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INTENSIVE SURVEYS OF
SAN ANTONIO RIVER
SEGMENTS 1901 AND 1911
JUNE 6, 1984 - MAY 16, 1985

Hydrology, Field Measurements, Water Chemistry
and Benthic Macroinvertebrates

By

Stephen R. Twidwell
and
Jack R. Davis

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ABSTRACT

Four intensive surveys of the San Antonio River (Segment 1911 and a portion of 1901) were conducted June 6, 1984 - May 16, 1985, by the Texas Water Commission, with assistance from the San Antonio River Authority and City of San Antonio. The study area consisted of the reach between Hildebrand Avenue in San Antonio to SH 72 near Runge, a distance of 199.9 kilometers (124.2 miles). River flow was highest in January 1985 due to runoff from melting snow and lowest in October 1984 when it approached the low flow criterion (4.07 m^3/s, 143.6 ft^3/s) at FM 1604. The discharge and assimilation of domestic effluents from the three largest City of San Antonio wastewater treatment plants dominated water quality in the San Antonio River during each survey. Ammonia nitrogen levels were in the range considered chronically toxic to warm water fishes in the reach between Camino Coahuilatechan and Blue Wing Road during each survey. Dissolved oxygen sags with levels less than the 5 mg/L criterion developed in the river due to downstream decay of oxygen demanding substances ($CBOD_5$ and ammonia nitrogen) discharged by the San Antonio wastewater treatment plants. The magnitude and longitudinal extent of each dissolved oxygen sag was different due to water temperature, headwater and tributary flows, and quality of domestic loadings. Dissolved oxygen levels at the bottom of the sags were chronically low (< 3 mg/L) on three of four surveys and full recovery usually did not occur until SH 81, a distance of 130 kilometers (80 miles). Although available nutrient compounds were elevated throughout the river there was little indication of substantial uptake by aquatic plants. Chloride, sulfate, total dissolved solids, water temperature and pH levels generally conformed to segment criteria. Fecal coliform levels exceeded the criterion (2,000/100 mL) most frequently in the reach downstream of the San Antonio domestic treatment plants; however, they were also elevated upstream of their influence. Benthic macroinvertebrate data reflected the effects of instream water quality degradation. Biological health was high upstream from the Rilling Road WWTP discharge, with severe degradation evident in the reach downstream of the Rilling Road and Salado Creek WWTP's. Community characteristics reflected a degree of improvement near FM 791, although water quality recovery was far from complete. Biological health in the Medina River near FM 1937 was moderately degraded by effluent from the Leon Creek WWTP, but complete recovery typically occurs between there and the mouth, and Medina River inflow generally enhances water quality in the San Antonio River.

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INTENSIVE SURVEYS OF
SAN ANTONIO RIVER
SEGMENTS 1901 AND 1911

INTRODUCTION

DIRECTIVE

These intensive surveys were accomplished in accordance with the Texas Water Code, Section 26.127. The report is to be used for the purpose listed below.

PURPOSE

The purpose of these intensive surveys was to provide the Texas Water Commission with a valid information source:

1. to determine quantitative cause and effect relationships of water quality;

2. to obtain data for updating water quality management plans, setting effluent limits, and where appropriate, verifying the classifications of segments;

3. to set priorities for establishing or improving pollution controls; and

4. to determine any additional water quality management actions required.

METHODS

Field and laboratory procedures used during these surveys are described in Appendix A. The field measurements, water chemistry, biological, and hydraulic data were collected at approximately quarterly intervals from June 5, 1984 - May 16, 1985 by the Texas Water Commission (Predecessor Agency -- Texas Department of Water Resources) Water Quality Assessment Unit personnel with assistance from the Commission's District 8 (San Antonio) personnel. The San Antonio River Authority (SARA) and the City of San Antonio (CSA) Monitoring and Testing Unit and Metropolitan Health District personnel also assisted in the studies. Laboratory analyses of in-stream water samples were conducted by the Texas Department of Health Chemistry Laboratory in Austin, Texas. Laboratory analyses of wastewater samples were conducted by the City of San Antonio's Monitoring and Testing laboratory in San Antonio, Texas. Bacteriological analyses were conducted by the San Antonio River Authority. Most benthic macroinvertebrate samples were collected by Jack R. Davis at selected stations during each survey and returned to Austin for identification and enumeration. Parametric coverages, sampling frequencies and spatial relationships of sampling stations were consistent with the objectives of the surveys and with known or suspected forms and variabilities of pollutants entering the river.

RESULTS AND DISCUSSION

SITE DESCRIPTION

Cooperative quarterly intensive surveys of the San Antonio River (Segments (1911 and 1901) were conducted by the Texas Water Commission (Predecessor Agency -- Texas Department of Water Resources), San Antonio River Authority, and the City of San Antonio June 5, 1984 - May 16, 1985. The study area primarily consisted of the San Antonio River from near its headwaters in metropolitan San Antonio to SH 72 near Runge, a distance of 199.9 river kilometers (124. 2 miles). The river's principal tributaries, Salado Creek (Segment 1910), Medina River (Segment 1903), and Cibolo Creek (Segment 1902), were also sampled (Figure 1, Table 1).

The San Antonio River originates in Brackenridge Park in northern San Antonio as pumped well water from the Edwards Aquifer. The wells that give rise to the San Antonio River maintain fairly consistent flows (0.3 to 0.6 m^3/s) (10 to 20 ft^3/s) even during summer months. Historically, the San Antonio River originated from springs supplied by the Edwards Aquifer. However, as municipal and industrial water demands from the surrounding area increased, the aquifer level fell below the spring openings and flow gradually decreased. These springs have been dry most of the time since 1930, and the river is maintained by a shallow well in the spring area. Discharges of surplus water from several wells in the downtown San Antonio area contribute to this base flow.

In the headwaters, the San Antonio River is a small, clear stream with alternating small pools and riffles. Stream characteristics change in downtown San Antonio as the river passes through artificially walled channels where the river has been developed into a parkway (San Antonio River Walk). The San Antonio River Walk is a major tourist attraction for the City and current plans indicate that it will be expanded to the north along the river to Brackenridge Park. The riverwalk has recently been expanded to the south to South Alamo Street. Three small dams exist between the downtown area and Interstate Highway 410 (IH-410). South of the City, flow in the river is augmented by discharges of treated domestic sewage and from tributary inflows (Salado Creek and Medina River), and the river develops a turbidity which becomes more pronounced as it flows toward the Gulf. Downstream of the Salado Creek confluence, the San Antonio River Valley broadens and the main channel becomes more deeply entrenched with steep, muddy banks. The gravelly, sandy bottom turns to deep, soft mud. Except for two artificial pools (Otillo Dam and the Braunig-Calaveras Lakes Intake) and a natural pool upstream of the falls at Mays Crossing near Falls City, the San Antonio River is generally deep and fast flowing.

Located at the headwaters of the river, the City of San Antonio, Texas' third largest city, is the economic center of the region with heavy wholesale and retail trade. Several military installations - Lackland, Kelly, and Randolph Air Force Bases, Fort Sam Houston - and other governmental offices contribute to large federal and state payrolls. The San Antonio River, with the developed riverwalk, is the focus for a major tourist industry. Small communities located along the river include Falls City, Floresville, Karnes City, Kenedy, and Goliad.

Natural resources such as oil, gas, uranium, gravel, and limestone are mined throughout the basin. With extensive irrigation, a wide variety of agricultural crops (sorghum, wheat, corn, cotton, peaches, strawberries and pecans) are grown. Cattle, sheep, hogs, poultry, and goats are grazed or fed throughout the basin.

Fourteen mainstream stations were established on the San Antonio River for these surveys. Sampling stations were also established on three tributaries (Salado Creek, Medina River and Cibolo Creek) and at three wastewater treatment facilities (City of San Antonio's Rilling Road, Leon Creek, and Salado Creek plants) (Table 1, Figure 1).

CLIMATOLOGY

The climate of the San Antonio River Basin is dry to sub-humid with mild winters and hot summers. Minimum temperatures during winter are seldom below freezing and daily maxima in the summer usually exceed 32.2°C (90°F) and occasionally 37.7°C (100°F). Average annual rainfall varies considerably over the basin, but average monthly rainfall is fairly consistent. Precipitation is generally heavier toward the southeast portion of the basin where the annual average is 91 centimeters (36 inches) compared to 71 centimeters (28 inches) in the northwest. The greatest percentage of precipitation occurs as thunderstorms, so the total monthly accumulation may occur in only a few days. The most abundant rainfall occurs in the spring, with May the wettest month. Surface winds prevail from the south year around, although north winds with sudden temperature drops are frequent in the winter. March and April are usually the windiest months (NOAA, 1985).

POPULATION

In 1980, the estimated population of the San Antonio River Basin was 1,054,400. Approximately 94 percent of that total reside within the San Antonio metropolitan area (mainly Bexar County) which is continuing to grow at a rapid rate. By the year 2000, the metropolitan population is expected to be 1,520,000 people, a 44 percent increase. Other cities in the San Antonio River Basin are much smaller than San Antonio. To illustrate the difference, the following incorporated places are shown with their projected year 2000 population figures: Floresville (5,060); Kenedy (5,315); Karnes City (4,460); and Goliad (2,750) (TDWR, 1984a).

WATER QUALITY STANDARDS

Water quality standards specifying desired water uses and numerical criteria have been developed for the San Antonio River. The current version of the Texas Surface Water Quality Standards was adopted by the Texas Water Development Board in December 1984 (TWDB, 1984). This document was written pursuant to Section 26.023 of the Texas Water Code to meet the goals in Section 303 of the Federal Clean Water Act, as amended. These goals require that, where attainable, water quality will support aquatic life and recreational uses.

The recent revision of the Texas Surface Water Quality Standards specific to the San Antonio River include: (1) division of Segment 1901 into separate parts; the river was divided at Mays Crossing near Falls City (km 246.8, mi 153.4) and upstream of this point to Hildebrand Avenue in San Antonio is Segment 1911, downstream of this point to the confluence with the Guadalupe River is Segment 1901, (2) deletion of domestic raw water supply as a water use deemed desirable for both segments, and (3) revision of the chloride, sulfate, and total dissolved solids criteria. These revisions to the water quality standards for the San Antonio River were supported by a use attainability analysis (Twidwell and Davis, 1984). The Texas Surface Water Quality Standards developed for the San Antonio River contain specific numerical criteria for selected parameters. The water uses deemed desirable in Segments 1901 and 1911 include noncontact recreation and high quality aquatic life habitat. The following are numerical criteria established for the San Antonio River and are intended to insure that water quality will be sufficient to maintain the desired uses:

Parameter	1911 Criteria	1901 Criteria
Dissolved Oxygen	Not less than 5 mg/L	Same
pH	Not less than 6.5 nor more than 9.0	Same
Temperature	Not to exceed 32.2°C (90°F)	Same
Chloride	Annual Average not to exceed 95 mg/L	180 mg/L
Sulfate	Annual Average not to exceed 95 mg/L	140 mg/L
Total Dissolved Solids	Annual Average not to exceed 620 mg/L	750 mg/L
Fecal Coliform	Thirty-day geometric mean not to exceed 2,000/100 mL	Same

These numerical criteria are not applicable in mixing zones nor whenever the stream flow is intermittent or less than the low-flow condition. At least four measurements are required to determine compliance for chloride, sulfate, and total dissolved solids criteria and at least five measurements are required to determine the attainment of the fecal coliform criterion.

For streams, or portions of streams, that are not designated by the Texas Water Commission as classified segments, the general criteria of the Texas Surface Water Quality Standards are applicable. The goals of the Commission are to maintain a minimum of 3 mg/L of dissolved oxygen and a 2,000/100 mL fecal coliform density (thirty-day geometric mean) to protect minimum aquatic life and recreational uses for these streams. These general criteria, and others specified in Texas Surface Water Quality Standards, apply to the extreme headwaters of the river from a point 0.1 km (0.06 mi) upstream of Hildebrand Avenue in San Antonio and to minor tributary streams located along Segments 1911 and 1901.

WATER QUALITY MONITORING STATIONS

The Commission has four active stream monitoring network (SMN) stations (1901.0105, 1901.0200, 1901.0250, and 1901.0352) on the San Antonio River at the Southern Pacific Railroad Bridge near Goliad, Farm to Market Road (FM) 791 near Falls City, County Road near Calaveras, and 0.1 km (0.06 mi) upstream of the Medina River confluence, respectively. Water quality data are collected at the FM 791 and Medina River confluence stations monthly and quarterly at the other two stations. The San Antonio River Authority, United States Geological Survey (USGS), and City of San Antonio also monitor water quality of the San Antonio River and their data are utilized in the Commission's Stream Monitoring Program (Table 2).

HISTORICAL WATER QUALITY

Historical stream monitoring data from stations on the San Antonio River and its principal tributaries, Salado Creek, Medina River, and Cibolo Creek are presented in Tables 3 and 4. Surface water temperatures, excepting two measurements at Ashley Road, have been less than the temperature criterion (32.2°C) at the 15 mainstream stations in Segments 1911 and 1901 during the past five water years (October 1980 - September 1985). Only 1 of 1,073 pH measurements has been less than the minimum criterion (6.5 units) and only two have exceeded the maximum criterion (9.0 units). Levels of chloride, sulfate, and total dissolved solids (TDS) occasionally ($\leq$ 30 percent) exceeded respective criteria of 95, 95, and 620 mg/L (annual averages) for the past five years at stations within Segment 1911. Levels of chloride, sulfate, and total dissolved solids infrequently exceeded ($\leq$ 10 percent) respective criteria of 180, 140, and 750 mg/L (annual averages) at the three stations in Segment 1901.

Dissolved oxygen levels less than the segment criterion have generally occurred infrequently (< 15 percent) at Hildebrand Avenue, South Alamo Street, Ashley Road, and Camino Coahuilatechan in Segment 1911 and SH 72, and US 77-A and 183 in Segment 1901 at opposite ends of the San Antonio River (Table 4). Throughout the middle portion of the river, dissolved oxygen levels have been less than the criterion more frequently during the past five years. Fifty percent or more of the the dissolved oxygen levels were less than 5 mg/L for all five years at Dietz Road (Station L). At Blue Wing Road (Station G), Calaveras Road (Station K), and FM 791 (Station O), fifty percent or more were less than the criterion for four of five years. Critically low levels of dissolved oxygen (< 2 mg/L) have been documented 23 times at Blue Wing Road, 5 times at Calaveras Road, 4 times at Dietz Road, and 19 times at FM 791 during the past five years. Low dissolved oxygen levels have contributed to eight San Antonio River fish kills since 1970, all of which occurred between the City of San Antonio's Rilling Road wastewater treatment plant outfall and FM 791 (TWC, 1985)(Table 5).

Surface water temperatures and pH measurements have been within the criteria (temperature maximum 32.2°C, pH range 6.5-9.0 units) at the lowermost stations on Salado Creek (Station F), Medina River (Station I), and Cibolo Creek (Station Q) during the past five years. The chloride criteria for Salado Creek (50 mg/L) and Cibolo Creek (170 mg/L) were frequently exceeded during the past five years; the causes of these elevated levels are unknown. The total dissolved solids criterion for Cibolo Creek (900 mg/L) was also frequently (> 60 percent) exceeded.

Dissolved oxygen levels from the tributary streams were generally in excess of the 5 mg/L criterion. None of the measurements made at Salado Creek were less than the criterion during the past five years and only one at Cibolo Creek (4.5 mg/L) was less than the criterion. Dissolved oxygen levels from the Medina River were generally lower and exceedences of the criterion more frequent (up to 46 percent in 1984). None of the dissolved oxygen measurements from the three tributary streams during the past five years are considered critically low (< 2 mg/L).

WASTEWATER DISCHARGERS

The more significant wastewater dischargers to the San Antonio River are the three largest City of San Antonio wastewater treatment plants (WWTP's). The Rilling Road and Salado Creek plants discharge directly to the San Antonio River. The Leon Creek Plant's effluent enters the lower portion of Comanche Creek and passes through the lower portions of Leon Creek and the Medina River before entering the San Antonio River. The three wastewater treatment facilities sampled during these intensive surveys have been issued permits from the Commission which specify limitations on flow (m^3/s - MGD) and effluent quality (BOD_5 and TSS, mg/L). The three San Antonio treatment facilities have monthly average permit limitations of 20 mg/L five-day biochemical oxygen demand (BOD_5) and total suspended solids (TSS). The permitted average flow from the three discharges totals 6.3 m^3/s (142 MGD) and resulting permitted loadings total 10,744 kg/d (23,685 lb/d) BOD_5 and TSS (Table 6).

PREVIOUS INTENSIVE SURVEYS

The Texas Water Commission has conducted four previous intensive surveys of the San Antonio River during low flow conditions in September 1975 (Twidwell, 1975a, 1975b), June 1983 (Twidwell, 1984a), and July 1984 (Twidwell, 1985). During these three studies the river was characterized by low levels of dissolved oxygen (< 4 mg/L), and elevated levels of ammonia nitrogen (> 4 mg/L), five-day carbonaceous biochemical oxygen demand (> 7 mg/L), and fecal coliform bacteria (> 500/100 mL) in the area between IH 410 in San Antonio and FM 791 near Falls City. These poor water quality conditions were influenced by the effluent qualities of the three large City of San Antonio wastewater treatment plants. A study of the San Antonio River in February 1984 by the Commission was conducted to define reaeration rates (Twidwell, 1984b). Another study of the upper portion of the San Antonio River (Brackenridge Park to Calaveras Road) was conducted in November 1975 by the San Antonio River Authority (SARA, 1975). Dissolved oxygen sags (DO < 5 mg/L) in the Medina River and San Antonio River were attributed to elevated oxygen demanding pollutants (BOD_5 and ammonia-nitrogen) released in effluents from the City of San Antonio's Leon Creek and Rilling Road plants, respectively. Additional intensive studies on the major tributaries of the San Antonio River have been conducted by the Texas Water Commission, including two on Segment 1902, Cibolo Creek (Tomme, 1974 and Buzan, 1980), and one each on Salado Creek (Segment 1910) (Buzan, 1981) and Segment 1903 of the Medina River (Twidwell, 1976).

CLASSIFICATION AND RANK

Due to the recurrent low dissolved oxygen levels and elevated fecal coliform levels, Segment 1911 of the San Antonio River was classified water quality limited by the Commission (TWC, 1986). Due to better water quality conditions, Segment 1901 of the San Antonio River was classified effluent limited.

Segments are classified as water quality limited if the effluent limitations for point source dischargers required by Section 301(b)(1)(A) and Section 301(b)(1)(B) of the Clean Water Act are not stringent enough for the receiving waters to meet the appropriate water quality standards. If effluent limitations for point source dischargers are stringent enough for the receiving waters to meet appropriate water quality standards, the segment is classified effluent limited. Segments were ranked from 1 to 342 by the Commission with 1 indicating the highest need for stringent water quality controls and 342 indicating the least feasible necessity of stringent water quality controls other than for public health considerations. Segment 1901 ranked 23, 17 and 6 of 311 segments in 1980, 1982 and 1984 respectively (TDWR, 1980, 1982, 1984b). In the most recent analysis, Segments 1911 and 1901 ranked 63 and 87, respectively, of 342 segments classified by the Commission (TWC, 1986).

INTENSIVE SURVEY DATA

Hydraulics

Hydraulic data were not collected during the four quarterly intensive surveys of the San Antonio River. The relationships among stream discharge, stream widths, and velocity during different flow conditions have been previously described (Twidwell, 1984a, 1984b, 1985). Stream discharge data were acquired from the United States Geological Survey (USGS) for two week periods prior to each quarterly study at the following stations:

Map Code	USGS Number	Location
B	08178000	San Antonio River at South Alamo Street in San Antonio
J	08181800	San Antonio River at FM 1604 near Elmendorf
O	08183500	San Antonio River at FM 791 near Falls City
T	08178800	Salado Creek at Loop 13 in San Antonio
V	08181500	Medina River at US 281
W	08186000	Cibolo Creek at SH 123 near Falls City

Attempts were made to schedule the intensive surveys when steady-state flow conditions of at least one week or longer occurred prior to the start of each study. This proved difficult to accomplish and maintain quarterly spacing of the studies.

Prior to the June 6, 1984 survey, stream flows in the San Antonio River and its tributaries were generally in steady-state conditions for about five days (Figure 2). Rainfall in the San Antonio area on May 28 increased stream flow in the San Antonio River. Prior to this rainfall, stream discharge in the San Antonio River varied between 5.2 and 6.7 m^3/s (184 and 238 ft^3/s) at FM 1604 and from 6.6 to 11.9 m^3/s (233 to 419 ft^3/s) at FM 791. The runoff from the rainfall increased stream discharge by about 11.3 m^3/s (400 ft^3/s) and 8.5 m^3/s (300 ft^3/s) at these respective stations, but as the hydrographs show, the river quickly receded, due to dry conditions prior to the event. Salado Creek was the only tributary that was affected by the rainfall. Its stream flow increased from 0.31 m^3/s (11 ft^3/s) to 0.85 m^3/s (30 ft^3/s), but it also quickly receded following the rainfall.

Before the October 3, 1984, intensive survey, stream flows in the San Antonio River and its tributaries were generally in steady-state conditions for two weeks (Figure 3). During this period, stream discharge in the San Antonio River at FM 791 ranged from 6.3 m^3/s (222 ft^3/s) to 11.9 m^3/s (420 ft^3/s). This survey was conducted when stream flows were lowest of the four surveys. As an indication of the dry conditions, the daily average stream discharge rates on October 3, 1984, from Salado Creek (0.16 m^3/s)(5.5 ft^3/s) and Cibolo Creek (0.22 m^3/s)(7.9 ft^3/s) were less than the respective seven day-two year low flow rates of 0.25 m^3/s (8.9 ft^3/s) and 0.33 m^3/s (11.7 ft^3/s). The discharge rates of the San Antonio River at FM 1604 (4.98 m^3/s)(176 ft^3/s) and the Medina River (1.84 m^3/s)(65 ft^3/s) only marginally exceeded their respective seven day-two year low flow rates of 4.07 m^3/s (143.6 ft^3/s) and 1.55 m^3/s (54.6 ft^3/s).

The hydrographs from all six stations indicate that a major runoff event occurred prior to the January 24, 1985 intensive survey (Figure 4). The increases in stream flow were caused by melting snow during the week of January 13-19, 1985. The highest stream flows recorded during the four intensive surveys occurred at each of the stations during this time period. The high flows for each station were: FM 791, 49.3 m^3/s (1,740 ft^3/s); FM 1604, 27.8 m^3/s (982 ft^3/s); South Alamo Street, 3.8 m^3/s (133 ft^3/s); Salado Creek, 4.9 m^3/s (174 ft^3/s); Medina River, 5.1 m^3/s (181 ft^3/s); and Cibolo Creek, 9.2 m^3/s (323 ft^3/s). The stream flows at each of the sites had returned to antecedent conditions by January 21, 1985, only three days prior to the start of sampling.

Prior to the May 16, 1985 survey, stream flows in the San Antonio River and its tributaries were generally in steady-state conditions for the entire two week period (Figure 5). As an indication of steady-state conditions during this period, stream flow at FM 791 varied from 14.1 m^3/s (497 ft^3/s) to 15.4 m^3/s (543 ft^3/s).

The flows from the San Antonio River at FM 791 for the two week periods prior to the start of each of the four intensive surveys are plotted in Figure 6 to illustrate relative conditions. Although the stream flows prior to the May 16, 1985, study indicate the most steady conditions, these flows are well above those preceding the June 6 and October 3, 1984, studies. This plot also graphically demonstrates the magnitude of the differences in stream flow among the January study and the three others.

Field Measurements

The diurnal field measurements from each of four intensive surveys indicate that the San Antonio River was not able to assimilate the treated municipal effluents from the City of San Antonio without exhibiting water quality problems. Longitudinal dissolved oxygen profiles from all four intensive surveys show similar trends (Table 7, Figure 7). Generally, background dissolved oxygen levels at the three control stations (Stations A, B, C) were high. Levels decreased sharply downstream of the City of San Antonio Rilling Road WWTP outfall (River kilometer 361.6, River mile 224.7). This is where the river became effluent dominated (≥ 90 percent of the flow). The length and magnitude of the dissolved oxygen sag zone varied considerably among the four intensive surveys. These differences were primarily due to water temperature, headwater and tributary stream flows, and quality of domestic loadings. Full recovery of dissolved oxygen to background levels usually did not occur until SH 81, a distance of approximately 130 kilometers (80 miles) downstream of the Rilling Road WWTP. The San Antonio River between FM 791 (Station O) and SH 81 (Station P) is characterized by numerous riffle areas and several major falls that create considerable turbulence within the river channel and replenish dissolved oxygen to the water.

On June 6, 1984, background dissolved oxygen levels at the three control stations upstream of the Rilling Road WWTP were variable. At the uppermost station (Hildebrand Avenue) dissolved oxygen levels were relatively low (mean, 5.1 mg/L)(Table 7, Figure 7). Flow at this station was nearly stagnant due to the dry conditions that preceded the survey. At South Alamo Street (Station B) the widest fluctuations in dissolved oxygen levels occurred (range, 4.7 - 12.0 mg/L), while at Ashley Road (Station C) the diurnal range was narrow (6.9 - 7.3 mg/L). Dissolved oxygen depression began to occur at Camino Coahuilatechan (Station E) downstream of the San Antonio Rilling Road WWTP. The bottom of the sag occurred at Blue Wing Road (Station G) where dissolved oxygen levels were acutely low (range, 1.5 - 3.2 mg/L). Momentary improvement in dissolved oxygen levels occurred at the next two stations downstream, due to reaeration at Otillo Dam and inflowing water from the Medina River. However, dissolved oxygen levels downstream of FM 1604 (Station J) responded to the oxygen demand and again declined as the sag continued downstream to Dietz Road (Station L). Mean levels for the five stations within the sag zone were less than 5 mg/L and early morning lows were less than 3 mg/L at three of the stations. Downstream of Dietz Road dissolved oxygen levels began a trend toward recovery and were essentially at background levels at FM 541. The longitudinal dissolved oxygen profile indicates the poorest water quality of the four surveys, in terms of magnitude, as the lowest dissolved oxygen level (1.5 mg/L) was measured at Blue Wing Road (Station G).

On October 3, 1984, background dissolved oxygen levels at the three control stations were high (means > 7.5 mg/L, lows > 6.5 mg/L). Dissolved oxygen depression began to occur at Camino Coahuilatechan (Station E) downstream of the San Antonio Rilling Road WWTP. The bottom of the sag again occurred at Blue Wing Road (Station G) where the mean was only 3.1 mg/L and the early morning low was 1.9 mg/L. Improvement in dissolved oxygen levels at the next two stations due to reaeration at Otillo Dam and inflowing Medina River water again occurred, but more importantly, the secondary sag downstream of FM 1604 was much less pronounced. Within this reach, mean dissolved oxygen levels exceeded 4 mg/L and the early morning low was 4 mg/L at FM 1604. Downstream of Calaveras Road (Station K), dissolved oxygen levels began a gradual trend toward recovery. Even though complete recovery to background dissolved oxygen levels did not occur until SH 81, the longitudinal profile indicates substantial improvement over the June 3, 1984 survey. The improved water quality occurred even though stream flow was the lowest of the four surveys.

On January 24, 1985, following a snow melt, stream flows were the highest (FM 1604, 7.8 m^3/s) and water temperatures the coolest (FM 1604, 10.4°C) of the four surveys. Background dissolved oxygen levels at the three control stations were very high (means $\geq$ 10.5 mg/L, lows > 10 mg/L). Dissolved oxygen depression began at Camino Coahuilatechan (Station E) downstream of the San Antonio Rilling Road WWTP. The bottom of the sag occurred at SH 97 (Station M) where the mean was 4.7 mg/L and the early morning low was 4.4 mg/L. Dissolved oxygen levels at Dietz Road (Station L) were very similar (mean 4.7 mg/L, low 4.3 mg/L). Dissolved oxygen levels at no other station were below 5 mg/L. Downstream of SH 97, dissolved oxygen levels began a trend toward recovery. Even though complete recovery to background dissolved oxygen levels did not occur until SH 81 (Station P), the longitudinal profile indicates the best water quality of the four surveys and demonstrates the effects of higher stream flows and cooler water temperatures.

On May 16, 1985 background dissolved oxygen levels at the three control stations were high (means $\geq$ 7.5 mg/L, lows > 6.2 mg/L). Dissolved oxygen depression began to occur at Camino Coahuilatechan (Station E) downstream of the San Antonio Rilling Road WWTP. The bottom of the sag occurred at Calaveras Road (Station K) (mean 2.4 mg/L, low 2.2 mg/L); however, the next four stations downstream also had depressed levels (means $\leq$ 3.5 mg/L, lows $\leq$ 2.4 mg/L). Even the dissolved oxygen levels at SH 81 (mean 5.7 mg/L, low 5.0 mg/L) were depressed compared to the other three surveys and recovery to background levels was not complete until SH 72 (Station R). The dissolved oxygen profile indicates the poorest water quality of the surveys in terms of longitudinal extent of low dissolved oxygen coverage. Between Camino Coahuilatechan (Station E) and SH 81 (Station P), a distance of 129 km (80 mi), only one measurement exceeded the 5 mg/L criterion.

Measurements of pH ranged between 6.8 and 8.5 standard units and were within the minimum-maximum criteria range (6.5 - 9.0 standard units) during all four surveys. All of the water temperatures measured were less than the criterion (32.2°C) for both mainstream segments.

Treatment Plant Performance

Effluent quality data from the three City of San Antonio WWTP's during two week periods prior to each of the four intensive surveys were provided by the City of San Antonio (Tables 8-11). All three plants currently have been issued discharge permits with monthly average effluent limitations of 20 mg/L BOD_5 and TSS. The plants currently have no effluent limitation for ammonia nitrogen. The 20/20 monthly average limitations are used as yardsticks to gage plant performances against the two week averages.

The City of San Antonio Rilling Road WWTP produced an average effluent quality better than the 20/20 limitations prior to two of four surveys. Of the four, the plant's best performance occurred prior to the October 1984 survey, when effluent BOD_5, TSS, $CBOD_5$ and ammonia nitrogen levels averaged 12.1, 6.9, 5.9, and 8.59 mg/L, respectively. Conversely, the plant's poorest performance occurred prior to the January 1985 survey when respective average levels of 59.0. 68.2, and 28.4 mg/L for BOD_5, TSS, $CBOD_5$ occurred.

The highest average ammonia nitrogen level (15.6 mg/L) in the Rilling Road WWTP effluent occurred prior to the May 1985 survey. On all occasions the effluent volume released by the plant was less than its monthly average flow limitation (4.2 m^3/s)(94 MGD); however, the plant's highest flow (3.7 m^3/s) (83.9 MGD) occurred prior to the January 1985 survey, when effluent quality parameters were poorest. Due to its sheer volume, the effluent from the Rilling Road WWTP tends to dominate water quality in the San Antonio River downstream of the outfall. Prior to the four surveys when its effluent quality was best (October 1984) the longitudinal dissolved oxygen profile in the river was also good. When the effluent quality of the Rilling Road plant was poorest (January 1985) the longitudinal dissolved oxygen profile was best, due to dilution by high stream flows and cooler water temperatures increasing the water's capacity to retain dissolved oxygen.

The City of San Antonio Salado Creek WWTP produced an average effluent quality better than the 20/20 limitations prior to two of four surveys. Of the four, the plant's best performance generally occurred prior to the October 1984 survey. Effluent TSS and ammonia nitrogen levels averaged 12.9 and 3.6 mg/L, respectively. The plant produced its best average effluent BOD_5 (6.4 mg/L) and $CBOD_5$ (5.9 mg/L) prior to the June 1984 survey. Conversely, the plants poorest performance occurred prior to the January 1985 survey when respective average levels of 80.1 and 98.4 mg/L for BOD_5 and TSS occurred. The highest average $CBOD_5$ (36.8 mg/L) and ammonia nitrogen (17.9 mg/L) occurred prior to the May 1985 survey. Prior to the January and May 1985 surveys the effluent volume exceeded the monthly average flow limitation (1.1 m^3/s)(24 MGD).

The City of San Antonio Leon Creek WWTP produced an average effluent quality better than the 20/20 limitations prior to three of four surveys. Of the four, the plant's best performance occurred prior to the June 1984 study. Effluent BOD_5, TSS, $CBOD_5$, and ammonia nitrogen levels averaged 12.3, 7.3, 9.8, and 5.0 mg/L, respectively. Conversely, the plant's poorest performance occurred prior to the January 1985 survey when respective average levels of 38.5, 55.8, 19.4, and 17.9 mg/L for BOD_5, TSS, $CBOD_5$, and ammonia nitrogen occurred. The monthly average flow limitation (1.1 m^3/s)(24 MGD) was exceeded prior to the January 1985 survey.

Ammonia Nitrogen and Carbonaceous Biochemical Oxygen Demand

Instream $CBOD_5$ levels varied considerably among the four surveys. The $CBOD_5$ levels at the three control stations upstream of the Rilling Road WWTP were generally less than 2.5 mg/L (Table 12). The exceptions occurred during the June 1984 survey when all three stations had levels greater than 3.0 mg/L and on the October 1984 survey when the $CBOD_5$ level (5.5 mg/L) at Hildebrand Avenue (Station A) was elevated. The $CBOD_5$ level at Camino Coahuilatechan (Station E) generally reflects direct input from the Rilling Road WWTP and was highest (15.0 mg/L) during the January 1985 survey. The $CBOD_5$ level (5.5 mg/L) at this station was about double the background level during the May 1985 survey. During the October 1984 survey there was little difference between the background levels at the three control stations and at Camino Coahuilatechan. The decay of the $CBOD_5$ levels in the river was generally rapid and background levels occurred at Calaveras Road (Station K) or upstream on three of four surveys. The momentary increases in $CBOD_5$ levels between Blue Wing Road (Station G) and the station upstream of the Medina River (Station H) that occurred during the January and May 1985 surveys reflect secondary input from the Salado Creek WWTP. During the January 1985 survey, the decay of $CBOD_5$ was much more gradual and background levels were not achieved through the study area. Presumably, this resulted from high input at the Rilling Road and Salado Creek WWTP's and cooler water temperatures slowing the rate of decay.

Ammonia nitrogen levels were highest at Camino Coahuilatechan (Station E) on each of the four surveys reflecting input of the City of San Antonio Rilling Road WWTP. Further, the elevated levels of ammonia nitrogen indicate that it is not being thoroughly stabilized during the wastewater treatment process (Table 12, Figure 8). Minor secondary peaks in concentration occurred at the station upstream of the Medina River (Station H) during the January and May 1985 surveys, indicating input from the Salado Creek WWTP. The ammonia nitrogen levels at Camino Coahuilatechan (Station E) typically exceeded 5.5 mg/L and were as high as 8.2 mg/L during the May 1985 survey. Prior to the May 1985 survey the average ammonia nitrogen concentration discharged at the Rilling Road WWTP was 15.5 mg/L (Table 11). The station at Camino Coahuilatechan was not sampled during the June 1984 survey, but the ammonia nitrogen level (5.8 mg/L) at Blue Wing Road (Station G) was elevated. These ammonia levels are in stark contrast to those at three upstream control stations where levels were typically less than 0.2 mg/L.

Ammonia nitrogen levels were in the range considered chronically toxic to warm water freshwater fishes in the reach between Camino Coahuilatechan (Station E) and Blue Wing Road (Station G) on all four surveys (USEPA, 1986)(Table 13). During the January 1985 survey, ammonia nitrogen levels exceeded chronic toxicity values as far as SH 72 near Runge (Station R).

Levels of nitrite nitrogen were generally low ($\leq$ 0.06 mg/L) at the three upstream control stations (Table 12). Elevated nitrite nitrogen levels ($\geq$ 0.5) generally occurred in the reach between Camino Coahuilatechan (Station E) and FM 1604 (Station J). The presence of ammonia and nitrite nitrogen in elevated concentrations and their trend toward downstream decline in concentration with concomitant increases in nitrate nitrogen concentrations provide evidence that nitrification was actively occurring in the San Antonio River, particularly between Camino Coahuilatechan and FM 1604 (Table 13, Figure 8).

The rates of nitrification varied greatly among the four surveys. During the June and October 1984 surveys, ammonia nitrogen levels were essentially stabilized (< 0.05 mg/L) at SH 97. During the January 1985 survey, ammonia levels declined gradually downstream and were elevated (2.7 mg/L) at the downstream station (SH 72) in the study area indicating stabilization was incomplete and the rate of nitrification was much slower. Compared to the first two surveys, the nitrogen data from the May 1985 survey also indicates a much slower rate of nitrification, but the ammonia levels were stabilized at the last station in the study area.

The effluents of the three large City of San Antonio WWTP's were the primary contributors of elevated $CBOD_5$ and ammonia nitrogen levels and the downstream decay of these carbonaceous and nitrogenous oxygen demanding substances contributed to the dissolved oxygen sag zones that developed in the San Antonio River during each of the four surveys. Of the two, reduction in nitrogen loading to the river has been shown by modeling studies to significantly improve dissolved oxygen (Espey, Huston, and Associates, 1983).

Nutrients and Chlorophyll a

The same general reach of the San Antonio River which had elevated $CBOD_5$ and ammonia nitrogen levels also had the highest orthophophorus levels (Table 12). Elevated levels (> 3 mg/L) were typical in the reach between Camino Coahuilatechan (Station E) and the station upstream of the Medina River (Station H) reflecting input from the City of San Antonio's Rilling Road and Salado Creek WWTP's. Orthophosphorus levels declined slowly downstream on each of the surveys, but remained elevated (> 2 mg/L) at the lower limit of the study area (SH 72) on three of the four surveys.

The downstream stabilization of ammonia nitrogen resulted in elevated nitrate nitrogen ($\geq$ 1.4 mg/L) downstream of FM 1604 (Station J) on each of the four surveys. The primary sources of the ammonia and nitrate nitrogen and orthophosphorus include the three City of San Antonio WWTP's. Nutrient enrichment from these sources creates favorable conditions for growth and proliferation of aquatic plants through most of the river.

During the four intensive surveys there was little indication of substantial nutrient uptake by aquatic plants. Chlorophyll a levels were typically less than 5 µg/L at most stations (Table 12). During the May 1985 survey, chlorophyll a levels exhibited a downstream trend toward increasing concentrations, and the level (82 µg/L) at the lower station (SH 72) was very high. However, the temporal variations in dissolved oxygen at this station (range, 6.9 - 9.7 mg/L) were not excessive and indicate stable aquatic plant productivity. Although the San Antonio River was not sampled extensively downstream of SH 72, the presence of algal bloom conditions in the lower portion has been documented by Twidwell (1975). The high turbidity of the river, which restricts light penetration, and swift velocity are natural factors that suppress phytoplankton productivity in the river. Macrophyte beds were observed in the river near the Medina River confluence and were most dense during the June 1984 and May 1985 surveys. The metabolism of these macrophyte beds did not impact water quality substantially during any of the surveys as dissolved oxygen diurnal ranges were fairly narrow in this area of the river.

Chloride, Sulfate, and Total Dissolved Solids

All of the total dissolved solids, all but four of the chloride, and all but one of the sulfate levels were less than the respective Segment 1911 criteria (620, 95, and 95 mg/L) during the four intensive surveys (Table 12). All of the chloride, sulfate, and total dissolved solids levels conformed to Segment 1901 criteria (180, 140, and 750 mg/L) during the four intensive surveys. Instream concentrations for these parameters generally exhibited downstream trends toward increasing concentrations.

Fecal Coliform Bacteria

Fecal coliform levels were elevated through most of the San Antonio River and exceeded the segment criterion (2,000/100 mL) at six of the 14 mainstream stations during the June 1984 survey; four of 14 (October 1984), two of 14 (January 1985), and eight of 14 (May 1985)(Table 14). Background fecal coliform levels at three upstream control stations were generally elevated (six of twelve samples exceeded the criterion). There are no permitted domestic discharges in this upstream reach. Possible contributors to the elevated fecal coliform levels include broken sewer mains, urban runoff, runoff from the zoo, and illegal discharges. The highest fecal coliform levels typically occurred between Camino Coahuilatechan (Station E) and FM 1604 (Station J) indicating input from the three San Antonio WWTP's. The San Antonio River is not classified as a recreational water due to elevated fecal coliform levels. During the four intensive surveys only five of 55 samples from the mainstream stations were equal to or less than criterion (200/100 mL) established for recreational waters.

Tributary Water Quality

Dissolved oxygen levels in the three major tributary streams were generally high and remained above 5 mg/L throughout the four diurnal sampling periods in Salado Creek and Cibolo Creek (Table 7). Dissolved oxygen levels in the Medina River were typically 2-4 mg/L lower than those of the other two tributaries. During the May 1985 survey the average dissolved oxygen level at the Medina River Station was 4.7 mg/L and two of the four measurements were less than 5 mg/L. Compared to Salado Creek and Cibolo Creek, the Medina River also had substantially higher levels of $CBOD_5$, ammonia, nitrate nitrogen, and orthophosphorus (Table 12). Its water quality is influenced by the discharge and assimilation of wastewater from the City of San Antonio Leon Creek WWTP.

All of the chloride, sulfate, and total dissolved solids levels measured from the Medina River conformed to the 120, 120, and 700 respective criteria. With the exceptions of two chloride exceedances (80 mg/L in October 1984 and 59 mg/L in January 1985) levels of chloride, sulfate, and total dissolved solids from Salado Creek conformed to the respective criteria (50, 200, and 550 mg/L). Levels of chloride, sulfate, and total dissolved solids measured from Cibolo Creek conformed to the respective criteria (170, 275, and 900 mg/L) during the January and May 1985 surveys and exceeded them during the June and October 1984 surveys when stream flow was low.

Fecal coliform levels were generally high in the tributary streams, the exception being Cibolo Creek where three of four samples were less than 200/100 mL (Table 14). Three of the four samples from the Medina River exceeded its criterion for recreational water (200/100 mL). Fecal coliform levels from Salado Creek were high (600 - 7,000/100 mL) considering it was the only tributary stream with no known domestic discharges.

Benthic Macroinvertebrates

San Antonio River 0.1 km Upstream from Rilling Road WWTP Outfall (Map Code D)

On June 6, 1984, October 2, 1984, and May 15, 1985, diversity and equitability values compared favorably with levels observed in unimpacted Texas streams (i.e., ≧ 3.0 and ≧ 0.70, respectively), reflecting a general prevalence of clean water and healthy environmental conditions (Table 15). The size of the standing crop reflected moderate secondary production on June 6, 1984 and May 15, 1985, and a slightly elevated level of production on October 2, 1984. Anomalous community characteristics on January 23, 1985 resulted from the effects of severe scouring during snowmelt runoff a week before sampling. Therefore, the stressed condition of the macrobenthos was due to physical perturbation rather than pollutional impact. Since the data for January 23, 1985, was unrepresentative, it was excluded from further evaluations.

All other community characteristics also indicated clean water conditions. Species richness was relatively high, with a total of 49 species collected and 27 to 32 species present on individual collection dates. Pollution-sensitive mayflies were well represented, and the biotic index values were relatively low, indicating a predominance of clean water and subpollutional-less tolerant species (Table 16). Community trophic structure was generally well balanced, although slight dominance was exhibited by miners of fine particulate organic matter (FPOM) on June 6, 1984, and by periphyton grazers on October 10, 1984. Healthy biological conditions were consistent with good physicochemical water quality in the reach, where all dissolved oxygen measurements were ≧ 6.3 mg/L (Stations C and D, Table 7).

Community indices were very similar to those observed at a nearby locality in a November 1983 study (Table 17). This plus the fact that community indices varied little during the present study documents a prevalence of consistently good environmental conditions in the reach through the 19 month period encompassed by the two studies.

Minimal changes in community structure observed between sampling dates are attributed to natural seasonal variation. The most obvious fluctuation was the drop in diversity between June 6, 1984 and October 2, 1984, which resulted mainly from increased numbers of two species, a microcaddisfly, *Hydroptila* sp., and an aquatic caterpillar, *Paragyractis* sp. Both are periphyton grazers and are relatively sensitive to environmental stress. Therefore, their increased abundance, which precipitated the reduction in diversity, was a response to an increased periphyton standing crop observed on October 2, 1984, rather than a product of organic pollution or similar disturbance.

In conclusion, biological and physicochemical data from this and the 1983 study reflect good water quality and healthy environmental conditions in the San Antonio River upstream from the Rilling Road WWTP outfall, which is not surprising since there are no major wastewater discharges in the reach. The data also indicate that pollutant inputs from urban runoff and other nonpoint sources in the San Antonio metropolitan area have no appreciable impact on the river. In accordance, macrobenthic community characteristics in the reach are judged to represent a good baseline to which downstream conditions can be compared.

San Antonio River 0.1 km Upstream from Medina River Confluence (Map Code H)

Diversity values were depressed compared to those at the control station, and were in the range generally associated with moderate organic pollution (i.e., 1.0 - 3.0; Wilhm, 1970) (Table 15). Species richness was low, with a total of only 28 species collected and 10 to 16 species present on individual collection dates. Pollution-sensitive mayflies were absent 75 percent of the time, and when present on January 24, 1985 comprised only 2.5 percent of the community (Table 16). Biotic index values were elevated, reflecting a predominance of pollution-tolerant and subpollutional-unusually tolerant species. Community trophic structure was generally fairly well balanced, except on May 16, 1985, when FPOM miners were highly dominant. Overall, macrobenthic community characteristics indicated persistently poor environmental conditions, despite the fact that the physical habitat was the best of any station.

Secondary production in an organically enriched habitat such as this would be expected to be high, with large numbers of organisms present in response to the abundant food supply. However, macrobenthic standing crops were extremely small on the first three sampling dates, which strongly suggests a high level of instream toxicity. Recent scouring may have been partially responsible on January 24, 1985, but was not a factor in the June 5, 1984 or October 3, 1984, collections. Potential causative factors related to municipal wastewater discharges might include ammonia nitrogen, which was elevated on all sampling dates. Unionized ammonia was typically present at levels that are chronically toxic to freshwater organisms (Table 13), but not at concentrations that are acutely toxic. Nitrite nitrogen, another potential toxicant, was also typically elevated, due to the high level of instream nitrification that occurs in the reach (Figure 8). However, toxic effects were not manifested in the May 16, 1985, sample, when ammonia nitrogen and nitrite nitrogen were high, which suggests that they are not the primary causative agents. Chlorine toxicity is another possible factor. Although instream chlorine measurements have not been made at the site, residuals in the Rilling Road and Salado Creek WWTP effluents would be expected to dissipate before reaching the area. The fact that similar effects were not observed at the station near Southton in the November 1983 survey (Table 17), which is located upstream from the Salado Creek WWTP, suggests that components of the effluent from that facility may be responsible. It is emphasized that any supposition regarding potential toxicity is highly conjectural at the present time, due to the limited data base. However, the implications are sufficient to warrant further investigation.

Regardless of the factor that suppressed the macrobenthos, one result was an overshadowing of any temporal trends that may have resulted from changes in organic loading. The May 16, 1985, sample resembled the November, 1983 sample (collected near Southton) in many respects (high standing crop, low species richness, elevated biotic index, and high dominance by FPOM miners), and both represented classical responses to organic pollution, indicating little temporal change in the degree of organic enrichment in the reach through the 19 month period. Although the May 16, 1985, sample was slightly better than the November 1983 sample (higher species richness and diversity, lower standing crop), this may reflect longitudinal water quality improvement rather than temporal improvement, since the 1985 sampling site was located 10.6 km (6.6 mi) downstream from the 1983 sampling site. The differences could also have resulted from seasonal or year-to-year variability.

In conclusion, biological and physicochemical data from this and the 1983 study indicate poor water quality and a high degree of environmental stress in the reach from the Rilling Road WWTP outfall to the Medina River confluence, attributable to the effects of wastewater discharges from the Rilling Road and Salado Creek WWTP's.

San Antonio River at Mays Crossing Downstream from FM 791 (Map Code O)

On June 5, 1984, October 2, 1984, and January 23, 1985, diversity and equitability values were at levels generally associated with moderate organic pollution, while the respective values for May 15, 1985, were within ranges considered indicative of clean water conditions (Table 15). The total number of species collected was slightly greater than at the control station (54 versus 49), but the range for individual collecting dates was slightly lower (20 to 29 versus 27 to 32). The size of the standing crop reflected moderate secondary production on October 10, 1984 and January 23, 1985, with very high secondary production on June 5, 1984, and May 15, 1985. Biotic index values were slightly higher than at the control station, and pollution-sensitive mayflies were not as well represented (Table 16), indicating that the community was more adapted for tolerating environmental stress. Community trophic structure was generally well balanced, although FPOM filterers were slightly dominant on October 2, 1984, and May 5, 1985. Overall, macrobenthic community structure indicated fair water quality and a moderate level of environmental stress.

The data indicate that macrobenthic community structure is primarily determined by food resources dynamics. Dissolved oxygen concentrations evidently are generally sufficient to support a relatively diverse macrobenthic community, although sensitive species are usually poorly represented. Diversity is sometimes high (e.g., 3.60 in November, 1983; 3.44 on May 15, 1985), apparently as a manifestation of the intermediate-disturbance hypothesis, in which diversity is sometimes maximized by spatio-temporal heterogeneity imposed by moderate environmental disturbances (Ward and Stanford, 1981).

During the five sampling periods, grazers were predominant twice, filterers twice, and miners once. This reflects shifts in community trophic structure in response to temporal changes in the primary food source, with preeminence exhibited at different times by periphytic algae, suspended FPOM, and deposited FPOM. This together with the typically high level of secondary production reflects the impacts of upstream wastewater discharges, with nutrient enrichment resulting in elevated production of periphytic and planktonic algae, and elevated levels of suspended and sedimented FPOM resulting from algal die-offs and point source organic loading.

Data from the present study verify the observation of Twidwell and Davis (1984) that the site is near the upstream limit of the zone of water quality recovery, where instream conditions begin to return to normal following severe pollutional stresses induced by wastewater discharges from the City of San Antonio. Although considerable recovery is generally evident at the site, an appreciable degree of induced environmental stress persists, as complete recovery does not occur until further downstream.

Medina River 0.1 km Downstream from FM 1937 (Map Code U)

Diversity values on three sampling dates were in the range generally associated with moderate organic pollution, with the value on January 24, 1985, in the lower end of the range considered indicative of clean water (Table 15). Equitability values were slightly to moderately below the minimum observed in unimpacted Texas streams. The total number of species collected was relatively high (51), but the numbers collected on individual collection dates were fairly low (17 to 27). The size of the standing crop indicated moderate secondary production levels on June 5, 1984 and May 16, 1985, a slightly elevated level on October 3, 1984, and a greatly elevated level on January 24, 1985. Clean water indicative mayflies were poorly represented, and the biotic index values were moderately elevated (Table 16), indicating a prevalence of pollution-tolerant and subpollutional-unusually tolerant species. Community trophic structure was moderately imbalanced, particularly on January 24, 1985 and May 16, 1985 when two groups (grazers and gatherers) were absent. Overall, macrobenthic community structure indicated fair water quality and a moderate level of environmental stress.

Based on macrobenthic community structure at a site near the mouth in November 1983 (Table 17), Twidwell and Davis (1984) categorized the site as having clean water and a low degree of environmental stress, and concluded that water quality recovery from the effects of the Leon Creek WWTP was virtually complete. The January 24, 1985, sample, which had the highest diversity and species richness values in the present study, resembled the November, 1983 sample fairly closely, but the other three were reflective of somewhat poorer environmental conditions. However, the sampling site in the present study was located 6.1 km (3.8 mi) upstream from the November 1983 sampling site, so somewhat poorer conditions would be expected. Travel time between the two sites under low flow conditions is on the order of 10.5 hours (Twidwell, 1984a), which would allow considerable changes in water quality.

Therefore, the slightly degraded level of macrobenthic health observed near FM 1937 should recover to near optimum conditions near the mouth under normal conditions, and the earlier conclusion that virtually complete water quality recovery prevails at the mouth still appears valid. This is also supported by the physicochemical data from the present study, which was collected near the mouth (Station I). The lowest dissolved oxygen concentration observed was 4.4 mg/L on May 16, 1984, with diel minima ≧ 5.2 mg/L on the other three sampling dates (Table 7), levels that compare favorably with the minimum observed at a control site upstream from Leon Creek in the 1983 study (i.e., Medina River at Pleasanton Road, dissolved oxygen minimum = 4.9 mg/L). Dissolved oxygen minima such as these are sufficient to support a diversity of aquatic life.

In conclusion, macrobenthic community structure reflected fair water quality and a moderate level of environmental stress in the vicinity of FM 1937, with degradation attributable to the effects of the Leon Creek WWTP discharge. However, biological and physicochemical data from this and the 1983 study indicate that water quality recovery is virtually complete at the mouth. Therefore, under normal conditions Medina River inflow should not adversely impact water quality in the San Antonio River. In fact, the poor mainstem water quality is enhanced by Medina River inflow.

CONCLUSIONS

Historical Texas Water Commission stream monitoring data, and previous intensive survey data indicate that water quality of the San Antonio River is relatively poor, particularly during periods of low stream flow. Under such conditions, river flow consists predominately of treated domestic wastewater from the City of San Antonio's three large wastewater treatment plants which cannot be sufficiently assimilated without the development of water quality problems.

The water quality and biological data from these four intensive surveys collected during different seasons of the year and different stream flow conditions further indicate that the San Antonio River is not able to assimilate the discharges of treated domestic wastewater from the City of San Antonio's three plants without exhibiting impairment of water quality.

Water quality trends were similar through the study reach during each intensive survey; however, magnitudes of parameter concentrations and longitudinal extent of impact coverage varied. Upstream of Camino Coahuilatechan (near IH 410) dissolved oxygen levels were generally high while nutrient levels and levels of oxygen demanding substances ($CBOD_5$ and ammonia nitrogen) were generally low. Levels of nutrients and oxygen demanding substances increased sharply at Camino Coahuilatechan reflecting the input of the Rilling Road WWTP effluent. Secondary spikes of these materials in the San Antonio River generally occurred between Blue Wing Road and the Medina River confluence reflecting input from the Salado Creek WWTP. Ammonia nitrogen levels were in the range considered chronically toxic to warm water fishes in the reach between Camino Coahuilatechan and Blue Wing Road on all four surveys. Although the rates for both parameters were considerably different during each survey, the downstream decay of $CBOD_5$ and ammonia nitrogen contributed to the development of dissolved oxygen sag zones with levels less than the 5 mg/L criterion during each survey. The magnitude and longitudinal extent of each dissolved oxygen sag was different due to water temperature, headwater and tributary flows, and quality of domestic loadings. Dissolved oxygen levels at the bottom of the sags were chronically low (< 3 mg/L) on three of four surveys and full recovery of dissolved oxygen levels usually did not occur until SH 81, a distance of 130 kilometers (80 miles).

Benthic macroinvertebrate data confirmed the conclusions of earlier surveys regarding longitudinal biological trends. Community structure upstream from the Rilling Road WWTP reflected clean water and healthy environmental conditions. Immediately upstream from the Medina River confluence, the macrobenthos was severely impacted due to poor water quality and a high level of environmental stress imposed by the Rilling Road and Salado Creek WWTP discharges. The standing crop was extremely depressed on three of the four sampling dates, which implies a high level of instream toxicity.

Near FM 791, the macrobenthos was considerably healthier, reflecting a degree of recovery from the severe impacts exerted by City of San Antonio wastewater discharges. However, recovery was not complete on any of the four sampling dates, which confirms earlier observations that the site is near the upstream limit of the water quality recovery zone. Community structure in the Medina River near FM 1937 indicated fair water quality and an intermediate level of environmental stress, with the moderate degree of degradation attributable to the Leon Creek WWTP discharge. Historical data indicates that virtually complete water quality recovery typically occurs between FM 1937 and the mouth, and that Medina River inflow generally has the effect of enhancing water quality in the San Antonio River.

A dissolved oxygen minimum of 5 mg/L has been assigned by the Texas Water Commission to protect the high quality aquatic life use in Segments 1911 and 1901. This criterion was violated during each of the four intensive surveys even though the three City of San Antonio's three wastewater treatments were generally within their 20/20 mg/L (BOD_5/TSS monthly) permit limitations. The water quality conditions of the San Antonio River have been documented and are likely to exist as long as the current levels of treatment at the three San Antonio plants are maintained.

The City of San Antonio has begun construction to upgrade the Leon Creek and Salado Creek WWTP's and to build the new Dos Rios WWTP near the San Antonio River-Medina River confluence. When construction of the Dos Rios facility is completed use of the existing Rilling Road WWTP will be terminated. Monthly average permit limitations for the Salado Creek, Leon Creek, and Dos Rios plants will be upgraded to 10/15/2 mg/L (BOD_5/TSS/NH_3-N) at respective monthly average effluent flows of 1.58 m^3/s (36 MGD), 1.53 m^3/s (35 MGD), and 3.64 m^3/s (83 MGD). Such limitations should reduce ammonia nitrogen below levels considered toxic to aquatic life. The combined reduction in carbonaceous and nitrogenous loading to the segment should result in substantial improvements in dissolved oxygen levels.

The water quality, hydraulic, and biological data collected during these four intensive surveys will be utilized by the Commission to evaluate water quality trends in the San Antonio River and evaluate specific wastewater dischargers to the segment.

PRESENTATION OF DATA

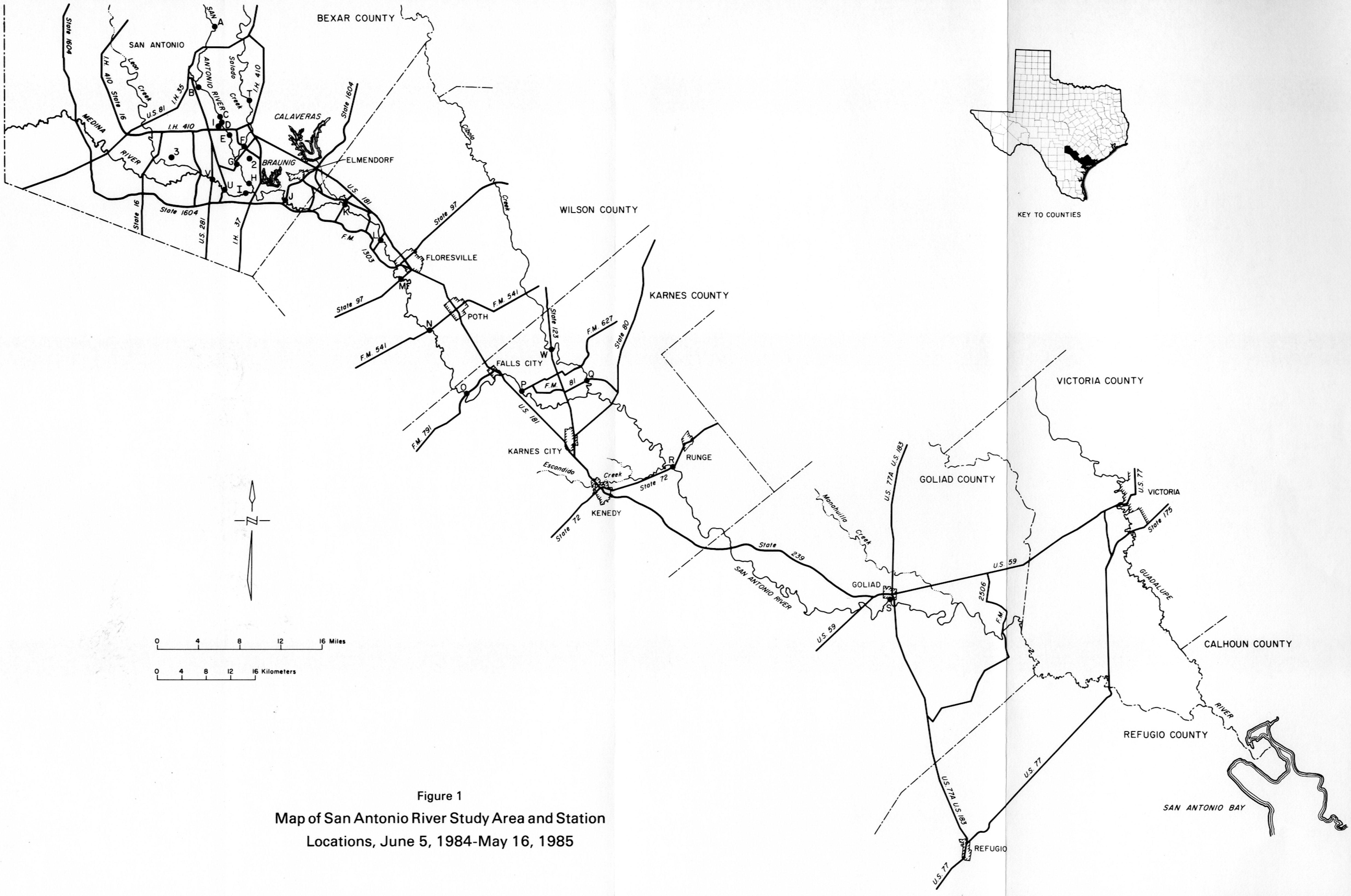

Figure 1

Map of San Antonio River Study Area and Station Locations, June 5, 1984-May 16, 1985

TABLE 1

San Antonio River Stations

Map Code	Statewide Monitoring Network Number	River Kilometer	Station Location
A	1911.0900	382.5	San Antonio River at Hildebrand Avenue in San Antonio
B	1911.0650	374.2	San Antonio River at South Alamo Street in San Antonio
C	1911.0450	362.8	San Antonio River at Ashley Road in San Antonio
D	1911.0430	361.7	San Antonio River 0.1 Km upstream of the San Antonio Rilling Road WWTP
E	1911.0400	360.5	San Antonio River at Camino Coahuilatechan in San Antonio
F	1910.0050	354.0/2.6	Salado Creek at Southton Road in San Antonio
G	1911.0375	352.6	San Antonio River at Blue Wing Road
H	1911.0352	345.3	San Antonio River 0.1 Km upstream of the Medina River
I	1903.0005	345.2/0.1	Medina River 0.1 Km upstream of the San Antonio River
J	1911.0300	333.3	San Antonio River at FM 1604 near Elemendorf
K	1911.0250	314.6	San Antonio River at County Road near Calaveras
L	1911.0220	300.9	San Antonio River at Dietz Road
M	1911.0213	288.3	San Antonio River at SH 97 near Floresville
N	1911.0210	267.1	San Antonio River at FM 541 near Poth

TABLE 1 CONTINUED

Map Code	Statewide Monitoring Network Number	River Kilometer	Station Location
O	1911.0200	247.4	San Antonio River at FM 791 near Falls City
P	1901.0145	231.6	San Antonio River at SH 81 near Hobson
Q	1902.0050	215.3/4.1	Cibolo Creek at SH 81 near Panna Maria
R	1901.0130	182.6	San Antonio River at SH 72 near Runge
S	1901.0100	111.1	San Antonio River at Southern Pacific Railroad near Goliad
T	1910.0100	354.1/11.7	Salado Creek at S.W. Military Drive (Loop 13) in San Antonio
U	1903.0050	345.2/6.4	Medina River at FM 1937
V	1903.0100	345.2/10.6	Medina River at US 281 near San Antonio
W	1902.0100	215.3/16.8	Cibolo Creek at SH 123 near Falls City
1	1900.9006	361.6	City of San Antonio Rilling Road WWTP
2	1900.9007	352.2	City of San Antonio Salado Creek WWTP
3	1900.9008	345.3/14.5/ 2.3/0.1	City of San Antonio Leon Creek WWTP

TABLE 2

Active Water Quality Monitoring Stations
on the San Antonio River

Station	Map Code	Sampling Agency/ Station Number	Frequency of Sampling/ Type of Record	Period of Record
San Antonio River at Artesian Well No. 1 on Hildebrand Avenue in San Antonio		SARA - 1911.0902	4 FD 3 CH,BA	July 1982 - Current Year
San Antonio River at Hildebrand Street in San Antonio	A	SARA - 1911.0900	4 FD 3 CH,BA	March 1975 - Current Year
		CSA - 1911.0900	3 FD,CH,BA	July 1974 - Current Year
San Antonio River at Artesian Well No. 3 Hippo Springs in San Antonio		SARA - 1911.0880	4 FD 3 CH,BA	July 1982 - Current Year
San Antonio River at Mulberry Street in San Antonio		CSA - 1911.0800	3 FD,CH,BA	Feb. 1975 - Current Year
San Antonio River at South Alamo Street in San Antonio	B	SARA - 1911.0650	4 FD 3 CH,BA	May 1983 - Current Year
		USGS - 08178000	1 Dd 5 CH,PS 3 BA	Feb. 1939 - Current Year Nov. 1968 - Current Year May 1976 - Current Year

TABLE 2 CONTINUED

Station	Map Code	Sampling Agency/ Station Number	Frequency of Sampling/ Type of Record	Period of Record
San Antonio River at Theo Avenue in San Antonio		CSA - 1911.0600	3 FD,CH,BA	Sept. 1974 - Current Year
San Antonio River at Ashley Road in San Antonio	C	SARA - 1911.0450	4 FD 3 CH,BA	Jan. 1976 - Current Year
		CSA	2 FD,CH,BA	May 1970 - Current Year
San Antonio River at Camino Coahuilatechan in San Antonio	E	SARA - 1911.0400	4 FD 3 CH,BA	Jan. 1976 - Current Year
		CSA	2 FD,CH,BA	May 1970 - Current Year
San Antonio River at Blue Wing Road	G	SARA - 1911.0375	4 FD 3 CH,BA	Jan. 1976 - Current Year
		CSA	3 FD,CH,BA	Jan. 1984 - Current Year
San Antonio River 0.1 km upstream of the Medina River	H	TWC - 1911.0352	3 FD,CH,BA 5 BN	June 1984 - Current Year
San Antonio River at IH 37		SARA - 1911.0350	4 FD 3 CH,BA	Jan. 1976 - Current Year

TABLE 2 CONTINUED

Station	Map Code	Sampling Agency/ Station Number	Frequency of Sampling/ Type of Record	Period of Record
San Antonio River at County Road near Calaveras	K	TWC - 1911.0250	5 FD,CH,BA	Oct. 1981 - Current Year
		SARA - 1911.0250	4 FD	Oct. 1973 - Current Year
		CSA	2 FD,CH,BA	April 1973 - Current Year
San Antonio River at Labatt Road near Calaveras		SARA - 1911.0225	3 FD,CH,BA	Jan. 1984 - Current Year
		CSA	2 FD,CH,BA	April 1973 - Current Year
San Antonio River at Dietz Road	L	SARA - 1911.0220	4 FD 3 CH,BA	Jan. 1976 - Current Year
		CSA	3 FD,CH,BA	Jan. 1984 - Current Year
San Antonio River at FM 546 near Floresville		SARA - 1911.0215	4 FD 3 CH,BA	Jan. 1976 - Current Year
San Antonio River at SH 97 near Floresville	M	SARA - 1911.0213	4 FD 3 CH,BA	Jan. 1974 - Current Year
San Antonio River at FM 541 near Poth	N	SARA - 1911.0210	4 FD 3 CH,BA	June 1976 - Current Year

TABLE 2 CONTINUED

Station	Map Code	Sampling Agency/ Station Number	Frequency of Sampling/ Type of Record	Period of Record
San Antonio River at FM 791 near Falls City	O	TWC - 1911.0200	3 FD,CH,BA,IC 6 PS,SD	Sept. 1968 - Current Year
		SARA - 1911.0200	4 FD 3 CH,BA	July 1973 - Current Year
		USGS - 08183500	1 Dd	April 1925 - Current Year
San Antonio River at FM 81 near Hobson	P	SARA - 1901.0145	4 FD 3 CH,BA	Jan. 1975 - Current Year
San Antonio River at SH 72 near Runge	R	SARA - 1901.0130	4 FD 3 CH,BA	Jan. 1974 - Current Year
San Antonio River at Southern Pacific Railroad Bridge in Goliad	S	TWC - 1901.0105	5 FD 5 CH,BA	Oct. 1984 - Current Year

Frequency of Sampling

1. Continuous
2. Weekly
3. Monthly
4. Bimonthly
5. Quarterly
6. Annually
7. Periodically

Type of Record

FD	Field measurements in water
CH	Chemical parameters in water
PW	Pesticides in water
PS	Pesticides in sediment
MT	Metals in water
SD	Chemical and metal parameters in sediment
Dd	Stream discharge
BA	Bacteriological parameters in water
IC	Inorganic constituents

TABLE 3

Historical Water Temperature, pH, Chloride, Sulfate, Total Dissolved Solids, and Fecal Coliform Data Collected by the Texas Department of Water Resources and San Antonio River Authority at 15 Locations on the San Antonio River and One Each on Salado Creek, Medina River, and Cibolo Creek, October 1980 - September 1985

Segment		Map Code	Criteria →	Water Temperature 32.2°C	pH Units 6.5-9.0	Chloride 95 mg/L	Sulfate 95 mg/L	Total Dissolved Solids 620	Fecal Coliform 2,000/100 mL
	Hildebrand Avenue	A	No. of Observations	165	122	76	74	26	78
	in San Antonio		Mean	21.0	---	38	35	314	930
	SMN 1911.0900		Range	3.0-29.4	6.9-9.4	7-103	10-147	160-514	10-50,400
			Percent > Criterion	0	1	1	4	0	33
	South Alamo Street	B	No. of Observations	123	80	28	25	31	26
	in San Antonio		Mean	20.4	--	33	41	296	474
	SMN 1911.0600		Range	8.0-29.0	7.2-8.8	11-95	16-141	224-434	9.0-270,000
			Percent > Criterion	0	0	0	4	0	23
1911	Ashley Road in	D	No. of Observations	115	68	25	22	23	21
	San Antonio		Mean	20.3	--	44	58	341	449
	SMN 1911.0450		Range	5.0-33.5	7.2-8.3	18-89	33-228	240-436	10-34,400
			Percent > Criterion	2	0	0	5	0	38
	Camino Coahuilatechan	E	No. of Observations	133	86	28	27	28	26
	in San Antonio		Mean	23.5	--	78	61	471	347
	SMN 1911.0400		Range	9.0-30.5	7.0-9.8	39-106	30-272	260-574	10-1300,000
			Percent > Criterion	0	1	7	4	0	15
	Blue Wing Road near	G	No. of Observations	132	87	31	27	27	27
	San Antonio		Mean	22.0	--	78	54	467	1390
	SMN 1911.0375		Range	8.0-31.0	7.0-8.4	38-108	30-110	332-560	3-78,000
			Percent > Criterion	0	0	10	4	0	48

TABLE 3 CONTINUED

Segment	Map Code	Criteria →	Water Temperature 32.2°C	pH Units 6.5-9.0	Chloride 95 mg/L	Sulfate 95 mg/L	Total Dissolved Solids 620	Fecal Coliform 2,000/100 mL
Above confluence with Medina River SMN 1911.0352		No. of Observations	31	48	20	20	20	14
		Mean	24.9	--	90	66	535	1636
		Range	14.6-30.0	7.1-8.1	54-101	27-206	428-749	60-250,000
		Percent > Criterion	0	0	20	5	10	43
FM 1604 SMN 1911.0300		No. of Observations	141	98	34	31	32	29
		Mean	216	--	76	60	478	689
		Range	9.0-30.2	7.0-8.2	32-106	18-90	180-608	20-46,000
		Percent > Criterion	0	0	9	0	0	31
Calaveras Road SMN 1911.0250		No. of Observations	147	100	34	32	33	30
		Mean	21.6	---	72	66	477	284
		Range	10.0-30.7	6.8-8.6	32-103	30-111	338-604	10-10,000
		Percent > Criterion	0	0	9	3	0	13
Dietz Road SMN 1911.0220		No. of Observations	138	84	29	27	27	26
		Mean	21.1	--	75	65	482	635
		Range	8.0-30.0	7.0-8.2	30-103	30-92	340-600	10-38,500
		Percent > Criterion	0	0	3	0	0	30
SH 97 near Floresville SMN 1911.0213		No. of Observations	81	78	26	25	26	24
		Mean	21.8	--	80	69	497	380
		Range	7.0-30.1	7.1-8.8	52-101	30-132	296-612	10-39,500
		Percent > Criterion	0	0	8	8	0	21
FM 541 near Poth SMN 1911.0210		No. of Observations	139	83	23	21	22	20
		Mean	21.0	--	82	72	491	527
		Range	7.0-30.0	6.8-8.3	34-104	22-105	292-580	10-57,800
		Percent > Criterion	0	0	26	5	0	25

TABLE 3 CONTINUED

Segment		Map Code	Criteria →	Water Temperature 32.2°C	pH Units 6.5-9.0	Chloride 180 mg/L	Sulfate 140 mg/L	Total Dissolved Solids 750 mg/L	Fecal Coliform 2,000/100 mL
	FM 791 near		No. of Observations	204	139	85	82	83	81
	Falls City		Mean	21.4	---	81	80	512	235
	SMN 1911.0200		Range	6.0-30.7	6.4-8.6	13-160	20-260	252-624	2-380,000
			Percent > Criterion	0	1	29	15	1	17
	FM 81 near Hobson		No. of Observations	44	46	14	13	14	12
	SMN 1901.0145		Mean	21.7	--	90	74	466	942
			Range	9.0-29.3	6.9-8.3	33-214	17-137	264-612	90-12,500
			Percent > Criterion	0	0	7	0	0	33
1901	SH 72 near Runge		No. of Observations	90	83	27	26	26	25
	SMN 1901.0130		Mean	212	--	111	94	605	592
			Range	7.0-30.5	6.5-8.6	10-270	28-138	372-768	10-11,200
			Percent > Criterion	0	0	4	0	4	28
	US 77-A and 183		No. of Observations	117	112	28	27	25	65
	near Goliad		Mean	20.9	---	124	98	606	314
	SMN 1901.0100		Range	8.0-30.0	7.1-9.2	19-460	28-165	320-832	2-21,600
			Percent > Criterion	0	1	7	7	20	26

TABLE 3 CONTINUED

Segment		Map Code	Criteria →	Water Temperature 32.2°C	pH Units 6.5-9.0	Chloride 50 mg/L	Sulfate 200 mg/L	Total Dissolved Solids 550 mg/L	Fecal Coliform 2,000/100 mL
1910	Salado Creek at	F	No. of Observations	88	91	68	66	15	64
	Southton Road in		Mean	20.5	--	76	58	407	116
	San Antonio		Range	8.6-29.4	7.3-8.5	28-282	14-253	259-614	1-60,000
	SMN 1910.0050		Percent > Criterion	0	0	82	2	7	9
			Criteria →	Water Temperature 32.2°C	pH Units 6.5-9.0	Chloride 120 mg/L	Sulfate 200 mg/L	Total Dissolved Solids 700 mg/L	Fecal Coliform 2,000/100 mL
1903	Medina River above	I	No. of Observations	35	47	15	15	15	14
	Confluence with		Mean	23.6	--	77	99	557	460
	San Antonio River		Range	10.7-29.4	7.0-8.0	53-101	45-265	400-996	10-11,800
	SMN 1903.0005		Percent > Criterion	0	0	0	13	7	71
			Criteria →	Water Temperature 32.2°C	pH Units 6.5-9.0	Chloride 170 mg/L	Sulfate 275 mg/L	Total Dissolved Solids 900 mg/L	Fecal Coliform 2,000/100 mL
1902	Cibolo Creek at	Q	No. of Observations	37	35	9	9	9	8
	FM 81 near Panna		Mean	21.4	--	184	262	947	132
	Maria		Range	6.0-29.4	7.6-8.8	74-284	122-377	484-1256	10-7,100
	SMN 1902.0050		Percent > Criterion	0	0	67	33	67	13

TABLE 4

Historical Dissolved Oxygen Data Collected by the Texas Department of Water Resources and San Antonio River Authority at 15 Locations on the San Antonio River and at One Each on Salado Creek, Medina River, and Cibolo Creek, October 1, 1980-September 1985

Segment	Station	Map Code		Water Year 1981	1982	1983	1984	1985
1911	Hilbrand Avenue in San Antonio SMN 1911.0900	A	No. of Observations	32	17	22	18	28
			Mean, mg/L	7.2	7.2	7.6	7.9	9.2
			Range, mg/L	6.0-16.8	6.3-9.6	6.1-9.6	4.0-12.6	5.7-14.3
			Percent < 5.0 mg/L	0	0	0	11	0
	South Alamo Street in San Antonio SMN 1911.0600	B	No. of Observations	32	17	18	30	14
			Mean, mg/L	8.6	8.0	9.3	8.6	8.1
			Range, mg/L	6.3-15.2	7.1-9.5	6.2-11.2	0.6-20.0	6.0-11.0
			Percent < 5.0 mg/L	0	0	0	13	0
	Ashley Road in San Antonio SMN 1911.0450	D	No. of Observations	34	17	27	19	18
			Mean, mg/L	8.8	8.6	8.8	8.8	8.8
			Range, mg/L	6.2-13.6	6.7-11.4	6.0-11.6	6.7-13.8	7.0-11.0
			Percent < 5.0 mg/L	0	0	0	0	0
	Camino Coahuilatechan in San Antonio SMN 1911.0400	E	No. of Observations	36	17	26	25	29
			Mean, mg/L	7.3	7.8	6.8	6.8	7.4
			Range, mg/L	1.3-12.6	5.5-10.8	2.9-9.2	4.4-9.8	4.7-9.7
			Percent < 5.0 mg/L	14	0	7	8	3
	Blue Wing Road near San Antonio SMN 1911.0375	G	No. of Observations	37	16	28	22	27
			Mean, mg/L	4.6	3.5	3.3	3.8	5.1
			Range, mg/L	1.1-10.0	1.0-9.3	0.4-8.8	0.9-7.2	1.9-9.0
			Percent < 5.0 mg/L	62	88	79	64	48
	Above confluence with Medina River SMN 1911.0352	H	No. of Observations				11	20
			Mean, mg/L				4.8	5.3
			Range, mg/L				3.7-8.1	2.3-7.8
			Percent < 5.0 mg/L				64	40

TABLE 4 CONTINUED

Segment	Station	Map Code		Water Year 1981	1982	1983	1984	1985
1911	FM 1604	J	No. of Observations	41	17	27	26	30
	SMN 1911.0300		Mean, mg/L	5.5	5.5	4.9	5.0	5.4
			Range, mg/L	3.1-9.3	3.7-7.6	1.8-8.2	0.6-8.1	3.1-8.4
			Percent < 5.0 mg/L	39	35	52	58	47
	Calaveras Road	K	No. of Observations	40	27	26	24	30
	SMN 1911.0250		Mean, mg/L	4.1	4.6	3.9	4.4	4.3
			Range, mg/L	1.3-7.2	1.8-7.1	1.8-6.9	1.8-7.2	2.0-7.7
			Percent < 5.0 mg/L	75	48	77	63	60
	Dietz Road	L	No. of Observations	40	22	22	26	28
	SMN 1911.0220		Mean, mg/L	3.4	4.1	3.6	4.8	4.0
			Range, mg/L	0.5-6.2	2.1-5.9	1.9-6.8	2.6-8.4	1.8-8.4
			Percent < 5.0 mg/L	95	59	82	62	68
	SH 97 near	M	No. of Observations		4	24	25	28
	Floresville		Mean, mg/L		4.0	4.1	5.9	4.5
	SMN 1911.0213		Range, mg/L		2.8-5.6	2.1-6.9	2.9-8.6	2.6-7.7
			Percent < 5.0 mg/L		75	75	24	64
1911	FM 541 near	N	No. of Observations	40	22	23	24	30
	Poth		Mean, mg/L	4.2	5.4	4.4	7.0	5.2
	SMN 1911.0210		Range, mg/L	1.9-6.3	3.1-6.9	1.8-7.3	3.7-9.8	2.4-7.9
			Percent < 5.0 mg/L	75	32	70	4	47
	FM 791 near	O	No. of Observations	52	34	35	38	45
	Falls City		Mean, mg/L	4.3	5.6	3.8	5.9	4.4
	SMN 1911.0200		Range, mg/L	1.2-7.6	1.8-14.9	1.1-6.7	0.3-12.5	0.3-7.8
			Percent < 5.0 mg/L	67	65	74	18	60

TABLE 4 CONTINUED

Segment	Station	Map Code		Water Year 1981	1982	1983	1984	1985
1901	FM 81 near	P	No. of Observations			4	10	30
	Hobson		Mean, mg/L			6.0	7.4	7.9
	SMN 1901.0145		Range, mg/L			4.5-8.1	5.6-8.4	5.0-11.2
			Percent < 5.0 mg/L			50	0	0
	SH 72 near	Q	No. of Observations		4	29	26	31
	Runge		Mean, mg/L		7.9	7.1	7.8	8.2
	SMN 1901.0130		Range, mg/L		7.6-8.5	2.9-9.7	5.1-10.8	5.1-11.0
			Percent < 5.0 mg/L		0	3	0	0
	US 77-A and 183	S	No. of Observations	29	20	23	26	18
	near Goliad		Mean, mg/L	7.5	7.9	7.7	8.0	8.3
	SMN 1901.0100		Range, mg/L	3.9-9.9	5.0-11.0	6.4-10.2	6.4-10.6	5.1-10.8
			Percent < 5.0 mg/L	3	0	0	0	0
1910	Salado Creek at	F	No. of Observations	3		5	13	16
	Southton Road		Mean, mg/L	9.5		7.6	8.3	10.0
	in San Antonio		Range, mg/L	7.9-11.0		5.7-9.9	6.5-12.4	7.6-11.6
	SMN 1910.0050		Percent < 5.0 mg/L	0		0	0	0
1903	Medina River above	I	No. of Observations	1		4	11	20
	confluence with		Mean, mg/L	6.9		5.1	5.0	6.3
	San Antonio River		Range, mg/L	6.9		4.6-5.6	3.8-6.7	4.4-9.0
	SMN 1903.0005		Percent < 5.0 mg/L	0		25	46	15
1902	Cibolo Creek	Q	No. of Observations			5	18	14
	at FM 81 near		Mean, mg/L			8.0	8.1	9.6
	Panna Maria		Range, mg/L			6.2-9.3	4.5-12.2	6.4-12.4
	SMN 1902.0050		Percent < 5.0 mg/L			0	6	0

TABLE 5

San Antonio River
Fish Kills

Date	Location	Total Fish Killed	Suspected Cause
10/19/70	San Antonio River from City of San Antonio Rilling Road WWTP to IH 410	20,000	Oxygen Depletion
03/24/72	San Antonio River at FM 791 near Falls City	10,000	Oxygen Depletion
04/24/72	San Antonio River at FM 791 near Falls City	3,500	Oxygen Depletion
01/05/73	San Antonio River between IH 410 and Blue Wing Road	3,000	Oxygen Depletion
06/22/73	San Antonio River between Blue Wing Road and Otillo Dam	5,000	Oxygen Depletion
08/13/82	San Antonio River at SH 97 near Floresville	2,000	Raw Sewage, Oxygen Depletion
07/11/83	San Antonio River at FM 791 near Falls City	9,952	Oxygen Depletion
09/12/83	San Antonio River at FM 791 near Falls City	6,832	Oxygen Depletion

TABLE 6

Monthly Average Permit Limitations for BOD_5 and TSS for Three San Antonio Treatment Facilities

Wastewater Discharger Permit Number	Map Code	Flow		BOD_5			TSS		
		m^3/s	MGD	mg/L	kg/d	lb/d	mg/L	kg/d	lb/d
City of San Antonio Rilling Road Plant	1	4.1	94	20	7,112	15,679	20	7,112	15,679
City of San Antonio Salado Creek Plant	2	1.1	24	20	1,816	4,003	20	1,816	4,003
City of San Antonio Leon Creek Plant	3	1.1	24	20	1,816	4,003	20	1,816	4,003
	Totals	6.3	142		10,744	23,685		10,744	23,685

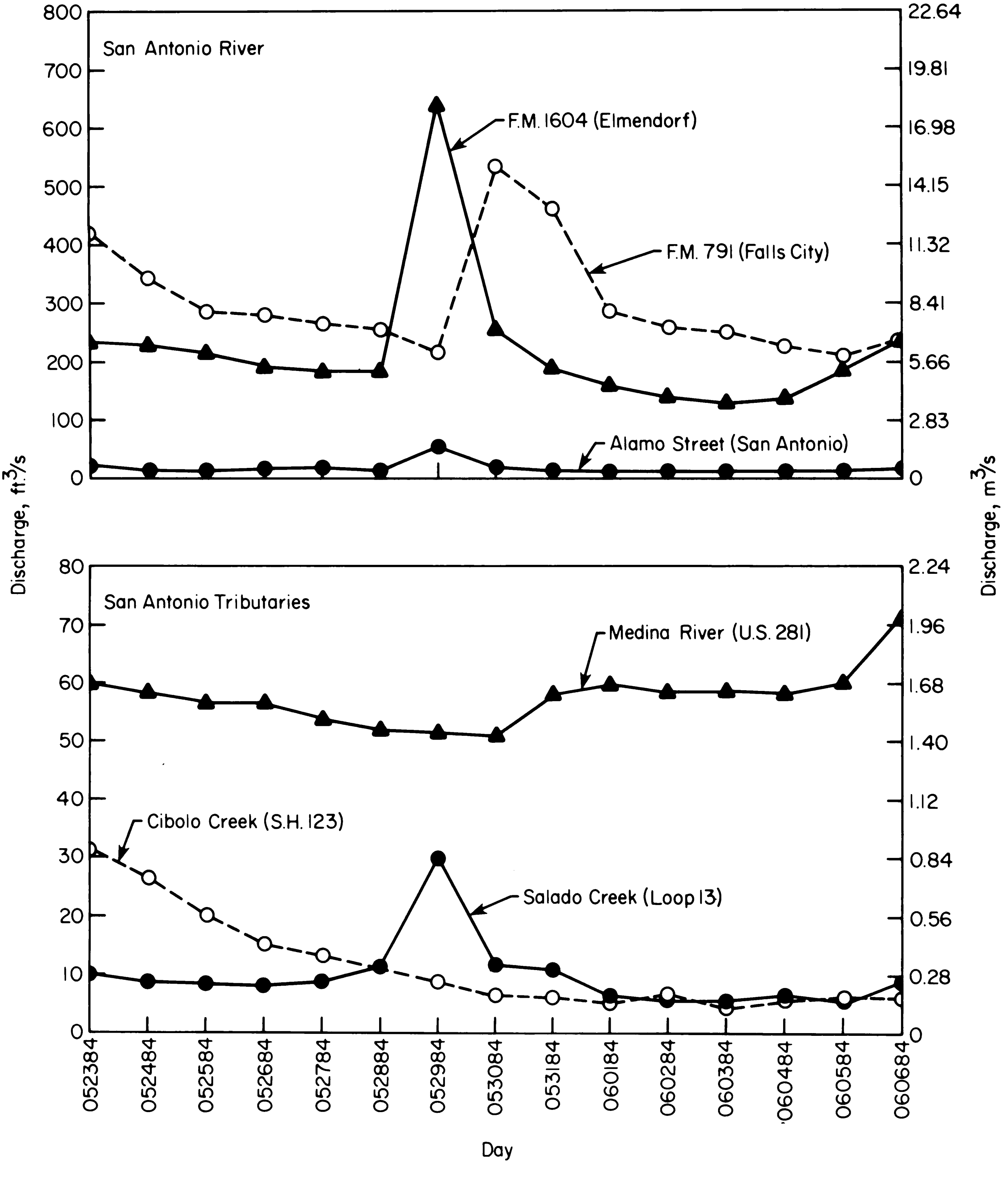

Figure 2

Mean Daily Discharge Rate from the San Antonio River, Salado Creek, Medina River, and Cibolo Creek, May 23-June 6, 1984 Provisional U.S.G.S. Data

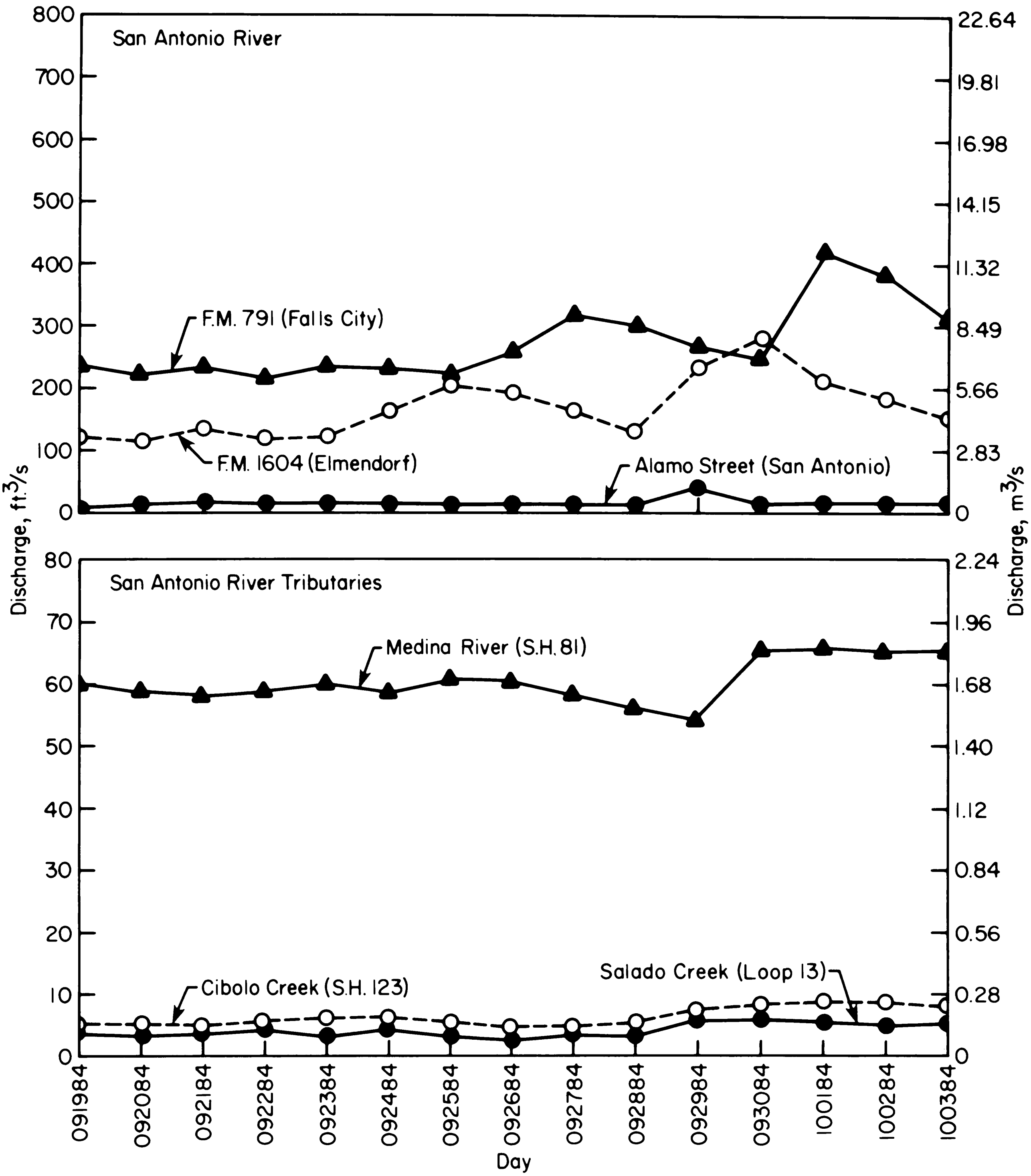

Figure 3

Mean Daily Discharge Rate from the San Antonio River, Salado Creek, Medina River, and Cibolo Creek, September 19-October 3, 1984

Provisional U.S.G.S. Data

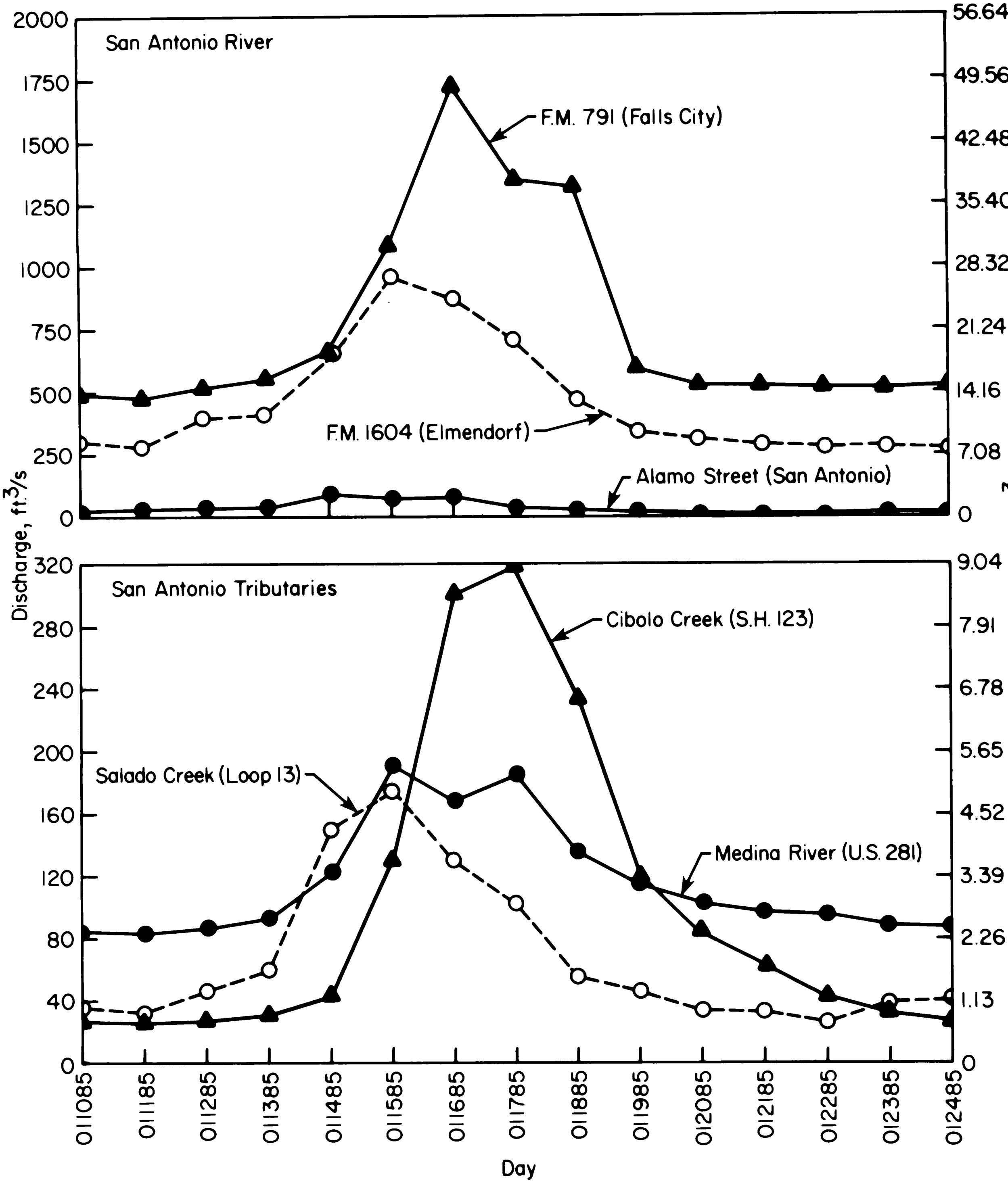

Figure 4
Mean Daily Discharge Rate from the San Antonio River, Salado Creek, Medina River, and Cibolo Creek, January 8-24, 1985
Provisional U.S.G.S. Data

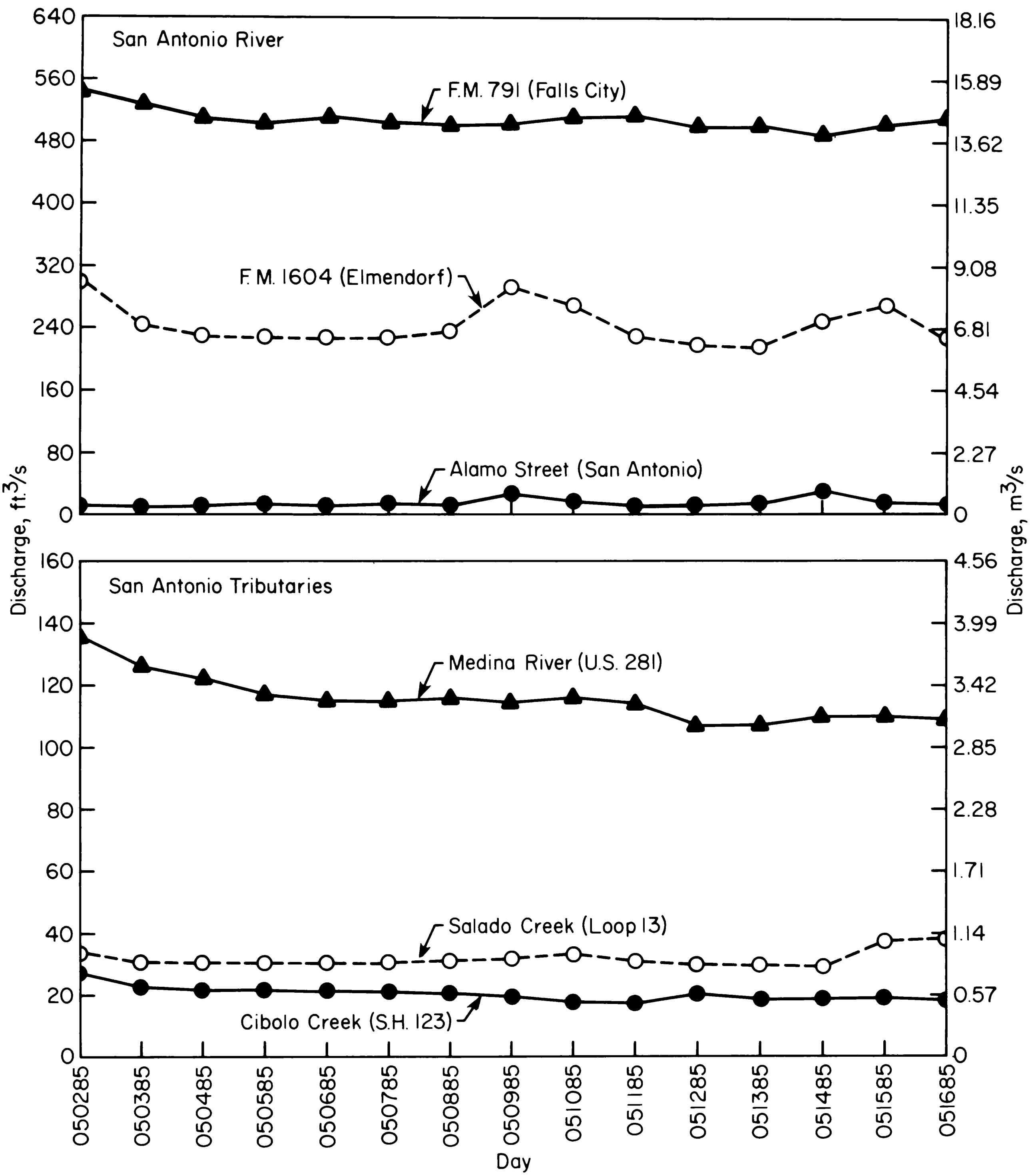

Figure 5

Mean Daily Discharge Rate from the San Antonio River, Salado Creek, Medina River, and Cibolo Creek, May 2-16, 1985

Provisional U.S.G.S. Data

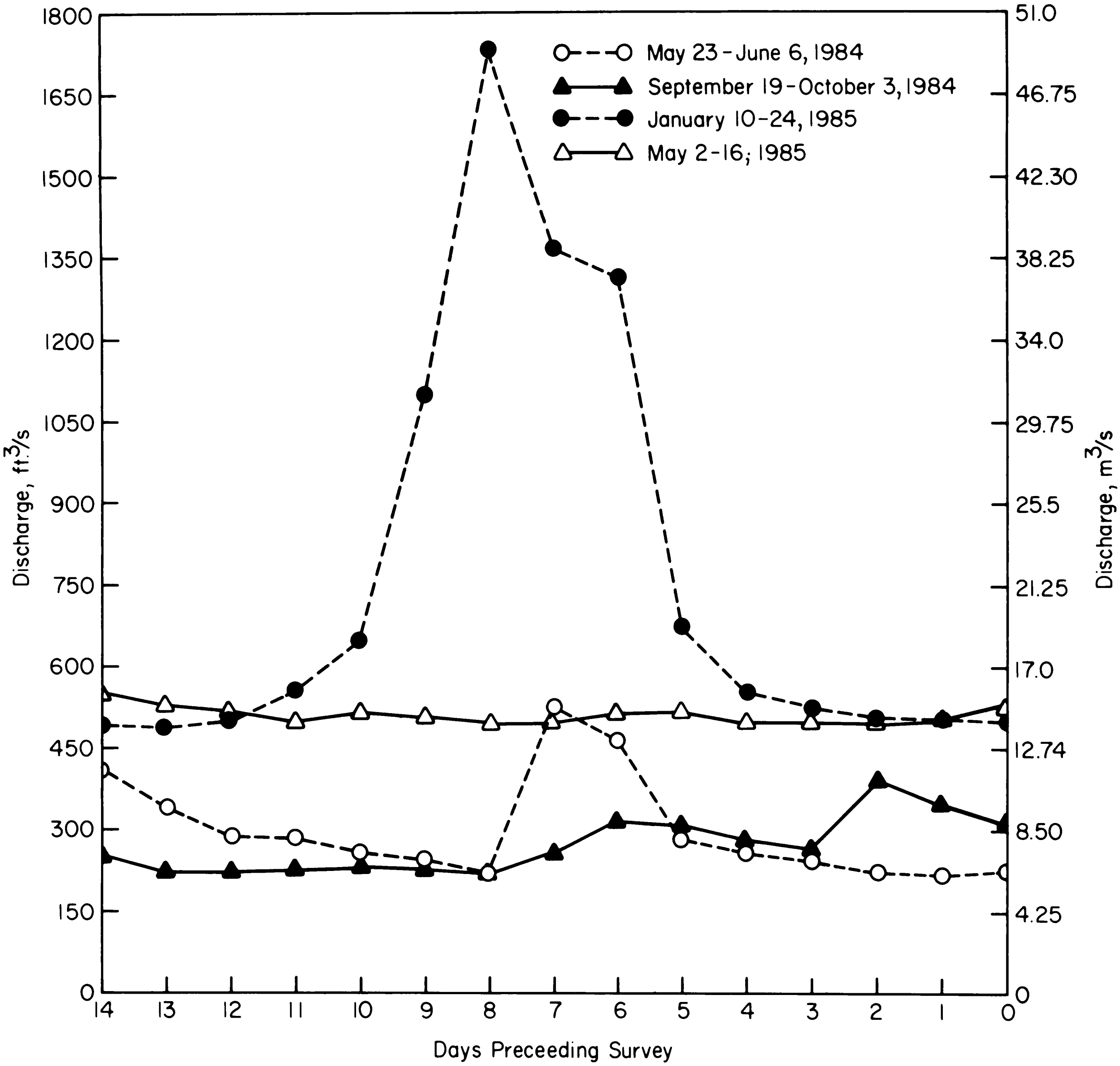

Figure 6

Mean Daily Discharge Rate from the San Antonio River at FM 791
Near Falls City, 14 Days Prior to Each Intensive Survey.
Provisional U.S.G.S. Data

TABLE 7

Field Measurements

Map Code and Station Number	Date	Time	Depth (m)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
A 1911.0900	06/06/84	0515	0.3	24.1	462	5.8	69.3	7.9
	06/06/84	1045	0.3	24.0	561	5.8	69.2	7.8
	06/06/84	1415	0.3	24.9	378	4.8	58.2	7.6
	06/06/84	1815	0.3	25.5	378	4.0	49.0	7.5
		DIEL MEAN		24.6	441	5.1	61.2	7.7
B 1911.0650	06/06/84	0610	0.3	23.6	535	4.7	55.6	---
	06/06/84	1115	0.3	25.1	495	12.0	146.0	8.2
	06/06/84	1445	0.3	27.5	530	10.9	138.5	8.1
	06/06/84	1845	0.3	26.8	518	9.7	121.8	8.1
		DIEL MEAN		25.5	522	8.6	106.0	8.1
C 1911.0450	06/06/84	0645	0.3	24.9	493	6.9	83.7	---
	06/06/84	1145	0.3	26.5	532	7.6	94.9	8.0
	06/06/84	1525	0.3	27.5	546	7.3	92.8	8.1
	06/06/84	1920	0.3	27.5	541	7.1	90.2	8.0
		DIEL MEAN		26.4	524	7.2	89.2	8.0
E 1911.0400	06/06/84	0925	0.3	26.9	761	4.7	59.1	---
	06/06/84	1305	0.3	28.6	898	6.4	83.0	7.8
	06/06/84	1645	0.3	29.5	808	5.9	77.7	7.7
	06/06/84	2020	0.3	28.5	802	5.6	72.5	7.7
		DIEL MEAN		28.1	803	5.5	70.2	7.8
F 1910.0050	06/06/84	0850	0.3	23.9	545	6.5	77.4	---
	06/06/84	1235	0.3	25.4	638	6.7	82.0	8.0
	06/06/84	1630	0.3	26.7	653	6.9	86.5	8.0
	06/06/84	2000	0.3	25.6	646	6.6	81.1	8.0
		DIEL MEAN		25.2	611	6.6	80.8	8.0

TABLE 7 CONTINUED

Map Code and Station Number	Date	Time	Depth (m)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
G 1911.0375	06/06/84	0810	0.3	26.5	850	1.6	20.0	---
	06/06/84	1215	0.3	27.0	925	1.5	18.9	7.7
	06/06/84	1600	0.3	28.5	862	3.2	41.4	7.6
	06/06/84	1945	0.3	29.3	810	3.0	39.4	7.8
		DIEL MEAN		27.8	851	2.3	29.7	7.7
H 1911.0352	06/06/84	0500	0.3	27.6	911	3.9	49.7	7.2
	06/06/84	1020	0.3	26.7	911	4.8	60.1	7.3
	06/06/84	1450	0.3	28.4	946	5.2	67.2	7.5
	06/06/84	1830	0.3	29.2	935	4.5	58.9	7.4
		DIEL MEAN		28.0	924	4.5	57.5	7.3
I 1903.0005	06/06/84	0450	0.3	26.7	853	5.2	65.2	7.3
	06/06/84	1015	0.3	25.6	844	5.5	67.6	7.4
	06/06/84	1445	0.3	27.4	827	5.9	74.9	7.6
	06/06/84	1840	0.3	28.6	832	5.2	67.4	7.6
		DIEL MEAN		27.2	840	5.4	68.0	7.5
J 1911.0300	06/06/84	0530	0.3	27.3	902	4.0	50.7	7.2
	06/06/84	1055	0.3	26.6	866	4.0	50.0	7.4
	06/06/84	1530	0.3	28.3	855	4.5	58.0	7.4
	06/06/84	1910	0.3	28.5	878	4.3	55.6	7.5
		DIEL MEAN		27.7	879	4.2	53.2	7.4
K 1911.0250	06/06/84	0555	0.3	27.2	834	2.2	27.8	7.2
	06/06/84	1110	0.3	26.9	814	3.0	37.7	7.3
	06/06/84	1550	0.3	28.6	843	3.6	46.7	7.5
	06/06/84	1925	0.3	28.6	855	3.2	41.5	7.5
		DIEL MEAN		27.8	838	2.9	37.1	7.4

TABLE 7 CONTINUED

Map Code and Station Number	Date	Time	Depth (m)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
L 1911.0220	06/06/84	0620	0.3	26.9	852	2.6	32.7	7.2
	06/06/84	1140	0.3	26.6	847	3.2	40.0	7.4
	06/06/84	1610	0.3	28.1	816	3.3	42.4	7.4
	06/06/84	1945	0.3	28.1	831	2.9	37.3	7.5
		DIEL MEAN		27.4	839	2.9	37.2	7.4
M 1911.0213	06/06/84	0650	0.3	26.7	894	4.3	53.9	7.5
	06/06/84	1155	0.3	27.1	890	4.5	56.8	7.4
	06/06/84	1630	0.3	28.2	871	5.5	70.8	7.6
	06/06/84	2000	0.3	27.8	856	6.0	76.7	7.7
		DIEL MEAN		27.4	878	5.0	64.1	7.6
N 1911.0210	06/06/84	0455	0.3	26.0	900	6.3	77.9	7.9
	06/06/84	0900	0.3	26.0	900	6.2	76.7	7.8
	06/06/84	1355	0.3	27.0	925	6.5	81.9	7.8
	06/06/84	1755	0.3	28.0	925	8.0	102.6	7.9
		DIEL MEAN		26.8	912	6.8	86.1	7.9
O 1911.0200	06/06/84	0525	0.3	26.5	950	5.5	68.7	7.7
	06/06/84	0920	0.3	26.0	925	5.5	68.0	7.5
	06/06/84	1415	0.3	28.0	1000	6.5	83.4	7.8
	06/06/84	1825	0.3	27.0	975	6.3	79.4	7.8
		DIEL MEAN		26.8	963	5.9	74.7	7.7
P 1901.0145	06/06/84	0600	0.3	27.0	900	7.0	88.2	7.8
	06/06/84	0940	0.3	25.0	900	7.1	86.2	7.9
	06/06/84	1435	0.3	27.0	97	7.8	98.3	7.9
	06/06/84	1845	0.3	27.5	97	7.9	100.4	7.9
		DIEL MEAN		26.8	490	7.5	93.7	7.9

TABLE 7 CONTINUED

Map Code and Station Number	Date	Time	Depth (m)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
Q 1902.0050	06/06/84	0620	0.3	25.0	1550	6.0	72.9	8.0
	06/06/84	1000	0.3	24.5	1550	6.2	74.6	8.0
	06/06/84	1455	0.3	27.0	1700	9.4	118.4	8.1
	06/06/84	1900	0.3	27.0	1700	8.6	108.3	8.1
		DIEL MEAN		25.9	1626	7.5	93.1	8.1
R 1901.0130	06/06/84	0645	0.3	26.0	950	6.8	84.1	7.9
	06/06/84	1025	0.3	26.0	950	6.9	85.4	7.8
	06/06/84	1520	0.3	28.0	1100	7.6	97.5	7.9
	06/06/84	1920	0.3	28.0	1100	7.7	98.8	8.0
		DIEL MEAN		27.0	1026	7.3	91.5	7.9

Map Code and Station Number	Date	Time	Depth (m)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
A 1911.0900	10/03/84	0715	0.3	19.0	538	7.7	83.3	7.3
	10/03/84	1310	0.3	21.6	534	8.7	99.1	7.5
	10/03/84	1532	0.3	22.9	528	11.3	132.0	7.6
	10/03/84	1920	0.3	22.1	518	11.3	130.0	8.0
		DIEL MEAN		21.0	529	9.5	107.6	7.6
B 1911.0650	10/03/84	0645	0.3	20.4	496	6.9	76.8	7.3
	10/03/84	1130	0.3	20.9	503	7.6	85.4	7.3
	10/03/84	1502	0.3	21.2	524	8.2	92.7	7.3
	10/03/84	1902	0.3	21.4	521	8.0	90.8	7.4
		DIEL MEAN		20.9	510	7.6	85.3	7.3
D 1911.0430	10/03/84	0520	0.3	20.5	576	7.6	84.7	7.3
	10/03/84	1010	0.3	20.7	580	8.2	91.8	7.2
	10/03/84	1410	0.3	22.4	574	10.5	121.4	7.6
	10/03/84	2013	0.3	22.9	572	9.3	108.6	7.6
		DIEL MEAN		21.7	575	8.9	101.2	7.4
E 1911.0400	10/03/84	0510	0.3	26.4	950	4.7	58.6	7.5
	10/03/84	0955	0.3	26.1	970	5.5	68.2	7.1
	10/03/84	1400	0.3	27.6	949	6.6	84.0	7.3
	10/03/84	2000	0.3	27.3	962	6.3	79.8	7.3
		DIEL MEAN		26.9	957	5.8	72.4	7.3
F 1910.0050	10/03/84	0610	0.3	19.2	864	7.6	82.5	7.8
	10/03/84	1105	0.3	19.6	862	8.0	87.6	7.5
	10/03/84	1430	0.3	20.5	881	10.1	112.6	7.6
	10/03/84	2040	0.3	20.9	914	11.4	128.1	7.7
		DIEL MEAN		20.1	883	9.4	104.3	7.7

TABLE 7 CONTINUED

Map Code and Station Number	Date	Time	Depth (m)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
G 1911.0375	10/03/84	0540	0.3	25.2	954	1.9	23.2	7.3
	10/03/84	1035	0.3	25.1	986	2.9	35.3	7.1
	10/03/84	1425	0.3	25.8	998	4.1	50.5	7.2
	10/03/84	2030	0.3	26.2	973	3.7	45.9	7.3
		DIEL MEAN		25.6	975	3.1	38.3	7.2
H 1911.0352	10/03/84	0530	0.3	24.5	939	4.3	51.8	7.1
	10/03/84	1015	0.3	25.0	914	5.2	63.2	7.2
	10/03/84	1520	0.3	26.1	921	6.0	74.4	7.4
	10/03/84	1840	0.3	25.8	956	4.6	56.7	7.3
		DIEL MEAN		25.3	936	4.9	59.5	7.2
I 1903.0005	10/03/84	0540	0.3	22.1	893	5.5	63.2	7.3
	10/03/84	1000	0.3	21.8	864	6.0	68.6	7.2
	10/03/84	1530	0.3	23.1	844	5.8	68.0	7.5
	10/03/84	1845	0.3	23.3	839	5.9	69.4	7.5
		DIEL MEAN		22.6	862	5.8	67.0	7.4
J 1911.0300	10/03/84	0610	0.3	23.3	892	4.0	47.1	7.1
	10/03/84	1110	0.3	23.4	899	4.2	49.5	7.2
	10/03/84	1610	0.3	24.6	915	5.2	62.7	7.4
	10/03/84	1905	0.3	24.5	913	4.6	55.4	7.5
		DIEL MEAN		23.9	903	4.4	52.6	7.3
K 1911.0250	10/03/84	0630	0.3	22.4	871	4.4	50.9	7.2
	10/03/84	1130	0.3	22.6	865	4.3	49.9	7.3
	10/03/84	1635	0.3	23.5	848	5.2	61.4	7.5
	10/03/84	1920	0.3	23.4	849	4.6	54.2	7.6
		DIEL MEAN		22.9	860	4.6	53.4	7.4

TABLE 7 CONTINUED

Map Code and Station Number	Date	Time	Depth (m)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
L 1911.0220	10/03/84	0645	0.3	21.6	845	5.0	56.9	7.3
	10/03/84	1140	0.3	22.1	838	5.0	57.5	7.4
	10/03/84	1650	0.3	23.0	840	5.3	62.0	7.6
	10/03/84	1945	0.3	23.0	849	6.2	72.5	7.6
		DIEL MEAN		22.3	844	5.4	62.4	7.5
M 1911.0213	10/03/84	0705	0.3	21.3	833	6.4	72.5	7.3
	10/03/84	1200	0.3	22.0	822	6.5	74.6	7.5
	10/03/84	1730	0.3	23.0	839	6.4	74.9	7.6
	10/03/84	1950	0.3	22.3	848	6.3	72.7	7.6
		DIEL MEAN		22.0	836	6.4	73.4	7.5
N 1911.0210	10/03/84	0530	0.3	21.0	750	6.4	72.0	8.0
	10/03/84	0910	0.3	21.0	750	6.6	74.3	7.9
	10/03/84	1400	0.3	21.0	750	7.5	84.4	7.9
	10/03/84	1730	0.3	21.0	700	6.8	76.5	7.9
		DIEL MEAN		21.0	734	6.8	76.0	7.9
O 1911.0200	10/03/84	0610	0.3	21.0	825	6.8	76.5	8.0
	10/03/84	0940	0.3	21.0	825	6.7	75.4	7.8
	10/03/84	1430	0.3	21.0	850	6.6	74.3	7.8
	10/03/84	1755	0.3	21.0	850	5.9	66.4	7.9
		DIEL MEAN		21.0	837	6.5	72.7	7.9
P 1901.0145	10/03/84	0640	0.3	20.0	800	7.1	78.3	8.0
	10/03/84	1000	0.3	21.0	800	7.8	87.8	8.1
	10/03/84	1450	0.3	21.0	800	9.1	102.4	8.1
	10/03/84	1810	0.3	21.0	800	8.3	93.4	8.2
		DIEL MEAN		20.7	800	8.0	89.0	8.1

TABLE 7 CONTINUED

Map Code and Station Number	Date	Time	Depth (m)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
Q 1902.0050	10/03/84	0655	0.3	20.0	1600	6.8	75.0	8.2
	10/03/84	1010	0.3	19.0	1600	7.7	83.3	8.2
	10/03/84	1505	0.3	21.0	1650	10.6	119.3	8.4
	10/03/84	1825	0.3	21.0	1650	9.8	110.3	8.3
		DIEL MEAN		20.3	1625	8.6	95.7	8.3
R 1901.0130	10/03/84	0720	0.3	21.0	950	6.9	77.7	8.2
	10/03/84	1040	0.3	20.0	950	8.1	89.4	8.2
	10/03/84	1530	0.3	21.0	950	8.4	94.5	8.0
	10/03/84	1850	0.3	21.0	925	8.3	93.4	8.1
		DIEL MEAN		20.8	942	7.8	87.7	8.1

TABLE 7 CONTINUED

Map Code and Station Number	Date	Time	Depth (m)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
A 1911.0900	01/24/85	0757	0.3	5.5	788	12.2	96.9	8.1
	01/24/85	1116	0.3	7.1	806	12.8	105.8	8.1
	01/24/85	1558	0.3	10.2	805	14.3	127.5	8.2
	01/24/85	2120	0.3	9.5	820	12.8	112.2	8.2
		DIEL MEAN		8.1	805	12.9	109.9	8.2
B 1911.0650	01/24/85	0724	0.3	9.4	657	10.5	91.9	7.8
	01/24/85	1059	0.3	10.7	662	11.2	101.0	7.8
	01/24/85	1544	0.3	12.5	664	10.5	98.7	7.8
	01/24/85	2100	0.3	12.4	669	10.1	94.8	7.8
		DIEL MEAN		11.3	663	10.5	95.8	7.8
D 1911.0430	01/24/85	0601	0.3	8.5	858	10.1	86.4	7.7
	01/24/85	0940	0.3	8.7	860	11.0	94.6	8.0
	01/24/85	1428	0.3	13.0	846	13.8	131.3	8.0
	01/24/85	1750	0.3	12.6	852	12.4	116.9	8.1
		DIEL MEAN		10.6	854	11.6	105.4	7.9
E 1911.0400	01/24/85	0610	0.3	15.5	1038	8.6	86.4	7.6
	01/24/85	0951	0.3	17.5	1002	8.6	90.2	7.7
	01/24/85	1412	0.3	20.5	986	9.2	102.5	7.7
	01/24/85	1740	0.3	19.6	1024	8.7	95.2	7.7
		DIEL MEAN		18.0	1019	8.7	92.6	7.7
F 1910.0050	01/24/85	0657	0.3	8.6	820	11.4	97.8	8.1
	01/24/85	1025	0.3	9.8	820	10.5	92.7	8.1
	01/24/85	1518	0.3	10.9	825	11.3	102.4	8.2
	01/24/85	2033	0.3	11.4	829	10.6	97.2	8.2
		DIEL MEAN		10.2	824	11.0	97.7	8.2

TABLE 7 CONTINUED

Map Code and Station Number	Date	Time	Depth (m)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
G 1911.0375	01/24/85	0630	0.3	10.6	1027	6.5	58.5	7.7
	01/24/85	1013	0.3	14.6	1014	7.3	72.0	7.7
	01/24/85	1450	0.3	16.4	996	7.0	71.7	7.6
	01/24/85	1810	0.3	17.4	973	7.2	75.3	7.7
		DIEL MEAN		14.5	1002	7.0	68.5	7.7
H 1911.0352	01/24/85	0610	0.3	14.6	983	7.6	74.9	7.5
	01/24/85	1000	0.3	15.2	1010	6.1	60.9	7.4
	01/24/85	1450	0.3	17.4	1000	6.6	69.1	7.3
	01/24/85	1830	0.3	16.6	978	6.9	71.0	7.5
		DIEL MEAN		15.8	989	6.9	70.1	7.4
I 1903.0005	01/24/85	0625	0.3	10.7	970	9.0	81.2	7.6
	01/24/85	1030	0.3	11.9	961	8.4	77.9	7.6
	01/24/85	1500	0.3	13.9	992	7.8	75.7	7.4
	01/24/85	1835	0.3	13.6	1002	7.7	74.2	7.6
		DIEL MEAN		12.4	982	8.3	77.5	7.6
J 1911.0300	01/24/85	0710	0.3	12.9	979	6.4	60.7	7.3
	01/24/85	1115	0.3	13.9	982	6.9	67.0	7.3
	01/24/85	1620	0.3	15.5	985	6.4	64.3	7.3
	01/24/85	1900	0.3	15.3	994	5.8	58.0	7.4
		DIEL MEAN		14.3	985	6.3	61.7	7.3
K 1911.0250	01/24/85	0730	0.3	12.4	969	5.5	51.6	7.1
	01/24/85	1130	0.3	13.3	976	5.2	49.8	7.2
	01/24/85	1640	0.3	14.8	986	5.8	57.4	7.3
	01/24/85	1920	0.3	13.9	986	5.4	52.4	7.5
		DIEL MEAN		13.4	978	5.5	52.5	7.3

TABLE 7 CONTINUED

Map Code and Station Number	Date	Time	Depth (m)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
L 1911.0220	01/24/85	0745	0.3	11.8	976	4.8	44.4	7.2
	01/24/85	1150	0.3	12.5	968	4.6	43.3	7.2
	01/24/85	1655	0.3	13.7	958	5.2	50.2	7.4
	01/24/85	1930	0.3	13.5	960	4.3	41.4	7.4
		DIEL MEAN		12.8	967	4.7	44.2	7.3
M 1911.0213	01/24/85	0805	0.3	11.1	968	4.6	41.9	7.4
	01/24/85	1210	0.3	12.2	985	5.1	47.6	7.2
	01/24/85	1720	0.3	13.1	971	4.9	46.7	7.4
	01/24/85	1945	0.3	12.8	970	4.4	41.7	7.5
		DIEL MEAN		12.2	972	4.7	43.7	7.4
N 1911.0210	01/24/85	0540	0.3	11.0	660	7.9	71.8	7.9
	01/24/85	0930	0.3	10.5	690	6.6	59.3	7.8
	01/24/85	1400	0.3	12.0	700	6.4	59.5	7.6
	01/24/85	1800	0.3	12.0	700	6.5	60.4	7.5
		DIEL MEAN		11.4	685	7.0	63.7	7.7
O 1911.0200	01/24/85	0622	0.3	9.0	650	7.8	67.6	7.9
	01/24/85	1000	0.3	10.0	690	6.7	59.5	7.7
	01/24/85	1420	0.3	12.0	700	6.3	58.6	7.6
	01/24/85	1825	0.3	11.0	700	6.5	59.1	7.7
		DIEL MEAN		10.4	682	6.9	61.8	7.7
P 1901.0145	01/24/85	0635	0.3	9.0	650	11.2	97.0	8.0
	01/24/85	1015	0.3	10.0	680	10.0	88.7	7.8
	01/24/85	1435	0.3	11.0	700	10.2	92.7	7.7
	01/24/85	1841	0.3	10.5	700	11.2	100.6	7.9
		DIEL MEAN		10.0	680	10.8	96.1	7.9

TABLE 7 CONTINUED

Map Code and Station Number	Date	Time	Depth (m)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
Q 1902.0050	01/24/85	0650	0.3	6.0	460	11.9	95.7	8.2
	01/24/85	1030	0.3	7.0	480	11.8	97.3	8.2
	01/24/85	1500	0.3	9.0	500	12.4	107.4	8.1
	01/24/85	1856	0.3	9.0	500	12.1	104.8	8.2
		DIEL MEAN		7.7	484	12.0	101.1	8.2
R 1901.0130	01/24/85	0700	0.3	9.0	620	10.7	92.7	8.0
	01/24/85	1054	0.3	9.5	650	10.2	89.4	8.0
	01/24/85	1515	0.3	11.0	700	10.2	92.7	7.9
	01/24/85	1922	0.3	10.0	700	10.2	90.5	8.0
		DIEL MEAN		9.8	666	10.4	91.4	8.0

TABLE 7 CONTINUED

Map Code and Station Number	Date	Time	Depth (m)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
A 1911.0900	05/16/85	0730	0.3	23.1	436	6.2	72.7	7.2
	05/16/85	1157	0.3	24.6	441	6.4	77.2	7.6
	05/16/85	1550	0.3	26.0	466	9.5	117.5	7.9
	05/16/85	1953	0.3	26.0	475	8.8	108.9	8.2
		DIEL MEAN		24.8	455	7.6	92.7	7.7
B 1911.0650	05/16/85	0714	0.3	24.3	527	8.4	100.7	7.2
	05/16/85	1140	0.3	25.0	532	8.1	98.4	7.6
	05/16/85	1530	0.3	26.5	556	10.6	132.3	7.7
	05/16/85	1940	0.3	26.3	564	14.0	174.2	8.3
		DIEL MEAN		25.4	545	10.6	129.7	7.7
D 1911.0430	05/16/85	0555	0.3	24.6	691	6.3	76.0	7.6
	05/16/85	1025	0.3	25.7	703	8.6	105.8	7.6
	05/16/85	1424	0.3	29.4	692	11.7	153.8	7.8
	05/16/85	1820	0.3	29.3	740	11.9	156.1	7.9
		DIEL MEAN		27.1	709	9.4	120.0	7.7
1 1900.9006	05/16/85	0525	0.3	27.0	1068	7.8	98.3	7.8
	05/16/85	1000	0.3	27.4	1025	8.1	102.8	7.1
	05/16/85	1402	0.3	28.6	984	8.0	103.7	7.4
	05/16/85	1800	0.3	28.3	1058	10.4	134.1	8.0
		DIEL MEAN		27.8	1043	8.7	111.5	7.7
E 1911.0400	05/16/85	0545	0.3	26.3	954	5.3	65.9	7.6
	05/16/85	1012	0.3	27.1	952	6.1	77.0	7.3
	05/16/85	1415	0.3	29.8	950	7.2	95.3	7.5
	05/16/85	1814	0.3	28.3	1029	8.2	105.7	7.9
		DIEL MEAN		27.7	977	6.7	85.7	7.6

TABLE 7 CONTINUED

Map Code and Station Number	Date	Time	Depth (m)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
F 1910.0050	05/16/85	0647	0.3	23.4	664	8.8	103.7	7.5
	05/16/85	1105	0.3	23.9	667	8.5	101.2	7.8
	05/16/85	1505	0.3	25.3	663	10.1	123.4	7.9
	05/16/85	1915	0.3	25.4	696	11.5	140.7	8.3
		DIEL MEAN		24.5	675	9.9	118.7	7.9
G 1911.0375	05/16/85	0632	0.3	25.7	949	3.1	38.1	7.4
	05/16/85	1052	0.3	25.9	935	2.9	35.8	7.3
	05/16/85	1453	0.3	27.7	936	3.8	48.5	7.4
	05/16/85	1855	0.3	28.5	971	5.4	69.9	7.9
		DIEL MEAN		27.0	952	3.9	49.8	7.5
2 1900.9007	05/16/85	0618	0.3	26.0	1131	7.5	92.8	7.4
	05/16/85	1042	0.3	26.4	1069	7.8	97.2	7.3
	05/16/85	1442	0.3	27.3	1050	7.8	98.8	7.3
	05/16/85	1840	0.3	26.9	1357	10.2	128.3	7.8
		DIEL MEAN		26.6	1180	8.5	106.1	7.5
H 1911.0352	05/16/85	0725	0.3	26.1	935	3.8	47.1	7.5
	05/16/85	1150	0.3	26.9	952	3.9	49.0	7.4
	05/16/85	1545	0.3	28.2	941	3.8	48.9	7.2
	05/16/85	1950	0.3	27.7	950	3.3	42.1	7.1
		DIEL MEAN		27.1	944	3.7	46.1	7.3
I 1903.0005	05/16/85	0735	0.3	24.6	966	4.7	56.7	7.5
	05/16/85	1200	0.3	25.7	960	5.2	64.0	7.5
	05/16/85	1600	0.3	26.9	950	5.0	62.9	7.2
	05/16/85	1955	0.3	26.8	978	4.4	55.2	7.1
		DIEL MEAN		25.9	966	4.7	58.5	7.3

TABLE 7 CONTINUED

Map Code and Station Number	Date	Time	Depth (m)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
J 1911.0300	05/16/85	0645	0.3	25.4	941	3.1	37.9	7.3
	05/16/85	1110	0.3	26.2	956	3.1	38.5	7.3
	05/16/85	1515	0.3	27.7	941	3.4	43.4	7.3
	05/16/85	1915	0.3	28.0	955	3.4	43.6	7.2
		DIEL MEAN		26.8	948	3.2	40.8	7.3
K 1911.0250	05/16/85	0620	0.3	25.7	929	2.2	27.1	6.8
	05/16/85	1050	0.3	26.3	926	2.3	28.6	7.1
	05/16/85	1455	0.3	27.3	930	2.5	31.7	7.3
	05/16/85	1850	0.3	27.2	916	2.6	32.9	7.2
		DIEL MEAN		26.6	924	2.4	30.0	7.1
L 1911.0220	05/16/85	0550	0.3	25.8	979	2.2	27.1	7.2
	05/16/85	1020	0.3	26.1	975	2.3	28.5	7.0
	05/16/85	1430	0.3	27.1	960	2.5	31.6	7.2
	05/16/85	1825	0.3	27.3	929	2.9	36.7	7.3
		DIEL MEAN		26.6	959	2.5	31.2	7.2
M 1911.0213	05/16/85	0805	0.3	25.0	910	2.6	31.6	7.7
	05/16/85	1240	0.3	26.0	940	3.3	40.8	7.7
	05/16/85	1630	0.3	26.0	990	3.6	44.5	7.6
	05/16/85	2005	0.3	25.0	990	3.1	37.7	7.8
		DIEL MEAN		25.3	954	3.0	37.2	7.7
N 1911.0210	05/16/85	0530	0.3	25.0	925	3.6	43.7	7.8
	05/16/85	1010	0.3	25.0	910	2.6	31.6	7.7
	05/16/85	1400	0.3	26.0	925	3.5	43.3	8.3
	05/16/85	1800	0.3	26.0	915	4.0	49.5	7.9
		DIEL MEAN		25.5	919	3.5	43.4	7.9

TABLE 7 CONTINUED

Map Code and Station Number	Date	Time	Depth (m)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
O 1911.0200	05/16/85	0600	0.3	25.0	1000	2.8	34.0	7.7
	05/16/85	1035	0.3	26.0	1000	2.4	29.7	7.6
	05/16/85	1425	0.3	26.0	1000	3.3	40.8	7.7
	05/16/85	1820	0.3	26.0	980	4.3	53.2	7.8
		DIEL MEAN		25.7	994	3.3	40.6	7.7
P 1901.0145	05/16/85	0620	0.3	25.0	1000	5.0	60.7	7.8
	05/16/85	1055	0.3	25.0	1010	5.2	63.2	7.8
	05/16/85	1440	0.3	26.0	1010	6.6	81.7	7.6
	05/16/85	1835	0.3	26.0	1000	6.2	76.7	7.9
		DIEL MEAN		25.5	1003	5.7	69.7	7.8
Q 1902.0050	05/16/85	0635	0.3	24.0	1315	6.4	76.3	8.2
	05/16/85	1125	0.3	25.0	1350	7.1	86.2	8.2
	05/16/85	1505	0.3	27.0	900	9.0	113.4	7.6
	05/16/85	1900	0.3	26.0	1390	8.6	106.4	8.4
		DIEL MEAN		25.3	1280	7.6	93.6	8.2
R 1901.0130	05/16/85	0705	0.3	25.0	1100	6.9	83.8	8.1
	05/16/85	1145	0.3	26.0	1130	7.9	97.7	8.2
	05/16/85	1535	0.3	27.0	1160	9.7	122.2	7.9
	05/16/85	1915	0.3	27.0	1150	8.9	112.1	8.5
		DIEL MEAN		26.1	1131	8.2	101.4	8.2

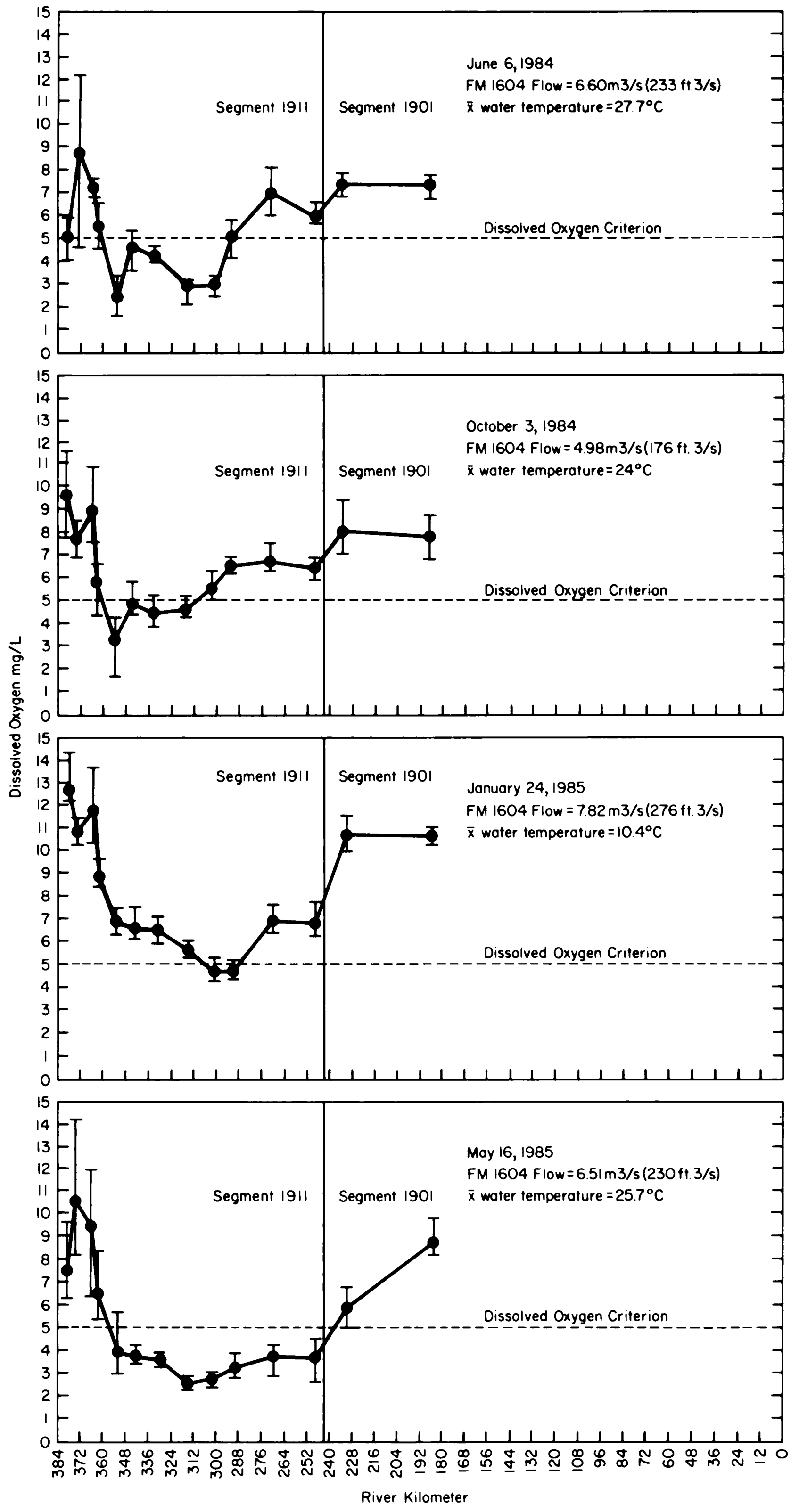

Figure 7

Mean and Range of Dissolved Oxygen Levels from the San Antonio River During Four Intensive Surveys by River Kilometer

TABLE 8

Effluent Quality Data from Three City of San Antonio Wastewater Treatment Plants Prior to the June 6, 1984 Intensive Survey

Facility	Date	Flow MGD	TSS mg/L	BOD_5 mg/L	$CBOD_5$ mg/L	NH_3-N mg/L
Rilling Road WWTP	05/23/84	79.70	26.0	20.0	13.0	9.90
	05/24/84	78.00	50.0	23.0	18.0	11.20
	05/25/84	79.60	38.0	20.0	12.0	10.40
	05/26/84	78.40	38.0	14.0	10.0	
	05/27/84	72.00				
	05/28/84	85.00	33.0	23.0	11.0	11.20
	05/29/84	82.60	30.0	17.0	12.0	9.80
	05/30/84	77.50	17.0	11.0	8.0	9.60
	05/31/84	74.50	15.0	9.0	6.0	9.40
	06/01/84	77.20	19.0	20.0	10.0	9.80
	06/02/84	73.80	15.0	8.0	5.0	10.10
	06/03/84	67.80	2.0	8.0	6.0	8.40
	06/04/84	76.30	10.0	10.0	7.0	9.80
	06/05/84	80.80	14.0	13.0	9.0	11.80
	06/06/84	79.10	28.0	17.0	10.0	10.40
	AVERAGE	77.49	23.9	15.2	9.8	10.14
Salado Creek WWTP	05/23/84	21.40	4.0	6.0	5.0	5.10
	05/24/84	21.20	8.0	7.0	5.0	7.10
	05/25/84	21.60	12.0	4.0	3.0	5.90
	05/26/84	21.10	24.0	8.0	6.0	5.90
	05/27/84	20.30				
	05/28/84	22.30	9.0	4.0	4.0	6.10
	05/29/84	21.70	23.0	8.0	8.0	5.10
	05/30/84	21.00	17.0	5.0	6.0	3.50
	05/31/84	20.60	36.0	10.0	10.0	4.10
	06/01/84	22.00	13.0	4.0	3.0	3.60
	06/02/84	21.50	23.0	6.0	6.0	5.10
	06/03/84	20.60	12.0	5.0		4.60
	06/04/84	20.60	11.0	5.0	5.0	5.10
	06/05/84	20.50	12.0	8.0	7.0	5.80
	06/06/84	21.60	18.0	9.0	9.0	5.10
	AVERAGE	21.2	15.9	6.4	5.9	5.15

TABLE 8 CONTINUED

Facility	Date	Flow MGD	TSS mg/L	BOD_5 mg/L	$CBOD_5$ mg/L	NH_3-N mg/L
Leon Creek WWTP	05/23/84	22.70	5.0	10.0	9.0	6.30
	05/24/84	23.20	8.0	13.0	11.0	6.30
	05/25/84	22.80	5.0	8.0	8.0	6.50
	05/26/84	22.20	11.0	18.0	12.0	6.70
	05/27/84	22.10				
	05/28/84	22.00	13.0	11.0	10.0	5.60
	05/29/84	23.30	9.0	24.0	14.0	5.80
	05/30/84	22.70	9.0	16.0	15.0	4.20
	05/31/84	23.30	10.0	14.0	16.0	4.10
	06/01/84	22.80	8.0	9.0	9.0	5.10
	06/02/84	21.80	8.0	7.0	6.0	4.70
	06/03/84	21.40	1.0	9.0	9.0	4.60
	06/04/84	22.10	6.0	21.0	8.0	4.70
	06/05/84	21.90	10.0	12.0	11.0	5.90
	06/06/84	22.90	6.0	13.0	9.0	4.70
	AVERAGE	22.47	7.3	12.3	9.8	5.01

TABLE 9

Effluent Quality Data from Three City of San Antonio Wastewater Treatment Plants Prior to the October 3, 1984 Intensive Survey

Facility	Date	Flow MGD	TSS mg/L	BOD_5 mg/L	$CBOD_5$ mg/L	NH_3-N mg/L
Rilling Road WWTP	09/19/84	74.00	6.0	10.0	6.0	9.40
	09/20/84	74.50	7.0	14.0	10.0	8.70
	09/21/84	75.30	7.0	14.0	6.0	7.10
	09/22/84	71.00	7.0	8.0	5.0	9.10
	09/23/84	74.00	7.0	16.0	6.0	6.90
	09/24/84	74.90	2.0	11.0	5.0	6.10
	09/25/84	76.50	5.0	11.0	5.0	8.40
	09/26/84	75.30	6.0	10.0	7.0	8.40
	09/27/84	75.40	12.0	24.0	5.0	9.70
	09/28/84	75.10	8.0	14.0	6.0	8.10
	09/29/84	70.10	7.0	22.0	4.0	8.10
	09/30/84	67.50	2.0	6.0	6.0	9.90
	10/01/84	71.10	4.0	8.0	6.0	8.40
	10/02/84	77.10	8.0	8.0	5.0	10.40
	10/03/84	80.50	16.0	6.0	7.0	10.20
	AVERAGE	74.15	6.9	12.1	5.9	8.59
Salado Creek WWTP	09/19/84	21.60	16.0	8.0	6.0	2.80
	09/20/84	22.10	44.0	78.0	20.0	2.40
	09/21/84	21.40	11.0	6.0	5.0	2.40
	09/22/84	21.30	5.0	4.0	4.0	2.70
	09/23/84	20.90	8.0	11.0	5.0	2.80
	09/24/84	20.60	8.0	24.0	5.0	4.30
	09/25/84	20.40	8.0	12.0	5.0	8.40
	09/26/84	20.50	6.0	22.0	5.0	3.70
	09/27/84	19.90	10.0	9.0	5.0	4.40
	09/28/84	20.00	12.0	6.0	4.0	3.00
	09/29/84	19.80	6.0	15.0	3.0	2.40
	09/30/84	19.50	4.0	5.0	5.0	3.10
	10/01/84	19.90	8.0	4.0	4.0	4.20
	10/02/84	20.00	21.0	8.0	7.0	3.90
	10/03/84	19.20	26.0	8.0	7.0	3.60
	AVERAGE	20.47	12.87	19.5	6.0	3.60

TABLE 9 CONTINUED

Facility	Date	Flow MGD	TSS mg/L	BOD_5 mg/L	$CBOD_5$ mg/L	NH_3-N mg/L
Leon Creek WWTP	09/19/84	23.10	22.0	15.0	11.0	5.90
	09/20/84	22.20	18.0	38.0	16.0	4.60
	09/21/84	22.70	11.0	11.0	9.0	4.20
	09/22/84	23.20	17.0	11.0	10.0	5.80
	09/23/84	21.60	15.0	17.0	9.0	7.10
	09/24/84	24.00	5.0	11.0	9.0	2.30
	09/25/84	24.30	13.0	10.0	11.0	6.50
	09/26/84	23.00	11.0	37.0	13.0	7.10
	09/27/84	21.30	18.0	17.0	13.0	6.70
	09/28/84	26.50	18.0	23.0	11.0	5.40
	09/29/84	22.40	30.0	37.0	13.0	4.10
	09/30/84	22.80	18.0	19.0	17.0	7.10
	10/01/84	25.20	11.0	13.0	12.0	7.10
	10/02/84	20.60	21.0	10.0	8.0	8.80
	10/03/84	22.60	28.0	11.0	10.0	6.10
	AVERAGE	23.03	17.1	18.7	10.5	5.92

TABLE 10

Effluent Quality Data from Three City of San Antonio Wastewater Treatment Plants Prior to the January 24, 1985 Intensive Survey

Facility	Date	Flow MGD	TSS mg/L	BOD_5 mg/L	$CBOD_5$ mg/L	NH_3-N mg/L
Rilling Road WWTP	01/10/85	75.20	41.0	30.0	22.0	18.30
	01/11/85	73.40	40.0	58.0	21.0	17.20
	01/12/85	80.30				
	01/13/85	92.50				
	01/14/85	93.90	56.0	45.0	25.0	8.70
	01/15/85	96.20	54.0	69.0	35.0	8.40
	01/16/85	89.40	80.0	74.0	43.0	13.70
	01/17/85	98.40	99.0	72.0	36.0	10.40
	01/18/85	85.20	60.0	40.0	26.0	11.50
	01/19/85	82.90	57.0	41.0	20.0	11.50
	01/20/85	69.00	56.0	38.0	24.0	15.40
	01/21/85	83.30	114.0	74.0	28.0	19.20
	01/22/85	82.40	99.0	99.0	36.0	22.00
	01/23/85	77.90	67.0	62.0	26.0	15.40
	01/24/85	77.70	64.0	65.0	27.0	20.80
	AVERAGE	83.85	68.2	59.0	28.4	14.80
Salado Creek WWTP	01/10/85	24.00	77.0	27.0	20.0	9.10
	01/11/85	23.30	19.0	8.0	6.0	7.10
	01/12/85	24.00				
	01/13/85	27.50				
	01/14/85	31.00	131.0	90.0	36.0	11.30
	01/15/85	36.50	115.0	89.0	32.0	8.40
	01/16/85	39.60	113.0	62.0	43.0	12.20
	01/17/85	33.10	33.0	40.0	23.0	13.70
	01/18/85	28.10	40.0	40.0	18.0	10.00
	01/19/85	27.70	90.0	79.0	37.0	14.90
	01/20/85	23.20	91.0	61.0	30.0	19.80
	01/21/85	26.00	65.0	115.0	26.0	18.80
	01/22/85	25.90	212.0	110.0	78.0	26.00
	01/23/85	25.40	146.0	119.0	48.0	11.40
	01/24/85	25.50	147.0	201.0	66.0	26.00
	AVERAGE	28.05	98.4	80.1	34.9	14.52

TABLE 10 CONTINUED

Facility	Date	Flow MGD	TSS mg/L	BOD_5 mg/L	$CBOD_5$ mg/L	NH_3-N mg/L
Leon Creek WWTP	01/10/85	27.20	22.0	23.0	19.0	13.00
	01/11/85	24.80	18.0	20.0	16.0	14.90
	01/12/85	24.50				
	01/13/85	28.00				
	01/14/85	35.90	92.0	87.0	29.0	14.10
	01/15/85	32.40	214.0	128.0	50.0	14.10
	01/16/85	37.60	44.0	23.0	20.0	15.40
	01/17/85	31.40	31.0	40.0	24.0	14.50
	01/18/85	29.40	28.0	16.0		14.10
	01/19/85	28.90	22.0	12.0	12.0	15.80
	01/20/85	28.00	34.0	22.0	20.0	19.20
	01/21/85	27.80	40.0	18.0	8.0	24.60
	01/22/85	25.80	54.0	40.0	16.0	21.40
	01/23/85	26.80	48.0	30.0	14.0	24.40
	01/24/85	26.60	79.0	42.0	24.0	27.40
	AVERAGE	29.00	55.8	38.5	19.4	17.92

TABLE 11

Effluent Quality Data from Three City of San Antonio Wastewater Treatment Plants Prior to the May 16, 1985 Intensive Survey

Facility	Date	Flow MGD	TSS mg/L	BOD_5 mg/L	$CBOD_5$ mg/L	NH_3-N mg/L
Rilling Road WWTP	05/02/85	75.10	15.0	11.0	11.0	17.20
	05/03/85	75.60	18.0	12.0	10.0	14.90
	05/04/85	71.30	17.0		10.0	17.70
	05/05/85	64.60	12.0	14.0	7.0	14.50
	05/06/85	74.40	12.0	15.0	9.0	13.70
	05/07/85	74.10	20.0	12.0	9.0	16.70
	05/08/85	85.40	19.0	11.0	9.0	10.00
	05/09/85	74.00	23.0	31.0	14.0	14.50
	05/10/85	73.80	22.0	41.0	16.0	16.30
	05/11/85	71.90	22.0	22.0	13.0	16.30
	05/12/85	67.10	20.0	15.0	10.0	16.70
	05/13/85	70.10	18.0	20.0	11.0	17.20
	05/14/85	76.60	22.0	15.0	11.0	17.20
	05/15/85	73.40	26.0	22.0	18.0	14.90
	05/16/85	73.30	21.0	24.0	15.0	15.40
	AVERAGE	73.38	19.1	18.9	11.5	15.55
Salado Creek WWTP	05/02/85	25.00	41.0	80.0	76.0	16.20
	05/03/85	25.40	54.0	76.0	66.0	18.80
	05/04/85	25.10	40.0	55.0	46.0	19.40
	05/05/85	26.20	33.0	49.0	31.0	31.60
	05/06/85	23.40	28.0	40.0	37.0	17.40
	05/07/85	23.60	30.0	38.0		20.00
	05/08/85	23.00	39.0	30.0		16.80
	05/09/85	27.80	35.0	40.0	37.0	14.20
	05/10/85	24.20	37.0	47.0	28.0	15.40
	05/11/85	26.60	32.0			14.50
	05/12/85	24.60	30.0	30.0	21.0	15.80
	05/13/85	27.10	30.0	28.0	23.0	17.70
	05/14/85	25.00	33.0	28.0	26.0	15.80
	05/15/85	25.40	47.0	28.0	26.0	16.70
	05/16/85	26.20	45.0	27.0	24.0	17.70
	AVERAGE	25.24	36.9	42.6	36.8	17.92

TABLE 11 CONTINUED

Facility	Date	Flow MGD	TSS mg/L	BOD_5 mg/L	$CBOD_5$ mg/L	NH_3-N mg/L
Leon Creek WWTP	05/02/85	24.60	7.0	13.0	11.0	15.40
	05/03/85	24.60	11.0	11.0	9.0	13.40
	05/04/85	23.00	6.0	12.0	8.0	14.10
	05/05/85	23.30	5.0	20.0	17.0	11.80
	05/06/85	23.70	7.0	13.0	13.0	12.60
	05/07/85	23.70	11.0	15.0	14.0	13.40
	05/08/85	24.50	7.0	10.0	8.0	16.80
	05/09/85	24.10	8.0	20.0	12.0	13.40
	05/10/85	24.10	8.0	20.0	7.0	13.70
	05/11/85	24.90	8.0			
	05/12/85	23.40	8.0	12.0	11.0	13.70
	05/13/85	27.30	8.0	9.0	8.0	15.80
	05/14/85	25.30	8.0	9.0	8.0	15.80
	05/15/85	24.90	8.0	14.0	13.0	13.70
	05/16/85	24.60		14.0	13.0	
	AVERAGE	24.40	7.3	13.7	10.9	13.96

TABLE 12

Laboratory Water Analyses

Map Code and Station Number	Date	Time	Depth m	5day CBOD mg/L	Filt. 5day CBOD mg/L	20day CBOD mg/L	Filt. 20day CBOD mg/L	Filt. TOC mg/L	TKN mg/L	NH_3-N mg/L	NO_2-N mg/L	NO_3-N mg/L	Ortho P mg/L	Total P mg/L	Chl. a µg/L	Pheo. a µg/L	Cl^- mg/L	$SO_4^=$ mg/L	TSS mg/L	VSS mg/L	TDS mg/L	Total Alk. mg/L	Cond. µmhos/cm	pH
A 1911.0900	06/06/84	COMP	0.3	6.0	-----	10.0	-----	9	0.80	<0.02	0.02	0.33	0.03	0.14	5	2	25	55	41	13	278	130	477	8.0
B 1911.0650	06/06/84	COMP	0.3	3.0	-----	5.0	-----	3	0.60	<0.02	0.02	1.07	0.01	0.08	12	4	23	30	27	5	326	211	576	8.4
C 1911.0450	06/06/84	COMP	0.3	3.5	-----	6.5	-----	5	0.70	0.10	0.03	0.39	0.01	0.09	15	5	41	50	38	9	348	163	596	8.2
C 1911.0450	06/06/84	0645	0.3	3.5	-----	7.0	-----	5	0.80	0.10	0.03	0.31	0.01	0.10	13	6	58	53	48	9	330	157	648	8.1
C 1911.0450	06/06/84	1145	0.3	2.5	-----	4.0	-----	5	0.90	0.19	0.03	0.36	0.03	0.10	9	2	43	49	51	10	314	167	604	8.3
G 1911.0375	06/06/84	COMP	0.3	5.0	-----	11.0	-----	8	9.20	5.81	0.88	0.73	4.31	4.62	5	2	88	58	<10	<10	528	240	944	8.0
H 1911.0352	06/06/84	COMP	0.3	3.0	-----	9.0	-----	8	8.50	4.19	1.39	1.57	4.37	6.85	2	<2	95	58	<10	<10	528	247	976	8.0
H 1911.0352	06/06/84	0500	0.3	2.5	-----	8.0	-----	7	7.30	3.26	1.54	2.11	3.65	4.12	<2	5	93	58	13	6	544	243	976	8.1
H 1911.0352	06/06/84	1020	0.3	2.5	-----	7.0	-----	7	6.90	3.41	1.32	1.47	3.43	3.76	3	<2	93	56	14	4	530	244	976	8.1
H 1911.0352	06/06/84	1450	0.3	2.5	-----	8.5	-----	8	8.00	4.52	1.10	1.67	4.39	4.94	2	4	96	59	24	6	526	252	1032	8.1
H 1911.0352	06/06/84	1830	0.3	3.5	-----	11.0	-----	8	9.20	5.48	0.82	1.88	4.93	5.65	<2	5	95	58	40	22	546	252	1000	8.0
I 1903.0005	06/06/84	COMP	0.3	2.0	-----	4.5	-----	5	1.20	0.50	0.68	4.82	2.39	2.57	5	<2	68	81	56	10	524	222	936	8.1
J 1911.0300	06/06/84	COMP	0.3	2.5	-----	7.0	-----	7	6.30	2.38	0.53	3.86	3.77	4.14	4	<2	84	64	84	11	550	233	966	8.0
K 1911.0250	06/06/84	COMP	0.3	2.0	-----	5.0	-----	5	1.30	0.70	0.95	4.95	2.86	2.93	2	12	76	65	51	9	500	225	930	8.1
L 1911.0220	06/06/84	COMP	0.3	1.5	-----	4.0	-----	6	1.30	0.23	0.55	5.41	2.06	2.21	15	<2	78	65	53	10	532	219	924	8.0
M 1911.0213	06/06/84	COMP	0.3	1.5	-----	4.0	-----	5	1.30	0.05	0.28	5.12	2.00	2.03	14	3	84	70	<10	<10	546	225	966	8.2
N 1911.0210	06/06/84	COMP	0.3	1.5	-----	4.5	-----	5	1.40	0.02	0.10	4.69	2.56	2.64	10	<2	91	73	33	16	562	231	996	8.2
O 1911.0200	06/06/84	COMP	0.3	1.0	-----	3.0	-----	6	1.30	0.13	0.05	4.60	2.39	2.54	22	<2	101	83	17	8	594	228	1072	8.3
P 1901.0145	06/06/84	COMP	0.3	1.5	-----	2.0	-----	6	1.10	0.03	0.05	4.89	1.98	2.03	3	<2	98	83	15	2	576	217	1024	8.2
Q 1902.0050	06/06/84	COMP	0.3	1.0	-----	2.0	-----	5	0.80	0.03	<0.01	0.10	0.21	0.25	7	<2	221	256	<10	<10	1022	238	1914	8.4
R 1901.0130	06/06/84	COMP	0.3	1.0	-----	2.5	-----	6	2.50	<0.02	0.02	3.58	1.33	1.43	4	<2	122	105	40	7	630	200	1128	8.3

TABLE 12 CONTINUED

	Map Code and Station Number	Date	Time	Depth m	5day CBOD mg/L	Filt. 5day CBOD mg/L	20day CBOD mg/L	Filt. 20day CBOD mg/L	Filt. TOC mg/L	TKN mg/L	NH_3-N mg/L	NO_2-N mg/L	NO_3-N mg/L	Ortho P mg/L	Total P mg/L	Chl. a µg/L	Pheo. a µg/L	Cl^- mg/L	$SO_4^=$ mg/L	TSS mg/L	VSS mg/L	TDS mg/L	Total Alk. mg/L	Cond. µmhos/cm	pH
A	1911.0900	10/03/84	COMP	0.3	5.5	4.0	11.0	10.0	17	0.90	0.04	0.09	0.38	0.02	0.08	6	5	35	70	<10	<10	320	122	556	8.0
B	1911.0650	10/03/84	COMP	0.3	2.0	1.5	5.0	3.5	6	0.60	0.15	0.08	1.05	0.07	0.12	9	<2	24	27	10	2	276	189	524	7.9
D	1911.0430	10/03/84	COMP	0.3	1.0	0.5	4.0	3.0	6	0.60	0.09	0.03	0.74	0.02	0.05	4	<2	34	45	16	7	348	184	600	8.1
E	1911.0400	10/03/84	COMP	0.3	1.5	1.0	6.5	4.5	8	7.00	5.53	3.19	1.22	2.89	3.06	3	<2	94	50	10	7	508	261	1015	8.0
F	1910.0050	10/03/84	COMP	0.3	1.0	1.0	2.5	2.5	5	0.40	<0.02	<0.01	0.10	0.04	0.05	2	<2	80	76	17	4	500	233	930	8.2
G	1911.0375	10/03/84	COMP	0.3	2.0	1.5	6.5	6.0	7	6.10	4.97	1.65	1.92	4.11	4.27	2	<2	95	52	14	3	528	261	1015	7.9
H	1911.0352	10/03/84	COMP	0.3	3.0	3.0	6.0	6.0	6	3.30	2.10	1.33	5.05	2.99	3.08	3	<2	95	57	<10	<10	544	246	1015	7.9
I	1903.0005	10/03/84	COMP	0.3	2.5	1.5	5.0	5.0	4	2.40	1.34	0.91	5.50	2.96	3.14	2	<2	70	85	51	4	506	215	954	8.0
J	1911.0300	10/03/84	COMP	0.3	3.0	2.0	5.5	5.0	6	2.83	1.82	0.65	6.03	3.61	3.70	2	<2	86	63	19	1	524	235	987	7.8
K	1911.0250	10/03/84	COMP	0.3	1.5	1.0	4.0	3.5	5	1.10	0.05	0.40	7.69	2.29	2.47	<2	<2	80	64	23	2	528	214	930	7.9
L	1911.0220	10/03/84	COMP	0.3	1.5	1.0	3.5	2.5	5	0.90	0.03	0.12	7.00	1.58	1.66	3	<2	81	68	14	3	492	205	924	7.9
M	1911.0213	10/03/84	COMP	0.3	2.0	2.0	5.0	3.5	6	1.10	0.05	0.12	6.37	1.31	1.36	2	<2	80	66	36	2	498	204	912	7.9
N	1911.0210	10/03/84	COMP	0.3	1.0	1.0	3.5	2.5	5	0.90	0.07	0.09	5.27	1.21	1.33	<2	<2	77	73	34	3	474	204	906	8.1
O	1911.0200	10/03/84	COMP	0.3	1.5	1.0	4.0	3.5	5	2.20	1.05	0.35	5.38	2.33	2.51	<2	<2	97	67	42	4	538	237	1043	8.2
P	1901.0145	10/03/84	COMP	0.3	1.0	1.0	3.5	3.0	5	1.00	0.07	0.09	6.02	2.39	2.57	<2	6	90	67	38	10	524	231	1008	8.1
Q	1902.0050	10/03/84	COMP	0.3	1.5	<0.5	3.0	2.5	4	0.50	<0.02	<0.01	<0.01	0.11	0.13	<2	<2	254	328	<10	<10	1140	207	2160	8.4
R	1901.0130	10/03/84	COMP	0.3	1.5	0.5	3.5	1.5	4	1.10	<0.02	0.02	5.25	2.71	2.96	3	<2	119	93	111	17	612	246	1184	8.3

TABLE 12 CONTINUED

	Map Code and Station Number	Date	Time	Depth m	5day CBOD mg/L	Filt. 5day CBOD mg/L	20day CBOD mg/L	Filt. 20day CBOD mg/L	Filt. TOC mg/L	TKN mg/L	NH_3-N mg/L	NO_2-N mg/L	NO_3-N mg/L	Ortho P mg/L	Total P mg/L	Chl. a µg/L	Pheo. a µg/L	Cl^- mg/L	$SO_4^=$ mg/L	TSS mg/L	VSS mg/L	TDS mg/L	Total Alk. mg/L	Cond. µmhos/cm	pH
A	1911.0900	01/24/85	COMP	0.3	2.0	2.0	3.0	3.0	3	0.50	0.04	0.01	1.31	0.03	0.04	<2	<2	70	141	<10	<10	514	222	1020	8.2
B	1911.0650	01/24/85	COMP	0.3	1.5	1.5	2.0	2.0	2	0.60	0.18	0.03	2.18	0.08	0.09	<2	2	48	54	10	3	418	234	750	7.9
D	1911.0430	01/24/85	COMP	0.3	1.5	1.0	3.0	1.5	2	0.50	<0.02	0.03	2.64	0.04	0.07	<2	3	62	88	21	6	428	173	810	8.1
E	1911.0400	01/24/85	COMP	0.3	15.0	5.0	30.0	12.0	5	12.30	7.60	0.50	0.98	2.90	3.85	<2	<2	90	74	62	42	574	296	1080	7.9
F	1910.0050	01/24/85	COMP	0.3	1.5	1.5	2.0	2.0	2	0.50	0.10	0.02	1.33	0.02	0.04	<2	4	59	80	11	1	418	220	840	8.2
G	1911.0375	01/24/85	COMP	0.3	10.0	5.0	20.0	10.0	5	9.40	6.82	0.76	0.95	3.18	3.56	<2	<2	88	75	25	13	560	282	1024	8.0
H	1911.0352	01/24/85	COMP	0.3	18.0	5.5	35.0	13.0	7	11.70	7.54	0.73	0.74	3.41	4.38	<2	<2	95	80	36	18	594	265	1120	7.9
I	1903.0005	01/24/85	COMP	0.3	6.5	3.0	13.0	8.0	7	7.70	5.78	0.73	2.29	1.88	2.28	<2	5	91	110	40	10	622	266	1120	8.0
J	1911.0300	01/24/85	COMP	0.3	15.0	3.5	23.0	8.5	6	9.60	6.37	0.75	1.40	2.70	3.53	3	<2	97	90	32	16	608	282	1128	7.9
K	1911.0250	01/24/85	COMP	0.3	11.0	4.5	21.0	9.5	6	8.80	6.38	0.74	1.60	3.14	3.74	<2	<2	94	90	56	18	604	278	1120	7.9
L	1911.0220	01/24/85	COMP	0.3	9.5	4.0	21.0	7.0	6	7.50	5.94	0.76	1.88	2.56	3.26	<2	<2	92	91	49	15	600	272	1112	7.7
M	1911.0213	01/24/85	COMP	0.3	11.0	3.5	21.0	7.5	6	8.50	6.06	0.74	2.10	2.96	3.63	<2	<2	94	93	57	17	612	276	1120	7.9
N	1911.0210	01/24/85	COMP	0.3	6.0	1.5	12.0	6.0	7	6.30	5.27	0.65	3.20	1.87	2.31	6	2	86	94	45	9	580	266	1080	8.0
O	1911.0200	01/24/85	COMP	0.3	4.0	2.5	8.0	6.0	6	6.60	4.89	0.50	3.10	2.38	2.62	<2	2	88	98	70	16	566	262	1080	8.0
P	1901.0145	01/24/85	COMP	0.3	5.5	3.5	20.0	8.5	6	6.80	4.73	0.33	3.03	2.88	3.07	14	<2	88	99	25	7	592	266	1096	8.0
Q	1902.0050	01/24/85	COMP	0.3	1.5	1.0	3.0	2.0	6	0.80	0.06	0.02	1.30	0.35	0.37	<2	<2	76	122	19	6	484	163	894	8.2
R	1901.0130	01/24/85	COMP	0.3	3.0	2.5	10.0	9.0	6	4.60	2.70	0.17	2.98	2.09	2.32	5	2	95	103	44	17	568	236	1072	8.1

TABLE 12 CONTINUED

	Map Code and Station Number	Date	Time	Depth m	5day CBOD mg/L	Filt. 5day CBOD mg/L	20day CBOD mg/L	Filt. 20day CBOD mg/L	Filt. TOC mg/L	TKN mg/L	NH_3-N mg/L	NO_2-N mg/L	NO_3-N mg/L	Ortho P mg/L	Total P mg/L	Chl. a µg/L	Pheo. a µg/L	Cl^- mg/L	$SO_4^=$ mg/L	TSS mg/L	VSS mg/L	TDS mg/L	Total Alk. mg/L	Cond. µmhos/cm	pH
A	1911.0900	05/16/85	COMP	0.3	2.5	1.5	5.0	4.0	10	0.80	0.14	0.06	0.58	0.04	0.11	4	<2	30	48	22	2	274	113	450	8.0
B	1911.0650	05/16/85	COMP	0.3	2.0	1.0	4.0	2.0	4	0.60	0.08	0.05	1.26	0.04	0.07	9	3	25	33	5	1	314	194	550	8.1
D	1911.0430	05/16/85	COMP	0.3	1.5	1.0	3.0	2.0	5	0.70	0.10	0.06	1.23	0.02	0.08	3	<2	48	68	27	3	408	199	735	8.1
1	1900.9006	05/16/85	COMP	0.3	13.5	8.0	35.0	18.0	13	14.40	11.53	0.25	0.09	3.66	4.39	---	---	90	57	26	20	540	316	1085	7.9
E	1911.0400	05/16/85	COMP	0.3	5.5	3.0	20.0	13.0	9	10.10	8.24	0.78	0.31	2.94	3.52	2	<2	83	59	21	9	530	287	973	7.9
F	1910.0050	05/16/85	COMP	0.3	2.0	1.5	4.0	3.0	3	2.40	1.82	0.13	1.07	0.79	0.90	<2	<2	50	50	11	1	402	235	770	8.2
G	1911.0375	05/16/85	COMP	0.3	5.5	3.0	11.0	6.0	5	6.40	4.95	0.48	0.70	2.37	2.67	2	<2	67	55	13	5	484	267	906	8.0
2	1900.9007	05/16/85	COMP	0.3	21.0	12.5	60.0	35.0	15	19.30	12.37	0.02	0.01	2.66	4.20	---	---	116	65	29	21	600	329	1224	7.8
H	1911.0352	05/16/85	COMP	0.3	11.0	4.5	14.0	11.0	7	9.00	7.69	0.75	0.45	2.87	3.25	2	<2	86	64	12	4	522	279	1015	7.8
I	1903.0005	05/16/85	COMP	0.3	3.0	2.0	6.0	5.0	4	2.50	2.56	1.27	2.74	0.87	1.03	<2	<2	79	99	30	3	574	256	1056	7.9
J	1911.0300	05/16/85	COMP	0.3	5.0	3.5	10.0	8.0	6	6.60	5.86	0.92	1.39	2.46	2.66	2	<2	84	74	7	2	536	270	1022	7.9
K	1911.0250	05/16/85	COMP	0.3	2.5	2.5	6.0	6.0	5	5.30	4.31	0.88	1.56	2.45	2.48	<2	<2	85	74	9	2	514	257	1008	7.9
L	1911.0220	05/16/85	COMP	0.3	2.0	2.0	6.0	6.0	5	6.50	5.68	0.76	1.87	2.76	2.88	<2	<2	87	74	8	1	546	267	1040	7.9
M	1911.0213	05/16/85	COMP	0.3	3.0	2.5	6.0	6.0	5	5.90	5.11	0.77	2.38	2.93	3.06	7	<2	84	77	11	2	556	272	1048	7.9
N	1911.0210	05/16/85	COMP	0.3	2.0	2.0	5.0	4.0	5	4.00	3.15	0.83	3.28	1.77	1.93	8	<2	81	81	10	1	538	254	1029	7.7
O	1911.0200	05/16/85	COMP	0.3	1.5	1.5	44.0	4.0	5	2.50	2.33	0.88	3.96	2.23	2.31	17	3	94	91	8	1	594	256	1112	7.6
P	1901.0145	05/16/85	COMP	0.3	1.5	1.5	4.0	4.0	5	1.40	0.76	0.87	4.60	2.33	2.45	15	6	100	95	13	3	576	248	1128	7.7
Q	1902.0050	05/16/85	COMP	0.3	1.0	1.0	2.5	2.0	4	0.60	0.02	0.01	0.24	0.25	0.28	4	<2	159	237	12	1	848	228	1606	8.0
R	1901.0130	05/16/85	COMP	0.3	1.0	1.5	4.0	2.0	4	1.10	<0.02	0.12	4.92	2.10	2.17	82	<2	131	118	42	6	670	246	1264	8.0

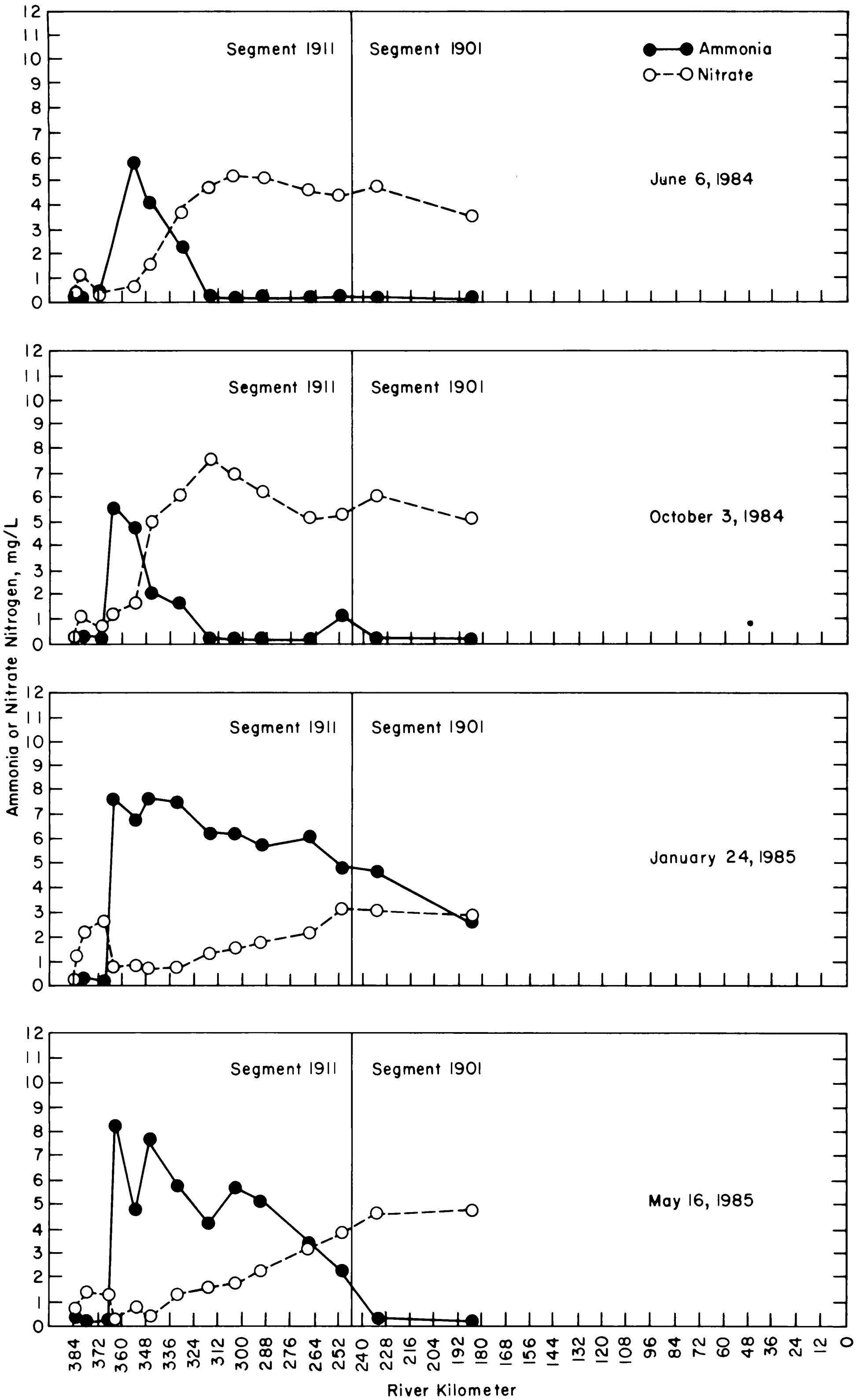

Figure 8

Ammonia and Nitrate Nitrogen Levels from the San Antonio River During Four Intensive Surveys, by River Kilometer

TABLE 13

Chronic Ammonia Nitrogen Toxicity Values

Map Code	Station Number	Date	Time	Temp. °C	pH Units	NH_3-N mg/L	Unionized NH_3-N mg/L	Chronic Unionized NH_3-N Toxicity Value mg/L
G	1911.0375	06/06/84	Composite	28.5	7.6	5.81	0.1628	0.0272
H	1911.0352	06/06/84	Composite	26.7	7.3	4.81	0.0606	0.0136
H	1911.0352	06/06/84	0500	27.6	7.2	3.26	0.0348	0.0180
H	1911.0352	06/06/84	1020	26.7	7.3	3.41	0.0429	0.0136
H	1911.0352	06/06/84	1450	28.4	7.5	3.52	0.0783	0.0216
H	1911.0352	06/06/84	1830	29.2	7.4	5.48	0.1027	0.0752
J	1911.0300	06/06/84	Composite	27.3	7.2	2.38	0.0249	0.0108
E	1911.0400	10/03/84	Composite	26.1	7.1	5.53	0.0423	0.0086
G	1911.0375	10/03/84	Composite	25.1	7.1	4.97	0.0355	0.0086
H	1911.0352	10/03/84	Composite	24.5	7.1	2.10	0.0144	0.0086
J	1911.0300	10/03/84	Composite	23.3	7.1	1.82	0.0114	0.0086
E	1911.0400	01/24/85	Composite	15.5	7.6	7.60	0.0848	0.0199
G	1911.0375	01/24/85	Composite	10.6	7.7	6.82	0.0658	0.0179
H	1911.0352	01/24/85	Composite	17.4	7.3	7.54	0.0488	0.0114
I	1903.0005	01/24/85	Composite	13.9	7.4	5.78	0.0362	0.0113
J	1911.0300	01/24/85	Composite	12.9	7.3	6.37	0.0294	0.0083
K	1911.0250	01/24/85	Composite	12.1	7.1	6.38	0.0179	0.0051
L	1911.0220	01/24/85	Composite	11.8	7.2	5.94	0.0200	0.0061
M	1911.0213	01/24/85	Composite	12.2	7.2	6.06	0.0211	0.0063
N	1911.0210	01/24/85	Composite	12.0	7.5	5.27	0.0359	0.0124
O	1911.0200	02/14/85	Composite	12.0	7.6	4.89	0.0419	0.0157
P	1901.0145	01/24/85	Composite	10.0	7.8	4.73	0.0547	0.0184
R	1901.0130	01/24/85	Composite	9.0	8.0	2.70	0.0455	0.0192
E	1911.0400	05/16/85	Composite	27.1	7.3	8.24	0.1066	0.0136
F	1910.0050	05/16/85	Composite	23.4	7.5	1.82	0.0287	0.0216
G	1911.0375	05/16/85	Composite	25.9	7.3	4.95	0.0590	0.0136
H	1911.0352	05/16/85	Composite	27.7	7.1	7.69	0.0658	0.0086
I	1903.0005	05/16/85	Composite	26.8	7.1	2.56	0.0206	0.0086
J	1911.0300	05/16/85	Composite	28.0	7.2	5.86	0.0643	0.0108
K	1911.0250	05/16/85	Composite	26.3	7.1	4.31	0.0335	0.0086
L	1911.0220	05/16/85	Composite	26.1	7.0	5.68	0.0346	0.0068
M	1911.0213	05/16/85	Composite	26.0	7.6	5.11	0.1209	0.0272
N	1911.0210	05/16/87	Composite	25.0	7.7	3.15	0.0870	0.0342
O	1911.0200	05/16/87	Composite	27.0	7.9	2.33	0.1148	0.0390

TABLE 14

Fecal Coliform Data

Station Number and Map Code		Date			
		June 6 1984	October 10 1984	January 24 1985	May 6 1985
1901.0500	A	700	900	110	7,110
1901.0650	B	10,400	3,500	320	4,030
1901.0450	C	460	-----	---	-----
1901.0430	D	---	2,500	630	3,120
1911.0400	E	---	>6,000	500	900
1910.0050	F	---	600	1,300	7,000
1911.0375	G	5,000	3,100	2,000	1,000
1911.0352	H	20,000	420	1,060	15,000
1903.0005	I	1,000	50	540	11,800
1911.0300	J	6,600	150	TNTC*	1,500
1911.0250	K	840	670	3,300	1,400
1911.0220	L	1,030	580	1,340	3,800
1911.0213	M	200	200	1,370	6,600
1911.0210	N	1,550	170	500	3,800
1911.0200	O	660	380	680	4,300
1901.0150	P	2,200	250	870	1,300
1902.0050	Q	110	50	80	1,200
1901.0130	R	4,900	2,000	700	1,250

* Bacterial colonies too numerous to count

Table 15
Benthic Macroinvertebrate data[a]

	San Antonio R. 100 m upstream from Rilling Rd. WWTP Outfall[b]				San Antonio R. 100 m upstream from Medina R. Confluence[c]				San Antonio R. @ Mays Crossing downstream from FM 791[d]				Medina R. 100 m downstream from FM 1937[e]			
	6/6/84	10/2/84	1/23/85	5/15/85	6/5/84	10/3/84	1/24/85	5/16/85	6/5/84	10/2/84	1/23/85	5/15/85	6/5/84	10/3/84	1/24/85	5/16/85
Number of Individuals/m²	1,630	4,149	112	1,361	338	300	394	7,598	19,776	3,895	2,652	19,941	2,126	4,971	16,839	3,388
Number of Species	30	32	5	27	10	11	16	10	20	29	23	27	19	24	27	17
Diversity	4.40	3.48	1.55	3.91	2.59	2.37	2.77	1.27	2.43	2.60	2.80	3.44	2.82	2.76	3.12	2.17
Redundancy	0.13	0.33	0.62	0.22	0.32	0.50	0.50	0.63	0.45	0.51	0.42	0.28	0.38	0.42	0.35	0.50
Equitability	0.90	0.69	0.67	0.82	0.78	0.69	0.69	0.38	0.56	0.53	0.62	0.72	0.66	0.60	0.66	0.53
Taxon	**Number of Individuals/m²**															
COELENTERATA																
Hydra sp.												102				
TURBELLARIA																
Dugesia tigrina										5		527	32	113		
NEMERTEA																
Prostoma rubrum	11										5					
NEMATODA																
unidentified species	5														54	
HIRUDINEA																
Helobdella elongata	16	5		16	5	5		5	5	5		5	48	54	151	81
Helobdella triserialis	70				5				43							
Mooreobdella microstoma	59	102		43	16	32				75		135				
OLIGOCHAETA																
Aeolosoma sp.										11						
Aulodrilus limnobius							5									
Aulodrilus pigueti		5														
Branchiobdellida				5												
Branchiura sowerbyi													16			
Bratislavia unidentata							5									
Chaetogaster diaphanus															108	
Chaetogaster diastrophus															54	

Table 15—Continued
Benthic Macroinvertebrate data[a]

	San Antonio R. 100 m upstream from Rilling Rd. WWTP Outfall[b]				San Antonio R. 100 m upstream from Medina R. Confluence[c]				San Antonio R. @ Mays Crossing downstream from FM 791[d]				Medina R. 100 m downstream from FM 1937[e]			
	6/6/84	10/2/84	1/23/85	5/15/85	6/5/84	10/3/84	1/24/85	5/16/85	6/5/84	10/2/84	1/23/85	5/15/85	6/5/84	10/3/84	1/24/85	5/16/85
Dero (Aulophorus) pectinatus								32								
Dero digitata											5	70			108	
Dero trifida		5					5				16				893	
Enchytraeidae							5									
Limnodrilus sp.		5		11												2,115
Limnodrilus cervix											11					
Limnodrilus hoffmeisteri	91					11	32	4,456		377	221	1,109	700	527	985	
Limnodrilus udekemianus													81			
Nais pardalis							5			59	5			27	108	
Nais variabilis							32								54	
Pristina americana		27											22			129
Pristina idrensis		5														
Pristina leidyi		27							129	5		129			684	
Pristina sima							5									
Slavina appendiculata												11				
Sparganophilus tamesis									5				22			
GASTROPODA																
Gundlachia radiata		38		27						38	11	484		199		
Physa virgata	86	11		16	27	5		5		16		5	16			
Planorbidae													16			
Pyrgophorus coronatus									43	5						
PELECYPODA																
Corbicula fluminea	11	22		27	97	11			54	1,846	5	27	16			
Pisidium casertanum										54		48				
Sphaerium transversum	11								43	210						
AMPHIPODA																
Hyallela azteca					108				48	11			651	16		86

Table 15—Continued
Benthic Macroinvertebrate data[a]

	San Antonio R. 100 m upstream from Rilling Rd. WWTP Outfall[b]				San Antonio R. 100 m upstream from Medina R. Confluence[c]				San Antonio R. @ Mays Crossing downstream from FM 791[d]				Medina R. 100 m downstream from FM 1937[e]			
	6/6/84	10/2/84	1/23/85	5/15/85	6/5/84	10/3/84	1/24/85	5/16/85	6/5/84	10/2/84	1/23/85	5/15/85	6/5/84	10/3/84	1/24/85	5/16/85
COPEPODA																
Cyclops sp.															11	
OSTRACODA																
Herpetocypris reptans		5														
Potamocypris sp.												54				
HYDRACARINA																
Sperchon sp.				5												
COLEOPTERA																
Dytiscus sp.														5		
Heterelmis vulnerata															43	5
Hexacylloepus ferrugineus														11		22
Stenelmis sp.			5				5						118	258	102	
Stenelmis mexicanus	11	97		22					2,454	818	1,141	1,066				
Stenelmis sexlineata								5								48
DIPTERA																
Ablabesmyia annulata	135	81	5	16					48	5	16	759				
Ablabesmyia mallochi				16								1,389	118	81	409	86
Chironomini sp. A																5
Chironomus decorus gr.	22				27	5	38	2,788				377				
Cricotopus sp.		86	27	70								5				
Cricotopus bicinctus	11	301	70	16		32	16	11			32		27		813	
Cricotopus tremulus gr.	54															
Cryptochironomus fulvus gr.															205	5
Dicrotendipes nemodestus	102	135					5		5	27	43	253		38		
Dolichopodidae												5				
Hemerodromia sp.	113	27		5					183		43			5		
Nanocladius sp.											11				205	5
Orthocladius sp.	188		5	81					48							

Table 15—Continued
Benthic Macroinvertebrate data[a]

	San Antonio R. 100 m upstream from Rilling Rd. WWTP Outfall[b]				San Antonio R. 100 m upstream from Medina R. Confluence[c]				San Antonio R. @ Mays Crossing downstream from FM 791[d]				Medina R. 100 m downstream from FM 1937[e]			
	6/6/84	10/2/84	1/23/85	5/15/85	6/5/84	10/3/84	1/24/85	5/16/85	6/5/84	10/2/84	1/23/85	5/15/85	6/5/84	10/3/84	1/24/85	5/16/85
Palpomyia tibialis										5						
Pentaneura sp.				16		22							5			
Polypedilum convictum	43	156		269	43	161	38	70	8,191		388	3,913	194	732	2,847	312
Polypedilum illinoense	43							11				253			409	
Polypedilum nr *scalaenum*										11	11	1,136		27	1,222	161
Psectrocladius sp.				27								506				
Pseudochironomus sp.	22	102								11						
Rheocricotopus sp.	11															
Rheotanytarsus sp.	75	135		43	5	5	188	215	619		371	5,048	22	210	6,717	221
Simulium sp.						11			86							
Simulium nr *bivittatum*											86	2,363				
Simulium vittatum															124	43
Tanytarsus guerulus gr.		5								11	11			5		
Thienemanniella sp.		70								5						
Thienemanniella xena												124				
EPHEMEROPTERA																
Baetis quilleri	102	38		81			5		312				11	91		
Caenis sp.	11			11			5				38			22		
Dactylobaetis mexicanus		48														
Leptohyphes packeri		11														
Thraulodes gonzalesi										16					5	
Tricorythodes albilineatus gr.	123	501		70						11						
LEPIDOPTERA																
Parargyractis sp.	38	737														
MEGALOPTERA																
Corydalus cornutus											5			11		

Table 15—Continued
Benthic Macroinvertebrate data[a]

	San Antonio R. 100 m upstream from Rilling Rd. WWTP Outfall[b]				San Antonio R. 100 m upstream from Medina R. Confluence[c]				San Antonio R. @ Mays Crossing downstream from FM 791[d]				Medina R. 100 m downstream from FM 1937[e]			
	6/6/84	10/2/84	1/23/85	5/15/85	6/5/84	10/3/84	1/24/85	5/16/85	6/5/84	10/2/84	1/23/85	5/15/85	6/5/84	10/3/84	1/24/85	5/16/85
ODONATA																
Argia sp. A	32	59		27						91	129			27	5	
Argia sp. B	11			11												
TRICHOPTERA																
Cheumatopsyche sp.	32	11		215	5				3,014	11						
Cheumatopsyche sp. A														2,330	388	
Cheumatopsyche sp. B														172		
Hydroptila sp.	91	1,276		172					4,150	140	48	43	11		108	
Ochrotrichia sp.		16		43					296	5				5	27	
Smicridea sp.										11						

a—two subsamples collected at each station using a Surber square foot sampler
b—corresponds to physicochemical station D
c—corresponds to physicochemical station H
d—located 0.6 river km downstream from physicochemical station O
e—located 6.2 river km upstream from physicochemical station I

TABLE 16

Additional Benthic Macroinvertebrate Community Indices

Station	Date	Biotic Index*	Mayflies # of species	Mayflies % of community	gr	ga	mi	fi	sh	pr
					Percentage Composition of Functional Feeding Groups*					
San Antonio River 0.1 km upstream from Rilling Road WWTP outfall**	06/06/84	2.25	3	14.5	15.0	24.4	40.3	0.0	0.0	20.3
	10/02/84	2.11	4	14.4	58.4	14.5	12.8	3.9	5.9	4.5
	05/15/85	1.90	3	11.9	21.5	12.1	18.9	23.7	11.5	12.2
San Antonio River 0.1 km upstream from Medina River confluence	06/05/84	2.70	0	0.0	4.0	4.0	12.2	31.7	36.2	11.9
	10/03/84	2.73	0	0.0	0.8	0.8	28.6	9.0	23.2	37.6
	01/24/85	2.69	2	2.5	1.3	2.5	40.0	47.7	5.3	3.2
	05/16/85	2.80	0	0.0	0.1	0.1	96.1	2.8	0.4	0.4
San Antonio River at Mays Crossing downstream from FM 791	06/05/84	1.75	1	1.6	29.6	8.4	14.2	18.9	14.2	14.7
	10/02/84	2.25	2	0.7	15.2	11.3	12.1	56.9	0.0	4.6
	01/23/85	2.33	1	1.4	25.0	24.0	15.9	18.5	5.2	11.3
	05/15/85	2.38	0	0.0	0.0	3.2	17.2	45.6	10.4	23.6
Medina River 0.1 km downstream from FM 1937	06/05/84	2.75	1	0.5	3.0	4.7	43.5	0.0	36.9	11.9
	10/03/84	2.25	2	2.3	7.2	5.3	17.0	59.7	5.4	5.4
	01/24/85	2.56	1	0.03	0.0	0.0	29.8	44.8	12.7	12.7
	05/16/85	2.63	0	0.0	0.0	0.0	75.3	6.9	7.6	10.2

* - calculated using the eight most abundant species at each station

** - data for 1/23/85 omitted because it was considered unrepresentative (see discussion in text)

functional feeding group abbreviations: gr = grazer; ga = gatherer; mi = miner; fi = filterer; sh = shredder; pr = predator

TABLE 17

Benthic Macroinvertebrate Community Indices, November 1983*

Station	# of Individuals per m^2	# of species	Diversity	Redundancy	Equitability	Biotic Index**	Mayflies: # of species	Mayflies: % of community	Percentage Composition of Functional Feeding Groups*: gr	ga	mi	fi	sh	pr
San Antonio River above Mission Dam[a]	893	23	3.23	0.35	0.71	2.0	2	34.6	17.8	29.1	17.7	3.1	17.7	14.6
San Antonio River near Southton[b]	16,879	8	0.22	0.93	0.07	2.9	1	0.2	0.3	0.3	99.1	0.0	0.3	0.1
San Antonio River near FM 791[c]	4,120	34	3.60	0.31	0.71	2.6	1	0.1	20.4	12.2	56.1	8.0	3.2	0.0
Medina River near the mouth[d]	3,349	26	3.20	0.34	0.68	2.3	3	8.4	7.9	30.3	23.9	3.1	21.6	13.2

* - data from Twidwell (1984a) and Twidwell and Davis (1984)

** - calculated using the eight most abundant species at each station

a - located 4.1 river km upstream from site sampled in present study (San Antonio River 0.1 km upstream from Rilling Road WWTP outfall)

b - located 5.9 river km upstream from site sampled in present study (San Antonio River 0.1 km upstream from Medina River confluence)

c - corresponds to site sampled in present study (San Antonio River at Mays Crossing downstream from FM 791)

d - located 6.1 river km downstream from site sampled in present study (Medina River 0.1 km downstream from FM 1937)

functional feeding group abbreviations: gr = grazer; ga = gatherer; mi = miner; fi = filterer; sh = shredder; pr = predator

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APPENDIX A

FIELD AND LABORATORY PROCEDURES

The following methods are utilized for field and laboratory determinations of specified physical and chemical parameters. Unless otherwise indicated composite water samples are collected at each sampling station and stored in polyethylene containers on ice until delivery to the laboratory. Sediment samples are collected with a dredge or coring device, decanted, mixed, placed in appropriate containers (glass for pesticides analyses and plastic for metals analyses), and stored on ice until delivery to the laboratory. Laboratory chemical analyses are conducted by the Water Chemistry Laboratory of the Texas Department of Health unless otherwise noted.

WATER ANALYSES

Field Measurements

Parameter	Unit of Measure	Method
Temperature	°C	Hand mercury thermometer, Hydrolab Model 60 Surveyor, or Hydrolab 4041.
Dissolved Oxygen (DO)	mg/l	Azide modification of Winkler titration method, Hydrolab Model 60 Surveyor, or Hydrolab 4041.
pH	Standard Units	Hydrolab Model 60 Surveyor, Hydrolab 4041 or Sargent-Welch portable pH meter.
Conductivity	µmhos/cm	Hydrolab Model 60 Surveyor, Hydrolab 4041, or Hydrolab TC-2 conductivity meter
Phenolphthalein Alkalinity (P-Alk)	mg/l as $CaCO_3$	Titration with sulfuric acid using phenolphthalein indicator(1).
Total Alkalinity (T-Alk)	mg/l as $CaCO_3$	Titration with sulfuric acid acid using phenolphthalein and methyl red/bromcresol green indicators(1).
Chlorine Residual	mg/l	N,N-diethyl-p-phenylene-diamine (DPD) Ferrous Tetrimetric method(1).
Transparency	m or cm	Secchi disc

Laboratory Analyses

Parameter	Unit of Measure	Method
Five Day, Nitrogen Suppressed, Biochemical Oxygen Demand (BOD_5, N-Supp.)	mg/l	Membrane electrode method(1). Nitrogen Suppression using 2-chloro-6-(trichloromethyl)-pyridine (TCMP) method(2).
Five Day, Filtered, Nitrogen Suppressed, Biochemical Oxygen Demand (BOD_5, Filt., N-Supp.)	mg/l	Samples filtered with glass fiber filter. Analysis conducted on filtrate. Membrane electrode method(1). Nitrogen Suppression using TCMP method(2).
Twenty Day, Nitrogen Suppressed, Biochemical Oxygen Demand (BOD_{20}, N-Supp.)	mg/l	Membrane electrode method(1). Nitrogen Suppression using TCMP method(2).
Twenty Day, Filtered, Nitrogen Suppressed, Biochemical Oxygen Demand (BOD_{20}, Filt., (N-Supp.)	mg/l	Samples filtered with glass fiber filter. Analyses conducted on filtrate. Membrane electrode method(1). Nitrogen Suppression using TCMP method(2).
One through Seven Day, Nitrogen-Suppressed, Biochemical Oxygen Demand (BOD_{1-7}, N-Supp.)	mg/l	Membrane electrode method(1). Nitrogen Suppression using TCMP method(2).
Total Suspended Solids (TSS)	mg/l	Gooch crucibles and glass fiber disc(1).
Volatile Suspended Solids (VSS)	mg/l	Gooch crucibles and glass fiber disc(1).
Kjeldahl Nitrogen (Kjel-N)	mg/l as N	Micro-Kjeldahl digestion and automated colorimetric phenate method(3).
Ammonia Nitrogen (NH_3-N)	mg/l as N	Distillation and automated colorimetric phenate method(3).
Nitrite Nitrogen (NO_2-N)	mg/l as N	Colorimetric method(1).
Nitrate Nitrogen (NO_3-N)	mg/l as N	Automated cadmium reduction method(3).

Laboratory Analyses - Continued

Parameter	Unit of Measure	Method
Total Phosphorus (T-P)	mg/l as P	Persulfate digestion followed by ascorbic acid method(1).
Orthophosphorus (O-P)	mg/l as P	Ascorbic acid method(1).
Sulfate (SO_4)	mg/l	Turbidimetric method(1).
Chloride (Cl)	mg/l	Automated thiocyanate method(3).
Total Dissolved Solids (TDS)	mg/l	Evaporation at 180°C(3).
Total Organic Carbon (TOC)	mg/l	Beckman TOC analyzer
Conductivity	μmhos/cm	Wheatstone bridge utilizing 0.01 cell constant(1).
Chlorophyll a	μg/l	Trichromatic method(1).
Pheophytin a	μg/l	Pheophytin correction method(1).

SEDIMENT ANALYSES

Field Measurements

Sediment Oxygen Demand

A benthic respirometer, constructed of clear plexiglass, is utilized on intensive surveys to measure benthal oxygen demand(14). A dissolved oxygen probe, paddle, solenoid valve and air diffuser are mounted inside the test chamber. The paddle issued to simulate stream velocity and produce circulation over the probe. The solenoid valve allows air to escape from the test chamber during aeration. The air diffuser is connected by plastic tubing to a 12-volt air compressor which is used to pump air into the test chamber if required.

The paddle, solenoid valve, and air compressor are actuated by switches on a control panel which is housed in an aluminum box. The control box also contains two 12-volt batteries, the air compressor, a stripchart recorder (for automatic recordings of dissolved oxygen meter readings), a battery charger, and a battery test meter.

Selection of a specific test site must be made in the field by the investigator with the depth, velocity, and benthic substrate taken into consideration. At the test site the dissolved oxygen meter, and strip-chart recorder are calibrated, the respirometer is dry tested by opening and closing switches and testing batteries; a stream velocity measurement is taken (for paddle calibration), and a water sample is collected just above the stream bottom near the sampling site. Portions of this water sample are poured into separate BOD bottles, one of which is opaque. The opaque bottle is placed on the respirometer and left for the remainder of the test. The initial dissolved oxygen value in the other bottle is measured when the test begins, while the dissolved oxygen in the opaque bottle is measured at the end of the benthic uptake test. The difference in the two dissolved oxygen values represents the oxygen demand of the water column.

The respirometer can be lowered from a boat or bridge, or can be placed by hand in shallow streams. Care is taken to insure that the sediment at the test location is not disturbed and that a good seal between the base of the instrument and bottom of the stream is made. After the respirometer has been placed in the stream, the dissolved oxygen is recorded. In shallow, clear streams the instrument is covered to prevent photosynthesis from occurring within the chamber. The test chamber is then closed and the paddle frequency adjusted. Recordings of dissolved oxygen are made until oxygen is depleted within the chamber or 6 hours has elapsed.

Paddle Frequency

$$f = 36\ v$$

where: f = Paddle frequency in revolutions per minute

v = Velocity to be simulated in m/s (measureed with current meter)

Benthic Oxygen Uptake

$$B^{T}DO_1\text{-}DO_2 = 196\ \frac{(DO_1 - DO_2) - BOD_t}{\Delta t}$$

where: $B^{T}DO_1\text{-}DO_2$ = Oxygen uptake rate in $g/m^2/d$ corresponding to the sample temperature, T

DO_1 = Initial DO reading in mg/l

DO_2 = Final DO reading in mg/l

Δt = Time interval between DO_1 and DO_2

T = Temperature of sample in °C

BOD_t = Measured difference in DO between the two BOD bottles

Laboratory Analyses

Parameter	Unit of Measure	Method
Arsenic (As)	mg/kg	Silver diethylidithcocarbonate method(3).
Mercury (Hg)	mg/kg	Potassium permanganate digestion followed by atomic absorption(3,4).
All other metals	mg/kg	Atomic absorption(3,4).
Volatile Solids	mg/kg	Ignition in a muffle furnace(3).
Chemical Oxygen Demand (COD)	mg/kg	Dichromate reflux method(3).
Kjeldahl Nitrogen (Kjel-N)	mg/kg	Micro-Kjeldahl digestion and automated colorimetric method(3).
Total Phosphorus (T-P)	mg/kg as P	Ammonium molybdate(3).
Pesticides	µg/kg	Gas chromatographic method(4,5).
Oil and Grease	mg/kg	Soxhlet extraction method(3).

BACTERIOLOGICAL

Bacteriological samples are collected in sterilized bottles to which 0.5 ml of sodium thiosulfate is added to dechlorinate the sample. Following collection, the samples are stored on ice until delivery to a laboratory or until cultures are set up by survey personnel (within 6 hours of collection). Bacteriological analyses are conducted by survey personnel or a suitable laboratory in the survey area.

Parameter	Unit of Measure	Method
Total Coliform	Number/100 ml	Membrane filter method(1)
Fecal Coliform	Number/100 ml	Membrane filter method(1)
Fecal Streptococci	Number/100 ml	Membrane filter method(1)

BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates are collected with a Surber sampler (0.09 m^2) in riffles and an Ekman dredge (0.02 m^2) in pools. Samples are preserved in 5 percent formalin, stained with Rose Bengal, and sorted, identified, and enumerated in the laboratory.

Diversity ($\bar{d}$) is calculated according to Wilhm's(6) equation:

$$\bar{d} = - \sum_{1}^{s} (n_i/n) \log_2 (n_i/n)$$

where n is the total number of individuals in the sample, n_i is the number of individuals per taxon, and s is the number of taxa in the sample.

Redundancy ($\bar{r}$) is calculated according to the equations derived by Young et al.(7)

(1) $\bar{d}\ max = \log_2 s$

(2) $\bar{d}\ min = - \frac{s-1}{n} \log_2 \frac{1}{n} - \frac{n-(s-1)}{n} \log_2 \frac{n-(s-1)}{n}$

(3) $\bar{r} = \frac{\bar{d}\ max - \bar{d}}{\bar{d}\ max - \bar{d}\ min}$

where s is the number of taxa in the sample and n is the total number of individuals in the sample.

Equitability is (e) is calculated according to Pielow's(8) equation:

$$e = \frac{\bar{d}}{\log_2 s}$$

where $\bar{d}$ is the calculated diversity value and s is the number of taxa in the sample.

The number of individuals per square meter is determined by dividing the total number of individuals by the area sampled.

PERIPHYTON

Periphyton are collected from streams and reservoirs from natural substrates or from artificial substrates placed in the water. Standard size, frosted microscope slides are commonly used as artificial substrates and are held in place a few centimeters beneath the water surface at the sampling sites in floating periphytometers. Following a 25 to 30 day incubation period the accrued materials are analyzed for chlorophyll *a*, pheophytin *a*, and for identification and enumeration of the attached organisms.

In the field, following retrieval of the periphytometer, two slides are placed in a brown glass container containing 100 ml of 90 percent aqueous acetone. The material from these two slides is used for pigment measurements. Two slides are placed in another brown glass container containing 100 ml of 5 percent buffered formalin. The material from these two slides is used for biomass measurements. The remaining slides are also placed in buffered formalin and utilized for identification and enumeration of organisms according to procedures discussed for the phytoplankton. The brown glass jars containing the material for laboratory analyses (pigment and biomass measurements) are placed in a deep freeze and kept frozen prior to analysis.

The autotrophic index is calculated according to the equation given by Weber and McFarland(9).

$$\text{Autotrophic Index} = \frac{\text{Biomass (g/m2)}}{\text{Chlorophyll } \underline{a} \text{ (g/m}^2\text{)}}$$

Periphyton samples may also be collected from natural substrates by scraping areas from each type of substrate available at each sampling location. Scrapings are made from a range of depths from subsurface to the stream bottom, from bank to bank, and at points spanning the range in stream velocity. The scrapings from each sampling location are composited into a container, preserved with Lugols solution and returned to the laboratory for identification and enumeration following procedures discussed in the phytoplankton section. Diversity, redundancy, and equitability statistics are calculated as described previously.

PLANKTON

Phytoplankton

Stream phytoplankton are collected immediately beneath the water surface with a Van Dorn sampler or by immersing a sampling container. Phytoplankton samples are collected with a Van Dorn water sampler at depths evenly spaced throughout the water column of reservoirs.

Samples are stored in quart cubitainers on ice and transferred to the laboratory where aliquots of each sample are analyzed live to aid in taxonomic identification. Samples (950 ml) are then preserved with 50 ml of 95 percent buffered formalin or 9.5 ml of Lugols solution and stored in the dark until examination is completed. The phytoplankton are concentrated in sedimentation chambers, and identification and enumeration are conducted with an inverted microscope utilizing standard techniques. If diatoms are abundant in the samples, slide preparations are made using Hyrax mounting medium(10). The diatoms are identified at high magnification under oil until a minimum of 250 cells are tallied. Diversity, redundancy, and equitability statistics are calculated as described previously.

Zooplankton

Zooplankton are concentrated at the site by either filtering a known volumne of water through a number 20 mesh standard Wisconsin plankton net or vertically towing the net a known distance or time. Concentrated samples are preserved with Lugols solution or in a final concentration of 5 percent buffered formalin. The organisms are identified to the lowest taxonomic level possible, and counts are made utilizing a Sedgwick-Rafter cell. Diversity, redundancy, and equitability statistics are calculated as described previously.

NEKTON

Nekton samples are collected by the following methods(1):

Common-sense minnow seine	- 6 m x 1.8 m with 0.6 cm mesh
Otter trawl	- 3 m with 3 cm outer mesh and 1.3 cm stretch mesh liner
Chemical fishing	- rotenone
Experimental gill nets	- 38.1 m x 2.4 m (five 7.6 m sections ranging in mesh size from 1.9 to 6.4 cm).
Electrofishing	- backpack and boat units (both equipped with AC or DC selection). Boat unit is equipped with variable voltage pulsator.

Nekton are collected to determine: (1) species present, (2) relative and absolute abundance of each species, (3) species diversity (4) size distribution, (5) condition, (6) success of reproduction, (7) incidence of disease and parasitism, (8) palatability, and (9) presence or accumulations of toxins.

Nekton collected for palatability are iced or frozen immediately. Samples collected for heavy metals analyses are placed in leak-proof plastic bags and placed on ice. Samples collected for pesticides analyses are wrapped in alumnium foil, placed in a waterproof plastic bag, and placed on ice.

As special instances dictate, specimens necessary for positive identification or parasite examination are preserved in 10 percent formalin containing 3 borax and 50 ml glycerin per liter. Specimens over 15 cm in length are slit at least one-third of the length of the body to enhance preservation of the internal organs. As conditions dictate, other specimens are weighed and measured before being returned to the reservoir or stream.

ALGAL ASSAYS

The "Selenastrum capricornutum Printz Algal Assay Bottle Test" procedure(11) is utilized in assaying nutrient limitation in freshwater situations, whereas the "Marine Algal Assay Procedure Bottle Test"(12) is utilized in marine and estuarine situations. Selenastrum capricornutum is the freshwater assay organism and Dunaliella tertiolecta is the marine assay alga.

PHOTOSYNTHESIS AND RESPIRATION

In areas where restricted flow produces natural or artifical ponding of sufficient depth, standard light bottle-dark bottle techniques are used. In flowing water the diurnal curve analysis is utilized.

Light Bottle-Dark Bottle Analyses

The light and dark bottle technique is used to measure net production and respiration in the euphotic zone of a lentic environment. The depth of the euphotic zone is considered to be three times the Secchi disc transparency. This region is subdivided into three sections. Duplicate light bottles (300 ml BOD bottles) and dark bottles (300 ml BOD bottles covered with electrical tape, wrapped in aluminum foil, and enclosed in a plastic bag) are filled with water collected from the mid-point of each of the three vertical sections, placed on a horizontal metal rank, and suspended from a flotation platform to the mid-point of each vertical section. The platform is oriented in a north-south direction to minimize shading of the bottles. An additional BOD bottle is filled at each depth for determining initial dissolved oxygen concentrations (modified Winkler method). The bottles are allowed to incubate for a varying time interval, depending on the expected productivity of the waters. A minimum of 4 hours incubation is considered necessary.

The following equations are used to calculate respiration and photosynthesis:

(1) For plankton community respiration (R), expressed as mg/l O_2/hour,

$$R = \frac{DO_I - DO_{DB}}{\text{Hours incubated}}$$

where DO_I = initial dissolved oxygen concentration

and DO_{DB} = average dissolved oxygen concentration of the duplicate dark bottles

(2) For plankton net photosynthesis (P_N), expressed as mg/l O_2/hour,

$$P_N = \frac{DO_{LB} - DO_I}{\text{Hours incubated}}$$

where DO_{LB} = average dissolved oxygen concentration of duplicate light bottles

(3) For plankton gross photosynthesis (P_G), expressed as mg/l O_2/hour,

$$P_G = P_N + R$$

Conversion of respiration and phtotsynthesis volumetric values to an aerial basis may be accomplished by multiplying the depth of each of the three vertical zones (expressed in meters) by the measured dissolved oxygen levels expressed in g/m^3. These products are added and the result is expressed in g $O_2/m^2/d$ by multiplying by the photoperiod. Conversion from oxygen to carbon may be accomplished by multiplying grams O_2 by 0.32 [1 mole of O_2 (32 g) is released for each mole of carbon (12 g) fixed].

Diurnal Curve Analysis

In situations where the stream is flowing, relatively shallow, and may contain appreciable growths of macropytes or filamentous algae, the diurnal curve analysis is tuilized to determine productivity and respiration. The procedure is adopted from the United States Geological Survey(13). Both the dual station and single station analyses are utilized, depending upon the various controlling circumstances.

Dissolved oxygen and temperature data are collected utilizing the Hydrolab surface units, sondes, data scanners, and strip chart recorders. Diffusion rate constants are directly measured in those instances where atmospheric reaeration rate studies have been conducted. In situations where direct measurements are not made, either the diffusion dome method is utilized, or an appropriate alternative. These alternatives are: (1) calculations from raw data, (2) substitution into various published formulas for determination of K_2, and (3) arbitrary selection of a value from tables of measured diffusion rates for similar streams.

HYDROLOGICAL

Parameter	Unit of Measure	Method
Flow Measurement	m^3/s	Pygmy current meter (Weather Measure Corporation Model F583), Marsh-McBirney Model 201 electronic flow meter, Price current meter (Weather Measure Corporation Model F582), or gage height readings at USGS gaging stations.
Time-of-Travel	m/s	Tracing of Rhodamine WT dye using a Turner Model 110 or 111 fluorometer(15).
Stream Width	m	Measured with a range finder
Tidal Period	hours	Level recorder
Tidal Amplitude	m	Level recorder
Changes in Stream Surface Level	m	Level recorder

Stream Reaeration Measurements

The stream reaeration technique is utilized to measure the physical reaeration capacity of a desired stream segment(16). The method depends on the simultaneous release of three tracers in a single aqueous solution: a tracer for detecting dilution and dispersion (tritiated water molecules), a dissolved gaseous tracer for oxygen (krypton-85), and Rhodamine WT dye to indicate when to sample for the radiotracers in the field. The tracer release location is chosen to meet two requirements: (1) it must be upstream of the segment for which physical reaeration data are desired, and (2) it must be at least 0.6 m deep and where the most complete mixing takes place. Before the release, samples are collected at the release site and at designated sampling stations to determine background levels of radiation. The first samples are collected 15 to 60 m downstream from the release site in order to establish the initial ratio of drypton 85 to tritium. Sampling sites are located downstream to monitor the dye cloud every 4 to 6 hours over a total period of 35 to 40 hours. The Rhodamine WT dye is detected with Turner 111 flow-through fluorometers. Samples are collected in glass bottles (30 ml) equipped with polyseal caps which are sealed with black electrical tape. Samples are generally collected every 2 to 5 minutes during the passage of the dye cloud peak. The three samples collected nearest the peak are designated for analysis in the laboratory (three alternate samples collected near the peak are also designated). Extreme caution is exercised throughout the field and laboratory handling of samples to prevent entrainment of air.

Samples are transferred to the laboratory for analyses within 24 hours of the collection time. Triplicate counting vials are prepared from each primary sample. All counting vials are counted in a Tracor Analytic 6892 LSC Liquid Scintillation Counter which has been calibrated. For each vial, counting extends for a minimum of three 10-minute cycles. The data obtained are analyzed to determine the changes in the krypton-85 to tritium ratio as the tracers flow downstream.

The calculations utilized in determining the physical reaeration raes from a stream segment from the liquid scintillation counter data are included here. Krypton-85 transfer in a well-mixed water system is described by the expression:

$$\frac{dC_{kr}}{dt} = - K_{kr}(C_{kr},t) \qquad (1)$$

where: C_{kr},t = concentration of krypton-85 in the water at time(t)

K_{kr} = gas transfer rate coefficient for krypton-85

The concentration of krypton-85 present in the earth's atmosphere can be assumed zero for practical purposes. Therefore, any krypton-85 dissolved in water which is exposed to the atmosphere will be steadily lost from the water to the atmosphere according to equation 1.

The gas transfer rate coefficient for oxygen (K_{ox}) is related to K_{kr} by the equation:

$$\frac{K_{kr}}{K_{ox}} = 0.83 \pm 0.04 \qquad (2)$$

Equation 2 is the basis for using krypton-85 as a tracer for oxygen transfer in stream reaeration because the numerical constant (0.83) has been experimentally demonstrated to be independent of the degree of turbulent mixing, of the direction in which the two gases happen to be moving, and of temperature. The disperion or dilution tracer (tritiated water) is used simultaneously with the dissolved gas tracer (krypton-85) to correct for the effects of dispersion and dilution in the stream segment being studied.

A single homogeneous solution containing the dissolved krypton-85 gas, tritiated water, and dye is released at the upstream reach of the stream segment being studied. As the tracer mass moves downstream, multiple samples are collected as the peak concentration passes successive sampling stations. In the laboratory, peak concentration samples from each station are analyzed and the krypton-85/tritium concentration ratio (R) is established by the equation:

$$R = \frac{C_{kr}}{C_h} \qquad (3)$$

where: C_{kr} = concentration of krypton-85 in water at time of peak concentration

C_h = concentration of tritium in the water at time of peak concentration

Applying this ratio concept, equation 1 can be modified to:

$$\frac{dR}{dt} = - K_{kr} R \qquad (4)$$

with terms as previously defined

Equation 4 can be transformed to:

$$K_{kr} = \frac{n(R_d/R_u)}{- t_f} \qquad (5)$$

where: R_u and R_d = peak ratios of krypton-85 to tritium concentrations at an upstream and downstream station

t_f = travel time between the upstream and downstream station determined by dye peaks

The tracers are used to evaluate the actual krypton-85 transfer coefficient (K_{kr}), and the conversion to the oxygen transfer coefficient (K_{ox}) is from the established gas exchange ratio:

$$K_{ox} = \frac{K_{kr}}{0.83}$$

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