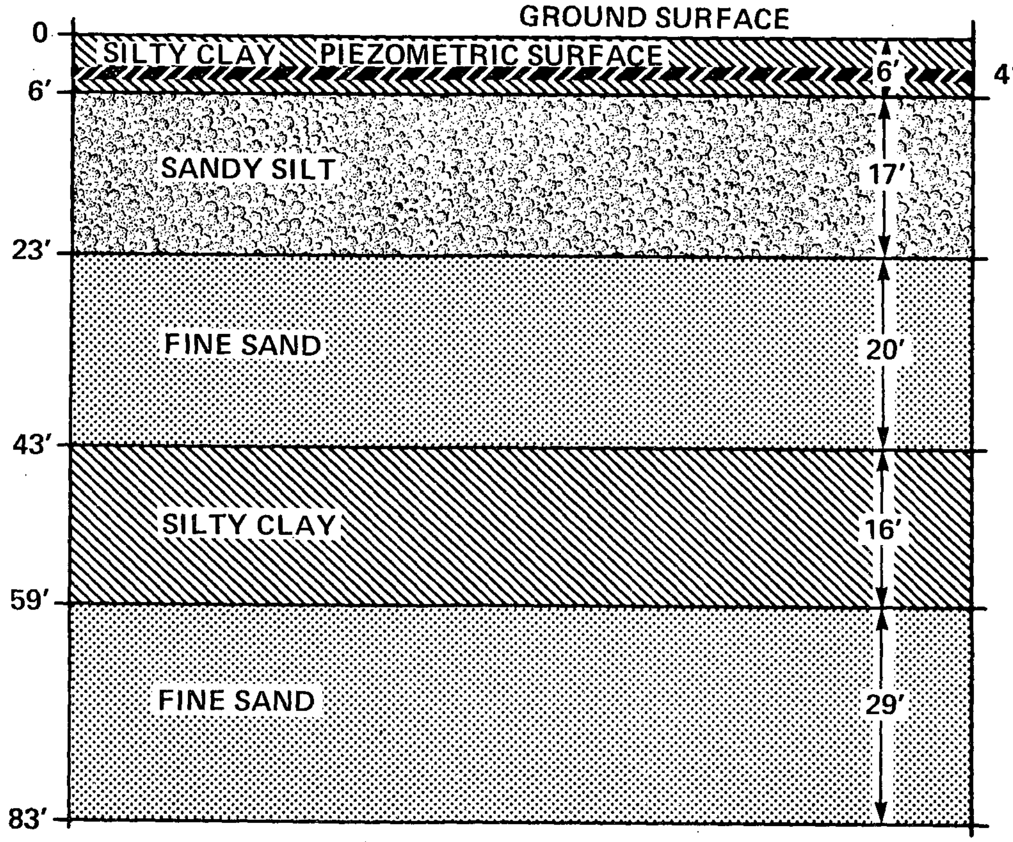

FIGURE C6.1-1

Profile of Soil Underlying the STP Cooling Reservoir

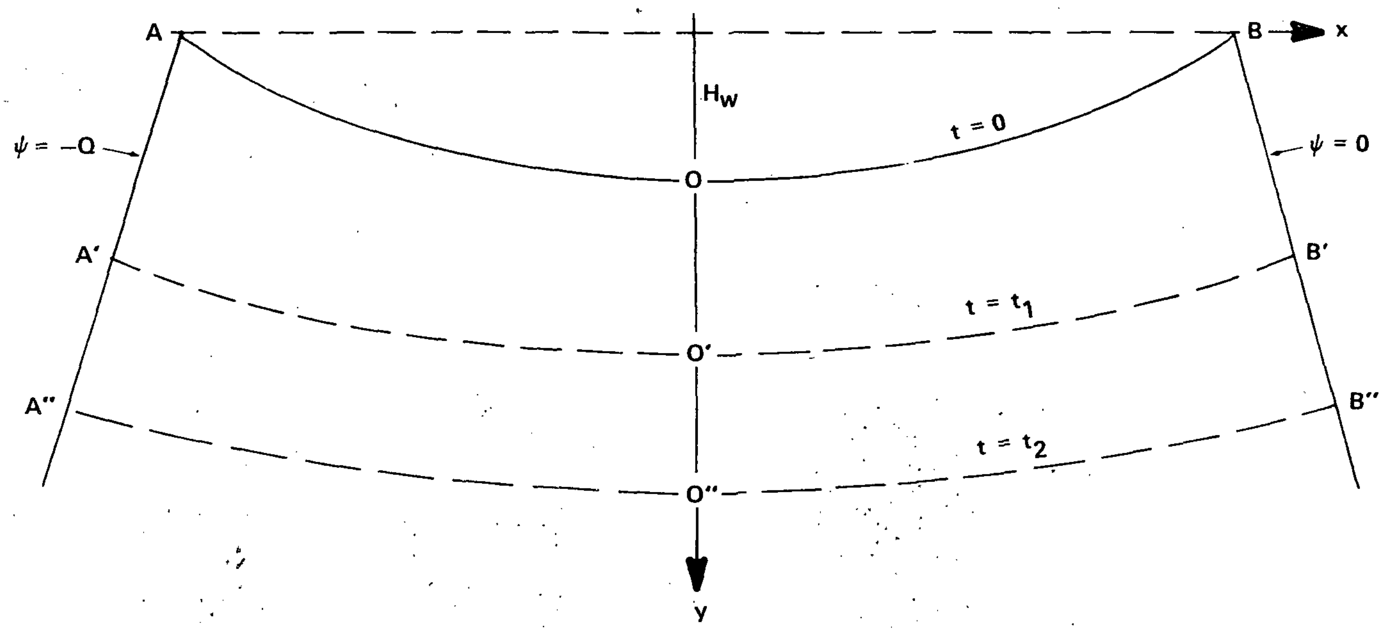

FIGURE C6.1-2

Schematic Diagram Showing the Flux Lines Out of the Reservoir

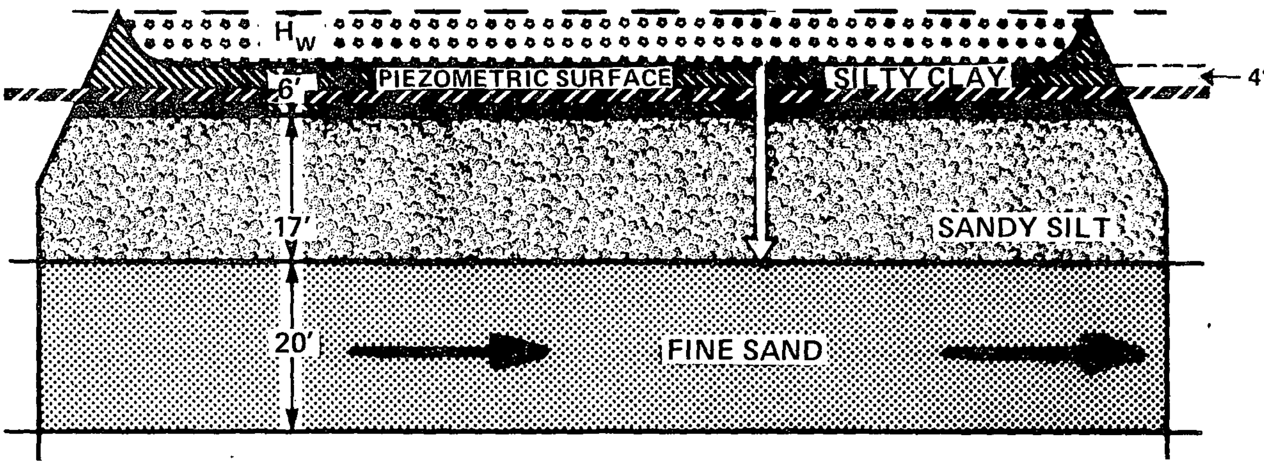

FIGURE C6.1-3

Schematic Diagram of the Groundwater Seepage Model

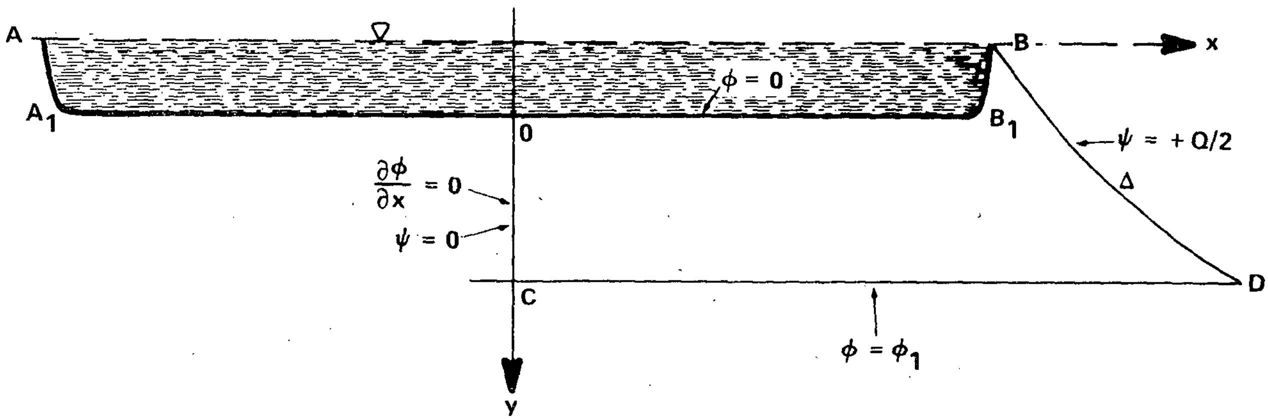

FIGURE C6.1-4

Flow Configuration for a Time Increment

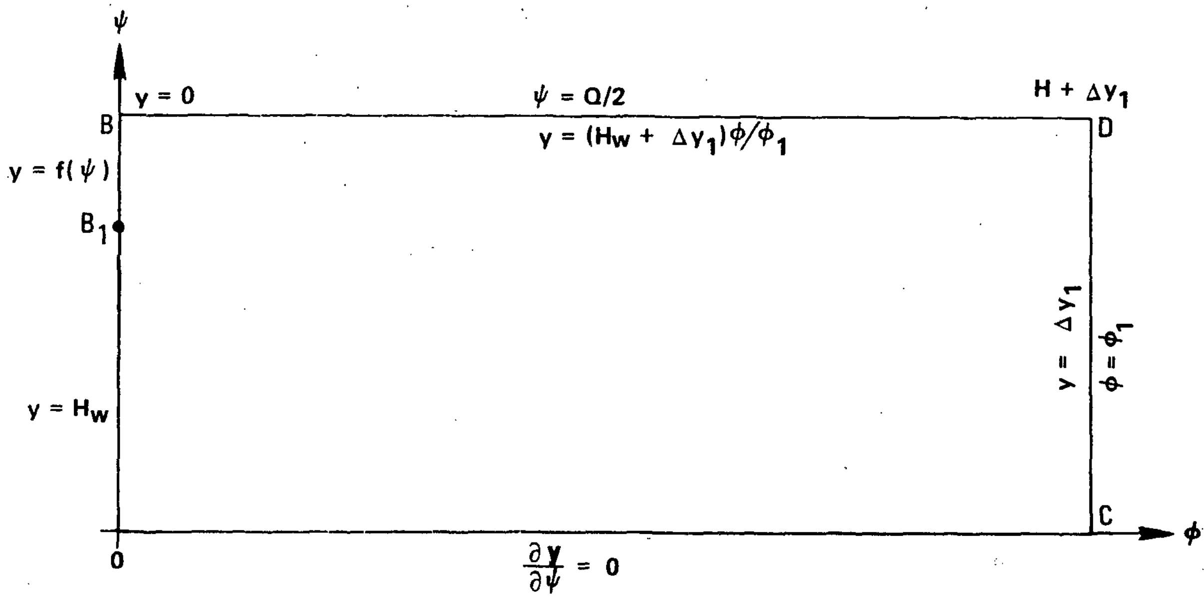

FIGURE C6.1-5

Boundaries Translated to the ϕ ψ Plane

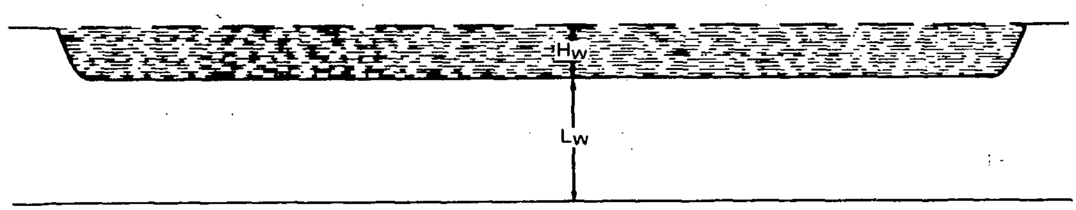

FIGURE C6.1-6

Diagram for Transient-Linear Model

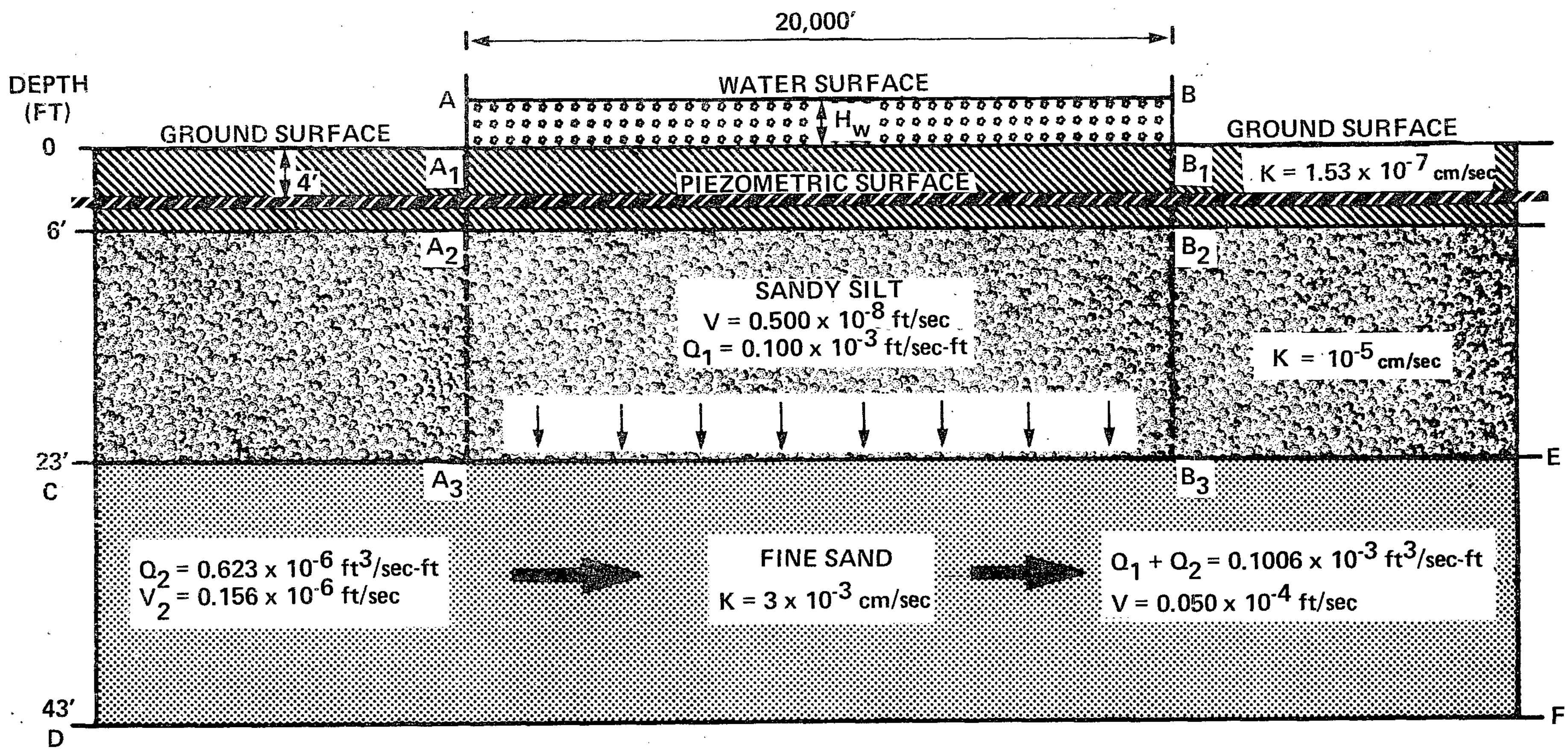

FIGURE C6.1-7

Diagram Showing Steady-State Model

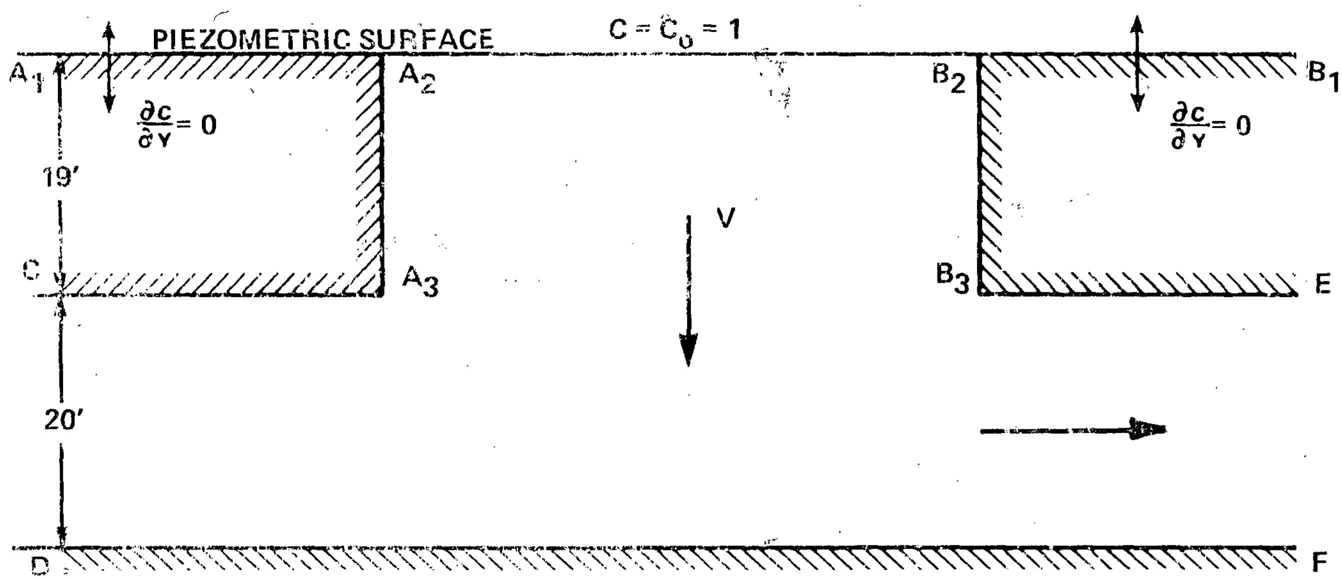

FIGURE C6.1-8

Schematic Diagram for Dispersion Model