TR-39
1971

Texas Water Resources Institute
make every drop count

Identification of Management and Planning Problems of Urban Water Resources in the Metropolitan Area of Greater San Antonio

J.K. Garner
C.S. Shih

Texas Water Resources Institute

Texas A&M University

TR-39

IDENTIFICATION OF MANAGEMENT AND PLANNING PROBLEMS OF URBAN WATER RESOURCES IN THE METROPOLITAN AREA OF GREATER SAN ANTONIO

Joseph K. Garner
C. S. Shih

SEPTEMBER 1971

RESEARCH PROJECT TECHNICAL INTERIM REPORT

Project Number A-017-TEX

September 1970 -- August 1971

Agreement Number
14-31-0001-3244

IDENTIFICATION OF MANAGEMENT AND PLANNING PROBLEMS OF URBAN WATER RESOURCES IN THE METROPOLITAN AREA OF GREATER SAN ANTONIO

Principal Investigators

Joseph K. Garner and C. S. Shih

The work upon which this publication is based was supported in part by funds provided by the United States Department of the Interior, Office of Water Resources Research, as authorized under the Water Resources Research Act of 1964, P.L. 88-379.

Technical Report No. 39
Water Resources Institute
Texas A&M University

September 1971

PREFACE

This interim report describes the research performed to date on Project A-017-TEX sponsored by the U. S. Department of Interior Office of Water Resources Research and the Texas A&M University Texas Water Resources Institute.

The research reported herein describes the region incompassed by the San Antonio river basin. Included in the description is a brief summary of the regional economy, demography, and geographical characteristics. Additionally, the quantitative and qualitative information including the inventory and planning control for both surface and ground Water Resource Management of the San Antonio area are presented. Emphasis has been placed upon the identification of the probabilistic nature of various decision-making parameters of Urban Water Resources Management. The methodogies and techniques for the handling of specific problems are being developed and will be presented in the project completion report.

Appreciation is expressed to the Alamo Area Council of Governments and the Texas Water Development Board for their assistance in this research. Numerous graduate students contributed to this research. Chief among these is Miss Sharon Tu for her efforts in developing the San Antonio Data Retrieval Program. Special acknowledgement is given to Mr. John Little for his assistance in preparing the manuscript for publication. The cooperation of Dr. J. R. Runkles and the entire staff of the Texas Water Resources Institute is appreciated. Finally, a special thanks to Mrs. Cynthia Fong for her diligent effort in typing the manuscript.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1
THE STUDY AREA

San Antonio, the fifteenth largest city in population in the United States, is located in Bexar County in South Central Texas, (See Figure 1). This area is not endowed with an abundance of surface water and is largely dependent on ground water resources for water supply. Although San Antonio is not facing an immediate water shortage its major problem is insuring itself an adequate supply in the future.

San Antonio is an old city that lies in the center of a populated area of almost 1 million persons. It is the largest city in the world primarily dependent on ground water as water supply. The city is presently 182.73 square miles in size. There are five separately incorporated cities, which are enclaves within the City of San Antonio and seven military installations within or adjacent to the city. San Antonio is an active business community and the region of the San Antonio river basin is well developed with both agricultural and commerical enterprises. There is comparatively little basic industrial activity within the region, thus the economy heavily depends upon the military complexes in the area and upon tourism.

The San Antonio River basin comprises an area of more than 4,100 square miles in south-central Texas. The river basin includes parts of two physiographic sections, the West Gulf Coastal Plain of the Coastal Plain province and the Edwards Plateau of the Great Plains province. These physiographic sections within the basin are separated by the Balcones Escarpment. Although both the Edwards Plateau and the top of the Balcones Escarpment are partly protected from erosion by a cap of resistant limestone, streams that

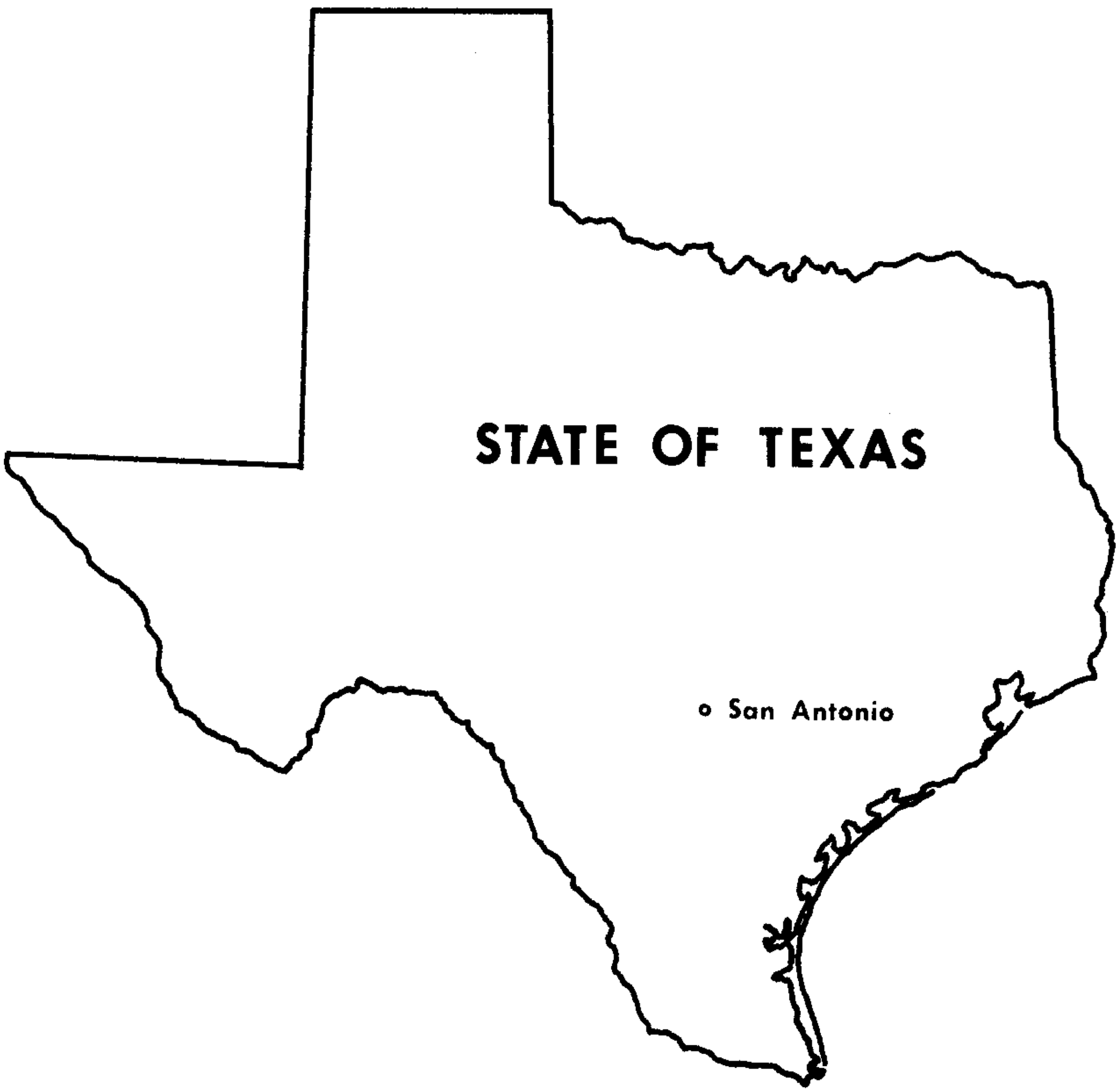


Figure 1.
Geographic Location of San Antonio, Texas

rise in the plateau have cut broad valleys below the upland surface. Between these valleys, remnants of the resistant limestone form steep cliffs. The resulting terrain is rough and rugged and the soil mantle is very thin except along the major stream valleys (20).

The West Gulf Coastal Plain extends from the Balcones Escarpment to the Gulf of Mexico. In this section, the rolling to moderately hilly country merges with the level Gulf Coast Prairie.

The principal stream that drains the Edwards Plateau section of the basin is the Medina River, which rises in the Northwestern part of Bandera County, flows eastward across the Edwards Plateau, and joins the San Antonio River about 15 miles south of the city of San Antonio.

The mainstream of the San Antonio River rises in the city of San Antonio near the center of Bexar County, flows southeastward across the West Gulf Coastal Plain, and joins the Guadalupe River about 11 miles upstream from San Antonio Bay.

Cibolo Creek, the principal tributary to the San Antonio River, rises in Kendall County in the Edwards Plateau section, flows southeastward across the Balcones Escarpment and West Gulf Coastal Plain section, and joins the San Antonio River in Karnes County (20).

Springflow from the Edwards and associated limestones in the Edwards Plateau contributes to the base flow of the Medina River and Cibolo Creek. In turn, most of the base flow and part of the flood flow infiltrates into the Balcones Fault zone on the outcrop of the Edwards and associated limestones. Consequently, south of Balcones Fault zone, these streams are often dry (24). Figure 2 shows the study area.

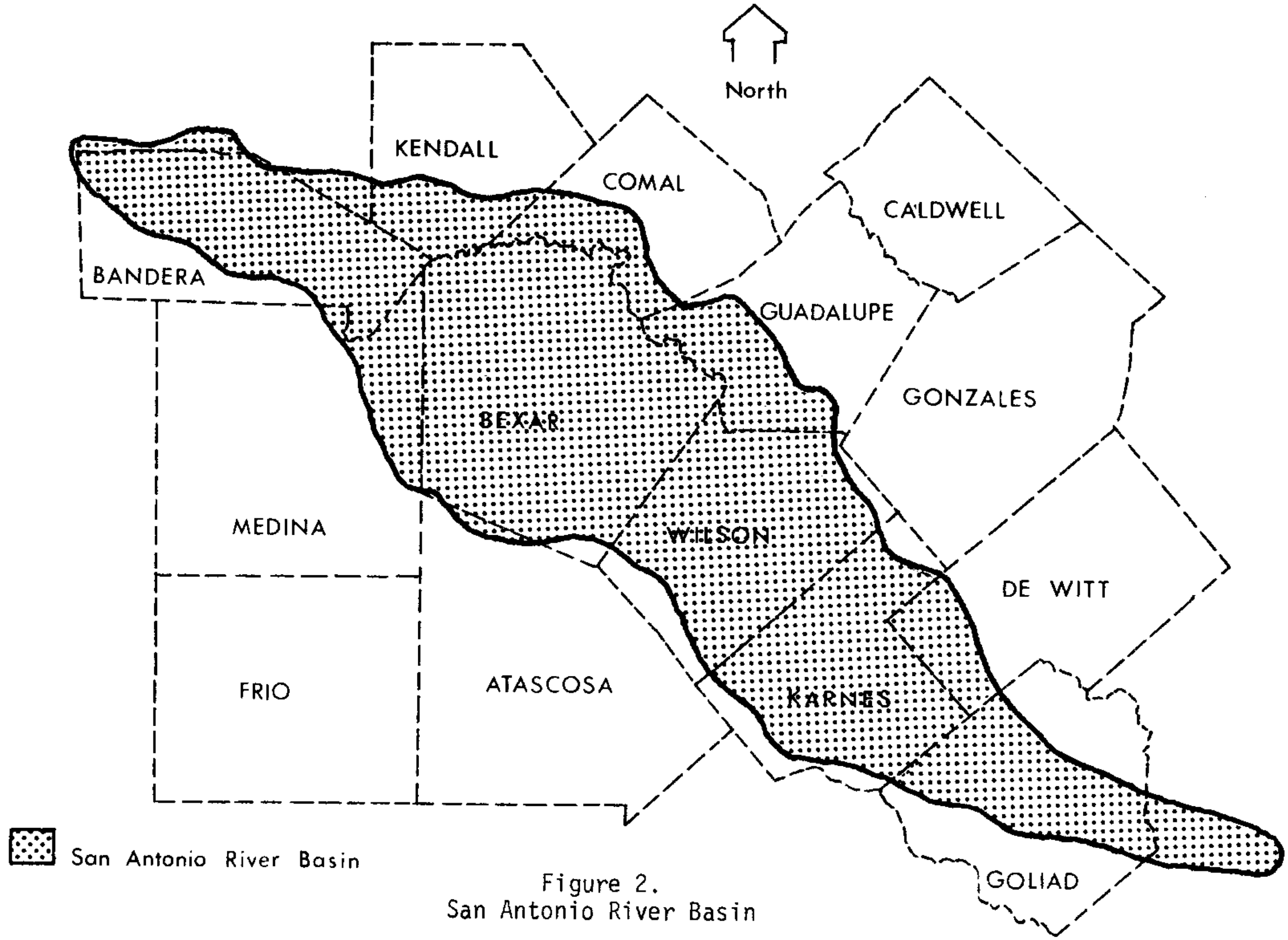


Figure 2.
San Antonio River Basin

The availability of mineral resources play an important part in the economy of the region. Ground water is acquired from several aquifers in the region. Crude oil, natural gas and natural gas liquids are also mined from the region. To the north of the Balcones Escarpment the cretaceous limestones and dolomites furnish building stone, lime and cement. To the south of the Balcones Escarpment, the tertiary formations contain large deposits of gravel, sand and clay (11).

The recharge zone of an aquifer coincides with the surface exposure or outcrop of the formation comprising the aquifer which is located along the Balcones fault zone. In Bexar County the recharge zone is part of the drainage area of Cibolo, Salado and Leon Creeks(14).

There are four major aquifers in the region. However, the Edwards and its associated limestones is the region's most important aquifer. The Edwards provides the water supply to the major population areas of the region including the City of San Antonio. The volume of water in storage within the aquifer fluctuates rapidly in response to precipitation and water demands placed upon the aquifer (11).

The San Antonio River Valley is classified as a modified subtropical climate, predominantly continental during the winter months and marine during the summer months. The river divides a semiarid area to the west and the coastal area of heavy precipitation to the southeast. The drainage to the east of the River Valley is toward the Mississippi Basin while the drainage west of the San Antonio River is toward the Rio Grande Basin. Nearly all of the streams east of the San Antonio River are right branched while the streams to the west are left branched. This is primarily due to the influence of the San Marcos Arch which strikes from the Llano Uplift to the Gulf Coast of Texas.

Average annual rainfall varies across the river valley from 25 inches per year to 36 inches per year. The rainfall is relatively well distributed throughout the year with heaviest amounts during the months of May and September. Precipitation from April through September usually occurs with thunderstorms, whereas most of the winter rain occurs as drizzle. Hail of damage intensity seldom falls but light hail is frequent in connection with the springtime thunderstorms. Measurable snow occurs only once in three or more years. The greatest amount, 7.4 inches, fell in 1926 at San Antonio.

Figure 3 is a contour map showing the average annual rainfall over the area. Several anomalies occur on this map around the San Antonio area. One high area occurs at the common junction of Comal, Hays, and Blanco counties. A notable low area occurs over the City of San Antonio. It was recognized that attributes for the low rainfall may be due to the upward air movement over the valley area of the San Antonio River. The Weather Bureau stated that air fronts approaching the city often break open over the valley. The broad valley creates a slight amount of uplift from the prevailing winds which forces precipitation to higher elevations. Annual readings from the San Antonio station are listed in Table 1 (23).

Tropical storms occasionally affect the area with strong winds and heavy rains. Rains that accompany these storms often bring 12 to 15 inches of rain in 24 hours. The record rainfall for the area occured in September of 1952 when 23 to 26 inches fell in 24 hours in the vicinity of Boerne and Blanco. The storm was triggered by an advancing cool front (23).

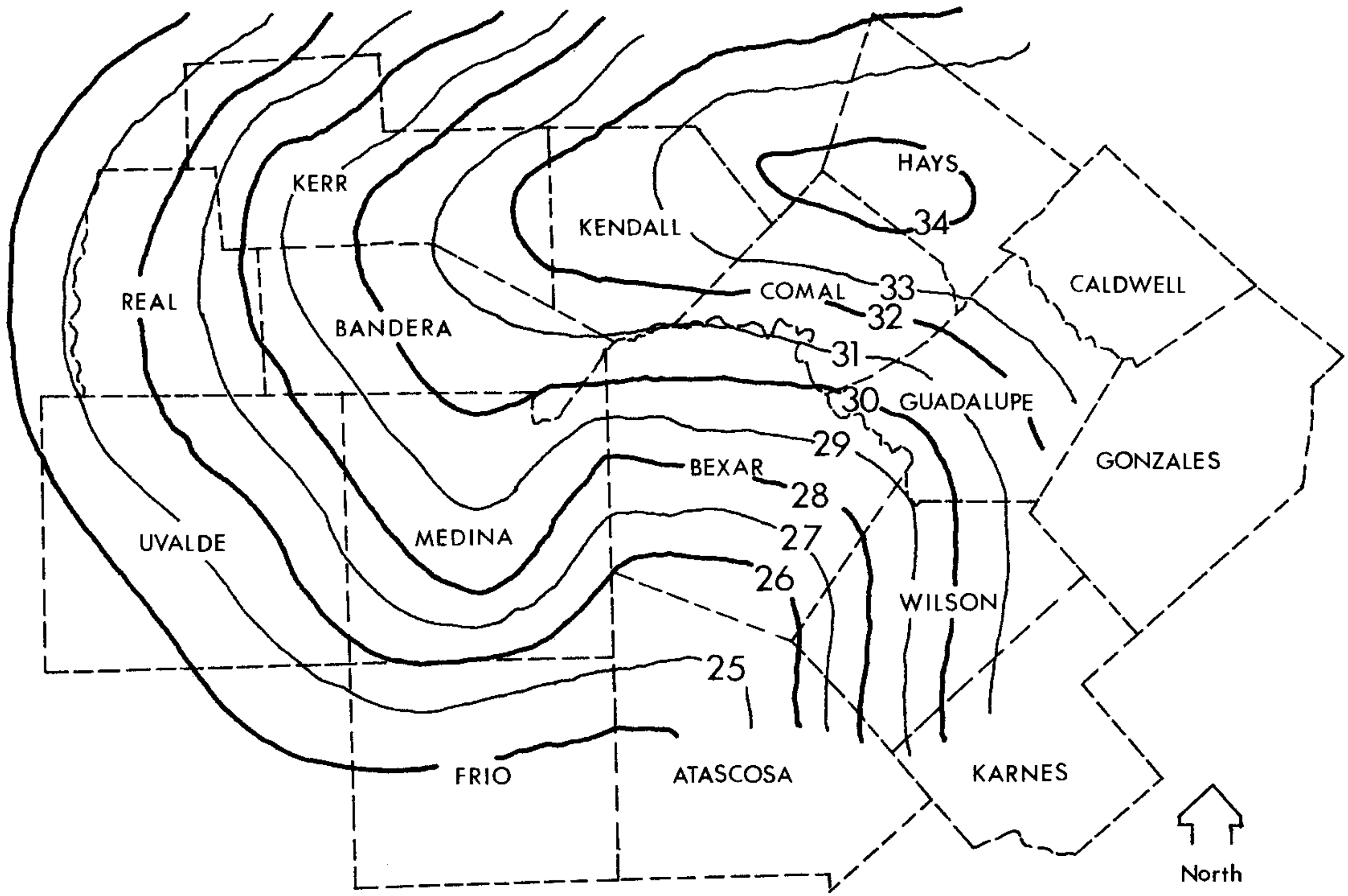


Figure 3.
Average Annual Rainfall

TABLE 1

ANNUAL RAINFALL
SAN ANTONIO, TEXAS
1871-1970

Year	Inches	Year	Inches	Year	Inches	Year	Inches
1871	22.79	1900	37.19	1930	22.79	1960	29.76
1872	29.09	1901	16.44	1931	25.00	1961	26.47
1873	34.02	1902	24.79	1932	35.57	1962	23.90
1874	41.55	1903	33.11	1933	17.64	1963	18.65
1875	21.95	1904	29.38	1934	27.65	1964	31.88
1876	-	1905	32.59	1935	42.93	1965	36.72
1877	30.20	1906	20.42	1936	34.11	1966	21.42
1878	39.60	1907	27.77	1937	26.07	1967	29.09
1879	22.80	1908	28.52	1938	23.26	1968	30.39
		1909	14.92	1939	18.83	1969	31.41
						1970	-
1880	41.91	1910	16.22	1940	30.79		
1881	26.78	1911	18.68	1941	26.34		
1882	36.39	1912	23.73	1942	38.46		
1883	-	1913	37.68	1943	20.51		
1884	-	1914	33.67	1944	33.19		
1885	32.92	1915	27.28	1945	30.46		
1886	26.22	1916	27.66	1946	45.17		
1887	20.13	1917	10.11	1947	17.32		
1888	40.55	1918	29.91	1948	23.64		
1889	38.95	1919	50.30	1949	40.81		
1890	29.79	1920	19.56	1950	19.86		
1891	30.04	1921	28.53	1951	24.44		
1892	25.81	1922	24.59	1952	26.24		
1893	18.24	1923	32.71	1953	17.56		
1894	21.75	1924	23.65	1954	13.70		
1895	26.07	1925	14.99	1955	18.18		
1896	34.09	1926	30.39	1956	14.31		
1897	15.92	1927	22.75	1957	48.83		
1898	22.49	1928	30.20	1958	39.69		
1899	19.71	1929	29.24	1959	24.50		

Soils in the area of the Edwards Plateau generally overlay cretaceous limestones and are characterized by steep slopes, shallow depths and limestone fragments in the surface soil. These types of soils are generally least suitable for agriculture and urban development due to the high cost of pre-use preparation. Soils in the lower regions of the valley are of the Rio Grande Plains Association. These soils have a medium to course texture with great depth. The permeability and stability of these soils render them ideal for intensive urban development. Soil will charaterize the type of vegetation and in turn the wildlife within the area. Juniper, oak, and mesquite which are surrounded by dense undergrowth dominate the area, and in the river bottoms cypress is not unusual. Turkey, deer, quail, javalina, and squirrels are the most abundant wildlife in the area. These species are non-migratory and will continue to inhabit and populate the area as sufficent water and feed are available. Freshwater fish exist in abundance in the reservoirs and streams in the basin. All game fish common to the southeastern area of the United States are found in the region and additionally rainbow trout can be found in the cold waters near Canyon Dam. Birdlife is likewise varied in the area including quail, duck, turkey, goose, hawk and eagle. The most famous North American bird which treverses the region is the almost extinct whooping crane, as it makes its annual migration between Texas and Canada(11).

Although the area depends solely upon groundwater to meet the water needs of the population, there is a limited amount of surface water in the region. Canyon, Medina, McQuency, Dunlap, Brauning, Calaveras, and Mitchell are the major lakes and reservoirs in the area. All are man made and are used primarily for flood control, waste treatment, power generation, or as recreational facilities. Mitchell Lake is part of the San Antonio waste treatment process and as such has limited recreational usage. It does, however, supply water for irrigation use (11).

The economy of the San Antonio area is centered in the city of San Antonio in Bexar County. The population of Bexar County was set at 830,460 by the 1970 census, up 20.9 percent from the 1960 census of 687,151 (4). The population figures for 1970 and 1960 along with the rate of change for the various subdivisions of Bexar County are shown in Table 2.

From Table 2 it can be seen that the trend of the area has been a steady movement to the suburbs, however, the city itself has experienced tremendous growth. Of the 830,460 people residing within Bexar County 764,621 are white, 56,630 are black and 9,209 are of other races. There are 408,334 males compared to 422,126 females. There are 23,567 households which house 794,033 individuals. The population is approximately evenly distributed between those over and under 25 years of age (4).

Portions of the area were declared a Standard Metropolitan Statistical Area (SMSA) by the Bureau of the Census. This is a designation applied to an area whose city bounderies and subdivisions are interconnected as such that compilation of data for one particular sector is meaningless. For this reason it is better to speak of the economy of the area in terms of the SMSA rather than the various governmental units.

Total population within the San Antonio SMSA in 1970 was 864,014. Of this 794,737 were white, 59,887 were black and 9,390 were of some other race. The 1967 Census of Business reports there were 6,301 retail establishments within the SMSA with total sales of $1,075,774,000.00 and a payroll of $132,524,000.00 annually. The Central Business District of San Antonio accounted

TABLE 2

POPULATION BY POLITICAL SUBDIVISION
1960 AND 1970

Political Subdivision	1970	1960	Percent Change
China Grove	329		
Randolph	5,329		
Kirby	2,558	680	267.2
St. Hedwig	690	589	17.1
Converse	1,383		
Hill County Village	636	418	52.2
Hollywood Park	2,299	783	193.6
Live Oak	2,779		
Selma	207		
Universal City	7,613		
Windcrest	3,371	441	664.4
Grey Forist	385		
Leon Valley	1,960	536	265.7
Shavano Park	881	343	156.9
Alamo Heights	6,933	7,552	8.2
Balcones Heights	2,504	950	163.6
Castle Hills	5,311	2,622	102.6
Fort Sam Houston	10,535		
Olmos Park	2,250	2,457	8.4
San Antonio City	654,153	587,718	11.3
Terrell Hills	5,225	5,572	6.2
Elmendorf	400		
Lackland	19,141		

for 18.6 percent of sales within the SMSA. Central Business District (CBD) sales were $200,480,000.00 and its payroll was $34,760,000.00. Table 3 shows the retail business by type for the SMSA and Table 4 shows the same information for the Central Business District (3).

In 1967,there were over 1300 financial institutions in the region including banking, insurance, and real estate. Of these 51 were commercial banks. In addition, there is a local Federal Reserve Branch Bank located in San Antonio. In 1967, total deposits of the region's banks were $1,374,105,000 and total loans outstanding were $650,643,000. Using the ratio of loans to deposits as a measure of responsiveness of area banks to the financial needs of the community, a ratio of .47 to 1 indicates that current banking policy should help sustain the continued economic growth demands of the area (8).

Educational institutions in the area account for more than 8 percent of the non-agricultural employment. There are forty-one independent school districts, two junior colleges and five senior colleges. In addition, numerous private organizations provide specialized training which is not provided in other educational institutions.

Agriculture in the area consists of private farms whose production is common to the southwest region. Cattle and beef production account for a portion while the rest are farm products. In the past several years, farm production has remained constant while the number of farms have decreased (8).

The water resource system of the region consists primarly of groundwater supplied by the Edwards and the assoicated surface sources. There is adequate water such that the area is not facing immediate water shortages. However, the lead time required for a long range planning program is such that an

TABLE 3

RETAIL TRADE BY TYPE SMSA

Type	Number Establishments	Sales	Payroll
Building Materials, Hardware, and Farm Equipment Dealers	205	$39,217,000	$4,877,000
Department Stores	28	171,954,000	26,861,000
Variety Stores	72	19,957,000	
Miscellaneous General Merchandise Stores	90	17,001,000	
Food Stores	1,200	227,105,000	16,200,000
Automobile	468	215,629,000	21,966,000
Gasoline Service Stations	986	91,229,000	8,573,000
Women's Clothing, Specialty Stores, Furriers	108	25,005,000	3,646,000
Other Apparel and Accessory Stores	191	37,612,000	6,012,000
Family Clothing Stores	25	7,730,000	1,155,000
Shoe Stores	66	11,600,000	1,610,000
Apparel and Accessory Stores	15	923,000	197,000
Furniture Stores	97	25,633,000	3,837,000
Home Furnishings Stores	50	4,460,000	813,000
Household Appliance, Radio, Television and Music Stores	127	18,343,000	2,879,000
Eating Places	925	68,899,000	16,311,000
Drinking Places (Alcoholic Beverages)	573	13,318,000	1,643,000
Drug Stores and Proprietary Stores	167	30,451,000	5,117,000
Liquor Stores	153	21,424,000	2,074,000
Sporting Goods Stores And Bicycle Shops	33	2,801,000	330,000
Jewelry Stores	72	10,994,000	1,606,000
Florists	84	2,779,000	471,000

TABLE 4

RETAIL TRADE BY TYPE CBD

Type	Number Establishments	Sales	Payroll
Building Materials, Hardware, and Farm Equipment Dealers	4	$1,305,000	$174,000
Department Stores	5	57,685,000	13,994,000
Variety Stores	9	6,490,000	1,258,000
Miscellaneous General Merchandise Stores	12	2,361,000	297,000
Food Stores	39	3,083,000	320,000
Automobile Dealers	30	56,646,000	5,358,000
Gasoline Service Stations	16	1,249,000	98,000
Women's Clothing, Specialty Stores, Furriers	27	12,310,000	1,890,000
Other Apparel and Accessory Stores	63	17,651,000	3,294,000
Family Clothing Stores	11	3,217,000	651,000
Shoe Stores	22	3,313,000	459,000
Apparel and Accessory Stores, N.E.C.	5	287,000	100,000
Furniture Stores	17	9,570,000	1,828,000
Eating Places	96	8,777,000	2,307,000
Drinking Places (Alcoholic Beverages)	46	1,779,000	340,000
Drug Stores and Proprietary Stores	27	5,202,000	937,000
Liquor Stores	6	712,000	35,000
Sporting Goods Stores and Bicycle Shops	8	1,465,000	186,000
Jewelry Stores	22	6,552,000	1,094,000
Florists	4	120,000	25,000

immediate effort for planning must be begun so that the appropriate responses may be made to potential problems in the future.

CHAPTER 2

GOVERNMENTAL ORGANIZATIONS

The San Antonio area, as the rest of the United States, is a pluralistic society with a mixed economy. The process of opinion formation, planning, development and utilization of water resources along with its decision-making and adminstration are partly public and partly private. At present numerous private organizations, both commerical and non-profit, exist in the San Antonio area. These private institutions act in their own interest and do not consider planning for future water resources as part of their present activities. The major planning tool that can be used to encourage private institutions to act in the interest of the public are the rules and regulations placed upon these private concerns or tax and/or other incentives made available to these private organizations.

The philosophy of the political system instigated in the United States has consciously attempted to maintain a nation in which the patterns of decision-making and adminstration often appear amorphous. This is certainly true for the San Antonio Area. However, this area is fortunate in that the myriad of public organizations at all levels are cooperating among themselves toward the common goal of water resource planning. This is unique in itself.

Within the region there exists an intricate network of governmental units which have the responsibility for water resource planning. These include competing agencies, at local and state levels. In addition to the problems which arise from the interaction of these various agencies, Texas Water Law gives little support to public development of integrated ground and surface systems (32). A short description and summary of activities of each of the agencies which have jurisdiction over the water resources of the San Antonio Basin is given below (32).

1. The San Antonio Water Board

The San Antonio Water Board was established 1925 and is governed by a Board of Trustees that is appointed by the City Council. In turn, the Board appoints the general manager who acts as chief administrator of the Board. Even though the Board is owned by the city, and must act in accordance with the terms of the bond ordinance under which the system's bonds are issued, it is still somewhat autonomous in conducting its business.

Since the City Water Board is the largest supplier and distributor of water in Bexar County, it is greatly concerned with the development of additional water resources and conservation of the existing supply. The Board has participated in various programs aimed at developing means of recharging the Edwards aquifer and developed supplemental surface water supplies from the surrounding areas.

2. Water Control and Improvement Districts

The Texas Legislature authorized water control and Improvement Districts to control irrigation, flood control, drainage, reclamation, forest preservation, conservation, creation of hydro-electric power, navigation, sewage, garbage collection and waste disposal within the district's boundries. The Legislature has also empowered these districts to issue bonds and levy taxes.

There are eleven water control and improvement districts in the San Antonio area. Seven of their districts actually furnish water to the area. Five of the districts deal in sewage disposal, and two of them also engage in garbage collection and disposal. Three are not active at this time.

All of the active districts have issued bonds for the construction of water systems. These bonds are paid off through water charges and taxes. Three of the districts have raised funds by levying taxes on property. In order to avoid heavily indebted, or inadequate systems from districts that are situated in newly annexed territory, the City Water Board requires these water districts to maintain adequate systems in accordance with a set of criteria.

3. Bexar-Medina-Atascosa Water Improvement District One

This district has approximately 34,000 acres under its jurisdiction; about 60% of the district lies within Medina County, about 10% in Atascosa County, and 30% in Bexar County. This district is empowered to obtain and distribute water for irrigation, domestic, power, and commercial purposes. Persons using water for domestic purposes must install their own purification facilities. The district also levies a 20% ad valorem tax and a "maintenance charge" on all persons residing within the boundaries of the district, and a "crop water charge" is paid by all persons who actually use water from Medina Lake.

4. Bexar Metropolitan Water District

The Bexar Metropolitan Water District is a multi-purpose conservation district with jurisdiction over "metropolitan" San Antonio (Alamo Heights, Olmos Park and Terrell Hills are excluded from this jurisdiction). The district has the power to "control, conserve, protect, preserve, distribute, and utilize storm and flood waters of rivers and streams and underground water situated in the district and to control and regulate the accumulation and disposal of sewage, wastes, refuse, and residuum." It also has the power to protect and preserve the purity of surface and underground waters, and to make rules and regulations pertaining to operations and providing penalties for violations thereof. In addition, the district is also authorized to regulate waters of the San Antonio River watershed, and to cooperate with the state and federal governments in such undertakings.

The functions and jurisdictional area of this district overlap those of the City Water Board and San Antonio River Authority; however, the district has limited itself to water supply, and confined its operation to Southwest San Antonio and Castle Hills.

5. San Antonio River Authority

The San Antonio River Authority is a conservation and reclamation district. It includes all of that part of the state within the boundaries of the counties of Bexar, Wilson, Karnes and Goliad.

The Authority is empowered to construct, maintain, and operate navigable canals and waterways, to effectuate flood control, conservation and use, for all beneficial purposes of ground, storm flood, and unappropriated water in the districts, and also to effectuate irrigation, soil conservation, sewage treatment, and pollution control. The Authority is also designated the responsibility to develop parks, recreational facilities, encourage forestation and reforestation, and to maintain the ecosystem balance.

In addition, the Authority is assigned the responsibility of preparing a master plan for the maximum development of the soil and water resources of the entire district, including plans for the complete utilization, for all economically beneficial purposes, of the water resources of the district. In accordance with the master plan, the Authority may act as a coordinating agency dealing with the problems of water supply and distribution on a basin-wide basis. It may also act as a bargaining agency in negotiating with other river authorities across the state, and agencies of the federal government.

The Authority can also issue negotiable bonds and levy taxes (maximum tax rate is two cents per one hundred dollars). However, a large segment of the Authority's revenue comes from a fifteen cent flood control tax which is levied and collected by the county.

6. The Edwards Underground Water District

The Edwards Underground Water District was created for the purpose of "protecting, conserving, and recharging the Edwards Underground Reservoir". The District consists of all of Uvalde County, most of Medina and Bexar Counties, and a small part of Comal and Hays Counties (See Figure 4).

Three directors from each county area make up the fifteen member Board of Directors of the district. An Engineer-Manager and Assistant Secretary, with a central office in the Tower Life Building, San Antonio, Texas constitutes the business set-up of the district. A 2 cent tax per $100 dollar property evaluation provides the funds for operation (9).

The U. S. Geological Survey carries on the continuing work of making studies of the amount of water that goes into and out of the reservoir, its movement through the reservoir, and the quality of the water.

The District operates a data gathering and evaluation program with the U. S. Geological Survey and expands the scope as needed to insure prevention of pollution from any source. Bulletins on water quality, recharge and discharge are published each year.

A policy of cooperating with all Soil Conservation Districts where proposed improvements will add to the natural recharge has been adopted. Each project is judged on its merits, and financial participation by the District is based on the value of the increased water made available.

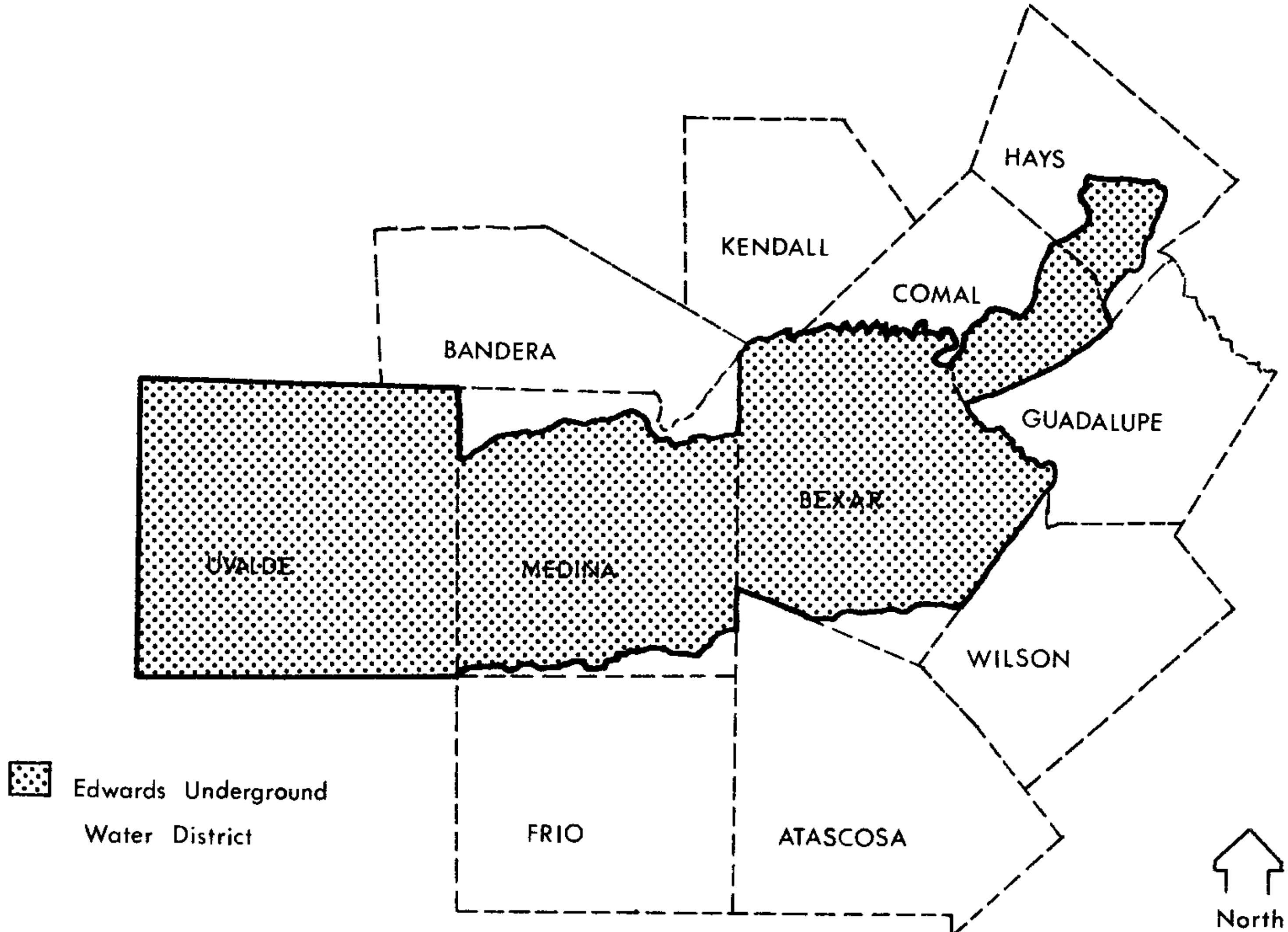


Figure 4.
Edwards Underground Water District

The District has participated in the Seco Creek Water-Shed Project in Medina, Uvalde and Bandera Counties, in the Leona River Watershed in Uvalde County, and in the Dry Comal-Blieders Creek Project in Comal County on field surveys. The District has also assisted the San Antonio River Authority in the construction of the Salado Creek Project in Bexar County in order to increase the recharge.

7. Alamo Area Council of Governments.

The Alamo Area Council of Governments (AACOG) is a regional planning organization whose headquaters are located in San Antonio. The organization consists of ten member counties, each of which pays dues to support the organization. The ten member counties of AACOG are Atascosa, Bandera, Bexar, Comal, Frio, Guadalupe, Kendall, Medina, Uvalde, and Wilson (See Figure 5).

The general objectives of AACOG are to promote the general welfare of the citizens of the region through planning. The areas of interest of AACOG are general government, health, public protection, human resources, recreation, economy, housing, transportation and education.

AACOG has been especially active in studying the water resources of the area and in helping promote necessary programs aimed to improve the water quality. During the past year a Regional Waste Water Development Plan was completed. In addition, a study was made of the recharge requirements and potential of the Edwards Aquifer. Another notable achievement is the development of a data storage and retrieval system for water related data, including rainfall, and data maps through the cooperation of local, state, and federal agencies. Due to the effort of AACOG there is an efficent method to exchange data and information concerning both quantity

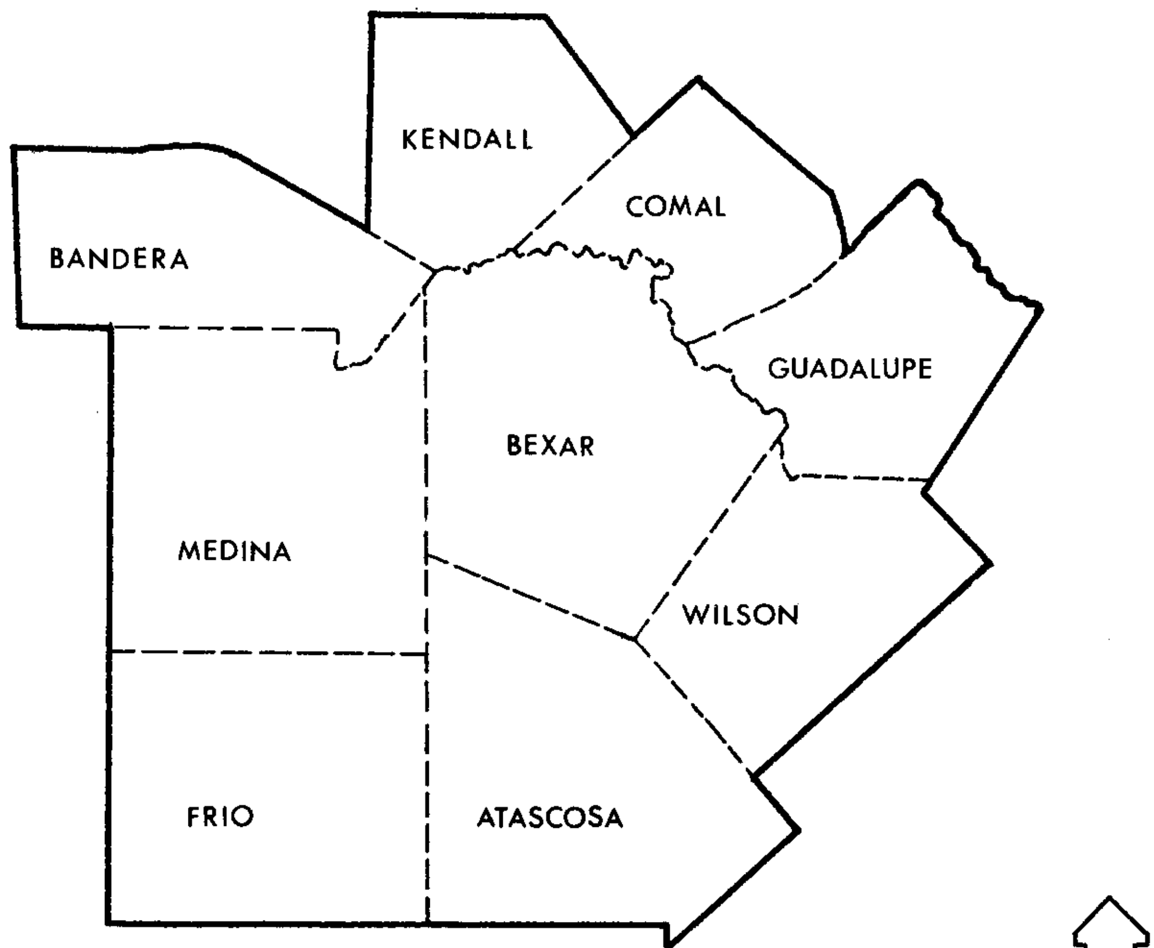


Figure 5.
Alamo Area Council of Governments

and quality in water among government agencies in the region.

8. Bexar County

Bexar County is authorized to issue bonds for flood control, navigation, irrigation, and drainage improvement. The county can also levy ad valorem taxes as well as other authorized taxes for flood control improvements.

9. Soil Conservation Districts

Soil Conservation Districts are created and surpervised by the State Soil Conservation Board. Each District is governed by an elected five-member Board of Supervisors. Each District serves as an independent subdivision of the state. Among other things, the Districts carry out control measures to prevent flood damage, and furnish equipment or other material that will assist farmers and ranchers in carrying out erosion control and water management. The Districts are also assigned the responsibility of cooperating with any other agency in order to prevent erosion and water damage within the District.

10. The Texas Water Rights Commission

The Commission is composed of three full-time members that are appointed by the Governor, and an Executive Director who is chief administrative officer of the Commission.

The primary functions of the Commission are regulating and permitting use of public water of the state. Its general responsibilities include the protection of public safety and private property from damage which could occur from improperly designed dams and reservoirs. It also regulates the diversion and distribution of canals. Along these lines, any particular project may be declared a public nuisance and ordered to be abated or removed if the project is found to be dangerous to public safety.

The Commission creates several kinds of water districts and approves the organization and feasibility of most water districts which propose to construct projects that are to be financed by the issuance of bonds. Most of the water districts and river authorities are subject to continuing supervision by the Commission.

The Commission recognizes and provides local interests with continuing opportunities to develop projects for local and regional needs; however, the Commission usually considers the State Water Plan as a guide for authorizing projects. Resolution of any conflict between the State Water Plan and private, local, and/or regional interests is vested in the Commission. Ultimate authority is vested in the courts (32).

11. The Texas Water Development Board

The Texas Water Development Board has been specifically charged with the prepration, development, and formulation of a comprehensive State Water Plan. This shall include a definition and designation of river basins and watersheds as separate units for purposes of water development, and inter-watershed transfers of water resources. In addition, the Board will assist and advise local governments in undertaking different water development projects.

The Texas Water Plan is to be used as a flexible guide to select policies for water resource development within the state. The Board also has the responsibility to investigate all matters concerning the quality of groundwater in the state and report its findings to the Texas Water Quality Board.

The Texas Water Development Board consists of six members, appointed by the Governor on six year terms with confirmation of the state Senate. Each Board member must have at least ten years of successful business or professional experience. The Governor has the power to designate the chairman of the Board.

In relation to the San Antonio area, the publications of the Board have proven to be an invaluable source of information. Published reports in the area of groundwater, quantity, quality and structural information are of particular importance. Also numerous studies defining and describing the surface water quantity and quality along with urban runoff and flooding studies are especially pertinent to the San Antonio area. The Systems Engineering Group of the Board has developed several mathematical models and stream simulation programs which aid in the study of discription of the San Antonio River itself (33).

12. The Texas Water Quality Board

The Texas Water Quality Board replaced the Texas Water Pollution Control Board. It is composed of seven members chosen as follows: Three are appointed by the Governor; the other four are the Executive Director of the Texas Water Development Board, the State Commissioner of Health, the Executive Director of the Parks and Wildlife Department, and the Chairman of the Texas Railroad Commission.

The Board is the principle authority in the state on matters relating to the quality of water within the state. Under the Water Quality Act, the Board is to be informed on all aspects of water quality, specifically water pollution, its control and abatement. The Board is further directed to assist in resolving questions as to the respective authorities and duties of state agencies which have a vested interest in water quality control functions, and in doing so, to minimize duplication of activities so that state policy for controlling and maintaining the quality of the state's water can be achieved.

13. The General Land Office

The General Land Office is administered by the Land Commissioner who is elected by the people of Texas. It has several roles in the supervision and management of state water, namely: 1) the power to assist and supervise levee improvement and drainage districts, 2) the power to make and approve agreements or contracts for cooperating with any branch of the federal, state, county, or city governments, 3) the power to regualte oil and gas development of public lands, and to prevent pollution of waters in the areas where such development occurs.

14. Texas Soil Conservation Board

The Soil Conservation Board is a state agency delegated to perform the state-level administration of soil conservation district programs. The Board's activities are primarily directed along three lines: 1) district program planning and assistance, 2) education and promotion of conservation in general, and 3) approval or disapproval of applications for federal assistance in planning and implementing watershed protection and flood prevention projects as contemplated in Public Law 566 and 1018. The federal government, through the Board, provides the entire financial support for the improvements of flood prevention (32).

15. The Environmental Protection Agency

In an effort to rationally and systematically organize the activities of the Federal Government related to the environment, the Environmental Protection Agency (E.P.A.) was formed and given the responsibility to oversee the major Federal pollution control programs. The agency is headed by an Administrator and a Deputy Administrator appointed by the President.

The agency was formed to integrate the control and responsibility of different programs related to water, air, solid wastes and radiation pollution from the departments of Agriculture, Interior and Health, Welfare and Education, the Atomic Engery Commission and the Federal Radiation Council.

The principal functions of E.P.A. include; 1) the establishment and enforcement of environmental proctection standards consistent with national environmental goals, 2) the conduct of research on the adverse effects of pollution and on methods and equipment for controlling it, 3) the gathering of information on pollution and the use of this information in strengthening environmental protection programs and recommending policy changes, 4) assisting the Council of Environmental Quality in developing and recommending to the President new policies for the protection of the environment, with particular reference to abating pollution by the establishment and enforcement of pollution control standards.

The establishment of the E.P.A. will permit quick response to environmental problems which were previously beyond the capability of individual pollution control programs. It will enable the establishment and enforcement of uniform standards not previously possible (29).

16. The U. S. Army Corps of Engineers

The Corps of Engineers is primarily responsible for naviagtion improvement of river and harbors, and an additional responsibility of undertaking flood control measures. The Corps is also concerned with the following; 1) drainage and soil conservation, 2) conservation of water for domestic, industrial and agricultural use, 3) hydro-electric power, 4) recreation, 5) public health and sanitation, 6) prevention of salt water intrusion,and 7) fish and wildlife preservation.

On December 23, 1970 President Nixon signed Executive Order 11574 which provides for the establishment of a federal permit program to regulate the discharge of waste in waters of the United States. The U. S. Army Corp of Engineers was designated as the responsible agency to the administer this Executive Order. The Executive Order provides for permits to be issued before waste may be discharged in waterways in order to insure that water quality standards are being met. This program applies to both existing and new installations and a comprehensive enforcement mechanism is provided.

17. Bureau of Reclamation (Department of Interior)

The Bureau of Reclamation is concerned not only with providing water facilities for irrigation, but also with water resource development in general. The Bureau is specifically concerned with the development of water resources for 1) generation of hydro-electric power, 2) drainage, 3) flood control, 4) improvement of navigation, 5) silt control, 6) creation of recreational facilities, 7) wildlife refuge, and most importantly 8) the provision of water supplies for municipal and industrial use. Probably the most important contribution of the Bureau in Texas is the many comprehensive studies of water problems in Texas which the Bureau has conducted itself or in which it has participated.

18. The United State Geological Survey

The U. S. Geological Survey is responsible for determining, appraising, and describing surface and underground water resources so as to aid in the solution of the nation's water problems. These investigations are undertaken by the Water Resources Division of the Survey, and are financed on a federal-local matching fund basis. Within the San Antonio area the U. S. Geological Survey is specifically charged with studying the quantity and quality of the water of the Edwards Underground aquifer. In addition, a continuing study of the structural conditions of this aquifer is pursued. The USGS also monitors eight stream guaging stations in the San Antonio River Basin.

19. Soil Conservation Service (Department of Agriculture)

The Soil Conservation Service conducts exhaustive research into various aspects of soil erosion problems. It has the responsibility of administering the upstream watershed programs which provide assistance to local watershed groups for building flood control and erosion prevention structures when these programs are approved by Congress. As mentioned previously, the Service cooperates closely with the State Soil Conservation Board and the local Soil Conservation Districts in their respective activities.

20. The Public Health Service (Department of HEW)

The Public Health Service collects data to show the degree of pollution of the nation's waterways, and conducts research for finding more effective and efficient means of treating municipal and industrial wastes. The Service is authorized to provide monetary grants to municipalities for the construction of needed sewage treatment plants. In addition, the Service conducts studies of the various state laws pertaining to pollution control. The Service also provides the states with model statutes that can aid the states in their attempts to abate pollution.

21. Other Federal Agencies

Numerous other federal agencies, as well as congressional committees, have responsibilities for various aspects of water planning and development, namely: the U. S. Weather Bureau, the Bureau of Mines, the Bureau of Census, the Federal Power Commission, the Forest Service, the Committees of Public

Works and Interior and Insular Affairs, The council on Environmental Quality and the Water Resources Council. In reality,one may justifiably conclude that all agencies at every level of government have responsibilities for conserving and developing our water resources, for everything we do deals with some aspect of water (32).

22. Other Local Agencies

Among the various local organizations which help construct San Antonio's water resource policy is the River Walk Commission. The River Walk is that area of the San Antonio River which winds through the Central Business District (See Figure 6). The River Walk Commission is a seven member advisory commission appointed by the city council (28). The purpose of the commission is to preserve and promote the natural beauty of the area. The success of the River Walk is evident by tourist visitation numbering more than 1 million people in 1969. Other local agencies which help shape San Antonio's water policy are the Department of Public Works, City Planning Department, San Antonio Parks and Recreation Department, and the San Antonio City Council.

In view of the overlapping and conjunctions of responsibility and authority of different governmental agencies, the general description of the duties of each individual agency and its interface with other agencies may be demonstrated in Table 5.

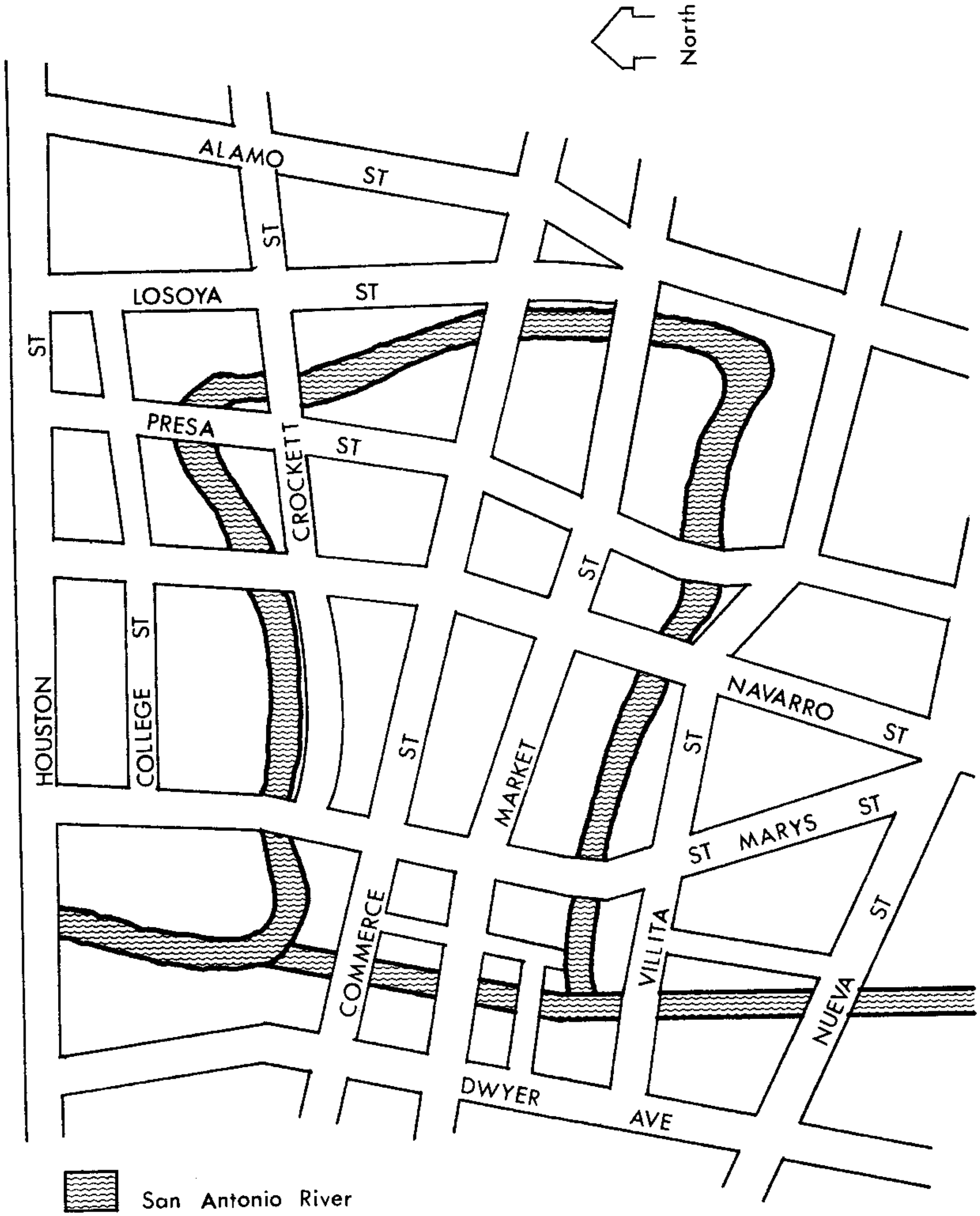


Figure 6.
River Bend Area, San Antonio, Texas

TABLE 5

MOST IMPORTANT MANAGEMENT AGENCIES IN SAN ANTONIO

LEVEL OF FUNCTION	FEDERAL	STATE	REGIONAL	LOCAL
WATER SUPPLY	Environmental Protection Agency Water Resources Council Bureau of Reclamation U. S. Geological Survey Public Health Service	Water Control and Improvement District Texas Water Development Board Texas Water Rights Commission	Edwards Underground Water District San Antonio River Authority	San Antonio City Water Board
SEWAGE DISPOSAL	Environmental Protection Agency Public Health Service Council on Environmental Quality	Water Control and Improvement District	San Antonio River Authority	Bexar Municipal Water District Sewer Division (Dept. of Public Works)
WATER QUALITY MANAGEMENT	Environmental Protection Agency Water Resources Council Public Health Service Council on Environmental Quality	Texas Water Quality Board	Edwards Underground Water District San Antonio River Authority	
FLOOD CONTROL & DRAINAGE	Environmental Protection Agency U. S. Army Corps of Engineers Soil Conservation Service	Water Control and Improvement District Soil Conservation Service General Land Service Texas Soil Conservation Board	San Antonio River Authority	Bexar Metropolitan Water District Bexar County
WATERFRONT LAND USE	Environmental Protection Agency U. S. Army Corps of Engineers		Alamo Area, Council of Governments	San Antonio River Walk Commission City Planning Department
RECREATION & OPEN SPACE	Environmental Protection Agency Bureau of Reclamation U. S. Army Corps of Engineers Council on Environmental Quality	Texas Parks And Wildlife	San Antonio River Authority	San Antonio Parks And Recreation Department
REGIONAL & CITY PLANNING			San Antonio River Authority Alamo Area, Counicl of Governments	San Antonio City Planning Department
MONITORING	U. S. Geological Survey Weather Bureau			

CHAPTER 3

WATER QUALITY

Water quality standards are usually based on one of two primary criteria: stream standard or effluent standards. Stream standards can be based on dilution requirements or the receiving water quality standard in terms of the threshold value of specific pollutants or the requirements restricted by a benefical use of the water. Effluent standards can be based on the concentration of pollutants which can be discharged or on the degree of treatment required (7). The water quality in terms of both criteria will be discussed in this chapter.

Wastewater of the San Antonio area emanates from four primary sources: (a) municipal sewage, (b) industrial wastewater, (c) agricultural runoff, and (d) storm and urban runoff. Of these the most important is domestic sewage treatment.

During the past twenty-five years, the quality of the San Antonio River has degenerated from one of the crystal clear spring waters to a murky oxygen defficient stream transporting essentially the diluted treated waste effluent from San Antonio Metropolitan area. The major source of the pollution to the river is the domestic sewage generated by the nearly 1 million inhabitants of the area. Each day more than 400,000 tons of treated waste are dumped into the San Antonio River. It is equivalent to 40 tons of biological chemical oxygen demands and eight tons of phosphate which is derived from the domestic detergents. Therefore, the downstream stretches of the San Antonio River have witnessed heavy algal growth as well as anaerobic biological growth.

The stream quality is found highly influenced by the climate and reliability of wastewater treatment facilities. Data collected along stretches of the San Antonio River downstream of the wastewater outfalls over the past 50 years indicates that excessive algal growth, dissolved oxygen depletion, and dissolved solids contamination can be controlled through imporved waste treatment operations. Existing wastewater treatment facilities in the region do not have the ability to remove the nutrients and biological oxygen demands in the effluent from secondary wastewater treatment. Though plans for advanced wastewater treatment have been invisioned, little progress has been made.

The total travel time of the river between San Antonio and the coast is approximately two weeks. This time period is not even adequate for the complete biological oxidation of those biodegradable pollutants which are discharged with treated effluents by natural purification process. Therefore, stretches of the San Antonio River between San Antonio and the coast are constantly under polluted situations. The esthetic value and the recreation activities along this 250 mile stretch of the San Antonio River, as well as the San Antonio Bay area have been completely ruled out of consideration. Two studies have been conducted (six, seven) and both concluded that the major cause of this pollution effect is the discharge of pollutants by the treated waste effluent in Bexar County.

In order to increase the recreational or esthetic values of the San Antonio River downstream from San Antonio to the estuaries of the Gulf Coast area, the improvements for wastewater treatment and quality management for the basin must be initiated immediately. The improvement of the treatment facility may be accomplished by the addition of advanced wastewater treatment processes or by the practice of domestic wastewater reclamation through industrial use, agricultural irrigation, and impoundment for power generation. The economic tradeoff between the benefits along with recreational use and the additional costs accrued by the supplementary treatment facilities must be studied in detail. The river basin quality management can also be improved with the utilization of the existing stochastic decision making procedures as well as the analysis for reliability of urban water quality control. Although tougher water quality standards may be the enforcement approach to facilitate or to push forward such improvements, the economic incentives associated with recreation, public response, and the marine resources may be emphasized.

The Alamo Area Council of Governments area presently has 43 domestic waste discharge facilities. The majority of these treatment facilities were built to service subdivision needs and treat less than one million gallons per day (MGD) of sewage. Over 90 percent of the sewage generated in the area is treated in a plant complex south of San Antonio City composed of Leon Creek and Rilling Road facility (25). A regional sewage system is currently planned which will eliminate the majority of the smaller disposal plants.

Planning for a regional sewage network must take into account a variety of problems, some have been resolved and some are still in the solution development stage. For example, the accurate prediction of population and population density is nearly impossible to attain. In addition, the type and amounts of wastes generated depend in part upon the state of current technology. As technology changes, types and amounts of wastes will change along with alternatives available to treat the waste effluent. The plan must be of a flexible nature; however, so that alternative land use plans may be considered and the associated sewer costs may be evaluated.

Sewer systems generally follow the natural paths of streams. This is the case for the regional plan being developed. A regional stream numbering system was developed to aid not only the sewer plan but also the total water resource system of the area. This system is utilized to store and retrieve all water related data of the region. The system has been named the AACOG SORET Numbering System.

The Soret Numbering System is the result of a concentrated effort to standardize the sample location points throughout the entire region. The Soret System is basically a systematic method of classifying all streams by relative location.

The major stream of the river basin is designated by the number 00.00. 00.00 throughout the length. First order streams are all streams greater than two miles that are direct tributaries of the major stream. Each first order stream is represented by the numbers of the first two digits starting at the first tributary from the mouth of the San Anronio River and increasing progressively upstream. As one progresses upstream, streams which enter the major stream from the right side are given even numbers and those which enter from the left side are given odd numbers (See Figure 7).

Second order streams are streams which enter first order streams and the same systematic numbering system is used to designate the location of these streams. Third, fourth and fifth order streams are streams which enter the next lower order streams and the same systematic numbering system is used.

Watersheds in the region are also represented by assigning similiar

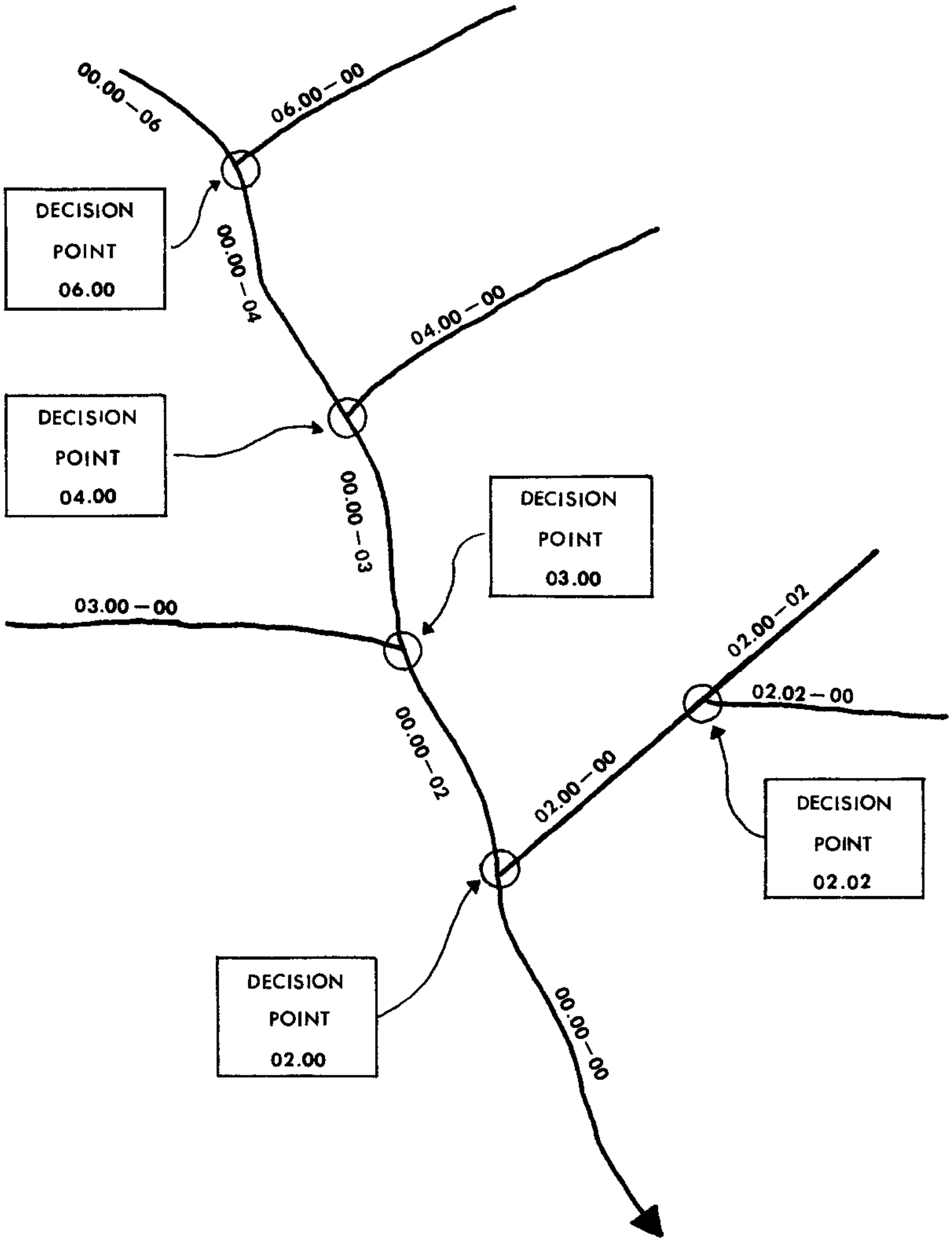


Figure 7.
Example of SORET Numbering System

location numbers. Watersheds are delineated only at the junction of streams. Therefore, one stream at the junction will always be of higher order than the other stream. The watershed number of the section of a stream is designated by the stream number followed by a hyphen and the number of the lower order stream which creates a junction (26).

This uniform numbering system is extremely adaptable to EDP techniques. For example, if the identification numbers are arranged in decending order, a network is established whereby one moves progressively downstream until the mouth is reached.

Obviously the junction of two streams is normally the decision point in the sub-system. There are over 500 decision points in Bexar County alone. At each decision point a set of constraints can be imposed upon the sub-system (25).

The San Antonio River Authority regularly (weekly) monitors the return flow quality for twenty-four treatment plants within the region. In addition, water quality at ten stream locations, eight of which are USGS stream guaging stations, are also monitored. In order to accomplish the monitoring program efficiently, the River basin has been broken down into six regions. Appendix I describes each region and the program for the region.

As discussed previously, the availability of natural surface water resources varies from season to season. During the winter, a substantial amount of good quality water is available to dilute the sewage generated in the AACOG region. During the summer the available natural flow decreases to almost zero.

Another factor which influences the quality of the stream is the temperature of the surface water. It was found that the stream assimilation capacity during winter is greater than that during summer in the San Antonio area.

In order to determine the treatment requirement, a dissolved oxygen contour graph has been established by the Alamo Area Council of Governments for three stream conditions: summer, winter, and average(25). These contour graphs are used to predict the dissolved oxygen level at specific locations downstream due to specific levels of organic pollutants. It should be noted that the operation of the waste treatment facility constitutes a very major portion of effective water resources management. Most treatment facilities are designed to remove ninety percent of the pollutants in the wastewater. The present dissolved oxygen deficiency in river waters in the region indicates that the treatment is not sufficient nor will it be in the future (25).

An integral part of this study was the development of an EDP data aquistion program. The EDP program will retrieve, and to a limited extent analyze selected data from user designated sampling points in the river basin. The program is based on the SORET Numbering System explained above. Appendix II contains the documentation and a brief description of this EDP program.

An analysis of the stream quality at selected sampling points within the river basin was conducted and the results are shown in Figures 9-20. The sampling points selected were 52.00.00.00 and 52.06.00.00. Their approximate location in the river basin is illustrated by Figure 8. The water quality parameters examined were BOD, DO, pH and Temperature. The histograms and associated data in Figures 9-16 are a portion of the output from the EDP data aquistion program. The histograms graphically indicate the frequency distribution of each selected parameter per sample point for the past two years.

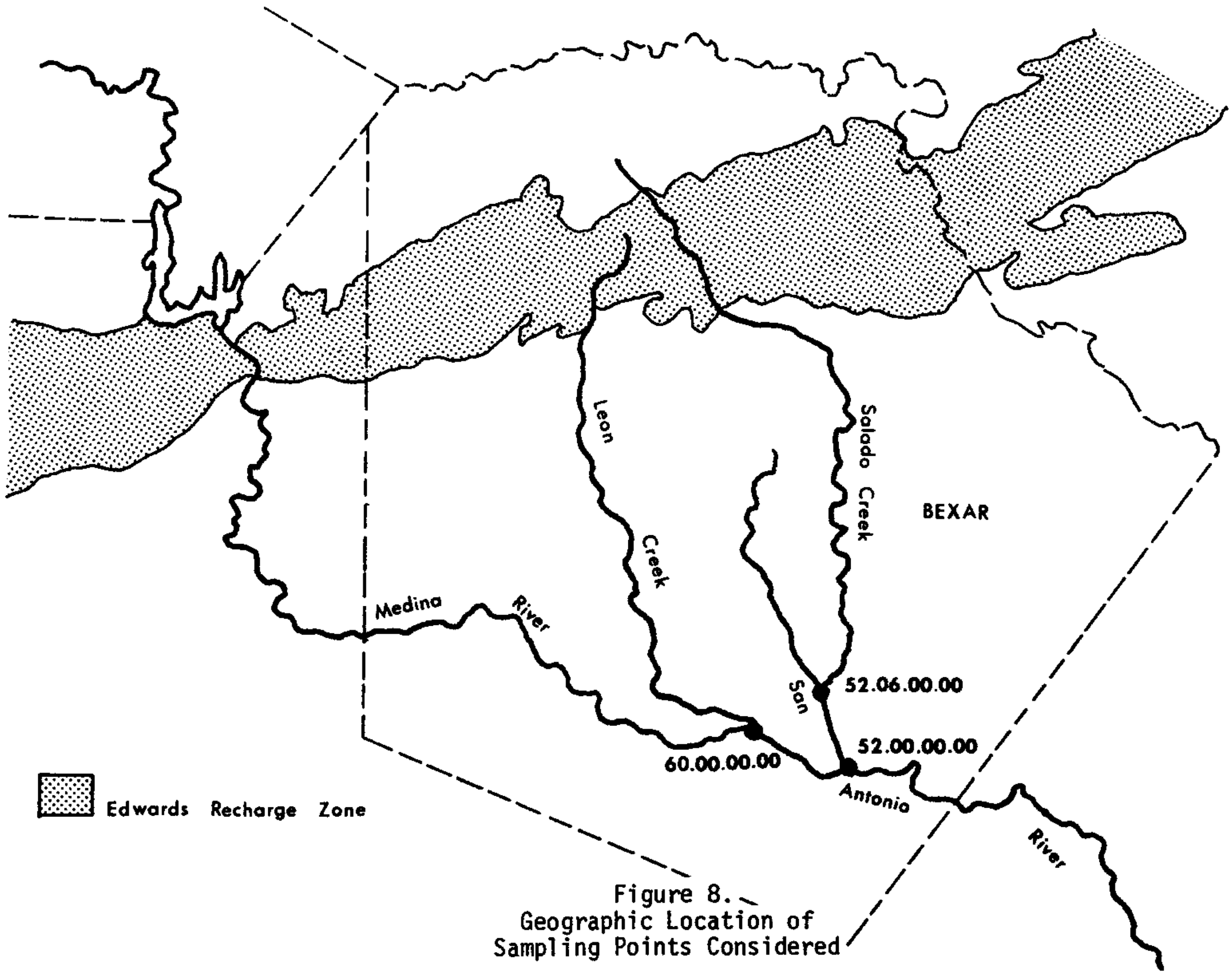
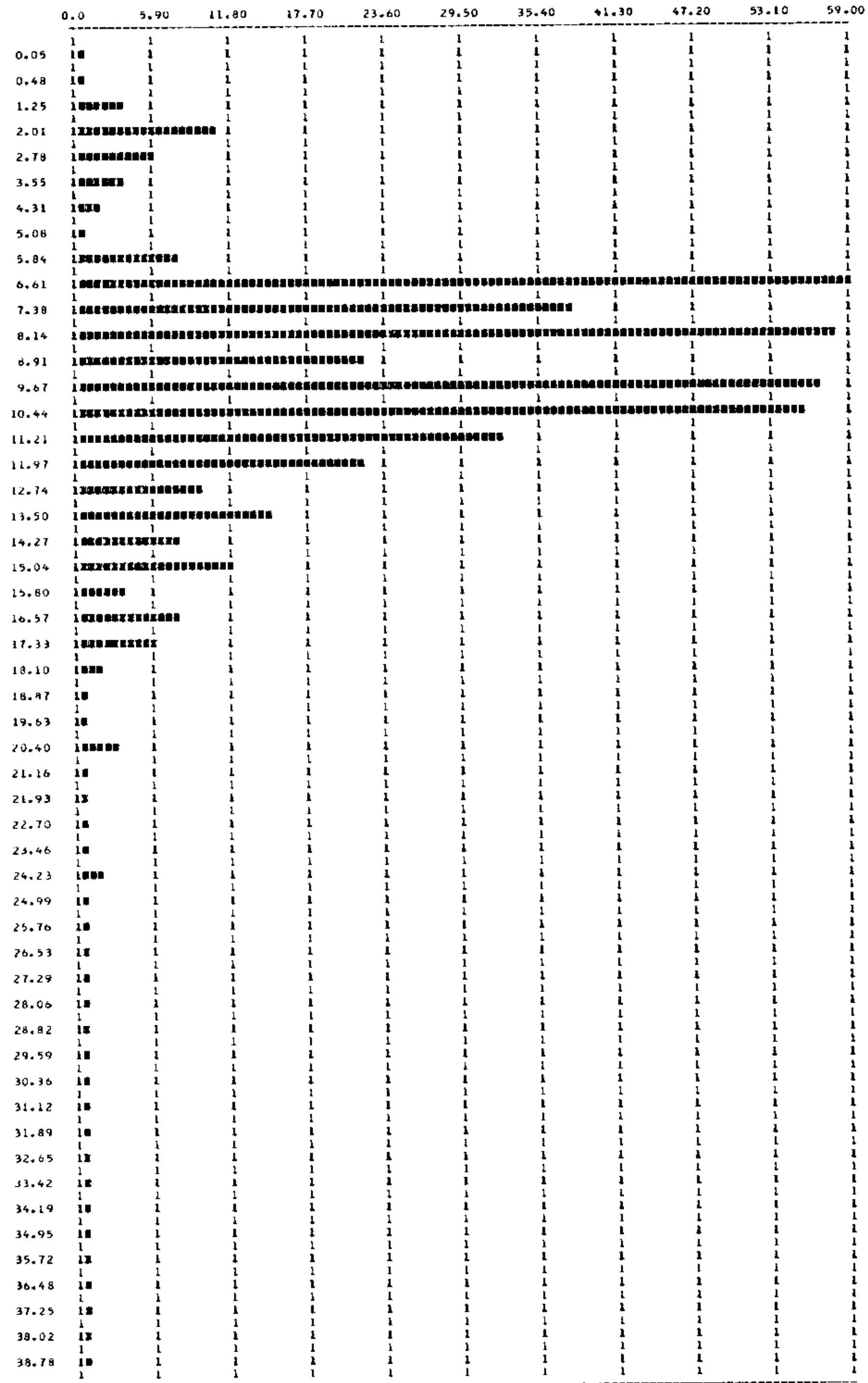


Figure 8.—
Geographic Location of
Sampling Points Considered

FREQUENCY HISTOGRAM OF BOD DATA

LOCATION 520000, WATERSHED 0, POINT 0, YEAR 0, DAY 0, TIME 0

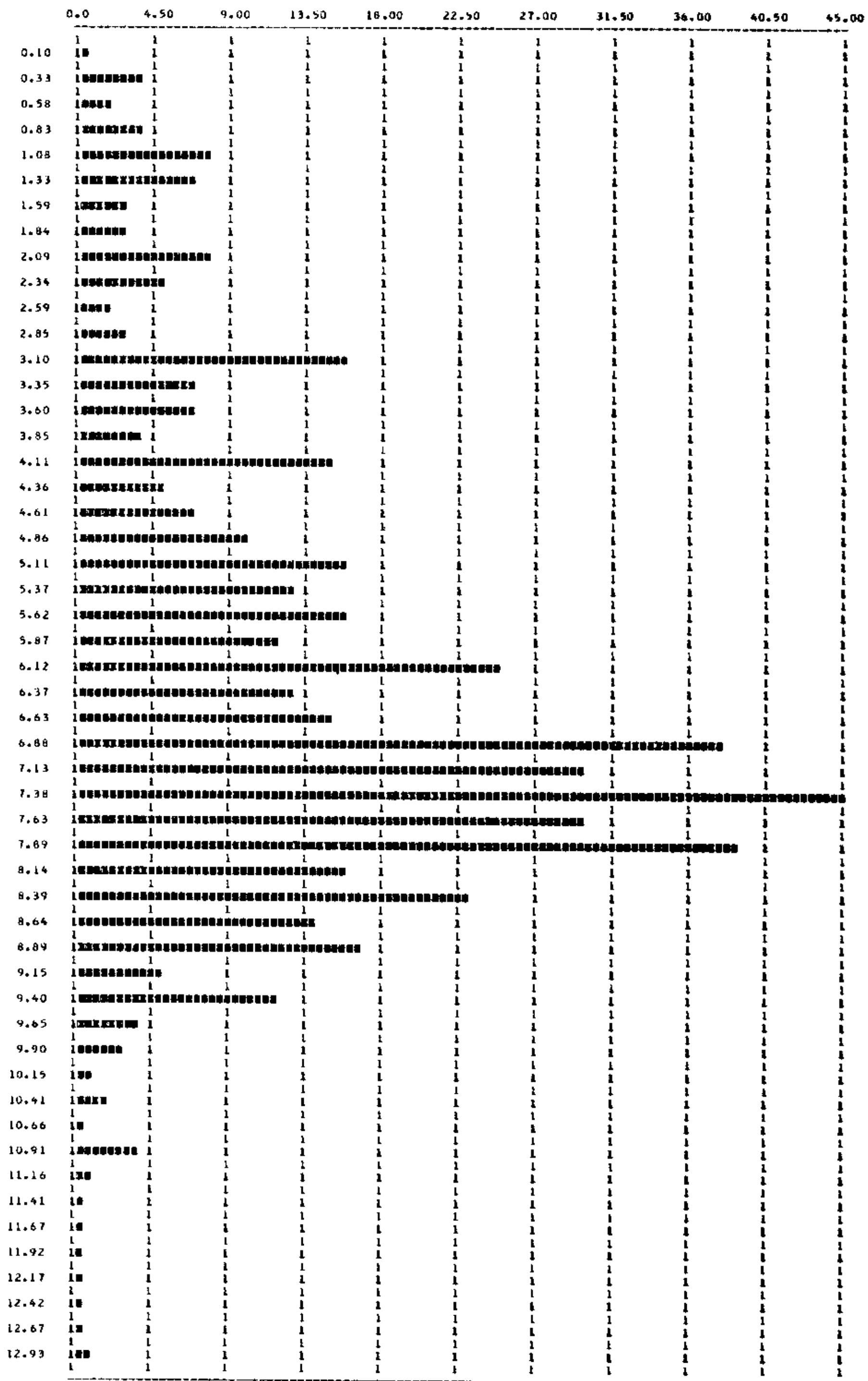


MEAN = 9.683 STANDARD DEVIATION = 3.940 MINIMUM = 0.100 MAXIMUM = 38.400

FIGURE 9

FREQUENCY HISTOGRAM OF DO DATA

LOCATION 520000, WATERSHED 0, POINT 0, YEAR 0, DAY 0, TIME 0



MEAN = 6.347 STANDARD DEVIATION = 2.259 MINIMUM = 0.200 MAXIMUM = 12.800

FIGURE 10

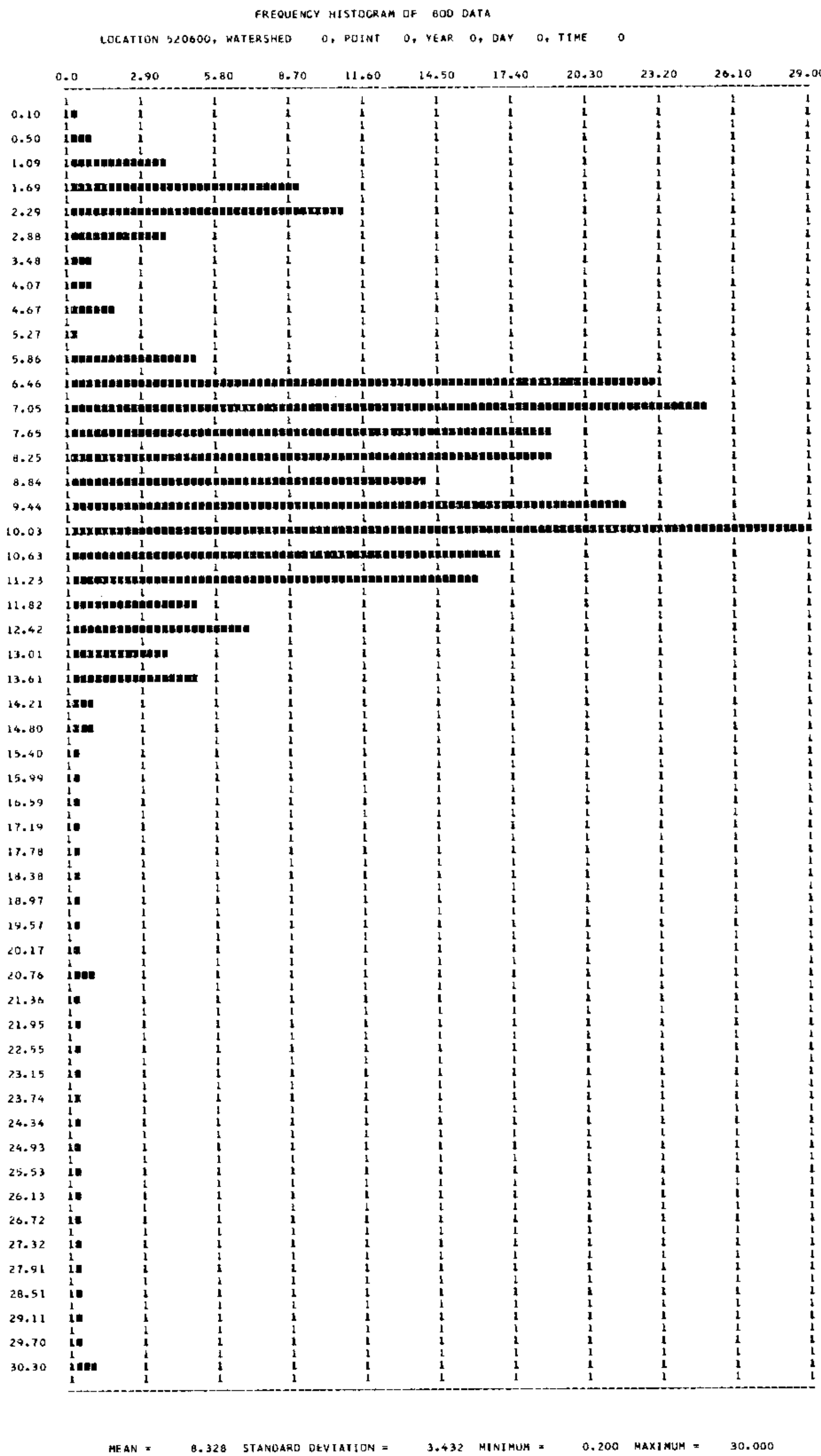

FREQUENCY HISTOGRAM OF BOD DATA
LOCATION 520600, WATERSHED 0, POINT 0, YEAR 0, DAY 0, TIME 0
0.0 2.90 5.80 8.70 11.60 14.50 17.40 20.30 23.20 26.10 29.00
0.10 0.50 1.09 1.69 2.29 2.88 3.48 4.07 4.67 5.27 5.86 6.46 7.05 7.65 8.25 8.84 9.44 10.03 10.63 11.23 11.82 12.42 13.01 13.61 14.21 14.80 15.40 15.99 16.59 17.19 17.78 18.38 18.97 19.57 20.17 20.76 21.36 21.95 22.55 23.15 23.74 24.34 24.93 25.53 26.13 26.72 27.32 27.91 28.51 29.11 29.70 30.30
MEAN = 8.328 STANDARD DEVIATION = 3.432 MINIMUM = 0.200 MAXIMUM = 30.000

FIGURE 13

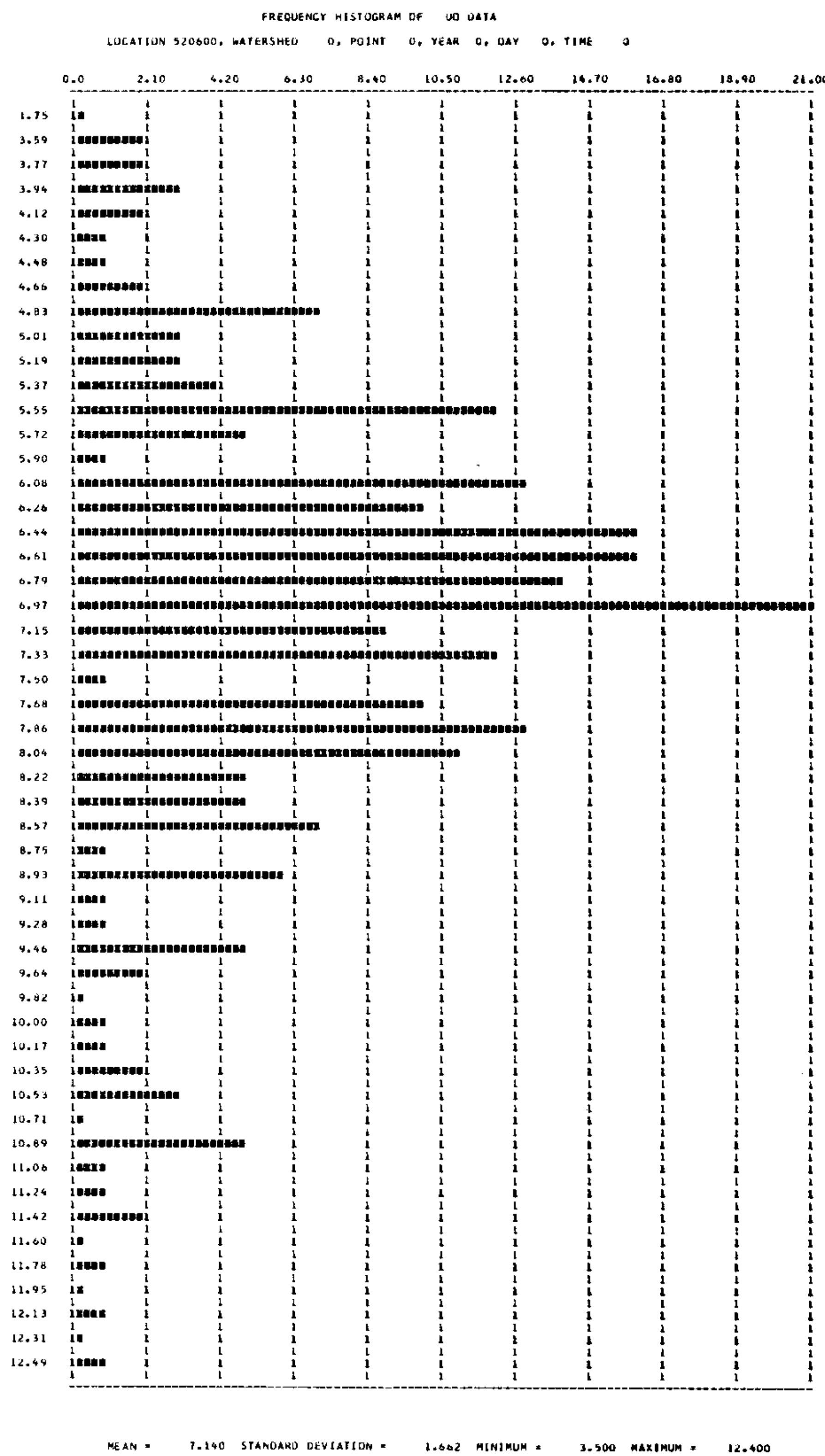
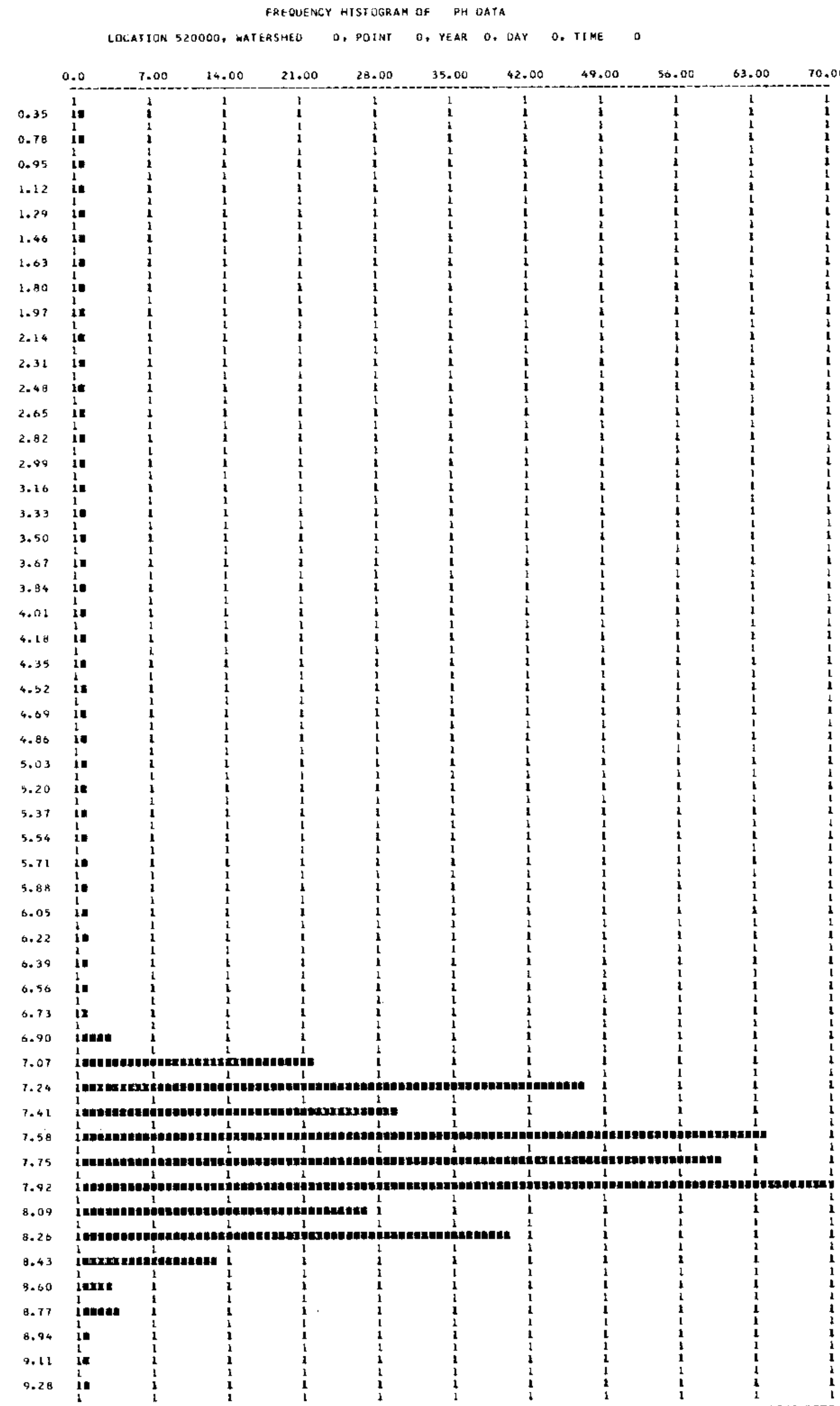

FREQUENCY HISTOGRAM OF UO DATA
LOCATION 520600, WATERSHED 0, POINT 0, YEAR 0, DAY 0, TIME 0
0.0
2.10
4.20
6.30
8.40
10.50
12.60
14.70
16.80
18.90
21.00
1.75
3.59
3.77
3.94
4.12
4.30
4.48
4.66
4.83
5.01
5.19
5.37
5.55
5.72
5.90
6.08
6.26
6.44
6.61
6.79
6.97
7.15
7.33
7.50
7.68
7.86
8.04
8.22
8.39
8.57
8.75
8.93
9.11
9.28
9.46
9.64
9.82
10.00
10.17
10.35
10.53
10.71
10.89
11.06
11.24
11.42
11.60
11.78
11.95
12.13
12.31
12.49
MEAN = 7.140 STANDARD DEVIATION = 1.662 MINIMUM = 3.500 MAXIMUM = 12.400

FIGURE 14



MEAN = 7.711 STANDARD DEVIATION = 0.555 MINIMUM = 0.700 MAXIMUM = 9.200

FIGURE 11

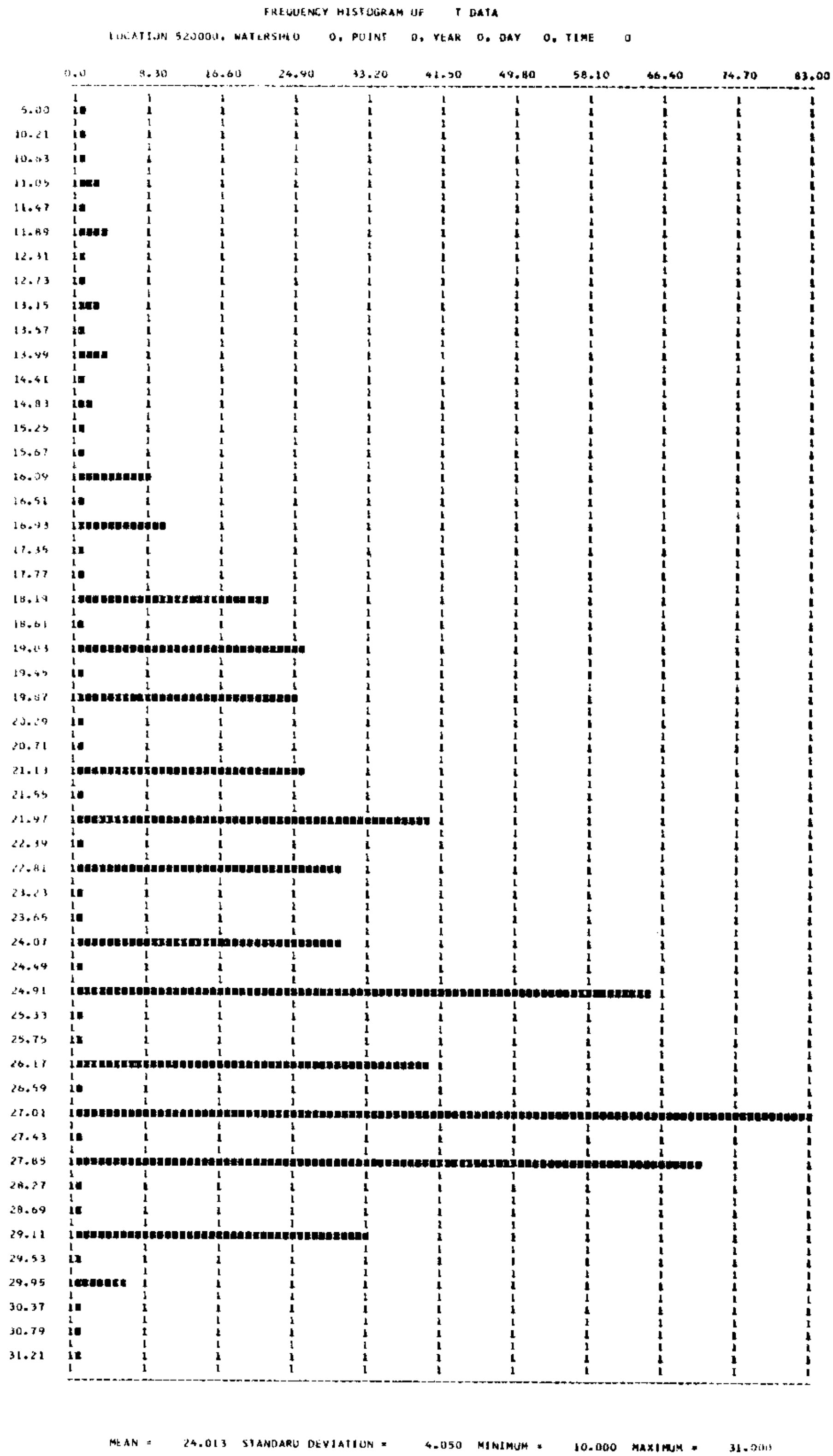
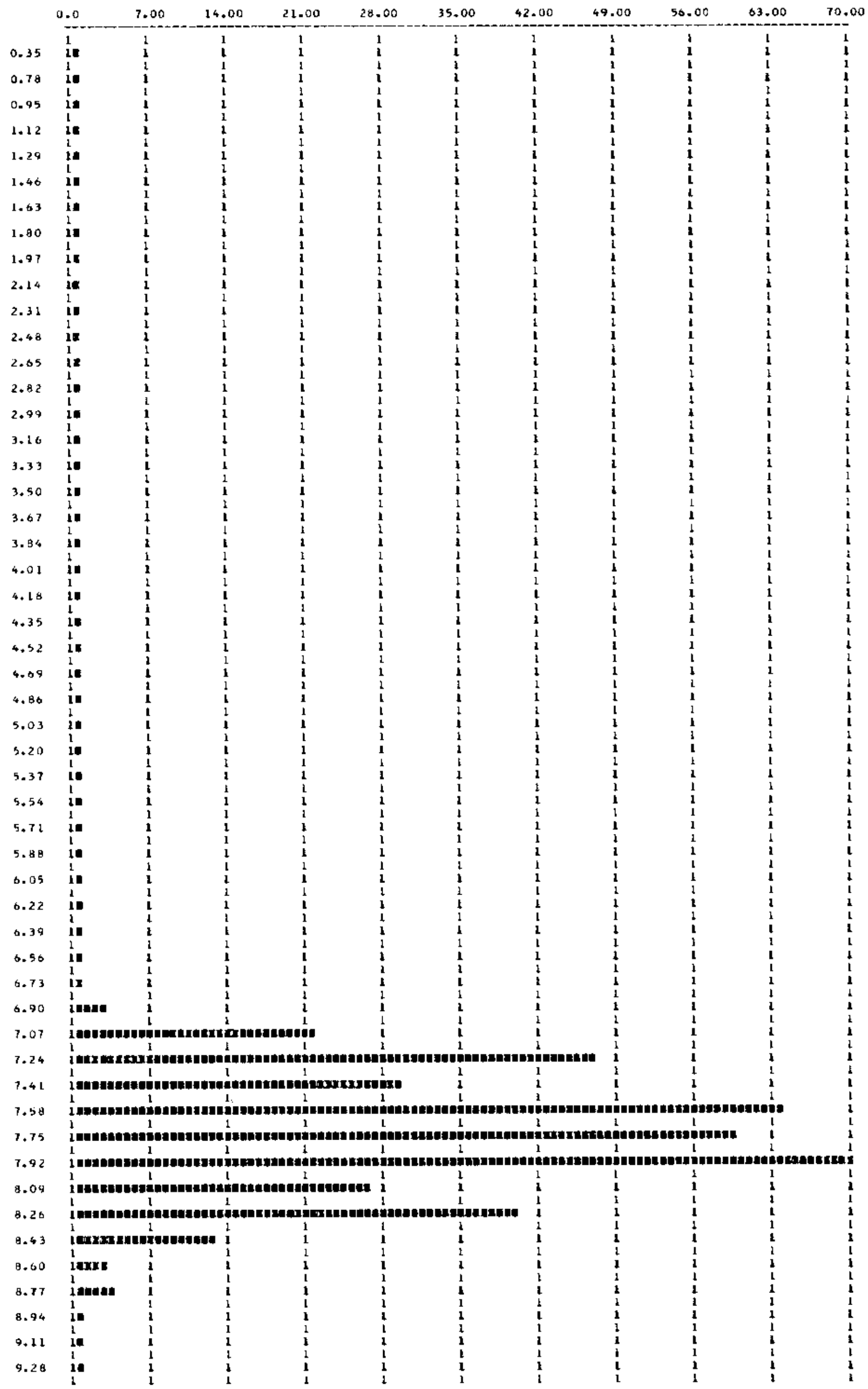

FREQUENCY HISTOGRAM OF T DATA
LOCATION 520000, WATERSHED 0, POINT 0, YEAR 0, DAY 0, TIME 0
0.0 8.30 16.60 24.90 33.20 41.50 49.80 58.10 66.40 74.70 83.00
5.00
10.21
10.63
11.05
11.47
11.89
12.31
12.73
13.15
13.57
13.99
14.41
14.83
15.25
15.67
16.09
16.51
16.93
17.35
17.77
18.19
18.61
19.03
19.45
19.87
20.29
20.71
21.13
21.55
21.97
22.39
22.81
23.23
23.65
24.07
24.49
24.91
25.33
25.75
26.17
26.59
27.01
27.43
27.85
28.27
28.69
29.11
29.53
29.95
30.37
30.79
31.21
MEAN = 24.013 STANDARD DEVIATION = 4.050 MINIMUM = 10.000 MAXIMUM = 31.000

FIGURE 12

FREQUENCY HISTOGRAM OF PH DATA

LOCATION 520000, WATERSHED 0, POINT 0, YEAR 0, DAY 0, TIME 0

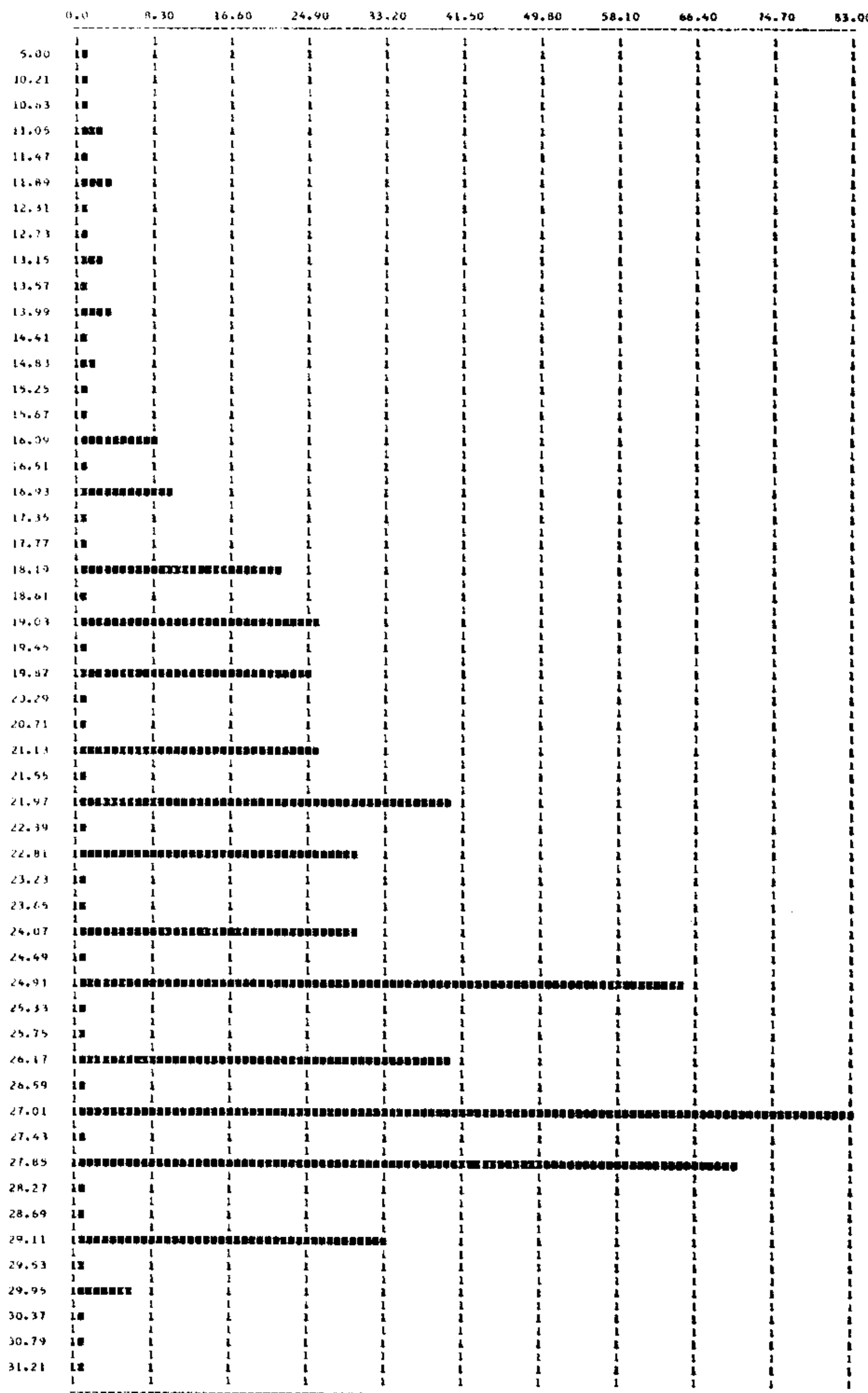


MEAN = 7.711 STANDARD DEVIATION = 0.555 MINIMUM = 0.700 MAXIMUM = 9.200

FIGURE 11

FREQUENCY HISTOGRAM OF T DATA

LOCATION 520000, WATERSHED 0, POINT 0, YEAR 0, DAY 0, TIME 0

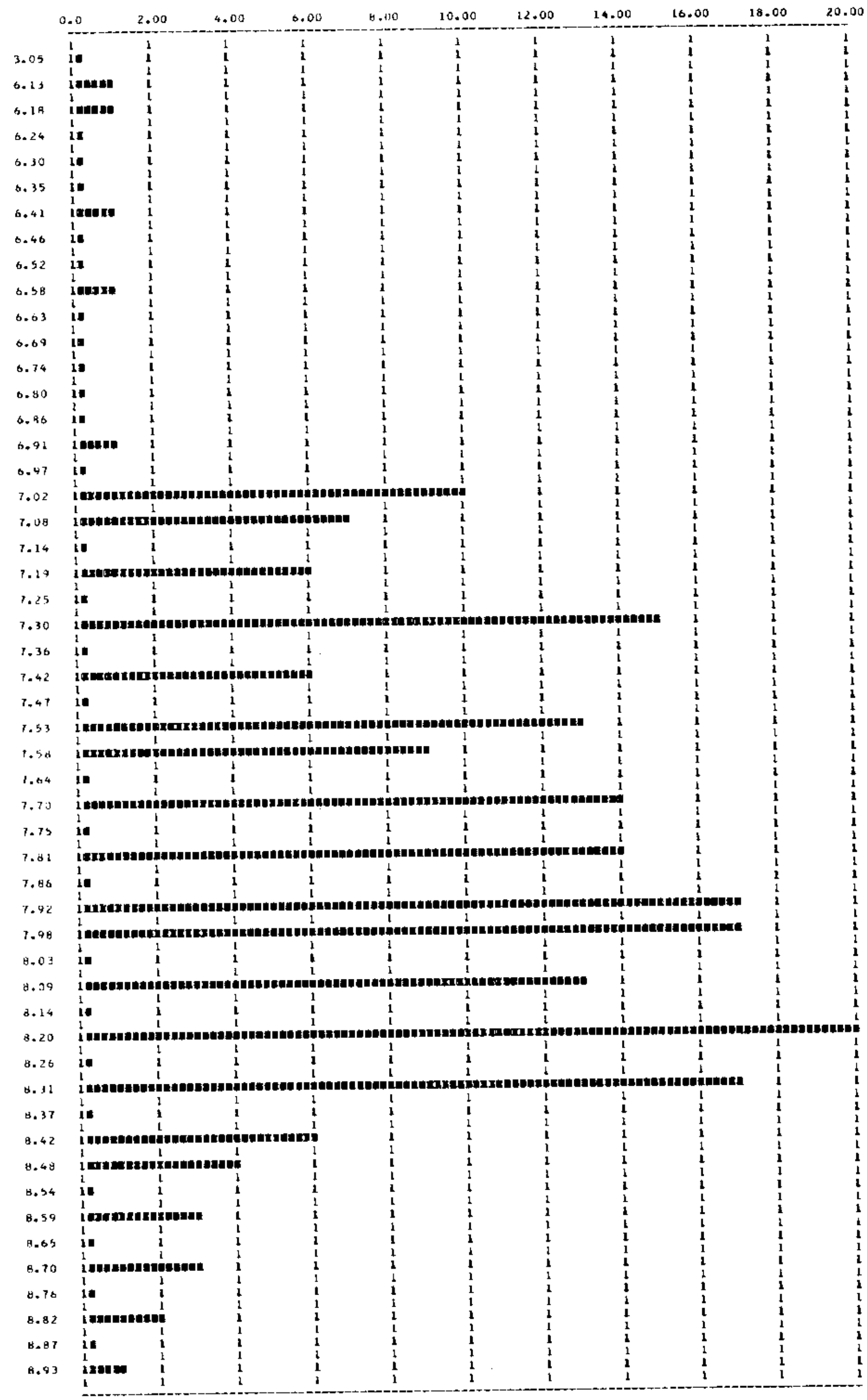


MEAN = 24.013 STANDARD DEVIATION = 4.050 MINIMUM = 10.000 MAXIMUM = 31.000

FIGURE 12

FREQUENCY HISTOGRAM OF PH DATA

LOCATION 520600, WATERSHED 0, POINT 0, YEAR 0, DAY 0, TIME 0



NUMBER OF DATA OBSERVATIONS = 875 NUMBER OF CONTROL CARDS = 2

MEAN = 7.799 STANDARD DEVIATION = 0.495 MINIMUM = 6.100 MAXIMUM = 8.900

FIGURE 15

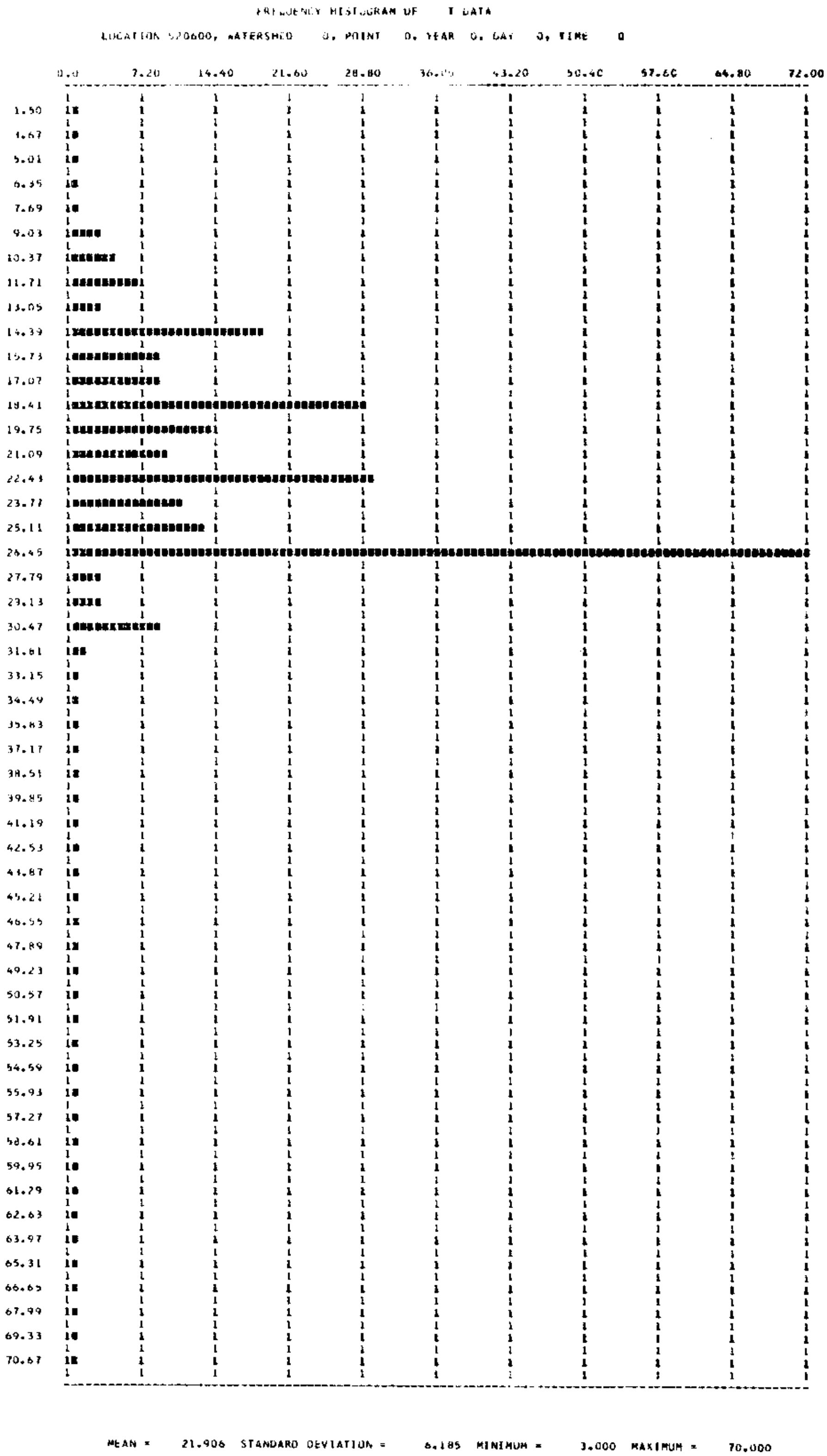

FREQUENCY HISTOGRAM OF T DATA
LOCATION 570600, WATERSHED 0, POINT 0, YEAR 0, DAY 0, TIME 0
0.0
7.20
14.40
21.60
28.80
43.20
50.40
57.60
64.80
72.00
MEAN = 21.906 STANDARD DEVIATION = 6.185 MINIMUM = 3.000 MAXIMUM = 70.000

FIGURE 16

Cumulative distribution functions can be empirically derived from additional data provided by the EDP data aquistion program. The cumulative distribution function indicates the probability that an observed value will be less than or equal to that indicated. Figures 17-20 show comparative cumulative distribution functions of each sampling point for each water quality parameter. For examples Figure 17 compares the cumulative distribution functions for BOD at the two points sampled. It can be seen that the probability of BOD being less than or equal to 7.5 mg/l at decision point 52.00.00.00. is .30 while at decision point 52.06.00.00 the probability is nearly .35. Since decision point 52.06.00.00 is nearer the treated waste outfalls of Rilling Road Plant than 52.00.00.00 this is an indication that the biodegradable organic material contained in stream water is oxidized as the diluted pollutants move downstream.

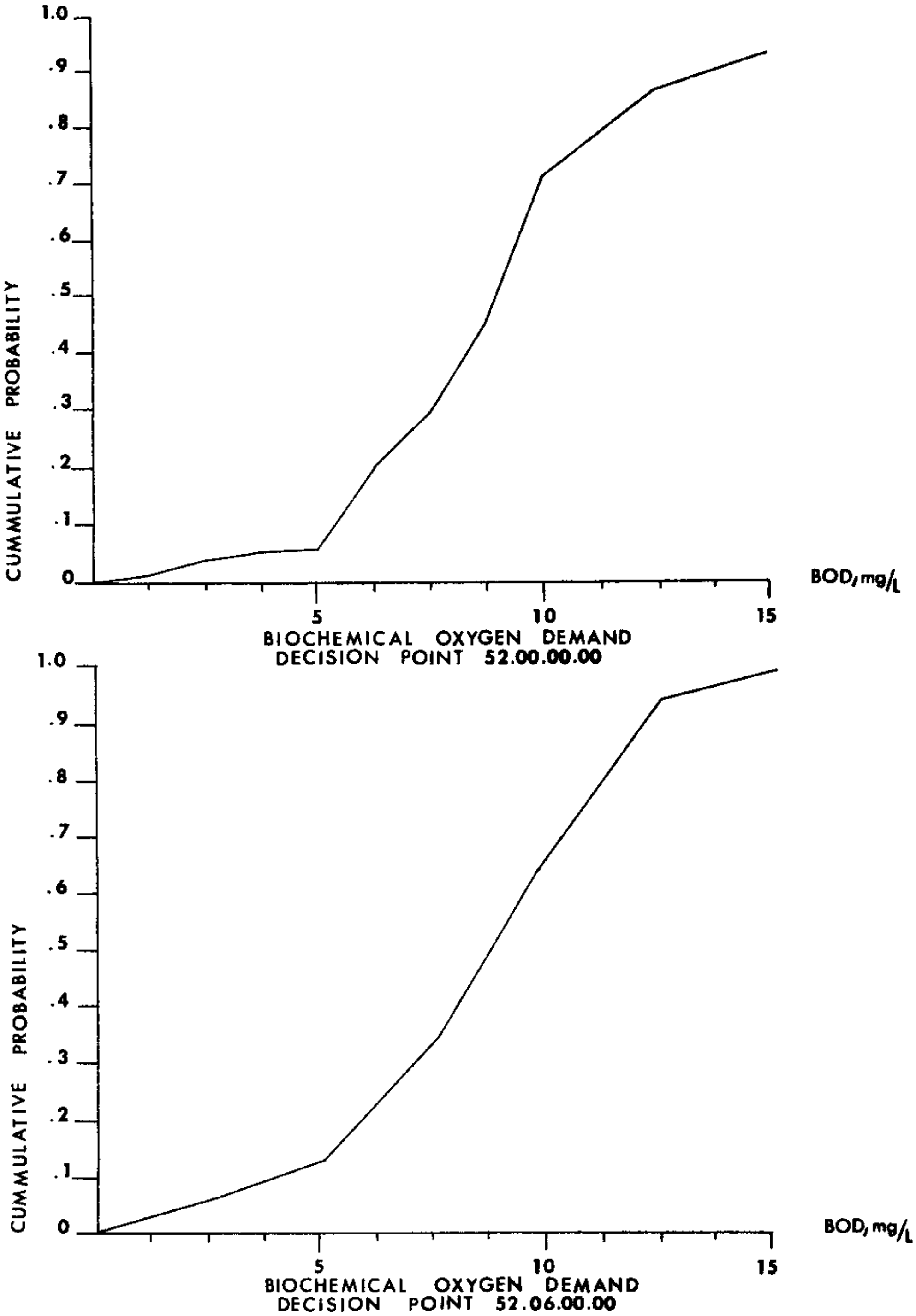


Figure 17. Comparison of Cummulative Distributions of BOD Between Location 52.00.00.00 and 52.06.00.00.

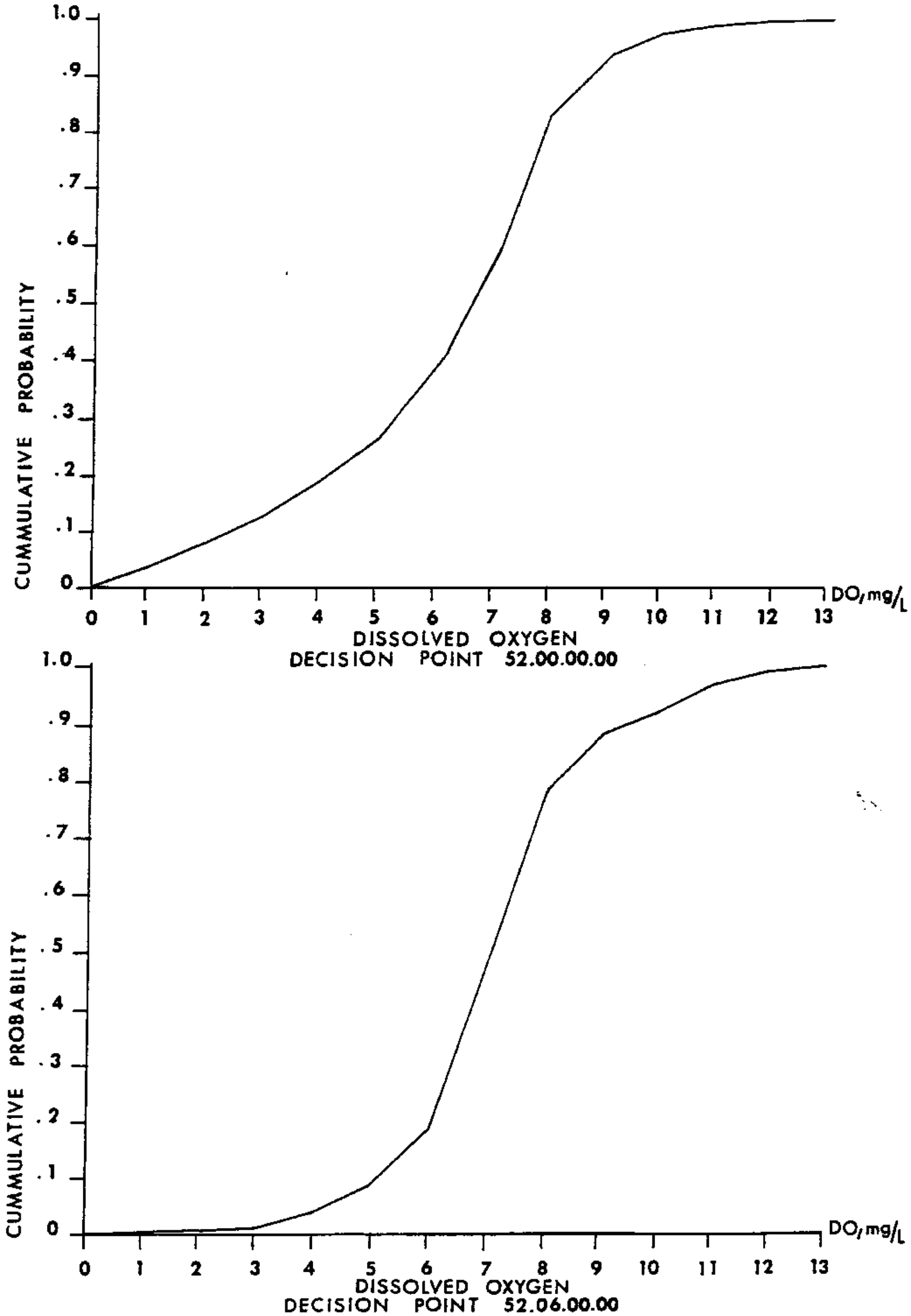


Figure 18. Comparison of Cummulative Distributions of DO Between Location 52.00.00.00 and 52.06.00.00.

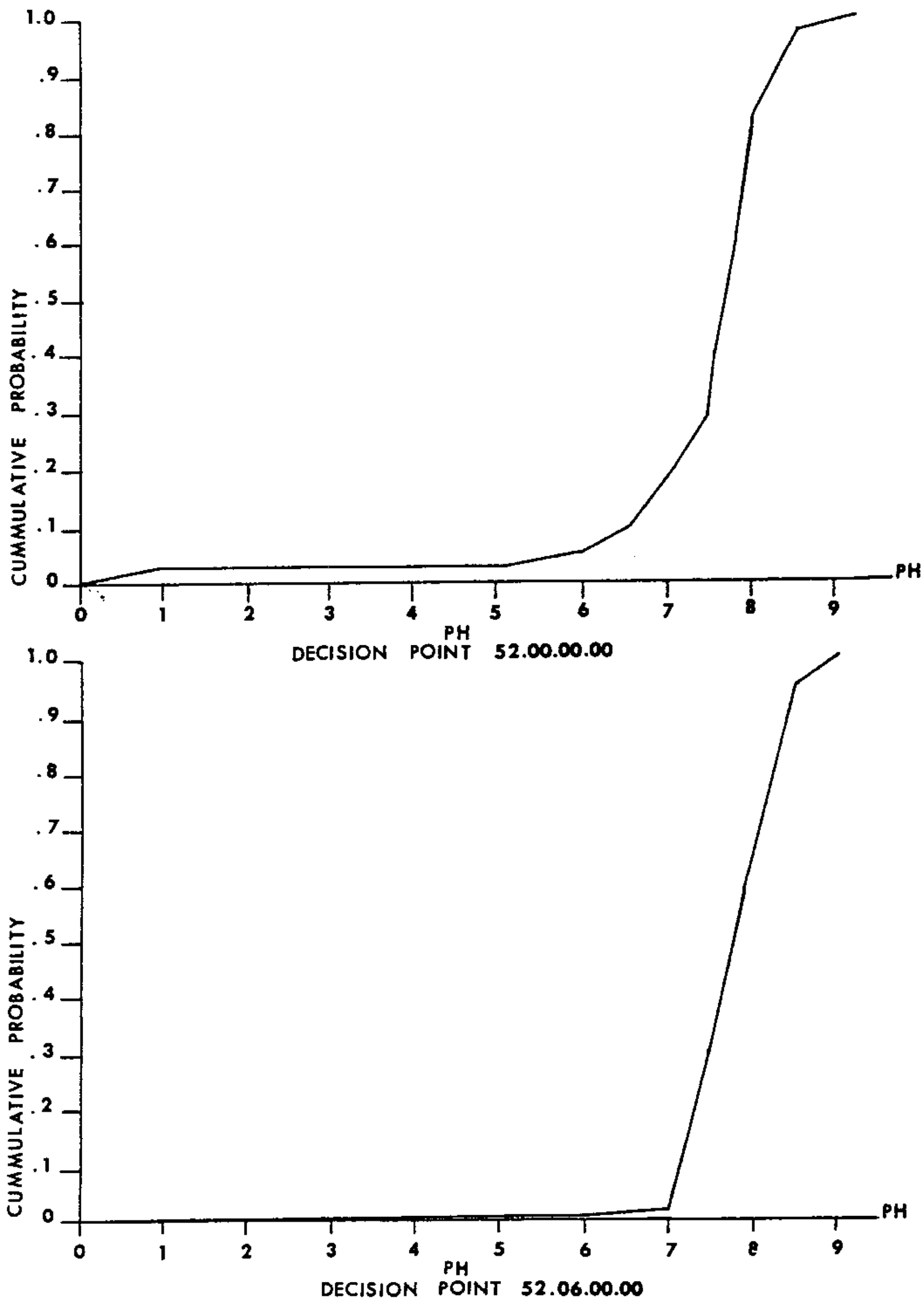


Figure 19. Comparison of Cummulative Distribution of pH Between Location 52.00.00.00 and 52.06.00.00.

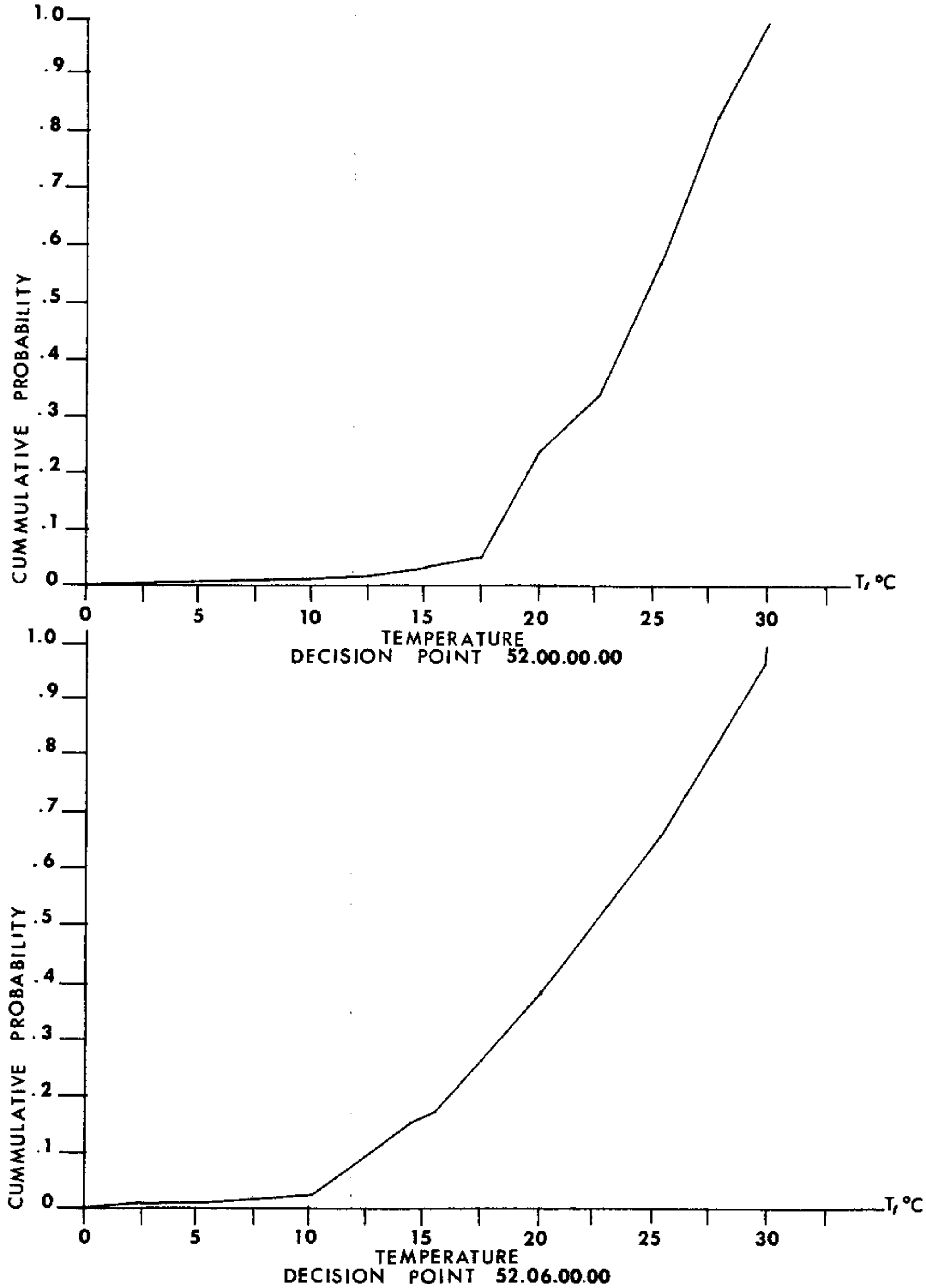


Figure 20. Comparison of Cummulative Distributions of Temperature Between Location 52.00.00.00 and 52.06.00.00.

CHAPTER 4

GROUND WATER RESOURCES

Four major aquifers in the San Antonio River Basin can supply approximately 343,500 acre-feet of ground water annually. These aquifers are the Edwards-Trinity (Plateau), Gulf Coast, Carrio-Wilcox, and the Edwards (Balcones Fault Zone) (22). These aquifers are shown in Figure 21. Other minor formations which are not shown in Figure 21 may provide limited quantities of water to supplement domestic and livestock supplies, and in some instances, to supply for the small municipal, industrial, and irrigation uses.

The Edwards-Trinity (Plateau) aquifer extends over Bandera county and part of the San Antonio River Basin. The aquifer is 400 to 500 feet thick and is composed of hard, massive, cherty, marly, and dolomitic limestone of the Edwards, Comanche Peak and Georgetown Formations. The water is found in channels and fractures in the rock under water-table conditions. Annual yields from wells in the basin are generally small; however, if developed, it may yield as much as 25,000 acre-feet annually. The water of the Edwards-Trinity (Plateau) aquifer is a calcium bicarbonate water having a hardness of more than 200 mg/l and 200 to 300 mg/l of dissolved soilds. This aquifer is a minor source of the total ground water available in the San Antonio River Basin (22).

The Gulf Coast aquifer extends from the central part of Karnes County to the Gulf of Mexico. The aquifer consists of the Catahoula, Oakville, Lagarto, Goliad, Lissie, and Beaumont Formations. It is composed of interbedded sand and clay, and extends as deep as 1,800 feet below the surface. The net sand thickness of the aquifer ranges from 200 to 600 feet. The

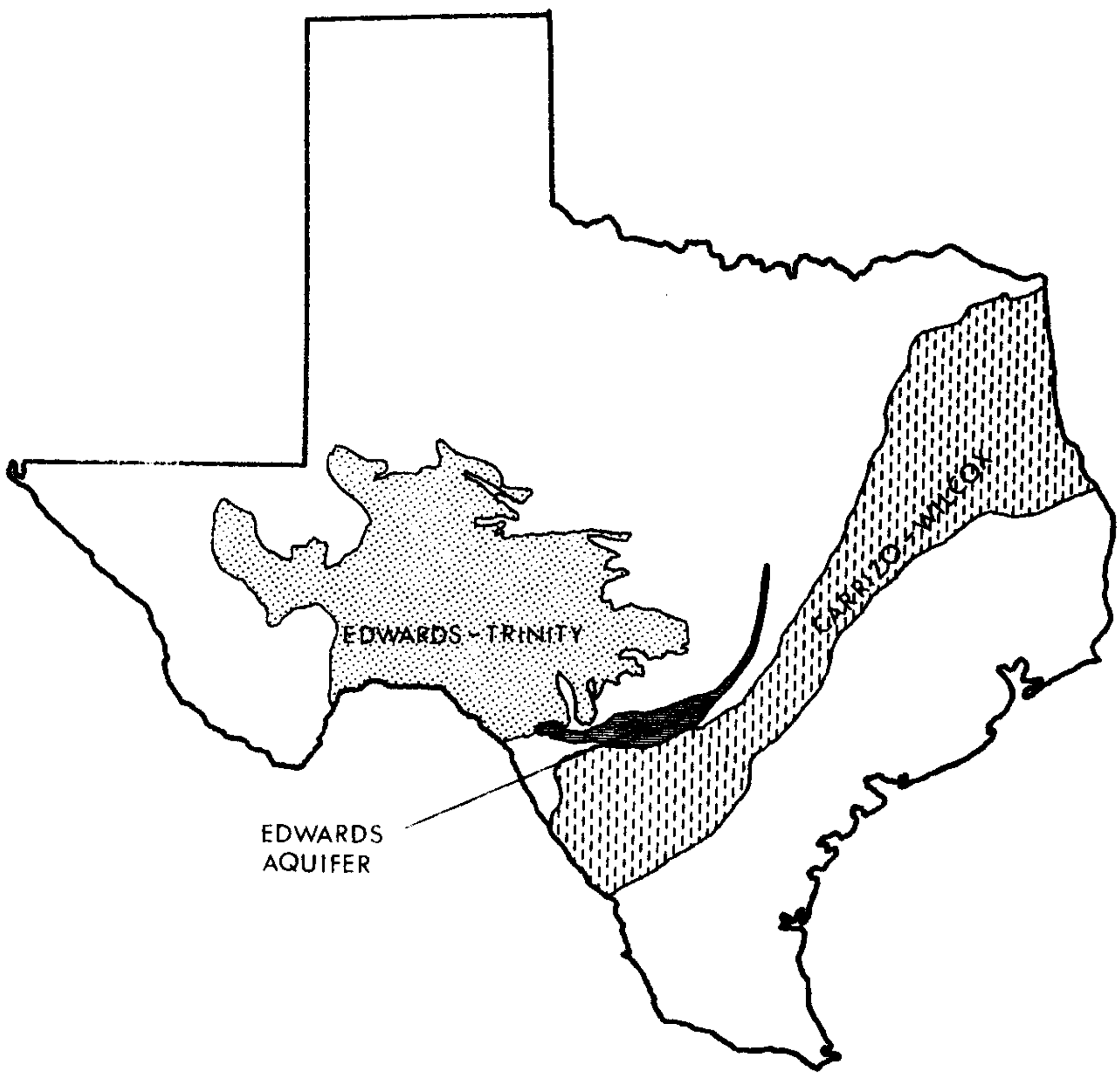


Figure 21.
Geographic Location of the Three Major
Aquifers Which Influence the San Antonio Area.

water is generally artesian but a considerable amount of water leaks through the confining clay layers. Yield from large-capacity wells average about 800 gallons per minute, with some yields as large as 2,000 gallons per minute. Salt water intrusion of the aquifer does not present a major problem at the present time; however, the southern edge contains a zone of transition between saline and fresh water. Water to the south of the zone generally contains at least 1000 mg/l of dissolved solids (22).

The Carrizo-Wilcox aquifer lies in southern Bexar County, Wilson County and the northern part of Karnes County. The aquifer is composed of course-to-fine-grained sand, sandstone, silt, and clay with a few thin beds of lignite. Thinckness of the aquifer ranges from 800 to more than 2,000 feet in the downdip area. Water table conditions generally exist in the outcrop, with artesian conditions in the downdip. Yields from the large capacity wells average about 900 gallons per minute, and some reach as high as 1,800 gallons per minute.

Approximately 33,500 acre-feet of ground water is available as an annual yield from the Carrizo-Wilcox aquifer in the San Antonio River Basin. The water in the aquifer varies from less than 500 mg/l dissolved solids to about 3,000 mg/l. In general, the water is suitable for most purposes but excessive iron is found in and near the outcrop (22).

The principal aquifer in the San Antonio area of the San Antonio River Basin is the Edwards as shown in Figure 22. It supplies most of the water for municipal, industrial, irrigation, and domestic purposes (35). The aquifer extends across the central part of Bexar County and is composed of hard massive limestone, dolomitic limestone, and marly limestone of the Edwards, Comanche Peak, and Georgetown Formations. Thickness of the aquifer

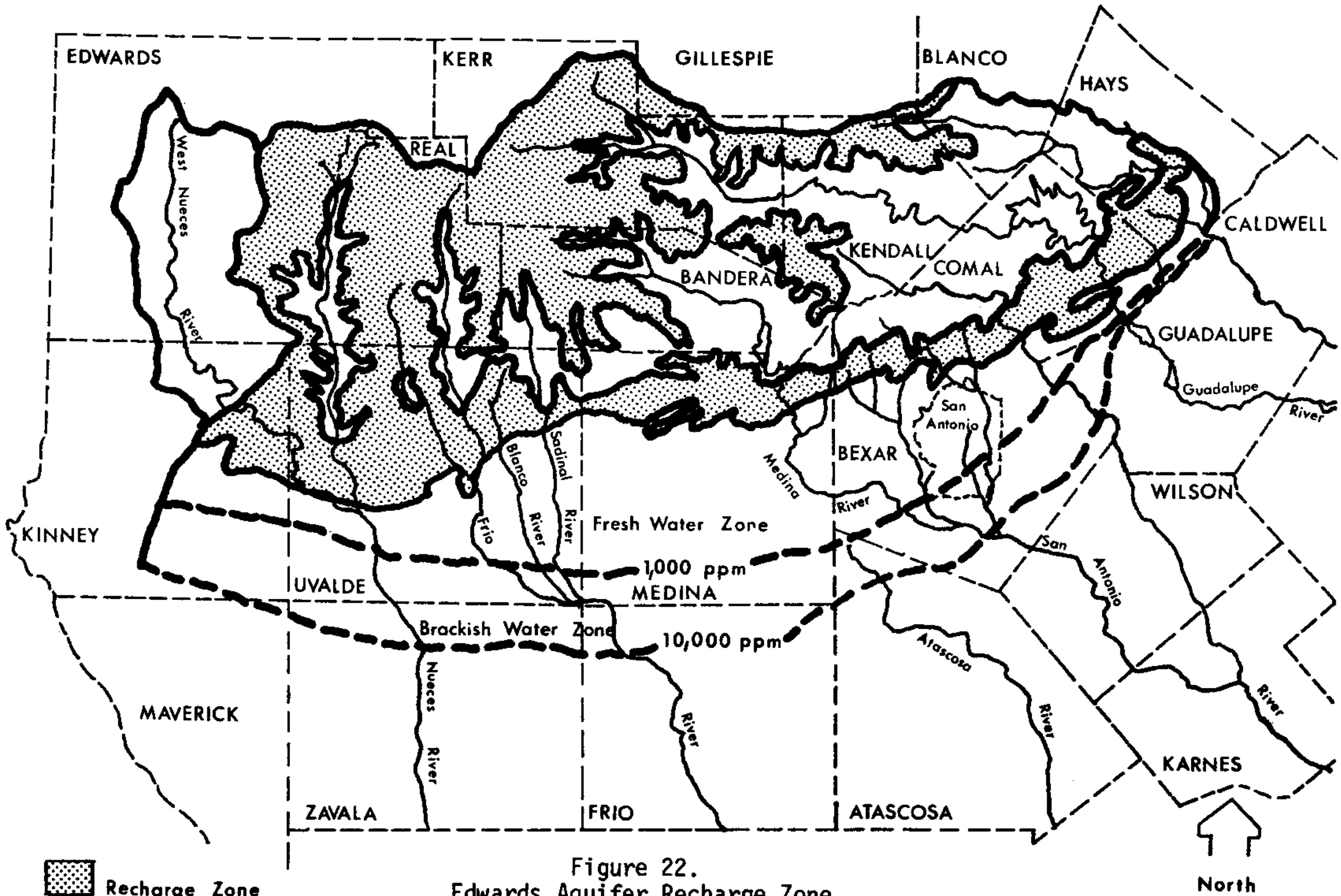


Figure 22.
Edwards Aquifer Recharge Zone

ranges from 400 to 900 feet with water in the interconnected solution cavities and fractures in the rock under artesian conditions. Yields from the large capacity wells average about 1,500 gallons per minute, and some reach 9,000(gpm) (22).

The aquifer yields approximately 260,000 acre-feet of water annually in the San Antonio River Basin. The water is a calcium biocarbonate type of very good quality although very hard. Generelly the water contains less than 500 mg/l dissolved solids, and increases very little in mineralization with depth. However, in the region where the formation is 1,000 ft or more below sea level, the water becomes brackish containing up to 10,000 mg/l of dissolved solids as shown in Figure 23.

The Edwards aquifer hydraulically connects three river basins: the Guadalupe, the San Antonio, and the Nueces. Springs in each of these river basins also discharge ground water from this formation when water levels are sufficiently high. Two of the largest springs in Texas discharge water from this aquifer, the Comal springs at New Braunfels and the San Marcos Springs at San Marcos. These springs provide the bulk of the dry-weather flow of the Guadalupe and San Marcos rivers. Pumping from the Edwards results in declining water levels, and consequently reductions in spring discharges. Hence, ground water use from the Edwards will affect the surface water supply of the lower part of the three river basins (22).

The Edwards aquifer is the only source of water for the cities of Uvalde, Knippa, Sabinal, D'Harnis, Castroville, La Coste, San Antonio, New Braunfels, San Marcos, Kyle, and other smaller communities (9). Domestic, industrial, irrigation, stock, and other uses also are dependent on water from the aquifer which is the sole supply of water for nearly one million people (9). Because

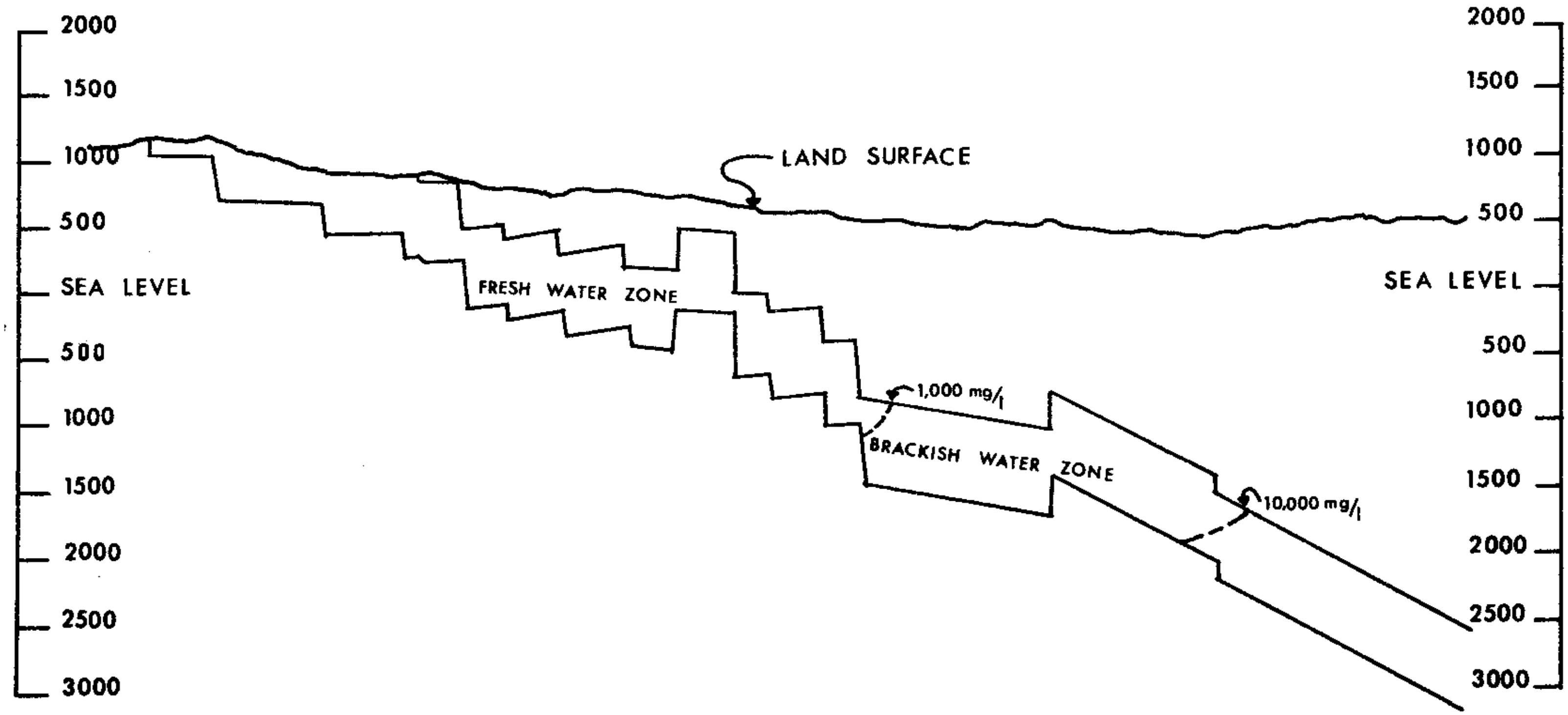


Figure 23.
Cross-Section, Edwards Aquifer

of the reliance of the San Antonio area on this aquifer, it will be discussed in more detail herein than the other three aquifers described above. Ground water is discharged from the Edwards by both springs and wells. Prior to 1954 most of the discharge was from springs, although the discharge from wells showed an annual increase. In 1964, the discharge from wells exceeded that from springs and by 1956 approximately 80 percent of the discharge was from wells (14). This trend has continued although the discharge from wells was only 54.6 percent in 1970.

The principal springs in the San Antonio area are Leona River Springs near Uvalde, San Antonio and San Pedro Springs at San Antonio and the Comal. Springs at New Braunfels. These springs issue along faults that have developed into open cracks and solution channels as water discharges naturally from the aquifer (14).

Spring flow during the period 1955-1970 is shown in Figure 24. The three principal springs, San Antonio, San Pedro and Leona River, ceased flowing between 1955-56. Comal Springs ceased flowing in 1956 for the first time on record (15).

The discharge from wells in terms of withdrawal from the Edwards for specific uses is shown in Figure 25. During the period between 1955 and 1970 one-half of the annual discharge from wells was used for municipal and military purposes. Out of that amount over 90 percent of this discharge is required for municipal and military purposes in Bexar County. Of this 90 percent, more than 70 percent is used by the City of San Antonio. Figure 26 also shows the total discharge from the Edwards including both springs and wells during the period 1934-1970.

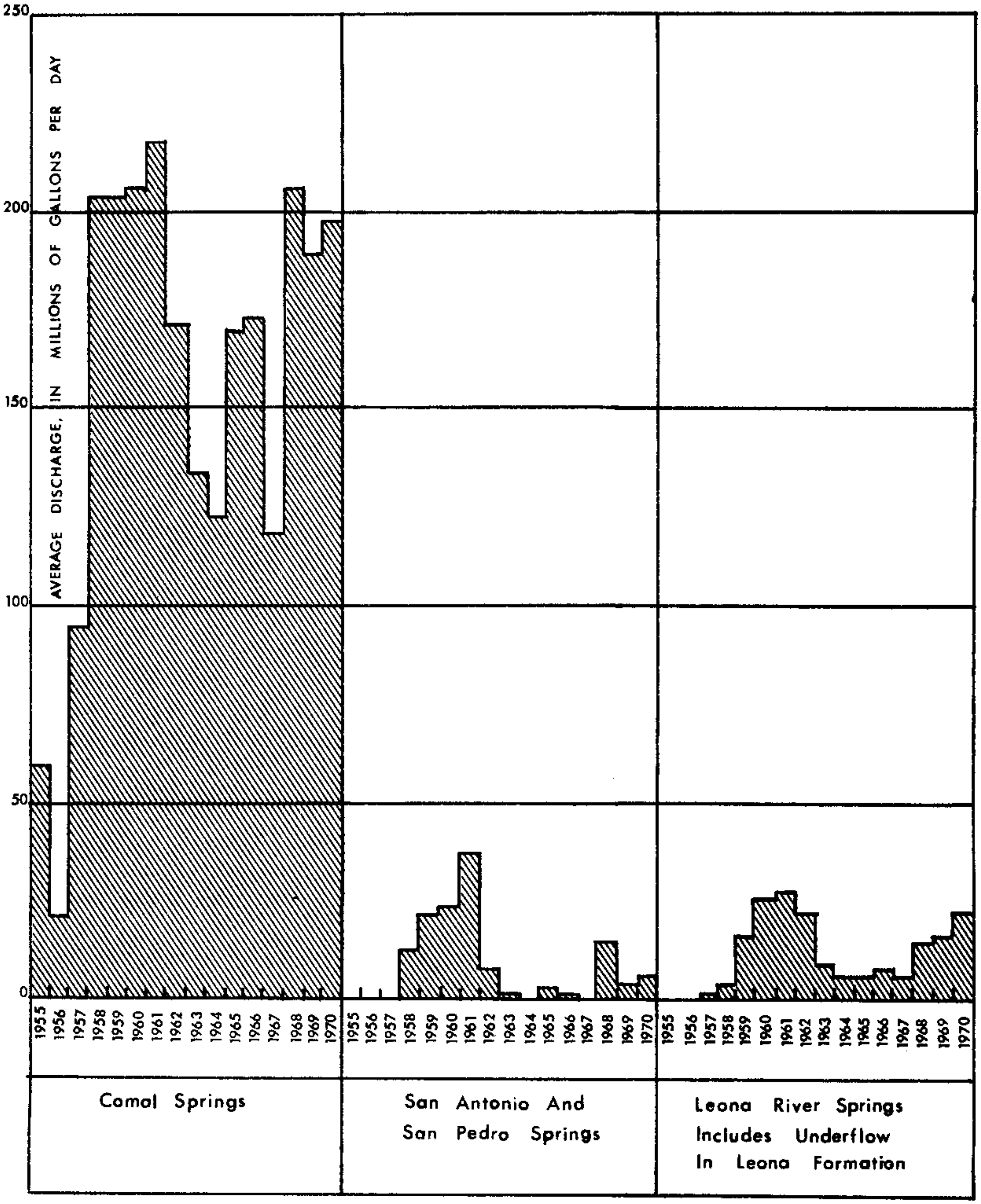


Figure 24.
Springflow in the Region
1955-1970

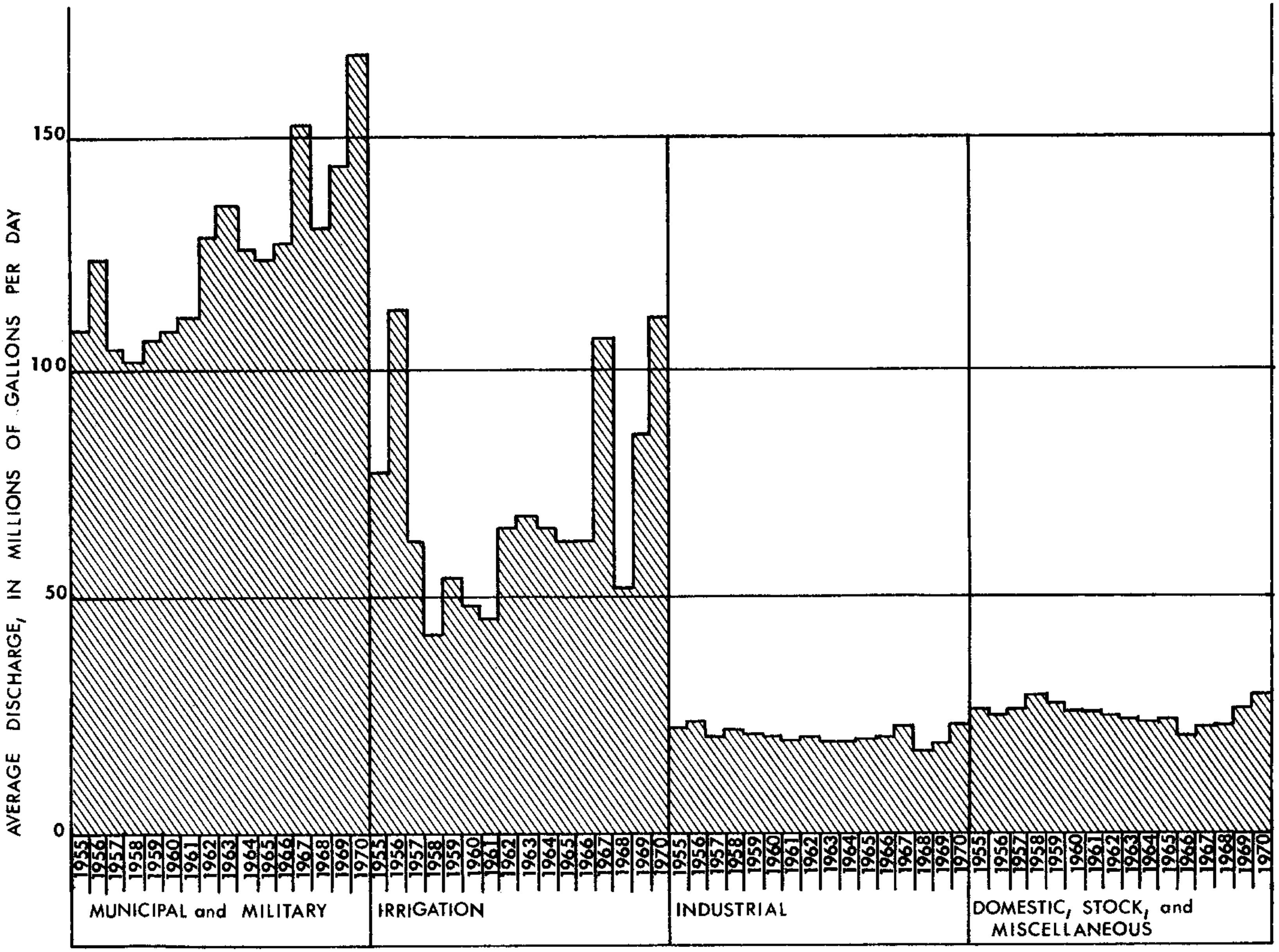


Figure 25. Water Use by Type in the Region 1955-1970

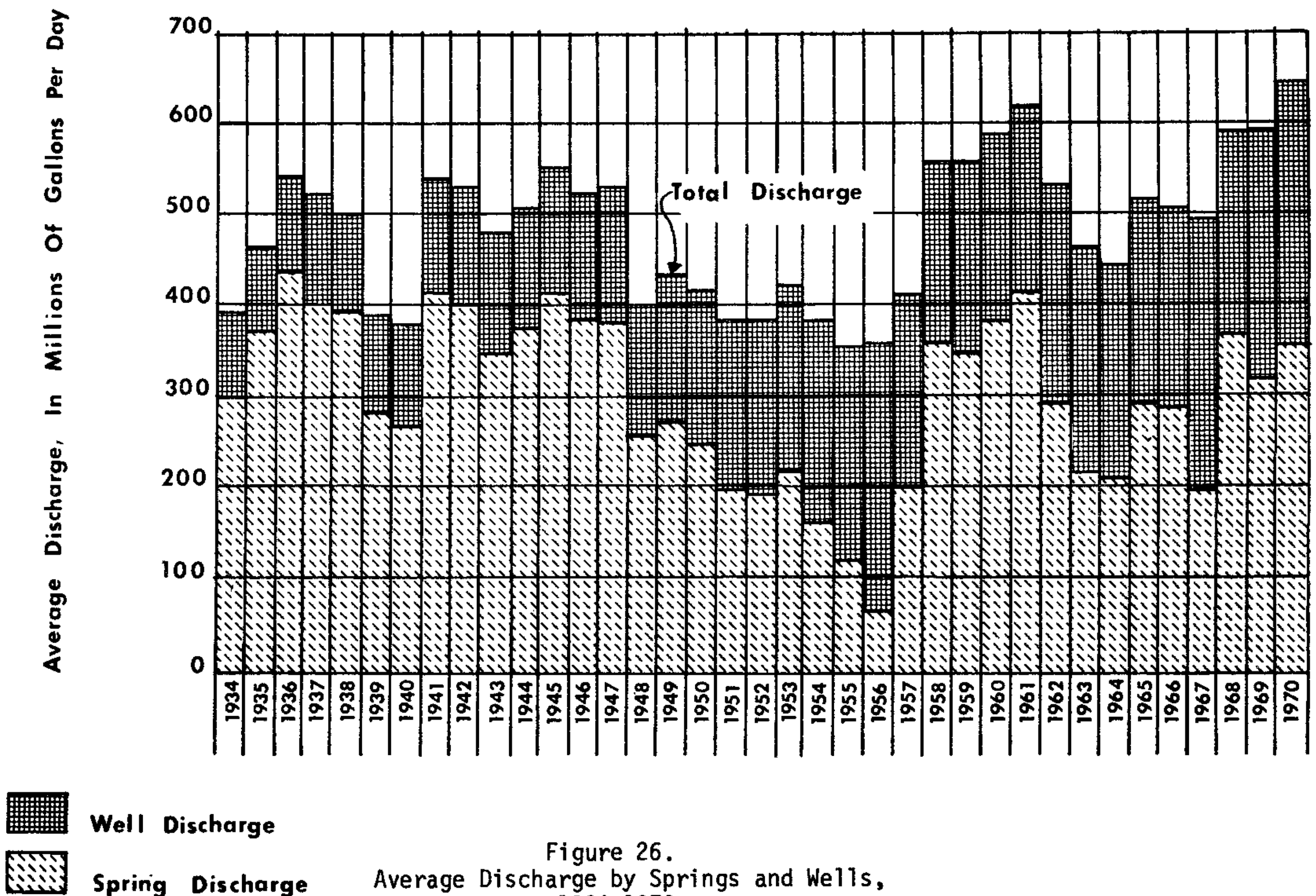


Figure 26.
Average Discharge by Springs and Wells,
1934-1970

Recharge to the Edwards in the San Antonio area is chiefly by seepage from streams that cross the outcrop of the aquifer in the Balcones Fault Zone, and to a lesser extent, by direct infiltration of rainfall on the outcrop (1). This recharging process is illustrated in Figure 27.

In general the method used to estimate the recharge of the aquifer is based on the assumption that recharge in each stream basin is the difference between total inflow above the infiltration area and total outflow below the infiltration area. Hence seepage investigations made at different stages of the streams have helped in locating the infiltration areas, which generally follow the outcrop of the aquifer along the Balcones Fault Zone. That part of the inflow above the infiltration area in each stream basin is measured at a gauging station. The flood runoff determined at this gauging station is used to estimate the direct infiltration or runoff on the outcrop itself. Those stream losses due to evaporation and transpiration by vegetation are assumed to be proportionally the same in the area of the outcrop and above the outcrop. The total outflow for each stream basin is measured at another gauging station below the outcrop (14). Generally, this method has worked well over long periods of time, probably because errors tend to balance out over such periods.

Because not all the streams in the recharge areas have been suitable for controlled gauging, assumptions concerning runoff in these and other areas have been made. Some areas having little or on runoff have been included either as part of the basis for which estimates of recharge have been made or as individual areas with assumed runoff characteristics similar to those in adjacent basins. For others an estimate of runoff is made by the following method. The runoff above the outcrop is usually applied to

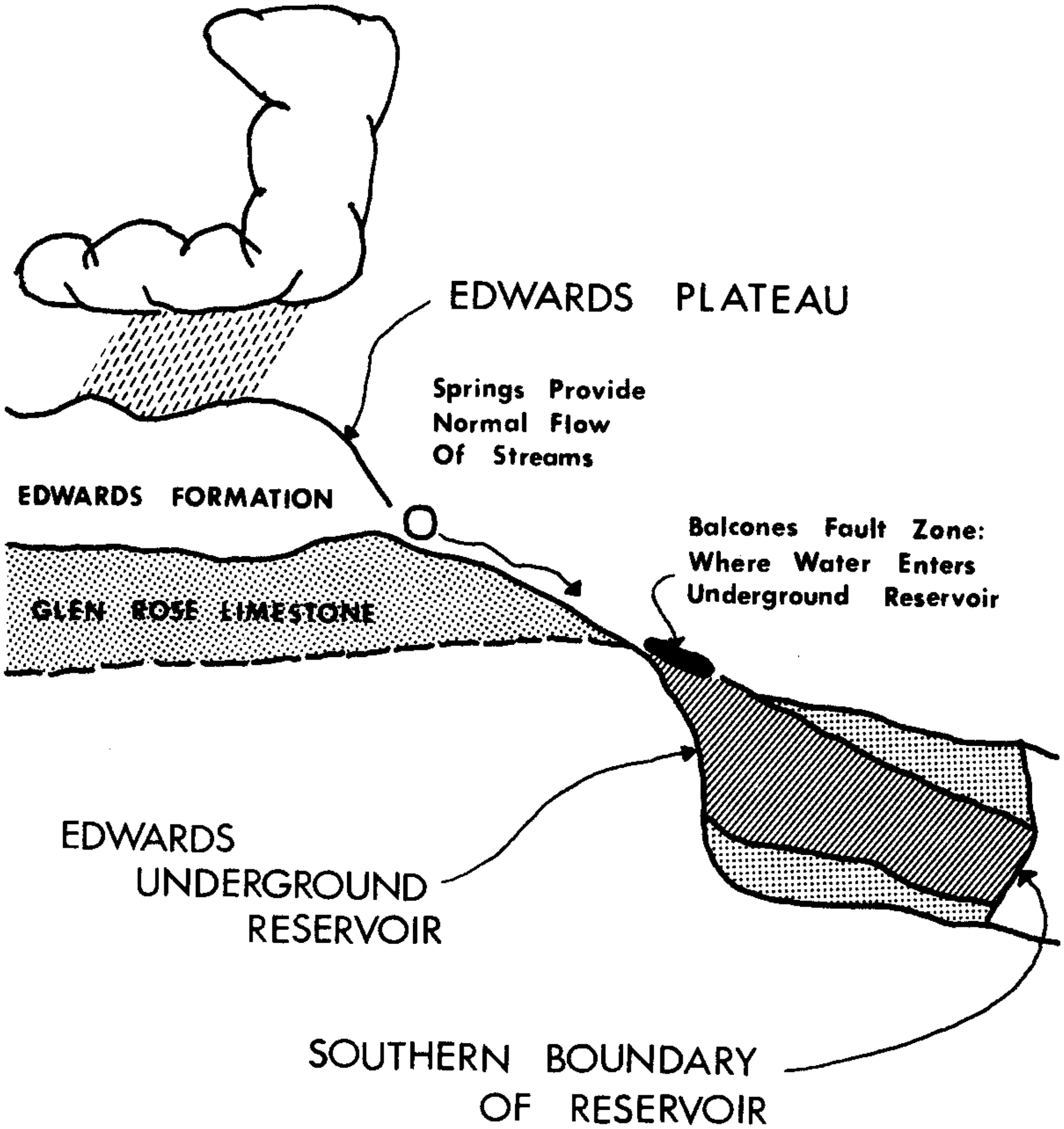


Figure 27.
Recharge of the Edwards

the outcrop area, except when rainfall records clearly indicate a wide variance of rainfall within the basin. In such cases, a correction factor based on rainfall, is applied to the runoff (14).

During the 1934-70 period, the annual recharge to the aquifer ranged between the minimum of approximately 44,000 acre-feet in 1956 and the maximum of more than 1,700,000 acre-feet in 1958. The annual average recharge was 519,700 acre-feet (14). This data is shown in Table 6. The above discussion indicated that average annual discharge from the aquifer exceeds average annual recharge to the aquifer. In the past 25 years, annual recharge has exceeded annual discharge in only 7 yearly periods, these being the years between 1957 to 1961, 1964 to 1966 and 1970 (35). Figure 28 illustrates the relationship between annual discharge and annual recharge graphically.

If this imbalance between discharge and recharge should continue, the discharge deficit will continue to increase. It has been projected that the huge springs at San Marcos and New Braunfels will cease to flow by the year 2000 (35). Another consideration is that at some point enough pressure would be taken off the fresh water zone of the aquifer to permit saline water intrusion as shown in Figure 23.

Along with the problem of discharge/recharge imbalance to water quantity is the increasing role of deterioration of the water quality along with time. Paramount to the problem of water quality of the aquifer is the fact that many of the streams which flow over the recharge zone are also used as a medium for transporting sewage and other waste material from cities and communities in the area (35). It is easy to see that as the population of the region increases, the volume of waste will also increase. Consequently,

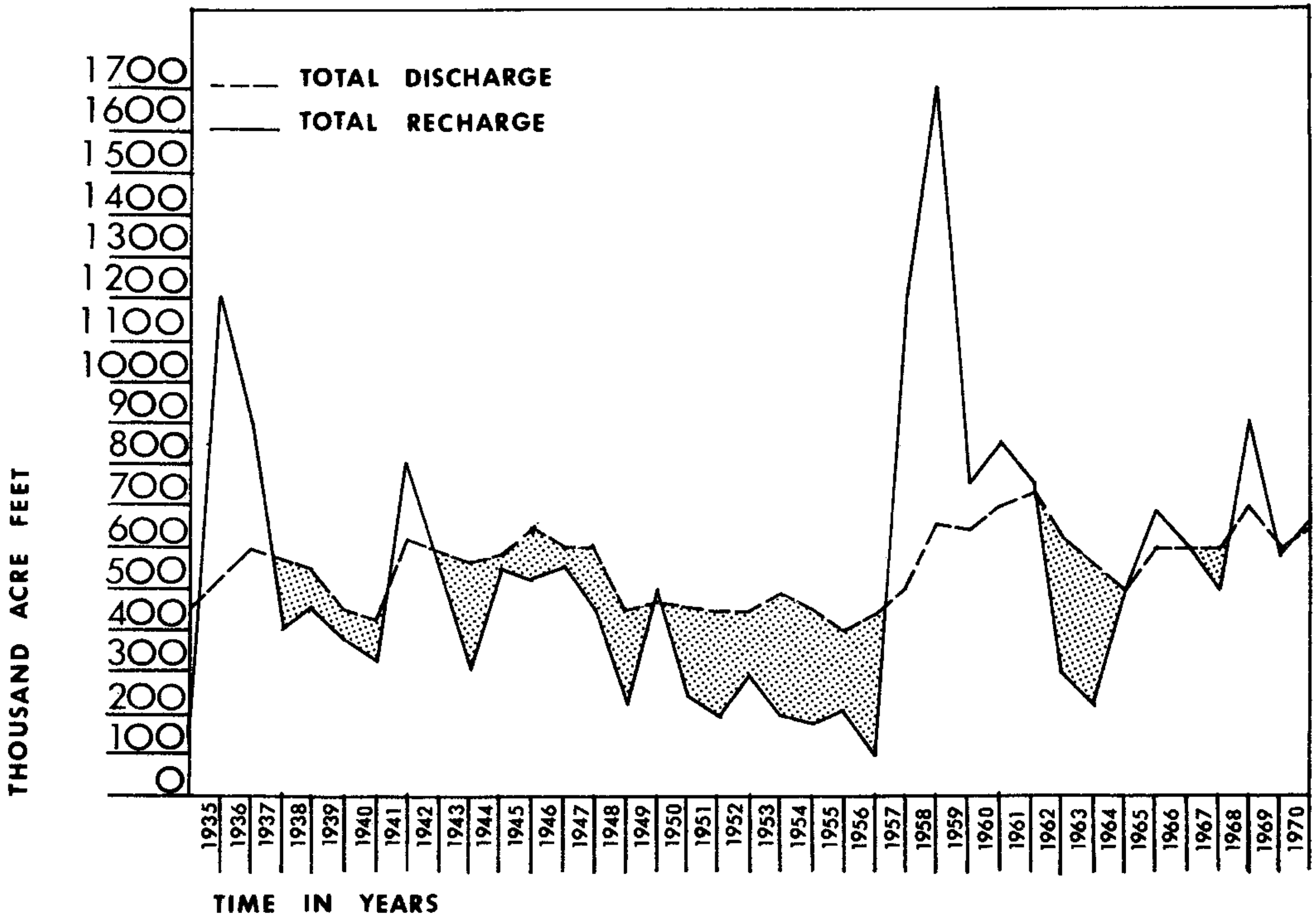


Figure 28.
Comparison of Total Recharge to
Total Discharge to the Edwards Aquifer
1935-1970

TABLE 6

ESTIMATED ANNUAL RECHARGE
1934-1970

Year	Nueces and West Nueces River basins	Frio and Dry Frio River basins	Sabinal River basin	Medina River basin	Cibolo and Dry Comal Creek basins	Blanco River basin and adjacent area	Area between Sabinal and Medina River basins	Area between Cibolo Creek and Medina River basins	Total
1934	8.6	27.9	7.5	46.5	28.4	19.8	19.9	21.0	179.6
1935	411.3	192.3	56.6	71.1	182.7	39.8	166.2	138.2	1,258
1936	176.5	157.4	43.5	91.6	146.1	42.7	142.9	108.9	909.6
1937	28.8	75.7	21.5	80.5	63.9	21.2	61.3	47.8	400.7
1938	63.5	69.3	20.9	65.5	76.8	36.4	54.1	46.2	432.7
1939	227.0	49.5	17.0	42.4	9.6	1.1	33.1	9.3	399.0
1940	50.4	60.3	23.8	38.8	30.8	18.8	56.6	29.3	308.8
1941	89.9	151.8	50.6	54.1	191.2	57.8	139.0	116.3	850.7
1942	103.5	95.1	34.0	51.7	93.6	28.6	84.4	66.9	557.8
1943	36.5	42.3	11.1	41.5	58.3	20.1	33.8	29.5	273.1
1944	64.1	76.0	24.8	50.5	152.5	46.2	74.3	72.5	560.9
1945	47.3	71.1	30.8	54.8	129.9	35.7	78.6	79.6	527.8
1946	80.9	54.2	16.5	51.4	155.3	40.7	52.0	105.1	556.1
1947	72.4	77.7	16.7	44.0	79.5	31.6	45.2	55.5	422.6
1948	41.1	25.6	26.0	14.8	19.9	13.2	20.2	17.5	178.3
1949	166.0	86.1	31.5	33.0	55.9	23.5	70.3	41.8	508.1
1950	41.5	35.5	13.3	23.6	24.6	17.4	27.0	17.3	200.2
1951	18.3	28.4	7.3	21.1	12.5	10.6	26.4	15.3	139.9
1952	27.9	15.7	3.2	25.4	102.3	20.7	30.2	50.1	275.5
1953	21.4	15.1	3.2	36.2	42.3	24.9	4.4	20.1	167.6
1954	61.3	31.6	7.1	25.3	8.8	10.7	11.9	4.2	160.9
1955	128.0	22.1	.6	16.5	3.3	9.5	7.7	4.3	192.0
1956	15.6	4.2	1.6	6.3	2.2	8.2	3.6	2.0	43.7
1957	108.6	133.6	65.4	55.6	397.9	76.4	129.5	175.6	1,143
1958	266.7	300.0	223.8	95.5	268.7	70.7	294.9	190.9	1,711
1959	109.6	158.9	61.6	94.7	77.9	33.6	96.7	57.4	690.4
1960	88.7	128.1	64.9	104.0	160.0	62.4	127.0	89.7	824.8
1961	85.2	151.3	57.4	88.3	110.8	49.4	105.4	69.3	717.1
1962	47.4	46.6	4.3	57.3	24.7	28.9	23.5	16.7	249.4
1963	39.7	27.0	5.0	41.9	21.3	16.2	10.3	9.3	170.7
1964	126.1	55.1	16.3	43.3	51.1	22.2	61.3	35.8	411.2
1965	97.9	83.0	23.2	54.6	115.3	66.7	104.0	78.8	623.5
1966	169.2	134.0	37.7	50.5	66.5	17.1	78.2	44.5	597.7
1967	82.2	137.9	30.4	44.7	57.3	19.0	65.0	30.2	466.7
1968	130.8	176.0	66.4	59.9	120.5	49.3	198.7	83.1	884.7
1969	119.7	113.8	30.7	55.4	99.9	46.6	84.2	26.6	576.9
1970	112.6	141.9	35.4	68.0	113.8	39.5	81.6	68.8	661.6
Total	3,566	3,252	1,192	1,900	3,356	1,187	2,704	2,075	19,231
Average	96.4	87.9	32.3	51.4	90.7	32.0	73.1	56.1	519.7

this increase in waste material flowing across the recharge zone will generate serious pollution to the aquifer. To help combat this problem an order was issued by the Texas Water Quality Board, July 31, 1970, which placed restrictions on the discharge of raw sewage or poorly controlled sewer effluent on the recharge zone of the Edwards Formation (35). It is too early at the present time to evaluate the effect of this order; however, it is definitely an applaudable move toward the water quality protection of the Edwards.

Currently, the fresh water zone of the aquifer is defined as water containing less than 1,000 mg/l of dissolved solids. The brackish zone is defined as water containing dissolved solids from 1,000 to 10,000 mg/l as shown in Figure 23. The total dissolved solids in the aquifer increase from east to west (35).

Table 7 shows the composite chemical analysis of water from four San Antonio deep wells in the Edwards Aquifer. Notable amounts of chloride, sulphate, magnesium, nitrate, calcium, sodium, and bicarbonate are present. It is interesting to note that the total dissolved solids increased 5 percent over a four-year period in well No. 59. The total dissolved solids also increased in well No. 60 over a three-year period. The location of well No. 60 is in the northern portion of the city. This trend toward an increase in dissolved solids in all wells should be carefully observed and examined in the years to follow. If the trend increases, it could mean that some of the brackish water is beginning to move into the fresh water zone (35).

Several studies sponsored by the Edwards Underground Water District, and the San Antonio City Water Board set what is considered to be a "safe" discharge from the Edwards in the San Antonio area. This "safe" discharge or

TABLE 7

COMPOSITE CHEMICAL ANALYSIS
CHEMICAL CHARACTERISTICS
1964-1969

		1964	1965	1966	1967	1968	1969
Iron	ppm	0.06	0.03	0.03	0.02	0.02	0.02
Maganese	ppm	0.05	0.05	0.05	0.05	0.05	0.05
Magnesium	ppm	16.3	16.0	17.0	17.0	15.0	17.0
Chloride	ppm	13.9	13.0	15.0	14.0	14.0	13.0
Sulphate	ppm	23.5	22.0	25.0	23.0	25.0	25.0
Carbonate	ppm	0.0	0.0	0.0	0.0	0.0	0.0
Bicarbonate	ppm	250.0	253.0	256.0	257.0	262.0	263.0
Fluoride	ppm	0.18	0.29	0.29	0.29	0.27	0.31
Nitrate	ppm	4.9	5.1	5.1	6.0	5.0	5.6
Calcium	ppm	68.0	70.0	70.0	68.0	74.0	73.0
Sodium	ppm	8.3	7.0	7.0	8.0	7.0	8.0
Total Solids	ppm	320.8	387.0	394.0	393.0	402.0	403.0
Total Hardness	ppm	241.3	241.1	247.0	240.0	248.0	251.0
Total Hardness	ppm	14.1	14.1	14.4	14.0	14.4	14.6
Source:	Deep Wells	59	61	60	56	59	60
	pH	7.3	7.6	7.6	7.6	7.6	7.5
Aquifer:	Edwards Limestone						
	Temperature	75°F	75°F	75°F	75°F	75°F	75°F

Note: 1 milligram/liter equals 1 part per million
1 grain per gallon equals 17.12 parts per million

recommended yield is that maximum amount of water withdrawal by wells from the aquifer so that it will not destroy or interrupt the spring flows. These "safe" discharge estimations vary between 235 MGD to 300 MGD. The average recommended well yield from the studies amounts to 266 MGD. The average pumpage rates in 1968 were 225 MGD and it is estimated the 1970 pumpage rates were close to the "safe" yield of 266 MGD (9).

In 1959, the Texas Legislature created the Edwards Underground Water District for the purpose of "protecting, conserving, and recharging the underground reservoir" (9). The District consists of all of Uvalde County, most of Medina and Bexar counties, and a small part of Comal and Hays Counties (See Figure 4).

Supplemental surface water supplies are necessary in the San Antonio area and should be made available as soon as possible. To supply the projected municipal and industrial demand of Bexar County in the year 2020 it is estimated a minimum surface water supply of about 220,000 acre-feet will be required annually in addition to the available ground water resources. To meet this additional water requirement,construction of two reservoirs is recommended in the Texas Water Plan. These reservoirs are to be located on the Sabinal and Frio Rivers (31).

In order to implement the proposed total water supply system, proper organizational, institutional, financial, administrative, and governmental cooperation is imperative among each entity in the area that would benefit. A regional planning and development program of the Edwards and the surrounding surface waters is the most popular method to insure that future demands for water are met. This regional program should have two main goals,(1) the augmentation of the water supply and, (2) the prevention of pollution (7).

It should be noted; however, that the implementation of such a regional program would be extremely difficult due to the existing institutional factors within the area. There is an intricate and complex network of overlapping governmental units which have the responsibility of water policy formulation. In the San Antonio Area alone there are seventeen such entities: two cities, one water district, eleven water control and improvement districts, and two non-supplying water districts. In addition, there are about thirty private water companies and several installations on military bases which are constructed and operated by the federal government. This situation may make it impossible to achieve a balanced, comprehensive water management policy (32).

As mentioned previously, the San Antonio region has been strictly dependent on ground water for the fresh water supply. It is inevitable that future water resources must come from a conjunctive use of ground and survace water. There are several alternatives presently available which will supply the conjunctive water needed. Lake Medina has a surface water supply which could be utilized; however, water rights forbid its use as a water supply to the San Antonio Area. Calaveras Reservoir and Cibolo Reservoir which are planned could be utilized. In addition, the Carrizo-Wilcox aquifer adjacent to the city could also be utilized. The combination of these possible alternatives would create a surface/ground water resourse base and should be studied and included in future planning programs.

The suggestion has been made that some type of regulatory agency should be formed in which is vested the power to manage the entire San Antonio River Basin. This encompassing "super agency" could either replace all existing agencies or act as a decision center whose approval is necessary before any subordinate agency could act. This is an idealistic approach although at first glance it appears to be an alternate solution. Further investigation, however, reveals that this approach would be all but impossible to implement and the question arises if it is really necessary.

Institutional organizations develop through time. Once established, they become responsive to the needs of the people they serve and although their basic structure does not change their immediate goals, objectives, and means of obtaining these objectives do change. Often the various water management agencies in the area operate to fulfill competing objectives. This is in the best interest of the people as it provides a check and balance in local government so that one sector of the populas is not dominate. They are immediate in acting against developing problems since a minimum amount of time elapses before decisions are made. Neither of these would be possible in one agency. Not only would it become politically oriented and disportionately powerful it would also become unwieldy with many levels of "red tape" which must be considered before a decision can be made. Due to the dynamic nature of San Antonio's water management problem this would not be in the best interest of the citizens of the city. In addition, very few of the existing agencies operating in the river basin could be utilized as subcomponents of the "super agency" once their powers had been usurped and their organization subordinated. These institutional conflicts and organizational barriers would alone prohibit the establishment of such an agency.

But assuming that these institutional and organizational barriers could be overcome the problem then arises of legal implications of the new agency and the tax structure necessary to support it. Naturally these problems must be taken to the people who must approve any change at the polls. The current attitude of the populus toward taxes is not favorable and such a move would be extremely difficult to gain voter approval. Each agency currently operating in the basin receives some type of revenue, either through taxation, or otherwise. This must all be changed and the details of distributing the tax equally over the basin would be enormous. As it is, each region serviced by an existing agency is taxed. To change this a formula must be developed which would allow taxation throughout the basin at an equitable rate for those who receive each service. This task would not only present a monumental problem at the outset of agencies organization but it would continue to be a problem throughout its existance.

Finally the question, if such an agency is really necessary must be answered. San Antonio and the surrounding area is unique in that there is a high degree of cooperation among all agencies. This includes transferal of data, mutual problem solving, and continuous communications among all agencies at each level. This is not to imply that the situation in San Antonio cannot be improved, but it should be emphasized that the formation of another agency to supervise the whole basin is not a feasible solution to the problem and should not be considered as an alternative.

CHAPTER 5

RECREATION

The San Antonio area is endowed with a wide range of recreational opportunities. Partly becuase of its geographical location and historical significance, and partly because of municipal encouragment to recreational development it is one of the major tourist areas of Texas.

Millions of people have traveled to the San Antonio area to see those historical sites which have played such an important role in the development of Texas and the Nation. The area Missions, the Spanish Governors Palace and of course the Alamo are only a few of the tourist attractions of the area. In addition, San Antonio itself has encouraged tourists with such attractions as the Hemisfair, The San Antonio Zoo, and various activities along the San Antonio River which include among others, the San Antonio Festival and the River Theater.

Water based recreation in the San Antonio area is scarce or nonexistant at the present time. The most popular boating facilities are on Canyon Reservoir, a 50,000 acre reservoir in the Guadalupe River Basin. Calaveras Lake supports a limited amount of pleasure boating but overcrowding is a problem. Boating is allowed on Brauning Lake but is limited to 10 m.p.h. Brauning Lake is the primary fishing facility of the area.

The Parks Department operates 16 public swimming pools in San Antonio and there are numerous private swimming pools available. There are no natural swimming facilities in the area. None of the lakes around San Antonio are suitable for swimming or other activities which require direct human contact with the water. This of course, preludes water sking and other associated water sports.

The city of San Antonio has 2,932 acres of park area. This represents less than 4.6 acres per thousand population. Brackenridge Park is the largest park in San Antonio. Several thousand feet of winding river channels are in the park, and are fed by pumped water from the Edwards. Limited fishing and paddle boating are permitted in the channel when the flow is sufficent. Water is used mainly for its scenic attributes and the main activites of the park are not related to water.

Paso Del Rio is considered to be as important a tourist attraction as it is a recreation area. The mile long horseshoe bend, or river bend, of the San Antonio River is as successful and imaginative use of the river for environmental purposes as can be found in the United States. Although origionally built as a flood prevention program active political efforts have turned the area into an aesthetically pleasing area (See Figure 6). The river in the horseshoe bend area is kept at a constant four foot depth by augmenting the river flow from deep wells. Restaurants and other private enterprises line portions of the river walk and sightseeing boats are permitted along this well lighted segment of the river. Part of the area south of the river bend known as "La Villita" dates back to Colonial times. This area has been restored to its origional character and the section has been designated as a cultural center.

The demand for water-oriented recreation within the San Antonio area has experienced a phenomenal rate of growth in the past several years. This increased emphasis and the demand for water-based recreation have caused future planning and water management policy making to include this aspect of water use. Recreation is essentially a non-consumptive use of water yet it competes for the available water along with other water (possibly conflicting) objectives. Meanwhile, most usages of water require the release of water from reservoirs to fulfill the required objective, yet recreation generally requires a containment of water along with the maintance of a fairly high water level in a reservoir or river. Thus while considering recreation in total water planning, the planner must compare the benefits of each objective and derive an equitable trade-off relationship.

In the pursuit of recreation there is a large economic turnover of money and goods. As leisure time increases, so will the economic impact of recreation. As a result, the total regional development of the San Antonio water resoruces systems should include the economic development of recreational opportunities. There are however, some difficulties engendered due to the intangible characteristics of recreation in a total water resources plan. Some of the most significant difficulties arise from the attempt to apply economic quantification for recreation. Specifically, these difficulties may be catargorized as the following three factors: (a) estimation of the demand for recreation, (b) measurement of recreational values and benefits and (c) evaluations of the quality of the recreational experience. Furthermore, they often are compounded by the fact that the public attitude may vary through time and that each factor is not independent of the other.

There is an unusual interaction among these three factors. That is, as the demand for the recreational facility increases, the quality of the recreational experience decreases, for people usually do not enjoy "crowded" areas. Then, as the quality of the recreational expense decreases the value of the facility decreases; however, it is also true that as the demand for a facility increases its value increases. Therefore, there is a direct relationship between demand and value of a recreational facility and between recreational quality and value of a recreation facility; yet an inverse relationship exists between demand and recreational growth of the facility. Hence, the interactions between these variables are unstable and extremely difficult if not impossible to predict.

Several attempts have been made to develop a model which successfully overcomes these difficulties. The most noteable models are by Clawson and Knetsch (6), Merewitz (21), and Grubb and Goodwin (17). The Grubb and Goodwin model was published by the Texas Water Development Board and is based in part on previous work done by Clawson (5). The final selection of adaptable planning techniques for the San Antonio Area cannot be made due to the constraints associated with the requirements of time and money as well as the staff and the data available.

A preliminary public attitude study is in progress by Texas Water Resources Institute of Texas A&M University of the San Antonio River Walk. In respect to the technique selected for the estimation of recreational benefit, several limiting factors to recreation must be considered.

Paramount among these are water quality and conflicts for water use. The water quality available influences not only the value of the recreational facility but also the type of recreation pursued. Different criteria of water quality with various forms of recreation demand are discussed herein.

Adequate amounts of dissolved oxygen, reasonable water temperatures, and the absence of toxic chemicals are prerequisites for the neccessary aquatic life to enhance sport fishing. Water favorable for a good mixed fish population should meet the following criteria; (a) dissolved oxygen should not be less than 5 mg/l, (b) pH should be approximately 6.7 to 8.6 but not exceed the limits of 6.0 to 9.0, (c) carbon dioxide should not exceed .3 percent in volume, (d) suspended solids should be such that the intensity level for light penetration will not be less than 5 meters.

Fish can; however, survive in water outside these limits. Amounts of oxygen over and above the minimun are recommended for all species to allow for activity increased body temperature, increased carbon dioxide, lowered pH, and the presence of toxic substances. Although fish can tolerate less than minimum amounts of dissolved oxygen for short periods of time, decreased levels of oxygen may destroy the fishing potential of streams.

A well rounded fish population does not occur when the dissolved oxygen content is less than 3.0 mg/l. Even the course fish, which can survive in a level of dissolved oxygen below that required for game fish, must have a dissolved oxygen level of 2.0 mg/l (2). Ellis (16) has suggested a minimum D.O. of 5.0 mg/l for all types of fish life.

The principal criteria for water used for boating and picnicking is that the water be free of objectional color, odor and floating or submerged solids. In addition, the pH should be such that the water will not damage the hull of boats. A minimum pH of 6.0 is suggested by Stephenson (30), he also suggested a minimum BOD of 3.0 mg/l and a minimum D.O. of 3.0 mg/l to eliminate vile odors.

Serious conflicts exist between the use of water for recreational purposes and other uses. There must be an economic tradeoff between these uses so that the water resource can effectively serve more than one use.

The chief conflict between water used for recreation and irrigation is the scarcity of actual water for both purposes. Irrigation reservoirs can and are used for recreation; however, in dry years it can be expected that they will be drained to well below the minimum recreational level.

A serious conflict may also arise between water used for industrial and recreational purposes. Water required for industrial production processes may also provide a body of water for recreational purposes. It must be remembered; however, that the water must meet the demands of its primary user. Again in dry periods the water level may fall below the minimum necessary for recreational purposes. Industries often use public water sources as a disposal medium for wastewater. Often the wastewater is treated to some degree, but in most cases it is unsatisfactorily treated. Thus, pollution of streams and lakes is the result, and recreational value is affected. To combat this stronger laws must be enacted and enforced concerning industrial pollution.

Conflicts between recreation and municipal water supply are similar to the conflicts experienced by flood control and power generators. Should a municipality allow recreation on their water resource, they must treat the water to a higher degree. This involves a higher cost of construction of water treatment plants (34).

These problems all exist in the San Antonio River Basin; however, some are more acute than others. The most serious problem to be faced at the present is the deterioration of water quality and hence the discouragement of recreation in the area, especially the lower reach of the San Antonio River.

CHAPTER 6

FLOOD CONTROL

Historically flood control and drainage has been a serious problem for the city of San Antonio. During the years, 1921 and 1946 considerable damage of property and loss of lives resulted from major flooding of the area. Residential and commerical buildings, railroads, roads and bridges in the watershed area have been damaged yearly by uncontrolled flooding.

Following the flood of 1921 the city of San Antonio adopted a flood control plan formulated by the engineering firm of Metclaf and Eddy. This plan included construction of the present Olmos Creek Dam and Reservoir, in addition to enlarging, straightening, deepening, and paving certain reaches of the San Antonio River and its tributaries. This work; however, did not prove sufficient against a major flood as was indicated by the serious damage which resulted from the flood of 1946.

Floods in the tributaries of the San Antonio River originating in the Edwards Plateau upstream from San Antonio rise and fall more rapidly and have higher velocities than those orginating at San Antonio and downstream in the Coastal Plain province (22). However, the slower moving floods occuring in the Coastal Plain overflood wider flood plains than those of the Edwards Plateau (22).

Average annual flood damages along the San Antonio River are $4,300 per mile above its confluence with Cibolo Creek and $8,000 per mile from Cibolo Creek to its mouth. For the principal tributaries, the average annual flood damages are less than $100 per mile along the Medina River and $300 to $2,800 along Cibolo Creek. San Antonio and Kenedy are among the cities in the basin which have experienced severe flood damage (22).

The frequency of major floods along the San Antonio River is about once every 12 years in the upper reaches and once every 5 years in the lower reaches. Minor flooding occurs about once every year and a half (22).

Urbanization of the San Antonio area has altered the characteristics of the the flood runoff. Previous studies have found that an increase in storm runoff coincided with urban development of the area (18). It is recognized that runoff and flooding within the area will continue to increase as urbanization moves further into the basin. As urbanization changes the natural watersheds, the characteristics of runoff will also change. Therefore, future plans for flood control should consider the expected future areas of population.

The San Antonio River Authority along with the U. S. Army Corps of Engineers are the major agencies responsible for flood control in the area. Several projects have been initiated to help relieve the flood and urban problem. Two planned reservoirs, Goliod and Cibolo, will have flood control storage capacities of 702,000 and 218,000 acre-feet respectively. In addition, a channel improvement project on the San Antonio River and its tributaries help relieve the existing problem (1). The Salado Watershed Project is also under construction, it will consist of sixteen floodwater retarding structures with a total drainage area of 117.7 square miles. This will represent 47,982 acre feet of storage capacity with a floodwater detention pool surface area of 2,887 acres. Each structure will be a class C type and the majority are constructed of rock.

The San Antonio Channel Improvement Project is a joint effort of the San Antonio River Authority and the U. S. Army Corps of Engineers. SARA provides the required land and easements and relocates utilities and bridges. The U. S. Army Corps of Engineers performs the actual construction of the structures. Presently five structures have been completed and two are under construction. The total length of the completed project is 64.79 miles. The completed portion consists of 36.30 miles.

As the magnitude and frequency of floods are reduced, the water carrying capacity of stream channels gradually decreases due to the natural encroachment of vegetation. Thus, overbank flooding will occur with less volume of flow than was required to cause flooding before the flood structures were built (22).

Flood protection for a large portion of the city of San Antonio is provided by Olmos Dam. This structure is located on Olmos Creek and is operated for flood control only. Olmos Creek is generally dry during periods of normal rainfall (22).

The Soil Conservation Service is actively administering the U. S. Department of Agriculture's programs of watershed protection and flood prevention on a number of watersheds in the San Antonio River Basin. Plans have been developed for five watersheds totaling about 361,500 acres. Development has been completed for four of the watersheds, and one is currently under construction. On these five planned watersheds, 31 floodwater retarding structures and over 2 miles of channel improvement have been constructed (22). Currently 60 percent of the planned river miles have been finished, and the remaining construction to be completed is in the urban area of the city. In addition, the regional wastewater collection system proposed by Alamo Area Council of Governments (See Chapter 3) also considers flooding and storm runoff (25).

It should be emphasized that once storm and urban runoff are considered as inputs to the wastewater treatment system the change of characteristics of wastewater must be considered. This effect manifests itself not only in the quality of wastewater but also in the quantity of the treatment facilities to handle peak periods of runoff. At present only 20 percent of the storm water runoff is drained by storm sewers. This limited drainage has resulted in partial flooding of the city during heavy periods of storm runoff. In addition,there was only a preliminary attempt to treat storm runoff in order to meet minimum water quality standards. Essentially the water quality in this area is highly dependent upon the ability to handle the pollution associated with storm drainage in the future. Currently, about 25 percent of the flow of the lower San Antonio River is composed of storm runoff.

The Cibolo Reservoir located in Wilson County near the center of the river basin is a multipurpose project currently under construction. This reservoir was designed to serve the purposes of flood control, water supply and recreation. The reservoir will store 179,000 acre feet for a water supply and 278,000 acre feet of water as a flood control measure. The project will require 19,000 acres of land, 7,000 of which are designated as flood control.

The Environmental Science Services Administration (ESSA), U. S. Weather Bureau,provides a flash flood warning service to the San Antonio area (12). Flash flooding results from heavy rainfalls, generally 3 to 4 inches or more. A limited amount of cooperative observations at military installations and five stations report rainfall.

The ability to accurately forecast flow quantity and flood data requires the timely rainfall and river gauging information. Moreover, timely receipt of such information is particularly important to areas subject to flash flooding. Unfortunately, present economic constraints do not permit Weather Bureau funding of the relatively dense networks required for optimum benefits. Meanwhile, a community flash flood reporting network of stream and rainfall stations, operated in cooperation with the Weather Bureau may be an approach that can be effective in reducing danger to life and property.

ESSA - U. S. Weather Bureau has facilitated an information dissemination facility called the ESSA Weather Wire Service. This Wire service links the weather bureau with the news media and other private or governmental agencies in the area by teletype. A community may, at their expense, arrange for a teletype drop on this circuit which could provide invaluable information regarding a hazardous weather situation (13).

Prior to the Corps of Engineers, in cooperation with San Antonio River Authority, undertaking the San Antonio Channel Improvement Project, urban flooding was a major problem of the region. Although the possibility of another occurance of urban flooding is not eliminated, this threat has been sharply reduced. Close cooperation of local, state and federal governmental agencies is imperative if this problem is to be completely resolved.

Executive Order No. 11296 signed by the President, August 11, 1966, prohibits any federal installation to be constructed on a flood plain and also prohibits the granting of federal loan or mortage insurance against any construction in a designated flood plain. This includes any federal loan insured under the Veterans Administration or Federal Housing Authority. This Executive Order only applies to those areas which have been officially designated as a flood plain. Local governmental authorities should request, from appropriate agencies, that areas susceptible to flooding be designated as flood plains. Once this is done for flood plains, private enterprises development will be sharply restricted thus reducing future flood damage. Perhaps a better solution would be State legislation requiring for proposed urban development areas to be evaluated for possible flooding before construction is premitted. This type of legislation would facilitate the reinforcement of Executive Order 11296 and in addition would reduce future flooding damage to common citizens significantly.

Other alternative methods of controling development in flood plain areas are the implementation of zoning ordinances or the refusal to issue building permits in potential flooding areas. Close cooperation of city officals and local and state water resource management agencies would be necessary for positive enforcement of this alternative.

LIST OF REFERENCES

1. Arnow, Ted, Bulletin #5911: Ground-Water Geology of Bexar County Texas., Texas Board of Water Engineers: Austin, Texas, October, 1959.

2. Bacterial-Quality Objectives for the Ohio River., Ohio River Valley Water Sanitation Commission: Columbus, Ohio, 1951.

3. Census of Business, 1967., U. S. Government Printing Office: Washington, D. C., 1967.

4. Census of Population, 1970. U. S. Government Printing Office: Washington, D. C., February 1971.

5. Clawson, M., Methods of Measuring the Demand For and Value of Outdoor Recreation, Resources For The Future Inc.: Washington, D. C., 1959.

6. Clawson, M., and Knetsch, J. S., Economics of Outdoor Recreation, John Hopkins Press: Baltimore, Maryland, 1966.

7. Eckenfelder, W. W., Water Quality Engineering For Practicing Engineers, Barnes and Noble, Inc.: New York, New York,1971.

8. Economic And Demographic Characteristics Of The Alamo Area Council Of Governments Area, An Overview, Alamo Area Council of Governments: San Antonio, Texas, May, 1969.

9. Edwards Underground Water District And Edwards Underground Reservoir, Edwards Underground Water District: San Antonio, Texas, 1966.

10. Ellis, Water Purity Standards For Fresh Water Fishes, U. S. Department of Commerce, Bureau of Fisheries: Washington, D. C., 1935.

11. Environmental Analysis For The Alamo Area Council of Governments, Alamo Area Council of Governments: San Antonio, Texas, April, 1970.

12. Flood Plain Information, Salado Creek, San Antonio, Texas, Corps of Engineers, U. S. Army: Fort Worth, Texas, October 1969.

13. Flood Plain Information, Rosillo Creek, Bexar County Texas, Corps of Engineers, U. S. Army: Fort Worth, Texas, January, 1970.

14. Garza, Sergio, Report #34: Ground-Water Resources Of The San Antonio Area, Texas, Texas Water Development Board: Austin, Texas, November, 1966.

15. Garza, Sergio, Bulletin #6201: Recharge, Discharge, and Changes In Ground-Water Storage In The Edwards And Associated Limestones, San Antonio Area, Texas, Texas Board of Water Engineers: Austin, Texas. January, 1962.

16. Gloyna, E. F., Report On The Water Quality Of The San Antonio River, San Antonio River Authority: San Antonio, Texas, 1956.

17. Grubb, Herbert W., and Goodwin, James T., Report # 84: Economic Evaluation Of Water-Oriented Recreation In The Preliminary Texas Water Plan, Texas Water Development Board: Austin, Texas, September, 1968.

18. Harris, and Ranty, Effect of Urban Growth On Streamflow Regimen. United States Geological Survey: Washington, D. C., 1964.

19. Hunter, H. A., Waste Treatment Report For SARA, Homer A. Hunter Associates: San Antonio, Texas, 1964.

20. Johnston, Leah C., San Antonio, St. Anthony's Town, The Naylor Company: San Antonio, Texas, 1947.

21. Merewitz, L.,"Recreational Benefits Of Water Resource Development," Water Resource Research, Vol. 2. No. 4, 1966.

22. Preliminary Plan For The Proposed Water Resources Development In The San Antonio River Basin, Texas Water Development Board: Austin, Texas, July,1966.

23. Rainfall Frequency, San Antonio River Valley, Texas Water Quality Board: Austin, Texas, October, 1970.

24. Rawson, J., Report # 93: Reconnaissance Of The Chemical Quality Of Surface Waters Of The San Antonio River Basin, Texas. Texas Water Development Board: Austin, Texas, April, 1969.

25. Regional Wastewater Development Plan, Alamo Area Council of Governments: April, 1971.

26. Regional Wastewater Development Plan-Technical Description Of Methodology, Alamo Area Council Of Governments: Austin, Texas, April, 1971.

27. San Antonio River Authority Monitoring Program, San Antonio River Authority, San Antonio, Texas, 1970.

28. San Antonio River Walk Policy Manuel, San Antonio River Walk Commission: San Antonio, Texas.

29. Senate Record #91-1250, 91st Congress, U. S. Government Printing Office: Washington, D. C., 1970.

30. Stephenson, A. H.,"Water Quality Requirements For Recreational Use", Sewage Work Journal, Vol 21, No. 1.

31. The Texas Water Plan, Texas Water Development Board: Austin, Texas, 1968.

32. Unpublished Report. A Study Of Development And Management Of Water Resources In The Area Surrounding The Edwards Aquifer. Water Resources Seminar, Lyndon B. Johnson School Of Public Affaris: University Of Texas, Austin, Texas, May 1971.

33. Vernon's Annotated Revised Civil Statues Of The State Of Texas. Vol. 21A, West Publishing Company: St. Paul, Minn., 1970.

34. Water For Recreation-Values And Opportunities, U. S. Department Of Interior: Washington, D. C., 1962.

35. Wilson, W. F., Edwards Aquifer, Alamo Area Council Of Governments: San Antonio, Texas, 1970.

APPENDIX I

WATER QUALITY MONITORING PROGRAM OF THE SAN ANTONIO RIVER AUTHORITY

APPENDIX I

WATER QUALITY MONITORING PROGRAM OF THE SAN ANTONIO RIVER AUTHORITY

Region I

This region is in the southeast part of the basin and contains approximately 1,200 square miles. The population is very scattered and all of the cities are less than 5,000 in population.

Following is a list of all regular sampling points and sampling frequency.

Return Flow Monitoring Program (STP)

Location	SARA No.	Decision Point	Frequency
Kenedy *	000380	47.07.00	Weekly
Floresville	000350	36.00.00	Weekly
Poth	000020	12.09.02	Monthly
Falls City	000030	12.00.00	Monthly
Karnes - New	000110	05.00.00	Monthly
Karnes - Old*	000120	47.04.04	Monthly
Stockdale	000140	02.20.02	Monthly
Goliad*	000710	18.00.00	Monthly
Runge*	000150	46.02.00	Monthly

*Lower Basin No. System

Stream Quality Program

SAR at Falls City	000000-069	17.00.00	Weekly
Cibolo Creek at Cestohowa	000000-054	02.07.00	Weekly

This region will be covered by a SARA representative once each week for approximately six hours. At this time, all regional pollution complaints will be investigated.

Region II

The region contains many small subdivisions around the military bases. The approximate area covers 500 square miles with an estimated population of 20,000. Most of the population is organized into Water Control and Improvement Districts (WCID's) except for two towns (La Coste and Castroville). All of the plants are relatively small (less than 1.0 mgd).

Following is a list of all regular sampling points and sampling frequency.

Return Flow Monitoring Program (STP)

Location	SARA No.	Decision Point	Frequency
BCWCID 16	000800	64.02.00	Daily
Valley-Hi	000100	64.02.00	Weekly
Gateway	000320	60.05.00	Weekly
Indian Creek	000810	60.03.00	Weekly
Tradewinds	000300	60.03.00	Monthly
Castroville	000510	76.00.00	Monthly
La Coste	000540	69.03.00	Monthly

Stream Quality Program

Medina River at Rio Medina	000000-781	89.00.00	Weekly

This region is visited once a week by a SARA representative for collecting the samples and investigating pollution complaints. The representative will actually spend approximately six hours in the region and an additional two hours at WCID 16 performing a SARA plant inventory.

Region III

This region is in the northwest area of the basin. The approximate area covered is 800 square miles with a population of 30,000. About 85% live within three miles of Loop 410. Much of the area in Bexar County is hilly but is being developed in scenic homesites. All of the plants are less than 1 mgd capacity.

Following is a list of all regular sampling points and sampling frequency based on the existing departmental manpower budget program.

Return Flow Monitoring Program (STP)

Location	SARA No.	Decision Point	Frequency
Oak Hills	000860	60.10.00	Daily
S. W. Research Fdn.	000330	60.09.00	Weekly
Lackland WCID	000820	60.07.00	Weekly
Thunderbird Hills	000830	60.10.00	Weekly
Southwest Util.	000900	60.07.00	Weekly
Bandera*	000730	00.28.00	Monthly

* Upper Basin No. System

The region is visited once each week by a field representative of SARA for the purpose of collecting samples and investigating pollution complaints. The personnel time involved is four hours except when the Bandera sample is collected (total of 6 hours). Also, two hours will be used for the SARA STP Operating Inventory Program at Oak Hills STP.

Region IV

This region is located in the north central part of the basin (parts of Bexar) and contains approximately 800 square miles with a population of 15,000. The area does not contain many waste treatment plants or stream sampling points. The area is increasing in population rapidly due to the development of the area.

Following is a list of all regular sampling points and sampling frequency.

Return Flow Monitoring Program (STP)

Location	SARA No.	Decision Point	Frequency
Kirby	000870	52.06.02.04	Daily
Rosillo Creek	000500	52.06.02.04	Weekly
Boysville	000040	02.37.06.08	Monthly
Boerne	000130	02.76.02	Monthly

Stream Quality Program

Location	SARA No.	Decision Point	Frequency
Cibolo Creek at Ih 10	020000-375	02.40.00	Daily

The field representative will spend about two hours per week in this region on sampling and investigating pollution complaints. Two hours will be used for the SARA STP Operating Inventory Program at Salatrillo.

Region VI

This region is in the south central part and includes the San Antonio River as it passes through downtown San Antonio. The area covered is approximately 200 square miles. The major City of San Antonio sewage plant in the basin is located in this region but the plant maintains its own laboratory and furnishes SARA with copies of all results. Following is a list of all regular sampling points and sampling frequency.

Stream Quality Program

Location	SARA No.	Decision Point	Frequency
SAR at Elmendorf	000000-431	49.00.00	Weekly
Medina River at U. S. 281*	000000-501	50.00.00	Weekly

Stream Quality Program, Region VI -- CONTINUED

Location	SARA No.	Decision Point	Frequency
SAR at 410 S	520000-049	52.11.00	Weekly
Salado Creek at Loop 13	520600-039	52.06.02	Weekly
SAR at Alamo St.	520000-071	52.13.00	Weekly

Dissolved Oxygen Program

SAR at Elmendorf	000000-431	49.00.00	Daily
Medina River at U. S. 281 *	000000-501	58.00.00	Daily
SAR at 410 S	520000-049	52.11.00	Daily
Salado Creek at Loop 13	520600-039	52.06.02	Daily
SAR at Alamo St.	520000-071	52.13.00	Weekly

* Now samples at F. M. 1937, 0055

Return Flow Monitoring Program

Southon	000700		Monthly

This region will require about three hours for one man to cover. Pollution complaints in this area should be considered as urgent or critical because of the developed nature of the river in downtown San Antonio.

SARA Sewage Treatment Plant Inventory Program

This program applies to all SARA operated treatment plants. The tests performed on the various parts of the system are: TSS and VSS in all zones; oxygen uptake rate on all zones of the modified activated sludge process; a settling test on various zones of plants using the modified activated sludge process (contact Stabilization or Extended Aeration). These values are then used to establish operating procedures (wasting rate, etc.) for the plant.

APPENDIX II

SAN ANTONIO RIVER BASIN DATA RETRIEVAL PROGRAM

APPENDIX II

SAN ANTONIO RIVER BASIN DATA RETRIEVAL PROGRAM

SARBDR is designed to be used in conjunction with the STORET numbering system developed by the Alamo Area Council of Governments. This system has been described above in Chapter 3.

Because IBM 360 allows 10 digit integers without double precision; the decision point number is expanded as two integers having 6 digits and 4 digits each with the omitted watershed number -00. Example as: 52.06.00 expanded to 52.06.00.00.00.

SARBDR retrieves selected data from the data base developed from the San Antonio River Basin. SORET Data is retrieved from Key Parameter, based on sample location watershed point, year, day and time. The water quality parameters for which data is available are listed below:

(1) Dissolved Oxygen (DO)
(2) Temperature (T)
(3) Biochemical Oxygen Demand (BOD)
(4) Total Suspended Solids (TSS)
(5) Volitile Suspended Solids (VSS)
(6) Acidity (pH)

SARBDR uses two kinds of data as inputs. One is request cards which require the user to specify the key parameters as well as the quality data in which he is interested. The second is the data base which contains all of the water quality data according to location, watershed point, year, day and time. After retrieving the requested data, TAB1 will calculate the frequency distribution of given data and PLOT will plot the frequency observations in form of histogram.

SARBDR was designed to be utilized with any standard FORTRAN program as a subroutine. SARBDR was developed on the IBM 360/65 and written in FORTRAN - G level. Program compilation and run time is approximately 1-5 minutes depending upon the number of request cards and number of data parameters requested on each card. The program requires 320 K of core. The SARBDR program can be utilized independently by replacing the subroutine definition statement and initializing the respective parameters.

The primary function of the program is to retrieve the water quality data at given control points (Decision points). The main program in SARBDR through calling the subroutines will handle the following jobs: predicting data, sorting data, calculate the frequency, relative frequency, and cumulative frequency over given class intervals, calculate the mean, standard deviation maximum and minimum value of retrieved data, then plot the frequency distribution in the form of histogram.

SUBROUTINE PREDIT

PREDIT will edit the control cards and data cards eliminating those cards with bad or embedded characters. Exception conditions in inputed data are noted on the output listing. The subroutine will then count the corrected data and place it in storage.

Example of invalid number:

52.01.02.00.04 52.00.12.46.00

SUBROUTINE SORT

SORT uses the modified Cascade Method to sort data in ascending order according to user specified keys. There are 6 keys: location (2), point, year, day and time.

SUBROUTINE ORDER

This subroutine orders the sorted and edited data. It initalizes the maximum and minimum value and number of intervals desired then passes it to subroutine TAB1.

SUBROUTINE TAB1

TAB1 calculates for one variable in an observation matrix the frequency, relative frequency, and cumulative frequency over given class intervals. It also outputs the mean, standard deviation, maximum and minimum of the retrieved data.

SUBROUTINE WRITE

WRITE outputs the retrieved data, DO, BOD, and PH are printed in real form with one decimal digit. While T, TSS and VSS are printed in integer form.

SUBROUTINE PLOT

This subroutine plots the frequency distribution in the form of a histogram. The vector Y(I) is the cross variable and is plotted against the vector X(I), the base variable.

INPUT/OUTPUT FILE

a) Input File:

To effectively use SARBDR one must be aware of the format of control cards as well as the print option available. Figure II-1 describes the order of job stream. Figure II-2 shows the data types to read. The format and content description of each types of cards are described in Table 1.

TABLE 1

Input File Description

Card or Field ID	Description	Format	Col.
Type 1			
Control Cards			
LOC	10 digits of decision pt. requested.	5I2	1-10
PARA (1)	Point requested	I3	13-15
PARA (2)	Year requested	I2	16-17
PARA (3)	Day requested	I3	18-20
PARA (4)	Time requested	I4	25-28
PARA (5)	'DO'	A4	29-32
PARA (6)	'T'	A4	33-36
PARA (7)	'BOD'	A4	37-40
PARA (8)	'TSS'	A4	41-44
PARA (9)	'VSS'	A4	45-48
PARA (10)	'PH'	A4	49-52
NFINI	'9999' if end of Control card file.	I4	77-80
Type 2			
Data Cards			
LOC	10 digits of decision pt.	5I2	1-10
PARA (1)	Point	I3	13-15
PARA (2)	Year	I2	16-17
PARA (3)	Day	I3	18-20
PARA (4)	Time	I4	25-28
PARA (5)	DO	I3	31-33
PARA (6)	T	I2	34-35
PARA (7)	BOD	I5	39-43
PARA (8)	TSS	I5	44-48
PARA (9)	VSS	I5	49-53
PARA (10)	PH	I3	58-60
NFINI	'9999' if end of data card file.	I4	77-80
Type 3			
IDEN	Identify control card or data card.	20A4	

b) Output File:

In order to provide a complete analysis of the system, as each exception condition is encountered, SARBDR will note it in its output. After each cycle of processing, a map of the status of the system including a copy of the original data and resulting performance in the histogram is printed as shown in the program listing.

A trace through the output should give the user a good feeling for the performance of the system model.

FORTRAN Variables--SARBDR

The following FORTRAN variables are used in the Main Program:

MOLD = Array of original data, NDATA by NC.

MNEW = Array of sorted data, NDATA by NC.

ICR = Query Array, NCO N by NC.

LOC = 10 digits decision pt. no. Vector length is 5.

IDEN = Identification cards

DPRINT = Data List Print Option:
if DPRINT = 1, Data will be printed.
DPRINT = 0, Data will not be printed.

NPATA = Number of valid data cards.

NCON = Number of valid control cards.

L = Index use to control number of retrieved data.

A = Observation matrix, used in TAB1.

S = Input vector, a subset of A used in TAB1.

FREQ = Output vector of frequencies used in TAB1.

PCT = Output vector of relative frequencies used in TAB1.

STATS = Output vector of summary statistics, used in TAB1.

IAB = Data block vector to initialize the name of quality paramenter, length is 6.

ICTBS = 6 Keys, length is 6.

SUBROUTINE PREDIT & SORT

PARA = Temporary vector for holding ACC parameter except decision point length is 10.

NAME = MOLD, MNEW or ICR. KOUNT by NC array.

NR = NDATA

NCTBS = 6 keys

IT = Temorary address for switching order.

KOUNT = NDATA or NCON

SUBROUTINE TAB1

A = Observation Matix .. number by NC.

S = Input vector, a subset of A. Vector length is number.

NOVAR = Variable to be tabulated

UBO = Vector length is 3.
UBO (1): Upper limit of variable to be tabulated.
UBO (2): Number of intervals.
UBO (3): Lower limit of variable to be tabulated.

FREQ = Output vector of frequencies. Vector length is UBO (2).

PCT = Output vector of relative frequencies. Vector length is UBO (2).

STATS = Output vector of summary statistics, ie. total, mean, standard deviaiton, max. and min. value. Vector length is 5.

NO = Number of observations.

NV = Number of variables for each observation.

SUBROUTINE ORDER

DATA = S in TAB1

UBO = UBO in TAB1

SUBROUTINE WRITE

FOR = Object time format vector length is 7. FOR (7) is either format FIX or BLKFOR depends on data value is equal to zero or not.

FOT = Object time format vector length is 8. FOT (7) is either format FLT or BLKFOT depends on data value is equal to zero or not.

FIX = Format

FLT = Format

BLKFOR

BLKFOT

POINT = An address to store real data transformed from integer number.

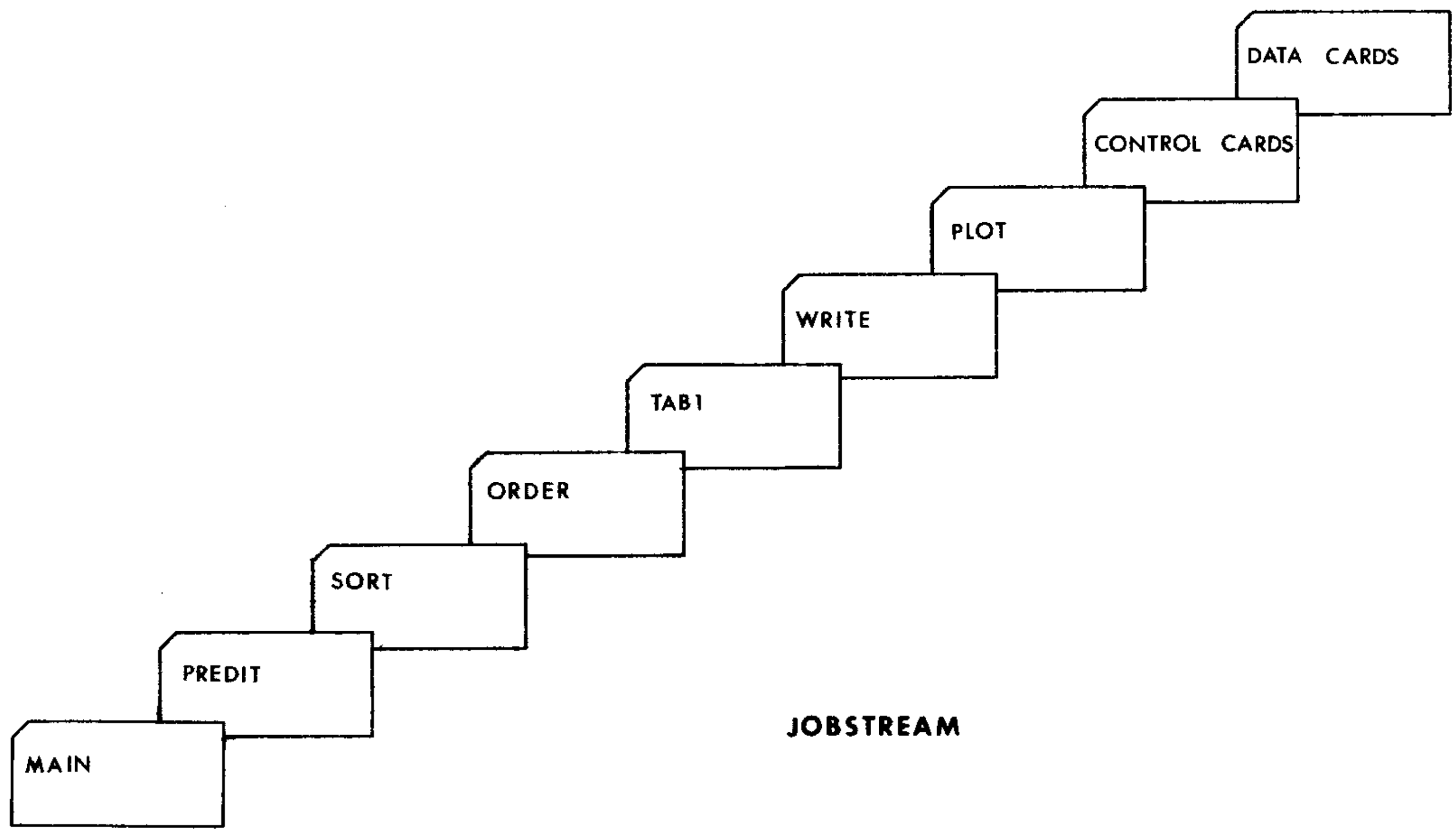


Figure II-1
Jobstream For SARBDR

TYPE 1 Control Card

LOC (5) PARA (10) NFINI

5I2 I3I2I3 I4 A4A4A4A4A4A4 I4

TYPE 2 Data Card

LOC (5) PARA (10) NFINI

5I2 I3I2I3 I4 I3I2 I3I2 I5I5I5 I3 I4

TYPE 3 IDEN Card

20 A4

Figure II-2
Control Card And Data Card Format

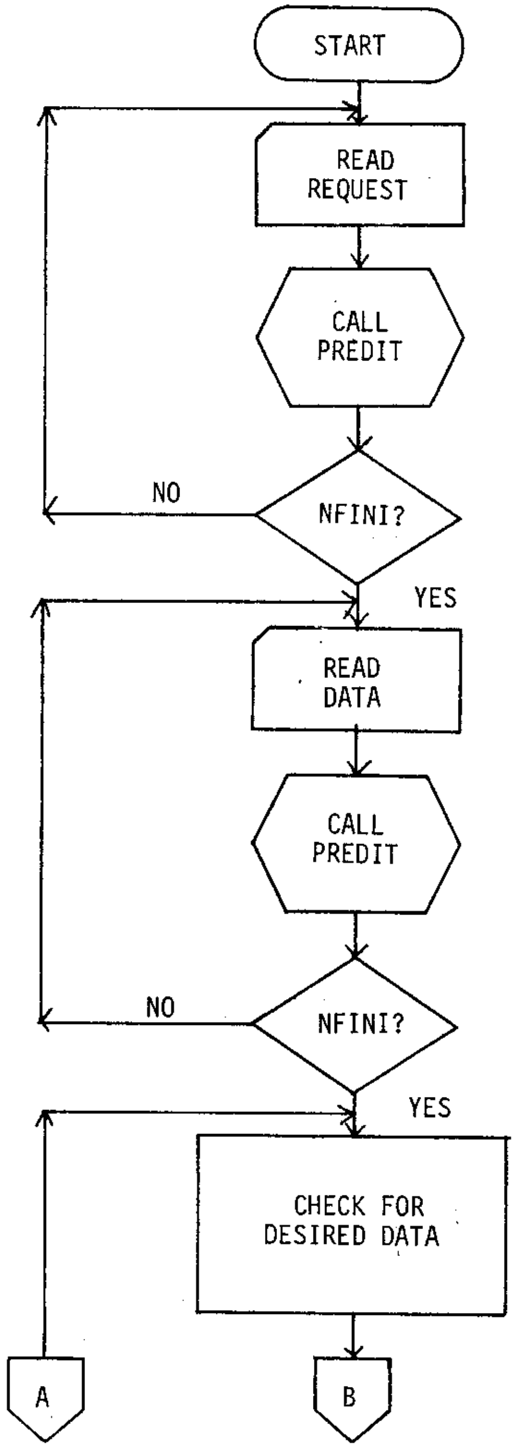


Figure II-3. MAIN Program

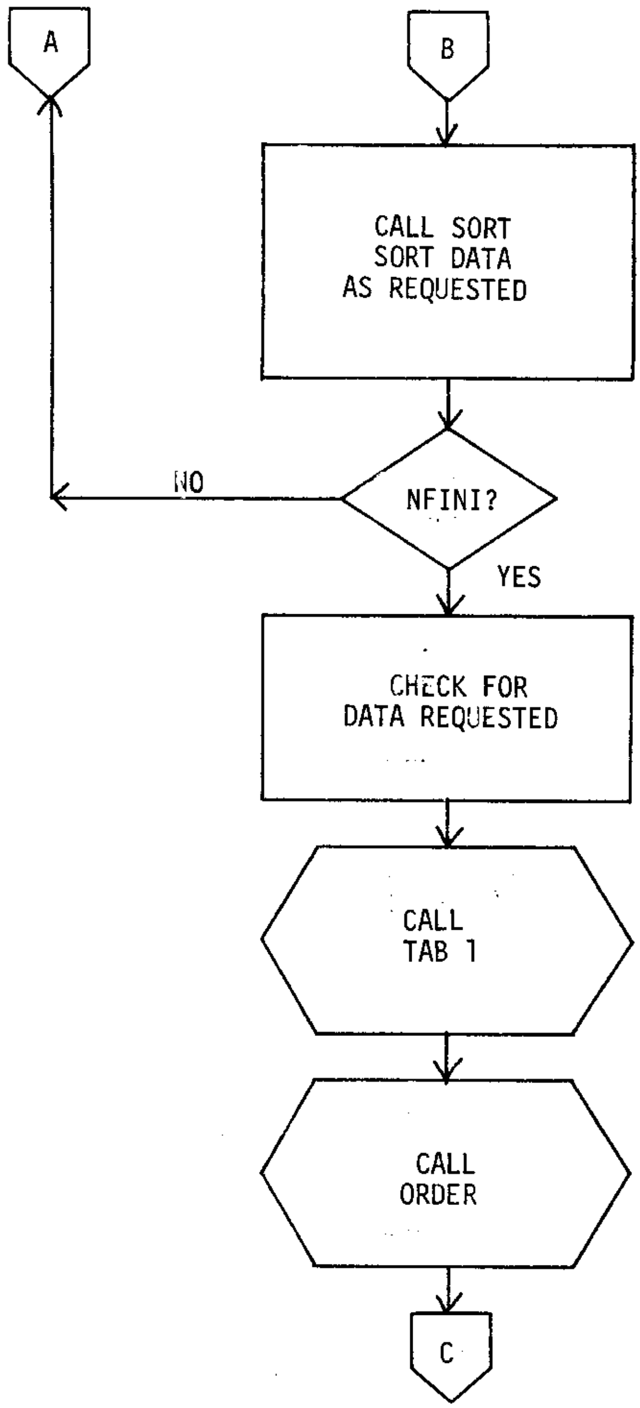


Figure II-3. Continued

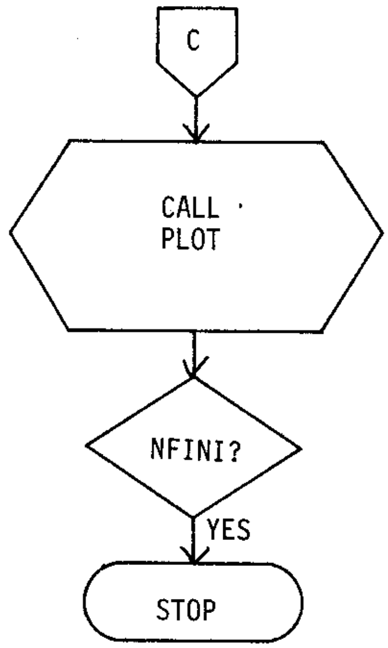


Figure II-3. Continued

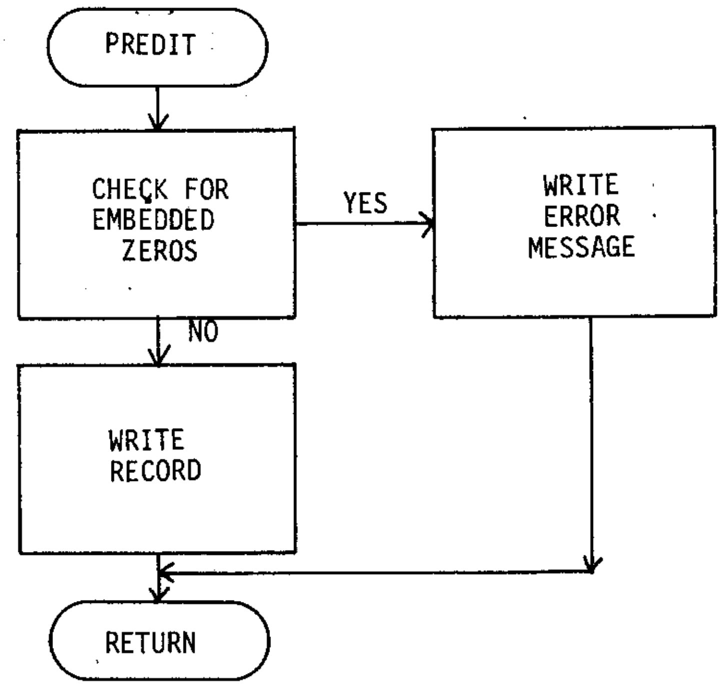


Figure II-4. Subroutine PREDIT

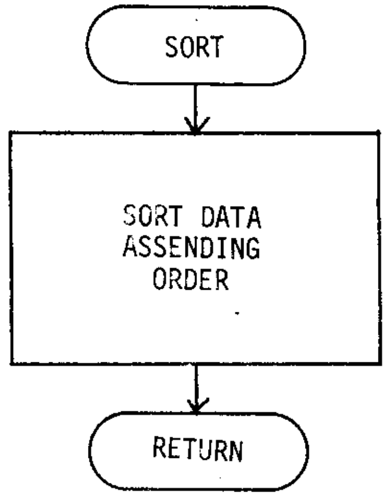


Figure II-5. Subroutine SORT

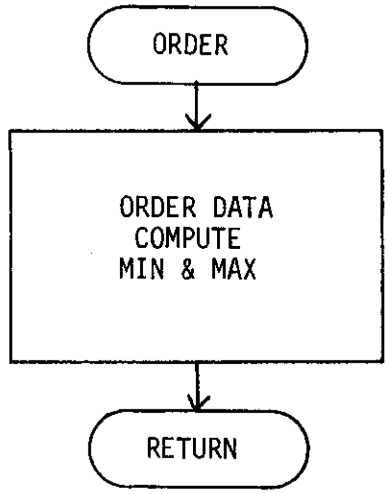


Figure II-6. Subroutine ORDER

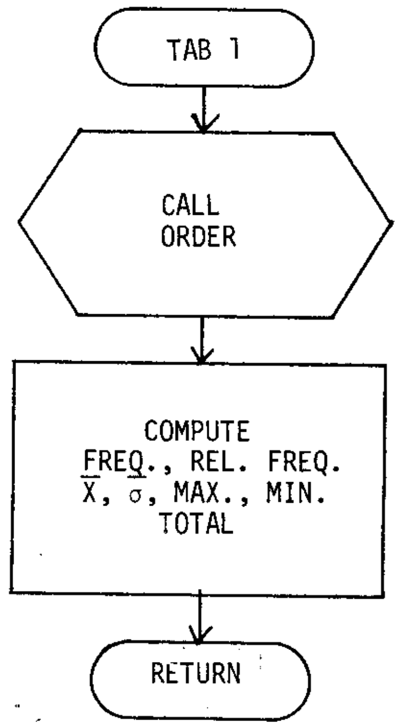


Figure II-7. Subroutine TAB-1

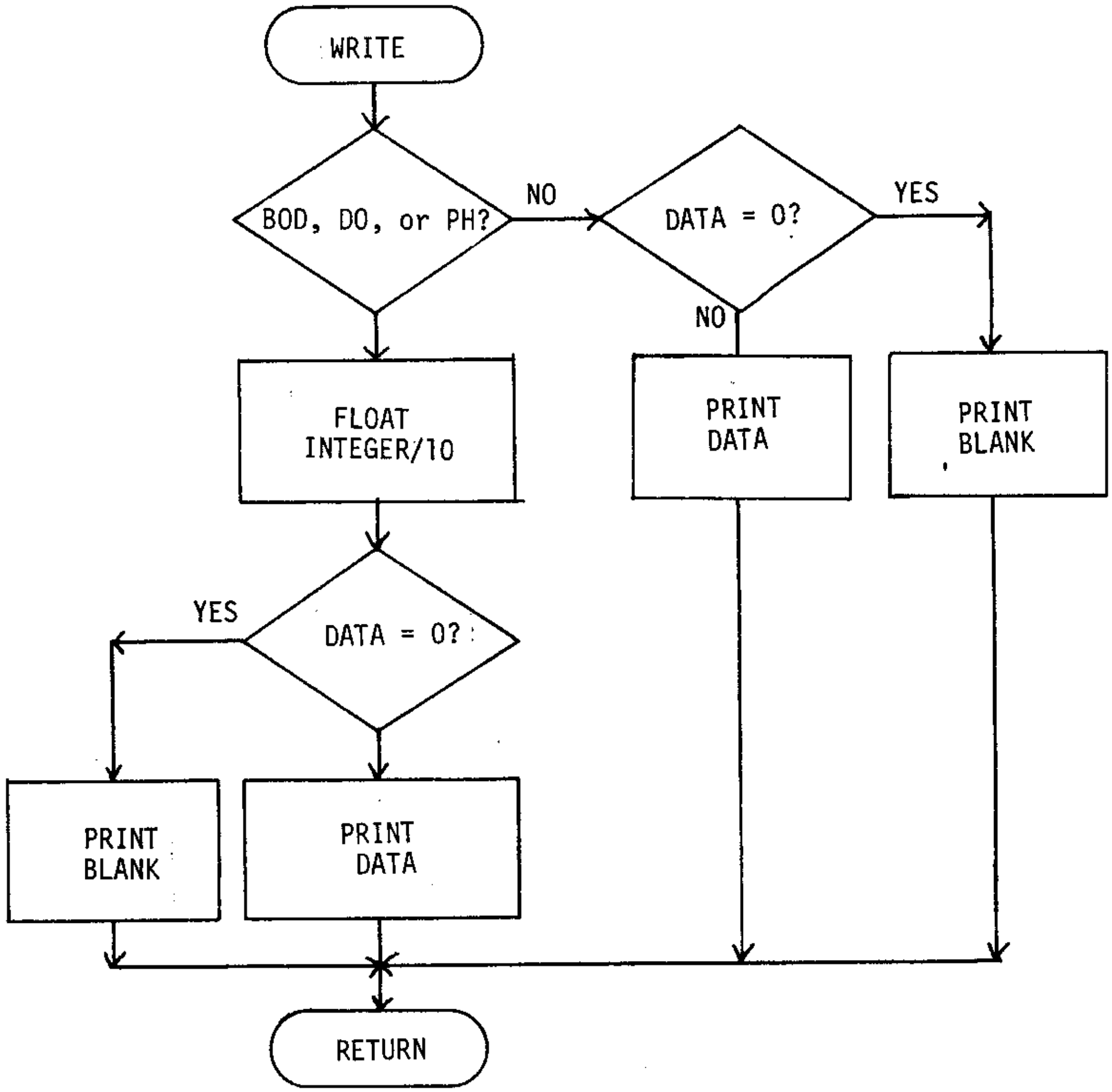


Figure II-8. Subroutine WRITE

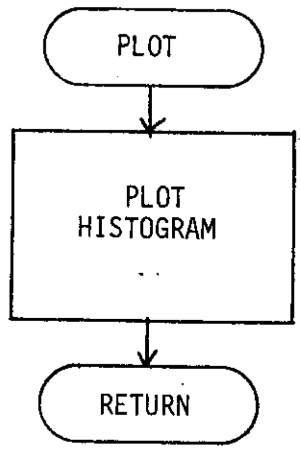


Figure II-9. Subroutine PLOT