Southwest Florida Water Management District

Northern Tampa Bay
Minimum Flows & Levels White Papers

White Papers Supporting The Establishment of Minimum Flows and Levels For:

- ❑ Isolated Cypress Wetlands
- ❑ Category 1 and 2 Lakes
- ❑ Seawater Intrusion
- ❑ Environmental Aquifer Levels, and
- ❑ Tampa Bypass Canal

PEER REVIEW FINAL DRAFT
March 19, 1999

Northern Tampa Bay
Minimum Flows and Levels
Overview

The Northern Tampa Bay area is comprised of the counties of Pinellas, Pasco and the northern portion of Hillsborough. These counties are located in southwest Florida and surround the northern half of Tampa Bay. Pinellas County is almost entirely urbanized, as are much of northwest Hillsborough County and southwestern Pasco County. Inland areas of Pasco are rapidly becoming urbanized also. Potable water supplies for these counties and municipalities within these counties are principally from eleven regional wellfields located in Hillsborough and Pasco counties drawing from the Upper Floridan aquifer.

The first of the regional wellfields began operating in the early 1930's. The eleventh wellfield began operating in 1992. In addition to other sources, wellfields continue to be brought on-line in the area to meet the potable water supply needs of the Northern Tampa Bay area.

The surface water environment within the Northern Tampa Bay area is highly interconnected with the ground water system. Because of the karst geology that characterizes the area, a discontinuous and leaky confining layer provides a relatively good hydraulic connection between the surficial aquifer and the underlying Upper Floridan aquifer. Although localized areas of good confinement exist, overall the Upper Floridan aquifer is described as poorly to moderately confined within the Northern Tampa Bay area. As a result, water levels in the aquifers are linked, and fluctuate similarly.

Without ground water withdrawals, recharge from rainfall to the surficial aquifer and discharge by evapotranspiration and flow from the surficial aquifer are the only significant driving forces of these fluctuations. Very little ground water is contributed to the area from lateral inflow. The variable head in the surficial aquifer in turn largely regulates the recharge to the Upper Floridan aquifer through the leaky semi-confining unit. Therefore, the fluctuations in the surficial aquifer affect the fluctuations in the Upper Floridan aquifer.

An additional stress is introduced to this process when ground water withdrawals from the Upper Floridan aquifer are added. Ground water withdrawals lower the potentiometric surface of the Upper Floridan aquifer, which in turn increase leakage from the surficial aquifer to the Upper Floridan aquifer. This additional recharge is referred to as induced recharge. The result is a lowering of the water table. Assessments have shown that in leaky areas of the Northern Tampa Bay area, most of the water withdrawn from the Upper Floridan aquifer by pumping is derived by vertical leakage downward from the surficial aquifer (Liu and Polmann, 1996). Thus, Upper Floridan aquifer water level fluctuations caused by ground water withdrawals affect surficial aquifer water level fluctuations, as well as the water levels of lakes and wetlands that are connected to the surficial aquifer.

Waters and wetlands account for approximately 23 percent of the land area within the Northern Tampa Bay area.

In the mid 1980's, the District declared the northwest Hillsborough County area and limited portions of Pinellas and Pasco Counties, within which several of the wellfields are located, to be an "area of special concern" regarding the condition of local water resources.

In 1987, the District undertook a water resource assessment project ("WRAP") to examine the water resources within the area of special concern. In 1989, based on preliminary information from the WRAP, the District declared an area as the "Northern Tampa Bay Water Use Caution Area" in recognition of environmental stress identified by the District.

In 1992, the WRAP study area was expanded and became identified as the "Northern Tampa Bay Water Resource Assessment Project" ("NTBWRAP"). The NTBWRAP is the District's most recent attempt at determining the condition of the water resources in the area of the regional wellfields. (The NTBWRAP is among the materials provided with the White Papers).

Due to environmental stress to the water resources in the Northern Tampa Bay area, Section 373.02 Florida Statutes (F.S.), as amended by the Florida Legislature in 1996, directed the District to establish minimum flows and levels for the region before October 1, 1997.

Section 373.042, F.S. defines the minimum flow to a surface water course to be the flow below which additional withdrawals would cause significant harm to the water resources or ecology of the area. Section 373.042, F.S. defines the minimum level of an aquifer or surface water body to be the level below which additional withdrawals would cause significant harm to the water resources of the area. The 1996 amendments to the statute required the District to adopt minimum flows and levels in Hillsborough, Pasco, and Pinellas County for priority waters that are experiencing or may be expected to experience adverse impacts. In response to this legislative direction, the District established 41 minimum wetland levels, minimum levels for 15 lakes, sea water intrusion aquifer levels, narrative aquifer levels and a minimum flow for the Tampa Bypass Canal. Work is ongoing to establish minimum flows and levels in the future for additional water bodies.

Section 373.042, F.S. requires the District to use the best data available to set minimum flows and levels. The legislative requirement to set the levels by October 1, 1997 was absolute, that is, there was a limited time to collect additional information. Because of the time deadline, and the associated requirement to use the best information available, the District was constrained to use existing data complete with any associated limitations of that data.

The process to develop the methods for determination of minimum flows and levels was an open public process with all interested parties invited to participate in the development of methodologies for determining the limit at which significant harm occurs to the lakes, wetlands, surface water courses and aquifers for which levels must be established. Many lay and technical representatives of the interested local governments, environmental groups and individuals did participate in the rule development process through months of meetings, public workshops, and public hearings.

Following this public process the District staff finalized methodologies and minimum levels and flows for approval by the Governing Board. However, effective July 1, 1997, subparagraph 373.042(l)(a), F.S. was added. That paragraph directs the District to consider changes and structural alterations to watersheds, surface waters, and aquifers and the effects such changes and alterations have had when establishing minimum flows and levels. Therefore, at the Board's direction, staff reviewed the previous work, additional data as appropriate, continued meetings and workshops with affected parties and held public workshops with the Governing Board to ensure that the changes to the statute had been assimilated into the methodologies.

On October 28, 1998, the Governing Board approved the subject minimum flows and levels.

As permitted under subsection 373.042(4), F.S., five parties requested Scientific Peer Review of the scientific and technical data and methodologies used to determine the flows and levels. The purpose of this series of reports is to document for the Scientific Peer Review Panel scientific and technical data and methodologies used to determine the flows and levels for priority waters in the Northern Tampa Bay area.

The reports are organized in the following sections. This first section provides a general explanation of the area, hydrogeology, the Legislature's direction to the District and the processes and constraints for the District's establishment of minimum flows and levels. The next four sections describe the specific methods developed for determination of minimum levels in certain wetlands, certain lakes, and in the Upper Floridan aquifer, respectively. The last section describes the methods used to develop the minimum flow for the Tampa Bypass Canal.

FINAL DRAFT

An Analysis of Hydrologic and Ecological Factors Related to the Establishment of Minimum Flows for the Tampa Bypass Canal at Structure 160

Southwest Florida Water Management District
March 17, 1999

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1. GENERAL MINIMUM FLOWS APPROACH FOR THE TAMPA BYPASS CANAL.

1.1 Boundaries and physical characteristics of the hydrologic system

This document describes the technical analyses that were conducted to support the establishment of the minimum flow for the Tampa Bypass Canal at Structure 160. The Tampa Bypass Canal (TBC) was constructed between 1966 and 1982 for purposes of flood control in the Hillsborough River basin. The canal system, which was largely excavated in the channel of the former Six Mile Creek and the Palm River, is connected to the Hillsborough River by a series of water control structures that are used to divert flood waters away from the Hillsborough River (see Figure 2.1 on page 2.2). Since 1985, the Tampa Bypass Canal has also been used to augment water supplies in the Hillsborough River Reservoir during the dry season. Greater details concerning the location, history, configuration, flood control and water supply use of the Tampa Bypass Canal are presented in following sections of this report.

Structure 160 is the most downstream water control structure on the Tampa Bypass Canal, as it separates the tidal and freshwater reaches of the canal system. The minimum flow established for the Tampa Bypass Canal pertains to flows at Structure 160. The ecological analyses associated with this minimum flow concentrated on the effects of freshwater discharge at Structure 160 on the downstream tidal estuarine ecosystem. In this report the tidal reach of the Tampa Bypass Canal downstream of Structure 160 is still referred to as the Palm River, while McKay Bay extends from the mouth of the Palm River to the 22[nd] St. causeway (see Figure 4.1 on page 4.4).

1.2. General minimum flows approach

The determination of minimum flows for the Tampa Bypass Canal took into consideration that this system has had extensive changes and structural alterations. The width, depth, and volume of the Tampa Bypass Canal are much greater than the streams that were excavated to form the canal (Six Mile Creek and Palm River). These physical changes have greatly altered the hydrographic, water quality, and ecological characteristics of the estuarine resources associated with the former Palm River. Construction of the canal also altered surface-water/ground-water interactions in the vicinity and the quantities of fresh water contributed from the local drainage basin to the tidal receiving waters. Accounting for these changes, the District evaluated the effects of various rates of freshwater flow from Structure 160 on salinity distributions, water quality and biological communities in the present-day Palm River/McKay Bay estuarine system. Considering all relevant factors, the District concluded that a minimum flow of zero cubic feet per second (cfs) should be established for the Tampa Bypass Canal at Structure 160.

Minimum flows are defined in Florida Statues as "*the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area*" (Section 373.042). Many recent technical articles and reports have emphasized that both inland streams and tidal estuaries need a range of freshwater flows to maintain their ecological integrity and productivity (SJRWMD, 1994; Odum et al., 1995; Richter et al., 1997; Sklar and Browder 1998). Over the last two decades, the District has increasingly emphasized this approach and taken regulatory measures to maintain natural patterns of freshwater flows in streams and to estuaries. However, due to highly modified nature of the Tampa Bypass Canal and its primary purpose of flood control, the District did not evaluate potential ecological changes that could result from withdrawals over the entire flow range of the canal. Instead, the District minimum flow analysis for the Tampa Bypass Canal concentrated on low-flow releases from Structure 160 that must be maintained to prevent significant harm to the downstream ecosystem. Such minimum flows would be linked to withdrawals from the canal, so that restrictions on withdrawals would go into effect if the minimum flows were not being met. Greater elaboration on the application and context of the minimum flow is presented in Chapter 7 or this report.

The District requested the Tampa Bay National Estuary Program form a minimum flow advisory group to provide technically sound recommendations to the District for identifying and evaluating water resource and ecological criteria necessary to establish minimum flows on the Lower Hillsborough River and Tampa Bypass Canal. The findings of the District's ecological analyses and the recommendations of the Tampa Bay Estuary Minimum Flows Advisory Group are presented in this report.

To a large extent, minimum flows for the Tampa Bypass Canal were evaluated simultaneously with minimum flows for the Lower Hillsborough River. Minimum flows for the Lower Hillsborough River are still under evaluation, so only the findings for the Tampa Bypass Canal are presented in this report. The Hillsborough River and the Tampa Bypass Canal are connected systems, however, and some information concerning the Hillsborough River is presented as it pertains to the connected hydrology and combined water use from these two systems.

1.3. Organization of the document

This introduction is followed by Chapter 2 which describes the physical and hydrologic characteristics of the Lower Hillsborough River and Tampa Bypass Canal. Chapter 3 describes historic and present-day water use from these systems. Chapter 4 describes the ecological information and data analyses the District relied on to evaluate the minimum flows. Chapter 5 presents the recommendations of the Tampa Bay National Estuary Program minimum flows advisory group. Chapter 6 discusses the hydrology and potential water supply yield of the Tampa Bypass Canal, including pumping various quantities of water from the canal to the Hillsborough River Reservoir. The adopted minimum flows are presented in Chapter 7, while the literature cited is listed in Chapter 8.

2. PHYSICAL AND HYDROLOGIC CHARACTERISTICS OF THE RESERVOIR/ CANAL SYSTEM

2.1 Physical Characteristics

The following text describes the physical and hydrologic characteristics of the Hillsborough River Reservoir and the Tampa Bypass Canal (TBC). The sources of data and the literature cited are the best available information for establishing minimum flows. A location map for the Tampa Bypass Canal and Hillsborough River Reservoir is given as Figure 2.1. A map of the entire Hillsborough River Watershed is given as Figure 2.2.

2.1.1 Hillsborough River Reservoir. The Hillsborough River flows 54 miles from its source in Pasco County southwest to Hillsborough Bay (Goetz, et al, 1978). The river was first dammed in 1898. The dam was destroyed in 1899 and rebuilt the following year. The river served as a water supply for the City of Tampa in the 1920s. The dam was subsequently destroyed by a hurricane in 1933, and rebuilt in 1945 (Tampa Tribune, September 4, 1994). The existing Tampa Reservoir Dam is located about 10 miles above the mouth of the river, and impounds a drainage area of approximately 650 square miles (Goetz, et al, 1978).

The reservoir created by the dam consists of 12.5 miles of natural river channel. The meandering, v-shaped channel and flood plain averages 15 feet in depth. Within the channel, there are many sinkholes, ledges, and sandbars. At a maximum stage of 22.5 feet NGVD, the reservoir has a capacity of nearly two billion gallons (Goetz, et al, 1978). The stage-storage relationship is presented in Table 2.1. The storage for the minimum observed stage of 14.9 feet, which occurred in 1977, is about 540 million gallons (Goetz, 1978).

2.1.2 Tampa Bypass Canal. The Tampa Bypass Canal, located east of the City of Tampa, was constructed during the period 1966 to 1982 (Figure 2.1). The canal was excavated in the channels of the former Six Mile Creek/Palm River drainage systems. The purpose of the TBC was to divert Hillsborough River flood waters to McKay Bay, bypassing the cities of Temple Terrace and Tampa. The TBC extends about 14 miles from Cow House Creek in the Lower Hillsborough Flood Detention Area (LHFDA) to McKay Bay at the mouth of the Palm River.

The canal is subdivided into three principal reaches, or pools: the upper, middle and lower pools (Figure 2.1). The TBC pools are separated by flow control structures. Each structure consists of multiple vertical lift gates that seat on the crest of an ogee weir. An array of overflow weirs is located at the top of each lift gate to control the upstream pool stage during low and moderate flows. TBC bottom widths and elevations range from 400 feet at elevation −21.0 feet NGVD (1929) near McKay Bay to 200 feet at elevation 16.0 at Cow House Creek.

Figure 2.1

Configuration of the Tampa Bypass Canal and Hillsborough River Reservoir

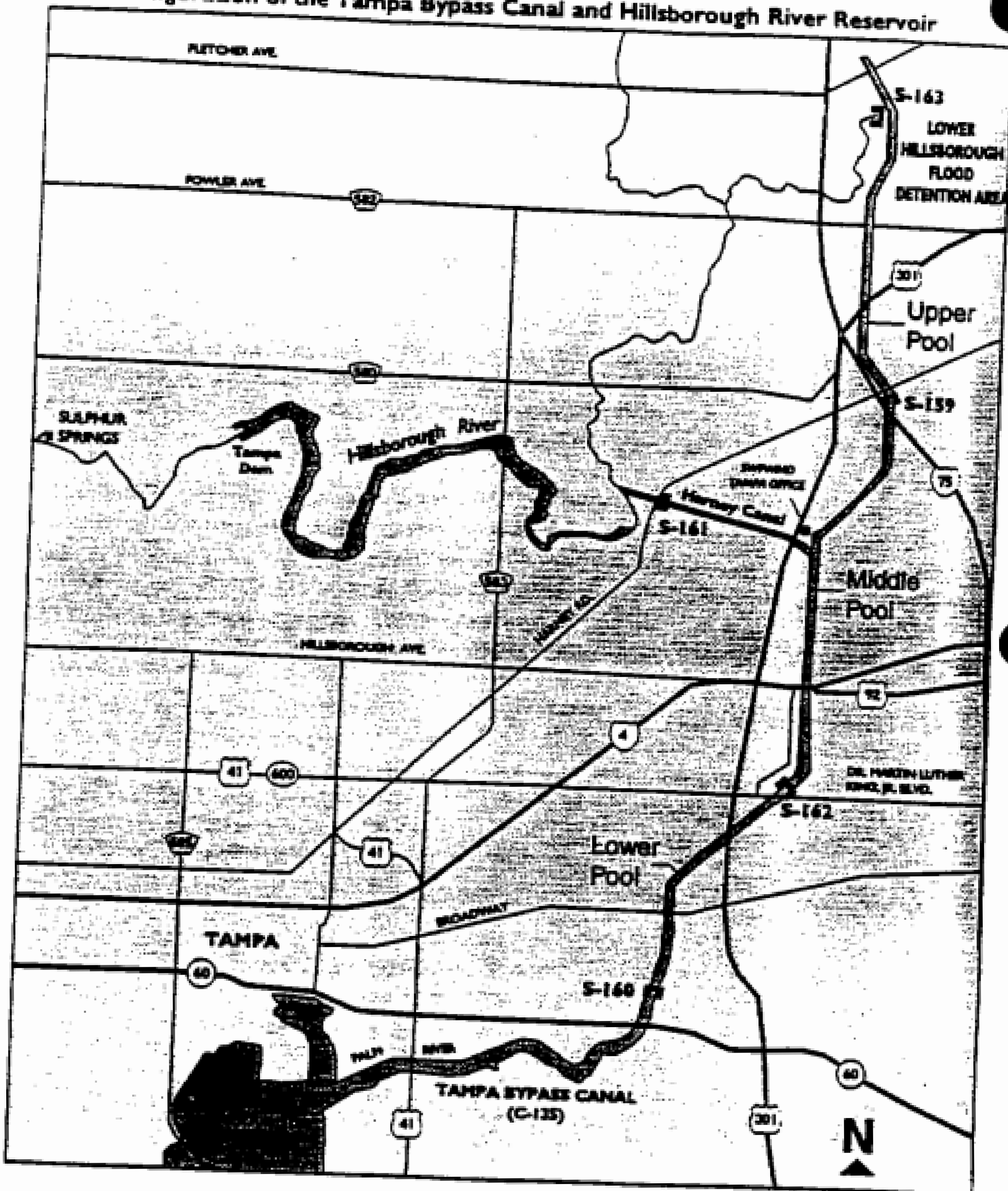
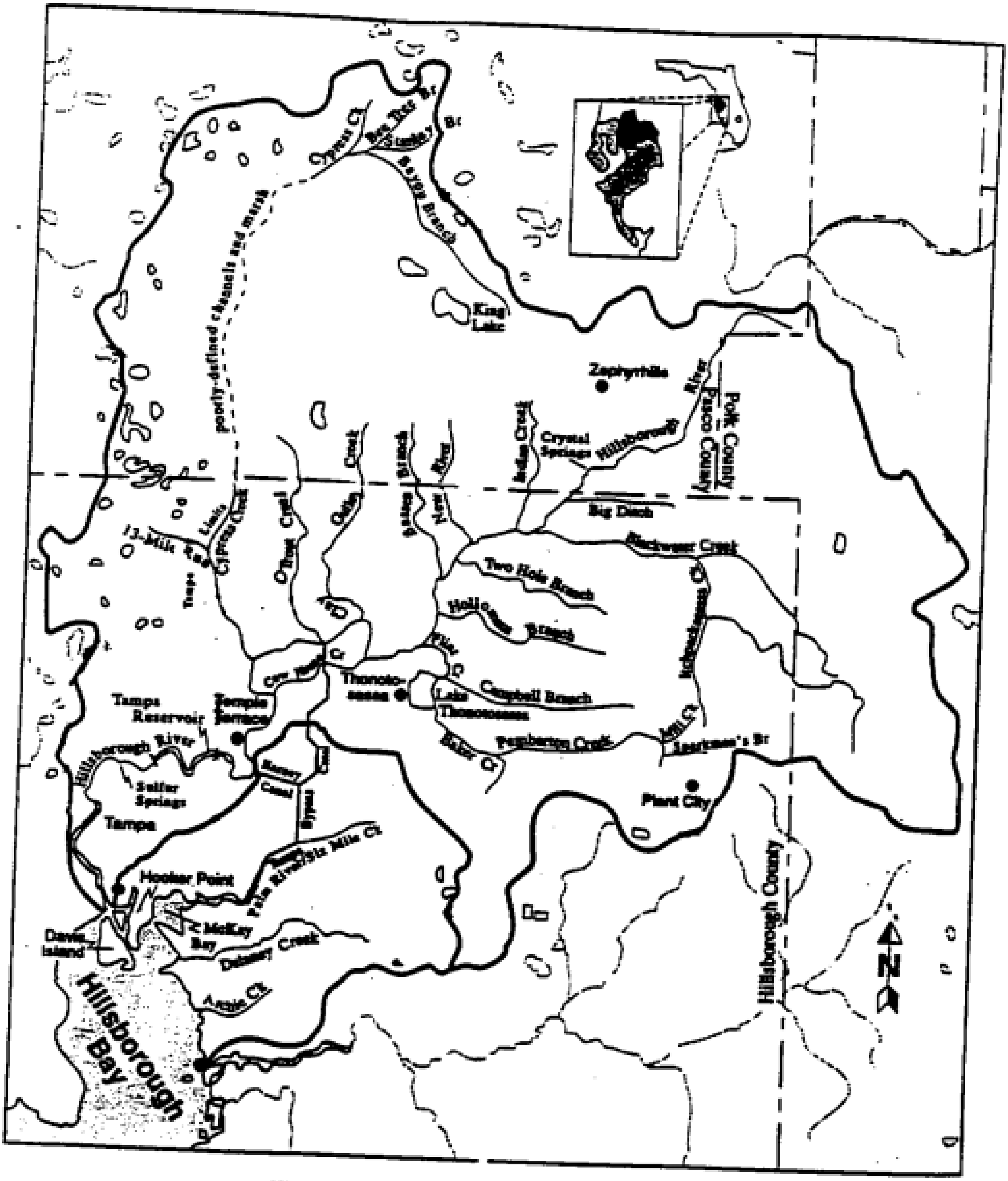


Figure 2.2



Hillsborough River and Tampa Bypass Canal drainage basins.

Table 2.1 Stage-Storage Relationship for the Hillsborough River Reservoir

Reservoir Stage ft. MSL	Reservoir Volume mgal
12.00	320
13.00	383
14.00	455
15.00	547
16.00	647
17.00	766
18.00	907
19.00	1069
20.00	1239
21.00	1419
22.00	1611
22.50	1715

Source: H. Nguyen, SWFWMD, 1997.

Flow into the upper pool is controlled by Structure 155, located on the Hillsborough River upstream of Fletcher Avenue, and Structure 163 on Cow House Creek. Closing Structure 155 causes water to back up into the LHFDA and flow into the TBC upper pool. Flow can also enter the upper pool from Cow House Creek. This flow, controlled by Structure 163, may back up into the LHFDA if Structure 159 is closed. Flow between the upper and middle pool is controlled by Structure 159. Structure 159 is actually three ogee weirs in series, but only the upstream weir has an operational structure with lift gates on it. The ungated weirs' purpose is to spread the head drop over a greater distance. The middle pool consists of the main channel and a reach called the Harney Canal. Flow into the middle pool is also controlled by Structure 161 on the Harney Canal. Flow from the middle to the lower pool is controlled by Structure 162. At the downstream end of the lower pool, Structure 160 controls the flow into the remains of the Palm River and finally into McKay Bay.

The Harney Canal, at 9,000 feet in length, connects the TBC middle pool and the City of Tampa's surface water reservoir on the Hillsborough River. Structure 161 is located near the confluence of the canal and the river and controls flow from the reservoir to the canal. The Harney Canal can divert up to 4,000 cfs of flow from the reservoir during flooding. The TBC can carry 12,000 cfs from the LHFDA for a combined total of 16,000 cfs at S-162. The lower pool, constructed in the channels of Six-Mile Creek and Palm River, was designed to pass a maximum flow of 26,700 cfs. Besides controlling water levels, S-160 acts as a physical barrier and prevents the upstream migration of saline water from the bay.

Besides carrying flow from the LHFDA and the City of Tampa Reservoir, the TBC is the drainage for some 33 square miles of surface area adjacent to the canal. Land use in the area is generally semi-rural and residential.

2.2 Hydrologic Characteristics

The following sections summarize the historic hydrologic conditions observed at the Hillsborough River Reservoir and Tampa Bypass Canal.

2.2.1 Hillsborough River Reservoir. The period of record for stage and discharge measurements for the Hillsborough River Reservoir is 1939 to present. The reservoir stage has ranged from less than 15 feet up to 22.9 feet NGVD. A minimum stage of 14.9 feet NGVD was recorded on June 29, 1977. The frequency distribution of stage for the period 1974 - 1996 is presented in Table 2.2. The period of 1974 - 1996 corresponds to the time period used for the minimum flows and yield analyses presented in this report. More than 65 percent of the stage values are between 20 and 22.5 feet NGVD. Approximately 5 percent of all stage measurements are below 18 feet NGVD.

Table 2.2 Frequency Distribution of Hillsborough River Reservoir Stage

	Stage (feet, NGVD)		
Percentile	Combined Periods 1974 - 1996	Pre-augmentation Period 1974 - 1983	Augmentation Period 1984 - 1996
1	16.4	15.9	18.1
5	18.4	17.6	19.5
10	19.4	18.5	20.3
20	20.6	19.7	21.1
30	21.1	20.6	21.6
40	21.7	21.1	22.0
50	22.0	21.5	22.3
60	22.2	21.9	22.4
70	22.4	22.1	22.5
80	22.5	22.3	22.6
90	22.6	22.5	22.6
95	22.6	22.5	22.7
99	22.7	22.6	22.7

Since the 1980s, the Hillsborough River Reservoir has been augmented by water pumped from Sulphur Springs (1984 to present) and the Tampa Bypass Canal (1985 to present). Annual augmentation quantities are discussed in Chapter 3. Augmentation has enabled the City of Tampa to maintain higher reservoir stages than would be possible if only river inflows were available. Table 2.2 shows the distribution of reservoir stage for three time periods: (1) 1974 to 1996, (2) 1974 to 1983, prior to augmentation and, (3) 1984 to 1996, with augmentation.

Stages for all percentile values are higher under augmented conditions. For the period 1984 to 1996, the reservoir stage was below 20 feet NGVD only 8 percent of the time, compared to nearly 25 percent of the time during the pre-augmentation period of 1974 to 1983. The daily stage record for the recent time period of 1984 to 1996 is shown as Figure 2.3. Differences in reservoir inflows and the increased use of the Morris Bridge well field to meet demands may also contribute to differences in stage between the two time periods.

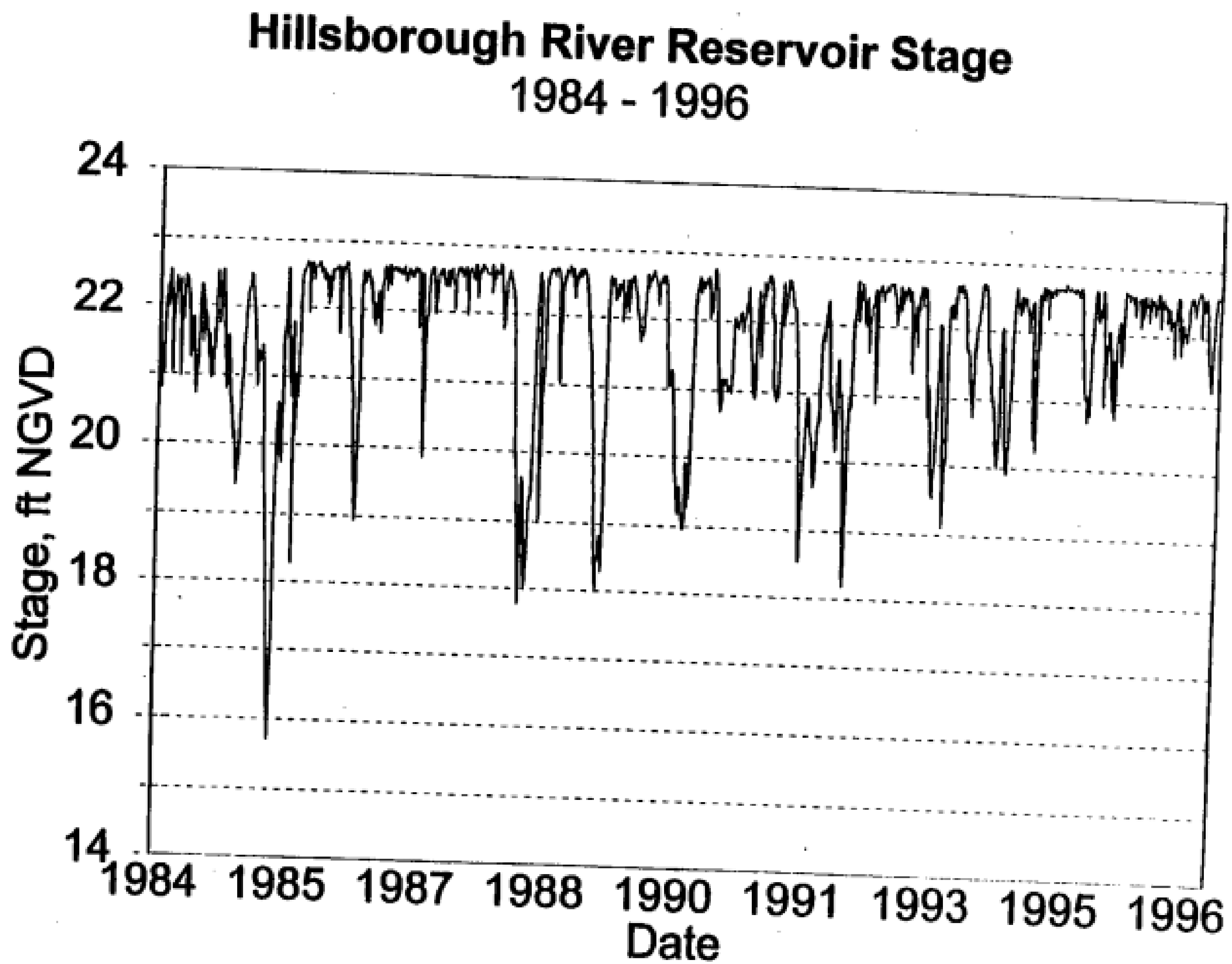
The distribution of reservoir stage, by month, for the period 1984 to 1996 is given in Table 2.3. Stage is generally lowest during May through July. For example, the stage is below 20 ft NGVD less than 5 percent of the time from December through March. However, May and June stage values have been below 20 feet NGVD 25 to 35 percent of the time.

The annual mean discharge at the dam, for the 1939 to 1996 period of record, is 463 cubic feet per second (cfs) measured at USGS site number 02304500. The median discharge for this same period is 152 cfs. Annual mean discharges for the 1939 to 1996 period of record range from less than 100 cfs to nearly 1700 cfs (Figure 2.4). The maximum daily discharge of 13,500 cfs was recorded on March 21, 1960. The U.S. Geological Survey (USGS) described the hydrologic records for the Hillsborough River Reservoir as "poor," indicating that differences between the actual and estimated values may exceed 15 percent (Stoker, et al, 1996). However, the data collected by the USGS represent the best available information.

The discharge at the dam depends on reservoir inflows, water supply withdrawals, and losses due to evaporation and seepage. Reservoir inflows are estimated based on upstream watershed areas and gaged flows from Trout Creek, Cypress Creek, the Hillsborough River at Morris Bridge and Crystal Springs (Figure 2.2). The period of record at the Morris Bridge gage only goes back to 1974, thus limiting the period for which inflows to the reservoir can be estimated. Daily estimates of reservoir inflows were developed for the period 1974 to 1996 (Appendix Q).

For the period 1939 to 1973, when only reservoir outflows were measured, it can be assumed that inflows to the reservoir equaled or exceeded outflows from the reservoir since water supply withdrawals were made from the reservoir during that time. A conservative estimate of inflows can therefore be made from the record of reservoir outflows from 1939 to 1973. These inflow records could be adjusted for yearly withdrawals from the reservoir, but such a correction was not performed for this report.

The frequency distribution of daily estimated reservoir inflows for the 1974 - 1996 time period is given in Table 2.4. Annual average inflows are shown on Figure 2.4. Figure 2.4 shows a hydrograph of outflows from the reservoir (1939 - 1996) and estimated inflows to the reservoir (1974 - 1996). Though the pre-1974 inflow values are conservative, there were many more high



Hillsborough River Reservoir Stage
1984 - 1996
Stage, ft NGVD
24
22
20
18
16
14
1984
1985
1987
1988
1990
1991
1993
1995
1996
Date

Figure 2.3

Table 2.3 Distribution of Hillsborough River Reservoir Stage, by Month, 1984 - 1996

January		February		March		April		May		June	
Percentile	Stage (ft. NGVD)	Percentile	Stage (ft. NGVD)	Percentile	Stage (ft. NGVD)	Percentile	Stage (ft. NGVD)	Percentile	Stage (ft. NGVD)	Percentile	Stage (ft. NGVD)
1	19.69	1	20.67	1	20.80	1	19.88	1	16.73	1	16.04
5	20.17	5	21.75	5	20.96	5	20.21	5	18.14	5	18.01
10	20.76	10	21.90	10	21.15	10	20.44	10	18.82	10	18.49
20	21.36	20	22.13	20	21.59	20	20.92	20	19.65	20	19.06
30	22.03	30	22.31	30	21.90	30	21.21	30	20.20	30	19.61
40	22.26	40	22.44	40	22.09	40	21.45	40	20.85	40	20.39
50	22.42	50	22.51	50	22.26	50	21.83	50	21.14	50	20.93
60	22.52	60	22.56	60	22.37	60	22.19	60	21.62	60	21.42
70	22.59	70	22.60	70	22.50	70	22.41	70	22.07	70	22.10
80	22.62	80	22.62	80	22.58	80	22.49	80	22.28	80	22.50
90	22.67	90	22.66	90	22.64	90	22.59	90	22.44	90	22.60
95	22.70	95	22.69	95	22.67	95	22.63	95	22.57	95	22.64
99	22.73	99	22.71	99	22.72	99	22.68	99	22.65	99	22.71

July		August		September		October		November		December	
Percentile	Stage (ft. NGVD)	Percentile	Stage (ft. NGVD)	Percentile	Stage (ft. NGVD)	Percentile	Stage (ft. NGVD)	Percentile	Stage (ft. NGVD)	Percentile	Stage (ft. NGVD)
1	18.09	1	19.32	1	19.66	1	20.94	1	18.64	1	19.48
5	18.92	5	20.00	5	20.60	5	21.34	5	19.82	5	20.08
10	19.55	10	20.82	10	20.91	10	21.77	10	20.70	10	20.40
20	20.92	20	21.34	20	21.35	20	22.16	20	21.35	20	21.05
30	21.74	30	21.75	30	21.96	30	22.38	30	21.68	30	21.57
40	22.03	40	21.96	40	22.18	40	22.47	40	22.05	40	22.45
50	22.19	50	22.16	50	22.29	50	22.54	50	22.46	50	22.54
60	22.32	60	22.34	60	22.38	60	22.57	60	22.55	60	22.59
70	22.42	70	22.44	70	22.46	70	22.60	70	22.59	70	22.61
80	22.49	80	22.49	80	22.57	80	22.63	80	22.62	80	22.63
90	22.56	90	22.57	90	22.63	90	22.66	90	22.65	90	22.66
95	22.60	95	22.60	95	22.65	95	22.69	95	22.69	95	22.68
99	22.65	99	22.66	99	22.67	99	22.74	99	22.72	99	22.70

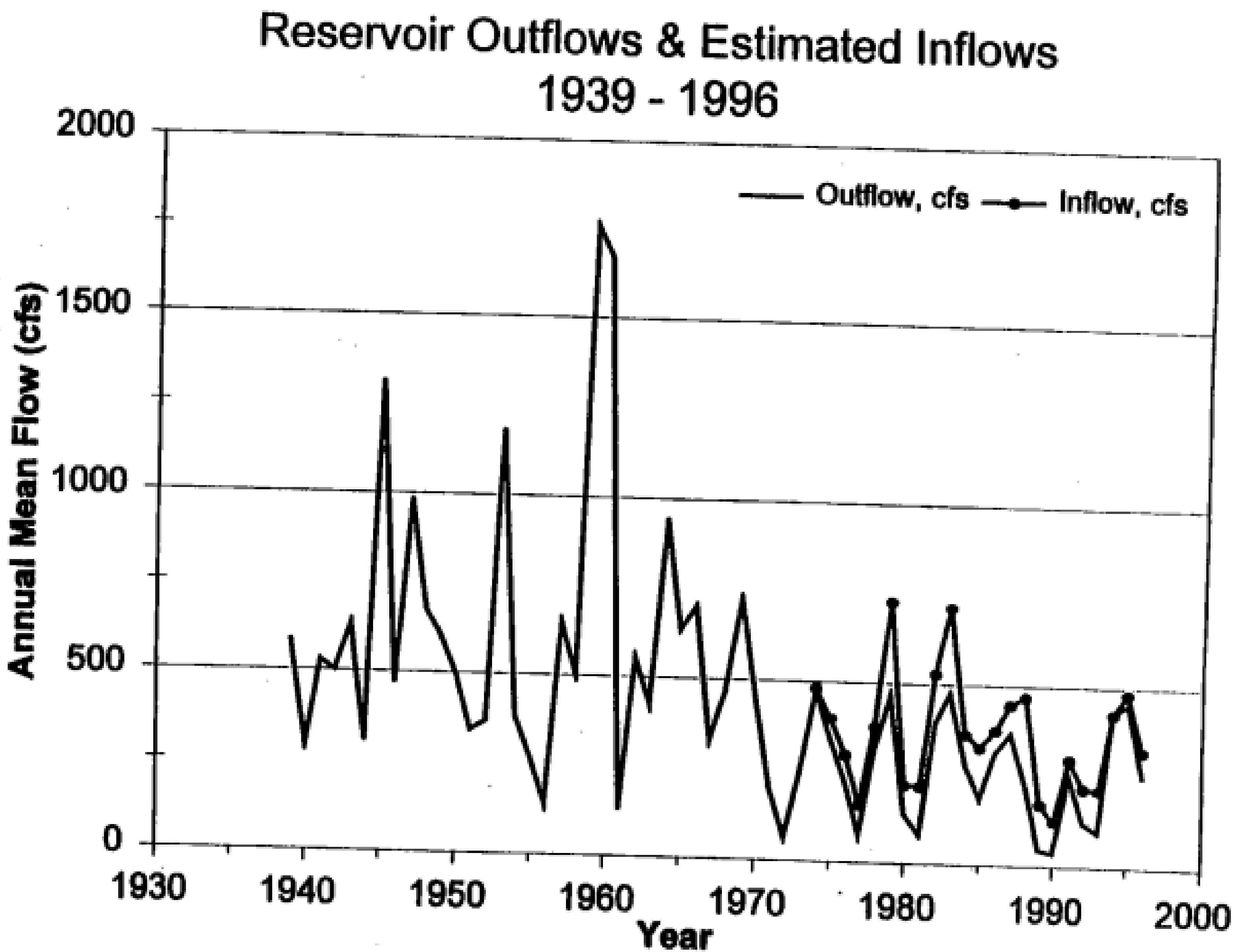

Reservoir Outflows & Estimated Inflows
1939 - 1996
Outflow, cfs
Inflow, cfs
Annual Mean Flow (cfs)
2000
1500
1000
500
0
1930
1940
1950
1960
1970
1980
1990
2000
Year

Figure 2.4

inflows years before the 1970s than afterward. Sixty percent of the years between 1939 and 1969 had average yearly flows greater than 500 cfs, whereas only 13 percent of the years after 1974 had average yearly flows greater than that amount. This study did not evaluate any possible causes of this reduction in average yearly inflows, or impacts to other stream flow characteristics such as base flow.

The U.S. Geological Survey (USGS) reported declining trends in reservoir outflow during 1939 to 1992 (Stoker, et al, 1996). The rate of decline in the annual mean discharge is 7.7 cfs per year. The USGS also identified decreases in 7-day and 30-day low flows and 7-day and 30-day high flows for the same time period. No attempt was made to identify the cause of stream flow declines, however, the authors cited deficit rainfall, increased water use, alteration of drainage patterns, and decreased base flows as possible causes.

Table 2.4 shows the frequency distribution for reservoir outflows for the recent period of 1974 to 1996. The outflow is less than one cubic foot per second about 30 percent of the time. The median outflow is 35 cfs.

Since 1979, reservoir discharge during storm events has been affected by the operation of the TBC flood control system. During large storm events, Structure 155 can be operated to divert upstream river flows through the Lower Hillsborough Flood Detention Area to TBC. Reservoir inflows can also be diverted through the Harney Canal to the TBC at Structure 161. Records of these diversions have not been well-maintained, and generally the magnitudes of these diversions are unknown.

Although actual withdrawals began in the 1920s, reported withdrawals from the reservoir began in 1946 with an annual average withdrawal of approximately 15 million gallons per day (mgd). During recent decades, the annual number of zero-flow days at the dam has increased. For the purposes of this analysis, a zero-flow day is a day where the estimated flow is less than 1 cfs. Due to seepage around the structure, small flows between zero and one cubic foot per second may be reported when there is no flow over the dam spillway. Between 1946 and 1972, there were few zero-flow days (Figure 2.5). The first zero-flow days occurred in 1968 when withdrawals reached 40 mgd and the frequency of zero-flow days increased substantially in the 1970s. At the same time, reservoir withdrawals increased to greater than 50 mgd. Noticeable spikes in the number of zero-flow days occurred during low rainfall years, such as 1981, 1985, and 1990.

Construction of the TBC, which was completed in 1982, may have affected ground-water inflows and outflows to the reservoir and the frequency of zero-discharge days. Construction breached the Upper Floridan aquifer and increased ground-water inflow to the canal by approximately 20 mgd (Knutilla and Corral, 1984). However, the fraction of this flow that originated in the vicinity of the Hillsborough River Reservoir has not been quantified. Augmentation of the reservoir with water from the TBC since the mid 1980s has returned some or all of the water lost by increased groundwater seepage from the reservoir.

Reservoir Withdrawals & Zero Flow Days

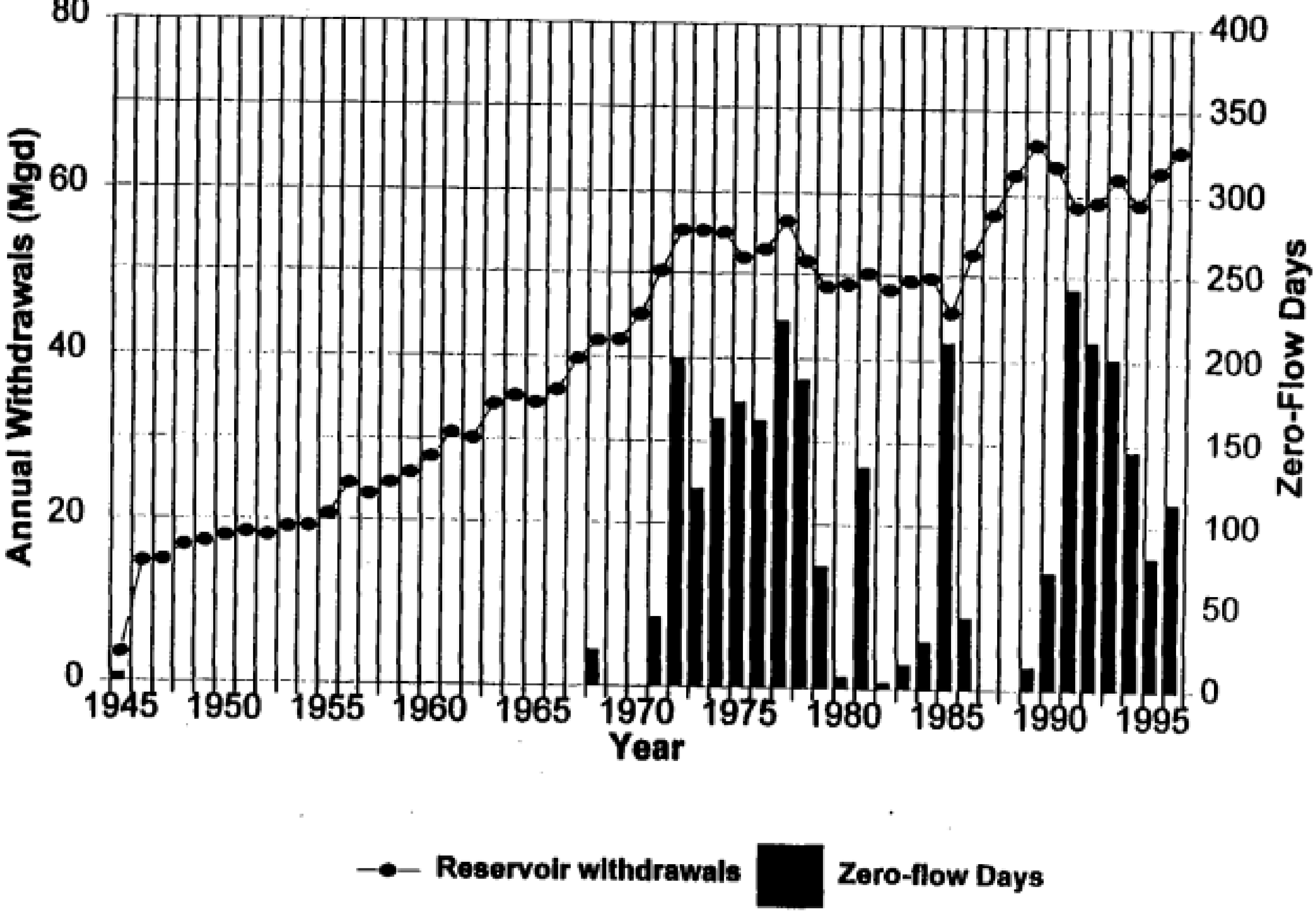


Figure 2.5

Table 2.4 Frequency Distribution for Estimated Daily Reservoir Inflows and Outflows, 1974 - 1996

Percentile	Reservoir Inflow (cfs)	Reservoir Outflow (cfs)
1	46	0
5	58	0
10	68	0
20	83	0
30	103	1
40	127	5
50	164	35
60	216	106
70	308	211
80	478	394
90	916	865
95	1379	1310
99	2565	2270

2.2.2 Tampa Bypass Canal. Hydrologic conditions in the TBC are affected by surface and groundwater inflows, direct precipitation, evapotranspiration, and direct surface water withdrawals. Construction of the Tampa Bypass Canal was completed in 1982. Since then, the District has monitored the stage in the upper, middle, and lower pools. Time series of canal stage are shown on Figures 2.6, 2.7, and 2.8.

Structure 160 is the only structure with historical flow records. From October 1974 to June 1990, the USGS estimated flow based on the measured canal stage and gate operation records provided by the District. Since June 1990, flow has been estimated by the District. Uncertainties exist in the estimated flows since the weir equations used to calculate flow have never been field calibrated and past structure operations records are poor.

The distribution of post-construction flows at S-160 for the period 1983 - 1996 is shown on Figure 2.9 and tabulated in Table 2.5. The median flow at S-160 for the 1983-1996 period of record is 75 cfs. Daily flows for the entire period of record of 1974 to 1996 are shown on Figure 2.10. During the early part of this period from 1974 - 1982, estimated flows may have been affected by TBC construction activities. The largest outflow recorded at S-160 was 10,800 cfs on September 10, 1988.

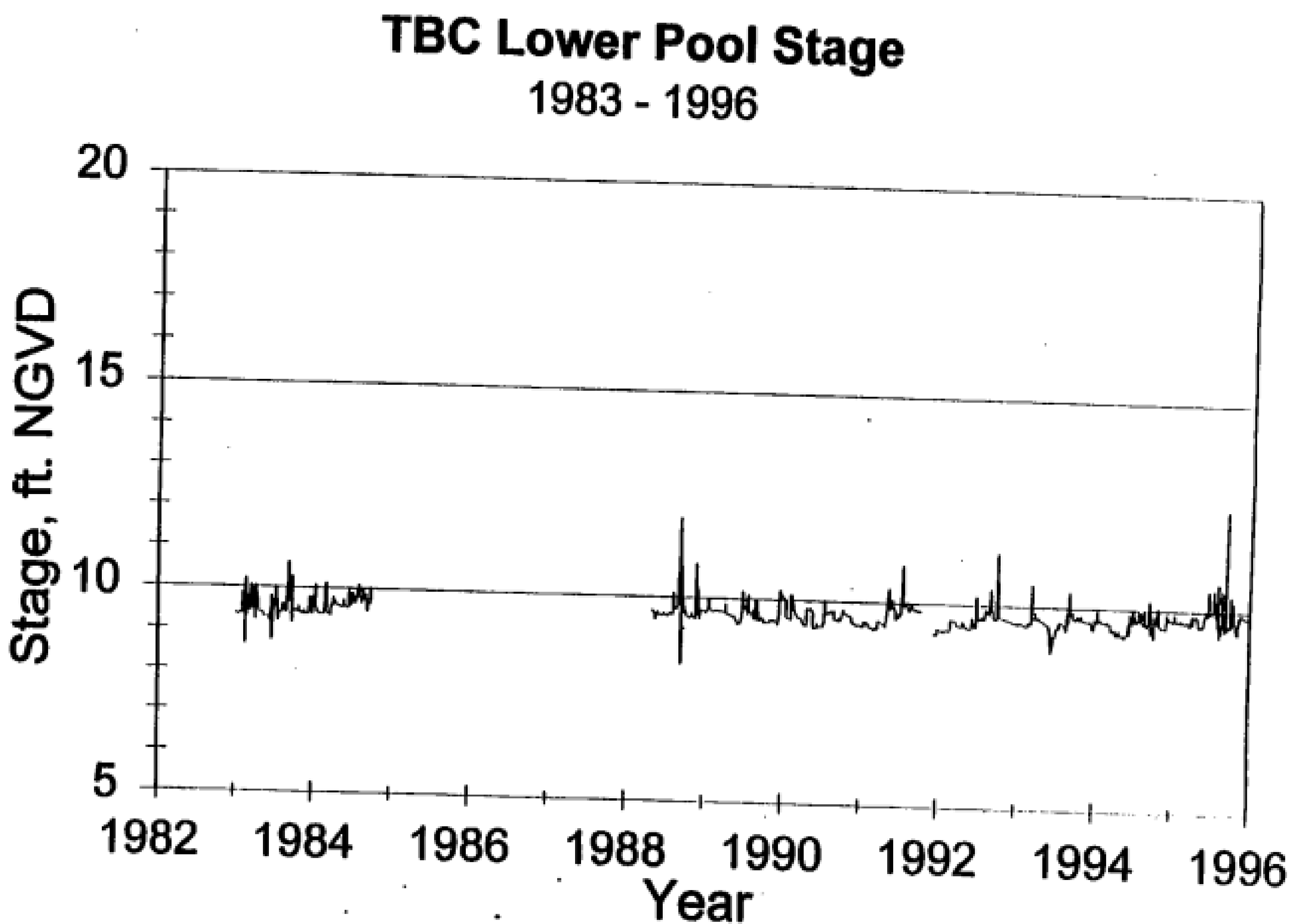
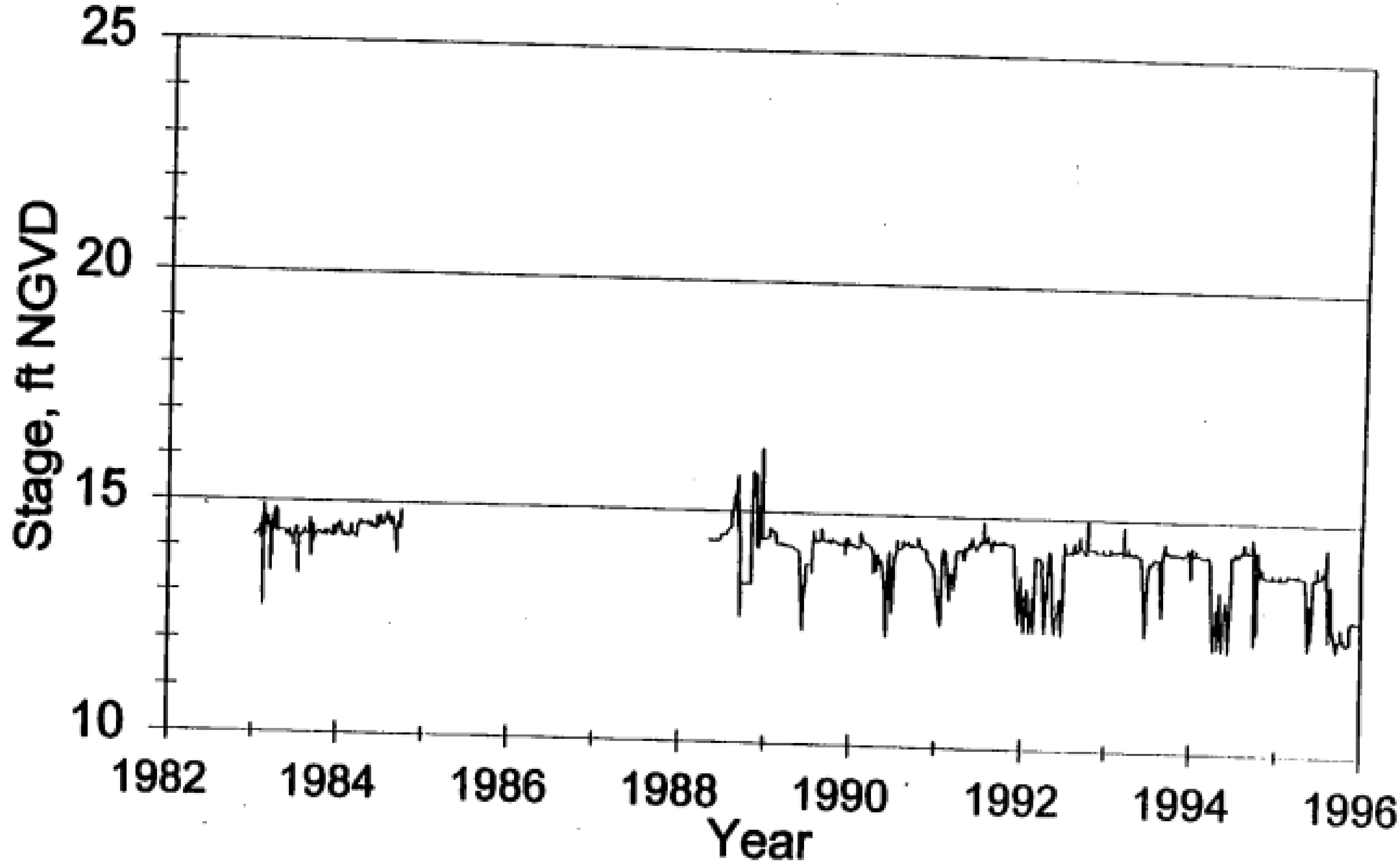

TBC Lower Pool Stage
1983 - 1996
Stage, ft. NGVD
20
15
10
5
1982
1984
1986
1988
1990
1992
1994
1996
Year

Figure 2.6

TBC Middle Pool Stage
1983 - 1996



F 2.7

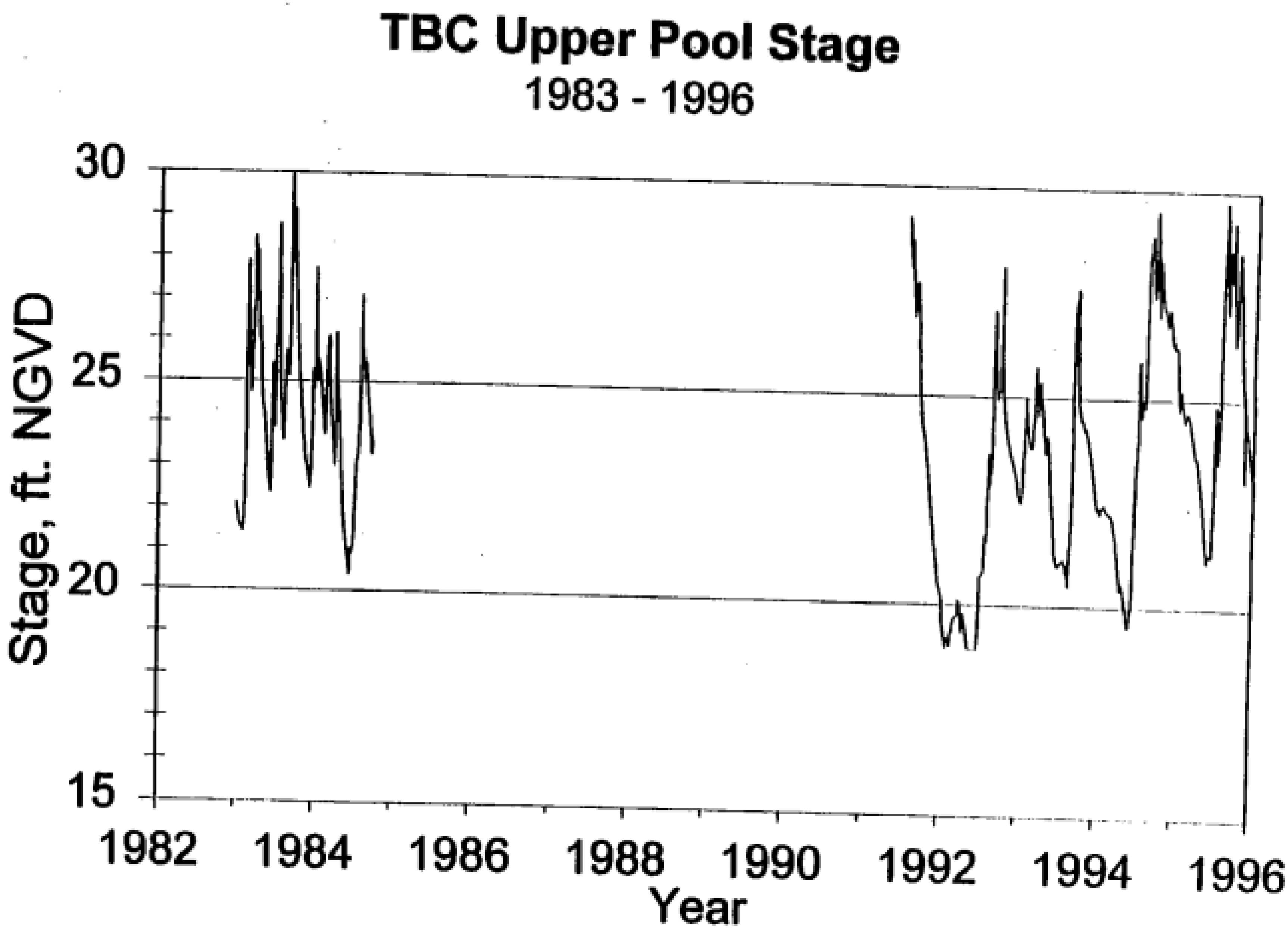
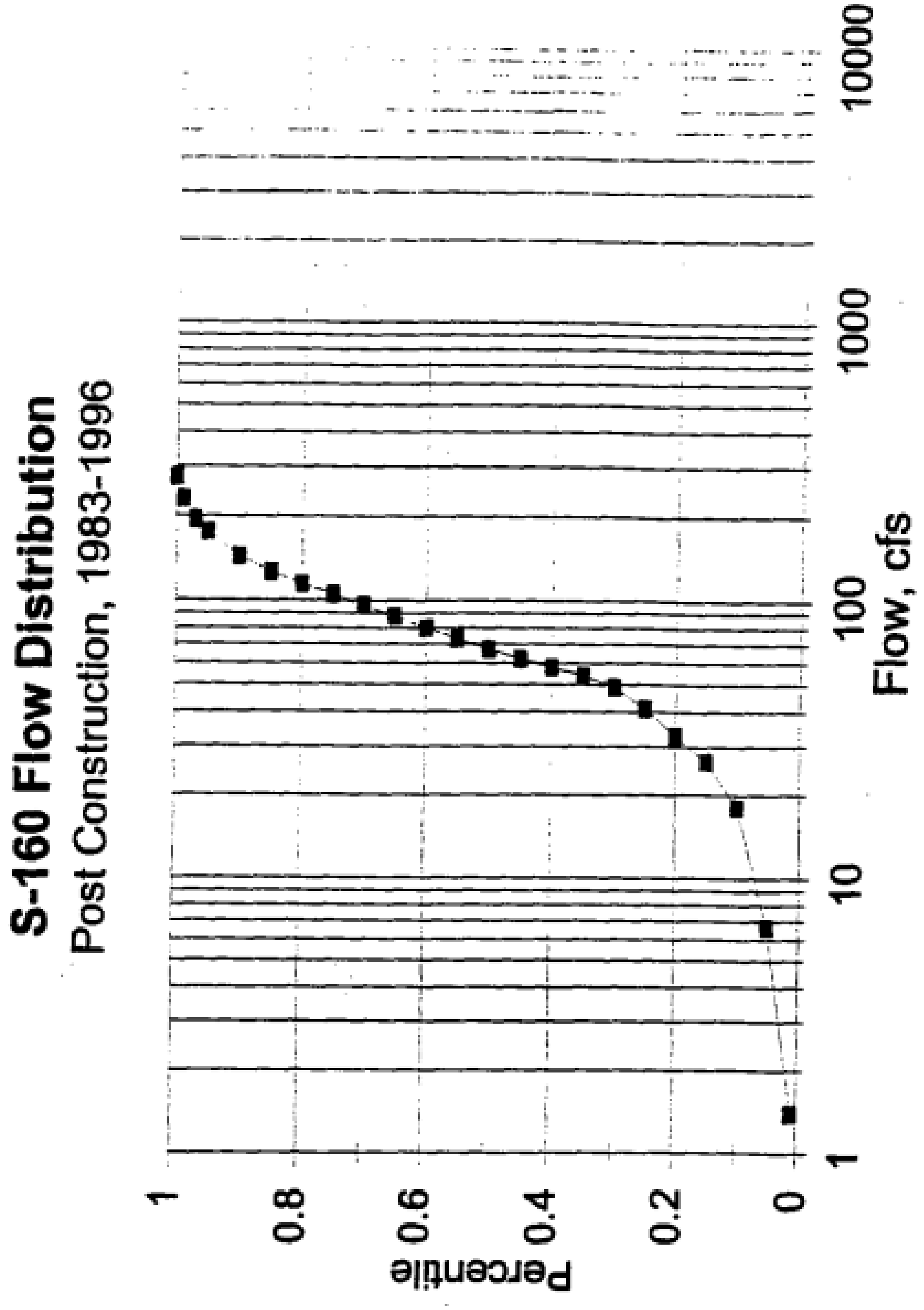

TBC Upper Pool Stage
1983 - 1996
Stage, ft. NGVD
30
25
20
15
1982
1984
1986
1988
1990
1992
1994
1996
Year

Figure 2.8

Figure 2.9



S-160 Flow Distribution
Post Construction, 1983-1996
Percentile
1
0.8
0.6
0.4
0.2
0
1
10
100
1000
10000
Flow, cfs

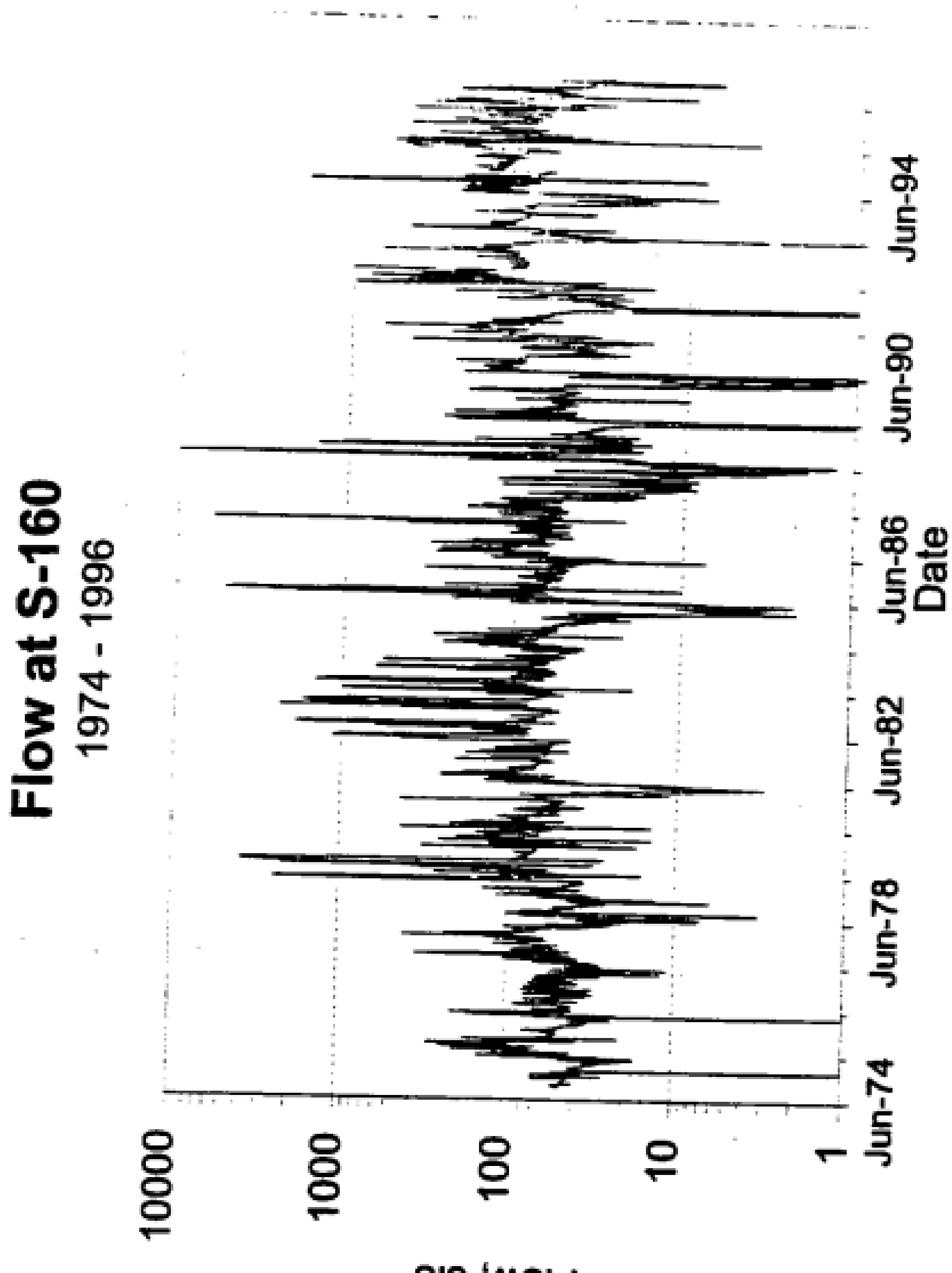

Flow at S-160
1974 - 1996
Flow, cfs
10000
1000
100
10
1
Jun-74
Jun-78
Jun-82
Jun-86
Jun-90
Jun-94
Date

Figure 2.10

Table 2.5. Flows at S-160, by Percentile for 1983 - 1996

Percentile	Flow (cfs)
1	1
5	7
10	20
20	35
30	51
40	60
50	71
60	85
70	103
80	126
90	179
95	304
99	1520

3. HISTORIC WATER USE

The City of Tampa has historically depended on four sources to meet water supply demands: the Hillsborough River Reservoir, the Morris Bridge well field, the TBC and Sulphur Springs. Currently permitted quantities are shown in the table below.

Table 3.1 Permitted withdrawal quantities (mgd) for the City of Tampa.

	Average Annual Day	Peak Month	Maximum Day
Hillsborough River	82	92	104
Tampa Bypass Canal	20	none specified	40
Sulphur Springs	5	10	20
Morris Bridge WF	15	27	30

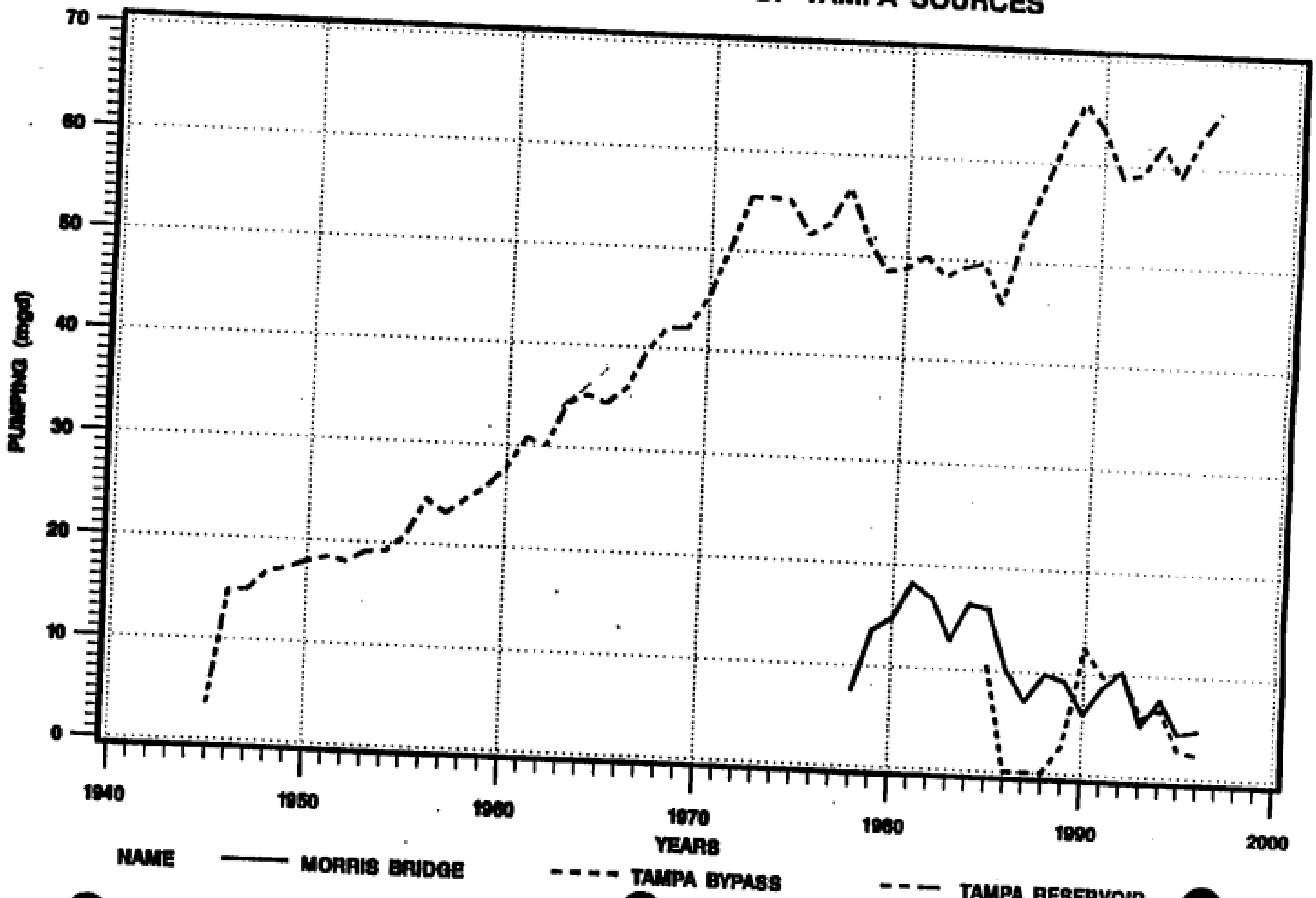
Continuous data of withdrawal quantities from the reservoir are available back to 1945. The first full year of withdrawals was 1946 when 15 mgd was withdrawn (Figure 3.1). Water demand increased steadily through 1972. Demand remained relatively constant from 1972 through 1977. The Hillsborough River was the sole source of water supply for the City of Tampa until 1978 when the Morris Bridge well field was brought on line. Total demand on the City's supply increased through 1981 but reservoir withdrawals remained about 50 mgd. In 1984 and 1985, the City of Tampa began to augment the reservoir from Sulphur Springs and the TBC, respectively (Figure 3.2). After 1985, withdrawals from Morris Bridge well field were reduced and withdrawals from the reservoir increased again. During the past ten years, yearly average rates of 58 to 66 mgd have been withdrawn from the reservoir.

Withdrawals from the Tampa Bypass Canal and Sulphur Springs are considered augmentation to the reservoir since they are pumped into the reservoir prior to withdrawal at the water treatment plant. Reported withdrawals from the reservoir include those waters augmented from the TBC and Sulphur Springs. Withdrawals from the TBC and Sulphur Springs for augmentation are reported separately.

Withdrawals from the TBC and Sulphur Springs are regulated by augmentation schedules that are based on water levels in the Hillsborough River Reservoir. A joint water use permit was issued to the City of Tampa and the West Coast Regional Water Supply Authority (now Tampa Bay Water) in 1990 for withdrawals from the TBC. The permit established that augmentation from the TBC will not occur until water levels in the reservoir recede to 21 ft. NGVD during the months of March through June, or to 19.0 ft. NGVD during the months of July through February. To maintain the stability of the Structure 161, withdrawals for augmentation will also not be allowed when water levels in the middle pool, including Harney Canal, are below 12.0 ft. Augmentation will also not be allowed when water levels in the Hillsborough River Reservoir

3.2

ANNUAL PUMPING FROM CITY OF TAMPA SOURCES



Fi 3.1

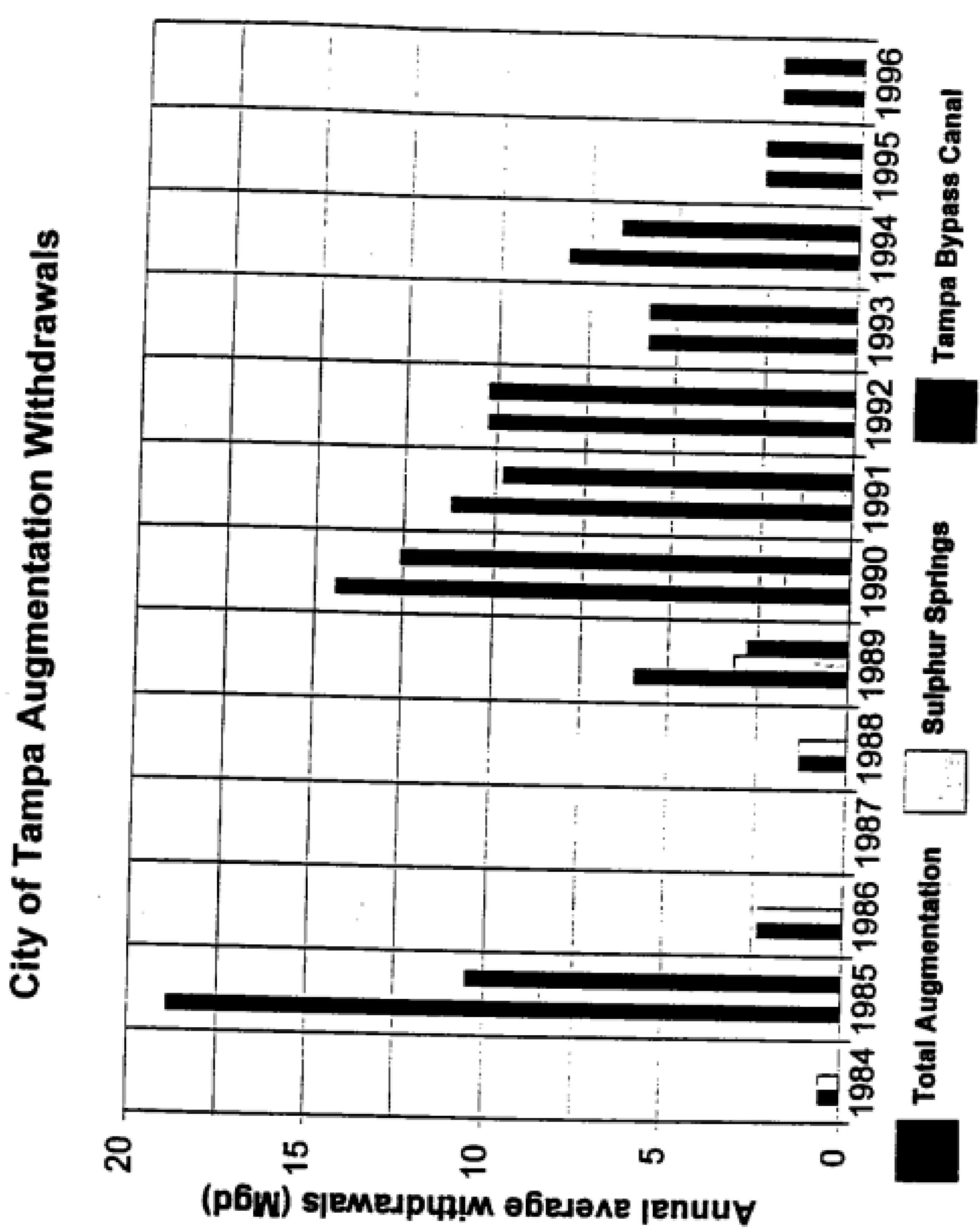

City of Tampa Augmentation Withdrawals
Annual average withdrawals (Mgd)
0
5
10
15
20
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
Total Augmentation
Sulphur Springs
Tampa Bypass Canal

Figure 3.2

are above 22.5 ft. NGVD, which is full reservoir stage. In addition to these limitations, provisions required additional "mitigation" augmentation from the Tampa Bypass Canal when withdrawals from the reservoir exceeded 62 mgd during periods of low flow at the Hillsborough River Dam (see Appendix A).

In 1993, upon request from the WCRWSA and the City of Tampa, the District modified the joint water use permit so that augmentation from the TBC could occur when water levels in the reservoir recede to 21.0 ft. on a year-round basis. Also, in response to the City and Authority's request, the permit was modified so that augmentation would cease when water levels in the reservoir recover to 22.0 ft.

In November 1996, the District authorized the WCRWSA/City of Tampa to implement a trial schedule that would allow augmentation from the TBC anytime water levels in the reservoir fall below 22.5 feet. This schedule has now been formally adopted in the water use permit for augmenting the reservoir with water from the canal. The TBC is generally used to augment the Hillsborough River Reservoir for short periods during the dry season months of April, May, June, and December.

The permit specifies that Sulphur Springs is not to be used for augmentation until after the TBC has been utilized. Augmentation schedules for Sulphur Springs are also based on water elevations in the Hillsborough River Reservoir. In the 1990 permit renewal it was established that augmentation from Sulphur Springs will not occur until water levels in the reservoir recede to 20.0 feet during the months March through June or to 18.0 feet during the months of July through February. From 1990 through 1996, the City has augmented every year from the TBC. Sulphur Springs has provided augmentation in only three of the seven years and generally provides 10 percent or less of the total augmentation quantity.

4. ECOLOGICAL ASSESSMENT OF THE TAMPA BYPASS CANAL AND PALM RIVER/MCKAY BAY SYSTEM

4.1 Sources of Ecological Data and Information

To evaluate minimum flows for the Tampa Bypass Canal the District principally relied on the three sources of ecological data and information that are listed below. Most of these sources also contained information pertaining to the ecology and freshwater inflow relationships of the Lower Hillsborough River.

1. A hydrobiological study of the Lower Hillsborough River and the Tampa Bypass Canal (WAR/SDI, 1995) required by special conditions of water use permits issued to the City of Tampa and the West Coast Regional Water Supply Authority.

2. Data for salinity, dissolved oxygen, and water quality parameters available from the Hillsborough County Environmental Protection Commission.

3. A recent report sponsored by the Tampa Bay National Estuary Program was requested by its minimum flows advisory group to the District. This report, which prepared by Coastal Environmental, Inc. (1997), analyzed data from the two sources listed above, plus data recorders operated on the Lower Hillsborough River by the US Geological Survey.

In addition to analyses conducted by the District, applicable results and conclusions from these other information sources are summarized below. The WAR/SDI (1995) and Coastal (1997) reports are available from the District and copies will be provided to each member of the scientific review panel. Other ecological studies the District considered in assessing minimum flows for the Tampa Bypass Canal are by Ross (1980), HDR (1994), Stoker et al. (1996), and the Florida Department of Community Affairs (1995). Overall, the combined sources of data and studies listed above comprise the best available information for establishing minimum flows on the Tampa Bypass Canal.

4.2 Hydrobiological Study of Lower Hillsborough River and Tampa Bypass Canal

Withdrawals from the Hillsborough River Reservoir are regulated under a water use permit issued to the City of Tampa, while withdrawals from the Tampa Bypass Canal for augmentation of the reservoir are regulated under a companion permit jointly held by the City of Tampa and the West Coast Regional Water Supply Authority (now Tampa Bay Water). Both water use permits were renewed in 1991. At that renewal, the average annual withdrawal quantity permitted from the Hillsborough River reservoir was increased from 62 to 82 million gallons per day (mgd). It was proposed that augmentation of the reservoir with water from the Tampa Bypass Canal be done on a more frequent basis, although the average annual permitted quantity from the canal remained the same (20 mgd).

Because the potential ecological impacts of these increases could not be quantified, the District required the permittees to conduct a hydrobiological study of the Lower Hillsborough River and the Tampa Bypass Canal. The technical objectives and regulatory aspects of this study were specified in special conditions of water use permit numbers 202062 and 206675, from which relevant excerpts are provided in Appendix A.

The goals of the hydrobiological study are summarized below:

1. Determine the hydrologic, water quality, and biological characteristics of the study area, the relationships of these characteristics to discharges from the structures, and whether the proposed increases in withdrawals will result in unacceptable adverse impacts to water quality and fish and wildlife in the study area.

2. Determine the habitat functions of the lower Hillsborough River, the Palm River and McKay Bay.

3. Determine how various levels of pumping from the Tampa Bypass Canal effect water levels in, and outflows from, the Tampa Bypass Canal.

4. Determine the importance of discharge from Sulphur Springs to the water quality and biology of the lower Hillsborough River.

5. Construct a hydrologic model of the Hillsborough River Reservoir and TBC that allows the simulation of dependable yields from the reservoir/canal system and downstream releases under various withdrawal and augmentation scenarios.

6. Based on the findings of the tasks above, determine an optimal withdrawal/augmentation schedule for the combined TBC/reservoir/Sulphur Springs system that minimizes environmental impacts while meeting water supply needs.

The consultants selected by the City and the Authority to perform this study was comprised of a team of Water and Air Research, Inc. and SDI Environmental Services, Inc. A draft report for this study was presented to the District on March 1995 (WAR/SDI, 1995). The District did not accept the report as final until recently, however, due to delays in obtaining an outside review of the hydrologic model presented in the report.

The District stated that acceptance of the report did not imply that it necessarily agreed with the conclusions or reservoir management schedule presented in the report). The District pointed out that considerable new analyses were recently completed as part of the minimum flows determination for the Lower Hillsborough River and TBC, and the objectives of the hydrobiological study could now be considered satisfied or superseded (SWFWMD, 1997).

The hydrobiological study included collection of a wide array of physical, chemical and biological variables including salinity, water quality, phytoplankton, benthic macroinvertebrates, fishes, and shoreline vegetation and habitat. Although the conclusions and withdrawal schedule in the report are not necessarily endorsed by the District, the hydrobiological study is a principal source of information the District relied on to evaluate the biological characteristics of the Lower Hillsborough River and Tampa Bypass Canal and their relationships to freshwater inflows.

A map of the stations that were sampled as part of the hydrobiological study are shown in Figure 4.1 Some general findings from the hydrobiological study relevant to the determination of minimum flows are summarized below.

4.2.1 Shoreline Habitat Inventory. Both the Lower Hillsborough River and the Tampa Bypass Canal below Structure S-160 (Palm River) are highly modified systems. Most of the wetlands associated with the shoreline of the lower Hillsborough River have been filled and considerable sections of the shoreline have been hardened by seawalls, rip-rap or other material. Twenty-four percent of the total shoreline is presently in natural cover. River segments nearest the dam have the highest percentages of natural shoreline, with 89 percent of the shoreline above Rowlett Park bridge (22nd St.) in natural cover.

Twenty-eight percent of the shoreline of the Palm River/Tampa Bypass Canal above McKay Bay is in natural shoreline. However, there is very little natural shoreline in the sections nearest structure 160. The shoreline of McKay bay is in relatively good condition, but the morphology of the Tampa Bypass Canal/Palm River has been drastically changed from the streams that were excavated to create the canal.

4.2.2 Salinity The Tampa Bypass Canal below Structure 160 had much higher salinity values than the lower Hillsborough River the dam. Bottom salinities at station 12, just below Structure 160, averaged 24.6 ppt with a minimum value of 20.0 ppt. Surface salinities at this station averaged 19.6 with a minimum value of 12.5 ppt. These relatively high salinity values were due to the large volume of the canal and dilution by saltwater, as on many days there was actually more freshwater inflow to the lower TBC than to the Lower Hillsborough River.

The Lower Hillsborough River had more of a horizontal salinity gradient characteristic of tidal rivers. Mean surface salinity values ranged from 3.9 ppt at station 2 (0.5 miles below dam) to 15.7 ppt. at station 10 near the river mouth. Salinity in the lower river was highly variable. As discussed in later sections, relatively small discharges from the dam resulted in fresh water at station 2. Other stations located downstream from the dam progressively became less saline with increasing discharges from the dam.

The response of salinity to freshwater inflows in both the Hillsborough River and Tampa Bypass Canal was subject to considerable analyses beyond that presented in the hydrobiological study report. The results of these analyses are presented in sections 4, 5 and 6 of this report.

4.2.3 Dissolved Oxygen. Surface dissolved oxygen (D.O.) values generally increased progressively downstream in both the lower Hillsborough River and the TBC/Palm River system.

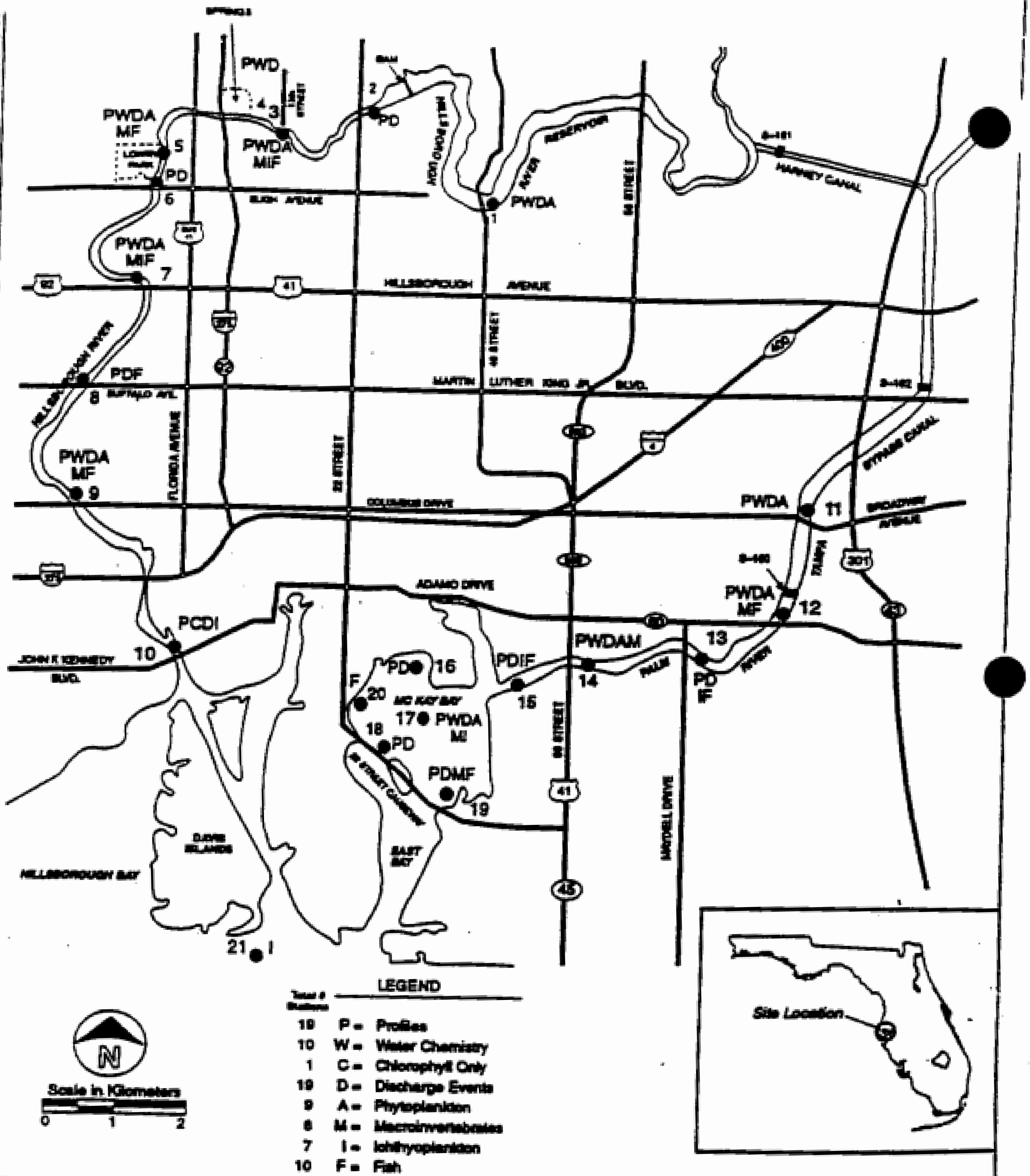


Figure 4.1 Location of WAR/SDI and USGS stations in the Lower Hillsborough River. Adapted from WAR/SDI (1995).

In the Hillsborough River below the dam, low surface D.O values were typically found at stations 3 and 5 during periods of no discharge from the dam. Surface D.O. concentrations at stations 2, 3, 5 and 6 were positively correlated with discharge from the dam. Depletion of D.O. with depth was common in the lower river, and there were frequent problems with hypoxia in bottom waters in the lower river. In stations nearest the dam (2 and 3) bottom dissolved oxygen concentrations were closely related to the rate of freshwater inflows.

In contrast to the lower Hillsborough River, dissolved oxygen concentrations in the Palm River/McKay Bay system were not correlated with freshwater discharge at Structure 160. Pronounced declines in D.O. concentrations with depth were observed in the lower canal, with mean bottom dissolved oxygen values ranging from 0.7 mg/l at station 12 to 3.0 mg/l at station 15. Minimum D.O. values near zero mg/l were recorded at all station above McKay Bay. Although periodic problems were observed, dissolved oxygen concentrations were generally higher in McKay Bay, which is shallow and frequently wind mixed.

The response of dissolved oxygen in the Lower Hillsborough River and the Tampa Bypass Canal to flow were the subject of considerable analyses beyond that presented in the hydrobiological study. The results of those analyses are presented in sections 4 and 5 of this report.

4.2.3 Water Chemistry

Total suspended solids (TSS) values in Palm River/McKay Bay system were considerably greater than in the Lower Hillsborough River. Greater phytoplankton (and possibly zooplankton) densities in the Palm/ McKay Bay system could have contributed to this difference. Other data have shown that high salinity waters in Tampa Bay have higher TSS values than the fresh and low salinity areas of the bay's tributaries, and the higher TSS values in the Palm/McKay system reflect the higher salinity and greater influence of the bay. Station means for TSS increased downstream in the Lower Hillsborough River and were negatively correlated with discharge at all river stations. Turbidity was also negatively correlated with discharge at two stations in the lower Hillsborough River. As with TSS, turbidity values were higher in the Palm River/McKay Bay system than in the lower river. Color was positively correlated with discharge in the Lower Hillsborough and Palm Rivers, while Secchi disk values were negatively correlated with discharge. Orthophosphorus was positively correlated with discharge in the Lower Hillsborough River but not the Palm River/McKay Bay system.

4.2.4 Chlorophyll a Chlorophyll a concentrations was generally higher in the Palm River/McKay Bay system than in the Lower Hillsborough River. Median values in the river generally increased downstream toward the bay, ranging from 3.8 μg/l at station 3 to 17.3 ug/l at station 9. Mean values also generally followed this pattern but were heavily influenced by a bloom on December 1992. Chlorophyll a was negatively correlated with discharge from the dam at all lower river stations. In contrast, chlorophyll a was either not correlated with discharge or was positively correlated with discharge from Structure 160 at the Palm River/McKay Bay stations.

4.2.5 Phytoplankton Phytoplankton densities were generally higher and more variable in the Palm River/McKay Bay system. The Bacillariophyaceae (diatoms) were the most abundant algal group in McKay Bay. There were greater shifts in group dominance in the lower Hillsborough River, reflecting the lower river's more variable physico-chemical environment. The highest algal populations were found in the freshwater portions of the Tampa Bypass Canal, and phytoplankton densities at station 12 below Structure 160 were positively correlated with discharge due to flow releases from the TBC. During times of high discharge to the Hillsborough River, freshwater taxa were found extending downstream from the dam.

4.2.6 Benthic Macroinvertebrates Many of the invertebrate collections in the Hillsborough River and Tampa Bypass Canal systems were indicative of stressed environments with low dissolved oxygen concentrations. Low values of organism abundance, species richness and diversity were common during the study, but were most frequent at stations nearest the structures (stations 3 and 12). Communities collected from shallow waters at stations 3, 5, and 19 during the second year of study generally had one to three orders of magnitude more organisms than collections from mid-channel areas, apparently due in large part to higher dissolved oxygen concentrations in the shallower waters.

Changes in salinity resulting from discharges from the Hillsborough River dam affected benthic communities primarily at stations 3 and 5. During periods of peak discharge, a shift in community compositions from estuarine species to freshwater species occurred at station 3. The freshwater populations rapidly decreased following termination of discharges from the dam and a return to more saline conditions. Because of the much higher salinity values and more subdued response to freshwater inflows, benthic macroinvertebrates in the Palm River/McKay Bay system did not show a clear response to changes in freshwater inflows.

4.2.7. Ichthyoplankton Ichthyoplankton captured in the Lower Hillsborough River and Palm River/McKay Bay system were primarily the egg, larvae, and juvenile stages of marine-derived fishes that tend to spawn in high salinity waters. These species migrate into lower salinity waters as juveniles and utilize these estuarine habitats. Compared to the Little Manatee River, which was sampled in another study (Peebles and Flannery, 1992), the Hillsborough and Palm River systems had lower taxonomic diversity, richness and evenness, which appeared to be related to poor representation of substrate associated fishes. A pronounced reduction in abundance of larval stages in the Lower Hillsborough and Palm Rive/McKay Bay systems appeared related to benthic hypoxia.

4.2.8. Juvenile Fish. Fishes collected during the two year period were primarily adults and juveniles of small-sized resident species and the juveniles of seasonally abundant immigrant species. Juvenile fish abundance increased progressively downstream in both the Hillsborough River and the TBC/Palm River/McKay Bay system. The TBC/Palm/McKay Bay system, however, consistently harbored more individuals and a greater number of taxa that did the Lower Hillsborough River.

The juvenile fish populations within the study area were clearly influenced by differing salinity regimes. The Hillsborough River hosted more freshwater and estuarine taxa than did the Palm River/McKay Bay system which harbored more marine taxa. The abundances of many taxa reflected responses to salinity regimes. Although numerically small, the freshwater resident community was an important component of the Lower Hillsborough River, where it was largely restricted to the two most upstream stations (3 and 5) during the WAR/SDI study.

The transient fish communities in both systems was important because most of the taxa represented juveniles of species of sport or commercial value. All transients were marine species that seasonally entered the study sites as young-of the year, using these systems as nursery areas.

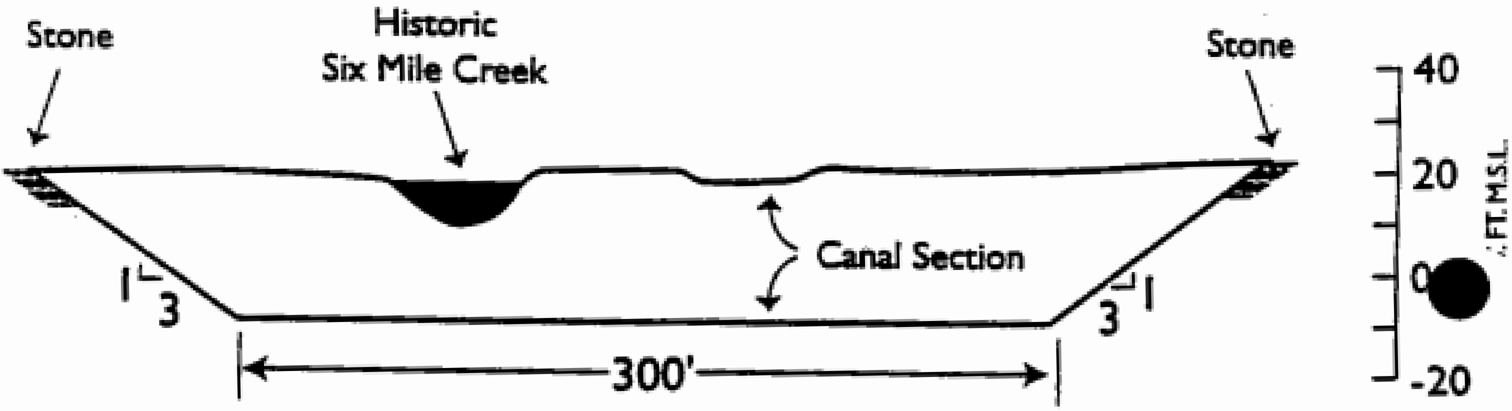
4.3 The Tampa Bypass Canal - Physical and hydrologic alterations of the former Six Mile Creek/Palm River system.

Prior to construction of the Tampa Bypass Canal, the region east of the Lower Hillsborough River basin was drained by Six Mile Creek which was named the Palm River in its lower reaches. Much of the canal was excavated in the channel of this creek/river system, highly altering the physical and hydrologic characteristics of the drainage basin. These alterations also greatly affected the ecological characteristics of the downstream estuary, including the response of water quality and ecological variables there to freshwater inflows. Accordingly, a brief description of the physical characteristics of the Tampa Bypass Canal is presented below prior to discussing the freshwater inflow relationships of the present-day estuary. This description is very general, as other reports can be consulted regarding the history, configuration, hydrology and operations of the Tampa Bypass Canal (Motz, 1975; Knutilla and Corral, 1984; Geraghty and Miller, 1982, 1986; HDR, 1994). In particular, the report by HDR (1994) presents a good comparison of the Tampa Bypass Canal with the former Six Mile Creek/Palm River system. Other physical and hydrologic comparisons between the canal and former creek/river system are presented in Chapters 2 and 6 of this minimum flows report.

Prior to construction of the Tampa Bypass Canal, the mouth of the Palm River where it entered McKay Bay was about 650 feet wide. The river quickly narrowed to about 400 feet one quarter of a mile upstream, then to 200 feet one-quarter mile above Maydell Drive (see Figure 4.1). Approaching a bend another quarter mile upstream, the river widened to 500 feet for a short stretch, then rapidly narrowed to under 100 feet. Where Structure 160 is now located the river creek was barely 50 feet across. A graphic comparing the cross sections of the TBC and Six Mile Creek before canal construction in the region upstream of Structure 160 is shown in Figure 4.2. Navigation charts from the 1870's to the 1960's show the river to be only five to six feet deep at its mouth, gradually shallowing to three to four feet less than a half mile upstream (HDR, 1994).

Construction of the canal enlarged the former river channel to around 500-550 feet wide from the Maydell Drive Bridge upstream to Structure 160, and 600 to 630 feet wide in the downstream reaches. In some places, the canal is much as twelve times the pre-project width of the Palm River. The banks were steepened and most of the natural shoreline vegetation was replaced by

Tampa Bypass Canal Cross Section



Tampa Bypass Canal Upstream of Structure 160

Figure 4.2

a grassy berm. The shallow bottom of the river was dredged to depth of roughly 20 feet and some of the river's meanders were straightened. A navigational/floodway channel that was dredged between Palm River mouth and the 22nd St. causeway bridge varies between 11 and 15 feet deep.

Bathymetric cross sections of the lower reaches of the canal are presented on pages 45 through 47 of HDR (1994). These show the generally steep sides and trapezoidal shape of the canal. An important feature is a relatively shallow sill that occurs at US Highway 41, which is apparently left intact to support the bridge pilings. HDR (1994) and various professionals in the area have suggested this sill inhibits tidal flushing and circulation of bottom waters in the lower canal. One proposal for canal restoration is to fill the region upstream of the sill, to make that reach of the canal shallower to provide better circulation and improve dissolved oxygen concentrations.

In addition to channel enlargement, construction of the Tampa Bypass Canal resulted in an increase in freshwater flows to the tidal reach of the former Palm River and McKay Bay. As described in Chapter 6 of this report, excavation of the canal breached the top of the Upper Florida Aquifer, increasing groundwater discharge to the canal. Also, flood flows from the Hillsborough River are now periodically routed through the canal system. Even without these storm diversions, analyses indicate that streamflow and baseflow have been increased by about 1.5 to 2 times their pre-construction values (Knutilla and Corral 1984, Chapter 6 of this report). Despite this increase in flows, salinity values below Structure 160 are typically relatively high due to the large dilution volume of the tidal reaches of the canal. Relationships of freshwater inflows to salinity and water quality parameters in the estuary below Structure 160 are discussed in the following section.

4.4 Salinity and Dissolved Oxygen Data in the Palm River/McKay Bay System recorded during the WAR/SDI Hydrobiological Study

Statistical summaries and plots of salinity and dissolved oxygen data from the Palm River/McKay Bay system collected by WAR/SDI are discussed below. Salinity data from that study were also analyzed in the report sponsored by the Tampa Bay National Estuary Program (Coastal, 1997). The findings of these other studies (WAR/SDI, 1995; Coastal, 1997) are discussed below along with the District analyses.

4.4.1 Salinity

Salinity values are considerably higher in the Palm River/McKay Bay system compared to the Lower Hillsborough River. The location of the WAR/SDI stations in the Palm River/McKay Bay system are shown in Figure 4.1 (page 4-4). Stations 12 through 15 are located in the channel of the former Palm River; stations 17 and 18 are in the navigation channel in McKay Bay; and stations 16 and 19 are shallow stations near the McKay Bay shore. A statistical summary of salinity at these stations is presented in Table 4.1.

Table 4.1. Summary statistics for salinity at WAR/SDI stations in the Palm River and McKay Bay. Unless noted in parentheses, the number of observtion is 24 for all stations except station 14 which has 38. All values as parts per thousand.

	Mean	Std	Min	Max
Station 12				
Surface	19.6	4.2	12.5	28.0
1 M	21.8	3.6	15.0	28.0
2 M	24.0	3.2	15.0	29.0
3 M	24.5	2.7	19.0	29.0
4 M	24.9	2.4	20.0	29.0
5 M (21)	24.4	2.6	20.0	29.0
Station 13				
Surface	20.4	4.1	12.0	28.0
1 M	22.6	3.6	15.0	28.0
2 M	24.0	3.1	16.0	29.0
3 M	25.0	2.1	21.0	29.0
4 M	25.2	2.1	21.0	29.5
5 M (20)	24.6	2.3	21.0	29.5
Station 14				
Surface	20.7	3.6	14.0	28.0
1 M	22.3	3.2	15.0	28.0
2 M	24.2	2.5	19.5	29.0
3 M (35)	24.4	2.6	16.0	29.5
4 M (33)	24.8	2.2	20.5	29.5
5 M (27)	24.3	1.9	20.5	28.5
6 M (6)	23.9	0.8	23.0	25.0
Station 15				
Surface	21.3	3.9	14.0	27.5
1 M	23.1	3.1	16.5	28.0
2 M	24.7	2.3	20.0	28.0
3 M	25.3	2.2	21.0	28.0
4 M (23)	25.3	1.9	21.5	29.0
5 M (4)	25.0	2.4	23.0	28.5
Station 16				
Surface (23)	22.4	4.4	15.0	30.0
1 M (15)	22.2	3.9	15.5	30.0
Station 17				
Surface	23.4	3.5	16.0	29.0
1 M	23.7	3.3	16.5	29.0
2 M	24.9	2.4	20.5	29.5
3 M	25.5	2.1	21.0	29.5
4 M (19)	25.9	1.8	23.0	29.5
5 M (8)	25.4	2.0	23.0	28.5
Station 18				
Surface	23.8	3.4	16.0	30.0
1 M	24.0	3.3	16.5	30.0
2 M	24.6	3.0	18.0	30.0
3 M	25.3	2.3	19.5	30.0
4 M (16)	25.8	1.8	23.0	30.0
Station 19				
Surface	23.4	3.4	14.0	27.5
1 M (13)	22.3	3.4	15.5	27.0

Mean values for surface salinity ranged from 19.6 ppt at station 12 to 23.8 ppt at station 18. Bottom salinities at the deep-water stations showed less spatial variation, with means ranging from 24.6 ppt at station 12 to 25.4 ppt at station 18. For the stations in the Palm River, vertical salinity gradients of 2 to 4 ppt were frequently observed in the top two meters of water, while vertical gradients were very slight at deeper depths. Salinity was more uniform from top to bottom at shallow and deep-water stations in McKay Bay, possibly due to greater fetch and wind mixing.

Time series plots of surface, bottom, and mean water column salinity are presented in WAR/SDI (1995). Plots of surface values are presented on page 6-37 of Volume 1 of that report, while mean water column and bottom values are plotted in Appendices Q and X. At station 12, which is near Structure 160, surface salinities were below 15 ppt on three occasions during the two years of sampling. Bottom salinity at this station declined to 20 ppt on only two dates during the summer of 1993. Horizontal salinity gradients at deeper waters were generally very slight above station 15 (Appendix X in WAR/SDI). Mean salinity values for bottom waters at stations 12 through 15 varied only between 24.6 and 25.3 ppt.

Plots of salinity at the WAR/SDI stations vs. flow at Structure 160 are shown in Appendix K of this minimum flows report. Plots are presented for the same four flow terms used for the Lower Hillsborough River (same-day, and preceding 3-, 8-, and 14-day average flows). Plots are presently separately for an expanded flow range and flows less than 200 cfs so the response to low flows can be more closely examined. All depths are combined so that several data points are aligned vertically for a given flow. Since surface salinity values are typically the lowest, they are oriented closest to the X axis in each data group with bottom salinities oriented toward the top of each graph. In contrast to the Lower Hillsborough River, where there were frequent no-discharge conditions, there were only two sampling dates for the Palm River/McKay Bay where there was no discharge from Structure 160. .

The plots of salinity vs. discharge in Appendix K can be compared to plots presented by WAR/SDI (1995) and Coastal (1997). The plots in these other reports may be easier to interpret because the depths are not combined. Plots of surface and mean water column salinity versus 14-day discharge at Structure 160 are presented in Appendices S and T of the WAR/SDI report. Coastal (1997) presented plots of salinity at separate depths at stations 12 through 15 vs. 3-day discharge from the canal, with regressions fitted to the data. Using these regressions, Appendix O in the Coastal report lists predicted salinity values at these stations for canal discharges ranging from 0 and 100 cfs in 10 cfs increments. These results are also presented in Table 4.2 on the following pages.

The regressions developed by Coastal (1997) show that relatively high salinity values persist in the Palm River at flows less than 100 cfs from Structure 160. Predicted surface salinity values at Stations 12 through 15 are between 19.3 and 21.2 ppt at flows of 100 cfs, while predicted salinities in bottom waters at these stations range from 23.4 to 24.5 ppt. Although salinity is

Station 12	FLOWVAL										
	0	10	20	30	40	50	60	70	80	90	100
	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)
	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM
DEPTH											
0m	24.90	23.86	23.02	22.31	21.70	21.18	20.71	20.30	19.92	19.58	19.27
1m	27.65	26.48	25.52	24.73	24.05	23.45	22.93	22.46	22.03	21.65	21.30
2m	30.54	29.23	28.16	27.27	26.51	25.85	25.26	24.74	24.26	23.84	23.44

Station 13	FLOWVAL										
	0	10	20	30	40	50	60	70	80	90	100
	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)
	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM
DEPTH											
0m	27.13	25.82	24.77	23.89	23.14	22.49	21.92	21.41	20.95	20.53	20.15
1m	29.03	27.74	26.69	25.82	25.07	24.42	23.84	23.33	22.87	22.45	22.07
2m	29.31	28.32	27.50	26.82	26.22	25.71	25.25	24.83	24.46	24.12	23.81

Table 4.2. Predicted salinity values at WAR/SDI staions in the Palm River for different rates of discharge at S-160 generated by regression models contained in Coastal (1997)

Station 14	FLOWVAL										
	0	10	20	30	40	50	60	70	80	90	100
	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)
	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM
DEPTH											
0m	28.30	26.85	25.69	24.72	23.89	23.18	22.55	21.99	21.49	21.04	20.62
1m	29.24	27.95	26.90	26.02	25.27	24.62	24.05	23.53	23.07	22.65	22.27
2m	28.22	27.54	26.99	26.52	26.11	25.74	25.42	25.13	24.87	24.62	24.40

Station 15	FLOWVAL										
	0	10	20	30	40	50	60	70	80	90	100
	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)	Predicted Salinity (ppt)
	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM
DEPTH											
0m	27.77	26.56	25.57	24.75	24.05	23.43	22.89	22.41	21.98	21.58	21.22
1m	28.73	27.67	26.80	26.08	25.45	24.91	24.42	23.99	23.60	23.24	22.91
2m	27.34	26.86	26.45	26.11	25.81	25.54	25.30	25.09	24.89	24.71	24.54

Table 4.2 continued

reduced at these stations as freshwater inflow increases, salinities remain within the polyhaline zone (18 to 30 ppt) of the Venice system (Anonymous, 1959 as cited in Bulger et al., 1993) and the outer-estuarine zone 4 (16 to 27 ppt) of the NOAA salinity classification system (Bulger et al. 1993).

As expected, the results presented by Coastal (1997) show the response of salinity in the Palm River is curvilinear, with salinity being most responsive at low flows. By increasing flow from 0 to 40 cfs, surface salinities in the Palm River (Stations 12 through 15) are predicted to decrease by 3.2 to 4.4 ppt to produce values in the low to mid-twenties (Table 4.2). Predicted salinity values corresponding to 40 cfs flow at depths 1 meter and greater in the Palm River range from 24.2 to 26.5 ppt. Since the median flow for the former Palm River was 43 cfs (page 6.6), salinity in the Palm River given pre-construction freshwater inflows would remain well above 20 ppt most of the time. The reason for these high salinity values is the large volume of tidal water in the canal system which acts to dilute freshwater inflows. In contrast to the Lower Hillsborough River, where relatively small increases in freshwater inflows produce expanded oligohaline and mesohaline habitats, it is unlikely if the important ecological characteristics of the Palm River related to salinity are changed at these levels of freshwater inflows.

4.4.2 Dissolved Oxygen Concentrations

Statistical summaries of dissolved oxygen (D.O.) at individual depths for the WAR/SDI stations in the Palm River and McKay Bay are presented Table 4.3. This information is compared to results presented in WAR/SDI (1995).

Problems with hypoxia were frequent at stations in the Palm River, particularly in deeper waters. Mean D.O. values of less than 3.0 mg/l were observed below two meters at station 12; below three meters at station 13; below five meters at station 14, and below four meters at station 15. Minimum D.O. values below 0.5 mg/l occurred at one meter and deeper at stations 12 through 14, and deeper than two meters at station 15. Dissolved oxygen concentrations were generally higher in McKay Bay, as mean values above 4.0 mg/l were found for all stations and depths except five meters at stations 17 and four meters at station 18. Periodic problems in deep waters at stations 17 and 18 largely occurred during the warm months between May and October (see Appendix X in WAR/SDI, 1995).

Plots of dissolved oxygen at stations in the Palm River/McKay Bay system vs. discharge at Structure 160 are presented in Appendix L of this District report. Plots are presented separately for the entire flow range and flows less than 200 cfs so the response to low flows can be more closely examined. Relationships of dissolved oxygen with discharge were weak as the plots show considerable scatter. There appeared to be some tendency for low D.O. values at stations in the Palm River at flows above 140 to 160 cfs. Coastal (1997) performed regression analysis of dissolved oxygen in the Palm River from the WAR/SDI data set and found the slope parameter for temperature was significant in all cases, but the slope for flow was not significantly different from zero ($p < .05$) except at Station 13 and a depth of 3 meters (page 6-11 in Coastal 1997).

[illegible] Summary statistics for dissolved oxygen concentrations at WAR/SDI stations in the Palm River/McKay Bay system. Unless otherwise noted in parentheses, the number of observations is 24 for all stations except for station 14 which has 38. All values reported in mg/l.

	Mean	Std	Min	Max
Station 12				
Surface	4.6	2.4	1.3	8.9
1 M	3.9	2.7	0.3	10.0
2 M	2.8	2.6	0.1	11.0
3 M	1.5	1.3	0.1	5.4
4 M	1.0	1.3	0.0	4.9
5 M (21)	0.5	0.6	0.0	2.2
Station 13				
Surface	6.4	3.0	0.8	13.9
1 M	6.1	3.4	0.4	13.0
2 M	3.8	2.2	0.2	8.2
3 M	2.5	1.7	0.1	6.0
4 M	2.0	1.6	0.0	5.2
5 M (20)	1.0	1.5	0.0	5.8
Station 14				
Surface	6.8	3.0	0.2	14.0
1 M	6.1	2.8	0.1	12.5
2 M	4.9	2.4	0.2	9.4
3 M (35)	3.7	2.1	0.3	7.9
4 M (33)	3.3	2.2	0.1	7.8
5 M (27)	2.4	1.9	0.1	7.0
6 M (6)	1.7	2.7	0.1	7.0
Station 15				
Surface	7.1	2.4	3.8	13.0
1 M	6.2	2.0	2.1	10.1
2 M	4.8	1.9	2.0	9.1
3 M	3.6	2.0	0.4	7.0
4 M (23)	2.9	2.1	0.2	6.8
5 M (4)	0.4	0.2	0.2	0.6
Station 16				
Surface (23)	7.1	1.8	4.2	11.4
1 M (15)	5.2	2.9	0.8	9.3
Station 17				
Surface	6.6	1.6	3.6	10.2
1 M	6.2	1.5	3.6	8.6
2 M	5.2	1.6	2.6	8.4
3 M	4.3	1.9	1.2	8.0
4 M (19)	3.6	2.1	0.6	7.7
5 M (8)	2.4	1.9	0.1	5.1
Station 18				
Surface	6.8	1.4	3.8	10.3
1 M	6.5	1.3	3.6	9.3
2 M	5.6	1.5	2.0	7.8
3 M	4.7	1.8	0.7	7.3
4 M (16)	3.6	2.1	0.4	7.0
Station 19				
Surface	6.6	2.1	3.1	11.0
1 M (13)	5.1	2.3	1.6	8.6

Plots of dissolved oxygen concentrations at deep-water stations in McKay Bay generally had more scatter than those in the Palm River, and there did not appear to be any consistent relationship with freshwater inflows. Regressions performed for this report similar in form to the regressions performed by Coastal (1997) for the Palm River did not find any statistically significant ($p < .05$) relationships with flow. Climatological conditions (wind and temperature) probably control dissolved oxygen concentrations in McKay Bay to a large extent. Dissolved oxygen concentrations were generally higher at the shallow stations (16 and 19), and similarly did not show any relationships with freshwater inflows.

Plots of surface and mean water column dissolved oxygen values vs. 14-day discharge are shown in Appendices S and T of WAR/SDI. For stations in the Palm River, these plots possibly indicate a negative relationship between discharge and mean water column D.O. between 0 and 80 cfs, some rebound in the 100 to 200 cfs range, and low values above 200 cfs. Surface values showed greater scatter, but with the exception of station 12, showed some tendency for higher D.O. values at flows less than 70 cfs. Plots for stations in McKay Bay showed no apparent relationships with freshwater inflows. WAR/SDI (1995) found no statistically significant correlations between dissolved oxygen concentrations and discharge from Structure 160 at all stations in the Palm River/McKay Bay system.

4.5 Salinity and Dissolved Oxygen Data for the Palm River and McKay Bay from the HCEPC

The Hillsborough County Environmental Protection Commission (HCEPC) collects water quality data at two stations in the Palm River and one in McKay Bay. Station 110 is located at the State Road 60 bridge (SR 60); station 109 is at U.S. Highway 41 (US 41) bridge; and station 58 is located near the center of McKay Bay. Salinity and dissolved oxygen data are collected for surface, mid-depth, and bottom waters. Data for mid-depth values began several years before data collection for surface and bottom waters. The HCEPC data for mid-depth values summarized in this report ranged from 1974 to 1995, while the data for surface and bottom waters ranged from 1987 to 1995.

4.5.1 Salinity Statistical summaries of salinity at the HCEPC stations in the Palm River and McKay Bay are presented in Table 4.4. The mean salinity values for surface, mid-depth and bottom waters at SR 60 (station 110) were 19.2, 20.1 and 25.6 ppt, respectively. The mean values for surface, mid-depth and bottom waters at US 41 (station 109) are 20.4, 20.1 and 25.8 ppt, respectively. The similarity of mean values for surface and mid-depth at these stations may due to different lengths of records for these depths.

Table 4.4 Statistical summary of salinity values at HCEPC stations in the Palm River and Mackay Bay.

Station 110 (State Road 60)

Depth	Mean	Std.	Min.	Max.	N
Surface	19.2	4.3	0.1	28.0	117
Mid	20.1	6.8	0.1	39.8	269
Bottom	25.6	3.6	0.1	33.0	117

Station 109 (US Highway 41)

Depth	Mean	Std.	Min.	Max.	N
Surface	20.4	4.0	7.0	31.4	119
Mid	20.1	6.3	0.1	31.3	271
Bottom	25.8	2.7	17.7	31.2	119

Station 58 (McKay Bay)

Depth	Mean	Std.	Min.	Max.	N
Surface	22.5	4.9	0.4	32.8	232
Mid	23.9	4.7	2.5	39.2	262
Bottom	25.3	3.8	3.9	35.2	232

The mean and standard deviations for the HCEPC salinity data for surface and bottom waters are very similar to statistics calculated for the same depths at the nearby WAR/SDI stations (12, 14, and 17). Again, horizontal salinity gradients are very slight, especially in bottom waters. The lower minimum values recorded for the HCEPC data reflect the longer period of record that includes observations taken when high flows were diverted from the Hillsborough River through the canal.

Plots of surface, mid-depth and bottom salinity at the HCEPC stations are plotted vs. eight-day discharge from the Structure 160 on the Tampa Bypass Canal in Appendix M-1. Plots are presented separately for flows less than 200 cfs and an expanded flow range. Similar to the WAR/SDI data for Station 12, surface salinity values near the SR60 bridge were only infrequently below 15 ppt even though the HCEPC data base covers monthly sampling over nine years. There was considerable scatter in the plot of mid-depth salinity at SR60 versus flow, possibly due to the longer period of record for these measurements. Also, salinity at mid-depth can vary considerably depending on the depth of sample in relation to the depth of the halocline. Vertical profile data from WAR/SDI show that strong gradients in salinity can occur between one and three meters depth. The very low values (<2 ppt) for mid-depth salinity at flows of less than 200 cfs are interesting. With only one exception, all were recorded before 1987 when there are no surface or bottom values for comparison. Data recorded after 1987 are grouped more closely with the rest of the data. The plot of bottom salinity at SR 60 versus flow is very flat at flows less than 200 cfs, showing the relative isolation of bottom waters in the canal to the effects of freshwater inflows.

The plots of salinity at US 41 versus are similar to the plots for SR 60, with the most scatter occurring in the mid-depth readings. Salinity values are somewhat higher in McKay Bay, with considerably less scatter for the mid-depth readings. This may be due to the greater vertical mixing that occurs in McKay Bay compared to stations in the Palm River. Although the plots of the HCEPC data show that very high flows (> 600 cfs) can reduce salinity to less than 10 ppt at some depths and stations in the Palm River/McKay Bay system, the response of salinity at the HCEPC stations is relatively flat compared to river/estuarine systems in southwest Florida. This is likely due to the large volume and morphometry of the canal system, which acts to diminish the effect of freshwater inflows compared to more natural river systems.

4.5.2 Dissolved oxygen Statistical summaries of salinity at the HCEPC stations in the Palm River and McKay Bay are presented in Table 4.5. As with the WAR/SDI data at station 12, strong vertical gradients in D.O. occur at SR 60, which is just downstream from Structure 160. Mean values at mid and bottom at this station are below the state standard for instantaneous readings for estuarine waters (4.0 mg/l), with bottom waters being particularly hypoxic. Again, similar to the WAR/SDI data, mean dissolved oxygen concentrations are improved somewhat downstream at US 41 and McKay Bay, but hypoxic waters are still frequently found in mid-depth and bottom waters.

Table 4.5 Statistical summary of dissolved oxygen concentrations at HCEPC stations in the Palm River and McKay Bay. All values except n are expressed as mg/l.

Station 110 (State Road 60)

Depth	Mean	Std.	Min.	Max.	N
Surface	6.4	3.9	0.2	18.8	121
Mid	3.1	3.1	0.0	17.2	276
Bottom	1.1	1.5	0.1	6.0	123

Station 109 (US Highway 41)

Depth	Mean	Std.	Min.	Max.	N
Surface	6.0	2.7	0.3	12.4	126
Mid	5.3	3.0	0.1	16.9	279
Bottom	3.2	2.1	0.1	7.9	126

Station 58 (McKay Bay)

Depth	Mean	Std.	Min.	Max.	N
Surface	7.0	2.9	1.9	18.8	210
Mid	5.7	2.5	0.2	15.0	211
Bottom	3.7	2.2	0.1	11.0	254

Plots of dissolved oxygen in surface, mid, and bottom waters are plotted versus discharge from Structure 160 in Appendix M-1 of this report. Plots are presented for flows less than 200 cfs and for an expanded flow range. The plots for SR60 show the high frequency of very low D.O. readings for middle and bottom water depths. Dissolved oxygen concentrations is improved at US 41, as there are markedly fewer observations of D.O. less than 2.0 mg/l. Dissolved oxygen is further improved in McKay Bay, where occurrences of concentrations of less than 2.0 mg/l are infrequent at mid-depth, but concentrations less than 1.0 mg/l continue to be found in bottom waters. It should be pointed out that this station is in the channel in the middle of McKay Bay, and bottom concentrations may be substantially higher in the widespread shallower regions of the bay bottom.

At all HCEPC stations there is considerable scatter in the relationship between dissolved oxygen and flow. Correlations between dissolved oxygen flow tested for the HCEPC stations are presented in Appendix M-4. Correlations were investigated using both log-transformed and untransformed flow variables. There were weak negative correlations (r values of -.18 and -.25) between surface dissolved oxygen with flow at State Road 60 and a weak negative correlation between mid-depth D.O. and log-transformed flow (r= -.15). Similarly, surface D.O. had weak negative correlations with flow at US 41, but significant correlations ($p < .05$) were found for only one of the two flow variables for mid-depth and bottom waters. In McKay Bay, weak negative correlations were found for surface, mid-depth, and bottom waters for one of the two flow variables. Probably the most conclusive finding of the correlation analysis is that there are no positive relationships between flow and dissolved oxygen concentrations in the Palm River McKay Bay system. The combined results from WAR/SDI and HCEPC data indicate that reductions in flows from the Structure 160 should have not have any negative effects on dissolved oxygen concentrations in the Palm River or McKay Bay.

As discussed in Chapter 7, proposals have been made to examine the feasibility of physically restoring portions of the Palm River. If physical modifications are made to the Palm River, this could change the relationships of dissolved oxygen with freshwater inflows. Accordingly, if physical modifications are pursued on the Palm River at a future date, the District will re-evaluate minimum flows for this water body at Structure 160.

4.11. <u>Water Quality characteristics of the Palm River monitored by the HCEPC</u>

Summary statistics for water quality parameters in the Palm River monitored by the HCEPC are presented in Appendix M-2. Plots of these parameters vs. 8-day discharge from Structure 160 on the Tampa Bypass Canal are presented in Appendix M-3, while correlations of these parameters with discharge are listed in Appendix M-4.

Mean values of pH at the three HCEPC stations ranged from 7.6 at US 41 to 8.0 in McKay Bay. There were significant negative correlations between pH and discharge at all stations. High flows tended to reduce pH concentrations as values above 8.0 mg/l were largely restricted to flows less than 140 to 170 cfs. There was an interesting pattern at the McKay Bay station in that pH seemed to reach its highest values at flows between 30 and 90 cfs. Color was positively correlated with flow at all stations, but values greater than 70 pcu were limited to SR60 and US41 at flows greater than 500 cfs.

Mean chlorophyll a concentrations were highest in the Palm River, with means of 31.5 and 27.9 μg/l at stations SR60 and US 41. Median values were also high (21.4 and 20.1 μg/l) at these stations indicating that large phytoplankton populations are common in the Palm River. Chlorophyll a was negatively correlated with discharge at both stations, but this appeared partly driven by several very high values at each station at flows less than 130 cfs and a tendency for low values at flows greater than 800 cfs. Plots of chlorophyll a vs. low flows at SR 60 appear to have somewhat of positive relationship at flows less than 60 cfs, but there was a tendency to not have high values (>40μg/l) when flows were above about 130 cfs. A reduction in high chlorophyll values at flows above 130 cfs was more apparent at US 41. It appears that low and medium flows don't have much effect on chlorophyll a concentrations in the Palm River, but high flows act to reduce very large algal blooms.

Mean and median chlorophyll a concentrations were 23.6 and 17.7 μg/l at the McKay Bay station. Similar to the pattern for pH, there appeared some tendency for maximum chlorophyll concentrations when flows were in the range of 30 to 90 cfs. Chlorophyl a and pH has significant positive correlation (r= .25) with each other and algal blooms may contribute to high pH readings. Chlorophyll a had a weak negative correlation with untransformed flow, but not log-transformed flow. Compared to stations in the Palm River, reductions in chlorophyll a were not as apparent at high flows. If a chlorophyll wash out process is operating in the Palm River, it may not be as pronounced in McKay Bay due to differences in circulation characteristics and residence times.

Biochemical oxygen demand (BOD) was negatively correlated with both discharge terms at the Palm River stations, with low values again being most consistent at flows above 120 to 130 cfs. BOD and chlorophyll a were positively correlated with one another at all stations and plots versus discharge showed similar patterns, indicating that much of the BOD in the Palm River/McKay Bay system may be related to phytoplankton abundance. Since algal blooms are frequent in the freshwater portions of the TBC (WAR/SDI, 1995), die-offs of freshwater algae washed into the brackish waters of the Palm River could contribute to oxygen demand there. Flows of a sufficient magnitude may inhibit large algal blooms in both the TBC and the Palm River.

There was a significant negative correlation of total suspended solids (TSS) with flow at US 41, but the correlations were weaker and non-significant at SR 60 and McKay Bay. Data from other studies have shown that the open waters of Tampa Bay have higher TSS readings than the brackish reaches of the bays tributaries. As with the Lower Hillsborough River, it appears high freshwater flows from Structure 160 displace high TSS water entering the mouth of the Palm River from McKay Bay and ultimately Tampa Bay.

Plots of all nitrogen and phosphorus forms exhibited considerable scatter with regard to discharge at Structure 160. No significant correlations were found, except a positive correlation of total nitrogen with flow at the McKay Bay station. The relationship of bacteriological parameters with flow were also very weak, with the exception of fecal coliforms which were positively correlated with flow at SR 60 and total coliforms which were positively correlated with flow at McKay Bay.

5. RECOMMENDATIONS OF THE TAMPA BAY NATIONAL ESTUARY PROGRAM MINIMUM FLOWS ADVISORY GROUP AND SUBMITTAL OF FINAL REPORT.

5.1. Role of Tampa Bay NEP minimum flows advisory group

In October, 1996, the Southwest Florida Water Management District requested that the Tampa Bay National Estuary Program (TBNEP) convene a technical advisory group for the establishment of minimum flows for the Lower Hillsborough River and the Tampa Bypass Canal/Palm River system. This advisory group met on approximately a monthly basis through May 1997. The advisory group included representatives of state, local and regional agencies, municipal and regional utilities, citizen environmental groups, and professionals from private firms and laboratories.

The objective of the minimum flow advisory group was defined at the initial meeting and subsequently clarified as follows:

- Provide technically sound recommendations to SWFWMD staff for identifying and evaluating the water resources and ecological criteria necessary to establish minimum flows on the Hillsborough River downstream of the dam and on the Palm River/Tampa Bypass Canal downstream of Structure 160.

The advisory group's final recommendations to the District are included in Appendix N-1. It was determined that the role of the group did not include providing a definition of "significant harm" as that term is used in Sec. 373.042 Florida Statutes, nor would the committee recommend a specific minimum flow rate for either the Lower Hillsborough River or the Tampa Bypass Canal (TBC). Instead, the advisory group recommended criteria the District should evaluate and consider in establishing minimum flows. Many of these recommendations pertained only to the Lower Hillsborough River. A chronological summary of the committee meetings prepared by TBNEP staff (Appendix N-2) provides some background on how the recommendations were developed.

In support of the advisory group's activities, the TBNEP managed a contract with Coastal Environmental to consolidate previously collected data for the river and canal and develop statistical models for salinity distributions and dissolved oxygen concentrations as a function of freshwater inflow. Also, in support of advisory group activities, staff from the Florida Department of Environmental Protection Marine Research Institute performed new analyses of data collected from three tributaries as part of the fisheries independent monitoring program for Tampa Bay. The District reviewed and considered the findings of these studies in its minimum flows evaluation. Conclusions and comments regarding these studies are summarized in Sections 5.4 and 5.5 of this report.

5.2. Minimum flows technical approach

The District and the TBNEP minimum flows advisory group identified several points of agreement regarding criteria for establishing minimum flows. Two key points were that salinity and dissolved oxygen are critical water quality variables affecting the abundance and distribution of organisms in the Lower Hillsborough River and the tidal reaches of the Tampa Bypass Canal. Accordingly, the determination of minimum flows evaluated how freshwater flows affect the distribution of salinity and dissolved oxygen concentrations in these watercourses. The protection and enhancement of fish populations in these watercourses is an important criterion for management and relationships of freshwater flows to potential fish habitat was an important ecological factor that was evaluated. The relationships of other biological parameters (e.g., benthic invertebrates, shoreline plant communities) to freshwater inflows were evaluated as they affect the overall biological integrity and productivity of the systems.

Based on these considerations, the basic approach for minimum flows determination was to evaluate salinity and dissolved oxygen distributions in the lower Hillsborough River and Tampa Bypass Canal as a function of flow releases from the corresponding water control structures. Statistical models and a physical deterministic model were used to evaluate salinity distributions in the Lower Hillsborough River as a function of freshwater inflows. Statistical models were used to predict salinity in the Tampa Bypass Canal. Statistical analyses were used to predict dissolved oxygen concentrations and the probability of experiencing hypoxic (low dissolved oxygen) conditions in the Lower Hillsborough River under various minimum flows releases.

Salinity and dissolved oxygen distributions calculated by these methods were compared to potential habitats available for fish and other organisms. Physical habitat features that were compared to salinity and dissolved oxygen distributions included shoreline length, vegetated shoreline, river distance, surface area, bottom area, and river volume. Previous biological data for the river were used to evaluate species that could be expected to use potential habitats. Also, relationships of different species to salinity, dissolved oxygen, and physical riverine/estuarine habitats described in the technical literature and data from other tributaries to Tampa Bay were used to evaluate potential habitat use.

The amount of freshwater and low and medium salinity habitats in the river were quantified for the various minimum flow releases. The probability of experiencing low dissolved oxygen concentrations were evaluated for the same releases. Starting with a zero flow condition, improvements in habitat quantity and quality were evaluated in a stepwise manner for incremental increases in minimum flows.

5.3 Dissolved oxygen criteria recommended by TBNEP advisory group

The recommendations of the advisory group (Appendix N-1) included some topics that pertained to the application of various analytical tools and future data collection. Many of those topics pertained only to the Lower Hillsborough River and were not applicable to the establishment of minimum flows for the Tampa Bypass Canal. The recommendation for dissolved oxygen criteria was oriented to the lower river, but could also be applied to the Palm River/McKay Bay system. The District concurs with the advisory group recommendation that criteria or goals for dissolved concentration oxygen should be a minimum of 4.0 mg/l or an average of 5.0 mg/l for optimizing fish utilization. Furthermore, if these criteria cannot be met at all times and all locations, minimize the time and areas of the river where dissolved oxygen is less than 4.0 mg/l. The District, however, suggests that other dissolved oxygen thresholds (2 or 3 mg/l) can also represent useful management criteria. For example, if a particular rate of flow is very effective at raising D.O. concentrations above 2.0 mg/l but not effective at raising them above 4.0 mg/l, the beneficial effect of the flow should still be considered.

5.4 Analysis of salinity/fish relationships from other Tampa Bay tributaries by the Florida Marine Research Institute

Several staff from the Florida Department of Environmental Protection Marine Research Institute (FMRI) participated on the minimum flows advisory group. In order to describe the use of tidal rivers by fish species present in the bay, FMRI staff made a presentation to the group regarding fish distributions observed in studies of the Little Manatee River. Discussions were held about the relationships of the different life stages of estuarine dependent fishes to salinity distributions in the bay's tributaries. Upon request by the advisory group, FMRI staff volunteered to perform new analyses of fish catch data from three tidal rivers monitored as part of the fisheries independent monitoring program. A summary of these analyses that was prepared by FMRI staff and presented to the group is included as Appendix N-4.

The FMRI presented data from three tidal rivers on the bay; the Alafia, Little Manatee and Manatee. Sampling in each river was by a 21-m boat seines and a 6.1 m otter trawl. Sampling for each gear was based on a stratified random design in which sampling was randomized within designated geographic areas. Efforts were made to sample across the salinity gradient and the fish catch data were classified into salinity zones determined by the Venice system. Because the freshwater/saltwater mixing zones moves many miles in these rivers on a seasonal basis, there were many sampling dates when certain salinity zones were not sampled. A summary of the number of samples taken in each salinity zone on each river is shown on page N4-8. The Little Manatee River had the most freshwater samples by seine, while the Manatee River had by far the most polyhaline (> 18.0 ppt) seine samples. These differences in sampling effort per salinity zone were due to differences in the prevailing salinity regimes of these rivers, combined with navigational limits to areas the sampling boats could get to. The average salinity of sampling was very similar for the Alafia and Little Manatee Rivers (about 9 ppt), but was considerably higher (23 ppt) for the Manatee River (page N4-2). Due largely to the inclusion of the Manatee River, more samples were collected in polyhaline waters than any other salinity zone.

Table 1 in the FMRI handout list the number of fish caught in each salinity zone (pages N4-9 to N4-12). The density weighted mean salinity at capture (and standard error) for each species that was caught in ten or more samples is presented on page N4-16. These same statistics are plotted for 13 important species on page N4-17. The snook (Centropus unidecimalis) had a mean salinity of capture of 4.05 ppt, while 3 species had mean salinities at capture of about 9 parts per thousand. Seven species has mean salinities at capture between 12 and 17 ppt. while two species, the silver jenny (Eucinostomus gula) and the sand seatrout (Cynoscion arenarius), had salinities at capture of greater than 20 ppt. It should be noted the standard errors around the mean for each species are relatively large and many species were widely distributed during the study.

The lengths of fishes analyzed are presented with the salinity at capture statistics (page N4-16). The FMRI study largely captured fishes in the juvenile stage, although this varied between species. For some species, the mean salinity at capture varied with the length. For example, the mean salinity at capture for two seatrout (Cynoscion) species was lower at lengths between 40 and 70 mm than for lengths less than 30 (pages N4-19 and N4-20). This pattern occurred because these species tend to migrate into low salinity zones as juveniles. Many estuarine dependent species migrate into low salinity waters as they grow from larval to juvenile stages, then migrate back to higher salinity waters as they mature from juveniles to adults.

Another useful document for examining the salinity at capture for early life stages of estuarine dependent fish is the ichthyoplankton study of the Little Manatee River by Peebles and Flannery (1992). This study used night-time plankton trawls with nets with a 505 micron mesh. Comparisons can be made of the salinity at capture for certain species between these two reports. For some species (e.g. Anchoa mitchilli), the salinity at capture is lower in the Peebles and Flannery report because earlier life stages and smaller lengths were capture.

The data presented by FMRI and included in Peebles and Flannery (1992) was used to assess general fish utilization and fish/salinity relationships in tributaries to Tampa Bay. This information was then compared to the fish data collected as part of the WAR/SDI study. Some members of the group suggested that potential fish utilization in the Hillsborough should be less than these other tributaries because of the highly urbanized nature of the river's shoreline. In essence, even if salinity and dissolved oxygen concentrations in the Hillsborough were suitable, fish populations would be less due to river's modified morphology and loss of tidal wetlands. In response in this issue, FMRI segregated their seine catch data into four shoreline classifications; unvegetated, emergent vegetation, overhanging vegetation, and hardened shoreline (pages N4-26 to N4-30). The results showed that substantial numbers of fishes were caught adjacent to hardened shorelines. For some notable species (Anchoa mitchilli, Scienops ocellatus, Cynoscion nebulosus) the shorelined was ranked first or second with regard to average number caught.

FMRI staff pointed out that these results are partly related to the sampling gear. Seines can be more effective at capturing fish against a hard shoreline than when the fish can escape into marsh plants or roots. Also, the rivers analyzed by FMRI also have substantial areas of natural shoreline and the functions of tidal wetlands in maintaining food-webs in those rivers are important. With regard to the Hillsborough and Palm Rivers, it may be true that these rivers will not support the same fish diversity and productivity as the other rivers, even if salinity and dissolved oxygen levels are suitable. However, the WAR/SDI data from the river and FMRI data from other tributaries indicate that although these rivers has been substantially modified, they are capable of supporting valuable fish communities that warrant proper management.

6. TAMPA BYPASS CANAL: HYDROLOGIC AND YIELD ANALYSES

6.1. Literature Review

The Tampa Bypass Canal was proposed by the U.S. Army Corps of Engineers (1961) to alleviate flooding such as had occurred in 1959 and 1960. The construction of the TBC breached the underlying Upper Floridan aquifer system (UFAS) in several places where the potentiometric surface is at or near land surface (Motz, 1975). This was predicted to produce considerable drainage from the aquifer and drawdowns over a large area. Motz evaluated the effects of the TBC on the UFAS by conducting three aquifer performance tests along the TBC and evaluating those results in a digital ground-water flow model. As a result of Motz's work, Structure 162 was added to the system to reduce the extent of areal drawdowns. Knutilla and Corral (1984), through analysis of field data, confirmed Motz's prediction of extensive ground-water declines by the canal. They showed that construction of the TBC had increased base flow by 1.5 to two times pre-construction values in the vicinity of Structure 160. It was also shown that spring flow in the TBC area had declined when compared with Crystal Springs near Zephyrhills. After construction of the canal, UFAS water levels declined two to 4 feet near the middle pool and increased about 4 feet near the lower pool. Barcelo (1985) confirmed flow from the UFAS to the TBC in the vicinity of the middle pool by a numerical ground-water flow model.

Geraghty and Miller (1982) first analyzed the TBC's water supply potential. During a very low rainfall period of May and early June 1981, Structure 162 was closed. The middle pool stage was stabilized and the City of Tampa pumped 15 to 32 mgd from the TBC to the Hillsborough River reservoir for the duration of the test. Analysis of this test indicated that 18 mgd could be withdrawn continuously from the TBC while maintaining a stage of 12 feet NGVD. Ground-water seepage back to the canal from the reservoir was estimated to be 2 percent of the average pumping rate. Geraghty and Miller (1986) reevaluated the TBC's water supply potential with a longer test during the 1985 low rainfall period. The analysis sought the 120 day safe yield for a one in 20 year drought. The estimated yield for a critical 60 day period with no rainfall was 20 mgd. SDI Environmental Services (Water & Air Research, Inc., 1995) developed an integrated surface-water and ground-water numerical model for the TBC. The purpose of the model was to confirm that a 20 mgd increase in the City of Tampa's withdrawals could be met from the TBC. Simulated withdrawal estimates were obtained by adjusting elevations at Structure 162 to simulate lowering the middle pool stage from 14.5 feet NGVD to 12.5 feet NGVD. The annual yield of the TBC middle pool was estimated at 43.6 mgd using 1990 hydrologic conditions. However, SDI recommends that 20 mgd could be continuously withdrawn from the TBC middle pool.

The idea of locating a well field along the TBC was investigated by CH2M Hill (1985). They constructed along the TBC an UFAS production well, five monitor wells in the production zone and four wells into the surficial aquifer. A simplified analysis based on Darcy's law indicated that 80 to 90 percent of the flow to the well came from the TBC and the remainder was leakage derived from the overlying surficial aquifer. The report suggested that a linear well field could withdraw up to 30 mgd although the effect of such withdrawals was not evaluated. Schreuder and

Davis (1993) reviewed existing data and monitoring programs. SDI (1997) reviewed two previous aquifer performance tests (Motz, 1975 and CH2M Hill, 1985). SDI concluded that only four to 14 percent of the flow to the well in the CH2M Hill test was derived from the canal.

In an analysis of the Hillsborough River reservoir reliable yields, Environmental Science and Engineering (1986) estimated that as much as 30 percent of the water pumped from the TBC returned to the TBC as seepage. This estimate was revised to 10 to 15 percent in a subsequent report (ESE, 1987). The first report estimated that 26 mgd could be withdrawn from the TBC, but the second report concluded only 20 mgd could be withdrawn.

Nguyen (1986) documented the development of a flood routing model for the TBC. The documentation includes stage-storage relationships for the TBC pools. Nguyen (1987) investigated the effects of secondary drainage (local runoff) on TBC flows. Secondary drainage was estimated to comprise as much as 10 percent of TBC flows.

6.2 Effects of Canal Construction on Flows in Six Mile Creek and the Palm River

6.2.1 Overview. Prior to construction of the TBC, Six Mile Creek flowed south from the area of Harney Flats/Eureka Springs. Near State Road 60, Six Mile Creek became the Palm River, which subsequently flowed into McKay Bay. A portion of the TBC was constructed by widening and deepening the former Palm River and Six Mile Creek stream channels. Canal construction significantly altered the local hydrology. The objective of this analysis was to examine available data for the Six Mile Creek/TBC system to confirm the effects of canal construction on stream flow.

6.2.2 Available Data. From October 1956 to September 1974, flow in Six Mile Creek was measured daily at a gaging station located near State Road 574. In October 1974, the flow gage was relocated 0.7 miles downstream to Structure 160. The period of record for flow at Structure 160 is October 1974 to present. During 1966-1982, measured flows were likely affected by dredging and construction of the TBC. In addition, many years have periods of missing data.

6.2.3 Effect of Canal Construction. The effects of canal construction on Six Mile Creek stream flow were previously evaluated by Knutilla and Corral (1984). In their analysis, Knutilla and Corral combined flow data at Six Mile Creek and Structure 160. Double-mass curves of cumulative annual discharge at Six Mile Creek/S-160 were compared to cumulative annual discharge measured at the Alafia River and the Hillsborough River gages. The results showed a distinct change in discharge between the 1957 to 1974 and 1975 to 1982 periods. The canal system exhibited an increase in discharge relative to both the Hillsborough and Alafia rivers.

Knutilla and Corral examined changes in baseflow by inspecting mean monthly discharges for months during 1957 - 1982 which had little or no runoff due to rainfall. These discharges were assumed to represent baseflow conditions, where most of the flow is derived from groundwater sources. Double mass curves were used to compare Six Mile Creek/Structure 160 baseflows to baseflows estimated for the Alafia River. The results indicated that Six Mile Creek/Structure 160 baseflows for 1975 - 1978 were about 1.5 times the baseflow for the pre-1975 period. Baseflows for 1979 - 1982 were about twice that of pre-1975 values.

Conclusions reached by Knutilla and Corral were based on comparing pre- and post-1975 over the period 1957 - 1982. However, flows measured during 1975-1982 were likely affected by ongoing construction activities in the middle and upper pools of the TBC. To re-evaluate the findings of Knutilla and Corral, a comparison of actual pre- and post construction flows has been made. The pre-construction period is October 1956 to April 1966. The post construction period is January 1983 to December 1996. Baseflow conditions for the two time periods were evaluated using an approach similar to that used by Knutilla and Corral (1984). For months where the total rainfall was less than 1.5 inches, flow was assumed to consist primarily of baseflow. Estimated baseflows for pre- and post-construction periods are presented in Table 6.1.

Table 6.1 indicates that the median flow for the post-construction period (71 cfs) is about 1.7 times the pre-construction value (43 cfs). The post-construction flows are more variable and exhibit larger maxima and minima than pre-construction values, due to the ability of the TBC structures to regulate flow and/or divert flow during storm events. The increase in flow magnitude and variability is also apparent on Figures 6.1 and 6.2, which depict frequency distributions for pre- and post- construction flows.

The post-construction baseflow is about 1.7 times the pre-construction value. Increases in baseflow were expected since canal construction breached the Upper Floridan aquifer, providing a direct connection between the groundwater system and the canal. In addition, the constructed canal acts as a linear sink relative to the regional potentiometric surface. This causes water to flow regionally to the canal.

In summary, the construction of the TBC has affected the hydrology of the former Six Mile Creek/Palm River system. Analyses performed by Knutilla and Corral (1984) and analyses presented here both indicate that stream flow and baseflow have increased by 1.5 to two times their pre-construction values.

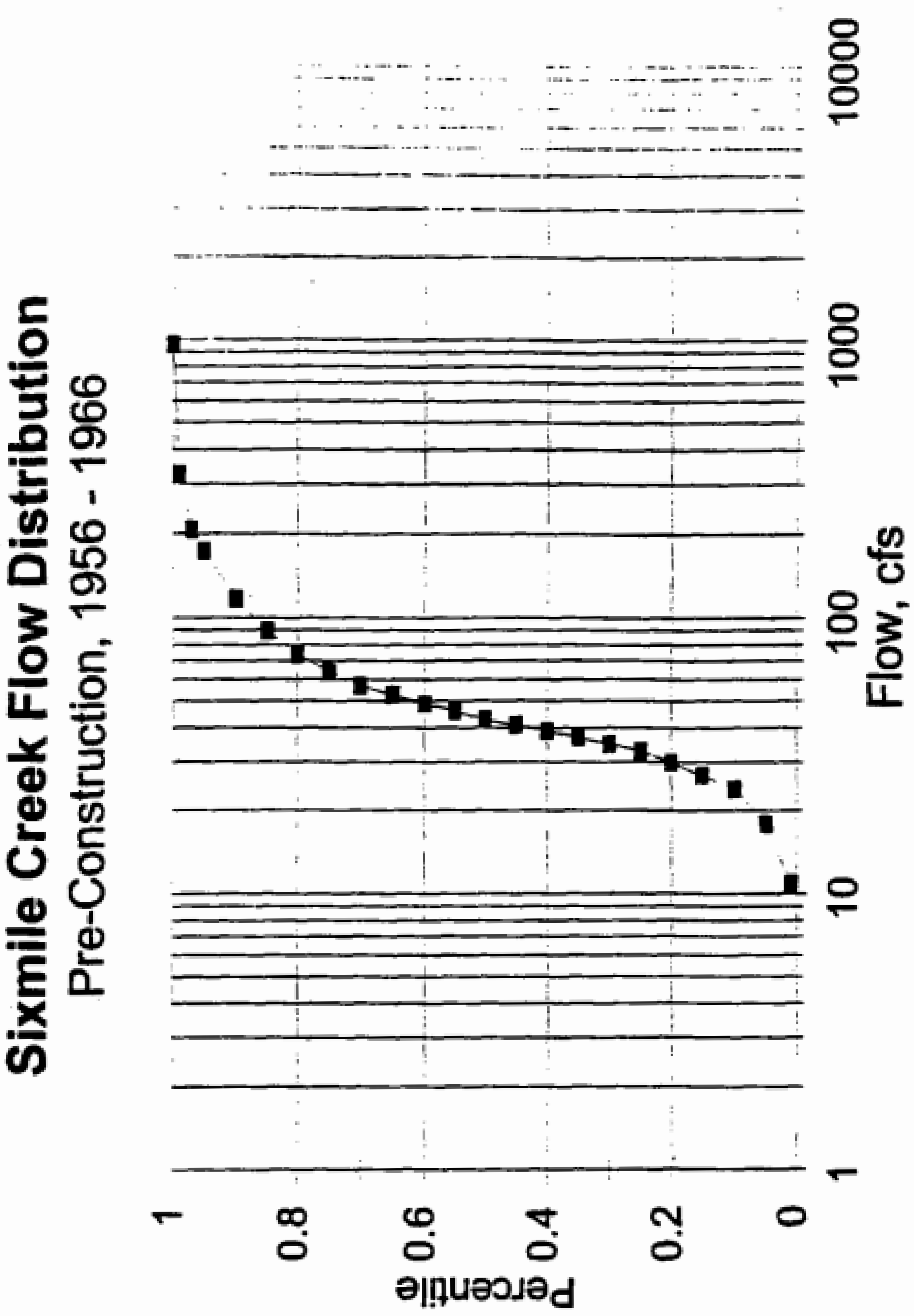

Sixmile Creek Flow Distribution
Pre-Construction, 1956 - 1966
Percentile
1
0.8
0.6
0.4
0.2
0
1
10
100
1000
10000
Flow, cfs

Figure 6.1

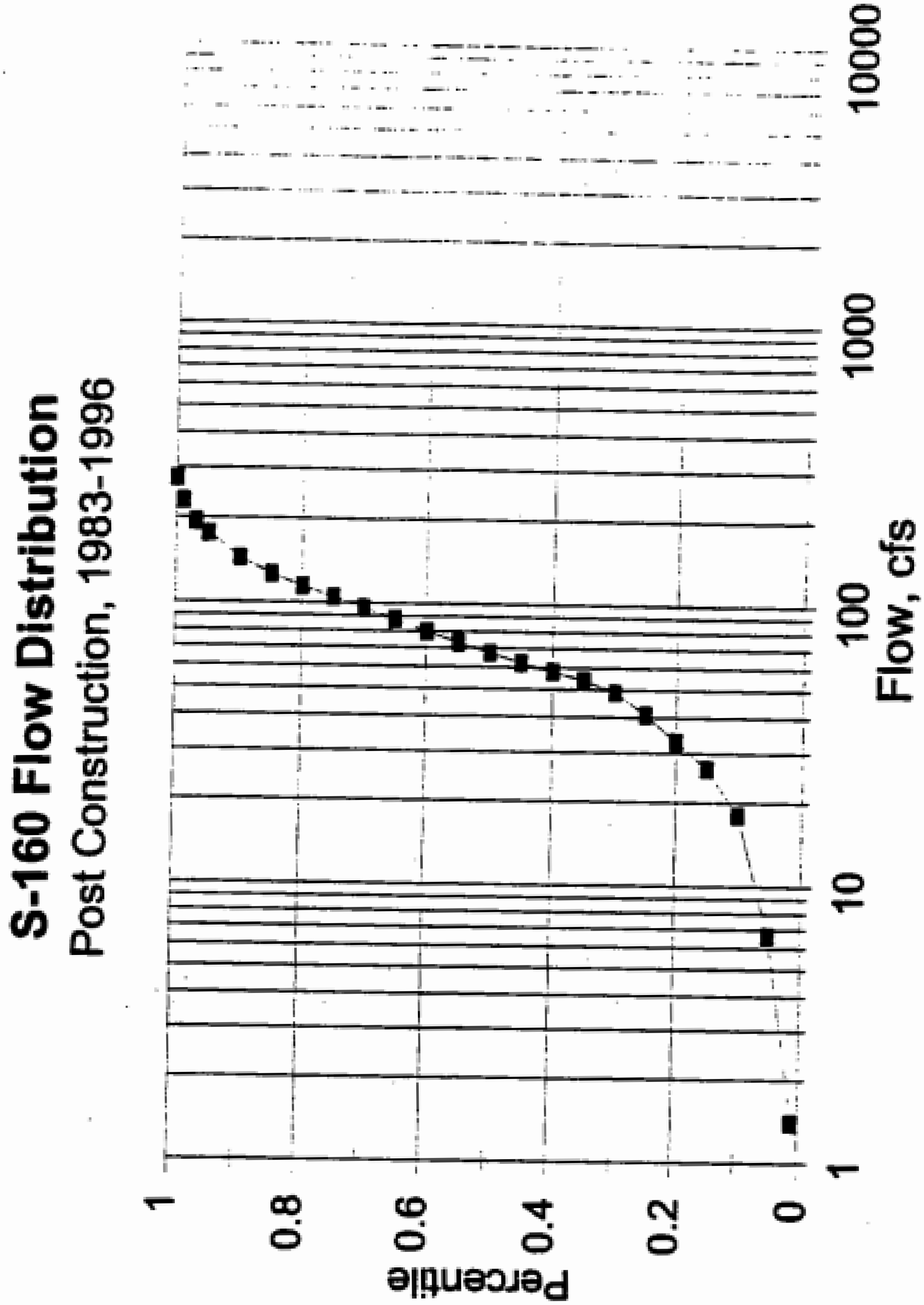

S-160 Flow Distribution
Post Construction, 1983-1996
Percentile
1
0.8
0.6
0.4
0.2
0
1
10
100
1000
10000
Flow, cfs

Figure 6.2

Table 6.1. Comparison of Pre- and Post- Construction Flows at Six Mile Creek and Structure 160

	Pre-Construction Six Mile Creek	Post Construction Structure 160
Period of Record	10/1/56 - 4/30/66	1/1/83 - 12/31/96
No. of Observations	3499	5017
Minimum	4	0
Maximum	961	10800
Median	43	71
Mean	62	140
Standard Deviation	62	444
Estimated Baseflow	36	61

6.3 Analysis of TBC Yield

Previous studies have estimated sustainable yield of the TBC on several occasions. After review of those studies, efforts were undertaken to corroborate and expand that information.

6.3.1 Dry Season Yield of Middle Pool. The short-term dry season yield of the TBC middle pool can be estimated from historic pumping events. The approach assumes that the average pumping rate for historic events is representative of the short-term yield. Table 6.2 summarizes the 24 pumping events, lasting five days or longer, that occurred between 1989 and 1996. Events last from several days to several weeks and generally occurred during the dry season. The average duration is 28 days. Pumpage ceased when either the city no longer needed to augment the reservoir, or the middle pool stage approached the limiting value of 12.0 ft NGVD. Daily pumping rates range from zero to nearly 40 mgd. Based on the 24 historic events, the average pumping rate or short-term dry season yield is 27 mgd.

The dry season sustainable yield can be qualitatively evaluated by examining graphs of canal stage, rainfall, and pumpage versus time. Figures 6.3, 6.4, and 6.5 depict measurements taken in May-June 1990, May-June 1992, and June-July 1993, respectively. The graphs indicate that stage remains relatively constant at a pumping rate of approximately 20 mgd, even with little or no rainfall. Under this condition, surface water withdrawals are balanced by groundwater inflows. The rate of 20 mgd can be considered to represent the sustainable dry season yield. Under wet season conditions, it is likely that the TBC could yield greater quantities of water.

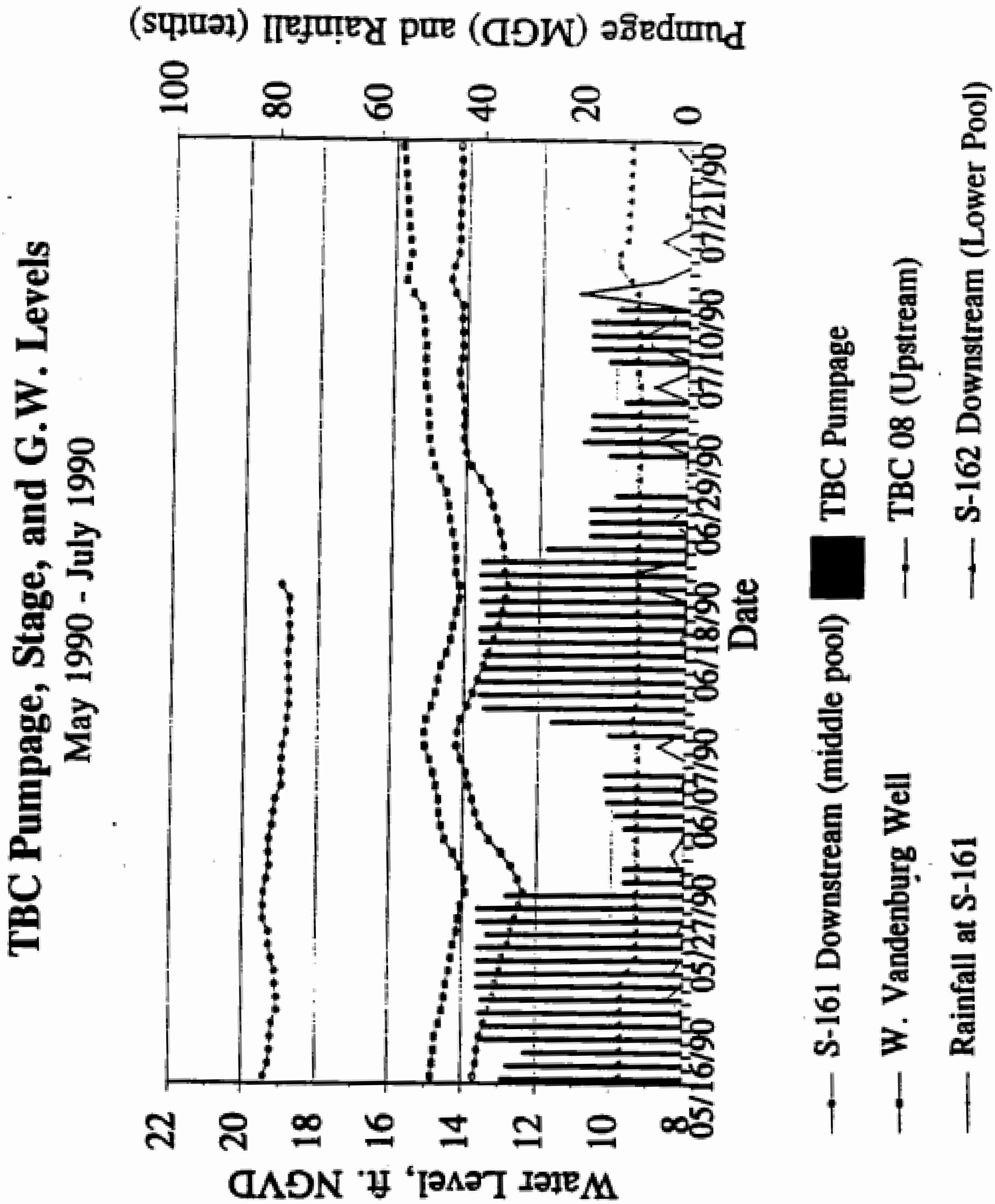
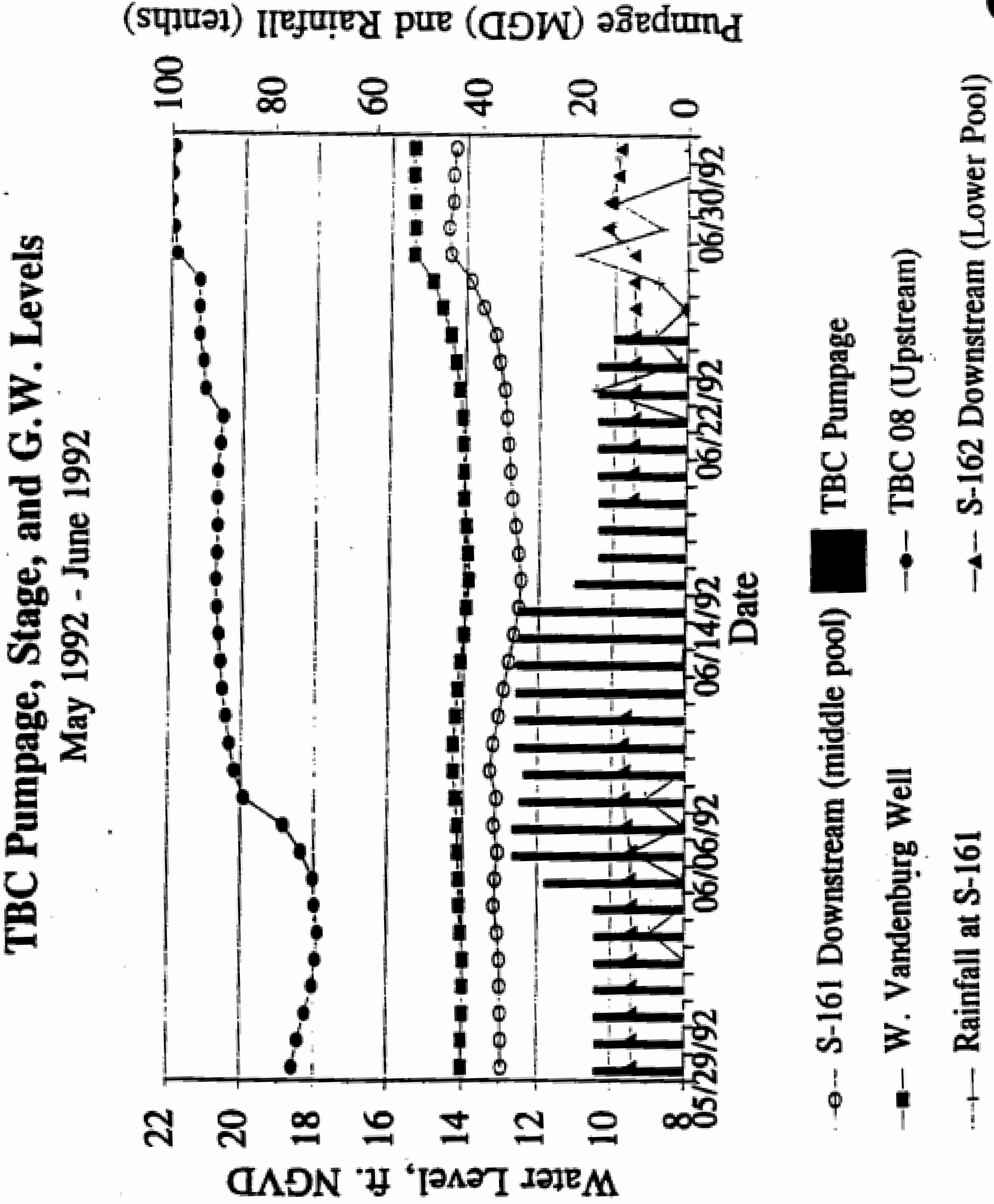
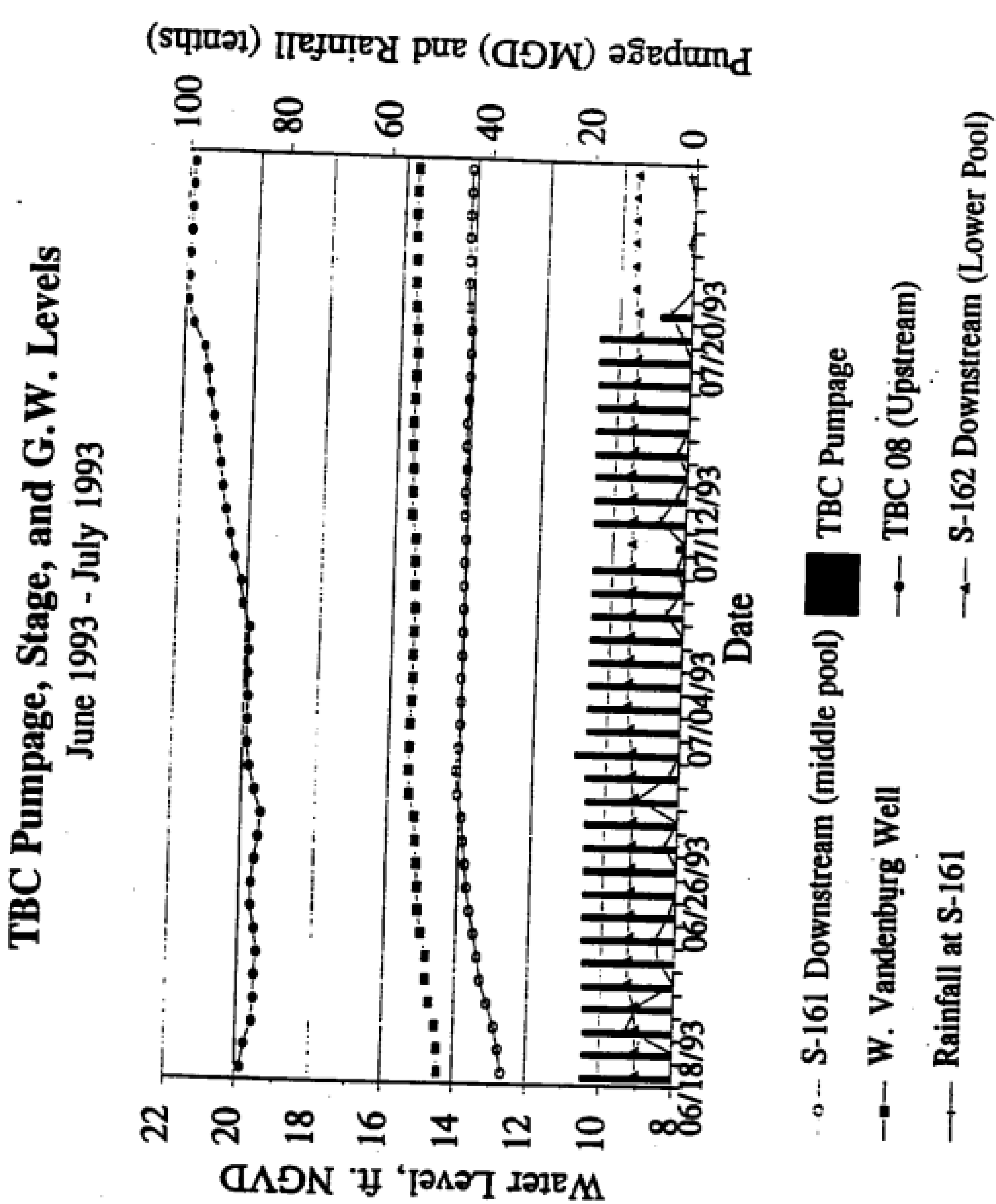

TBC Pumpage, Stage, and G.W. Levels
May 1990 - July 1990
Water Level, ft. NGVD
22
20
18
16
14
12
10
8
Pumpage (MGD) and Rainfall (tenths)
100
80
60
40
20
0
05/16/90
05/27/90
06/07/90
06/18/90
06/29/90
07/10/90
07/21/90
Date
S-161 Downstream (middle pool)
W. Vandenburg Well
Rainfall at S-161
TBC Pumpage
TBC 08 (Upstream)
S-162 Downstream (Lower Pool)

Figure 6.3



TBC Pumpage, Stage, and G.W. Levels
May 1992 - June 1992
Water Level, ft. NGVD
Pumpage (MGD) and Rainfall (tenths)
22
20
18
16
14
12
10
8
100
80
60
40
20
0
05/29/92
06/06/92
06/14/92
06/22/92
06/30/92
Date
S-161 Downstream (middle pool)
W. Vandenburg Well
Rainfall at S-161
TBC Pumpage
TBC 08 (Upstream)
S-162 Downstream (Lower Pool)

Figure 6.4



TBC Pumpage, Stage, and G.W. Levels
June 1993 - July 1993
Water Level, ft. NGVD
22
20
18
16
14
12
10
8
Pumpage (MGD) and Rainfall (tenths)
100
80
60
40
20
0
06/18/93
06/26/93
07/04/93
07/12/93
07/20/93
Date
S-161 Downstream (middle pool)
TBC Pumpage
W. Vandenburg Well
TBC 08 (Upstream)
Rainfall at S-161
S-162 Downstream (Lower Pool)

Figure 6.5

Table 6.2 Summary of TBC Pumping Events, 1989 -1996

Date Pumpage Began	Date Pumpage Ended	Average Pumpage (MGD)	No. of Days TBC Pumped
05/23/89	06/09/89	30.8	18
06/12/89	06/16/89	30.4	5
06/19/89	06/23/89	26.8	5
12/04/89	12/08/89	26.8	5
03/28/90	06/01/90	31.3	66
06/04/90	06/08/90	14.6	5
06/11/90	06/29/90	32.4	19
07/02/90	07/06/90	17.4	5
07/09/90	07/13/90	17.5	5
11/15/90	01/17/91	35.4	64
02/04/91	02/22/91	37.2	19
02/25/91	03/18/91	32.1	22
04/15/91	04/25/91	31.4	11
11/22/91	02/29/92	27.0	100
03/22/92	04/25/92	26.5	35
05/03/92	06/25/92	24.6	54
05/28/93	07/21/93	23.4	55
08/13/93	08/30/93	28.1	18
12/20/93	12/29/93	31.5	10
03/17/94	06/17/94	26.1	93
05/04/95	05/28/95	31.1	25
05/30/95	06/04/95	32.3	6
09/05/96	09/11/96	15.1	7
11/12/96	12/07/96	27.2	26
	Average	27.4	28

6.3.2 Closing of Structure 162 and Baseflow Yield of the Lower Pool. Water budget analyses indicate that groundwater may account for up to 85 percent of the total inflow to the middle pool. Groundwater inflows to the lower pool are likely also significant. It was questioned whether the lower pool could generate sufficient quantities for use or to meet minimum flows at the Hillsborough River reservoir spillway, independent of the operation of the middle pool. To address this question, data were reviewed for periods when Structure 162 was closed. When Structure 162 is closed, the lower pool is assumed to be hydraulically isolated from the middle pool. Under this condition, flows measured at Structure 160 reflect water generated by the lower pool.

Table 6.3 summarizes the data collected during three test periods when Structure 162 was closed. Time series of Structure 160 flows are given as Figures 6.6, 6.7, and 6.8. The data suggest that very little additional baseflow is generated in the lower pool. For the 1981 and 1985 time periods, the median flows at Structure 160 were 5 cfs and 6 cfs, respectively. Part of this flow may be due to seepage from the middle pool to the lower pool near Structure 162. During the 1997 test, divers placed sawdust around Structure 162 to prevent seepage from occurring. The median flow for the 1997 test period was only 2 cfs. The maximum flows resulted from the direct precipitation and local runoff that occurred during small rainfall events. Note that the gate settings at Structure 160 were not changed during the test period. However, it may be possible to generate additional quantities of water by lowering the gate elevation at Structure 160 to induce additional groundwater inflow to the lower pool, if such were desirable.

Table 6.3 Summary of Flow at Structure 160 For Periods When Structure 162 Was Closed

Dates	Length of Test (days)	Minimum Flow at Structure 160 (cfs)	Maximum Flow at Structure 160 (cfs)	Median Flow at Structure 160 (cfs)
May 4 - June 3, 1981	31	3	15	5
Mar. 21 - May 26, 1985	67	2	49	6
Jan. 23 - May 1, 1997	99	0	42	2

6.3.3 Water Budget and Regression Modeling Three water-budget models were developed to estimate yields from the TBC. Two models simulated conditions in the middle pool and, the other, conditions in the lower pool. All three model developments followed a similar methodology. The form of the water budget was

$$\text{Change in canal volume, dVol} = \text{Inflow} - \text{Outflow}, \quad (1)$$

which was expanded to

$$\text{dVol} = \text{Rainfall} + \text{Runoff} + \text{Seepage} - \text{Discharge} - \text{Evaporation} - \text{Pumping}. \quad (2)$$

Rainfall represents direct rainfall to the middle pool. Discharge is the outflow through Structure 162 for the middle pool models and Structure 160 for the lower pool model. Evaporation and pumping were available from SWFWMD data bases. During these analyses there were no upstream inflows. Seepage and runoff were unknown and a multivariate regression analysis was performed to derive those variables from available data.

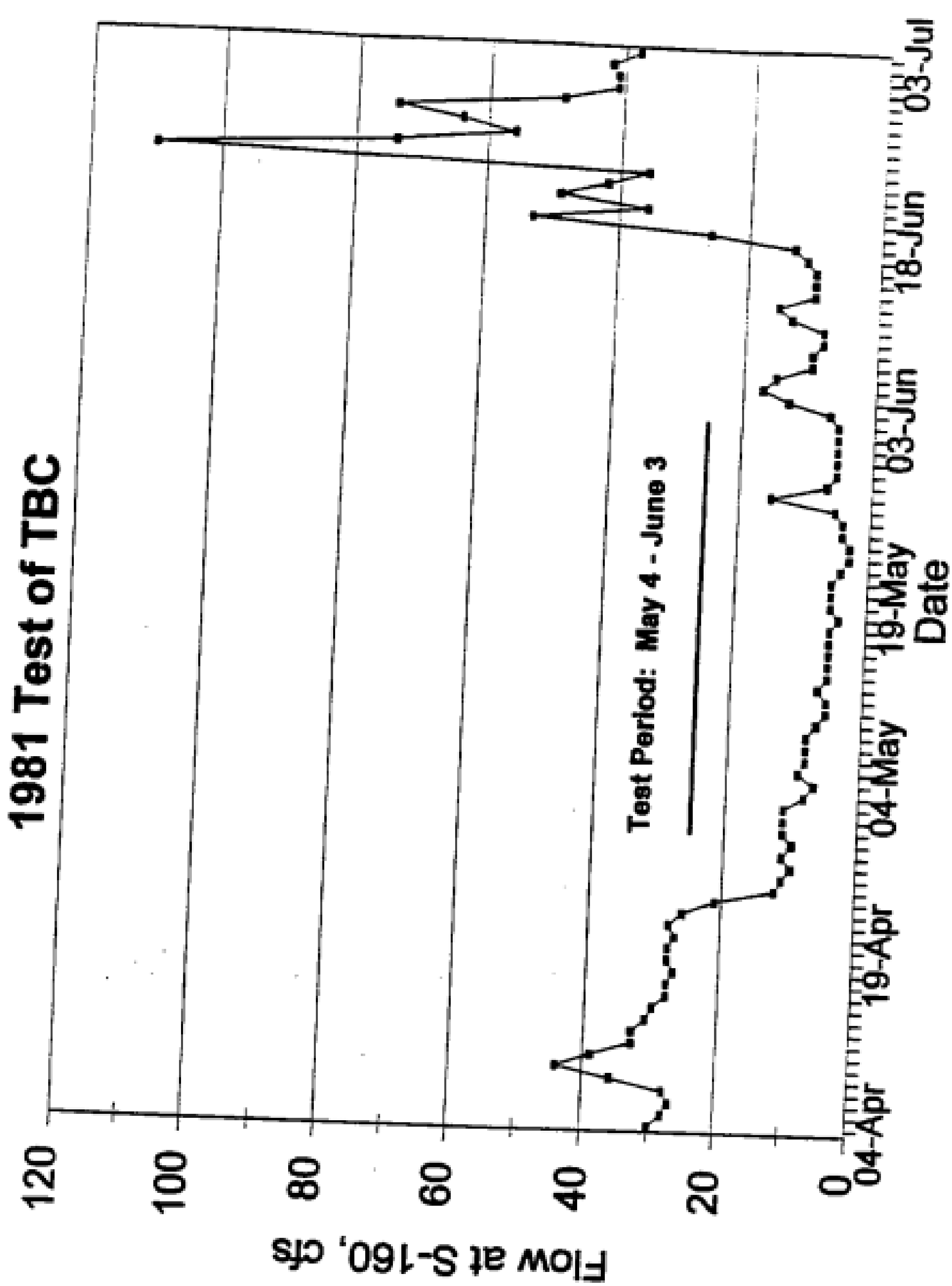
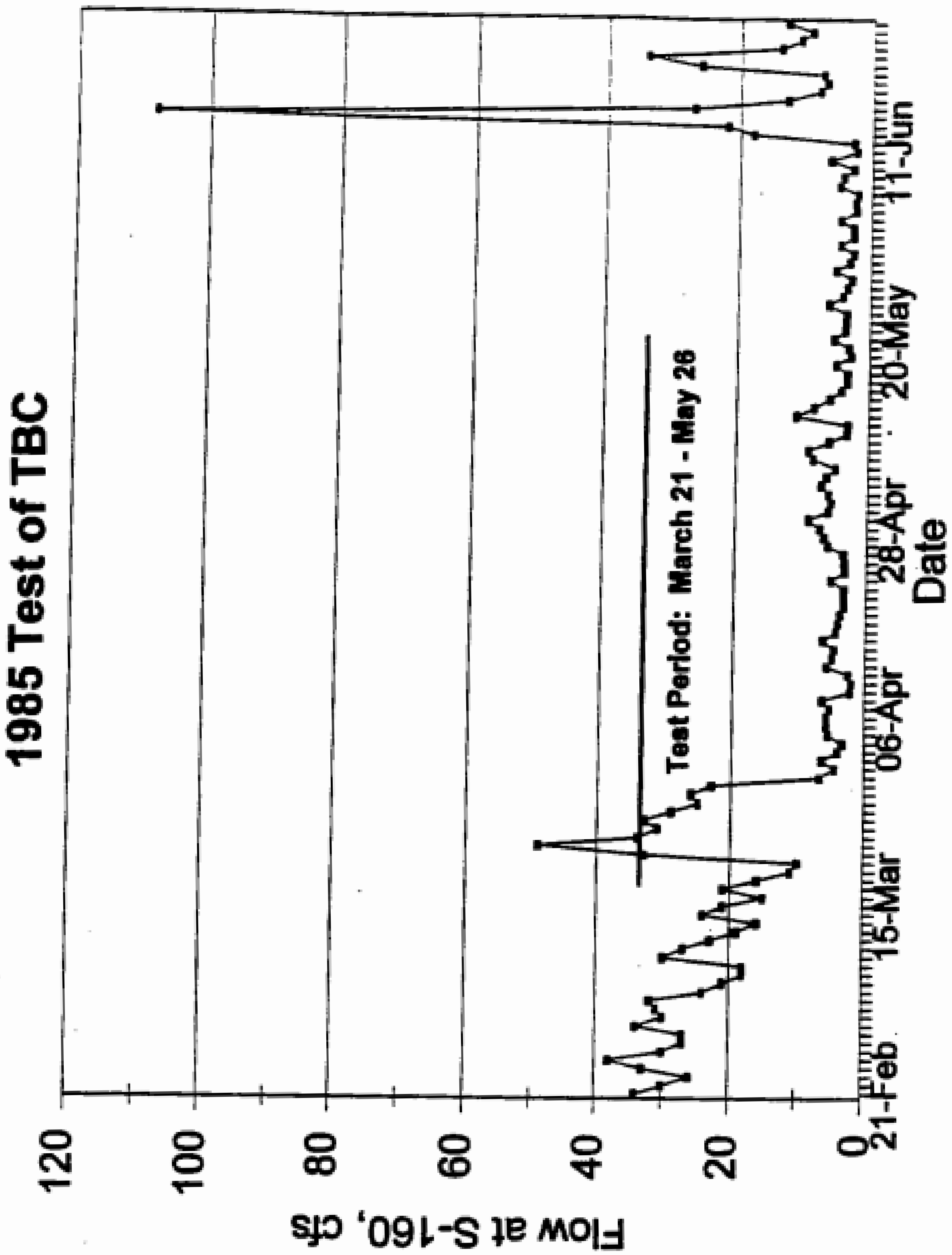

1981 Test of TBC
Test Period: May 4 - June 3
Flow at S-160, cfs
Date
0
20
40
60
80
100
120
04-Apr
19-Apr
04-May
19-May
03-Jun
18-Jun
03-Jul

Figure 6.6



1985 Test of TBC
Test Period: March 21 - May 26
Flow at S-160, cfs
120
100
80
60
40
20
0
21-Feb
15-Mar
06-Apr
28-Apr
20-May
11-Jun
Date

Figure 6.7

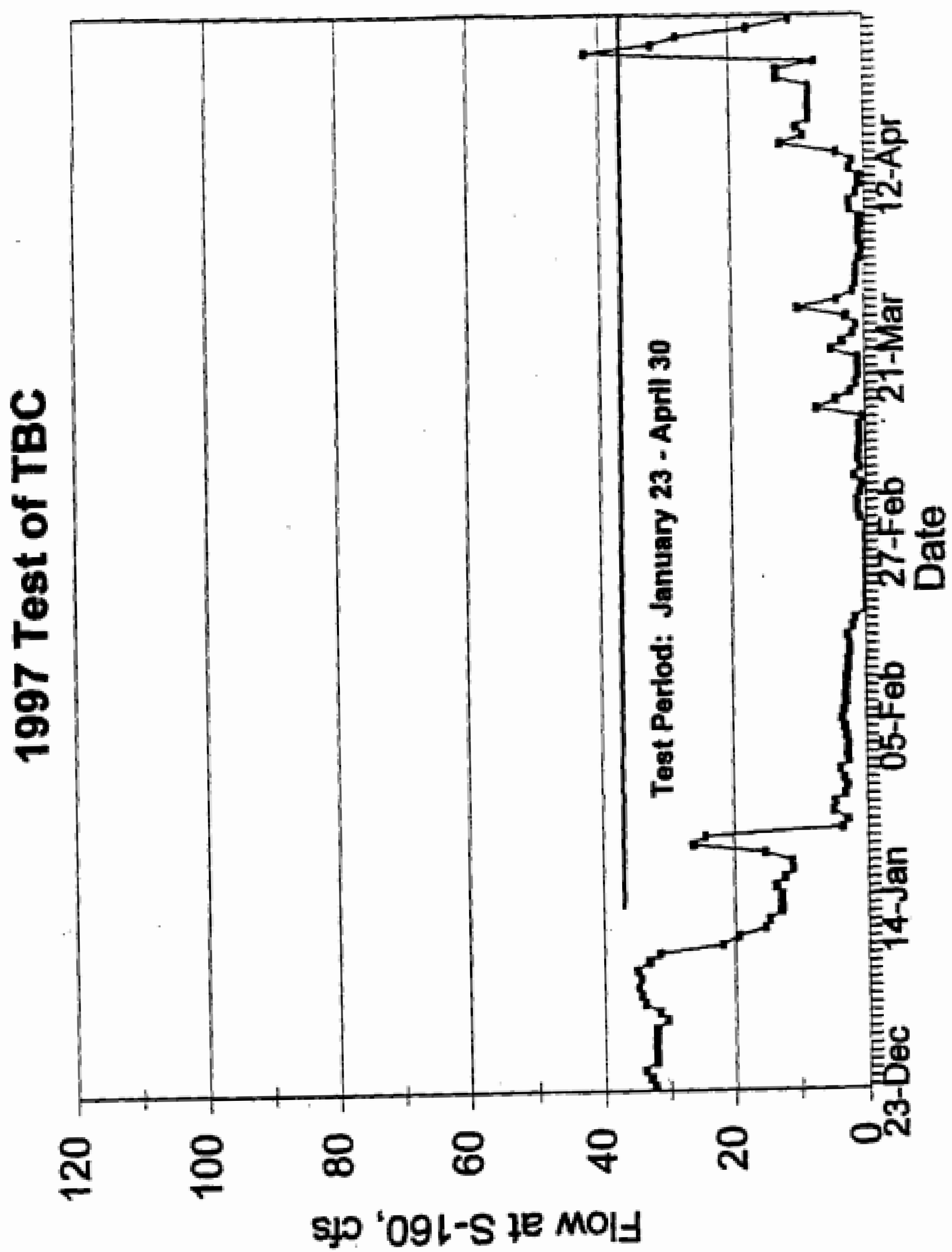

1997 Test of TBC
Test Period: January 23 - April 30
Flow at S-160, cfs
120
100
80
60
40
20
0
23-Dec
14-Jan
05-Feb
27-Feb
21-Mar
12-Apr
Date

Figure 6.8

The regression models followed the general form of the water budget equation. Discharge was moved to the left-hand side of the equation where dVol plus discharge became the dependent variable. Rainfall and runoff were replaced by rainfall and one or more lags of rainfall. A seepage term was included relating the head difference between the canal pool stage and a reference ground-water level. The general form for regression was

$$\text{dVol} + \text{Discharge} = a_0 + a_1\text{Pumping} + a_2\text{Head Difference} + a_3\text{Evaporation} + a_4\text{Rainfall} + a_5\text{-}a_n(\text{Rainfall lags}). \quad (3)$$

The resulting regression equation was equated to the water budget through the change in volume term. This method produced expressions for runoff and seepage into the TBC.

A field test of the TBC middle pool production capability was performed during the period January 22, 1997 through April 30, 1997. A water budget model was developed to simulate the test results. The Spring 1997 model derived ground-water seepage to the middle pool and estimated yield for the test period. Structure 162 was closed for the duration of the test; stage and ground water levels were monitored; and the City of Tampa pumped nearly constantly for the duration of the test. Regression analysis was used to estimate seepage into the middle pool during the test. The test results are discussed in section 6.3.3.1. This was similar to the tests done by Geraghty and Miller (1982, 1986) during 1981 and 1985 drought periods. During the Spring 1997 period, there was little rainfall so ground-water seepage was the principal inflow available to maintain withdrawals from the middle pool.

Flow data were only available for Structure 160. Additionally, existing equations estimating Structure 160 flows have never been field calibrated. During most periods there was flow over the weirs at Structure 162, but flow has not been calculated or recorded in the data base. Structures 161 and 159 are opened infrequently and the records of those operations are poor and not maintained in any data base. Local runoff is unknown. Continuous daily ground-water level data exist intermittently for a small number of wells, although there are many wells in the vicinity of the TBC. Periods of record are fairly short.

Additional analyses were performed to estimate seepage and runoff into the middle pool for years 1990 through 1996, but due to data limitations, only a 1994 Water Year model could be developed. The 1994 Water Year model was significant because the model data spanned a full annual rainfall cycle and there was discharge through Structure 162. The lower pool data was analyzed for the Spring 1997 period to estimate flows produced only from the lower pool drainage area.

6.3.3.1 Middle Pool Model, Spring 1997 The Spring 1997 middle pool model was to corroborate previous flow yield estimates made by Geraghty and Miller (1982 and 1986). A water budget model was used to estimate the seepage flows from the middle pool. A regression model was developed to estimate the runoff and seepage components of the water budget. The only outflows were withdrawals by the City of Tampa and evaporation, as Structure 162 was closed for this test. Inflows consisted of direct rainfall, runoff and seepage. The City of Tampa varied withdrawals between 20 mgd or 40 mgd during most of the test. Six existing UFAS wells were fitted with continuous recorders for the test. Documentation of this model is located in Appendix P-2.

The analysis concluded that a sustained yield in the absence of rainfall would be 20 mgd. This was very consistent with the work performed by Geraghty and Miller (1982 and 1986) and analysis presented elsewhere in this report. The seepage expression depended on a constant and pumping only. Several head differences were included in the regression analysis: difference between the middle pool stage and ground-water levels, difference between the middle pool stage and the reservoir at Structure 161, and difference between the middle pool and lower pool stages at Structure 162. No head differences were statistically significant. The model was not designed to estimate flows through Structure 162, so it was not easily compared with the Water Year 1994 model.

<u>6.3.3.2 Middle Pool Model, Water Year 1994</u> The Water Year 1994 model was developed for the period October 1, 1993 through September 19, 1994. The original purpose of the effort was to generate inflow data for a TBC yield model. The proposed study period was 1990 through 1996. Gaps in the data for the period of interest precluded developing a sufficient period of record for TBC yield analysis. The 1994 Water Year model was still useful because the model data covered a full annual rainfall cycle and presented a somewhat different seepage estimate than was derived for the 1997 dry season test. Also, monthly TBC water budgets for the 1994 Water Year were developed from the results.

An estimate of flows at Structure 162 was necessary for the Water Year 1994 model. Since flow data are not available, a method was developed to estimate the flow at Structure 162. A regression model of the lower pool for the period January 22, 1997 through April 30, 1997 (Appendix P-3) resulted in the development of a relationship betweem flow at Structure 160 and flow produced from the lower pool drainage area. An estimate of flow through Structure 162 was made by subtracting estimated lower pool drainage area flows from Structure 160 flows when Structure 162 was open.

The Water Year 1994 model approach was the same as the Spring 1997 model: regression analysis to complete a water budget model. It was estimated from the Water Year 1994 model that an annual yield of 32.7 mgd would have been available for the year (Appendix P-4). Seepage in the Water Year 1994 model depended on the head difference term, pumping and the constant. However, the head difference term appears to account principally for change in seepage flow when there are no withdrawals. These results are quite different from the Spring 1997 model results and reflect the larger yields available over the annual rainfall cycle as opposed to the Spring dry period only.

Monthly water budgets were created from the Water Year 1994 model. The absolute error in those budgets ranged from 0.2 percent to 15.3 percent and averaged 7.02 percent.

6.3.4 Flows in the Tampa Bypass Canal Under Augmentation Conditions. Outflows occur at Structures S-160 and S-162 even when the City of Tampa is pumping between 20 and 40 mgd from the middle pool. For the past several years, the crest gates at Structure 162 have been set at an elevation of approximately 13.5 feet NGVD (personal communication, Bucky Poole, SWFWMD). Under this condition, when the stage exceeds 13.5 feet, outflow from the middle pool to the lower pool occurs.

Flows are not directly estimated at Structure S-162. Flows are estimated downstream at Structure 160. These flows consist of the outflow at Structure 162, plus any inflows and losses that might occur in the lower pool. A regression model was developed to partition estimated flows at Structure 160 into flows at Structure 162 plus gains and losses from the lower pool. Using this model, a time series of estimated flows at Structure 162 was developed for the period January 1990 to December 1996. The distribution of estimated flows at Structure S-162 is presented in Table 6.4.

The distribution of estimated flows at Structure S-162, shown in Table 6.4, represents all days during the 1990-1996 time period. A subset of this data was created which contains estimated Structure 162 flows for days when the City of Tampa was pumping from the TBC middle pool. In all, 649 observations were available. The distribution of estimated flows at Structure S-162, under pumping conditions, is given in Table 6.5. The data for historic conditions suggest that outflow may occur from the middle pool even when the City of Tampa is pumping from the middle pool to augment the Hillsborough River Reservoir.

Historic data indicate that outflow occurs from the lower pool over Structure S-160 when the City of Tampa is pumping from middle pool. As noted previously, flows at Structure 160 represent flows at Structure 162 plus gains and losses from the lower pool. The distribution of flows at Structure S-160, for the same 649 pumping days between 1990 and 1996, is given in Table 6.6.

Table 6.4 Distribution of Estimated Flows at Structure 162
1990 - 1996

Percentile	Flow, cfs
5	0
7	11
10	20
20	33
30	57
40	78
50	91
60	102
70	116
80	135
90	175
95	235
99	579

Table 6.5 Distribution of Estimated Flows at Structure 162, 1990 - 1996, Under Pumping Conditions

Percentile	Estimated Flow at Structure 162 (cfs)
5	0
7	0
10	0
15	0
20	0
25	13
30	18
40	22
50	27
60	31
70	38
80	47
90	73
95	101
99	830

Table 6.6 Distribution of Estimated Flows at Structure 160, 1990 - 1996, Under Pumping Conditions

Percentile	Estimated Flow at Structure 160 (cfs)
5	0
7	1
10	2
15	4
20	10
25	18
30	21
40	26
50	30
60	35
70	43
80	55
90	81
95	114
99	836

7. DETERMINATION OF THE MINIMUM FLOW

7.1 Application and Context of the Minimum Flow

As discussed in previous chapters, the Tampa Bypass Canal is a highly altered water body that was constructed for flood control purposes. Excavation of the canal and construction of its associated water control structures greatly altered the hydrographic and ecological characteristics of both the freshwater and estuarine watercourses that drained the region (Six Mile Creek and the Palm River). These alterations have been so extensive that some functions of the resource, such as providing low salinity estuarine habitats, have essentially been lost. However, there are remaining ecological characteristics and valuable natural resource values that warrant proper management.

In evaluating minimum flows for the Tampa Bypass Canal, the District evaluated releases from Structure 160 that must be maintained to provide for the health of the downstream ecosystem. This analysis accounted for the structural alterations of the water resource that resulted from construction of the canal and how these alterations have affected the freshwater inflow requirements of the downstream estuary. As described in the following section, the District determined that a minimum flow of zero cfs be established for the Tampa Bypass Canal at Structure 160. This means that water use from the canal will not be linked to a specific flow rate at Structure 160, and flows at this structure may periodically recede to zero without requiring any cutbacks by the water users.

It is important to emphasize the zero cfs minimum flow does not mean that all waters flowing from the Tampa Bypass Canal are automatically available for withdrawal. Section 40D-8.031(6) F.A.C. of the proposed rule states " *the establishment of a Minimum Flow or Level shall not be deemed to be a determination by the Governing Board that any quantity above the established Minimum Flow or Level is available for allocation to consumptive use. The District may by regulation or order reserve such quantifies as it deems necessary pursuant to Section 373.223 (3), F.S.*" . Compliance with a minimum flow or level is an important step for the issuance of a water use permit. However, the allocation of water from the canal may be subjected to further technical analyses and regulatory restrictions on withdrawal quantities in order to protect natural resources.

Some parties have suggested the ecological characteristics of the Tampa Bypass Canal/Palm River system could be significantly improved by physical modification and restoration of the canal's tidal reaches. The proposed rule allows for this possibility by stating "*the Minimum Flow for the Tampa Bypass Canal at Structure 160 is established specific to the physical configuration and operations constraints of the Tampa Bypass Canal as they exist at the time of adoption of the Minimum Flow. If substantial physical modifications to the Tampa Bypass Canal are made, the District shall reevaluate the Minimum Flow at Structure 160.*" This language corresponds to the intent of recommendations submitted by the Tampa Bay National Estuary Program Minimum Flows Advisory Group.

7.2 Hydrologic and ecological basis for the minimum flow

Numerous studies have demonstrated the importance of freshwater inflows to the biological structure and productivity of estuarine ecosystems (Jassby et al., 1995; Sklar and Browder, 1998). Similarly, the occurrence of seasonal patterns of freshwater inflows can be important to various biological processes (Texas Water Resources Board, 1994). Over the last two decades, the District has increasingly taken the approach of managing natural patterns of freshwater inflows and developing regulations that account for the entire flow regimes of rivers. However, because of unique nature of the Tampa Bypass Canal and its use for flood control, the District did not evaluate ecological changes that could result from withdrawals over the entire flow range of this system.

To determine minimum flows for the Tampa Bypass Canal the District examined flow releases that must be maintained during dry periods to sustain the downstream estuary. As described above, such regulations would require reductions in water use from the canal if the minimum flows were not being met. Based on factors described below, the District concluded that the minimum flow at Structure 160 can be zero. In essence, the District concluded there is not a logical rate of flow that should be maintained at Structure 160 and flows at the structure can periodically recede to zero without requiring cutbacks in water use. This does not imply that flows at Structure 160 should be maintained at zero cfs indefinitely, as historical streamflow and water use data from the canal indicate that zero flows at Structure 160 will occur only periodically when the canal is being used to augment water supplies in the Hillsborough River Reservoir.

A principal factor contributing to the determination of the zero cfs minimum flow was the highly altered status of this resource. Excavation of the Palm River to form the Tampa Bypass Canal dramatically altered the salinity regime of this system and its relationship to freshwater inflows. The Palm River is now a truncated estuary, which even during high flows, does not encompass a complete salinity gradient that extends from fresh to high salinity waters. On most days, oligohaline (0 to 5 ppt) and mesohaline (5 to 18 ppt) waters are not present below Structure 160. When waters below 18 ppt do occur, they are often limited to the surface or very shallow depths in the water column. Bottom waters in the Palm River apparently have poor flushing characteristics and are relatively isolated from the effects of freshwater inflows. Bottom waters near Structure 160 averaged over 24 ppt in both the WAR/SDI and HCEPC data sets and horizontal salinity gradients in deeper depths are very slight, typically ranging only 1 or 2 ppt over the length of the Palm River.

Regressions to predict salinity as a function of flow indicate that surface salinity values will remain over 20 ppt over the length of the Palm River, even if the flows at Structure 160 are maintained at their post-construction median value (73 cfs). Similarly, increasing flows from zero to 20 cfs reduces salinity by about 2 ppt to produce values of 23 to 28 ppt between the surface and two meters depth at the station nearest Structure 160. It is unlikely that salinity changes of this magnitude for short periods of time will change the basic ecological characteristics of the Palm

River or McKay Bay. This is particularly the case in the Palm River, where the steep shorelines limit the distribution of inter-tidal habitats which would be most susceptible to changes in shallow water salinities. Overall, it is difficult at this time to conclude that water use should be restricted from the canal if a given low-flow rate (e.g. 20 cfs) is not maintained at Structure 160, considering that salinity distributions and ecological characteristics under no-flow conditions are relatively similar.

In addition to salinity, other important water quality characteristics in Palm River show either no relationship or a weak response to freshwater inflows. In contrast to the Hillsborough River, where there are positive relationships between dissolved oxygen concentrations and freshwater inflows, there is very little relationship between dissolved oxygen concentrations and freshwater inflows in the Palm River/McKay Bay system. Bottom waters throughout the length of the Palm River exhibited problems with hypoxia regardless of the rate of freshwater inflow. WAR/SDI (1995) concluded that benthic invertebrate communities in the deep portions of the Palm River were not readily affected by changes in freshwater inflows, and hypoxia was a dominant factor affecting the abundance and diversity of benthic invertebrates throughout much of the Palm River. Similarly, chlorophyll a showed no apparent relationships with freshwater inflows in the long-term HCEPC data, and phytoplankton taxa observed in the Palm River were indicative of high salinity environments (WAR/SDI 1995). Despite weak relationships with freshwater inflows, phytoplankton abundance and chlorophyll a concentrations are typically high in the Palm River and McKay Bay. This is probably due to the influence of East Bay and Hillsborough Bay, which historically have been the most nutrient enriched regions of Tampa Bay (King Engineering, 1992; HCEPC, 1995). In short, it is unlikely that a zero minimum flow will have any limiting effect on phytoplankton production or related zooplankton abundance in the Palm River and McKay Bay.

From a hydrologic perspective, it is not expected that flows at Structure 160 will remain at zero cfs for long periods of time even though a zero minimum flow has been established. Construction of the Tampa Bypass Canal breached the top of the Upper Floridan Aquifer and increased baseflow and total discharge at Structure 160 by about a factor of 1.5 to 2 compared to the previous creek/river system. Due in part to this increase in flow, the Tampa Bypass Canal has been used since 1985 to periodically augment water supplies in the Hillsborough River Reservoir. These augmentation events have occurred during the dry seasons of most years since 1988, with withdrawal rates averaging about 27 mgd. During these augmentation periods there has generally been considerable flow over Structure 160, as the median flow during augmentation events has been 30 cfs while flows less than 11 cfs occurred only 20 percent of the time. Since permitted withdrawal rates for reservoir augmentation are not projected to increase from the canal, there should continue to be flows at Structure 160 most of the time even if a zero cfs minimum flow is implemented.

Many of the fish species that in the Palm River/McKay Bay system are estuarine dependent, meaning they utilize estuaries as a habitat at some point in their life cycle. Numerous studies, including extensive data collected from tributaries to Tampa Bay (Peebles and Flannery, 1992; Edwards, 1992), have shown that the juvenile stages of many of these species respond to sources of freshwater inflows by migrating into and utilizing low and medium salinity habitats in tidal rivers. As described above, low and medium salinity habitats no longer exist in the Palm River. Many fishes, however, continue to respond to the freshwater signal and migrate toward Structure 160, where habitat values are poor due to the altered shorelines and hypoxia in bottom waters. The authors of the WAR/SDI (1995) study considered this to create a "habitat bottleneck" and suggested that a reduction of flows could possibly be beneficial by not attracting fish into this highly impacted region.

The District concurs that a habitat bottleneck occurs below Structure 160, but any benefit of a reduction in flows at Structure 160 is uncertain. In general, though, the very small changes in salinity and water quality that occur downstream of Structure 160 at low to medium flows from the canal do not, at this time, call for specific minimum flow rates that would result in corresponding reductions in water use from the canal. In this regard, it is expected that the proposed zero cfs minimum flow will not allow significant harm to the ecology or water resources of the Palm River/McKay Bay system.

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FINAL DRAFT

APPENDICES

for

An Analysis of Hydrologic and Ecological Factors Related to the Establishment of Minimum Flows for the Tampa Bypass Canal at Structure 160

Southwest Florida Water Management District
March 17, 1999

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APPENDIX A

Excerpts from water use permits for withdrawals from the Hillsborough River Reservoir, Sulphur Springs and the Morris Bridge Wellfield (#202062.02) and the Tampa Bypass Canal (#206675.01) pertaining to the hydrobiological study

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
INDIVIDUAL WATER USE PERMIT

PERMIT GRANTED TO:
City of Tampa
306 East Jackson St.
Tampa, Florida 33602
(HILLSBOROUGH RIVER RESERVOIR and
the MORRIS BRIDGE WELLFIELD)
(Legal Name and Address)

PERMIT NO.: 202062.02
DATE PERMIT GRANTED: January 17, 1991
DATE PERMIT APPLICATION
FILED: September 28, 1989
June 1, 1990
PERMIT EXPIRES ON: January 17, 2001
SOURCE CLASSIFICATION: Surface, Groundwater
USE CLASSIFICATION: Public Supply
COUNTY: Hillsborough
LOCATION: Sections 19, 20, 21, 28, 29 and 3
of T27S, R20E
Section 29 of T28S, R19E
Section 25 of T28S, R18E

TERMS AND CONDITIONS OF THIS PERMIT ARE AS FOLLOWS:

1. If any of the statements in the application and in the supporting data are found to be untrue and inaccurate, or if the Permittee fails to comply with all of the provisions of Chapter 373, F.S., Chapter 40D, or the conditions set forth herein, the Governing Board shall revoke this permit in accordance with Rule 40D-2.341, following notice and hearing.

2. This permit is issued based on information provided by the Permittee demonstrating that the use of water is reasonable and beneficial, consistent with the public interest, and will not interfere with any existing legal use of water. If, during the term of the permit, it is determined by the District that the use is not reasonable and beneficial, in the public interest, or does impact an existing legal use of water, the Governing Board shall modify this permit or shall revoke this permit following notice and hearing.

3. The Permittee shall not deviate from any of the terms or conditions of this permit without written approval by the District.

A. HILLSBOROUGH RIVER RESERVOIR

This Permit authorizes the applicant named above to make withdrawals from the Hillsborough River Reservoir at a total average annual withdrawal of 82,000,000 gallons of water per day, a total peak monthly withdrawal of 92,000,000 gallons per day, and a maximum total withdrawal rate not to exceed 104,000,000 gallons per day.

B. MORRIS BRIDGE WELLFIELD

This Permit authorizes the applicant named above to make withdrawals from the Morris Bridge Wellfield at a total average annual withdrawal of 15,500,000 gallons of water per day, a total peak monthly withdrawal of 27,000,000 gallons per day, and a maximum total withdrawal rate not to exceed 30,000,000 gallons per day.

C. TOTAL COMBINED SOURCES

This Permit authorizes the applicant named above to make withdrawals from the all sources named in this permit, with the limits specified in Condition 3.A. and 3.B., at a combined average annual withdrawal of 88,100,000 gallons of water per day, a combined peak monthly withdrawal of 106,000,000 gallons per day, and a maximum combined withdrawal rate not to exceed 128,000,000 gallons per day. Individual source withdrawal quantities are authorized as shown in the table below.

D. ENVIRONMENTAL MITIGATION PLAN
By January 1, 1992, the Permittee shall submit for approval by the Director Tampa Permitting Department, a plan to mitigate on-site and off-site advers environmental impacts associated with the wellfield's pumpage. The plan shall b coordinated with the Resource Projects Department. The plan shall include a proposal for mitigating adverse environmental impacts to the natural environmen within the 90-day peak season one-foot water table drawdown contour. The limits of the environmental mitigation area are subject to change upon mutual agreement between the Permittee and the Director, Tampa Permitting Department. The Permittee shall implement the provisions of the approved plan.

This plan will include, but not be limited to the following:

1. The management of the wellfield operation to prevent or alleviate any water deficient stress within environmentally sensitive areas;
2. Development of criteria that will be used to implement the plan;
3. Development of methods of assessing the effectiveness of the plan;
4. Development of methodology to estimate quantities of water needed; and
5. Measures to assure the continued survival of affected wetlands during drought and associated public supply requirements.

E. SINKHOLE MONITORING
The Permittee shall monitor, investigate, and catalog the development of sinkholes within one-half mile of each wellfield withdrawal.

F. LOOP ROAD STRUCTURE OPERATION
The Permittee shall consult with Land Resources Department concerning a plan for the operation of the loop road surface water control structures by 120 days from this permit's issuance date. The Permittee shall submit a plan for the operation of the surface water control structures on the south loop road to the Land Resources Department for approval. This final plan shall be due within 180 days from this permit's issuance date.

G. ANNUAL REPORT
A summary report of surface water conditions, environmental conditions, and sinkholes that may have occurred during the annual reporting period shall be summarized in the annual report, as described in Condition 23.

19. HYDROLOGIC IMPACTS, MONITORING, AND MITIGATION AT THE RESERVOIR AND SPRINGS

A. QUANTITY

1. OPERATION OF EXISTING FLOW MEASURING DEVICES
The Permittee shall continue to maintain and operate existing flow meters or other flow measuring devices as approved by the Director, Tampa Permitting Department, for the District Withdrawal Numbers designated below. Such devices shall have and maintain an accuracy within five percent of the actual flow. Reclaimed water at the water treatment plant shall also be reported. The reclaimed water meter shall be identified as District Identification No. 33.

District Withdrawal No.	Permittee Withdrawal No.
10	Sulphur Springs
11	Hillsborough River Reservoir
33	Reclaimed Reservoir Water

2. <u>WITHDRAWAL QUANTITY REPORTING</u>
Total flow from each metered withdrawal, and for the mitigation quantity [illegible] to the reservoir from the Tampa By-pass Canal (TBC), shall be recorded on [illegible] basis and reported monthly to the District, by the 15th day of the following month.

3. <u>ANNUAL REPORT</u>
Pumpage data recorded during the annual reporting period shall be summarized in the annual report, as described in Condition 23.

B. <u>WATER QUALITY SAMPLING AND ANALYSIS</u>

1. <u>DATA COLLECTION AND ANALYSIS</u>
By January 1, 1991, the Permittee shall begin collection and analysis of water quality samples as indicated in the table below. Reports of the analyses shall be submitted to the District (on District forms) on or before the fifteenth (15th) day of the following month. The parameters and frequency of sampling and analysis may be modified by mutual agreement between the Director, Tampa Permitting Department and the Permittee as necessary to ensure the protection of the resource. However, nothing in this condition shall be construed to limit the authority of the Board to act pursuant to Condition 2 of this permit.

User ID	District ID No.	Parameter	Sampling Frequency
SS	10	Color	Monthly
HRR	11	pH	
		Biochemical Oxygen Demand	
		Conductivity	
		Salinity	
		Temperature	
		Total Suspended Solids	
		Dissolved Oxygen	
		Total Organic Carbon	
		Kjeldahl Nitrogen	
		Nitrate/Nitrite	
		Total Nitrogen	
		Ammonia	
		Total Phosphorus	
		Ortho Phosphorus	
		Turbidity	

Collection and analysis of Chloride, Sulfate, and Total Dissolved Solids shall also be undertaken for Sulphur Springs on a monthly basis. When Sulphur Springs is pumped, water quality shall be collected and analyzed on a weekly basis.

To the maximum extent possible, monthly sampling shall be performed during the same week of each month and weekly sampling shall be performed during the same day of each week. The sample collection time and date shall be included with all data.

Analyses shall be performed according to procedures outlined in the current edition of <u>Standard Methods for the Examination of Water and Wastewater</u> by APHA-AWWA-WPCF or <u>Methods for Chemical Analyses of Water and Wastes</u> by the USEPA.

2. SAMPLING AND ANALYTICAL METHODOLOGIES
The Permittee shall submit a report describing the sampling and analytica methodologies employed. The report shall address all parameters for whi analyses are performed. The report shall be included with the first dat submitted after the date this permit is granted, and upon any change in samplin and/or analytical methodology. Any change in sampling and/or analytica methodology shall have prior approval of the Director, Tampa Permittin Department.

3. QUALITY CONTROL AND ASSURANCE PROGRAM
The Permittee shall use standard quality control and assurance programs for wate quality data required by this permit. At the request of the Director, Tampa Permitting Department, the Permittee shall provide a description of the program.

C. WATER LEVEL AND DISCHARGE MONITORING

1. RESERVOIR
By January 1, 1991, the Permittee shall begin collection of the average daily stage elevation and the average daily discharge from the Reservoir. The monitor station shall be labelled District Identification No. 300. The reservoir discharge shall be reported in two parts: (1) discharge over the dam; (2) discharge through the spillway gates. The average daily values shall be calculated by an appropriate method, as approved by the Director, Tampa Permitting Department. The stage elevation (referenced to NGVD) and flow data shall submitted to the District (on District forms) on or before the fifteenth (15th) day of the following month. The recording frequency may be modified by mutual agreement between the Director, Tampa Permitting Department and the Permittee as necessary to ensure the protection of the resource. However, nothing in this condition shall be construed to limit the authority of the Board to act pursuant to Condition 2 of this permit. The recorded flow shall be submitted in cubic feet per second (cfs).

2. SULPHUR SPRINGS
By January 1, 1991, the Permittee shall begin collection of the average daily spring pool stage elevation and the average daily discharge from Sulphur Springs. The monitor station shall be labelled District Identification No. 301. The average daily values shall be calculated by an appropriate method, as approved by the Director, Tampa Permitting Department. The stage elevation (referenced to NGVD) and flow data shall be submitted to the District (on District forms) on or before the fifteenth (15th) day of the following month. The recording frequency may be modified by mutual agreement between the Director, Tampa Permitting Department and the Permittee as necessary to ensure the protection of the resource. However, nothing in this condition shall be construed to limit the authority of the Board to act pursuant to Condition 2 of this permit. The recorded flow shall be submitted in cubic feet per second (cfs).

D. STRUCTURE OPERATION COORDINATION PLAN
By June 30, 1991, the Permittee shall submit a Structure Operation Coordination Plan to the Director, Tampa Permitting Department for approval. The Flood Coordination Plan shall be a comprehensive but concise report on the operation of the Tampa Reservoir Spillway and how it is operated in conjunction with the District's Tampa By-Pass Canal system. The goal of the plan shall be to describe the structure operations at the reservoir, and allow for optimal coordination between the City and the District during periods of time where it is necessary to operate the reservoir spillway structures and coordinate with the District regarding operation of TBC structures. The plan shall emphasize the conservation of the water resource, coordination between District and City operators, and diversion of water into TBC which can later be pumped to the reservoir. The

Permittee shall coordinate with the District's Operations Department during tl development of the plan. This plan is required as a means to develop a fu management plan which maximizes the Hillsborough River Reservoir and Tamp Canal system as a water supply source.

E. REGULATORY LIMITS

1. RESERVOIR AUGMENTATION AND WITHDRAWAL SCHEDULE DURING STUDY PERIOD
Because potential impacts could not be quantified at the time of permi issuance, a net increase in river withdrawals will be allowed only in accordanc with Condition 20.A.3. During the term of the first study period, the City wil be required to adhere to the reservoir pumpage schedule specified in the tabl below. On a daily basis, the Permittee shall compare the quantity pumped fro the reservoir and the "average monthly quantity limit" designated in the tabl below. The Permittee shall also compare the recorded average daily flow rate a the reservoir dam with the 25 cfs low flow limit.

If the average daily flow rate over the dam during any day is less than 25 cfs, the Permittee shall calculate the quantity difference between the quantity pumped from the reservoir and the "average monthly quantity limit." This calculation shall be undertaken regardless of whether the quantities pumped during that particular day are less than, or greater than the "average monthly quantity limit." The difference shall be termed the "daily mitigation quantity", and shall be a negative number for days where quantities pumped from the reservoir were less than the "average monthly quantity limit" and a positive number for days where quantities pumped from the reservoir were greater than the "average monthly quantity limit". For days where the average daily flow rate over the dam exceeds 25 cfs, the "daily mitigation quantity" shall be designated as zero, and the Permittee shall be allowed to withdraw up to the permitted quantities the reservoir without later augmentation mitigation from TBC.

The Permittee shall record the "daily mitigation quantity" value daily and report the values monthly, in a form acceptable to the District, by the fifteenth day of the following month. These daily quantity differences shall be added cumulatively for each day that average daily flows at the dam are less than 25 cfs. When no flow conditions exist at the dam, and water levels in the reservoir recede to 22.0 feet NGVD, the Permittee shall pump water from the TBC to the reservoir until the cumulative daily quantity differences that were pumped from the reservoir, have been made up by TBC pumpage, or until water levels in the reservoir have rebounded to the crest of the dam (i.e. 22.5 feet NGVD). If water levels in the reservoir rebound to the crest of the dam before the cumulative daily quantity difference has been made up by TBC pumpage, the quantity that was not made up shall be recorded, and shall be carried over for augmentation during the next no flow period for which water levels in the reservoir recede to 22.0 feet NGVD. This will allow for storage in the reservoir to be maintained, and shall assist in minimizing the effects of decreases in storage on the occurrence of low and no flow days.

The cumulative quantity of water that is required to be pumped from TBC shall be designated in the pumpage reports to the District, and shall be termed the "cumulative mitigation quantity". The "daily mitigation quantity" pumped from the TBC, shall also be clearly stated on the pumpage report for the reservoir.

If such mitigation is not feasible during the construction of the perma pumping facility for the TBC, the Permittees shall submit a written request the Director, Tampa Permitting Department, within 60 days prior to initiation of construction. The request shall detail the specific reasons why mitigation during the construction period is not feasible, when construction of the permanent facility is proposed to be completed, and when the mitigation pumpage will resume again. The request will require written approval of the Director, Tampa Permitting Department prior to discontinuance of mitigation pumpage from TBC to the reservoir.

RESERVOIR WITHDRAWAL SCHEDULE

MONTH	AVERAGE MONTHLY QUANTITY LIMIT (MGD)	AVERAGE DAILY FLOW OVER DAM (CFS)
January	60.0	25
February	60.0	25
March	66.0	25
April	66.0	25
May	66.0	25
June	66.0	25
July	60.0	25
August	60.0	25
September	60.0	25
October	60.0	25
November	60.0	25
December	60.0	25

The Director of the Tampa Permitting Department may modify this limiting condition or extend this condition to other periods of the study, based on the results of hydro-biological monitoring for the TBC or the reservoir.

2. RESERVOIR SYSTEM PUMPING SCHEDULE
The Permittee shall minimize withdrawals from Sulphur Springs to the maximum extent possible. TBC will be the first and primary augmentation source for the reservoir. During the months of March through June, augmentation from Sulphur Springs will not begin until water levels in the reservoir recede to 20.0 feet NGVD. During the months of January through February, and July through December, augmentation from Sulphur Springs will not begin until water levels in the reservoir recede to 18.0 feet NGVD. If water levels recede to the aforementioned levels, the Permittee will attempt to meet augmentation demands with the TBC before initiating withdrawals from Sulphur Springs.

During the months of March through June, augmentation from TBC to the reservoir will not begin until water levels in the reservoir recede to 21.0 feet NGVD, unless augmentation is required by Condition 19.E.1. for the purpose of mitigation of increased reservoir withdrawals. During the months of January through February, and July through December, augmentation from TBC to the reservoir will not begin until water levels in the reservoir recede to 19.0 feet NGVD, unless augmentation is required by Condition 19.E.1. for the purpose of mitigation of increased reservoir withdrawals.

3. MAXIMIZING HILLSBOROUGH RIVER WITHDRAWALS
The ability to maximize reservoir withdrawals may be limited in accordance with Condition 19.E.1, 19.E.2., or Condition 20.B. However, within the limits imposed by Condition 19.E.1., 19.E.2., or Condition 20.B, withdrawals from the Hillsborough River Reservoir shall be maximized to the greatest extent possible, while complying with the conditions of this permit, and shall be utilized before the TBC, Morris Bridge Wellfield, or Sulphur Springs sources.

4. SULPHUR SPRINGS WATER QUALITY
The Director of the Tampa Permitting Department reserves the right to set upper limits on chloride, sulfate, and total dissolved solids concentration le water withdrawn from the Spring. These limits shall be determined consultation with the Permittee. At such time as the concentration in wate samples retrieved from the Spring intake exceed the designated concentratio limit(s), the Permittee shall take appropriate action to reduce paramete concentration to below the limit(s).

20. ENVIRONMENTAL IMPACTS, MONITORING, AND MITIGATION AT RESERVOIR AND SPRINGS

A. HYDRO-BIOLOGICAL MONITORING - HILLSBOROUGH RIVER
The qualified consultant(s) shall be selected by the Permittee, and data collection for the HBM program shall begin by October 1, 1991 and end September 30, 1994. District staff shall be provided copies of all proposals received in response to the Permittee's request for proposals, and shall be provided the opportunity to attend all oral presentations regarding the proposals. The Director of the Tampa Permitting Department shall be provided written notice of oral presentations at least one week in advance of such presentations. Through all steps of the consultant selection process, the District will provide the Permittee a non-binding recommendation of the consultants who propose to undertake the project.

The final scope of work shall be written after discussion and negotiations with the consultant. The final scope of work will at a minimum address the seven items outlined below and where appropriate, changes to the seven items can be made as a result of acquiring additional information not available at the time the permit was issued. The District shall be provided the opportunity to participate in the drafting of the final scope of work. Five copies of a scope of work shall be submitted to the Director of the Tampa Permitting Department for approval, by no later than July 15, 1991.

The Study Area for the initial three year period of the permit shall extend from above the reservoir dam to the vicinity of the Columbus Drive bridge, and shall include Sulphur Springs. The scope of work and study area for the remainder of the duration of the permit shall be revised according to recommendations contained in the final report due February 15, 1995 (covering Water Years 1992 to 1994), subject to approval of the Director of the Tampa Permitting Department.

1. MONITORING SITE LOCATIONS
A total of six sampling stations shall be established. One station each shall be located in the reservoir and Sulphur Springs. Four additional sites shall be located in the vicinity of the following locations:

(A) Hillsborough River at S.R. 585 (22nd St.)
(B) Hillsborough River at U.S. 41
(C) Hillsborough River at Hillsborough Avenue
(D) Hillsborough River at Columbus Drive

Sites A through D shall be reviewed by the selected consultant for appropriateness (including consideration of effect of stormwater input in the vicinity of the sites) during preparation of the final scope of work. These four sites are tentative and subject to review and approval by the District under final scope of work. However, if any of these four sites are moved, they will replaced on a 1:1 basis, with no additional sites being required.

2. MONITORING SITE WATER QUALITY DATA COLLECTION

a. In-situ and laboratory water quality analyses for the sample sites listed in Section 1 above shall be collected and analyzed on a monthly basis for at least one year (see section 2.b. below for years two and three). To avoid duplication of effort, the Permittee may use monitoring sites available from other agencies, where applicable. Water quality analyses shall include:

(A) dissolved oxygen (DO)
(B) total suspended solids
(C) temperature
(D) salinity
(E) turbidity
(F) total nitrogen
(G) total phosphorus
(H) ortho-phosphorus
(I) nitrate/nitrite
(J) ammonia
(K) kjeldahl nitrogen
(L) Total Organic Carbon
(M) Biochemical Oxygen Demand
(N) color
(O) pH
(P) conductivity

Analysis of Chloride, Sulfate, and Total Dissolved Solids concentrations shall also be undertaken for Sulphur Springs on a monthly basis. When Sulphur Springs is pumped, water quality shall be collected on a weekly basis.

Regular monthly sampling shall also include salinity/DO/temperature profiles at the six stations identified in the approved scope of work, plus an additional four stations in the river below the dam.

In addition to regular monthly sampling, salinity/DO/temperature profiles shall also be conducted at the ten stations in the above paragraph shortly after the beginning of a discharge event at the dam, following a no flow period (to the extent that appropriate flow conditions exist). These profiles shall be conducted on a schedule not to exceed four times per year, and shall be used to determine the impact of flows immediately after a rainfall/discharge event.

To the maximum extent possible, water quality sampling shall be performed during the same tidal and time of day conditions each month. The sample collection time and date shall be included with all data. Analyses shall be performed according to procedures outlined in the current edition of <u>Standard Methods for the Examination of Water and Wastewater</u> by APHA-AWWA-WPCF or <u>Methods for Chemical Analyses of Water and Wastes</u> by the USEPA.

b. Following the first year of water quality data collection, the District and the Permittee will review all data collected, as required by the approved final scope of work, as a basis to determine any justified change to the sample frequency of water quality monitoring for the second year. If applicable, a similar review will take place at the end of the second data collection year for the third year of monitoring.

3. MONITORING SITE BIOLOGICAL DATA COLLECTION

a. Biological monitoring shall be conducted at the sites identified in the approved final scope of work, for a period of two years, as designated in the table below. The same sites shall be used for water quality and biological monitoring, except as designated below.

ORGANISM	LOCATIONS	FREQUENCY
Phytoplankton	All sites except Sulphur Springs	Year 1 - Monthly Year 2 - See Section 3.c. Below
Benthic Macro-invertebrates	All sites except Sulphur Springs and reservoir	Year 1 - Quarterly Year 2 - See Section 3.c. Below
* Aquatic Vertebrates (Fisheries)	See Paragraph below	Year 1 - Monthly Year 2 - See Section 3.c. Below

* Aquatic vertebrates shall be collected by means of ichthyoplankton surveys and juvenile fish surveys. Ichthyoplankton surveys shall be accomplished by boat tows with plankton nets, and juvenile fish surveys shall be accomplished by using seines and trawls. Ichthyoplankton surveys shall be conducted at four river sites located below the dam (not including Sulphur Springs), while juvenile fish surveys shall be collected at 5 river sites depending on site suitability. Site locations can be the same as the water quality monitoring locations of section 2.a.. However, due to physical limitations of sampling equipment, alternate sites may be necessary.

b. A one time shoreline habitat inventory, including aquatic macrophytes, of the lower Hillsborough River shall be conducted during the first year of the monitoring period.

c. Following the first year of biological data collection, the District and the Permittee will review all data collected, as required by the approved final scope of work, as a basis to determine any justified change to the sample frequency of biological monitoring for the second year.

4. PREVIOUS STUDY REVIEW

The consultant shall review and summarize all previous biological, hydrologic, and water quality studies of the reservoir, lower river, and Sulphur Springs. This shall include a review of the District's SWIM library. The collected information shall be used in the analysis as appropriate, and the findings of the reports shall be summarized in the first interpretive report required by this condition.

5. STORMWATER INPUT SURVEY

A survey of the stormwater inputs and associated treatment efficiencies shall be conducted the first year to evaluate the potential impacts of direct watershed discharge into the Hillsborough River.

6. MONITORING PLAN GOALS

The goals of the plan shall be:

a. To determine hydrologic, water quality, and biological relationships in the study area, and their relationship to discharge at the reservoir dam, and to determine whether the proposed increase in withdrawals of 20 MGD will have an unacceptable adverse impact on water quality, and fish and wildlife in the lower Hillsborough River.

b. To determine the habitat functions of the lower Hillsborough River.

c. To determine the importance of Sulphur Springs discharge to water quality and biology of the lower Hillsborough River, during all times of the year.

d. The construction of a mathematical hydrological model (not a water quality model) of the reservoir that includes, but is not limited to terms for: inflows into the reservoir, infiltration to the TBC, bank seepage gains and losses, evaporation, changes in storage, and withdrawals from and augmentation to the reservoir. This model shall allow the simulation of dependable yields and downstream releases under various withdrawal and augmentation scenarios. The model shall include the TBC.

e. In relation to the items above, the ultimate goal of the study shall be to determine an optimal withdrawal/augmentation management schedule for the reservoir, TBC, and Sulphur Springs that minimizes downstream impacts, while at the same time meeting water supply needs.

7. MONITORING AND REPORTING PERIODS

Joint review of all draft reports shall take place by the Authority, the City, and the District. All reports shall be subject to District review and suggested revisions. Five copies of all reports shall be submitted. The results of the monitoring program shall be submitted to the District in a series of three reports, plus end of year data reports for the purpose of defining future monitoring requirements. However, depending on changes to the sampling program after the first and second data collection years, it may be necessary for the Director, Tampa Permitting Department, to modify the reporting schedule described below.

By September 1 of each data collection year (excluding the third data collection year), the Permittee shall submit all data collected to date, on hard copy and on electronic media in a format meeting District specifications, to the Director, Tampa Permitting Department. This data shall be reviewed in accordance with Conditions 20.A.2.b. and 20.A.3.c. to determine the extent of future monitoring. The data shall be reviewed by the Permittee and the District between September 1 and September 30 of each applicable year. By September 30, the District will notify the Permittee of the future monitoring requirements, which are to be implemented beginning October 1 of the same year.

A progress report shall be submitted by February 15, 1993. This report shall include all raw data for the first year of the project on hard copy and essential graphs and text with little or no interpretive discussion. The report shall include a summary of data collected during the first study year and text providing a description of monitoring progress.

A second report shall be submitted to the District by February 15, 1994. This report shall serve as an interpretive report for the biological and first two years of water quality data collection for the monitoring program, and shall include: a review of previous data collection programs and biological and water quality studies of the lower Hillsborough River, the shoreline habitat inventory of the lower Hillsborough River, and an assessment of the habitat functions of the lower river emphasizing the relationships of biological communities to salinity and water quality variables affected by discharge from the reservoir or Sulphur Springs. Accompanying the second report shall be the data collected in the second year of the project on hard copy, and the complete set of data collected for the first two years of the project provided on electronic media in a format meeting District specifications. The second report shall be subject to the District review, and require the approval of the Director of the Permitting Department.

A third report shall be submitted to the District by February 15, 1995. This shall be an interpretive report which includes the following: a final analysis of the relationships of salinity and other water quality variables to discharge from the reservoir and Sulphur Springs, the hydrologic model of the reservoir system, and presentation and discussion of the optimal withdrawal/augmentation management schedule for the reservoir system. This recommended schedule will be used to determine the most appropriate withdrawal and augmentation schedule for the reservoir, spring, and TBC, based on best available data.

Although the biological data were evaluated in detail in the second report, the third report shall discuss discharge/water quality relationships and the optimal reservoir management schedule as they pertain to biological communities in the Hillsborough River and the Tampa Bypass Canal. The third report shall also contain recommendations for continuation of the monitoring program or other analyses relevant to designing or updating an optimal reservoir management schedule for the reservoir system. Accompanying the third report shall be the data collected in the third year of the monitoring program on hard copy and on electronic media in a format meeting District specifications, and the hydrologic model for the reservoir system provided on electronic media.

The findings of the third report shall be subject to review by the District, and the recommendations contained in the report shall require approval of the Director of the Tampa Permitting Department. The approved withdrawal/augmentation management schedule will replace the requirements Condition 19.E.1. ("reservoir augmentation and withdrawal schedule during study period").

B. Impact Assessment
If at any time during the term of the permit the interpretive reports or District staff's analysis indicates that unacceptable adverse impacts are occurring, or are anticipated to occur, due to the increased withdrawals from the reservoir, the City will be required to limit withdrawals from the reservoir to an acceptable impact. However, nothing in this condition shall be construed to limit the authority of the Board to act pursuant to Condition 2 of this permit. If, based on the conclusions of the final interpretive report, additional monitoring assessment is deemed necessary, additional monitoring will be required by the District.

21. WATER CONSERVATION
The Permittee shall continue to develop, implement, and expand existing water conservation programs to reduce demands on the water resources and increase efficiency of water use. Within six (6) months of Permit issuance, the Permittee shall submit, for approval by the Director of the Tampa Permitting Department, a modification of the water conservation plan submitted on June 1, 1990, that has the current water demand figures (submitted June 1, 1990) incorporated into the plan in the appropriate areas. This modified plan, when approved, shall be implemented in conjunction with existing programs. The Permittee shall submit three copies of this modified water conservation plan. At the Permittee's option, one plan can be submitted to cover this permit and WUP No. 206675.01, to meet the revised plan requirements above and to meet requirements of Conditions 21.A. and 21.B. The two following requirements must met:

A. The Permittee shall carry out the provisions of its District-approved Water Conservation Plan in a timely manner. The Permittee shall submit progress reports concerning implementation of the plan on September 30, 1995 and September 30, 1999.

B. Permittee shall establish and/or maintain data gathering procedures that allow amounts of water to be accounted into various categories. These categories may be by either meter size or use, such as residential, commercial, industrial, unaccounted, and other. The procedures must produce data suitable for developing reliable estimates of current water use and projections of future water demand.

22. FUTURE WATER SOURCES
The Permittee shall pursue the planning, development, and implementation of alternate water sources prior to the expiration of this permit. As stated in Condition 20.B, if unacceptable adverse impacts are occurring or are anticipated to occur, due to the increased withdrawals, the Permittee will be required to decrease withdrawals from the river, and to makeup water (beyond an annual average quantity of 62 MGD) from another water source. Therefore, the Permittee shall evaluate alternative water supply options during the term of this permit to avoid the possibility that water demands will not be able to be met, due to permitting constraints. The Permittee shall be prepared to exercise these alternative water supply options whether the reservoir quantities are allowed to be increased to 82 MGD or not.

For the term of this permit, the Permittee shall provide the District with the status of alternative water supply options that the Permittee is currently undertaking. The report shall be included in the annual report required by Condition 23. The report shall include updates on the Aquifer Storage and Recovery study, Hooker's Point Reuse Study, Cypress Bridge interconnection, the City's potential wellfield property near Lake Thonotosassa and Pemberton Creek, feasibility of further interconnection to the regional system, and any other water supply options the City is pursuing. How these sources will be managed in conjunction with the optimal withdrawal/augmentation management schedule to be developed during the term of the permit for the reservoir system shall be described. Further interconnection to the regional system will include investigation of methodologies to overcome the current incompatibility of City and Authority finished water. The updates on the Hooker's Point Reuse study will include potential impacts to Hillsborough Bay if discharges to the Bay are decreased due to reuse. The annual updates shall include copies of any reports the City published or received regarding these sources. Alternate water sources shall stress the development of the local resource, use of the lowest quality water able to be used (including desalination), and hydrologic and environmental constraints. Development of alternate water sources may be required prior to authorization to increase existing source quantities.

23. ANNUAL REPORT
The Permittee shall prepare a comprehensive but concise annual report on Morris Bridge Wellfield, Hillsborough River Reservoir and Sulphur Springs. At the Permittee's option the Tampa Bypass Canal (TBC) may also be included in this report. For the reservoir, the Sulphur Springs, and the TBC, only the requirements of Section "A" below shall be required. The information required by the additional sections below are not required for the surface water systems as these are required to be addressed under the hydro-biological monitoring plan described in Condition 20. For the Morris Bridge Wellfield, an assessment of the water resources and environmental systems of the wellfield area is required for all sections listed below. This report shall concisely summarize the elements listed below, with emphasis on the interactions between these elements, where appropriate. Data sources shall be referenced, but no raw data shall be included in the report. Only essential text, graphs, and tables should be included in the report. The Permittee's staff shall arrange to meet with District staff to discuss the draft report prior to submittal. District staff will be

INDIVIDUAL WATER USE PERMIT

PERMIT GRANTED TO:	PERMIT NO.: 206675.01
City of Tampa	DATE PERMIT GRANTED: November 27, 1990
306 East Jackson St.	DATE PERMIT APPLICATION
Tampa, Florida 33602	FILED: September 2
and	PERMIT EXPIRES ON: November 27, 2000
West Coast Regional Water	SOURCE CLASSIFICATION: Surfacewater
Supply Authority	USE CLASSIFICATION: Public Supply
2535 Landmark Drive, Suite #211	COUNTY: Hillsborough
Clearwater, Florida 34621	LOCATION: Section 26, T28S, R19E
(Tampa Bypass Canal (TBC))	
(Legal Name and Address)	

TERMS AND CONDITIONS OF THIS PERMIT ARE AS FOLLOWS:

1. If any of the statements in the application and in the supporting data are found to untrue and inaccurate, or if the Permittees fail to comply with all of the provisi of Chapter 373, F.S., Chapter 40D, or the conditions set forth herein, the Govern Board shall revoke this permit in accordance with Rule 40D-2.341, following notice hearing.

2. This permit is issued based on information provided by the Permittees demonstrati that the use of water is reasonable and beneficial, consistent with the publ interest, and will not interfere with any existing legal use of water. If, during t term of the permit, it is determined by the District that the use is not reasonab and beneficial, in the public interest, or does impact an existing legal use of wate the Governing Board shall modify this permit or shall revoke this permit fol'owi notice and hearing.

3. The Permittees shall not deviate from any of the terms or conditions of this permi without written approval by the District.

This Permit authorizes the applicant named above to make a combined average annua withdrawal of 20,000,000 gallons of water per day, and a maximum combined withdrawa rate not to exceed 40,000,000 gallons per day. Withdrawals are authorized as shown i the table below.

USER I.D.	DIST. I.D.	WITHDRAWAL POINT SEC-TWN-RGE	LATITUDE	LONGITUDE	GALLONS PER DAY AVERAGE	PEAK MONTHLY	MAXIMUM
1	1	26-28S-19E	28 00 54	82 22 12	20,000,000	N/A	40,000,000

4. In the event the District declares that a Water Shortage exists pursuant to Chapter 40D-21, the District shall alter, modify, or declare inactive all or parts of this permit as necessary to address the water shortage.

5. The District shall collect water samples from any withdrawal point listed in the permit or shall require the permittee to submit water samples when the District determines there is a potential for adverse impacts to water quality.

6. The Permittees shall provide access to an authorized District representative to enter the property at any reasonable time to inspect the facility and make environmental or hydrologic assessments. The Permittees shall either accompany District staff ont property or make provision for access onto the property.

7. Issuance of this permit does not exempt the Permittees from any other District permitting requirements, including a Works of the District Permit.

the purposes of flood management.

F. REGULATORY LIMITS

1. The TBC will be the first and primary augmentation source for the reservoi If water levels in the reservoir recede to the proposed augmentation leve described in Condition 19.E.2 of WUP No. 202062.02 for Sulphur Springs, t Permittees will attempt to meet augmentation demands with the TBC befo initiating withdrawals from Sulphur Springs.

2. During the months of March through June, augmentation from TBC to t reservoir will not begin until water levels in the reservoir recede to 21 feet NGVD, unless augmentation is required by Condition 18.C for the purpo of mitigation of increased reservoir withdrawals. During the months of Ju through February, augmentation from TBC to the reservoir will not beg until water levels in the reservoir recede to 19.0 feet NGVD, unles augmentation is required by Condition 18.C for the purpose of mitigation c increased reservoir withdrawals.

3. Withdrawals from the TBC will cease when:

a. The surface water elevation in the Harney Canal, as read on the gage at S 161, is at or below twelve (12) feet NGVD, or

b. Stage at the reservoir dam is at 22.5 feet NGVD. Augmentation of the reservoir shall not occur when water levels in the reservoir are at or above 22.5 feet NGVD.

4. If a safety elevation above 12 feet NGVD at Harney Canal is necessary to assist the Permittees in avoiding violation of Condition 17.F.3.a, then such a safety elevation shall be implemented. If the District determines that the Permittees are in violation of Condition 17.F.3.a, the District may impose a safety elevation above 12 feet NGVD, after discussion with the Permittees. The new safety factors shall then supersede those contained within Condition 17.F.3.a above.

G. TBC MITIGATION SCHEDULE DURING RESERVOIR AND TBC STUDY PERIOD

Because potential impacts to the lower Hillsborough River could not be quantified at the time of permit issuance for WUP No. 202062.02 (Hillsborough River Reservoir), a net increase in river withdrawals will not be allowed until a District-approved optimal withdrawal/augmentation schedule is implemented, as described in Condition 18.A. For this reason, the TBC will be used to provide mitigation water to the reservoir in accordance with the mitigation criteria of Condition 19.E.1 of WUP No. 202062.02.

In coordination with Condition 19.E.1 of WUP No. 202062.02, when no flow conditions exist at the dam, and water levels in the reservoir recede to 22.0 feet NGVD, the Permittees (the City and the Authority) shall pump water from the TBC to the reservoir until the cumulative daily quantity differences that were pumped from the reservoir, have been made up by TBC pumpage, or until water levels in the reservoir have rebounded to the crest of the dam (i.e. 22.5 feet NGVD). If water levels in the reservoir rebound to the crest of the dam before the cumulative daily quantity differences that were pumped from the reservoir have been made up by TBC pumpage, the quantity that was not made up shall be recorded, and shall be carried over for use during the next no flow period for which water levels in the reservoir recede to 22.0 feet NGVD. This will allow for storage in the reservoir to be maintained, and shall assist in minimizing the effects of decreases in storage on the occurrence of low and no flow days

The "daily mitigation quantity" pumped from the TBC, shall be clearly the pumpage report for the reservoir, and shall be easily discer... augmentation from the TBC for non-mitigative augmentation. The cumulat quantity of mitigation water pumped from TBC shall also be designated in pumpage reports to the District, and shall be termed the "cumulative mitigat quantity".

If such mitigation is not feasible during the construction of the perman pumping facility for the TBC, the Permittees shall submit a written request the Director of the Tampa Permitting Department, within 60 days prior initiation of construction. The request shall detail the specific reasons mitigation during the construction period is not feasible, when construction the permanent facility is proposed to be completed, and when the mitigati pumpage will resume again. The request will require written approval of t Director of the Tampa Permitting Department prior to discontinuance of mitigati pumpage from TBC to the reservoir. The Director of the Tampa Permitti Department may modify this limiting condition or extend this condition to oth periods of the study, based on the results of hydro-biological monitoring for t TBC or the reservoir.

18. ENVIRONMENTAL IMPACTS, MONITORING, AND MITIGATION

A. HYDRO-BIOLOGICAL MONITORING - TBC

The qualified consultant(s) shall be selected by the Permittees, and dat collection for the HBM program shall begin by October 1, 1991 and end Septembe 30, 1994. District staff shall be provided copies of all proposals rec response to the Permittees' request for proposals, and shall be provi opportunity to attend all oral presentations regarding the proposals. Th Director of the Tampa Permitting Department shall be provided written notice o oral presentations at least one week in advance of such presentations. Throug all steps of the consultant selection process, the District will provide th Permittees a non-binding recommendation of the consultants who propose t undertake the project.

The final scope of work shall be written after discussion and negotiations with the consultant. The final scope of work will at a minimum address the seven items outlined below and where appropriate, changes to the seven items can be made as a result of acquiring additional information not available at the time the permit was issued. The District shall be provided the opportunity to participate in the drafting of the final scope of work. Five copies of a final scope of work shall be submitted to the Director of the Tampa Permitting Department for approval, by no later than July 15, 1991.

The Study Area for the initial three year period of the permit shall extend from above S-160 to the vicinity of McKay Bay at 22nd St. Causeway bridge. The scope of work and study area for the remainder of the duration of the permit shall be revised according to recommendations contained in the final report due February 15, 1995 (covering Water Years 1992 to 1994), subject to approval of the Director of the Tampa Permitting Department.

1. MONITORING SITE LOCATIONS

A total of five sampling stations shall be established. The sites sha located in the Tampa Bypass Canal at the upstream side of S-160 and in ...e vicinity of four of the following locations:

(A) Palm River at S.R. 60
(B) Palm River at Maydell Drive
(C) Palm River at U.S. 41
(D) Central McKay Bay in deepest portion of channel
(E) South side of McKay Bay
(F) North side of McKay Bay
(G) McKay Bay at 22nd St. Causeway bridge

Sites A through G shall be reviewed by the selected consultant f appropriateness (including consideration of effect of stormwater input in t vicinity of the sites) during preparation of the final scope of work. Sites through G are tentative and subject to review and approval by the District und the final scope of work. However, if any of the four downstream sites are move they will be replaced on a 1:1 basis, with no additional sites being required.

2. <u>MONITORING SITE WATER QUALITY DATA COLLECTION</u>

a. In-situ and laboratory water quality analyses for the sample sites listed : Section 1 above shall be collected and analyzed on a monthly basis for : least one year (see section 2.b. below for years two and three). To avoi duplication of effort, the Permittees may use monitoring sites availabl from other agencies, where applicable.

Water quality analyses shall include:

(A) dissolved oxygen (DO)
(B) total suspended solids
(C) temperature
(D) salinity
(E) turbidity
(F) total nitrogen
(G) total phosphorus
(H) ortho-phosphorous
(I) nitrate/nitrite
(J) ammonia
(K) kjeldahl nitrogen
(L) Total Organic Carbon
(M) Biochemical Oxygen Demand
(N) color
(O) pH
(P) conductivity

Analysis of Chloride, Sulfate, and Total Dissolved Solids concentrations shall also be undertaken for the TBC site on a monthly basis.

Regular monthly sampling shall also include salinity/DO/temperature profiles at the five stations identified in the approved scope of work, plus an additional four stations (total) in the Palm River and McKay Bay.

In addition to regular monthly sampling, salinity/DO/temperature profiles shall also be conducted at the nine stations in the above paragraph shortly after the beginning of a discharge event at the S-160 structure, following low or no flow period (to the extent that appropriate flow conditions exist). These profiles shall be conducted on a schedule not to exceed four times per year, and shall be used to determine the impact of flows immediately after a rainfall/discharge event.

To the maximum extent possible, water quality sampling shall be performed during the same tidal and time of day conditions each month. The s collection time and date shall be included with all data. Analyses performed according to procedures outlined in the current Standard Methods for the Examination of Water and Wastewater by A.-A WPCF or Methods for Chemical Analyses of Water and Wastes by the USEPA.

b. Following the first year of water quality data collection, the District the Permittee will review all data collected, as required by the appr final scope of work, as a basis to determine any justified change to sample frequency of water quality monitoring for the second year. applicable, a similar review will take place at the end of the second collection year for the third year of monitoring.

3. MONITORING SITE BIOLOGICAL DATA COLLECTION

a. Biological monitoring shall be conducted at the sites identified in approved final scope of work, for a period of two years, as designated the table below. The same sites shall be used for water quality biological monitoring, except as designated below.

ORGANISM	LOCATIONS	FREQUENCY
Phytoplankton	Above S-160 and 3 water quality sites	Year 1 - Monthly Year 2 - See Section 3.c. Below
Benthic Macro-invertebrates	All sites	Year 1 - Quarterly Year 2 - See Section 3.c. Below
* Aquatic Vertebrates (Fisheries)	See paragraph below	Year 1 - Monthly Year 2 - See Section 3.c. Below

* Aquatic vertebrates shall be collected by means of ichthyoplankto surveys and juvenile fish surveys. Ichthyoplankton surveys shall b accomplished by boat tows with plankton nets, and juvenile fish survey shall be accomplished by using seines and trawls. Ichthyoplankto surveys shall be conducted at four sites located below S-160, whil juvenile fish surveys shall be collected at 5 sites below S-16 depending on site suitability. Site locations can be the same as th water quality monitoring site locations of section 2.a.. However, du to physical limitations with sampling equipment, alternate sites may b necessary.

b. A one time shoreline habitat inventory, including aquatic macrophytes, o the Palm River shall be conducted during the first year of the monitoring period.

c. Following the first year of biological data collection, the District and the Permittees will review all data collected, as required by the approved final scope of work, as a basis to determine any justified change to the sample frequency of biological monitoring for the second year.

4. PREVIOUS STUDY REVIEW

The consultant shall review and summarize all previous biological, hydrolo.., and water quality studies of the TBC, Palm River, and McKay Bay. This shall include a review of the District's SWIM library. The collected information shall be used in the analysis as appropriate, and the findings of the reports shall summarized in the first interpretive report required by this condition.

5. STORMWATER INPUT SURVEY
A survey of the stormwater inputs and associated treatment efficiencies shall conducted the first year to evaluate the potential impacts of direct watersh discharge into the TBC, Palm River, and McKay Bay.

6. MONITORING PLAN GOALS

The goals of the plan shall be:

a. To determine hydrologic, water quality, and biological relationships in t study area, and their relationship to discharge at S-160, and to determi whether the withdrawals from TBC will have an unacceptable adverse impact water quality, and fish and wildlife in the Palm River and McKay Bay.

b. To determine the habitat functions of the Palm River and McKay Bay.

c. To determine how various levels of pumping the TBC will effect water level and outflows in the TBC.

d. The construction of a mathematical hydrological model (not a water qualit model) of the TBC that includes, but is not limited to terms for: inflow into the reservoir, infiltration to the TBC, bank seepage gains and losses, evaporation, changes in storage, and withdrawals from and augmentation to the reservoir. This model shall allow the simulation of dependable yields and downstream releases under various withdrawal and augmentation scenarios. The model shall include the reservoir.

e. In relation to the items above, the ultimate goal of the study shall be to determine an optimal withdrawal/augmentation management schedule for the reservoir, TBC, and Sulphur Springs that minimizes downstream impacts, while at the same time meeting water supply needs.

7. MONITORING AND REPORTING PERIODS
Joint review of all draft reports shall take place by the Authority, the City, and the District. All reports shall be subject to District review and suggested revisions. Five copies of all reports shall be submitted. The results of the monitoring program shall be submitted to the District in a series of three reports, plus end of year data reports for the purpose of defining future monitoring requirements. However, depending on changes to the sampling program after the first and second data collection years, it may be necessary for the Director, Tampa Permitting Department, to modify the reporting schedule described below.

By September 1 of each data collection year (excluding the third data collection year), the Permittee shall submit all data collected to date, on hard copy and on electronic media in a format meeting District specifications, to the Director, Tampa Permitting Department. This data shall be reviewed in accordance with Conditions 18.A.2.b. and 18.A.3.c. to determine the extent of future monitoring. The data shall be reviewed by the Permittee and the District between September 1 and September 30 of each applicable year. By September 30, the District will notify the Permittee of the future monitoring requirements, which are to be implemented beginning October 1 of the same year.

A progress report shall be submitted by February 15, 1993. This repo include all raw data for the first year of the project on hard copy graphs and text with little or no interpretative discussion. Th include a summary of data collected during the first study ye... providing a description of monitoring progress.

A second report shall be submitted to the District by February 15, 1994 report shall serve as an interpretive report for the biological and fi years of water quality data collection for the monitoring program, an include: a review of previous data collection programs and biological ar quality studies of the TBC, Palm River, and McKay Bay, the shoreline inventory of the Palm River, and an assessment of the habitat functions Palm River and McKay Bay emphasizing the relationships of biological comm to salinity and water quality variables affected by discharge from Accompanying the second report shall be the data collected in the second y the project on hard copy, and the complete set of data collected for the two years of the project provided on electronic media in a format m District specifications. The second report shall be subject to the Di review, and require the approval of the Director of the Tampa Perm Department.

A third report shall be submitted to the District by February 15, 1995. shall be an interpretive report which includes the following: a final ana of the relationships of salinity and other water quality variables to disc from S-160, the hydrologic model of the TBC/reservoir system, and present and discussion of the optimal withdrawal/augmentation management schedule for TBC. This recommended schedule will be used to determine the most appr withdrawal and augmentation schedule for the reservoir, spring, and TB best available data.

Although the biological data were evaluated in detail in the second report, third report shall discuss discharge/water quality relationships and the opt reservoir management schedule as they pertain to biological communities in Hillsborough River and the Tampa Bypass Canal. The third report shall a contain recommendations for continuation of the monitoring program or ot analyses relevant to designing or updating an optimal reservoir managem schedule for the TBC/reservoir system. Accompanying the third report shall the data collected in the third year of the monitoring program on hard copy a on electronic media in a format meeting District specifications, and t hydrologic model for the reservoir system provided on electronic media.

The findings of the third report shall be subject to review by the District, a the recommendations contained in the report shall require approval of t Director of the Tampa Permitting Department.

The approved withdrawal/augmentation management schedule will replace th requirements of Condition 17.G.

B. <u>Impact Assessment</u>

If at any time during the term of the permit the interpretive reports or Distric staff's analysis indicates that unacceptable adverse impacts are occurring, o are anticipated to occur, due to the withdrawals from the TBC, the Perm...ee will be required to limit withdrawals from the TBC to an acceptable ... However, nothing in this condition shall be construed to limit the author... o the Board to act pursuant to Condition 2 of this permit. If, based on the conclusions of the final interpretive report, additional monitoring assessment is deemed necessary, additional monitoring will be required by the District.

19. <u>WATER CONSERVATION</u>
The Permittees shall continue to develop, implement, and expand existing wa conservation programs to reduce demands on the water resources and increase efficie of water use. Within six (6) months of Permit issuance, the Permittees shall subm for approval by the Director of Tampa Permitting, a modification of the wa conservation plan submitted on June 1, 1990, that has the current water demand figu (submitted June 1, 1990) incorporated into the plan in the appropriate areas. Th modified plan, when approved, shall be implemented in conjunction with existi programs. If the Permittees' conservation plan addresses both CUP 206675.01 and W 202062.01, the Permittees can submit one plan for this permit file. Otherwise, t Permittees shall submit three copies of this modified water conservation plan. addition, the two following requirements must be met:

A. The Permittees shall carry out the provisions of its District-approved Wat Conservation Plan in a timely manner. The Permittees shall submit progre reports concerning implementation of the plan on September 30, 1995 and Septemb 30, 1999.

B. Permittees shall establish and/or maintain data gathering procedures that allo amounts of water to be accounted into various categories. These categories ma be by either meter size or use, such as residential, commercial, industrial unaccounted, and other. The procedures must produce data suitable for developin reliable estimates of current water use and projections of future water demand.

20. <u>FUTURE SOURCES</u>
Due to the tentative nature of the Permittees' ability to meet future demand with the present water sources, the Permittees shall pursue the planning, development, and implementation of alternate water sources prior to the expiration of this permit. As stated in Condition 18.B, if unacceptable adverse impacts are occurring, or are anticipated to occur, due to the withdrawals from the TBC, the Permittees will be required to limit withdrawals from the TBC to an acceptable impact. Therefore, the Permittees shall evaluate alternative water supply options during the term of this permit to avoid the possibility that water demands will not be able to be met, due to permitting constraints. The Permittees shall be prepared to exercise these alternative water supply options if withdrawals are required to be limited due to unacceptable adverse impacts.

For the term of this permit, the Permittees shall provide the District with the status of alternative water supply options that the Permittees are currently undertaking. The report shall be included in the annual report required by Condition 21. The report shall include updates on the Aquifer Storage and Recovery study, Hooker's Point Reuse Study, Cypress Bridge interconnection, the City's potential wellfield property near Lake Thonotosassa and Pemberton Creek, feasibility of further interconnection to the regional system, and any other water supply options the City is pursuing. How these sources will be managed in conjunction with the optimal withdrawal/augmentation management schedule to be developed during the term of the permit for the reservoir system shall be described. Further interconnection to the regional system will include investigation of methodologies to overcome the current incompatibility of City and Authority finished water. The updates on the Hooker's Point Reuse study will include potential impacts to Hillsborough Bay if discharges to the Bay are decreased due to reuse. The annual updates shall include copies of any reports the City published or received regarding these sources. Alternate water sources shall stress the development of the local resource, use of the lowest quality water able to be used (including desalination), and hydrologic and environmental constraints. Development of alternate water sources may be required prior to authorization to increase existing source quantities.

be used in the analysis as appropriate, and the findings of the reports shal summarized in the first interpretive report required by this condition.

5. STORMWATER INPUT SURVEY

A survey of the stormwater inputs and associated treatment efficiencies shall conducted the first year to evaluate the potential impacts of direct waters discharge into the TBC, Palm River, and McKay Bay.

6. MONITORING PLAN GOALS

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7. MONITORING AND REPORTING PERIODS

Joint review of all draft reports shall take place by the Authority, the City, and the District. All reports shall be subject to District review and suggested revisions. Five copies of all reports shall be submitted. The results of the monitoring program shall be submitted to the District in a series of three reports, plus end of year data reports for the purpose of defining future monitoring requirements. However, depending on changes to the sampling program after the first and second data collection years, it may be necessary for the Director, Tampa Permitting Department, to modify the reporting schedule described below.

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APPENDIX K

Plots of salinity at the WAR/SDI stations in the Palm River/McKay Bay system vs. discharge from Structure 160 on the Tampa Bypass Canal. (All depths shown. Units are parts per thousand for salinity and cfs for discharge).

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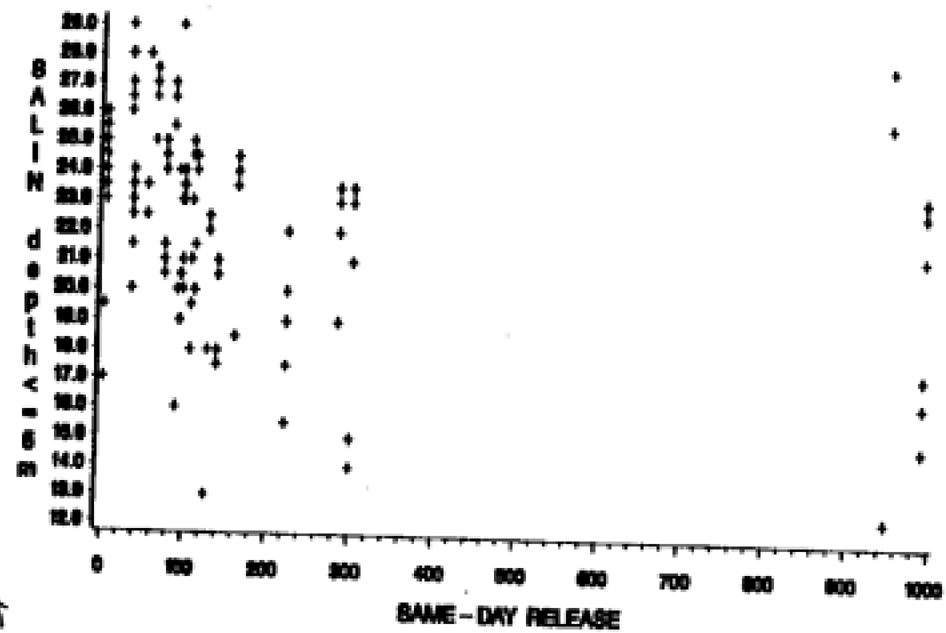

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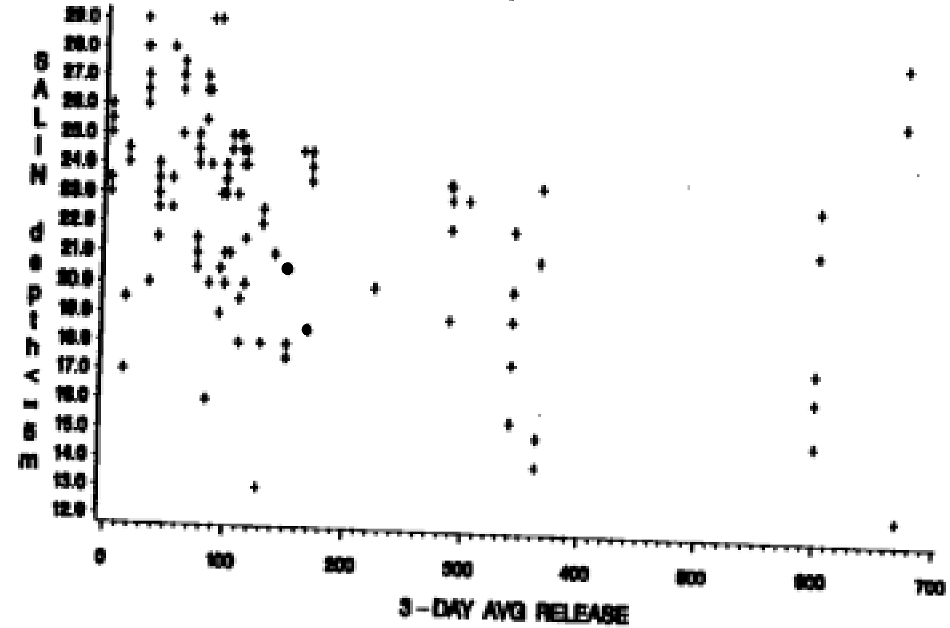

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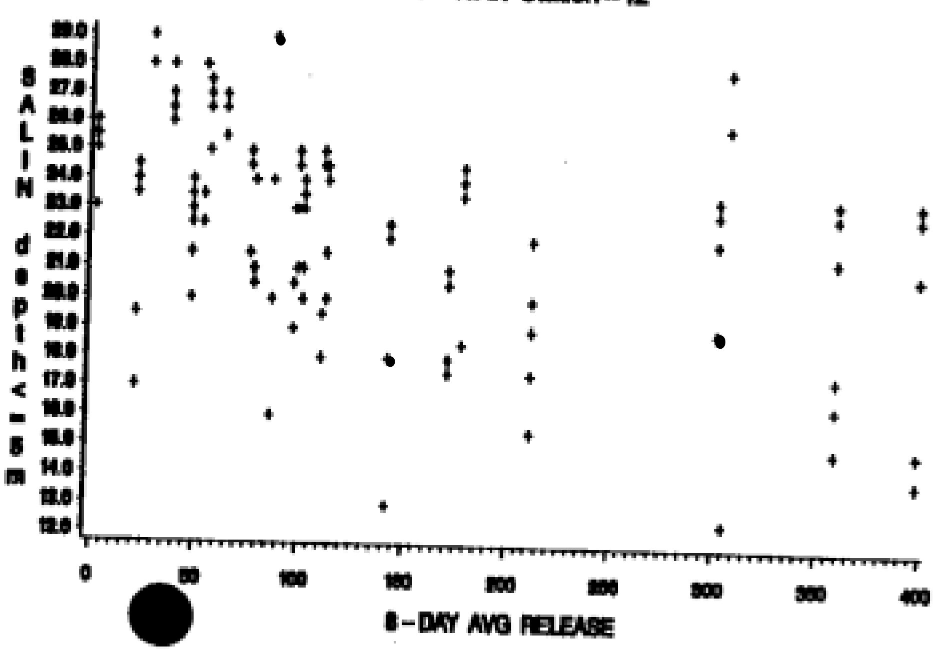

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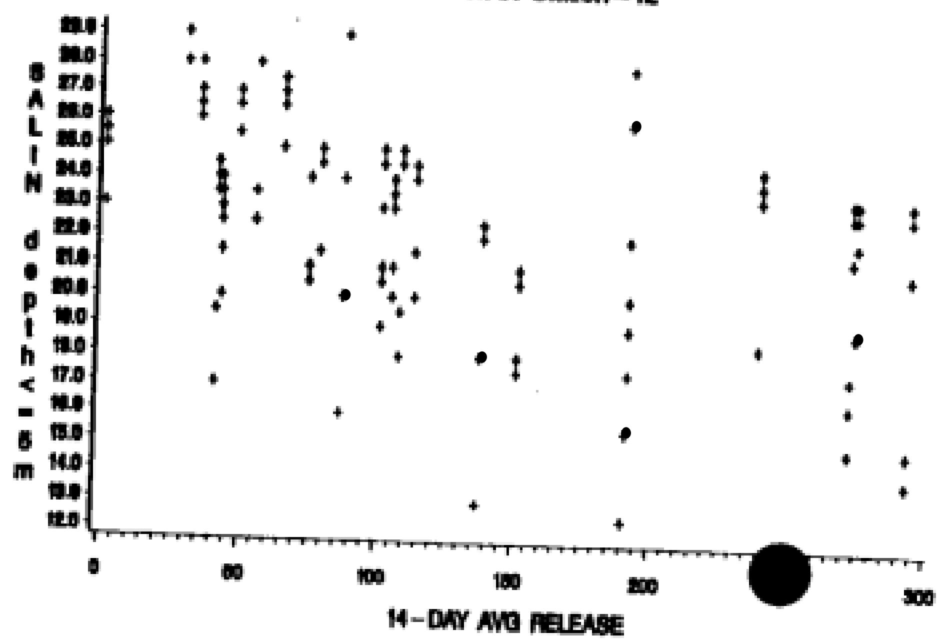

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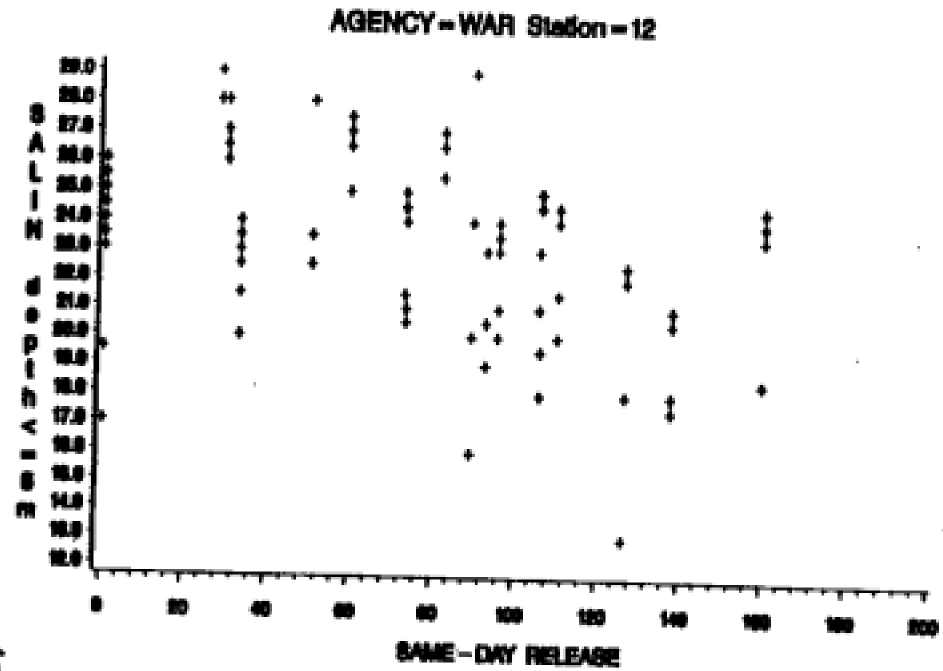
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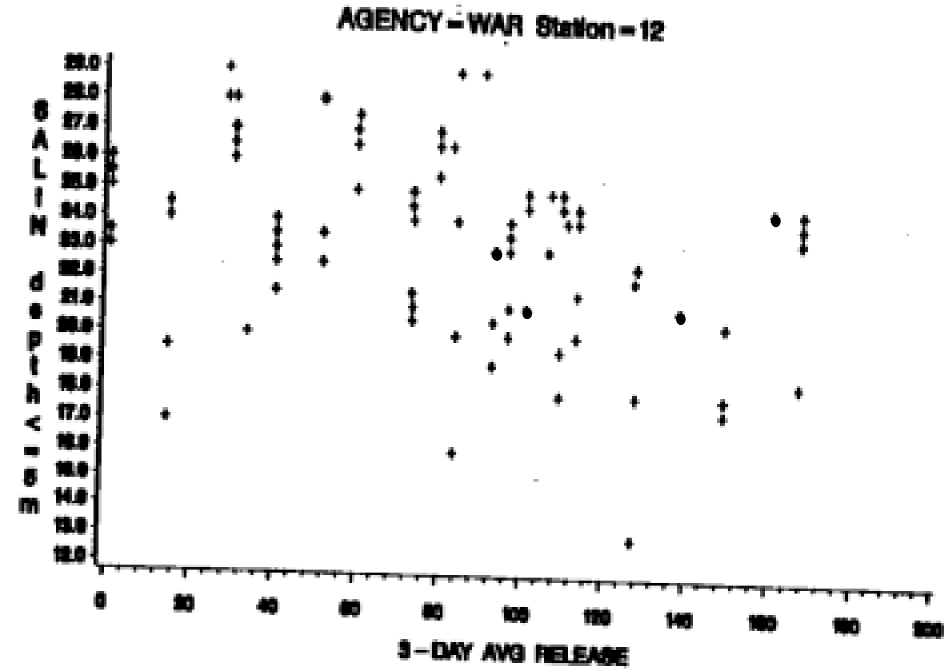
SAME-DAY RELEASE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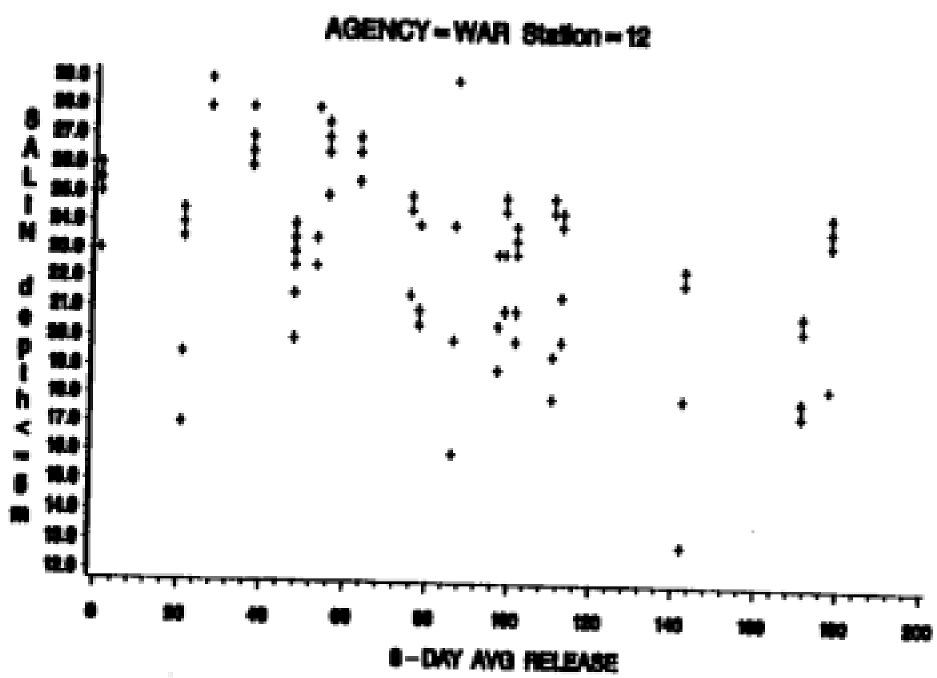
3-DAY AVG RELEASE

K2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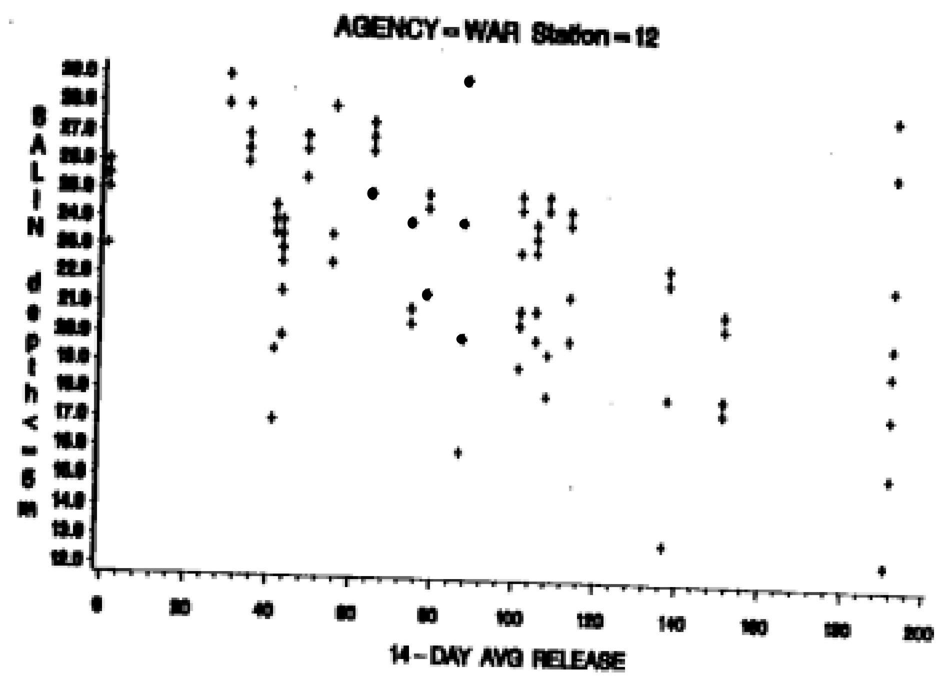
DAY AVG RELEASE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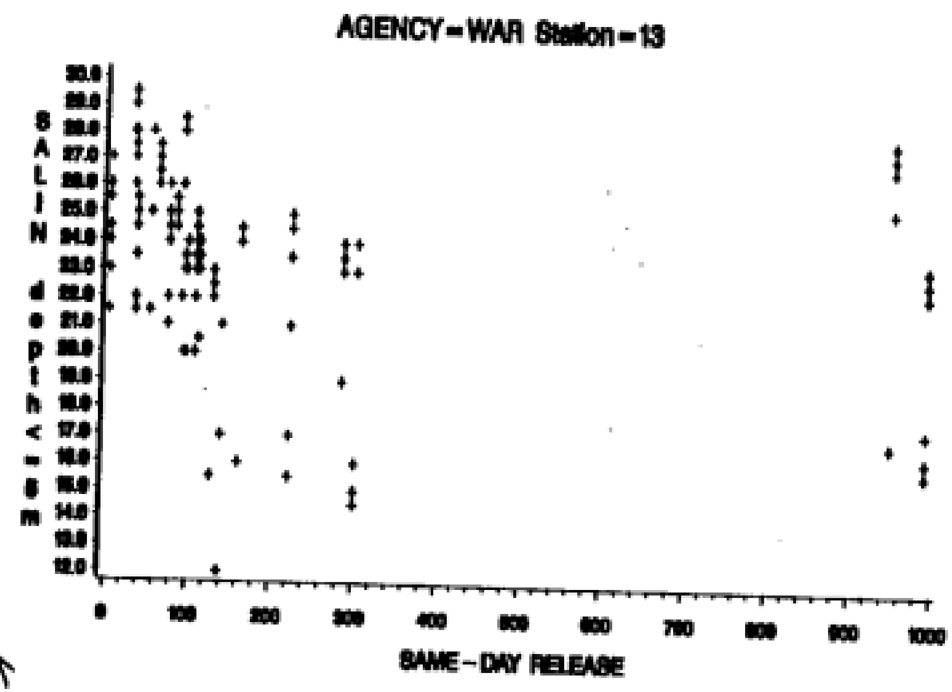
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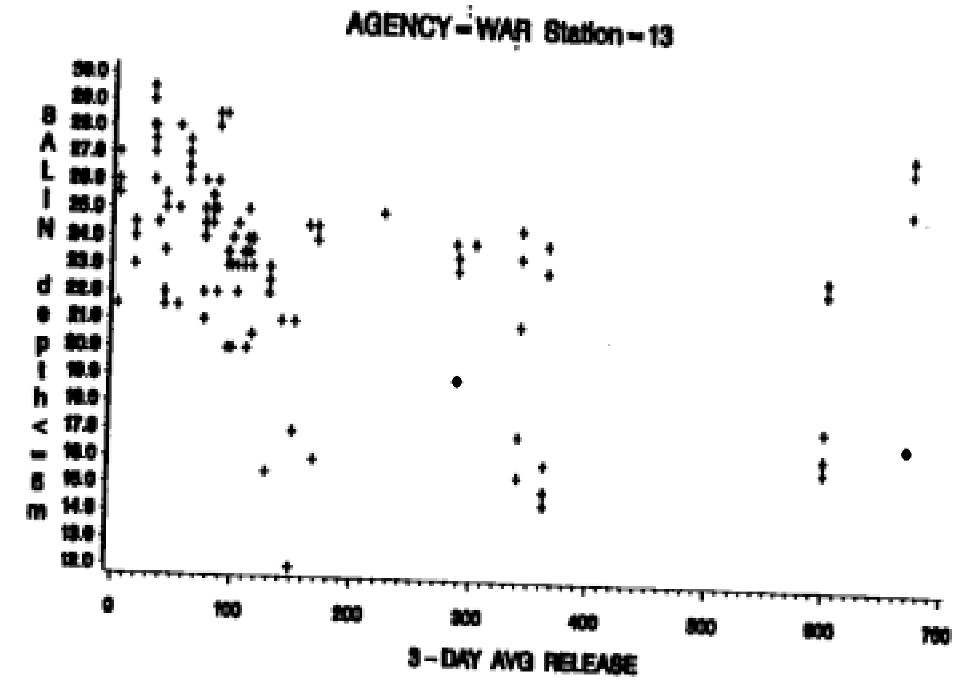
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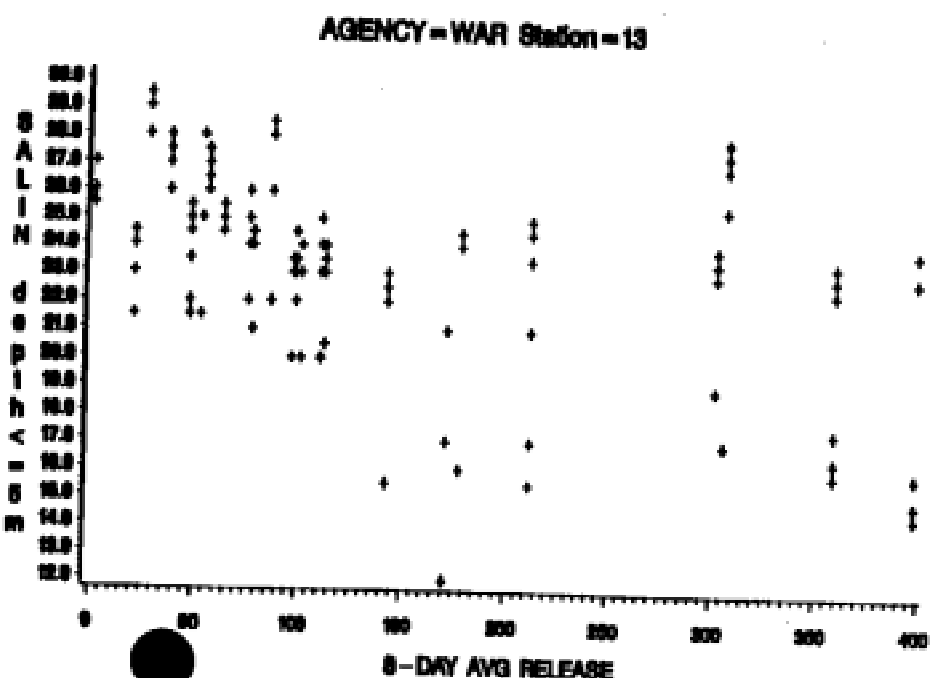
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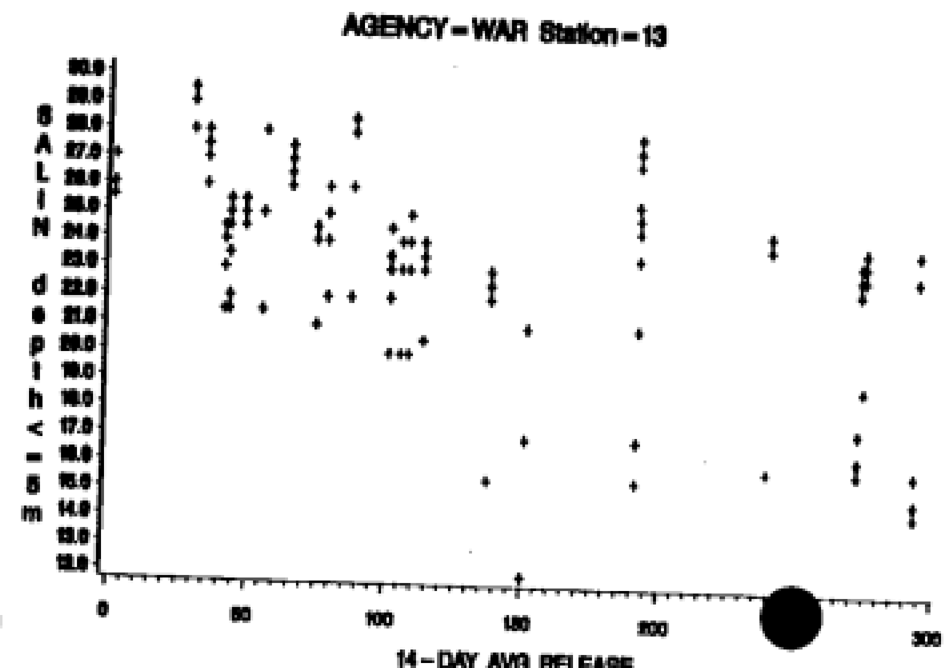
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14-DAY AVG RELEASE

K3

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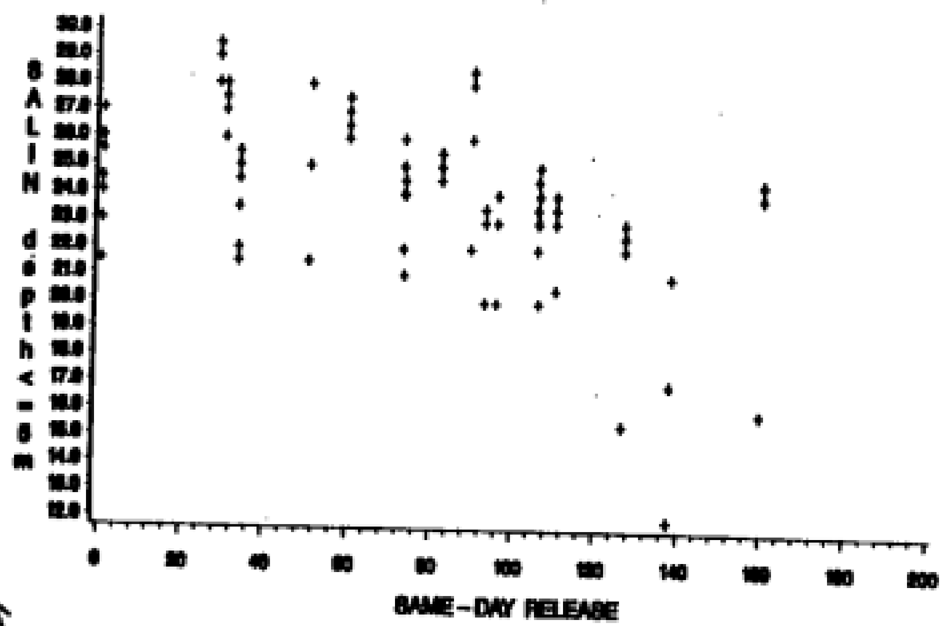

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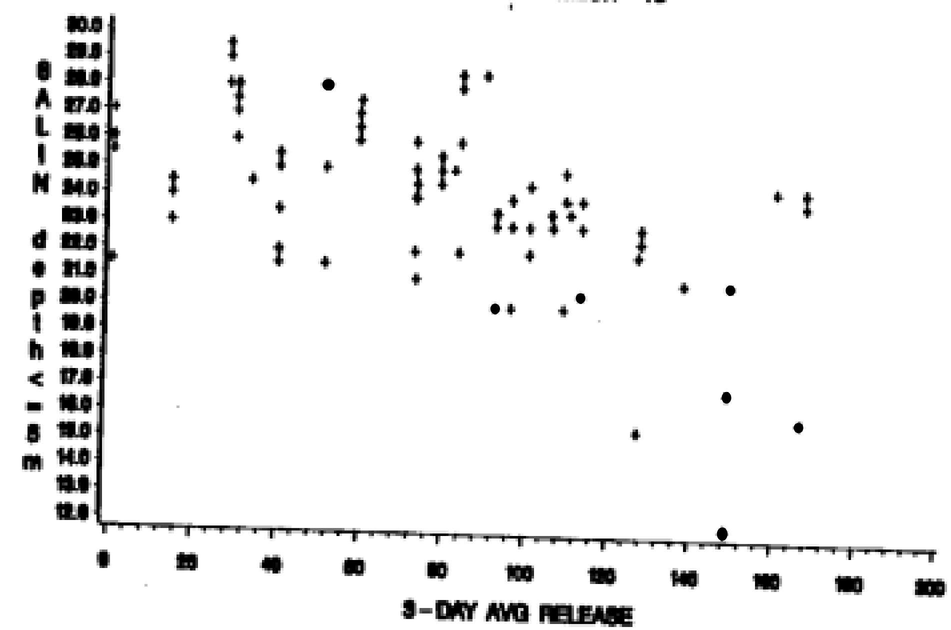

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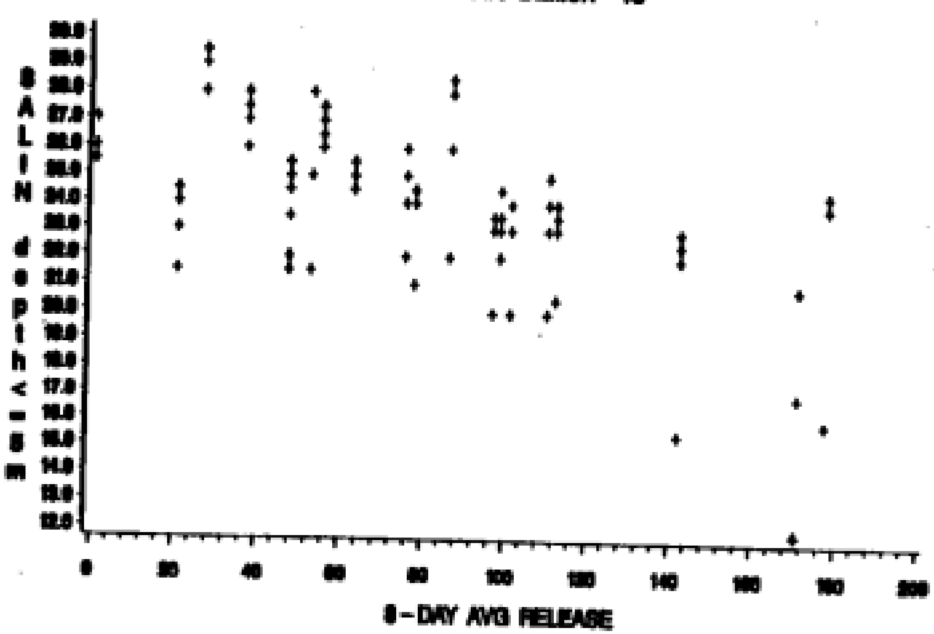

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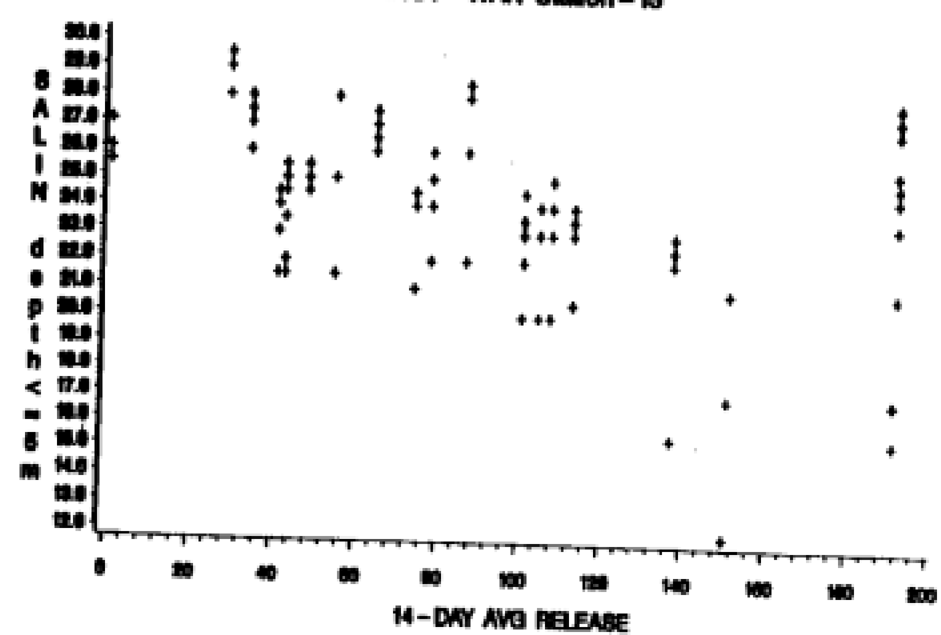

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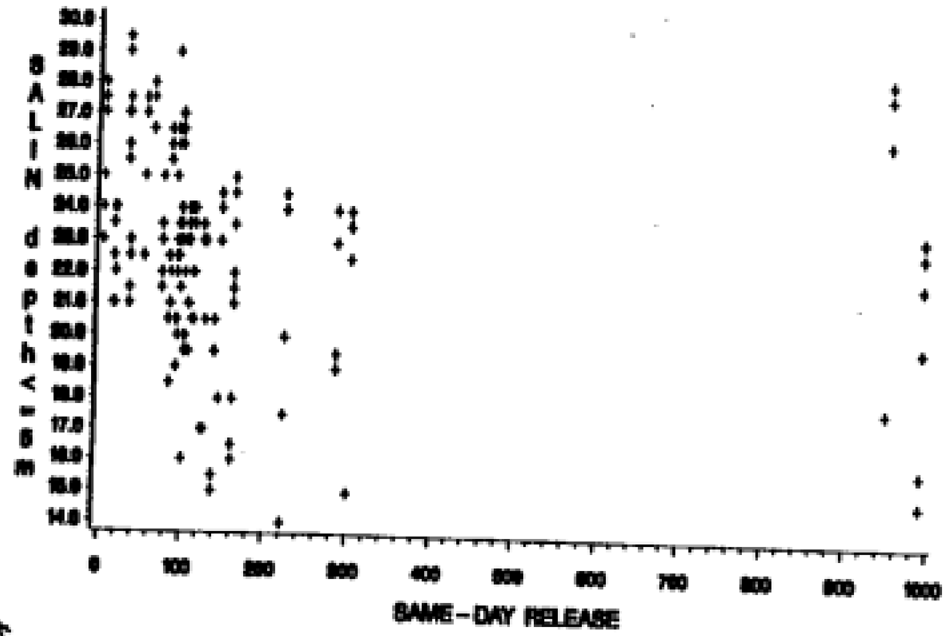

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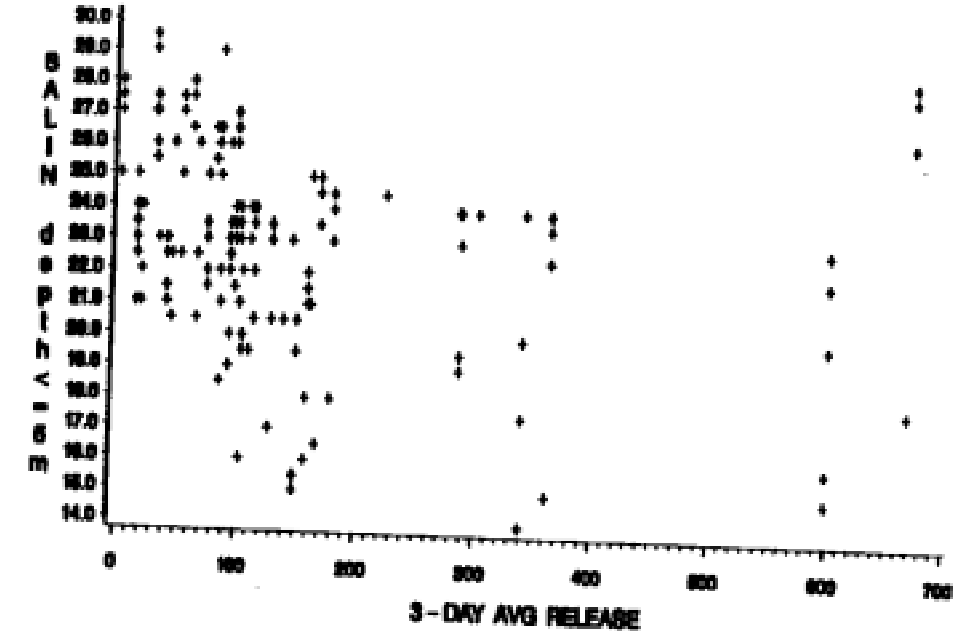

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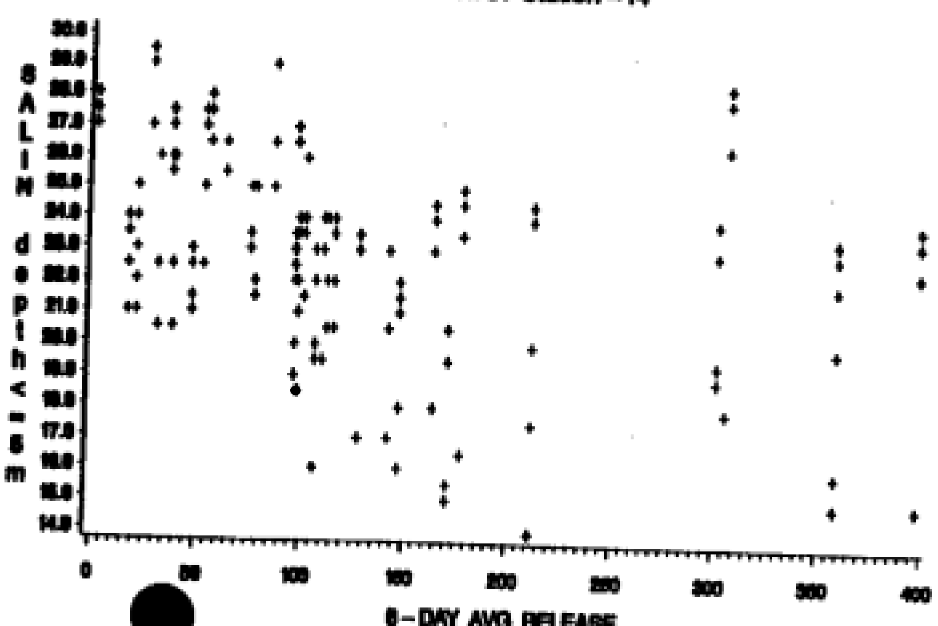

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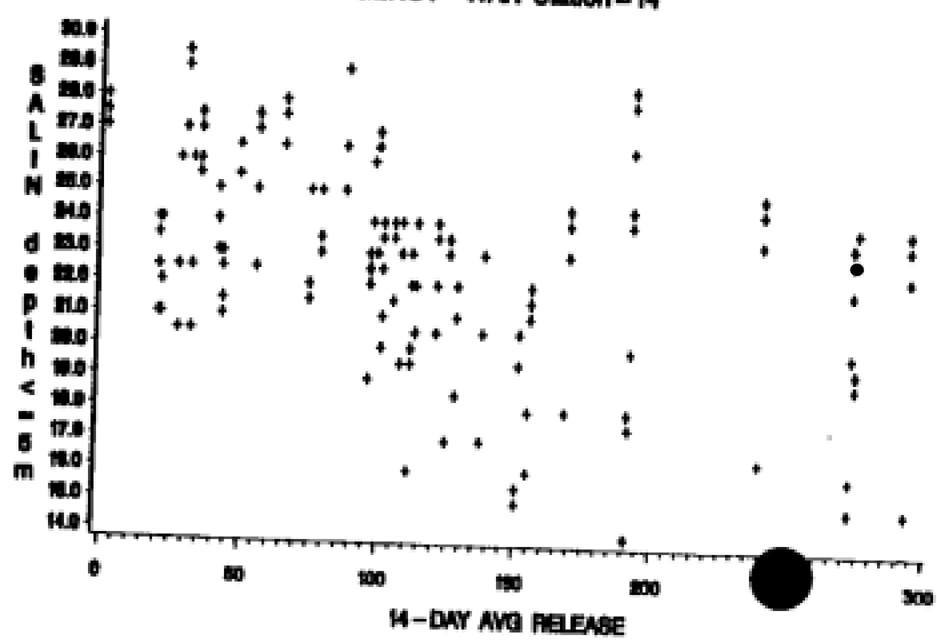

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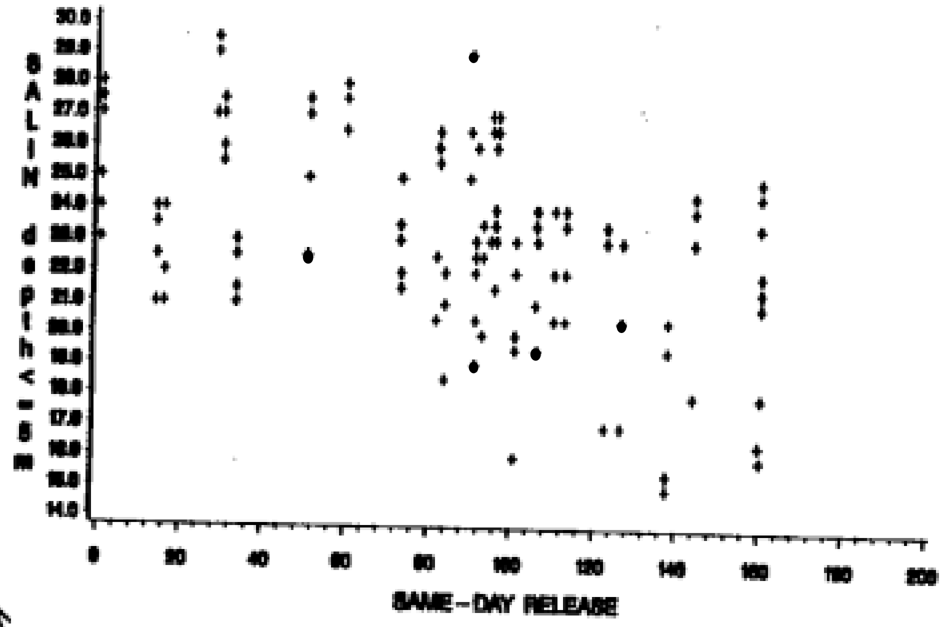

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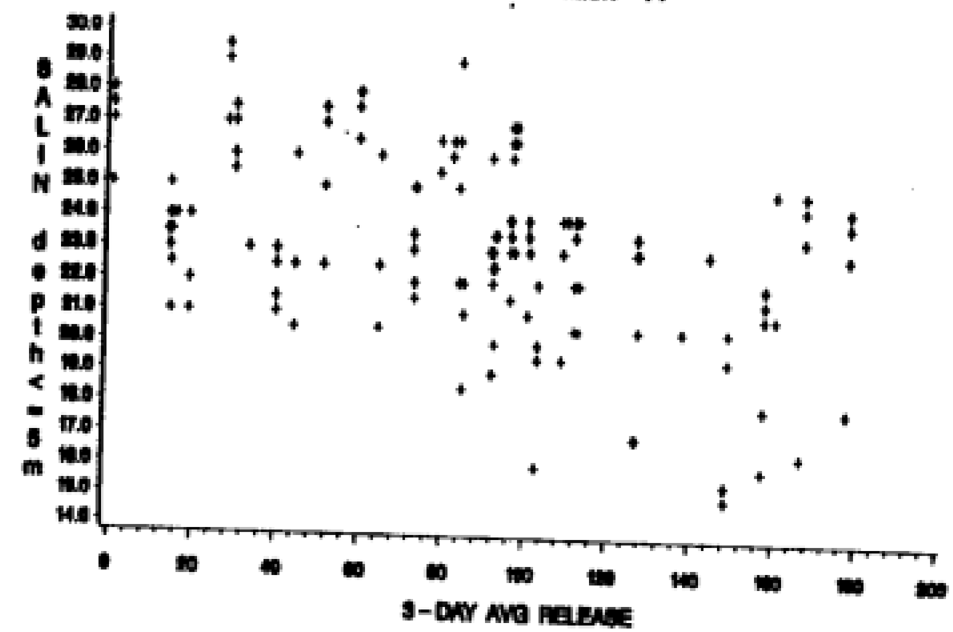

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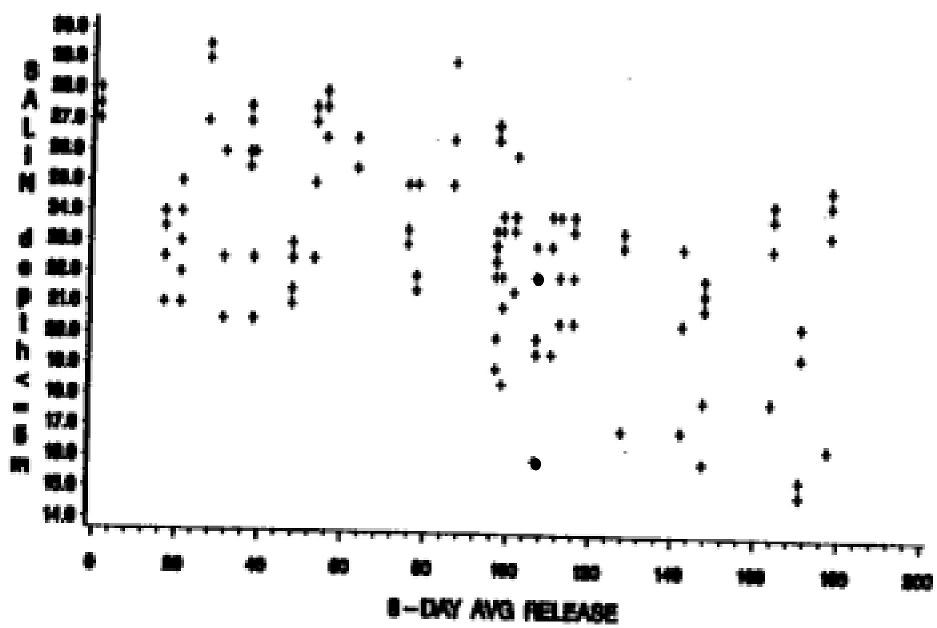

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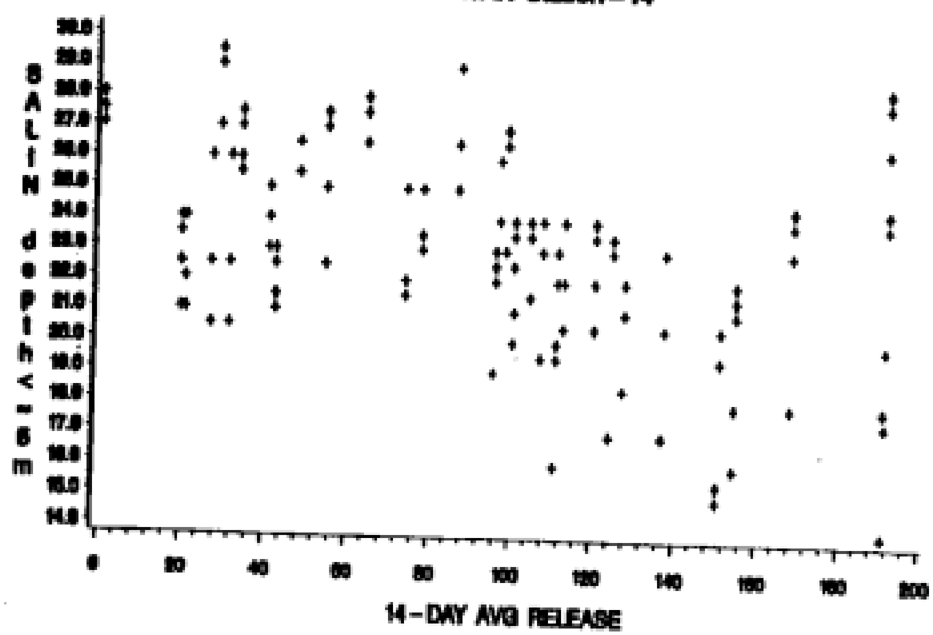

K6

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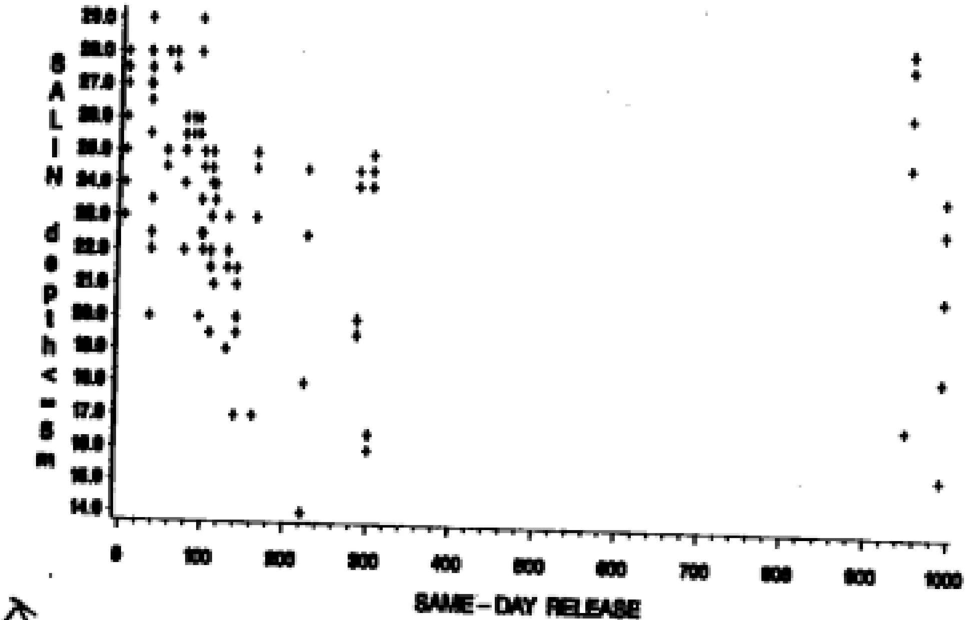

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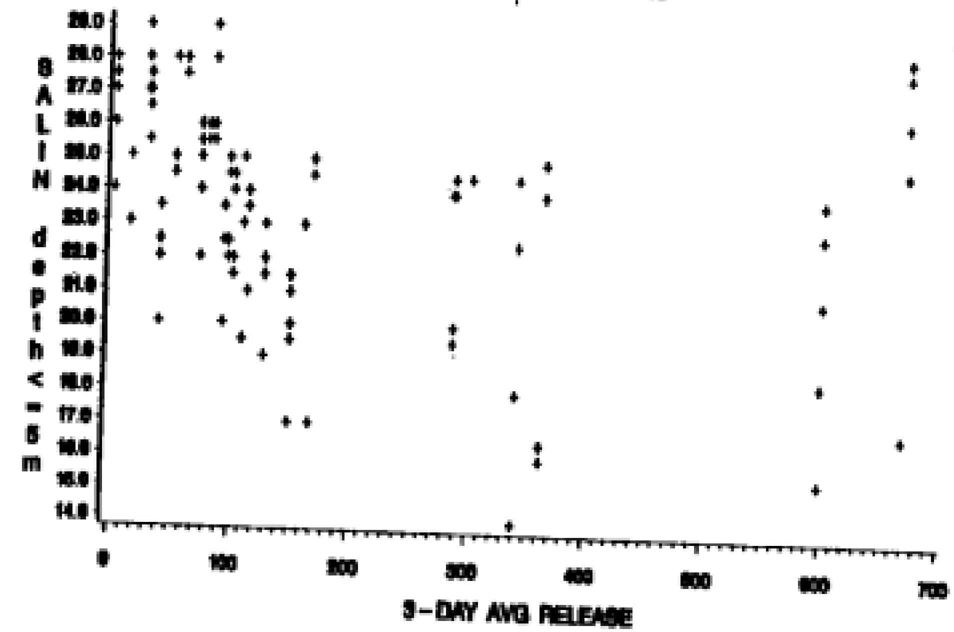

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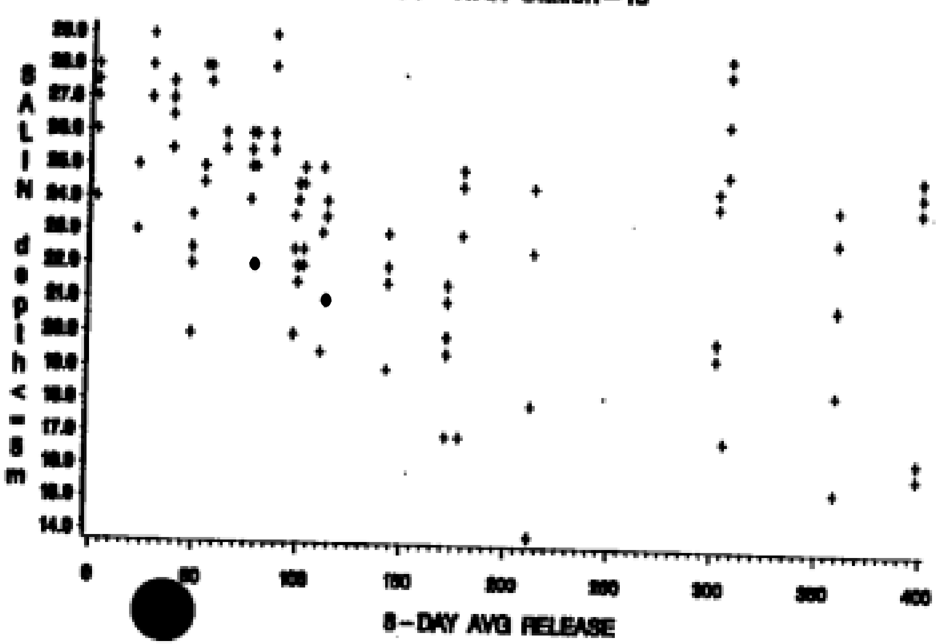

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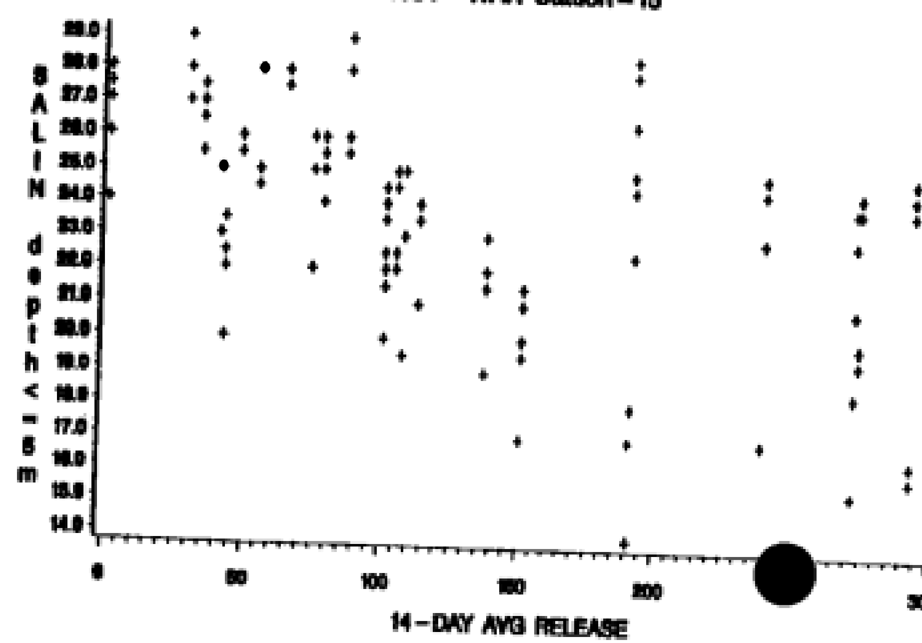

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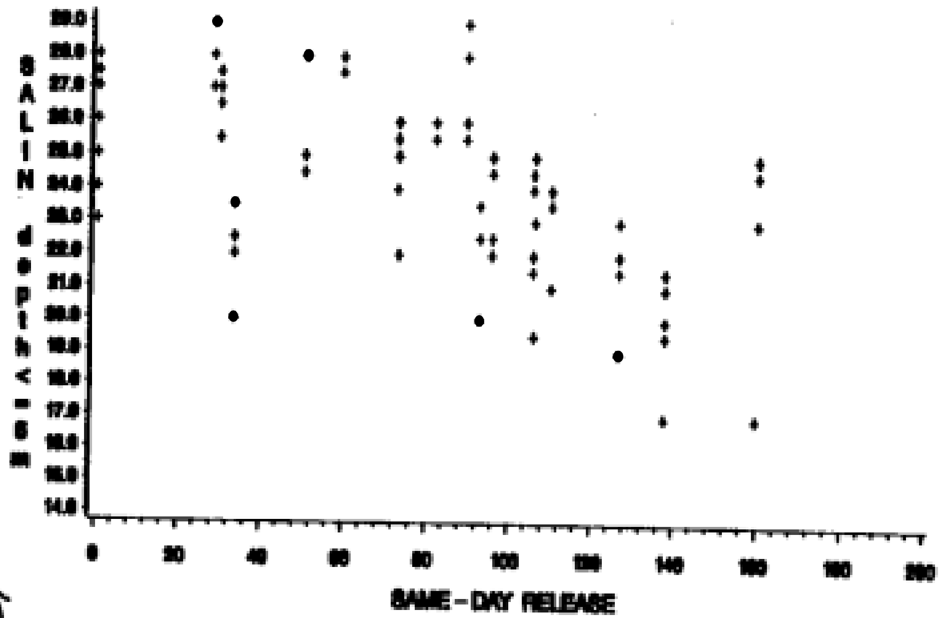
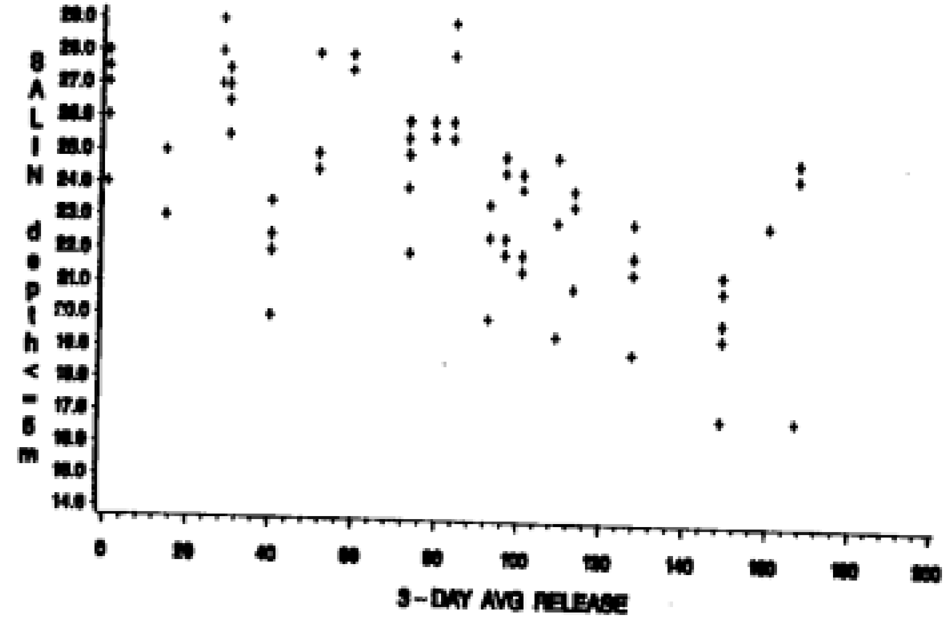
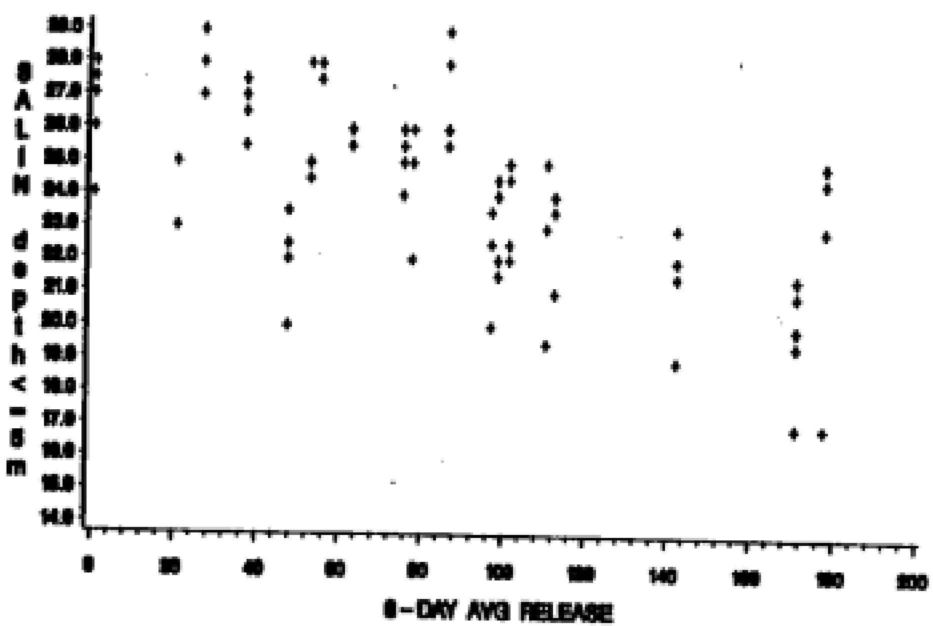


AGENCY=WAR Station=15

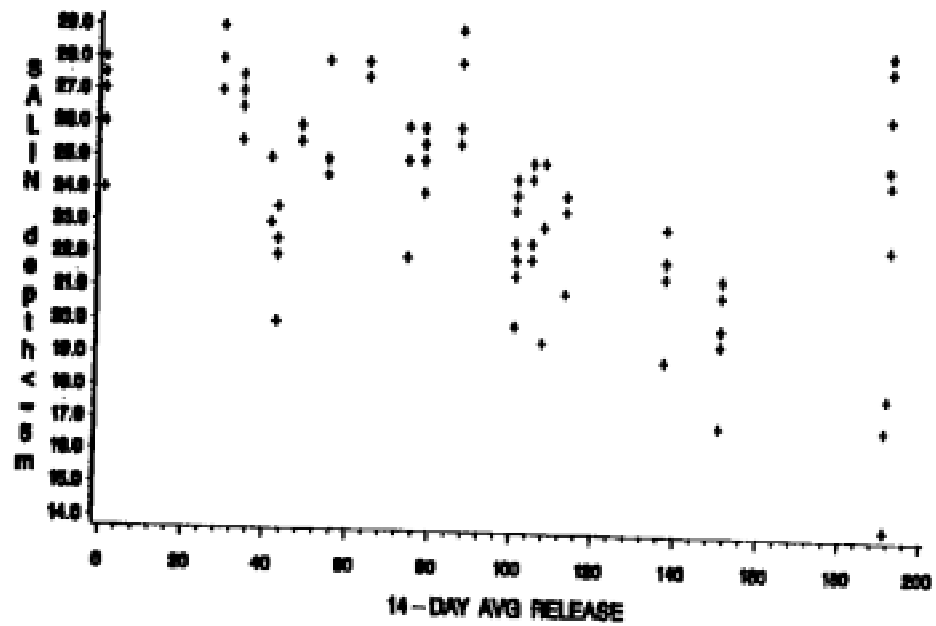


K8

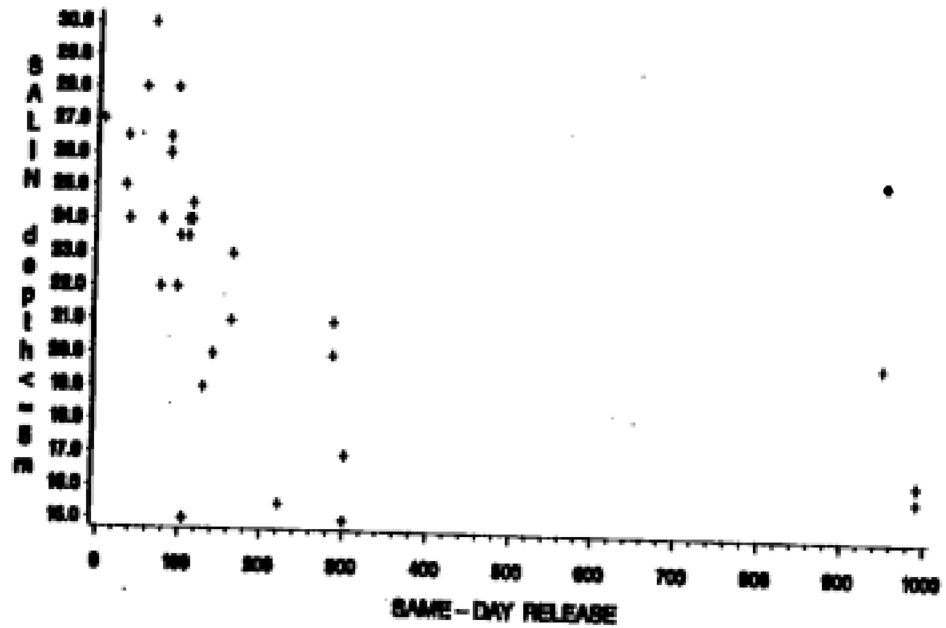
AGENCY=WAR Station=15



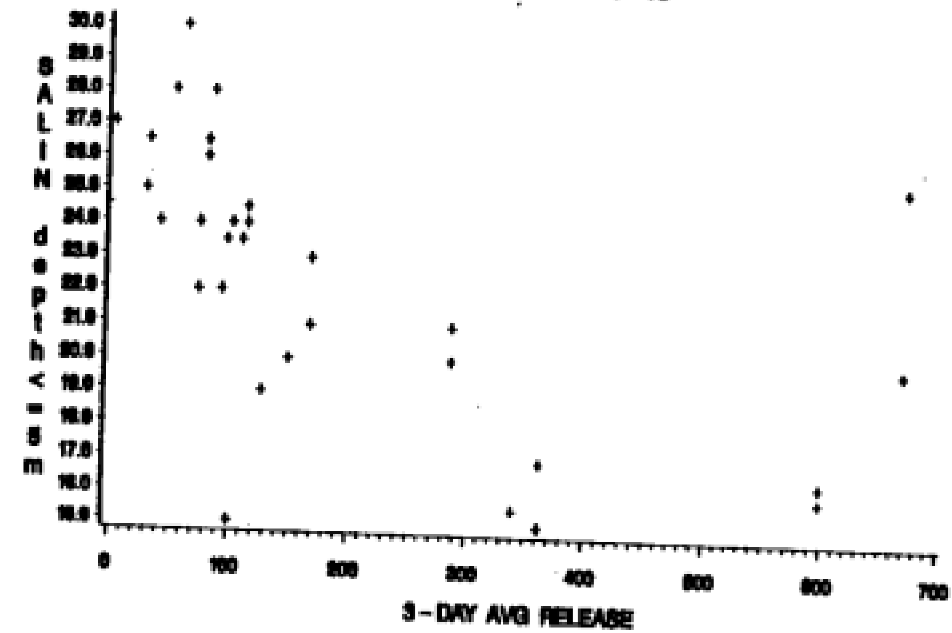
AGENCY=WAR Station=15



AGENCY=WAR Station=16

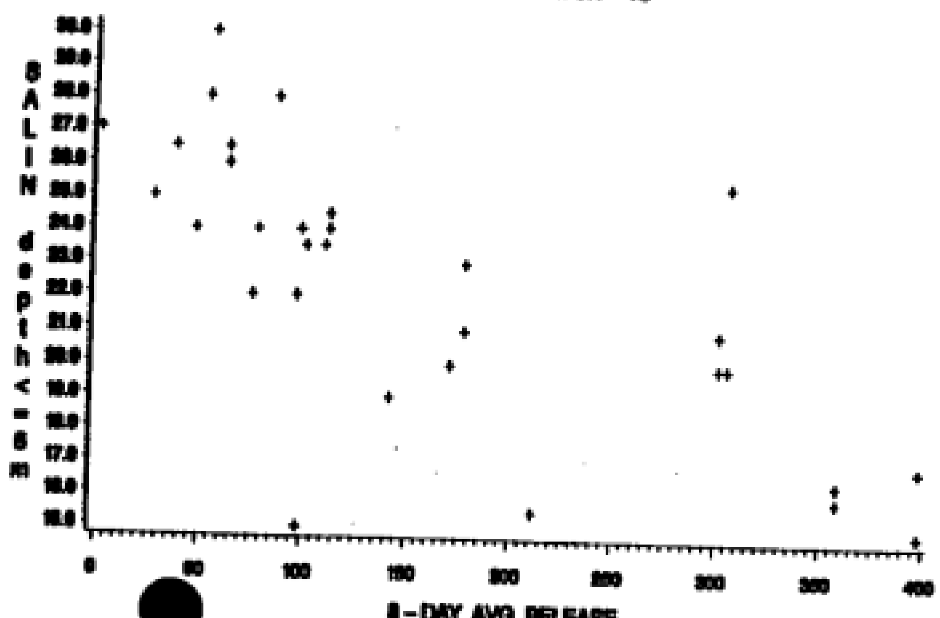


AGENCY=WAR Station=16

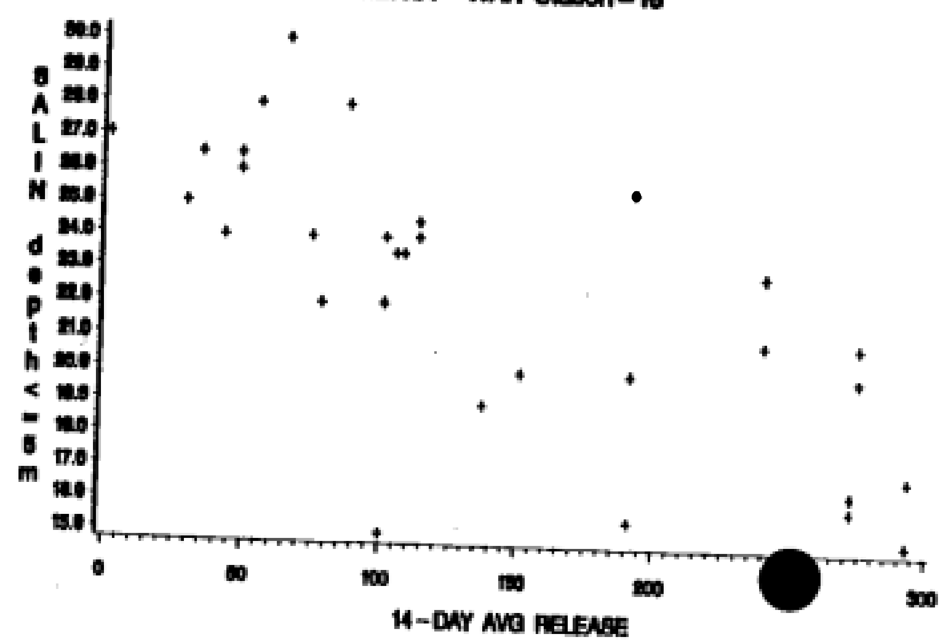


K9

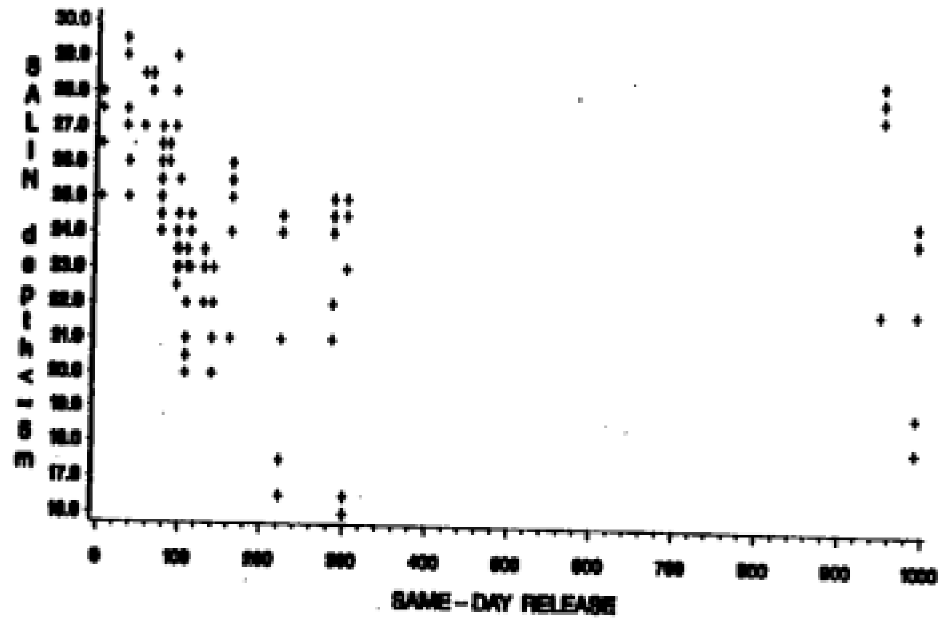
AGENCY=WAR Station=16



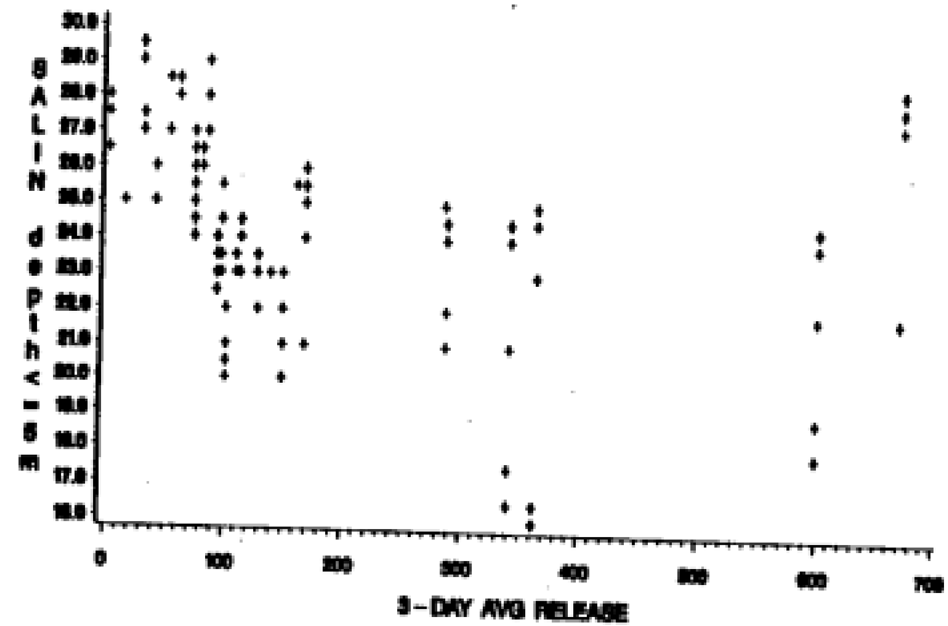
AGENCY=WAR Station=16



AGENCY=WAR Station=17

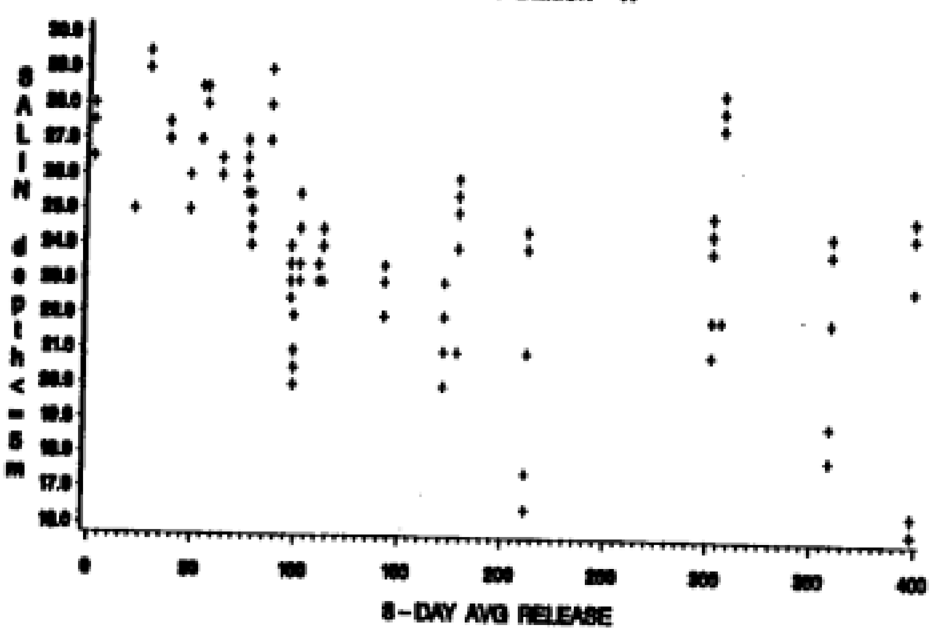


AGENCY=WAR Station=17

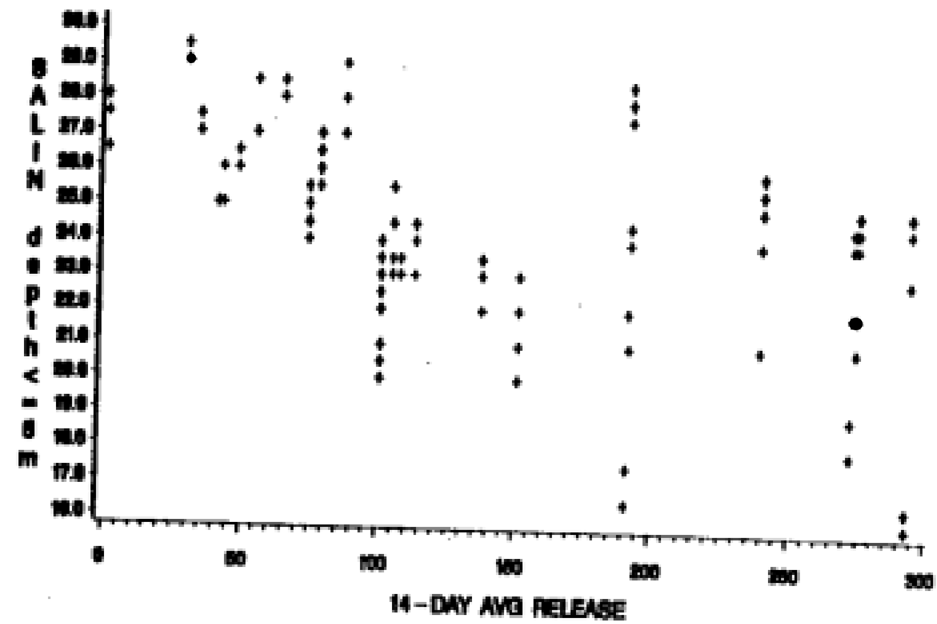


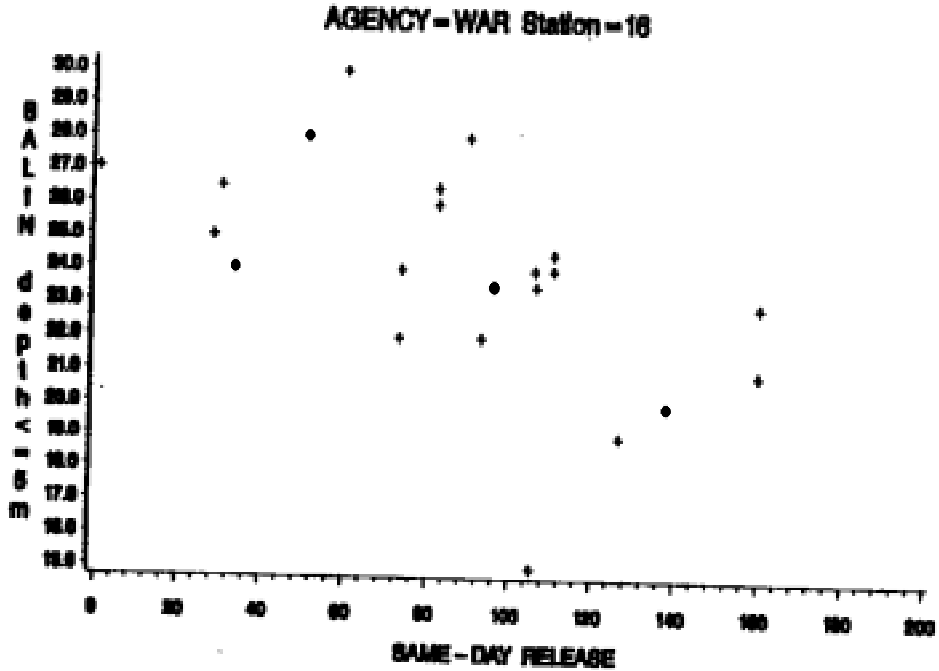
K10

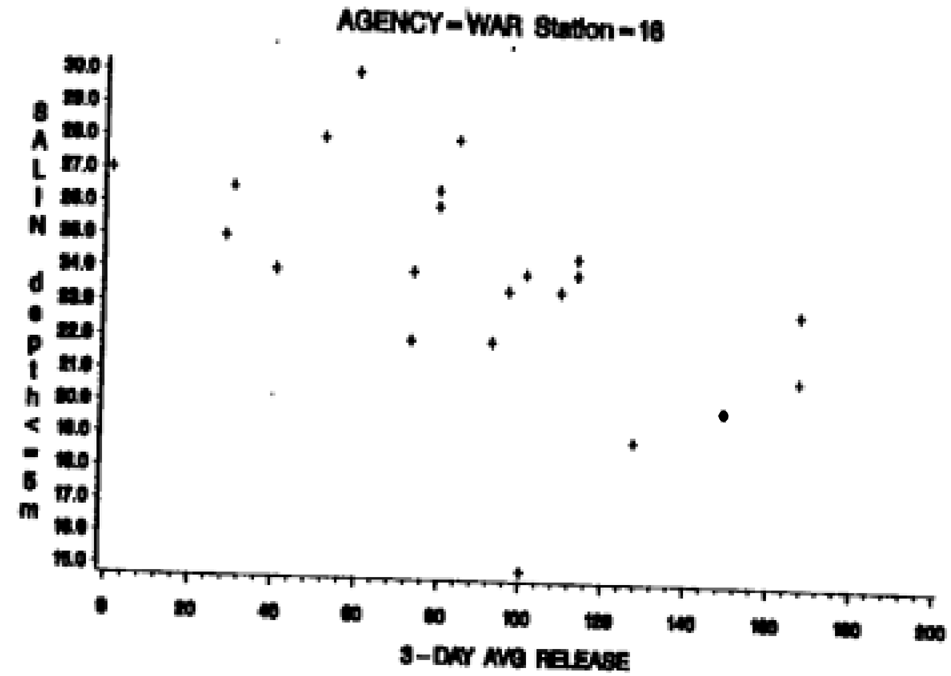
AGENCY=WAR Station=17



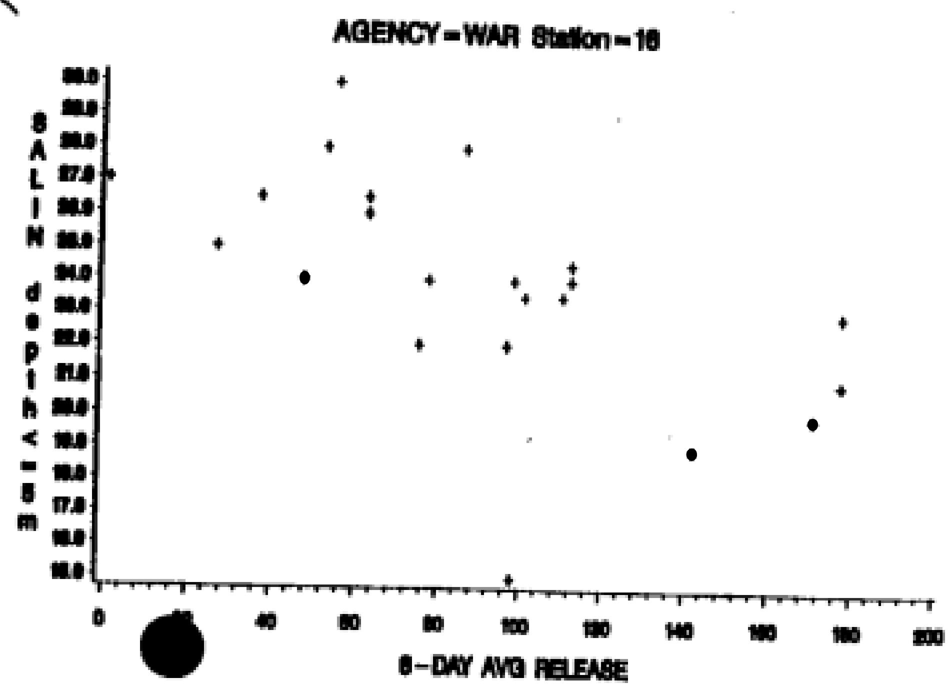
AGENCY=WAR Station=17

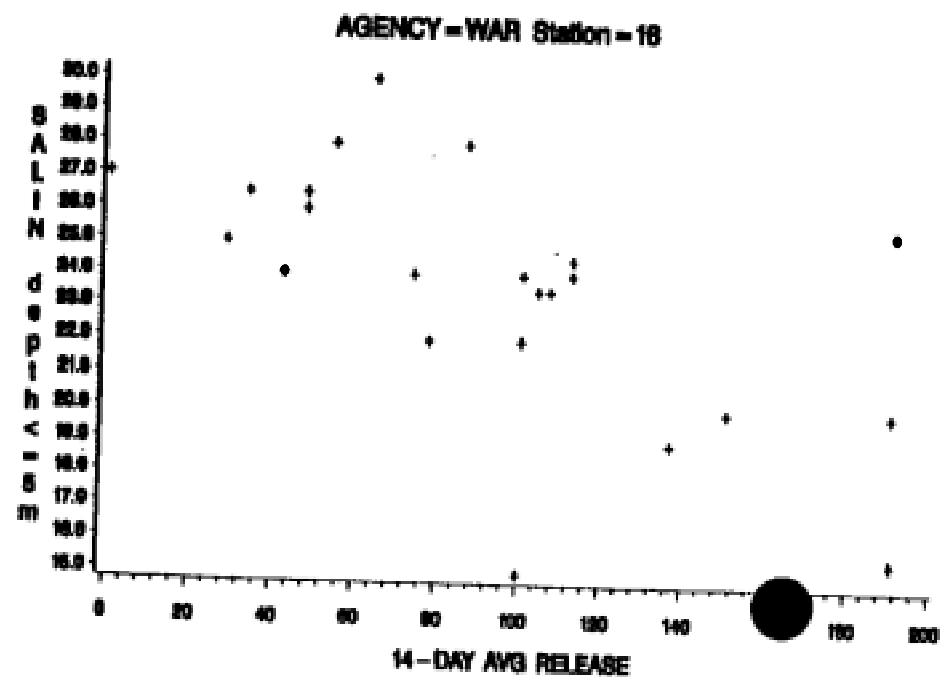



AGENCY=WAR Station=16
SALIN depth<=5m
SAME-DAY RELEASE

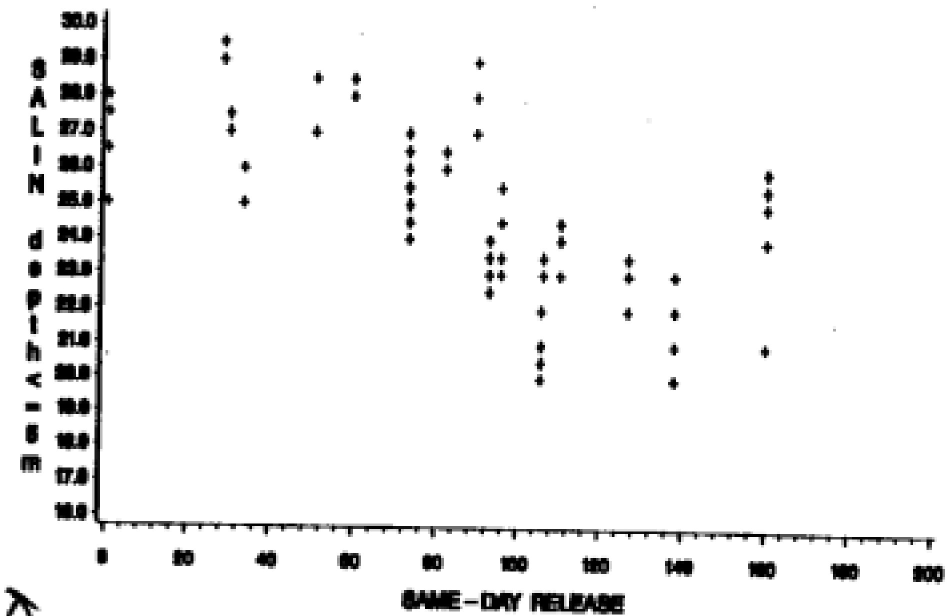

AGENCY=WAR Station=16
SALIN depth<=5m
3-DAY AVG RELEASE

K11

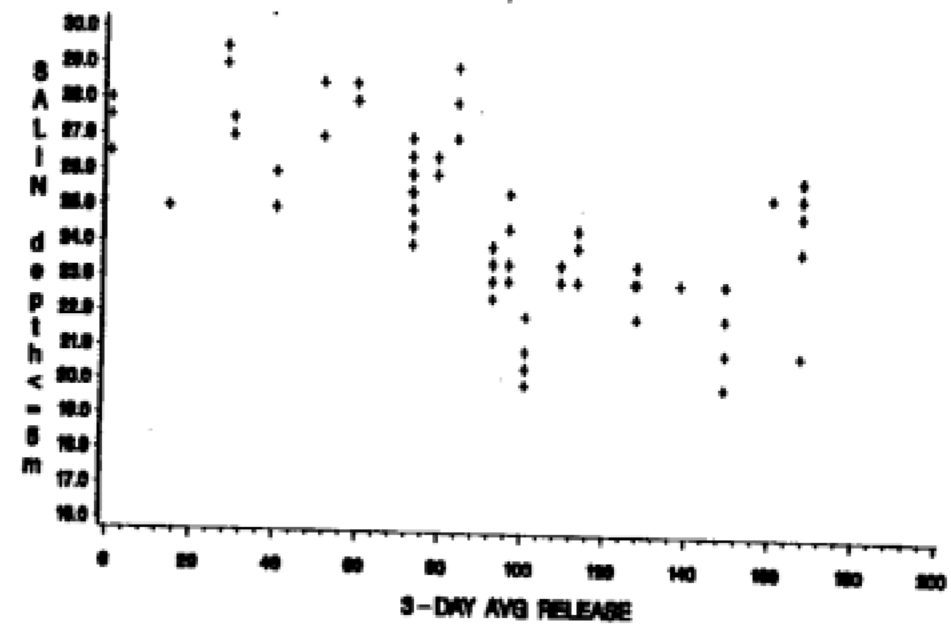

AGENCY=WAR Station=16
SALIN depth<=5m
6-DAY AVG RELEASE


AGENCY=WAR Station=16
SALIN depth<=5m
14-DAY AVG RELEASE

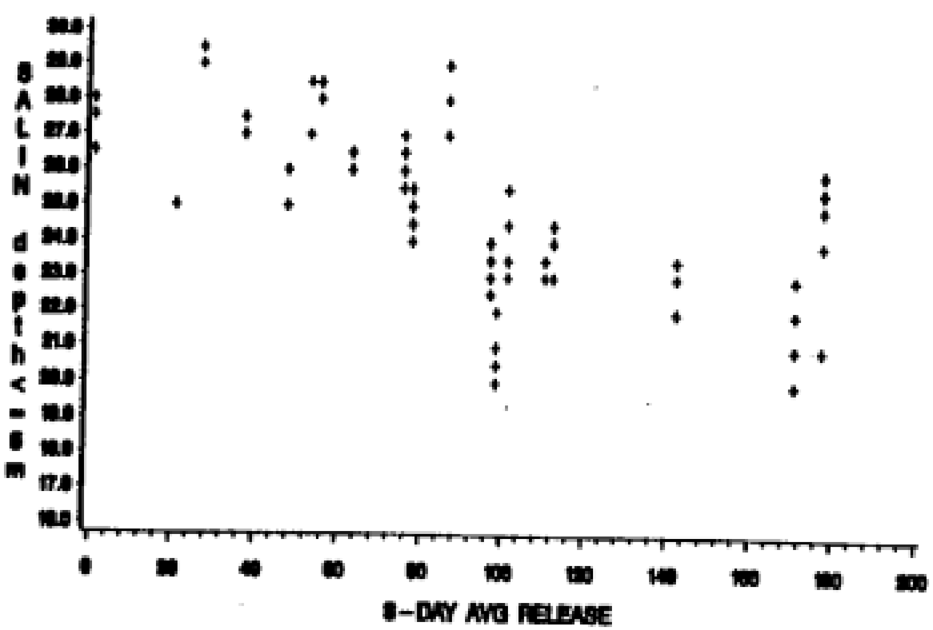
AGENCY=WAR Station=17



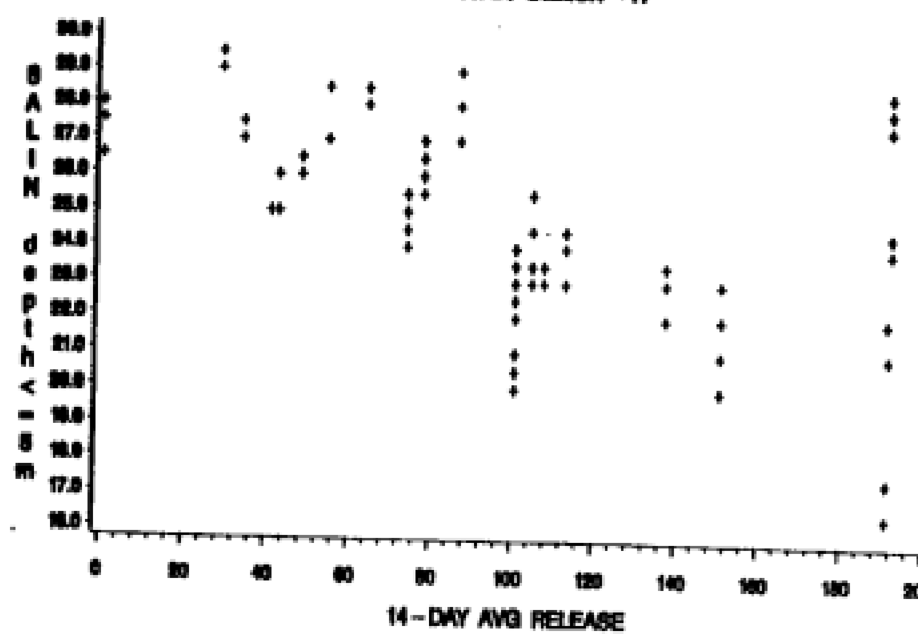
AGENCY=WAR Station=17



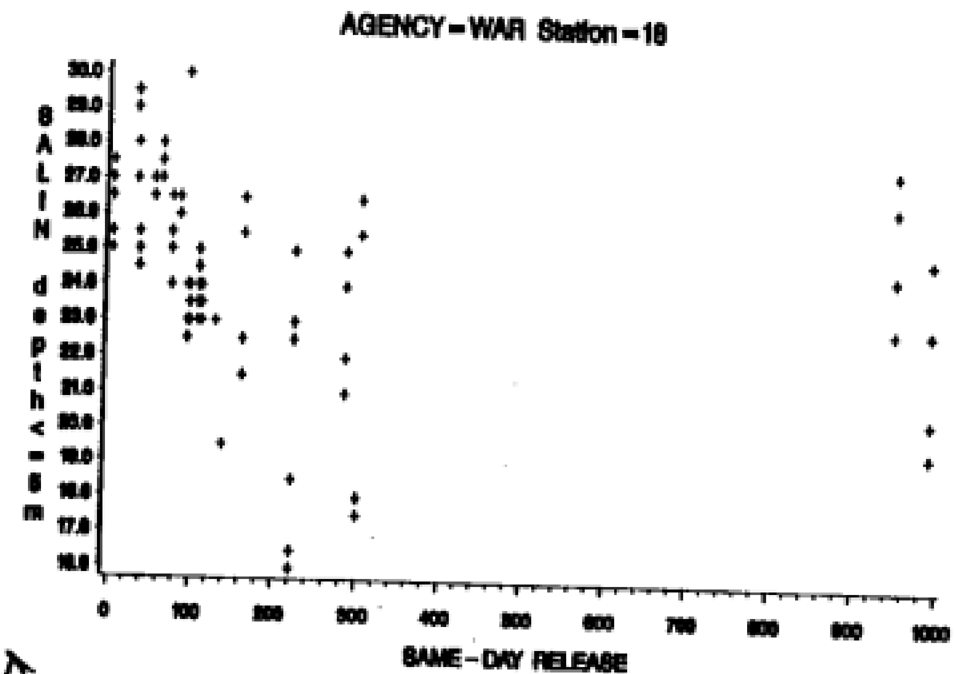
AGENCY=WAR Station=17

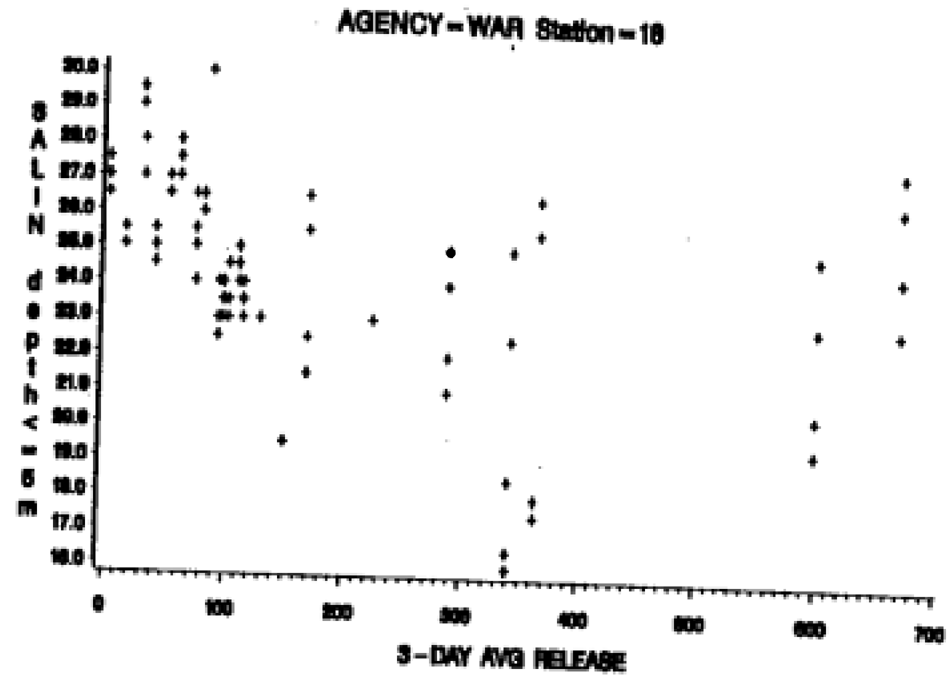


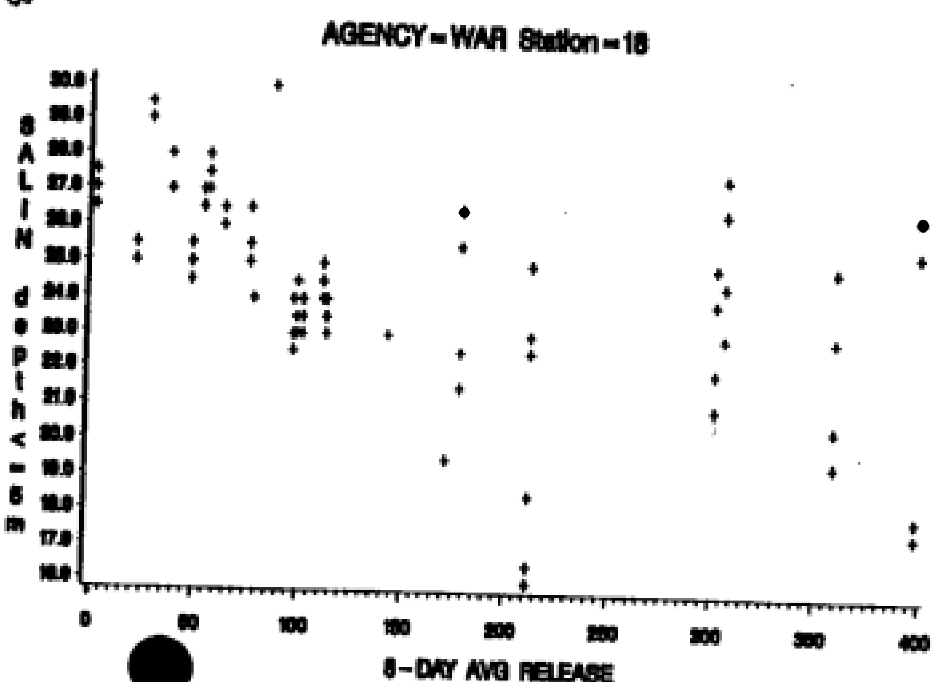
AGENCY=WAR Station=17

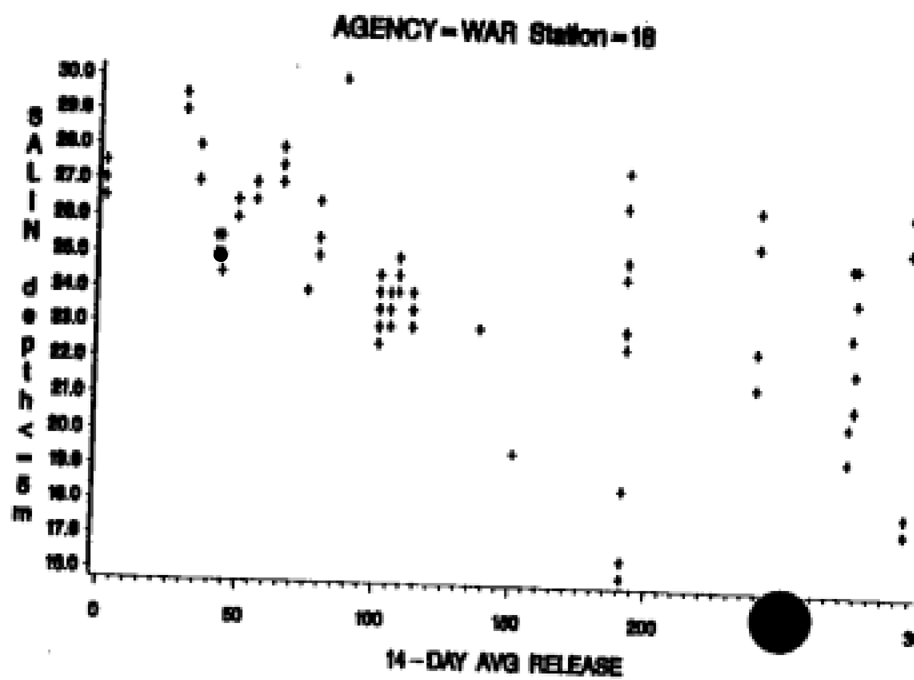


K12


AGENCY=WAR Station=18
SALIN depth<=5m
SAME-DAY RELEASE

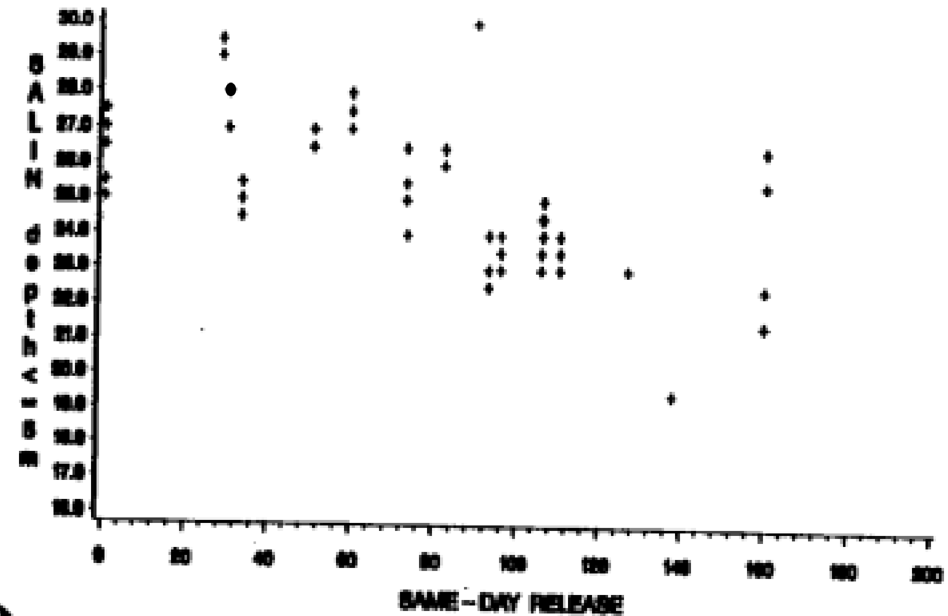

AGENCY=WAR Station=18
SALIN depth<=5m
3-DAY AVG RELEASE


AGENCY=WAR Station=18
SALIN depth<=5m
8-DAY AVG RELEASE

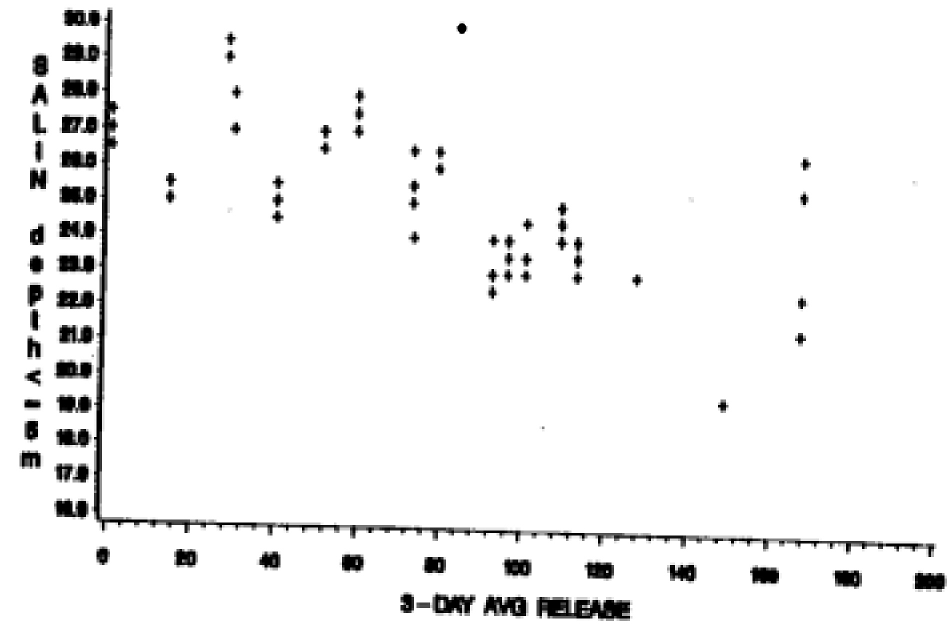

AGENCY=WAR Station=18
SALIN depth<=5m
14-DAY AVG RELEASE

K13

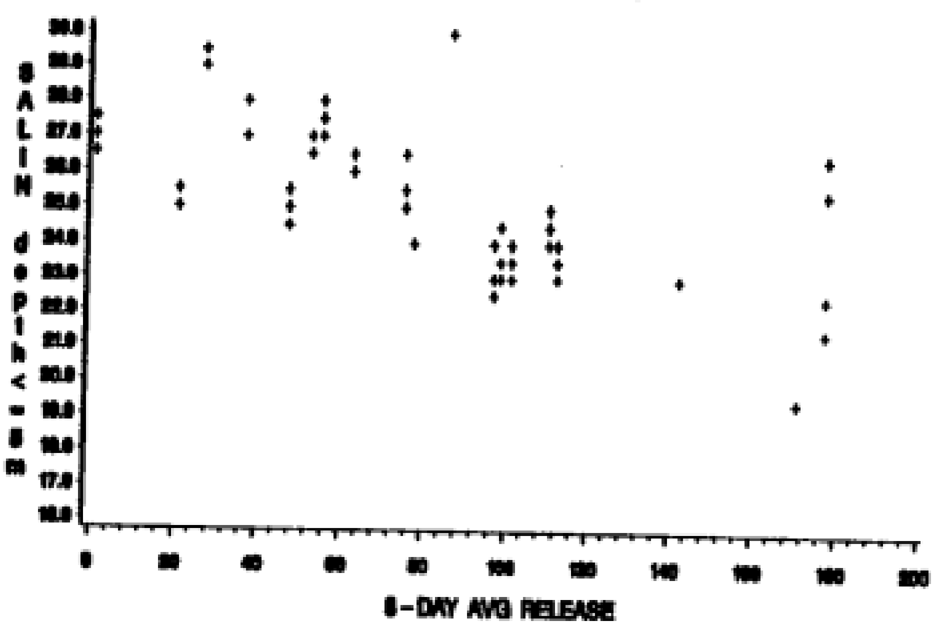
AGENCY=WAR Station=18



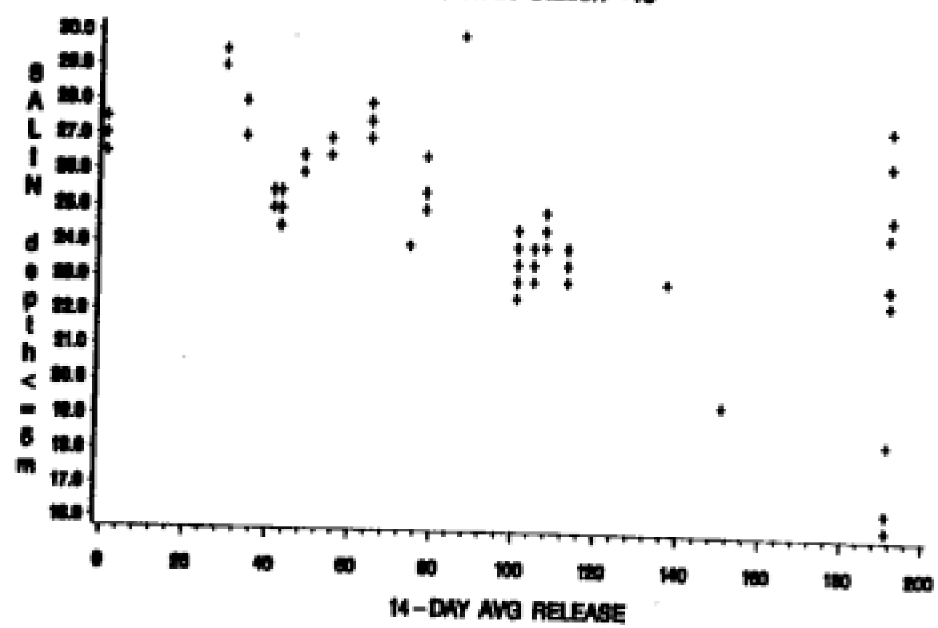
AGENCY=WAR Station=18



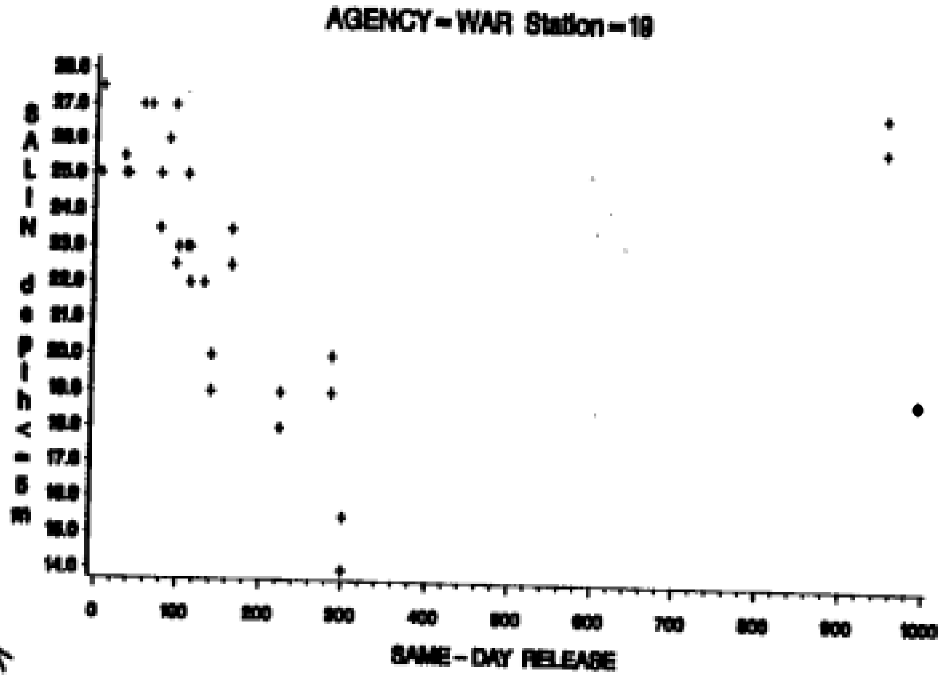
AGENCY=WAR Station=18

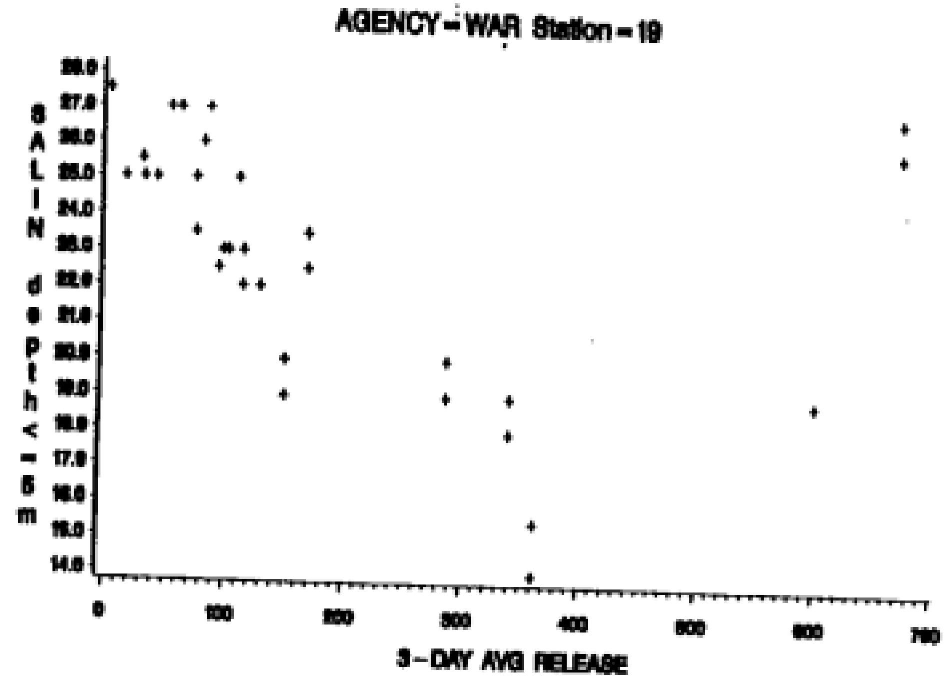


AGENCY=WAR Station=18

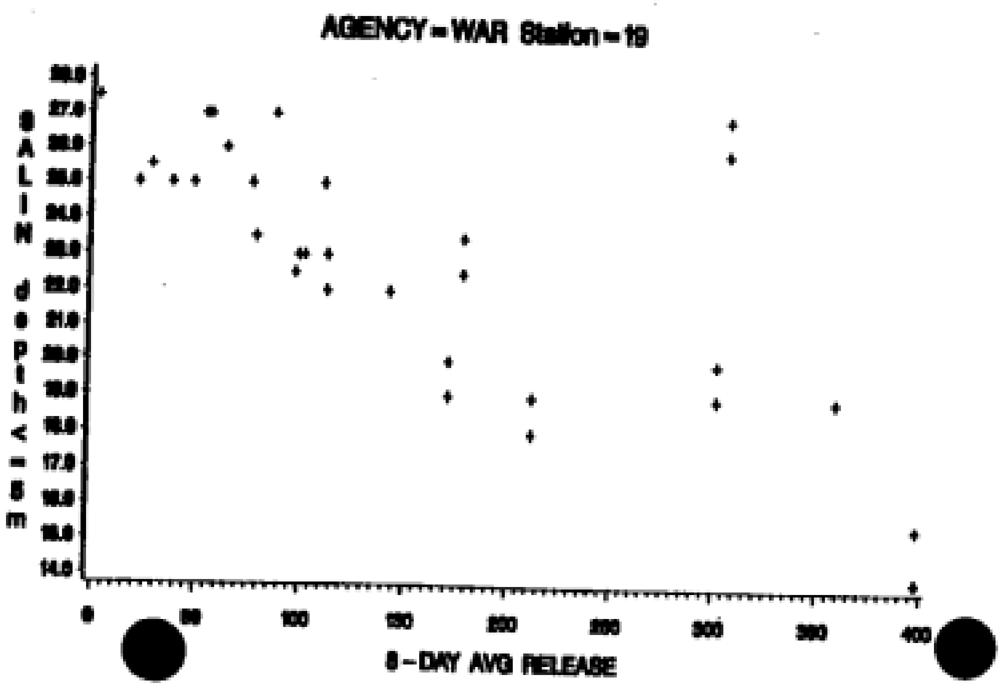


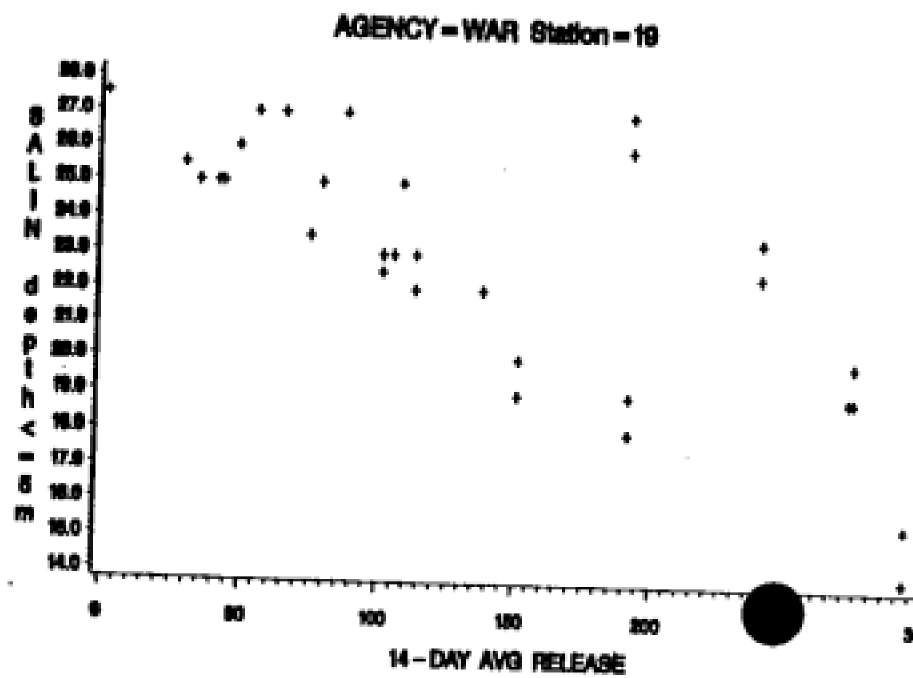
K14


AGENCY=WAR Station=19
SALIN depth<=5m
14.0 15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0 26.0 27.0 28.0
0 100 200 300 400 500 600 700 800 900 1000
SAME-DAY RELEASE

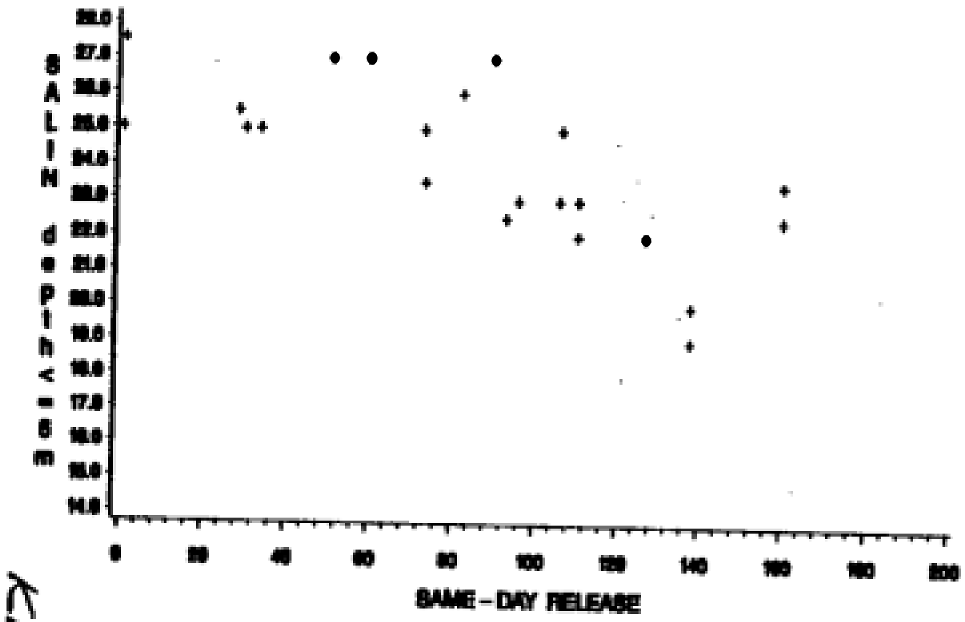

AGENCY=WAR Station=19
SALIN depth<=5m
14.0 15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0 26.0 27.0 28.0
0 100 200 300 400 500 600 700
3-DAY AVG RELEASE

K15

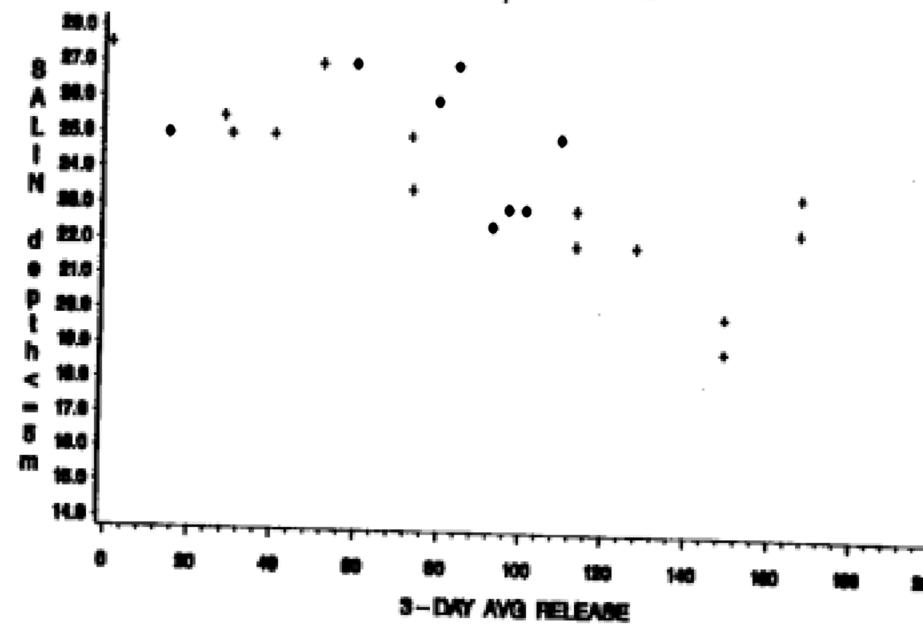

AGENCY=WAR Station=19
SALIN depth<=5m
14.0 15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0 26.0 27.0 28.0
0 50 100 150 200 250 300 350 400
8-DAY AVG RELEASE


AGENCY=WAR Station=19
SALIN depth<=5m
14.0 15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0 26.0 27.0 28.0
0 50 100 150 200 250 300
14-DAY AVG RELEASE

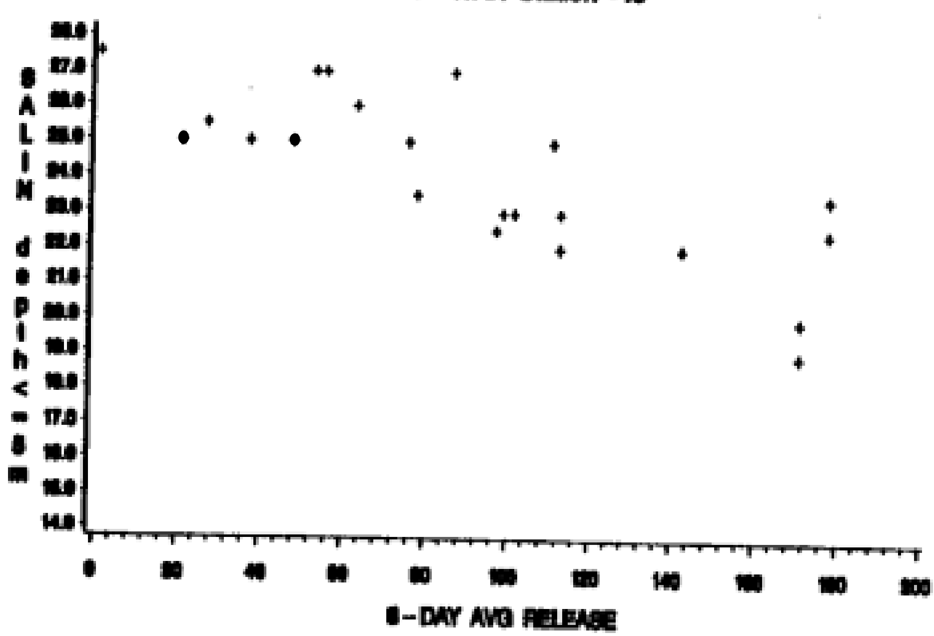
AGENCY=WAR Station=19



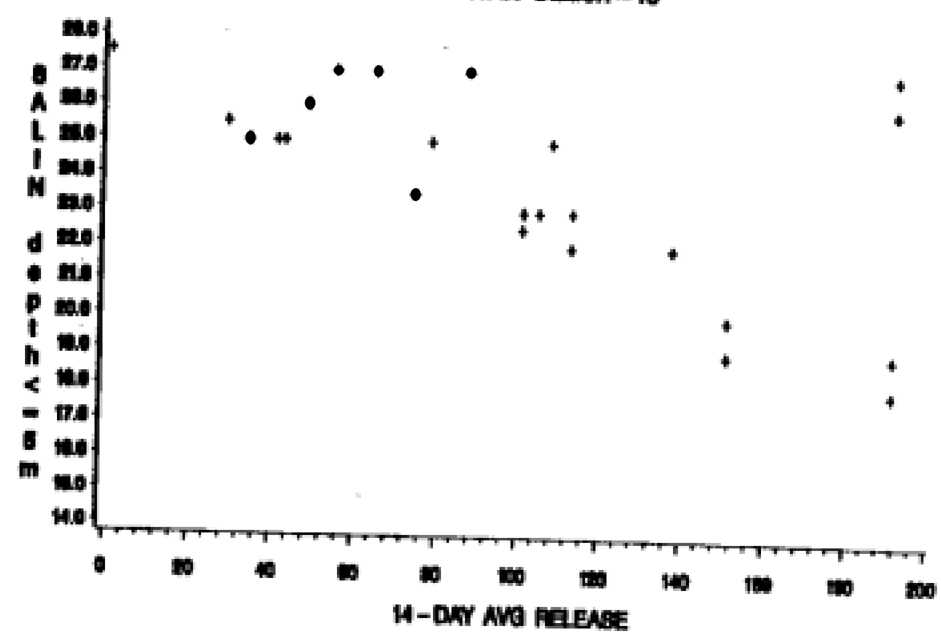
AGENCY=WAR Station=19



AGENCY=WAR Station=19



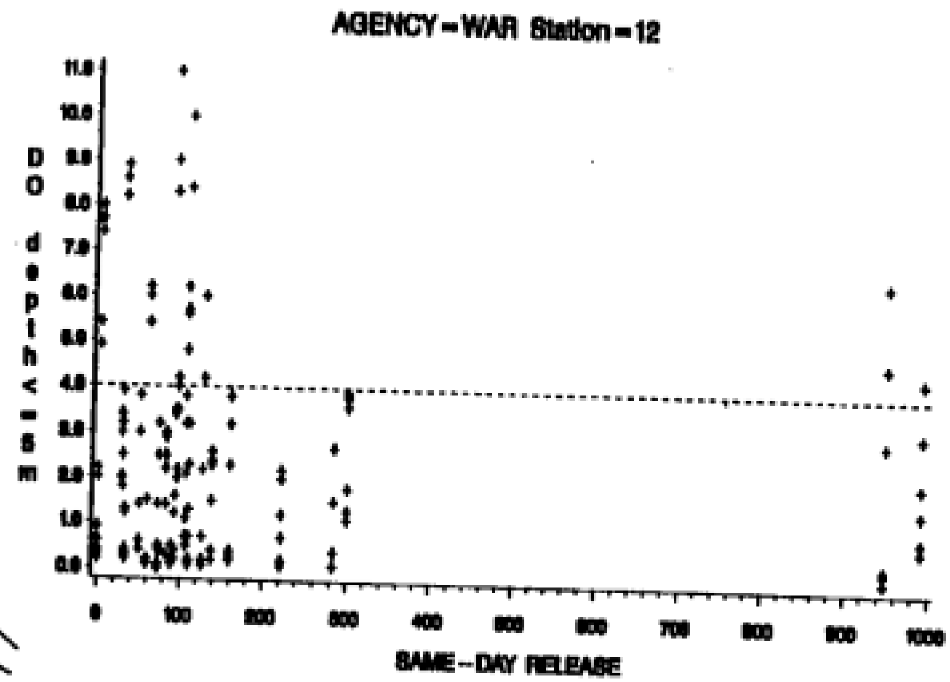
AGENCY=WAR Station=19



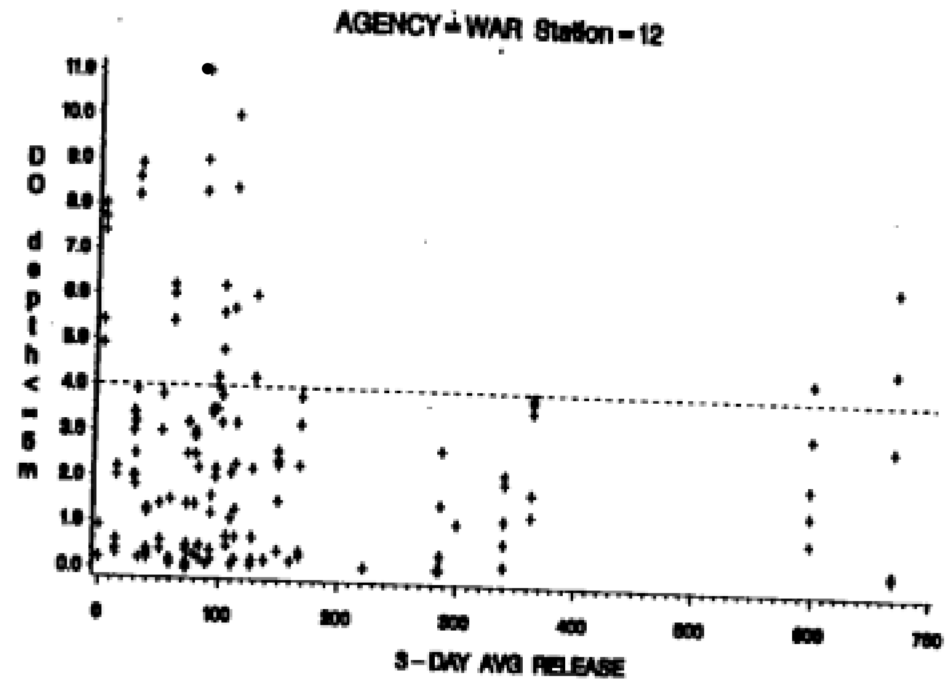
K16

APPENDIX L.

Plots of dissolved oxygen at the WAR/SDI stations in the Palm River/McKay Bay system vs. discharge from Structure 160 on the Tampa Bypass Canal. (All depths shown. Units are parts per thousand for salinity and cfs for discharge).

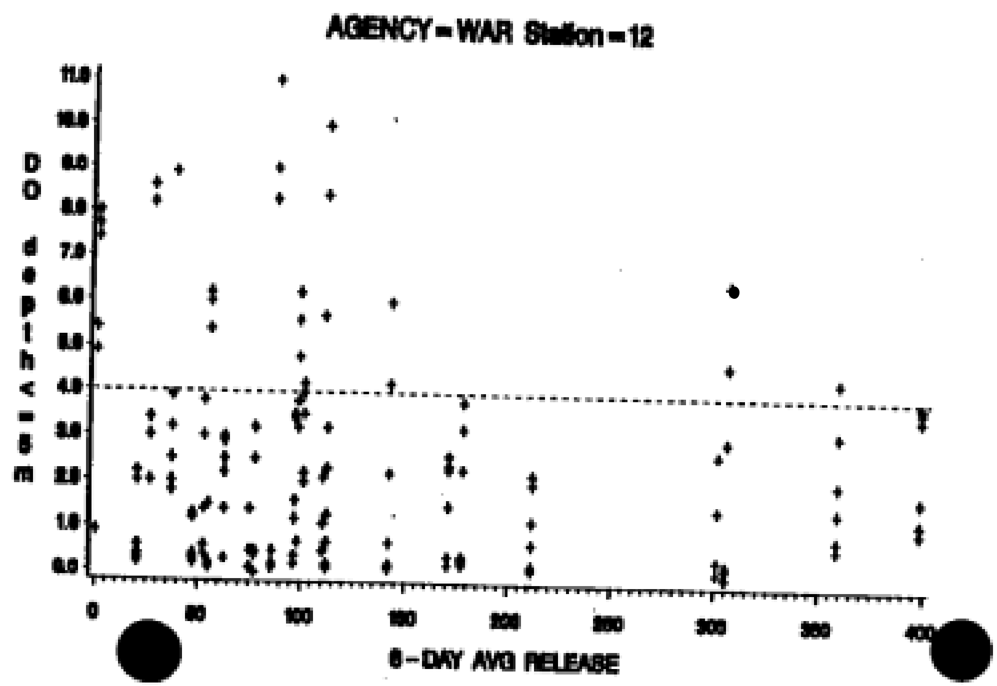


AGENCY = WAR Station = 12
DO depth <= 5 m
SAME-DAY RELEASE

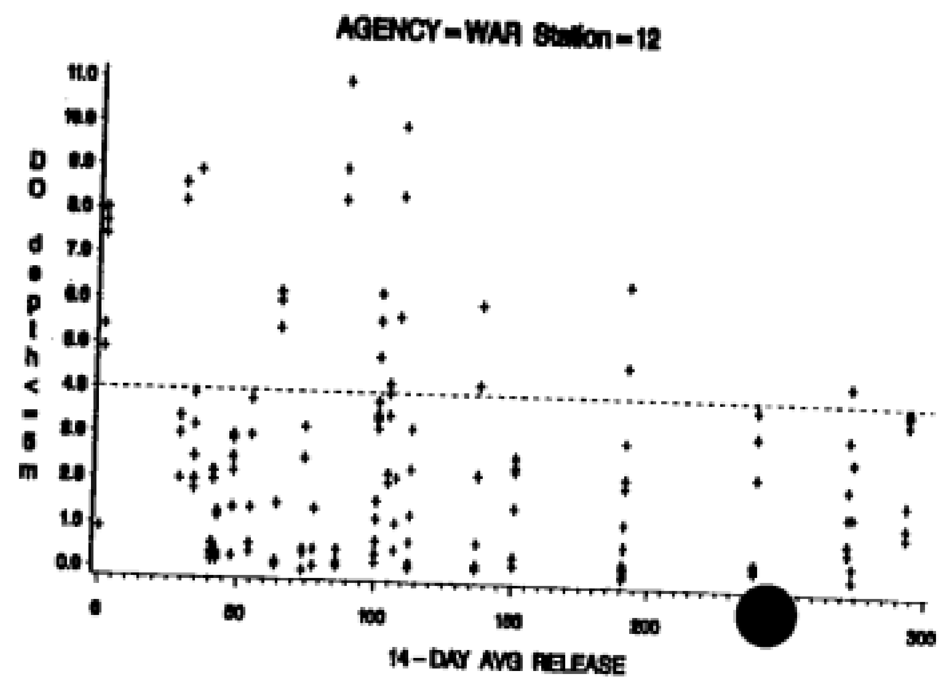


AGENCY = WAR Station = 12
DO depth <= 5 m
3-DAY AVG RELEASE

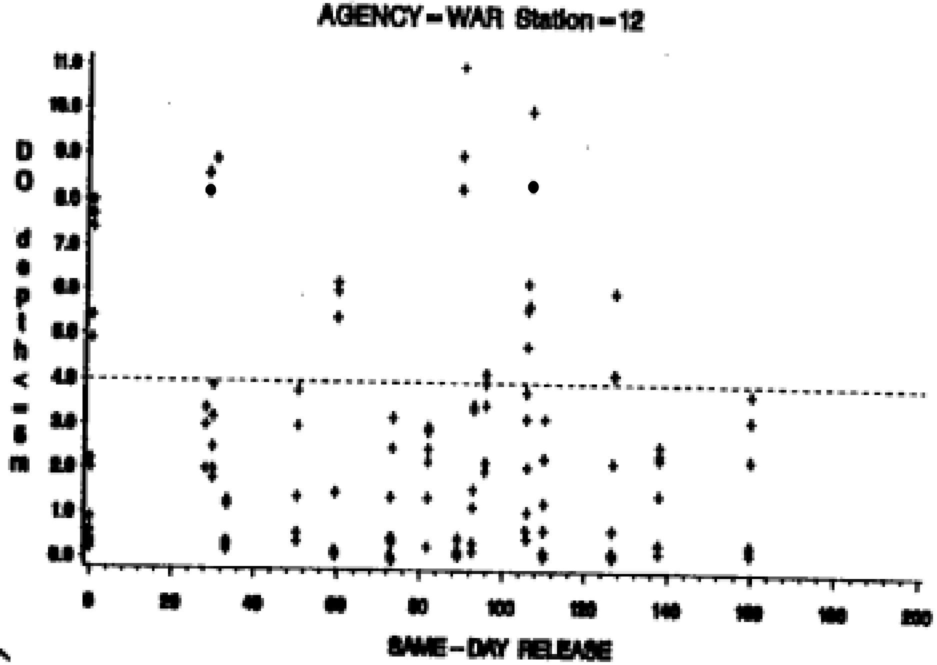
17

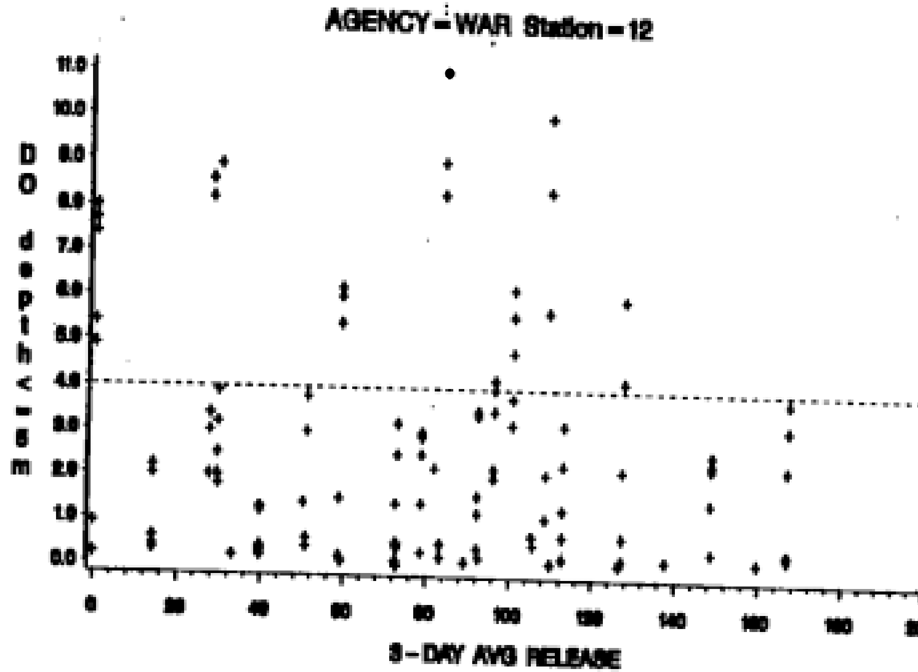


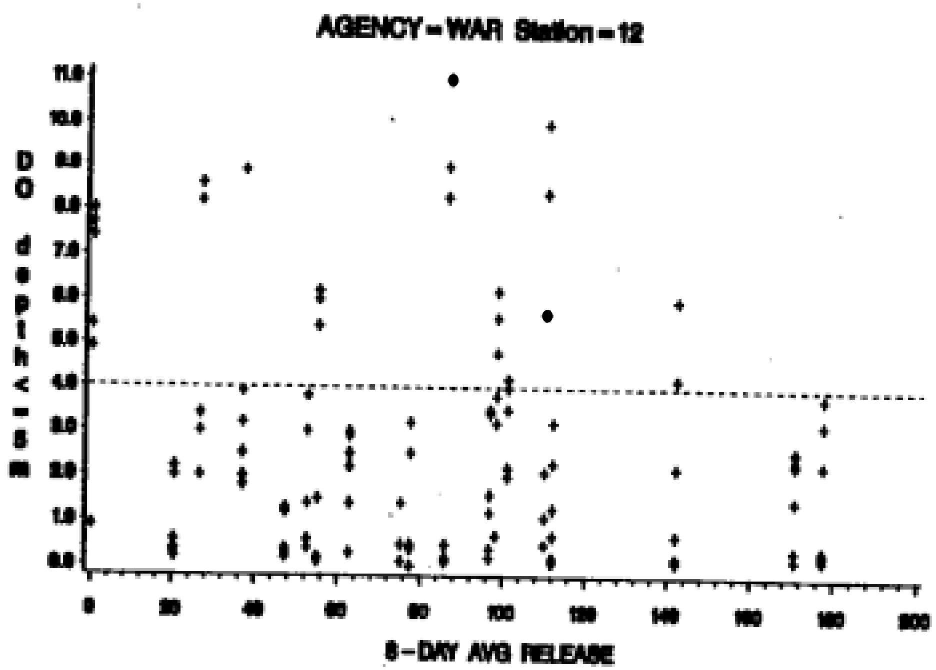
AGENCY = WAR Station = 12
DO depth <= 5 m
6-DAY AVG RELEASE

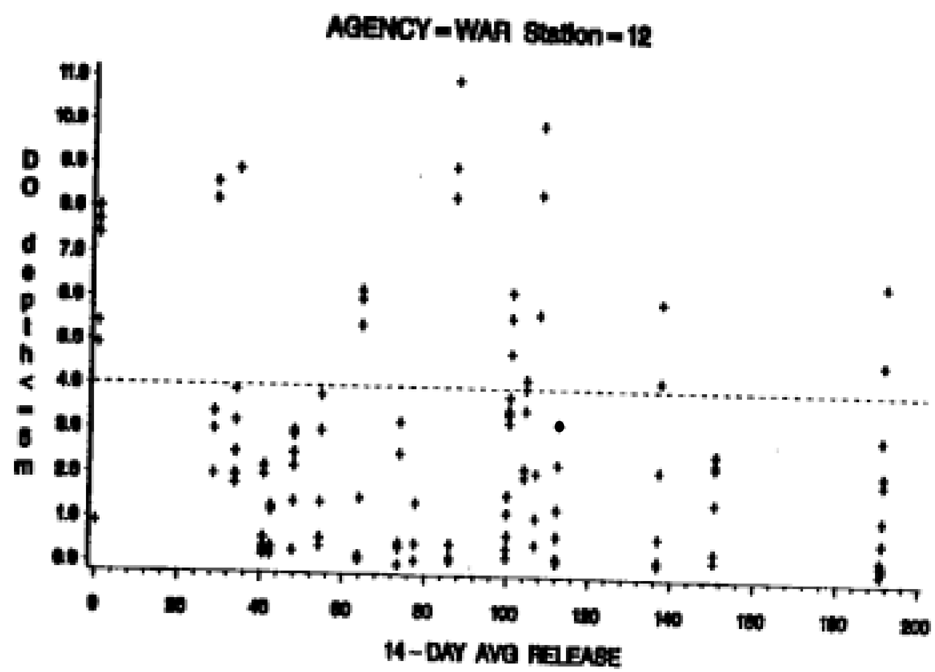


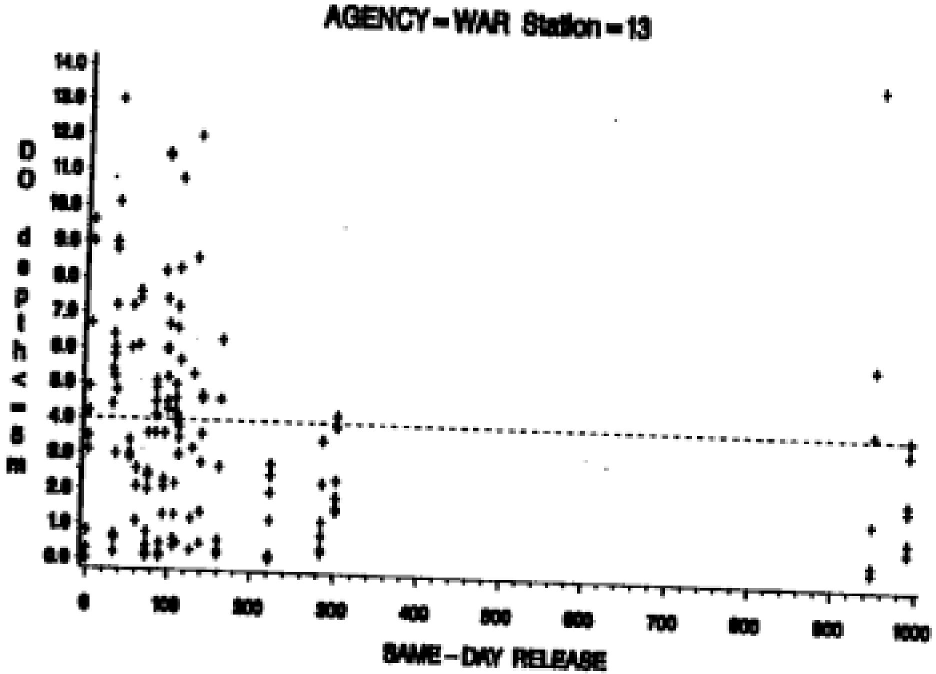
AGENCY = WAR Station = 12
DO depth <= 5 m
14-DAY AVG RELEASE

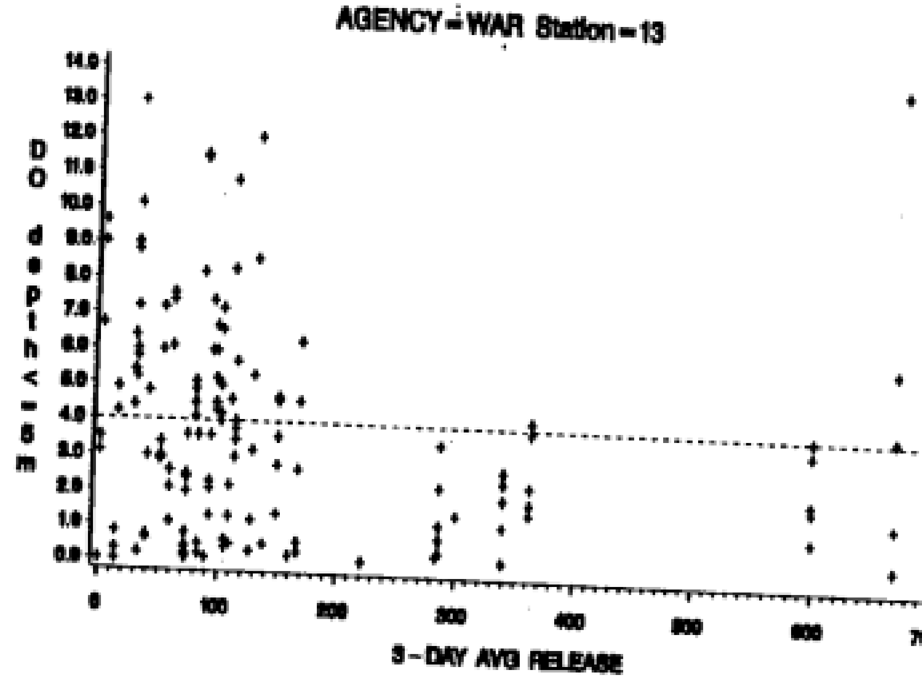

AGENCY=WAR Station=12
DO depth<=5m
SAME-DAY RELEASE

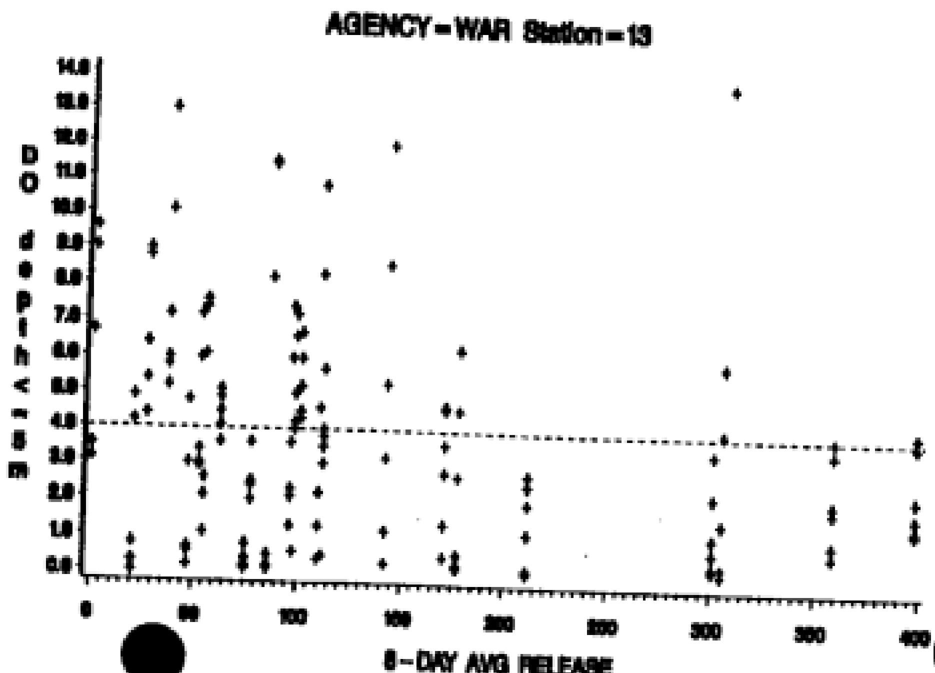

AGENCY=WAR Station=12
DO depth<=5m
3-DAY AVG RELEASE

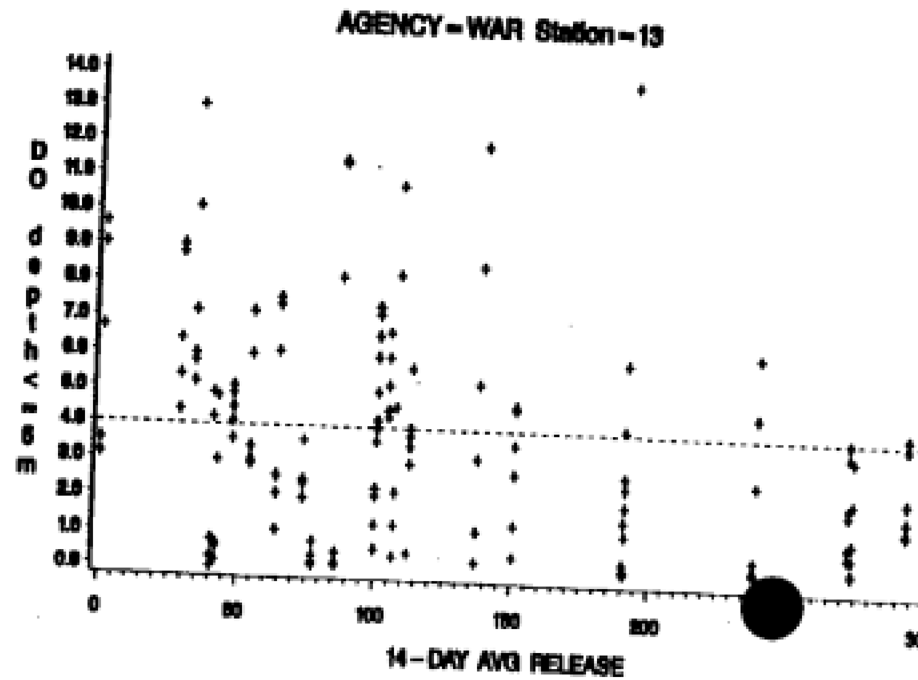

AGENCY=WAR Station=12
DO depth<=5m
6-DAY AVG RELEASE

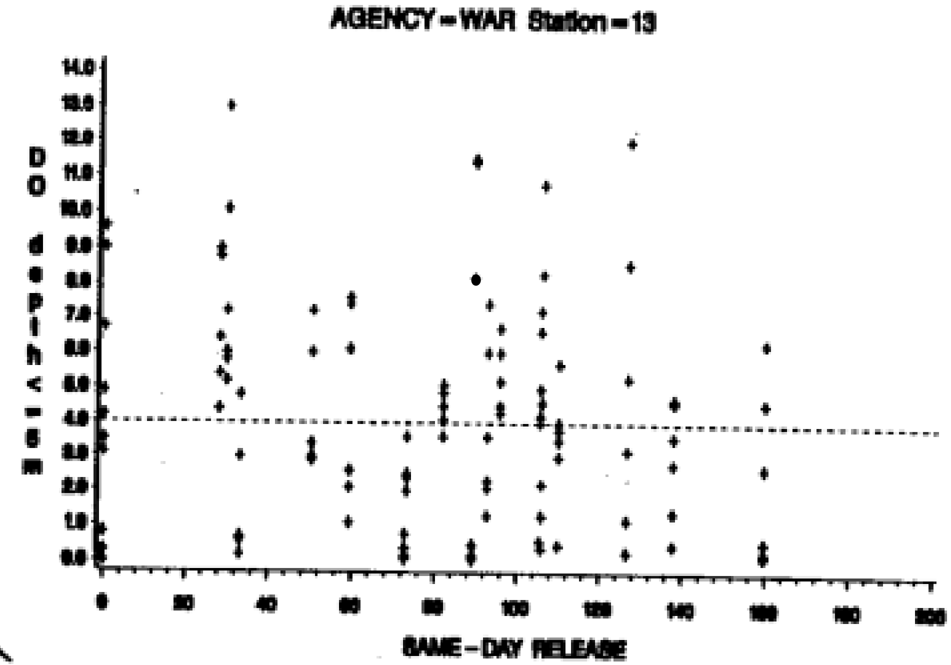

AGENCY=WAR Station=12
DO depth<=5m
14-DAY AVG RELEASE


AGENCY=WAR Station=13
DO depth
SAME-DAY RELEASE
0 100 200 300 400 500 600 700 800 900 1000

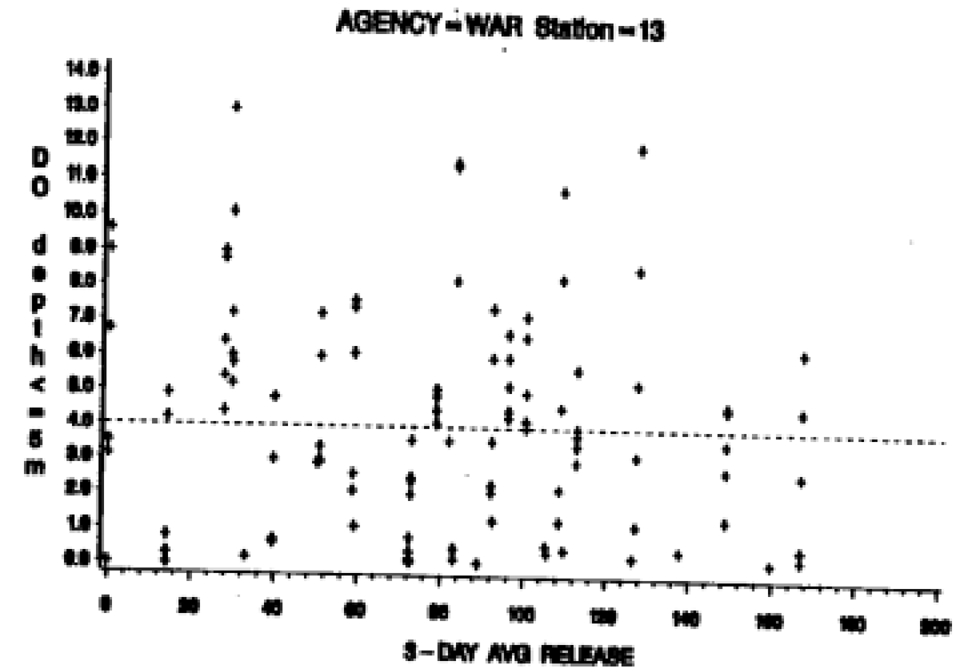

AGENCY=WAR Station=13
DO depth
3-DAY AVG RELEASE
0 100 200 300 400 500 600 700


AGENCY=WAR Station=13
DO depth
8-DAY AVG RELEASE
0 50 100 150 200 250 300 350 400

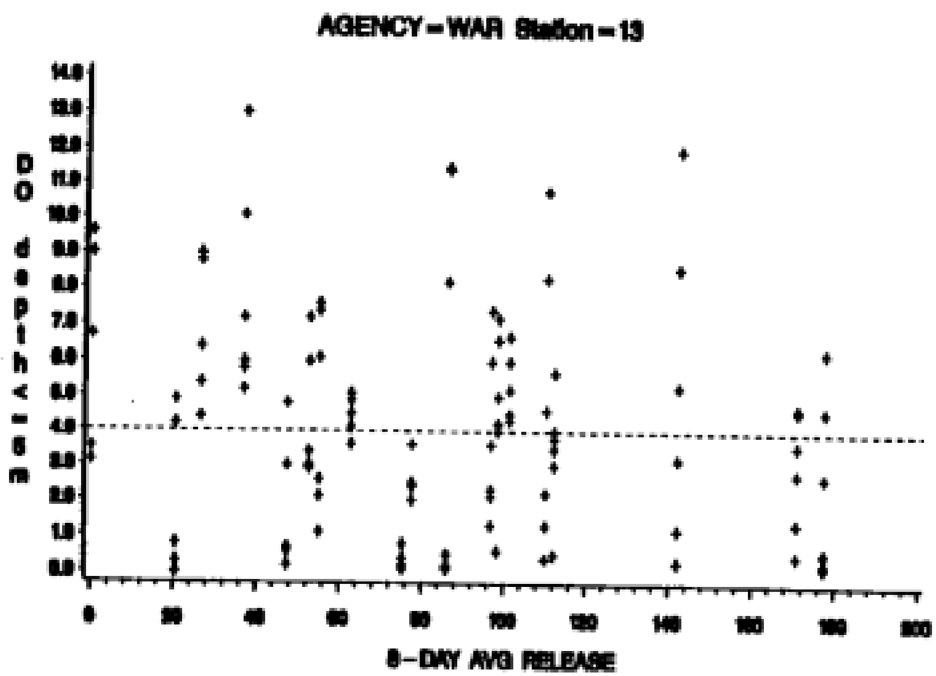

AGENCY=WAR Station=13
DO depth
14-DAY AVG RELEASE
0 50 100 150 200 250 300



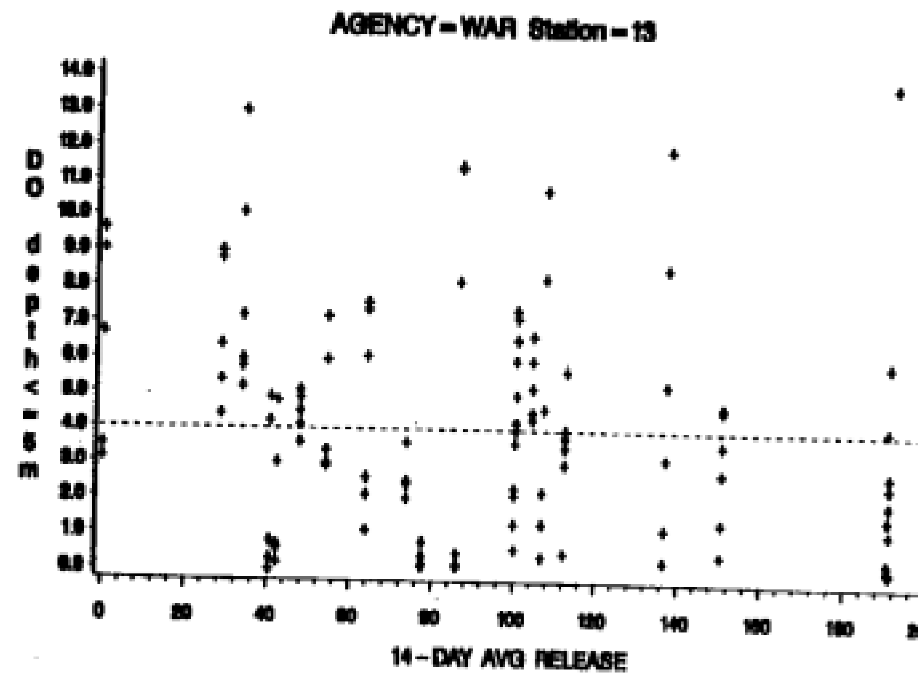
AGENCY=WAR Station=13
DO depth<=5m
SAME-DAY RELEASE



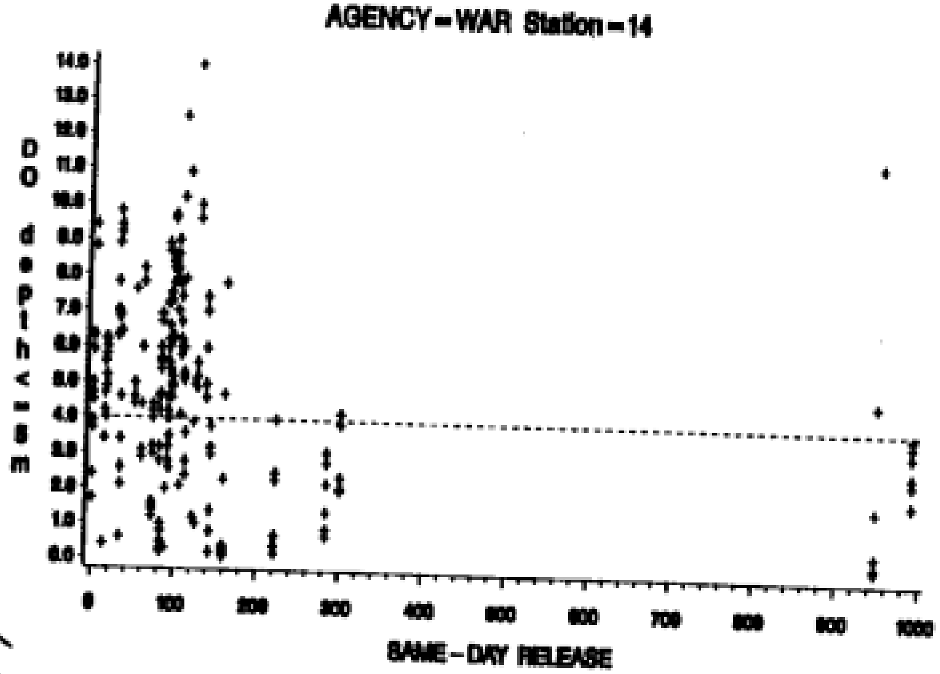
AGENCY=WAR Station=13
DO depth<=5m
3-DAY AVG RELEASE

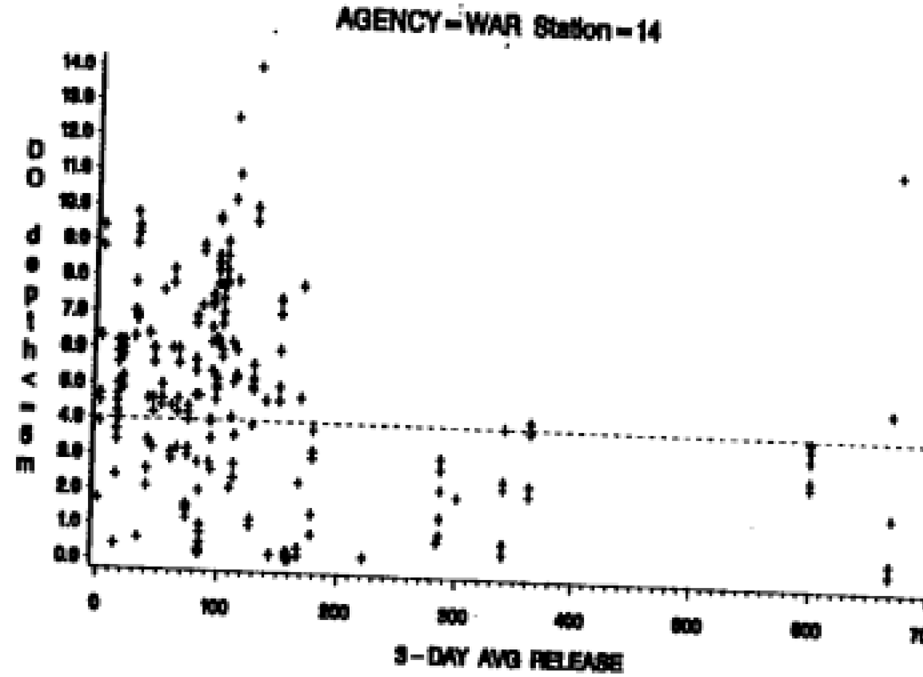


AGENCY=WAR Station=13
DO depth<=5m
8-DAY AVG RELEASE

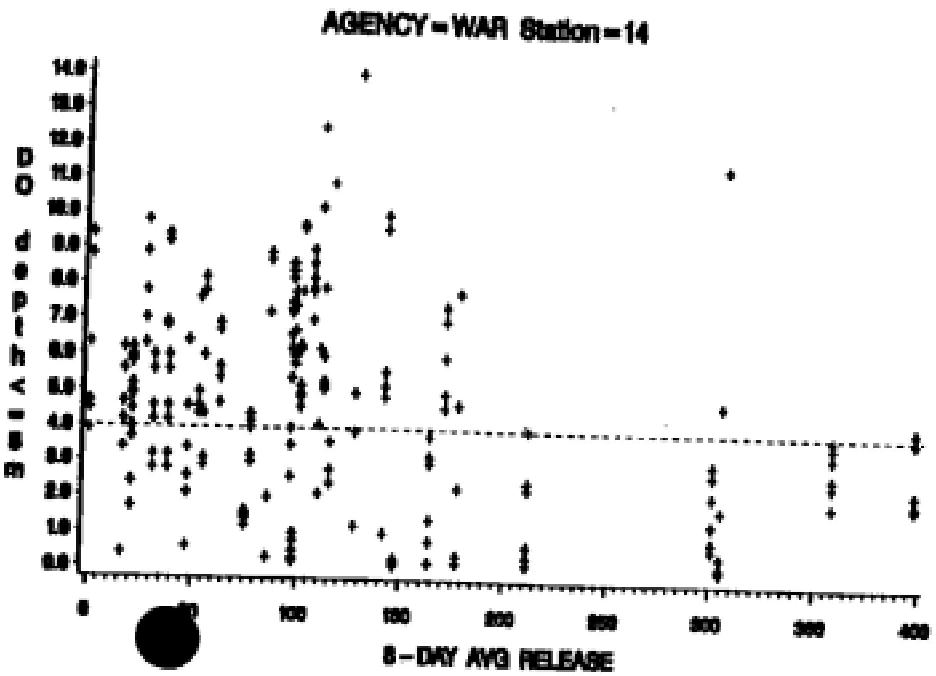


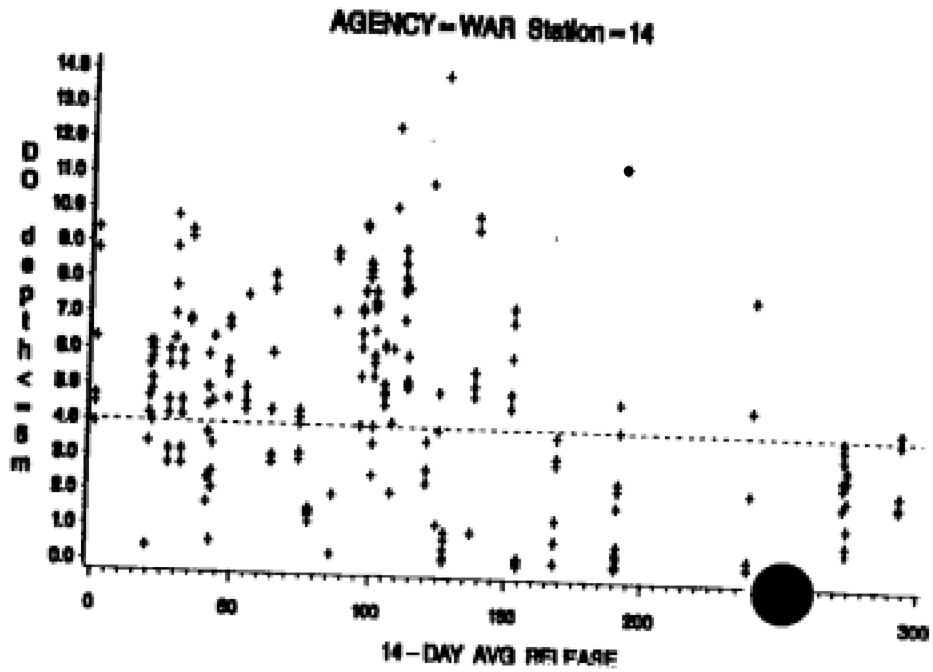
AGENCY=WAR Station=13
DO depth<=5m
14-DAY AVG RELEASE

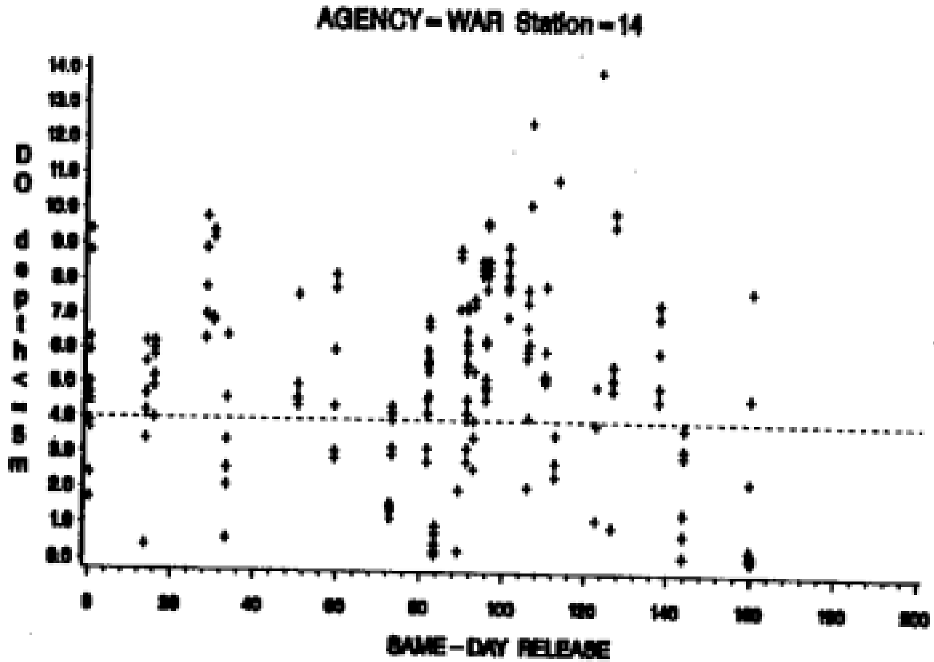

AGENCY=WAR Station=14
DO depth<5m
SAME-DAY RELEASE

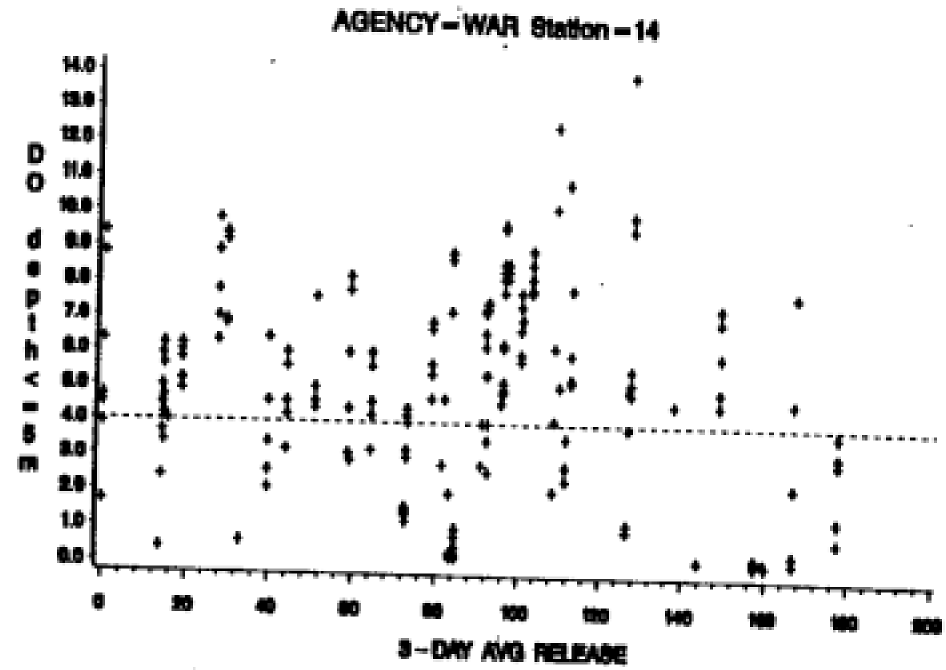

AGENCY=WAR Station=14
DO depth<5m
3-DAY AVG RELEASE

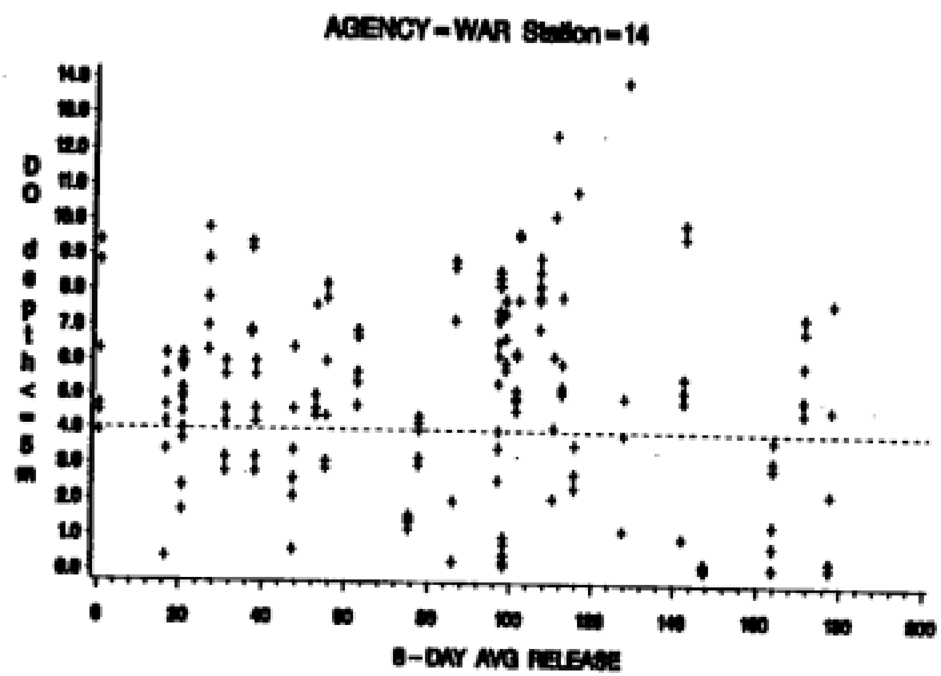
97

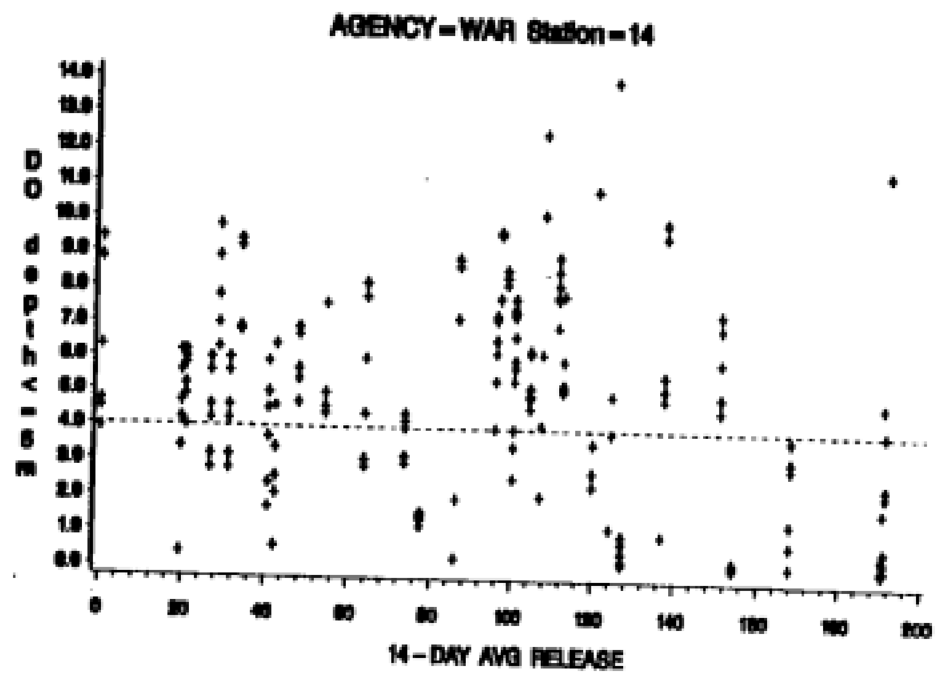

AGENCY=WAR Station=14
DO depth<5m
8-DAY AVG RELEASE

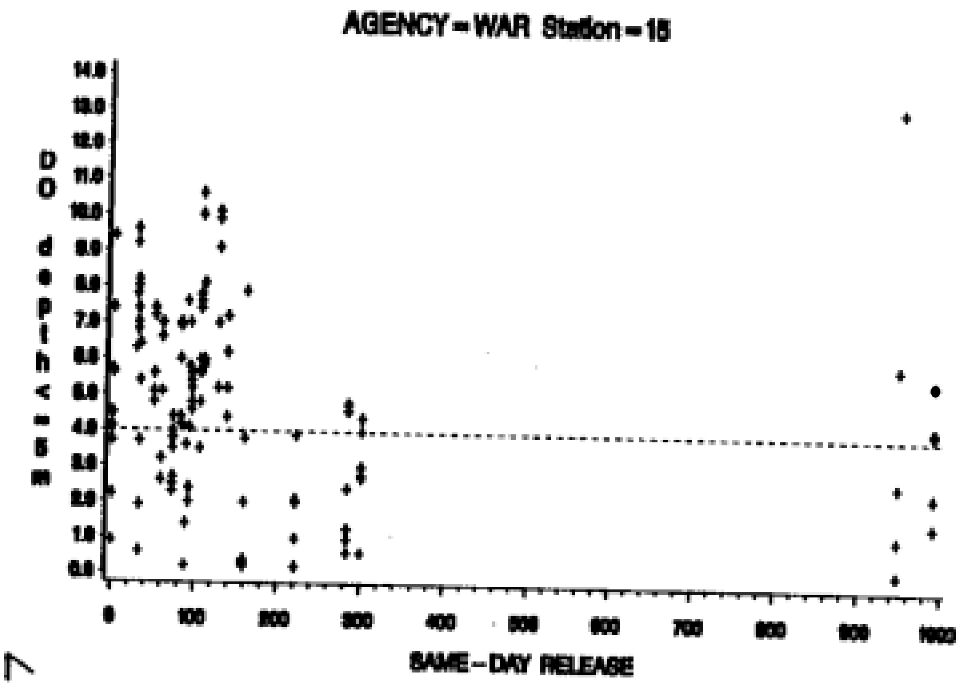

AGENCY=WAR Station=14
DO depth<5m
14-DAY AVG RELEASE

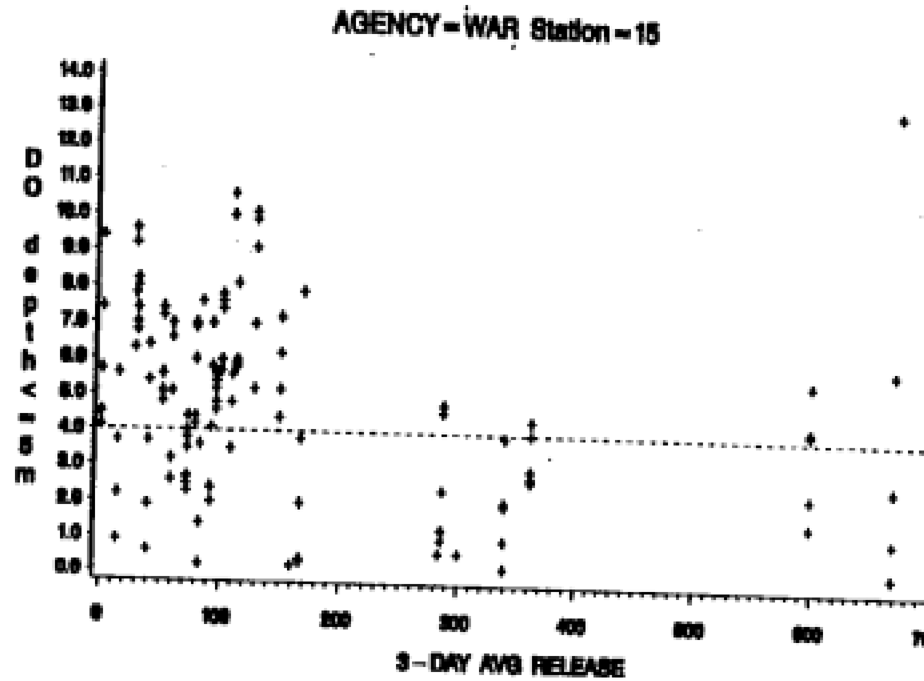

AGENCY=WAR Station=14
DO depth<=5m
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
20
40
60
80
100
120
140
160
180
200
SAME-DAY RELEASE

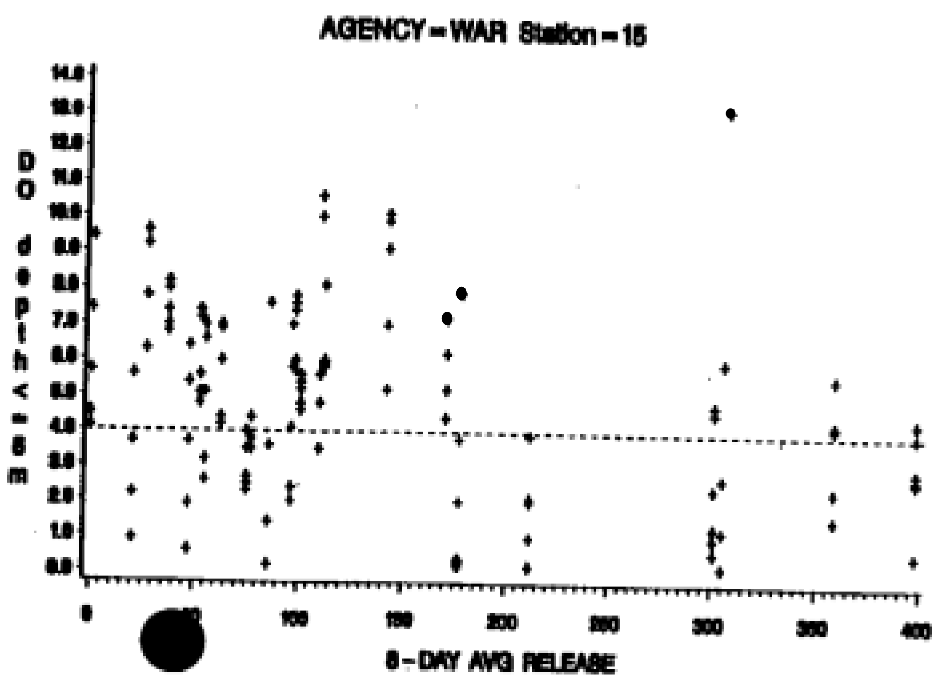

AGENCY=WAR Station=14
DO depth<=5m
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
20
40
60
80
100
120
140
160
180
200
3-DAY AVG RELEASE

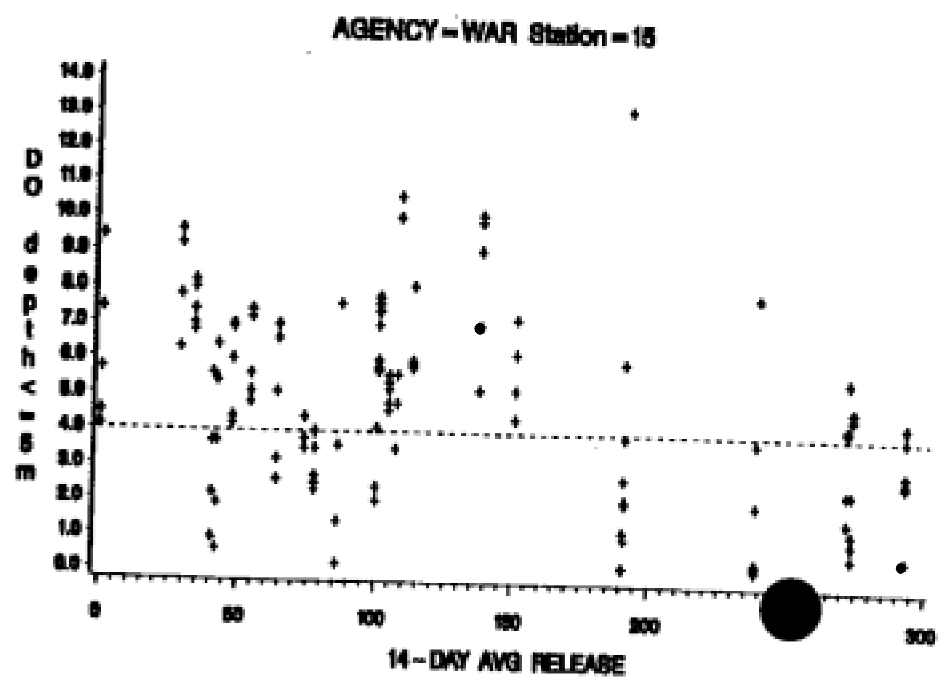

AGENCY=WAR Station=14
DO depth<=5m
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
20
40
60
80
100
120
140
160
180
200
8-DAY AVG RELEASE


AGENCY=WAR Station=14
DO depth<=5m
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
20
40
60
80
100
120
140
160
180
200
14-DAY AVG RELEASE

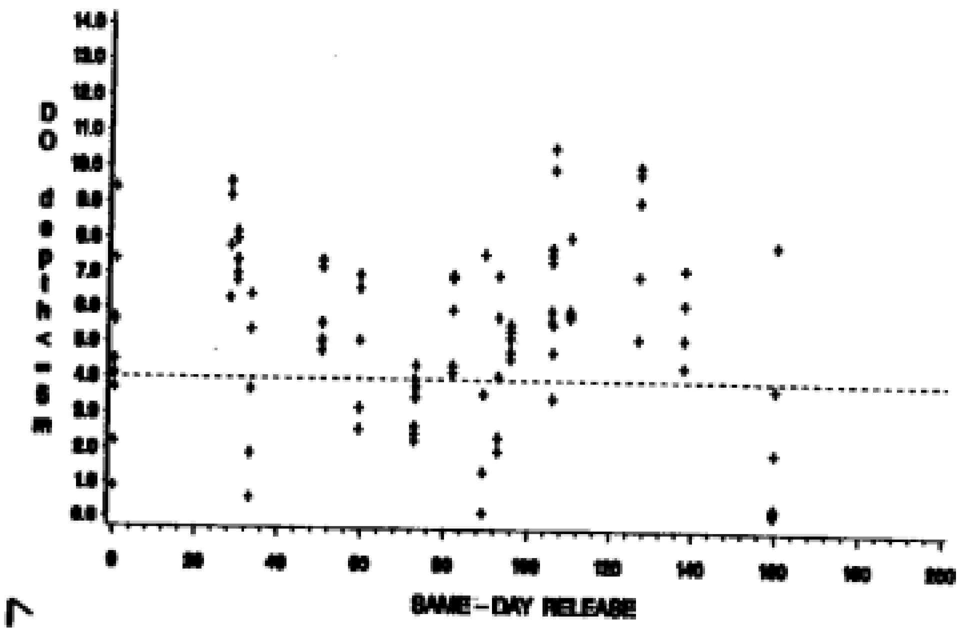

AGENCY=WAR Station=15
DO depth<=5m
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0
0 100 200 300 400 500 600 700 800 900 1000
SAME-DAY RELEASE


AGENCY=WAR Station=15
DO depth<=5m
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0
0 100 200 300 400 500 600 700
3-DAY AVG RELEASE

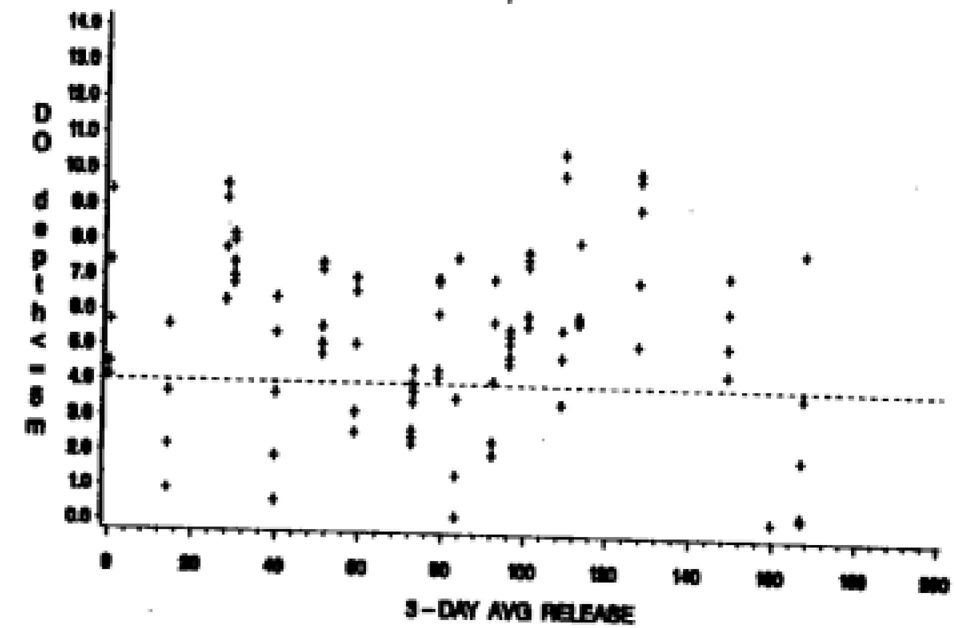

AGENCY=WAR Station=15
DO depth<=5m
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0
0 100 150 200 250 300 350 400
5-DAY AVG RELEASE


AGENCY=WAR Station=15
DO depth<=5m
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0
0 50 100 150 200 300
14-DAY AVG RELEASE

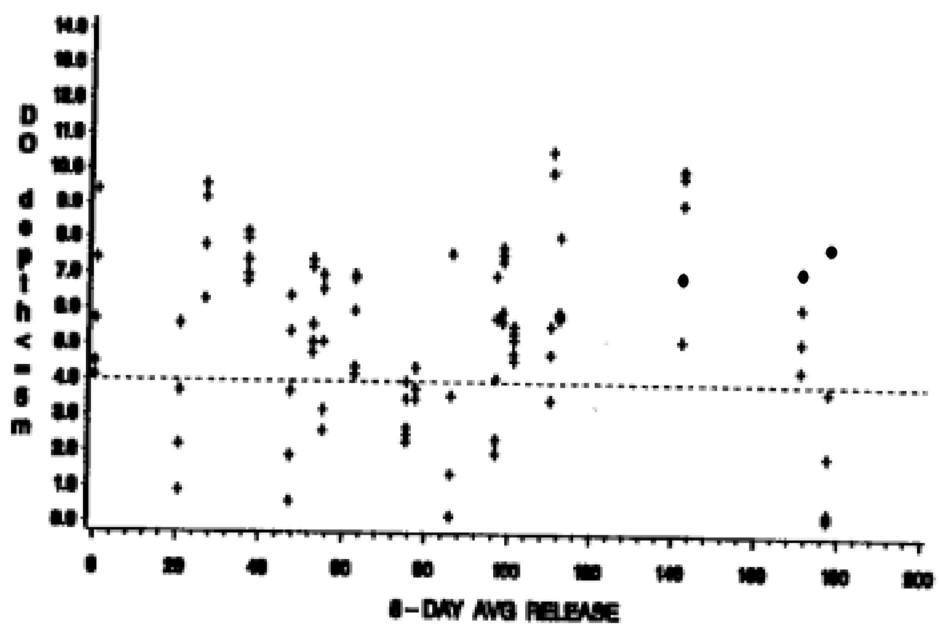
AGENCY=WAR Station=15



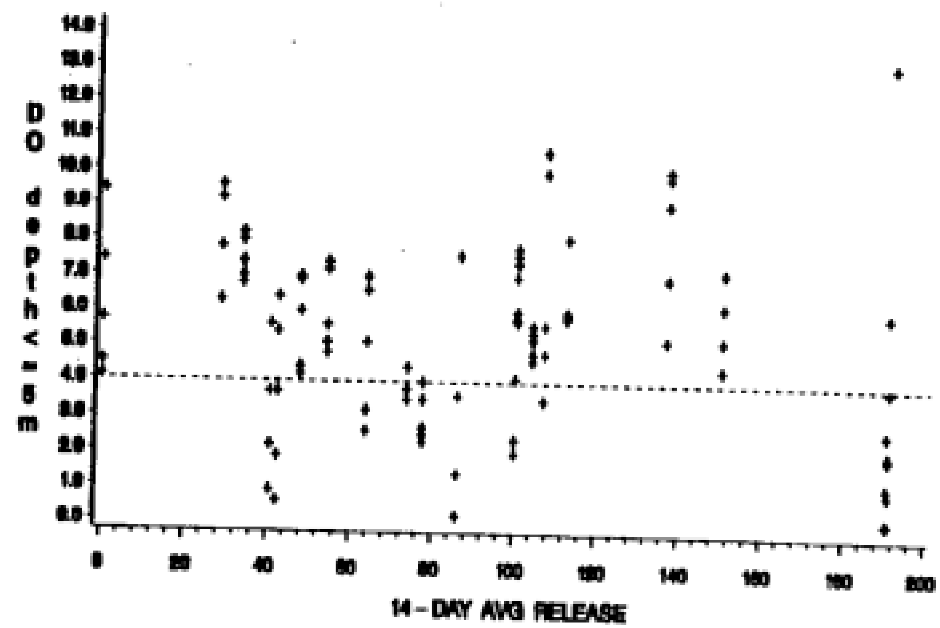
AGENCY=WAR Station=15



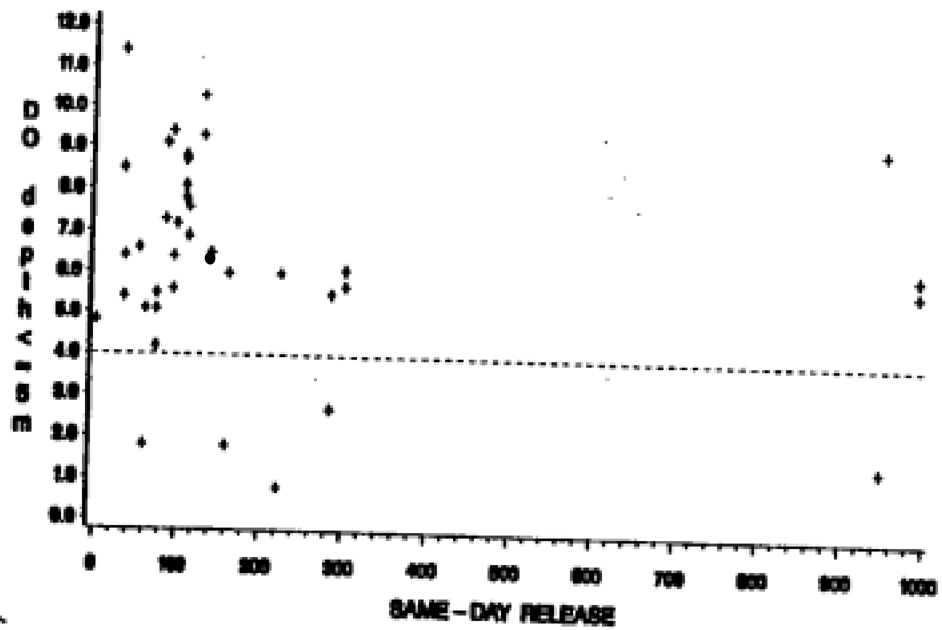
AGENCY=WAR Station=15



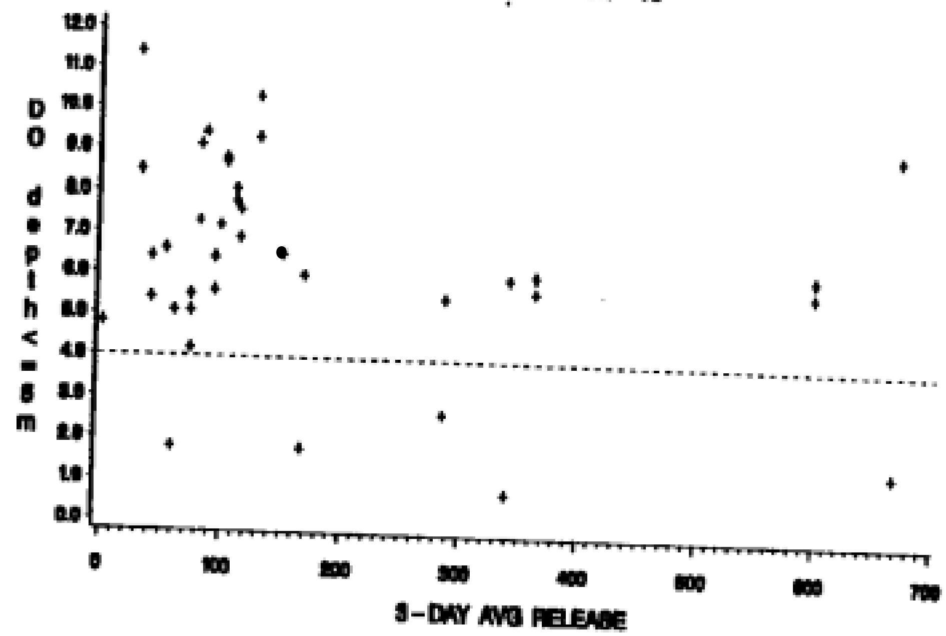
AGENCY=WAR Station=15



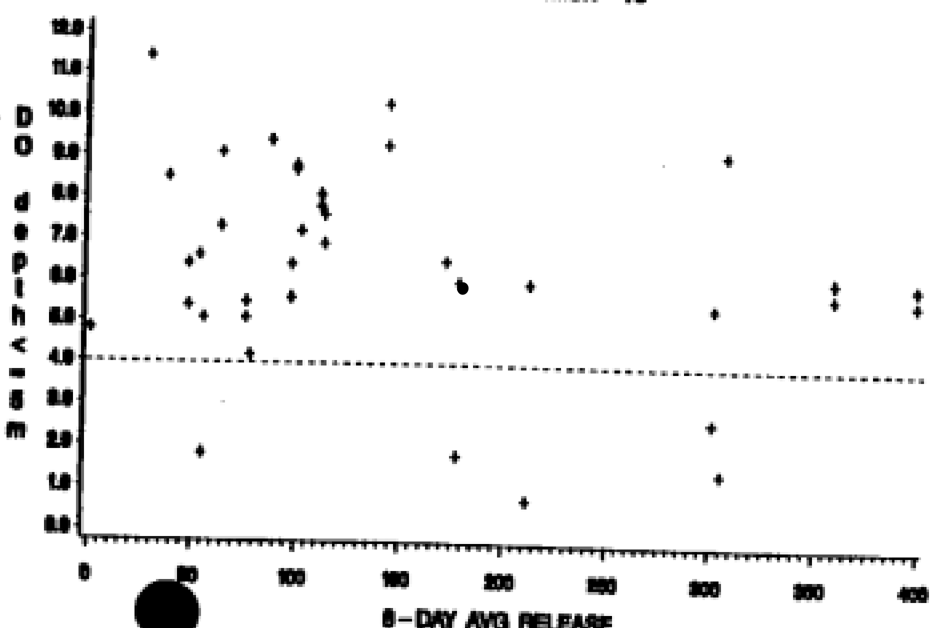
AGENCY=WAR Station=16



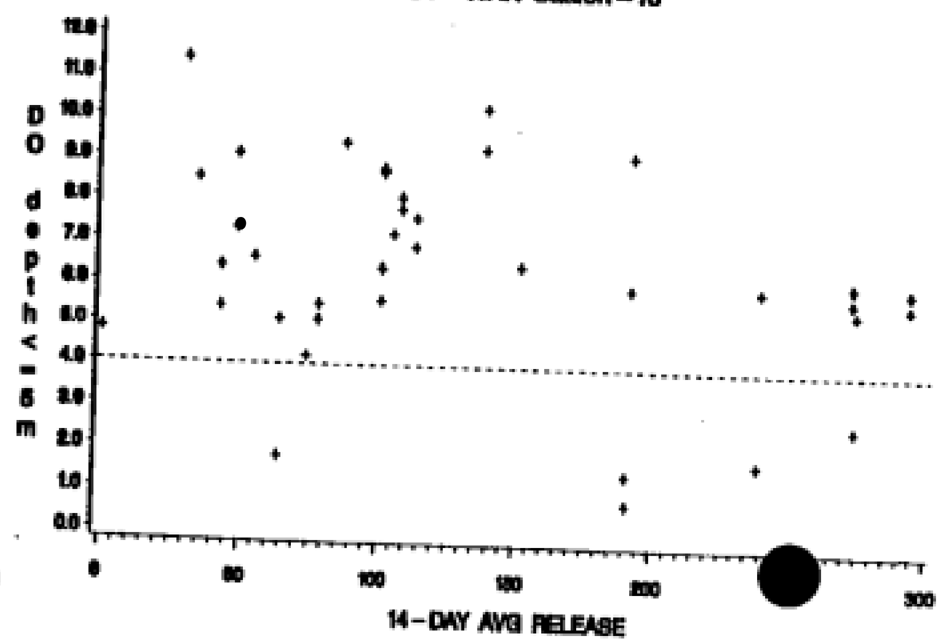
AGENCY=WAR Station=16

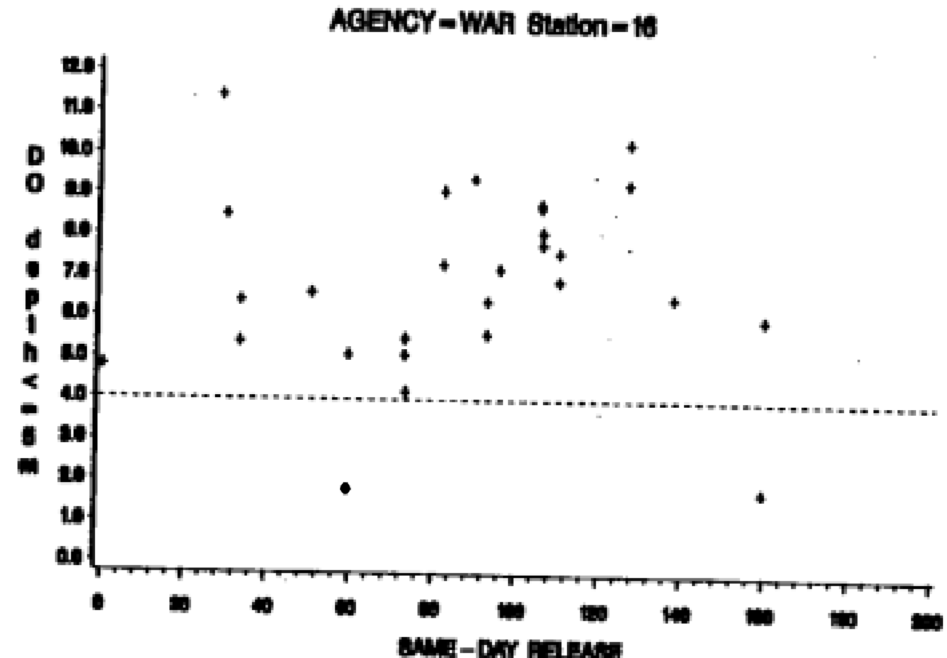


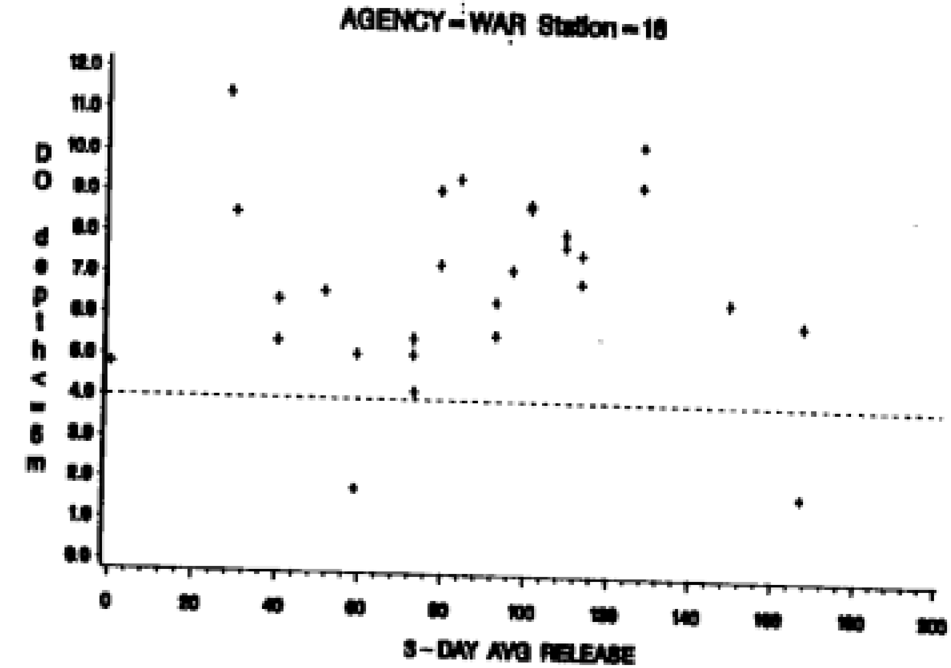
AGENCY=WAR Station=16

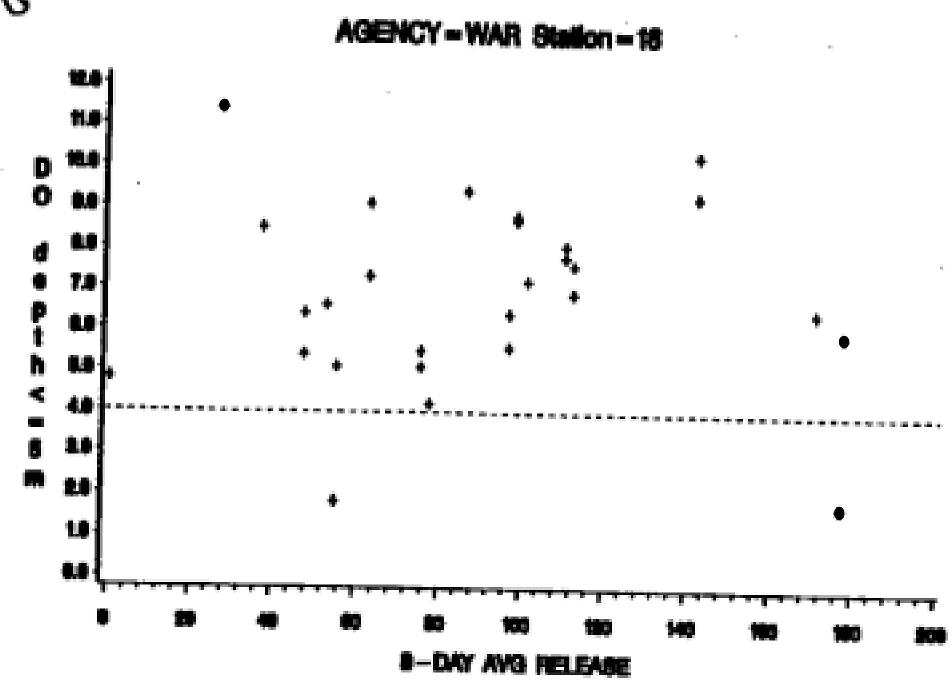


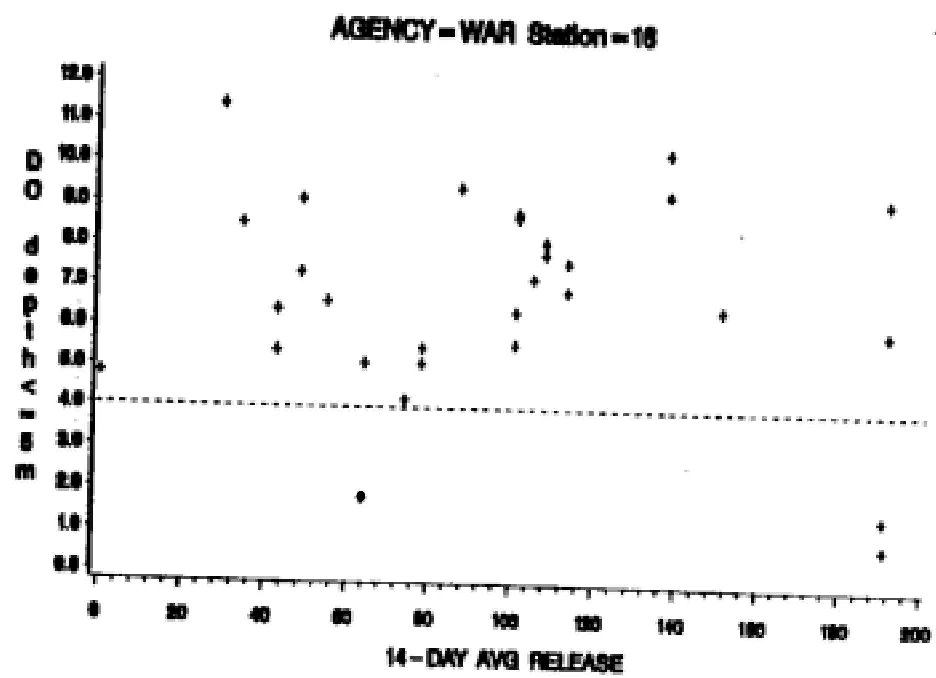
AGENCY=WAR Station=16



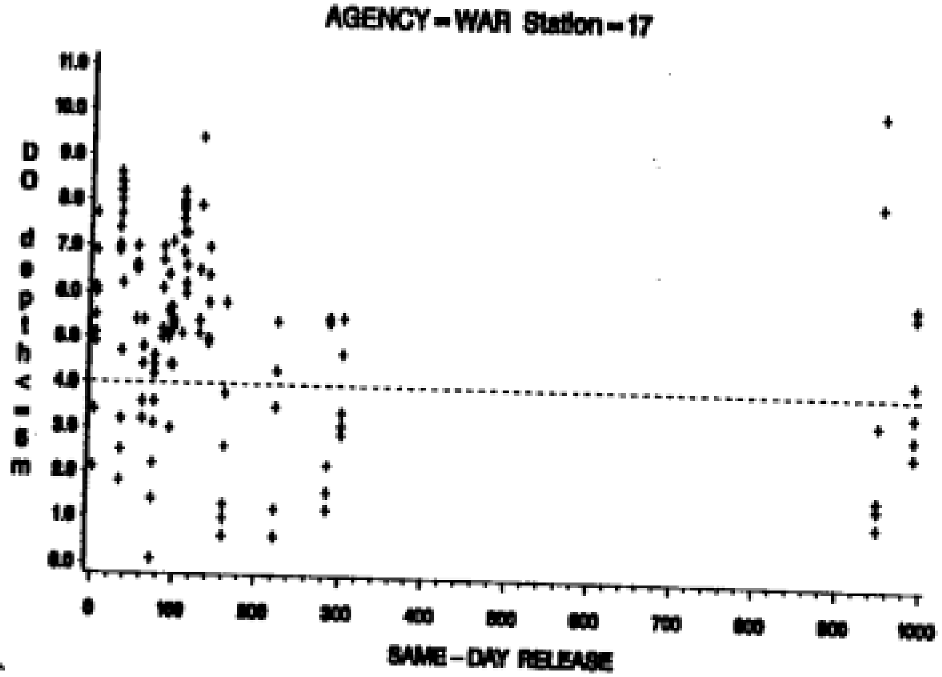

AGENCY=WAR Station=16
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0 20 40 60 80 100 120 140 160 180 200
SAME-DAY RELEASE


AGENCY=WAR Station=16
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0 20 40 60 80 100 120 140 160 180 200
3-DAY AVG RELEASE

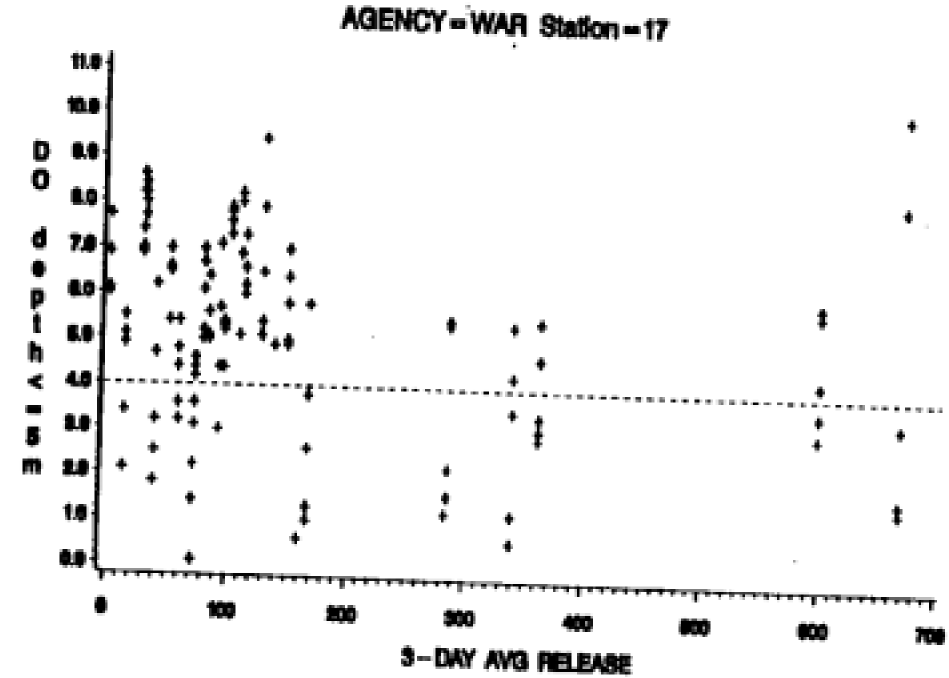

AGENCY=WAR Station=16
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0 20 40 60 80 100 120 140 160 180 200
8-DAY AVG RELEASE


AGENCY=WAR Station=16
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0 20 40 60 80 100 120 140 160 180 200
14-DAY AVG RELEASE

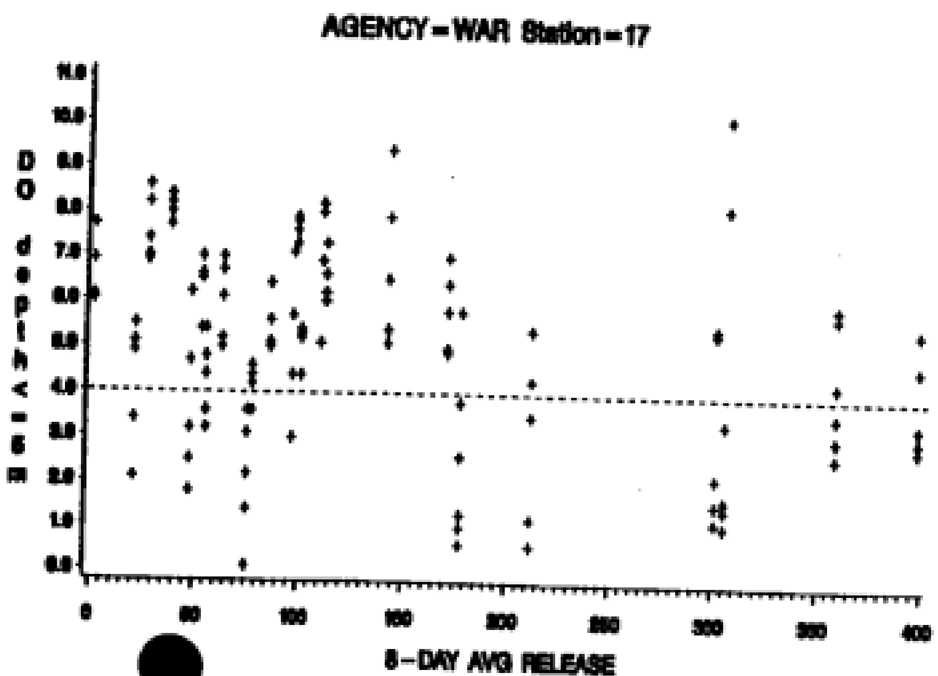
L10



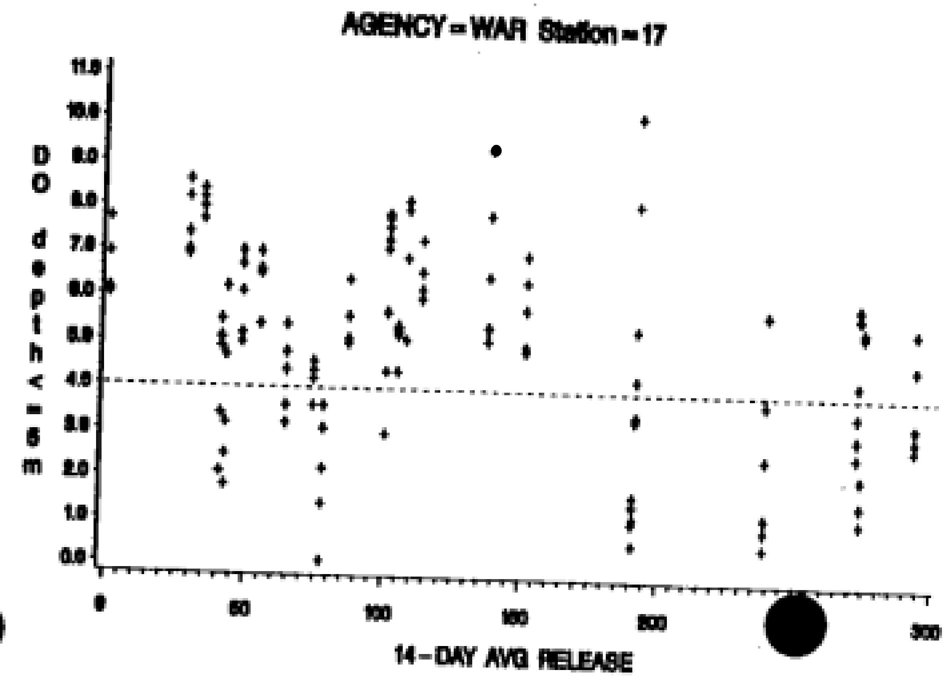
AGENCY = WAR Station = 17
DO depth <= 5 m
SAME-DAY RELEASE



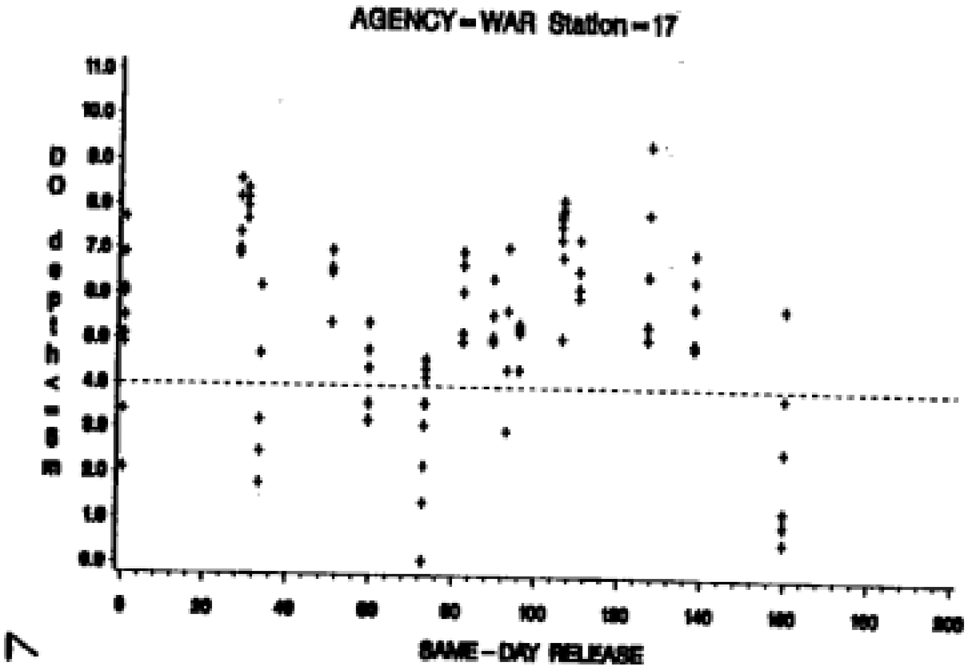
AGENCY = WAR Station = 17
DO depth <= 5 m
3-DAY AVG RELEASE

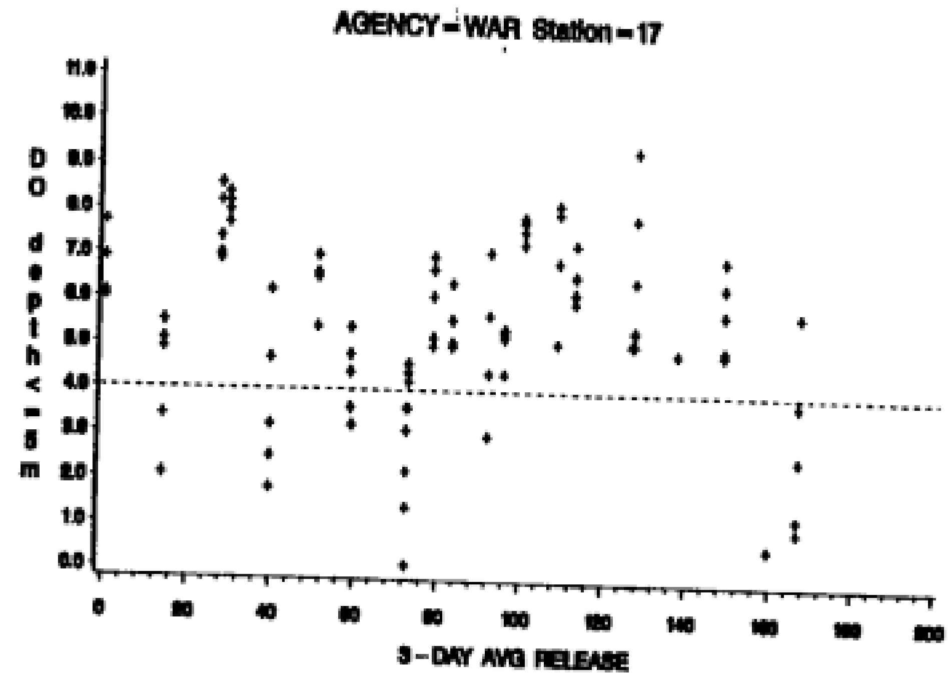


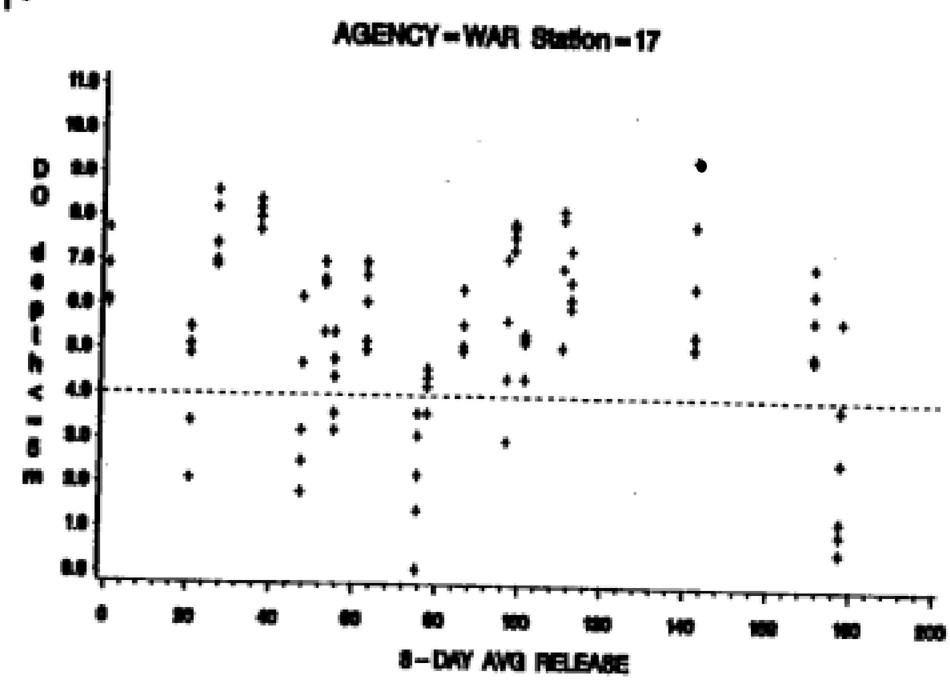
AGENCY = WAR Station = 17
DO depth <= 5 m
8-DAY AVG RELEASE

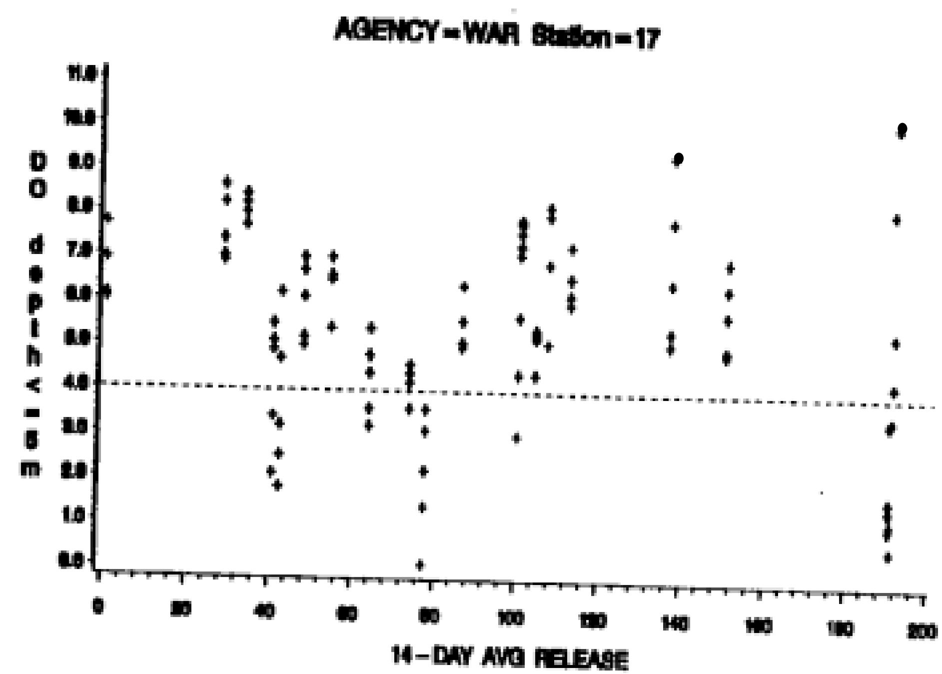


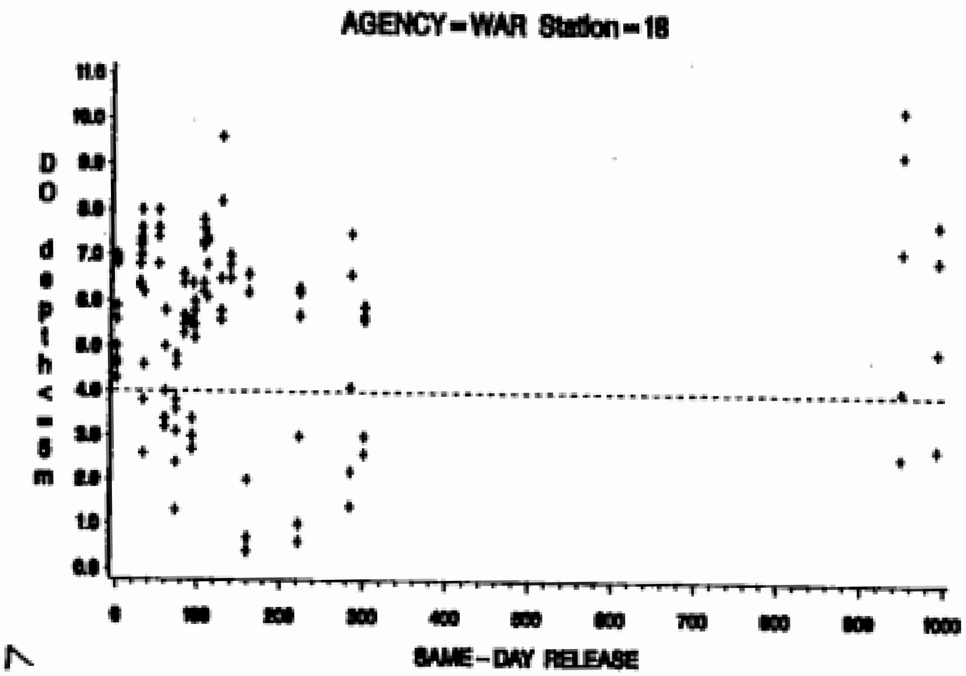
AGENCY = WAR Station = 17
DO depth <= 5 m
14-DAY AVG RELEASE

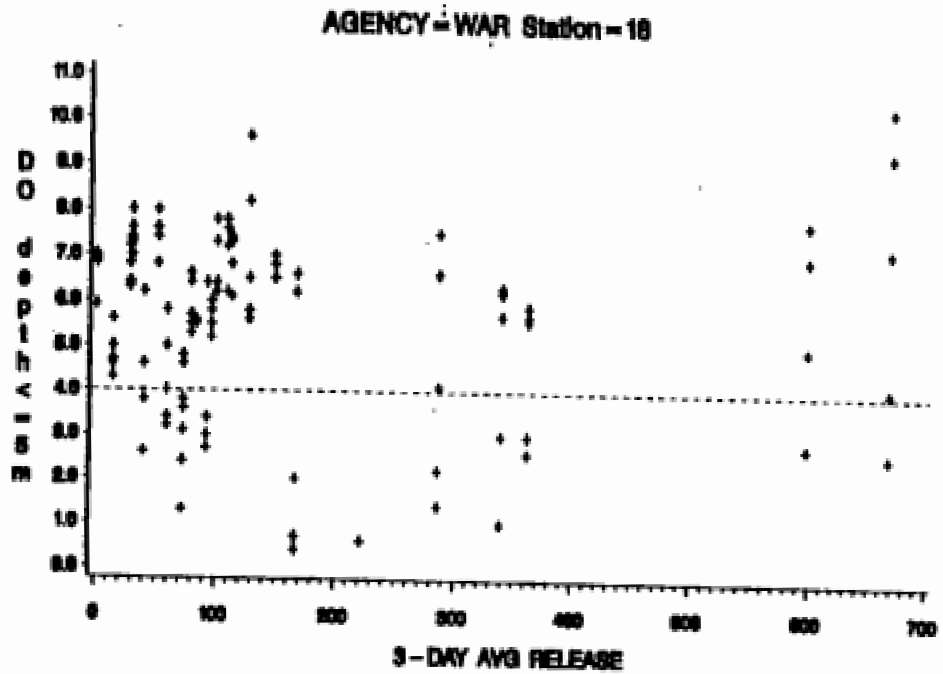

AGENCY=WAR Station=17
DO depth-avg
SAME-DAY RELEASE

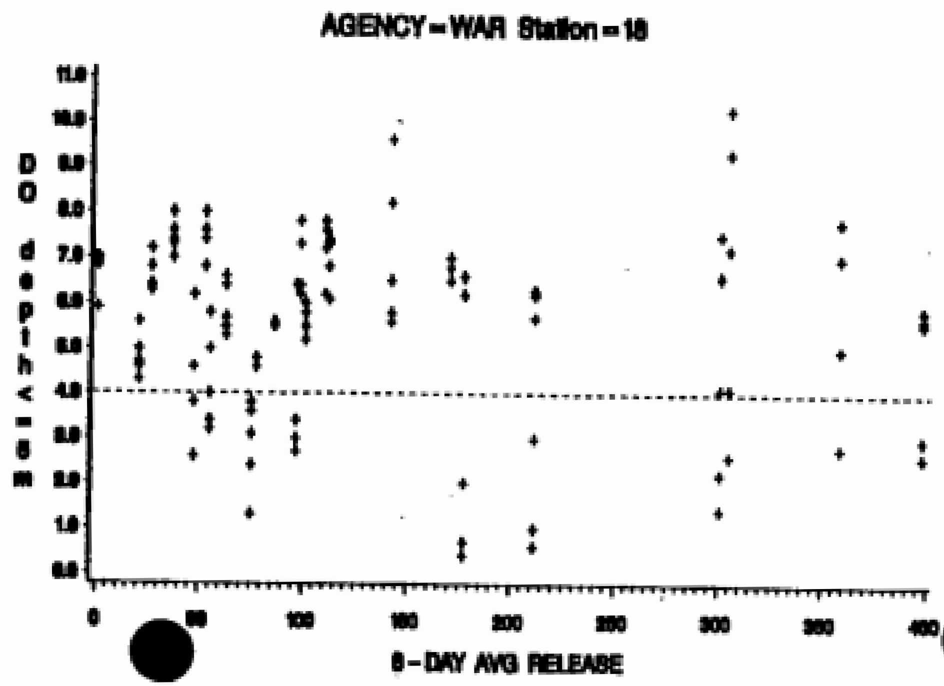

AGENCY=WAR Station=17
DO depth-avg
3-DAY AVG RELEASE

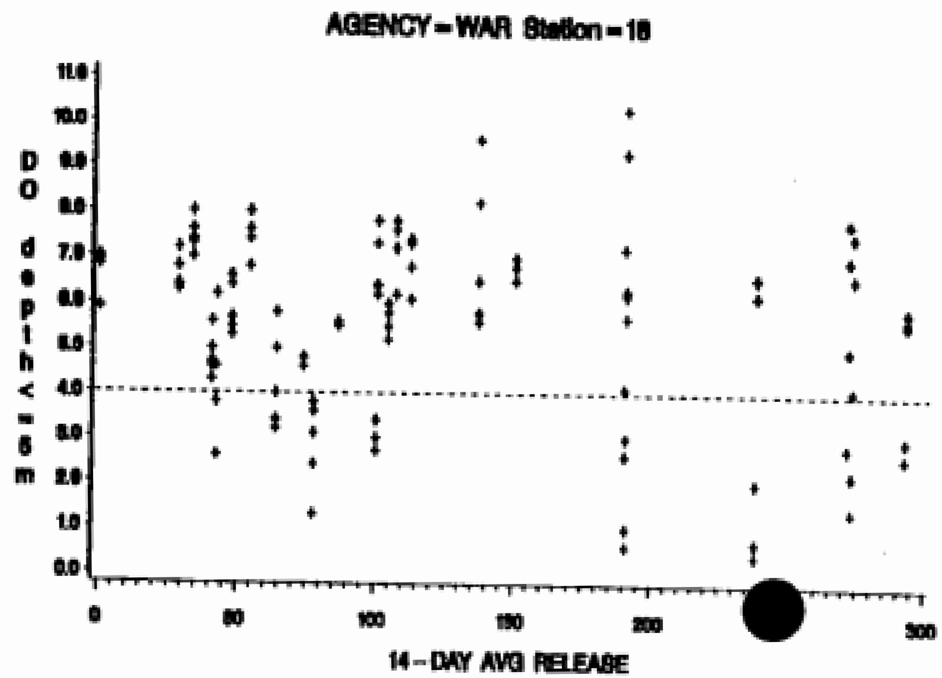

AGENCY=WAR Station=17
DO depth-avg
8-DAY AVG RELEASE


AGENCY=WAR Station=17
DO depth-avg
14-DAY AVG RELEASE

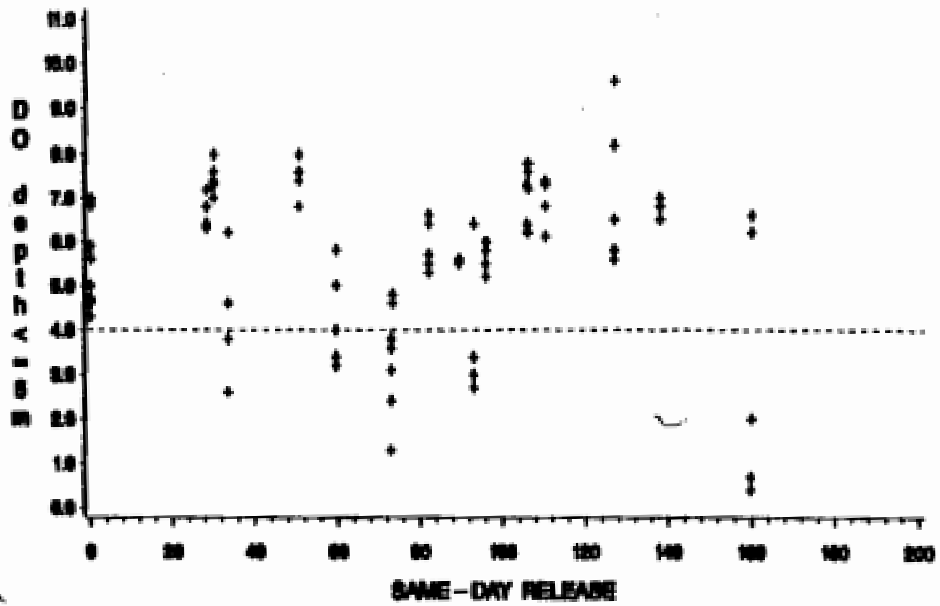

AGENCY=WAR Station=18
DO depth-avism
SAME-DAY RELEASE


AGENCY=WAR Station=18
DO depth-avism
3-DAY AVG RELEASE

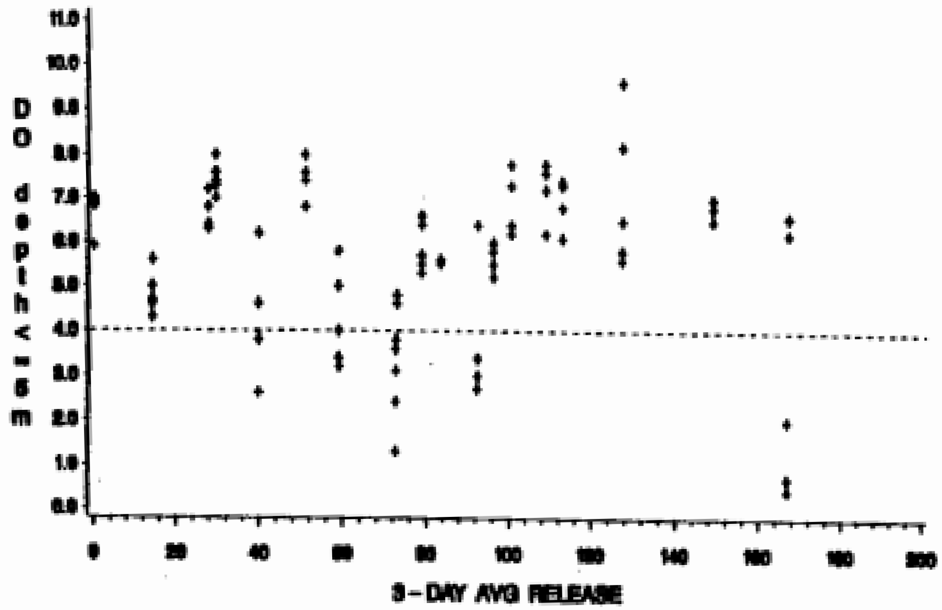

AGENCY=WAR Station=18
DO depth-avism
8-DAY AVG RELEASE


AGENCY=WAR Station=18
DO depth-avism
14-DAY AVG RELEASE

AGENCY=WAR Station=18

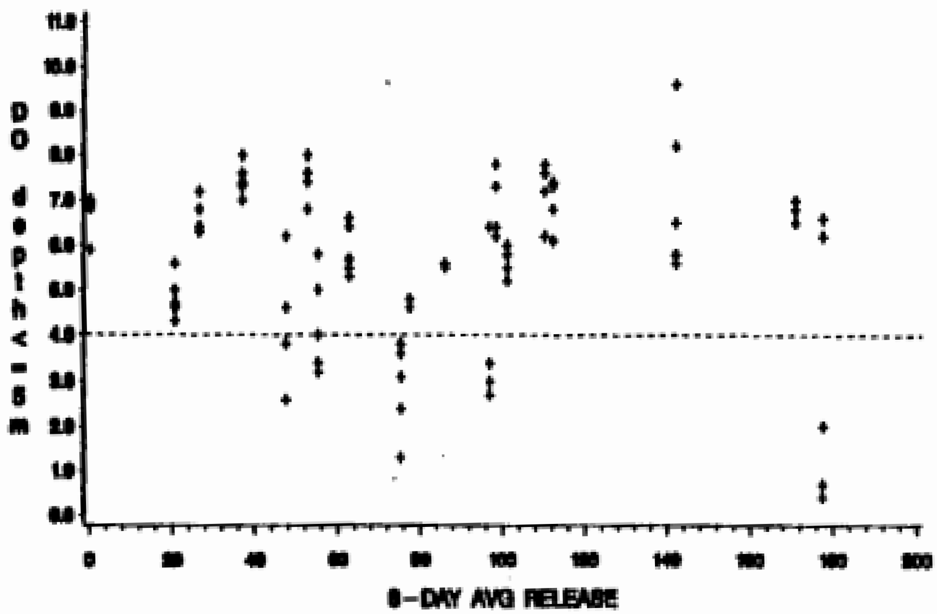


AGENCY=WAR Station=18

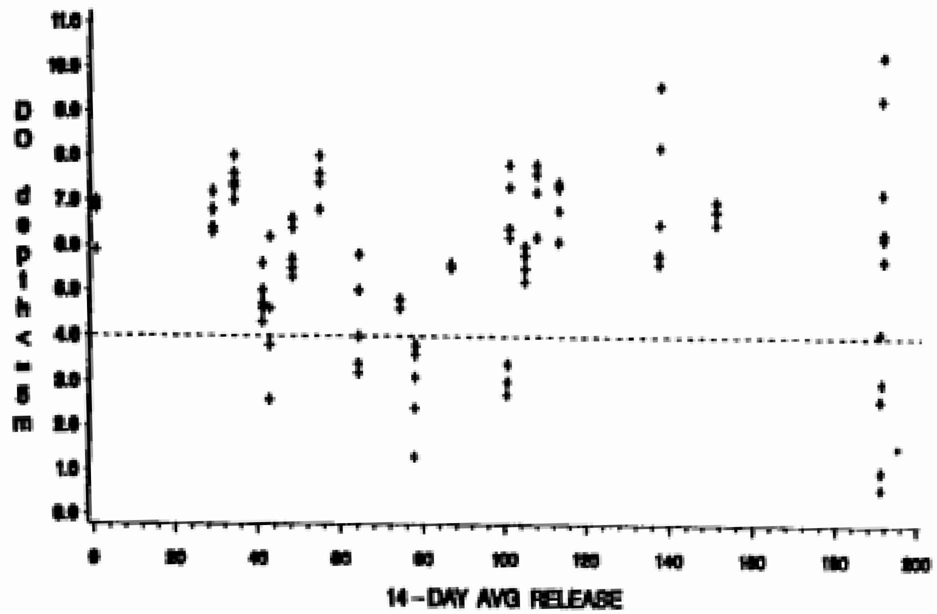


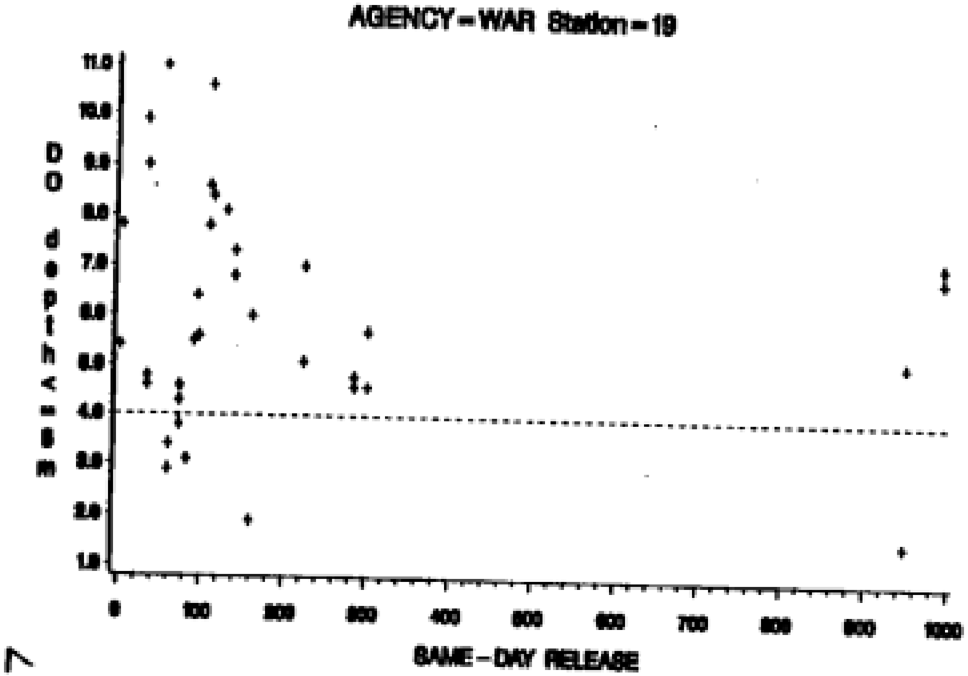
L14

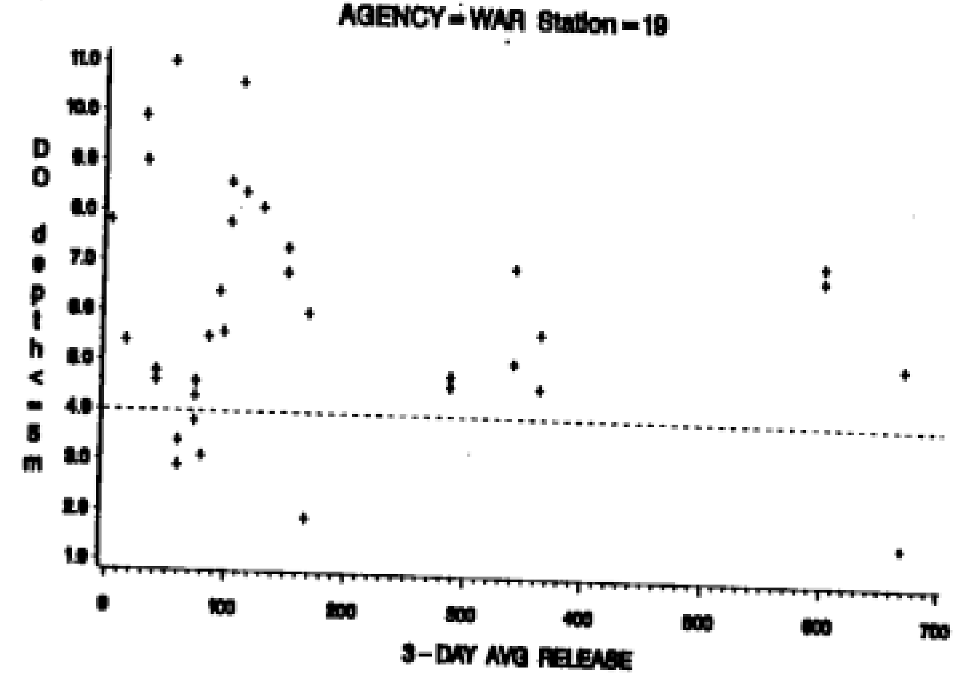
AGENCY=WAR Station=18



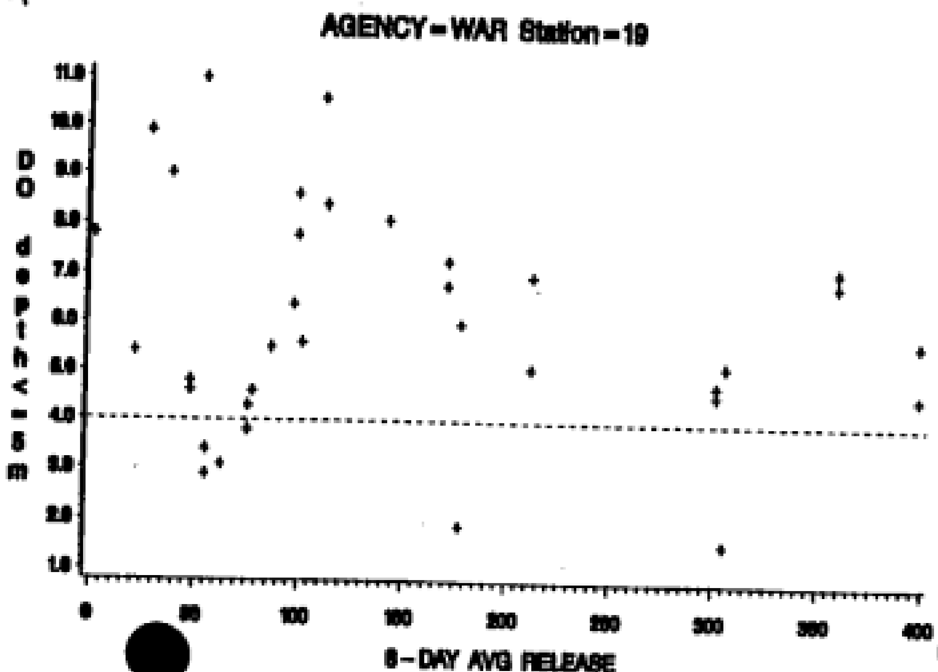
AGENCY=WAR Station=18

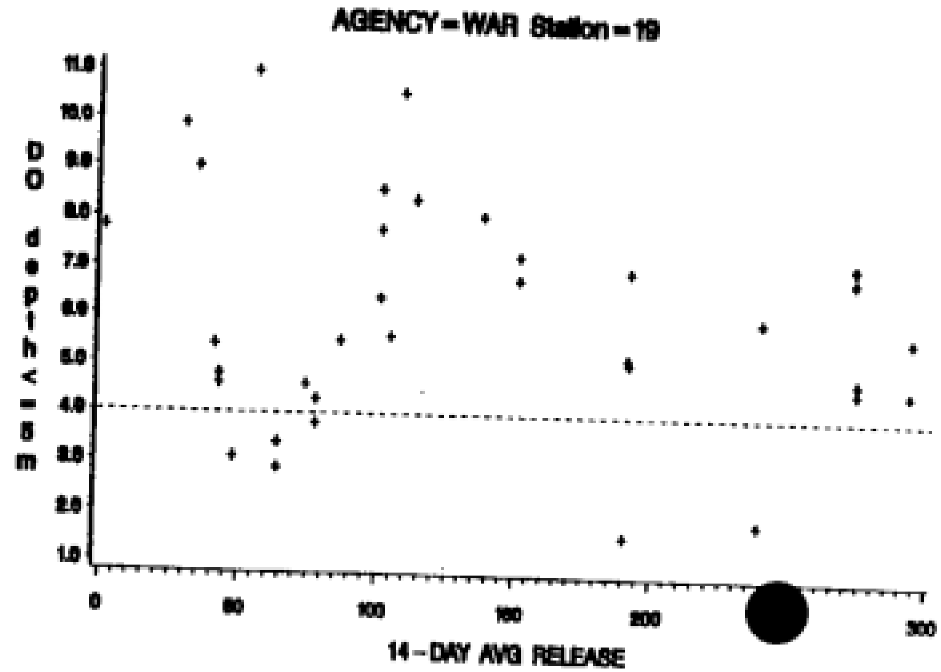


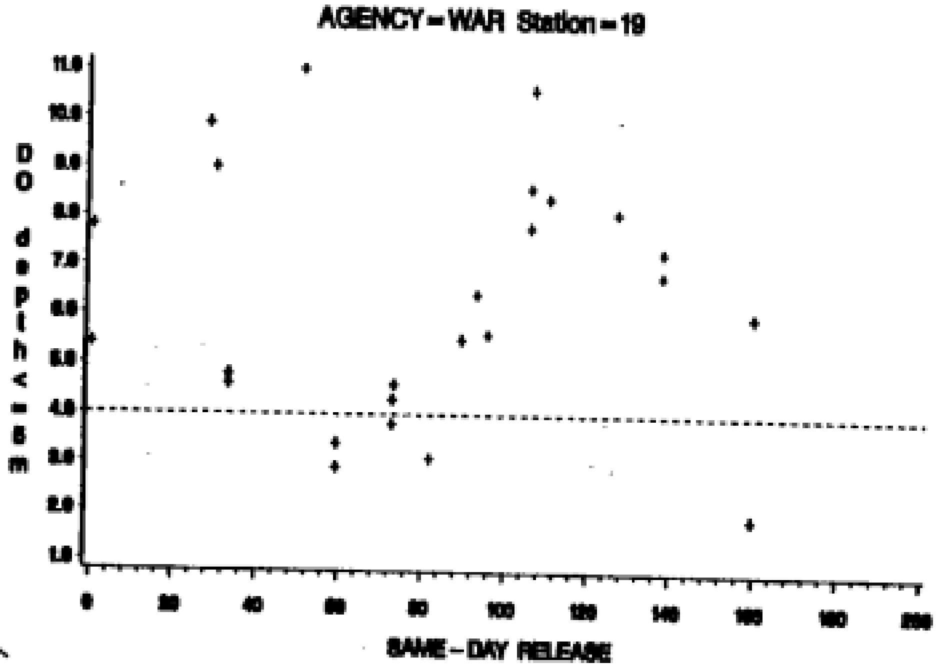

AGENCY=WAR Station=19
DO depth<=5m
SAME-DAY RELEASE

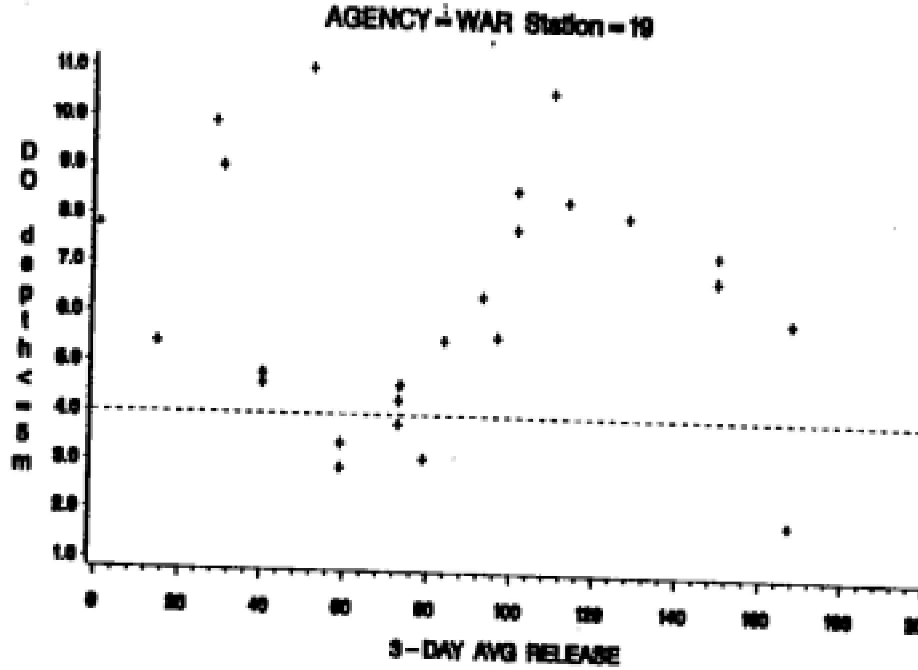

AGENCY=WAR Station=19
DO depth<=5m
3-DAY AVG RELEASE

L15

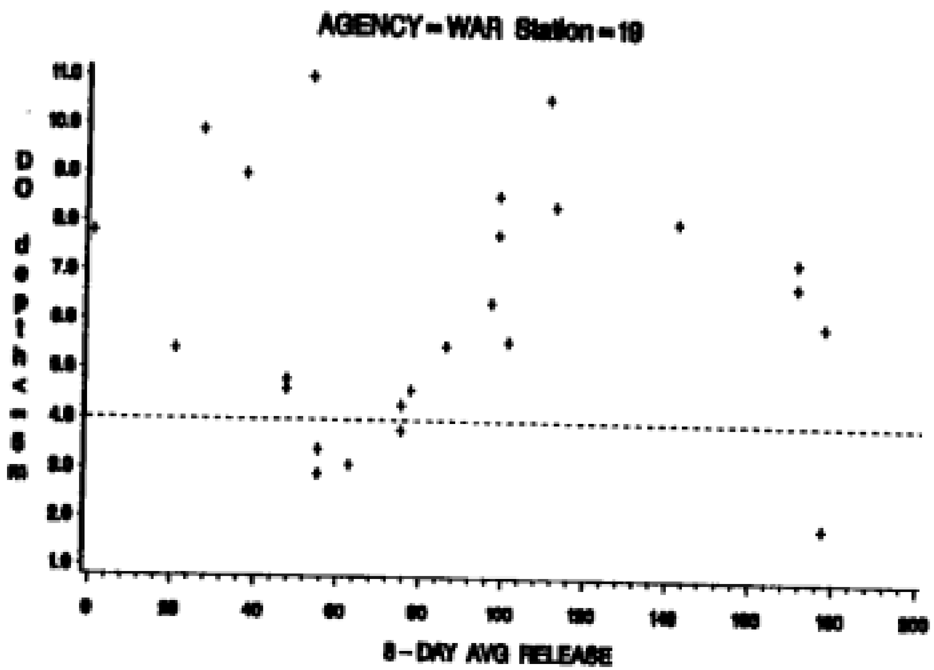

AGENCY=WAR Station=19
DO depth<=5m
8-DAY AVG RELEASE

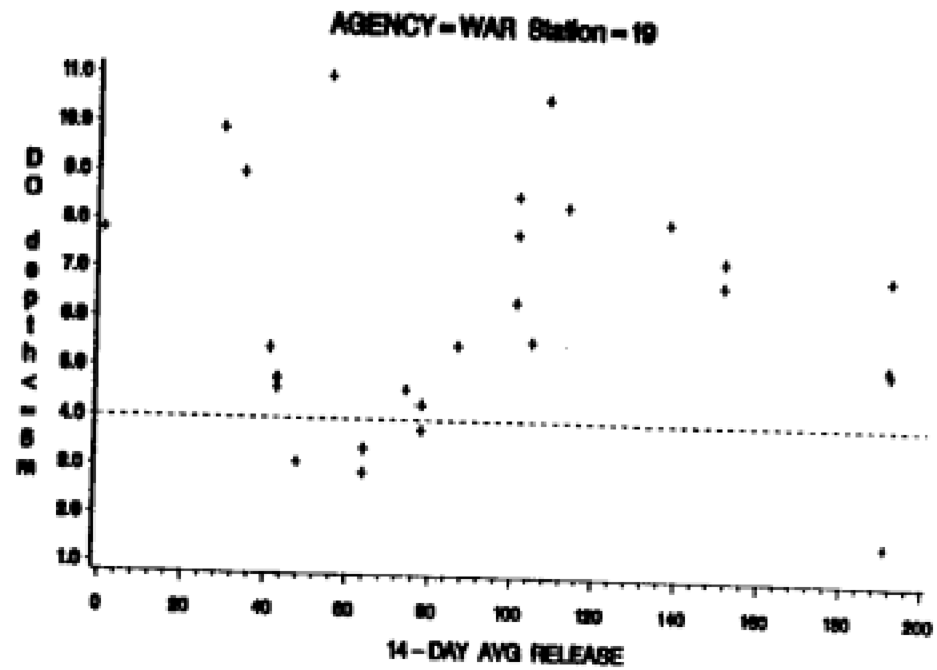

AGENCY=WAR Station=19
DO depth<=5m
14-DAY AVG RELEASE


AGENCY=WAR Station=19
DO depth=avg
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
20
40
60
80
100
120
140
160
180
200
SAME-DAY RELEASE


AGENCY=WAR Station=19
DO depth=avg
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
20
40
60
80
100
120
140
160
180
200
3-DAY AVG RELEASE

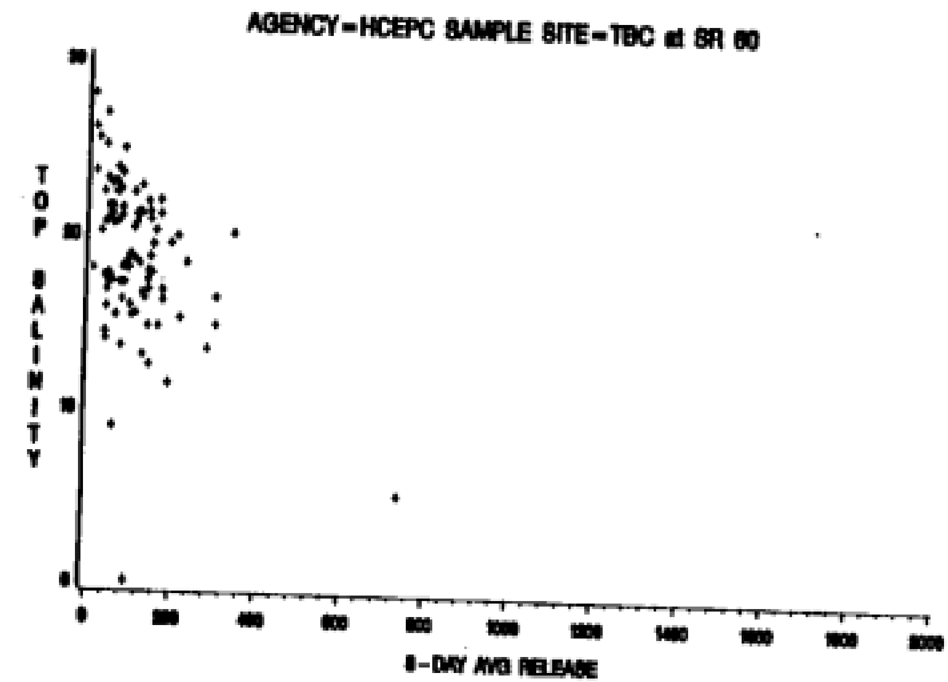
L16

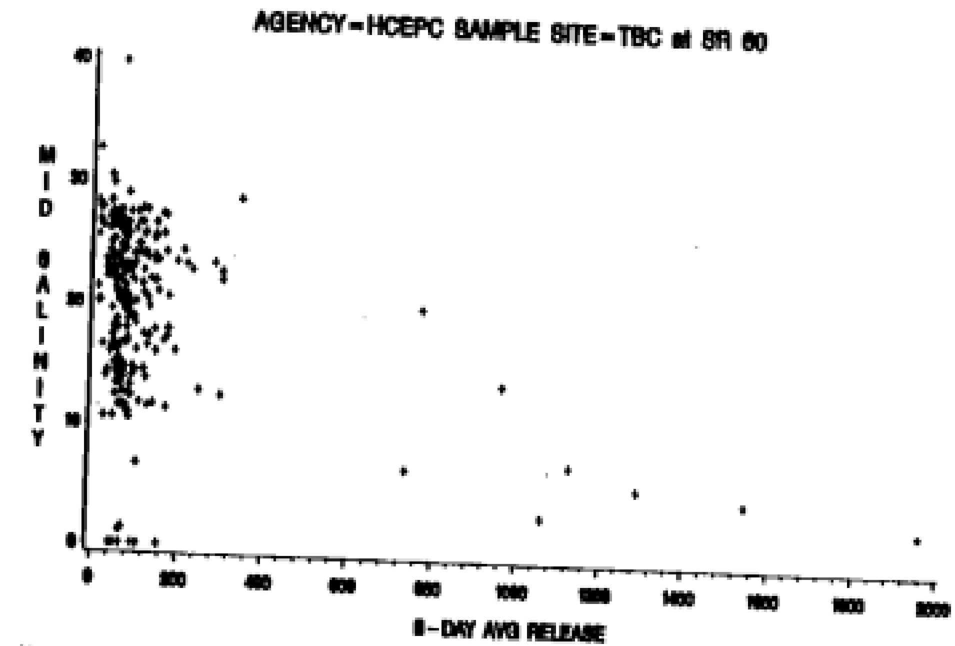

AGENCY=WAR Station=19
DO depth=avg
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
20
40
60
80
100
120
140
160
180
200
8-DAY AVG RELEASE


AGENCY=WAR Station=19
DO depth=avg
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
20
40
60
80
100
120
140
160
180
200
14-DAY AVG RELEASE

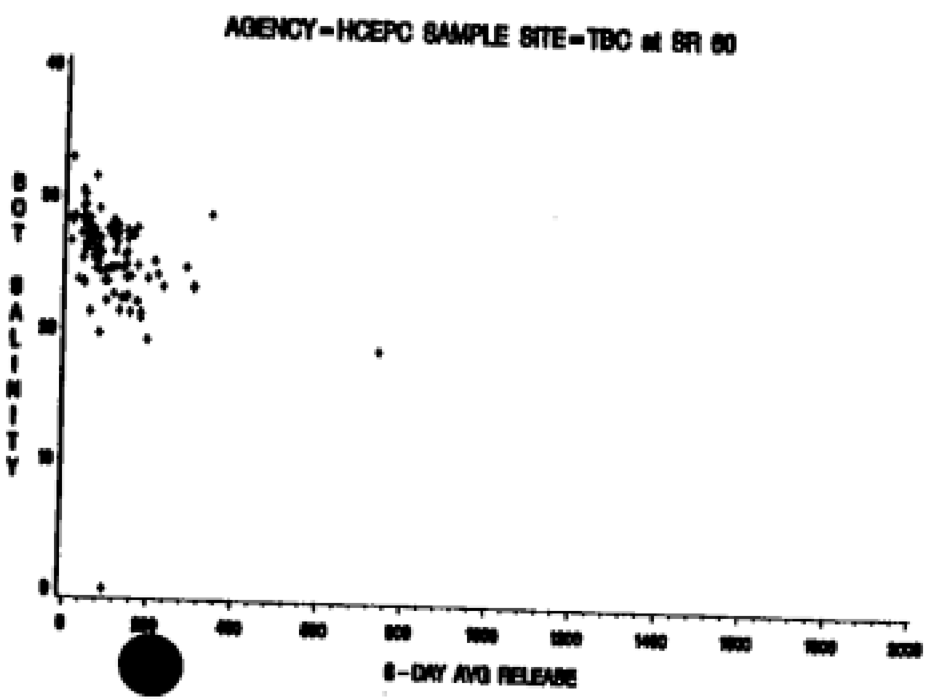
APPENDIX M-1

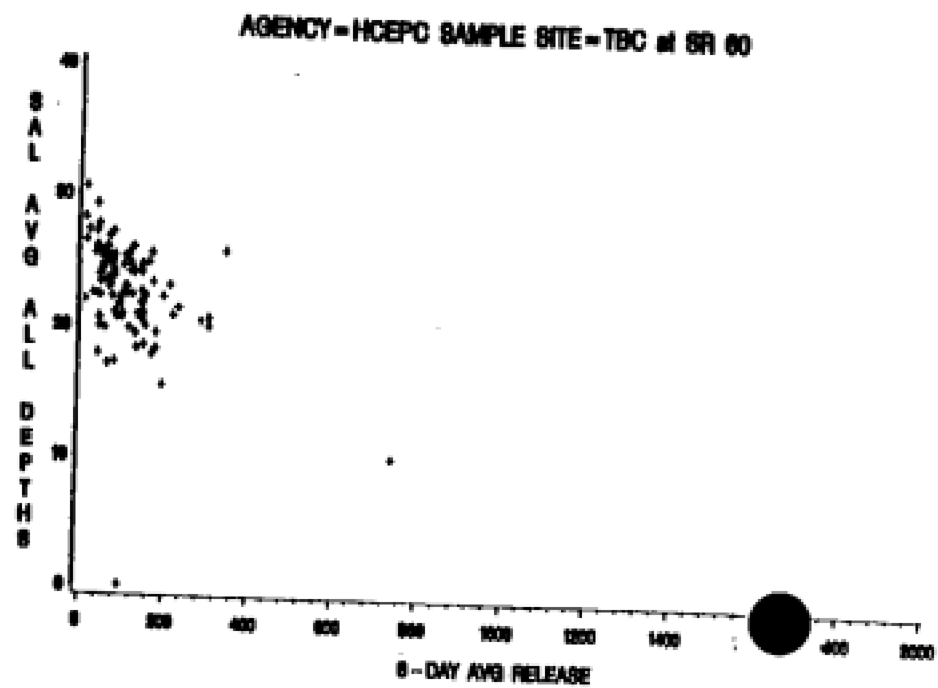
Plots of salinity and dissolved oxygen in the Palm River measured by the HCEPC vs. discharge from Structure 160 on the Tampa Bypass Canal





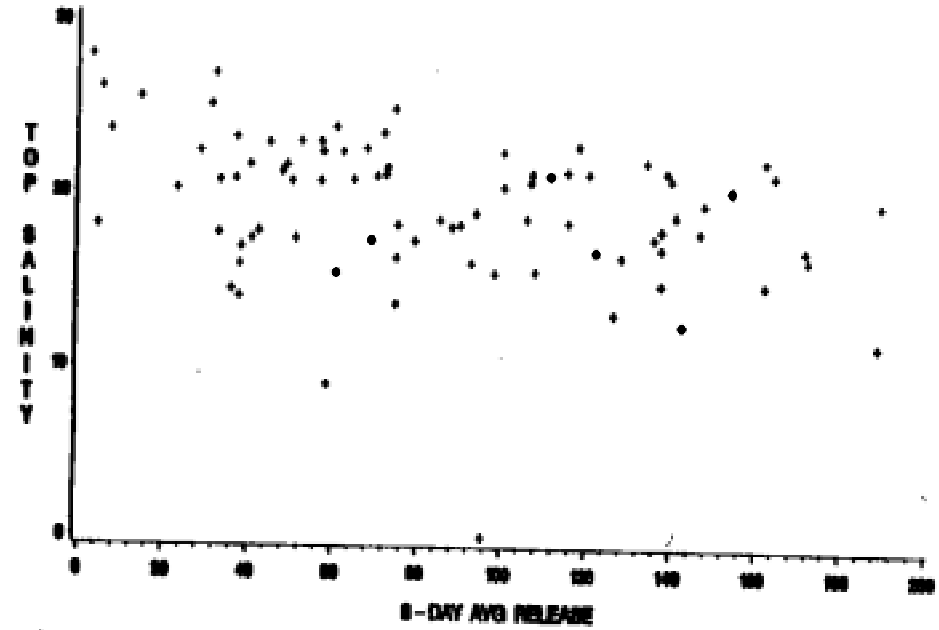
Not shown: 8-day avg release=[illegible], salinity=0; 8-day avg release=[illegible], salinity=1



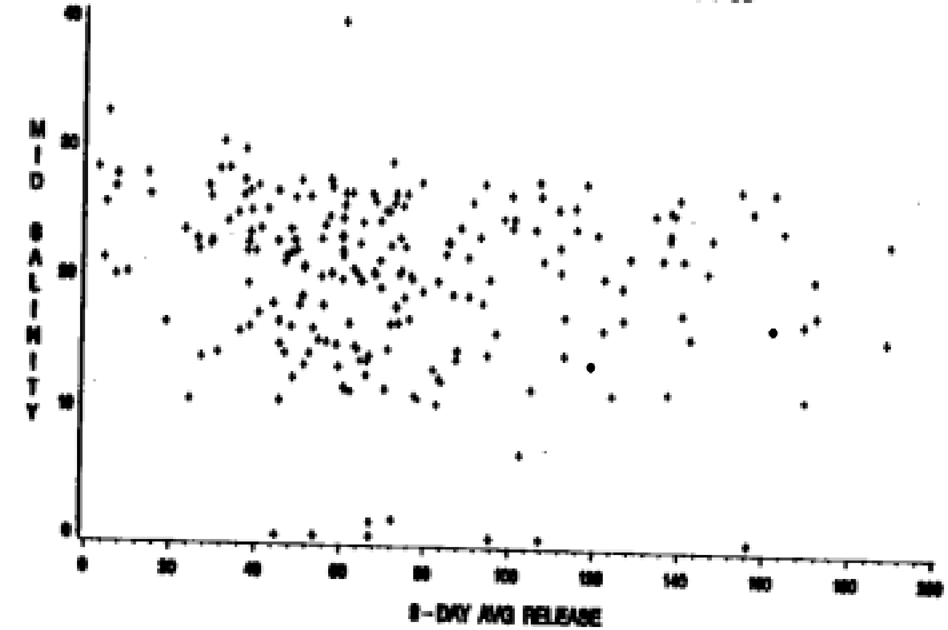


MI-1

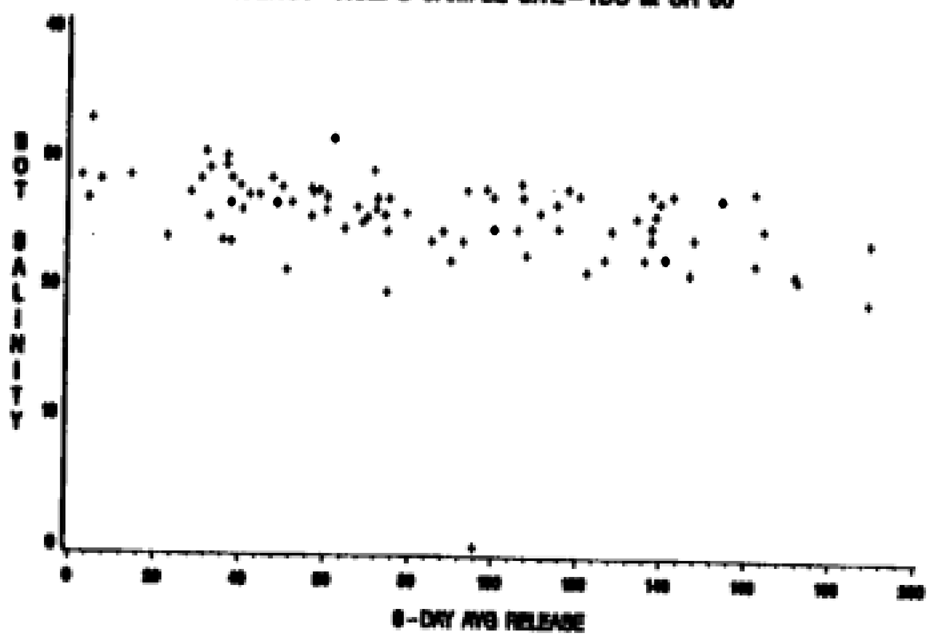
AGENCY=HCEPC SAMPLE SITE=TBC at SR 60



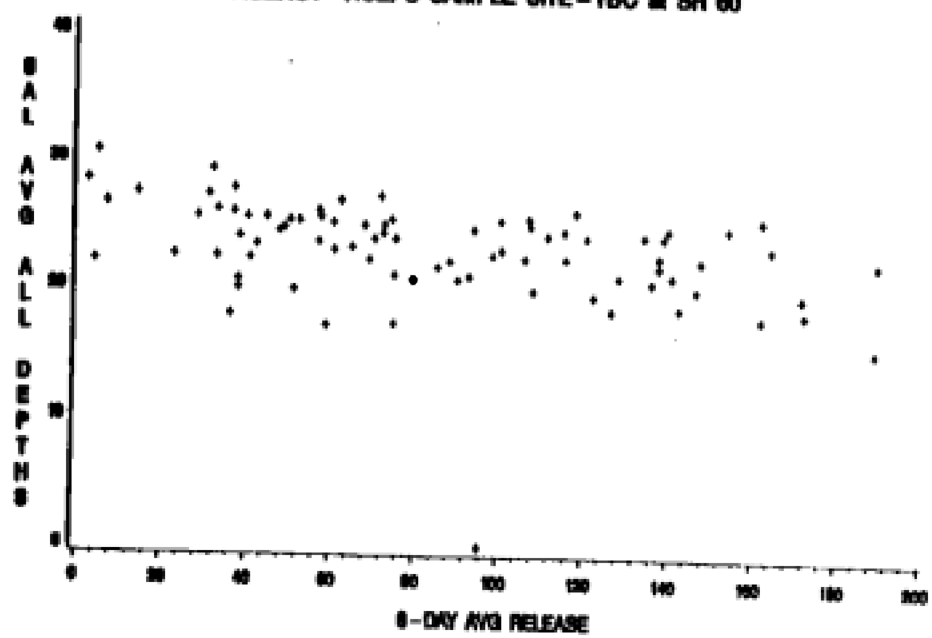
AGENCY=HCEPC SAMPLE SITE=TBC at SR 60



AGENCY=HCEPC SAMPLE SITE=TBC at SR 60

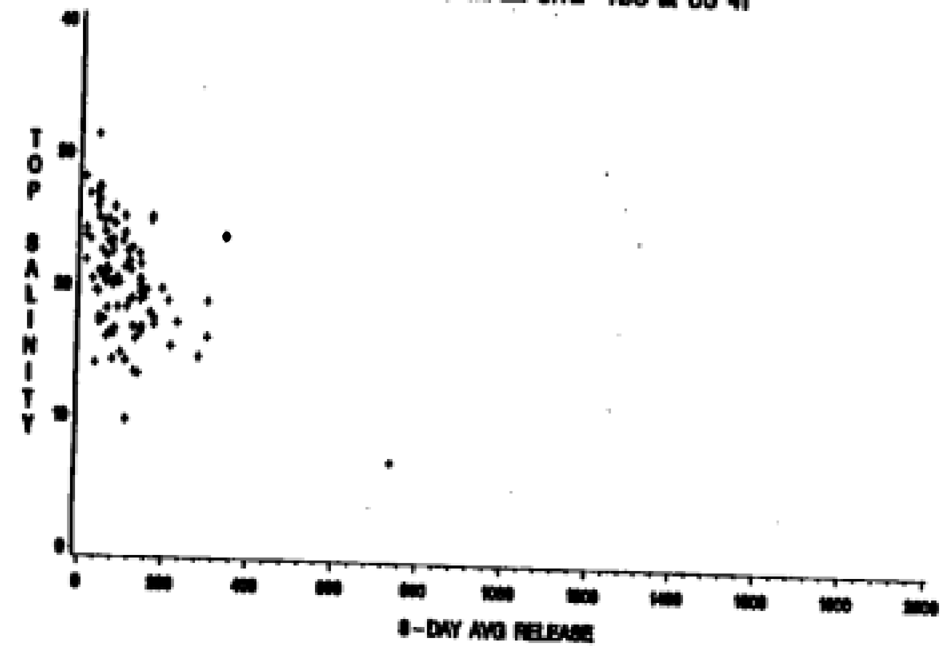


AGENCY=HCEPC SAMPLE SITE=TBC at SR 60

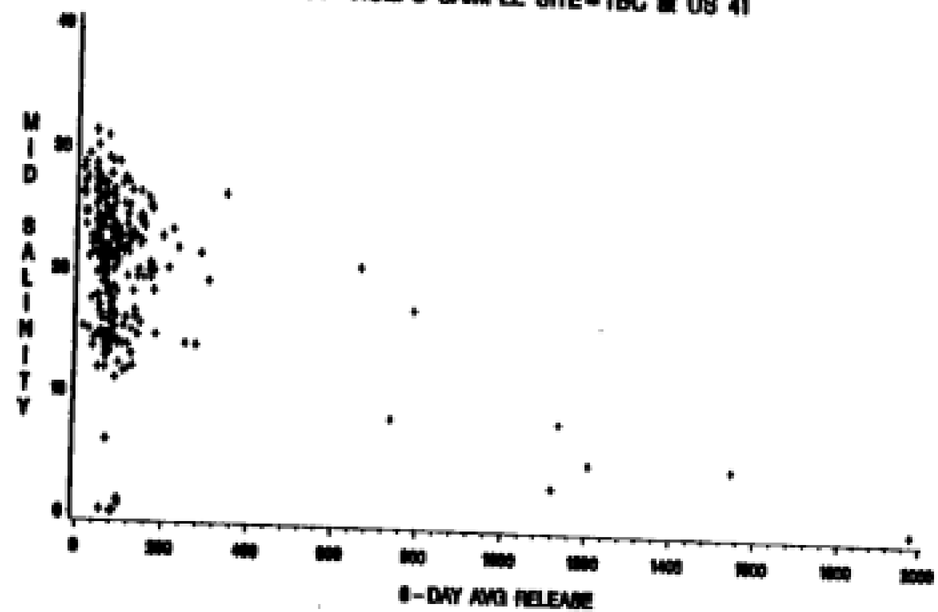


M1-2

AGENCY=HCEPC SAMPLE SITE=TBC at US 41

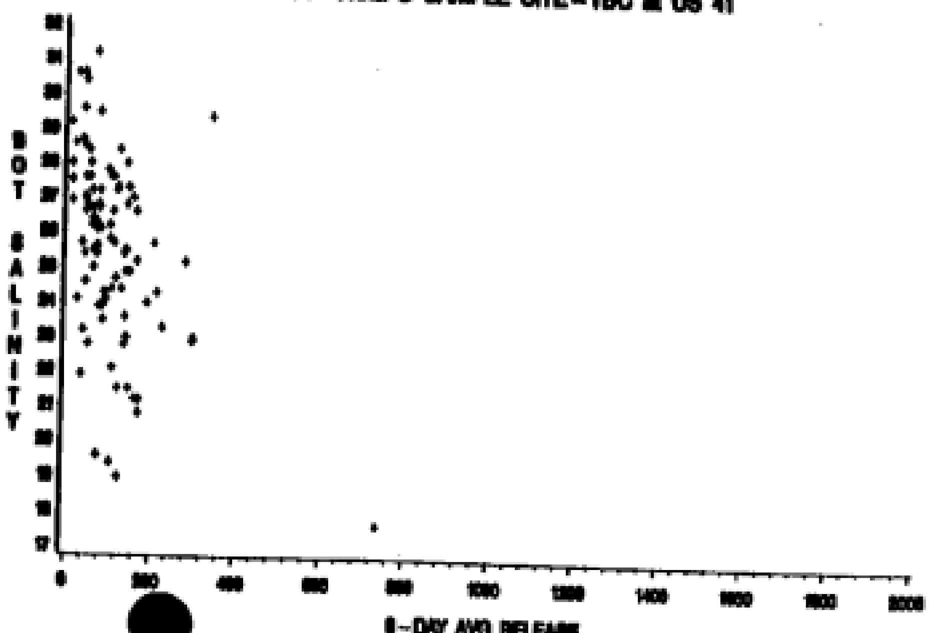


AGENCY=HCEPC SAMPLE SITE=TBC at US 41

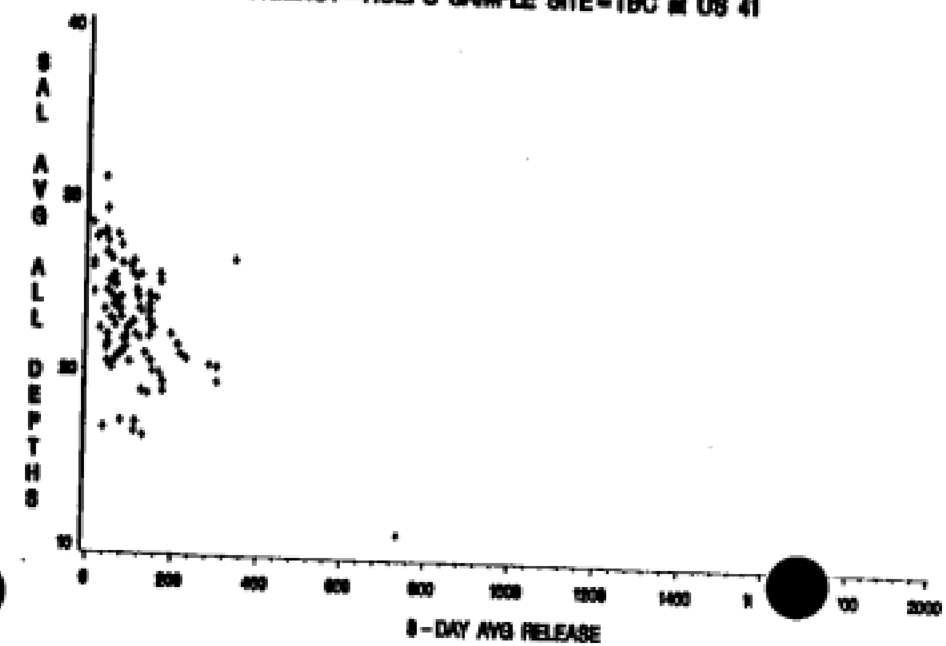


Not shown: 8-day avg release=[illegible], salinity=[illegible]; 8-day avg release=[illegible], salinity=2

AGENCY=HCEPC SAMPLE SITE=TBC at US 41

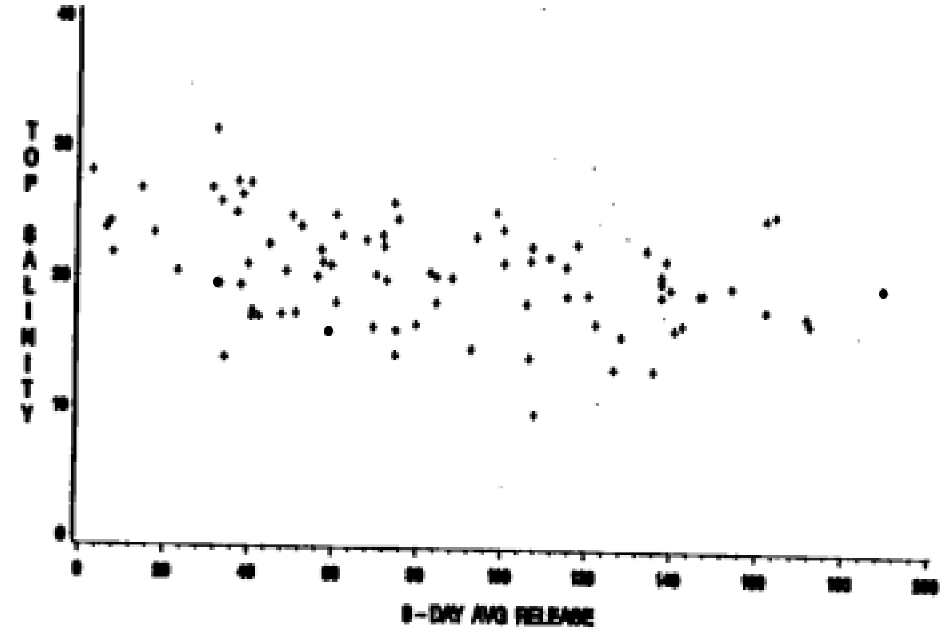


AGENCY=HCEPC SAMPLE SITE=TBC at US 41

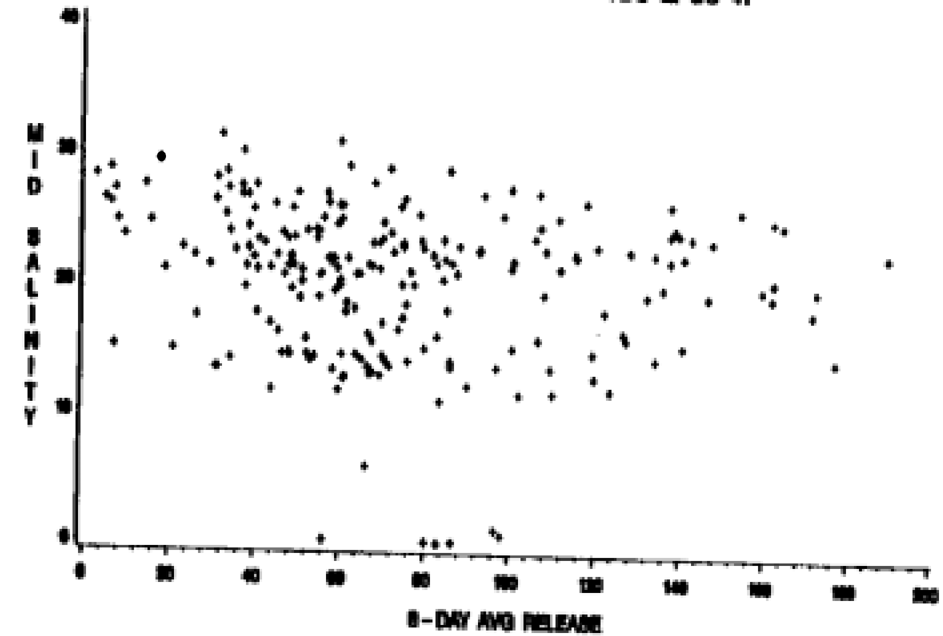


MI-3

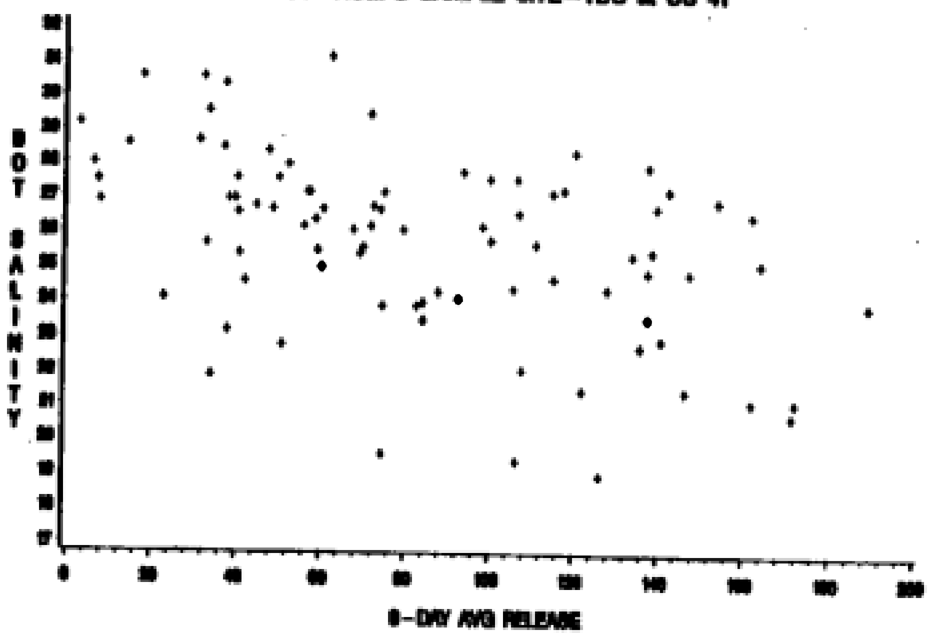
AGENCY=HCEPC SAMPLE SITE=TBC at US 41



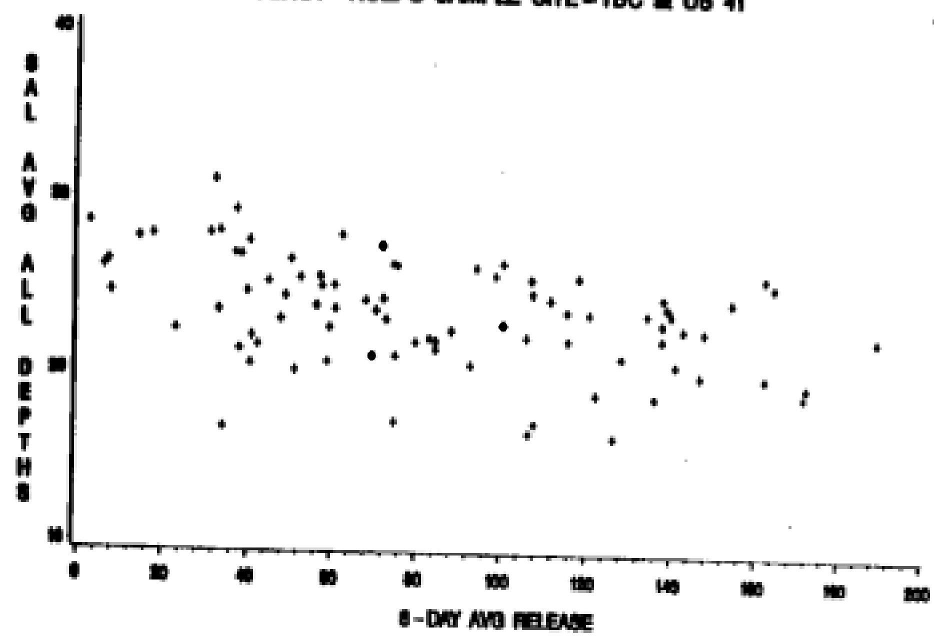
AGENCY=HCEPC SAMPLE SITE=TBC at US 41



AGENCY=HCEPC SAMPLE SITE=TBC at US 41

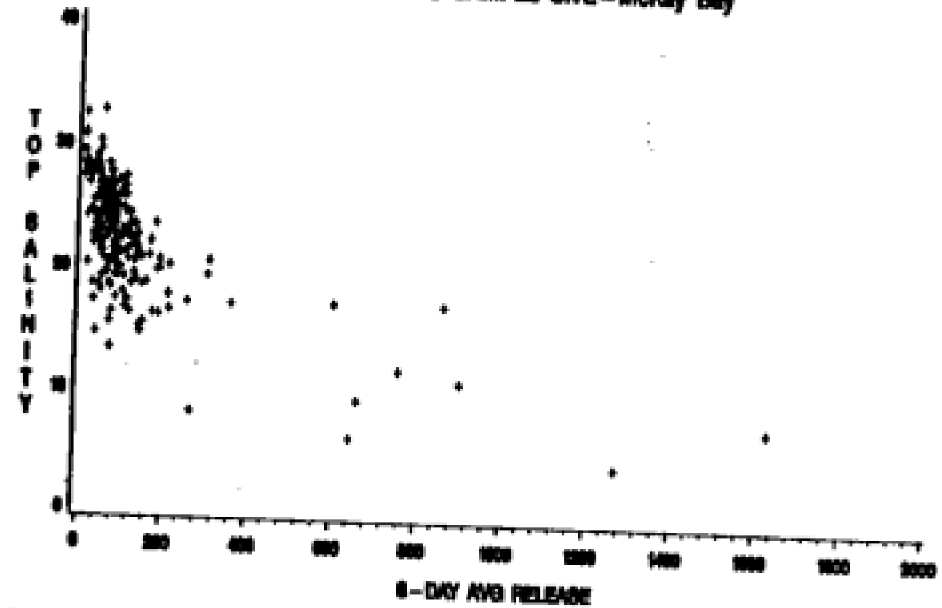


AGENCY=HCEPC SAMPLE SITE=TBC at US 41



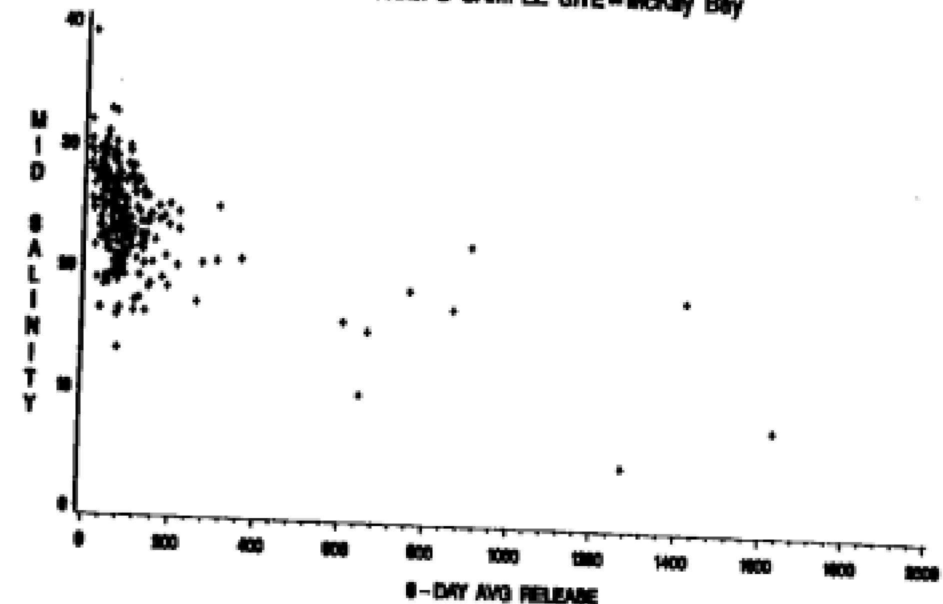
M1-4

AGENCY=HCEPC SAMPLE SITE=McKay Bay



Not shown: 8-day avg release=7176, salinity=8

AGENCY=HCEPC SAMPLE SITE=McKay Bay



Not shown: 8-day avg release=4885, salinity=4; 8-day avg release=7176, salinity=5

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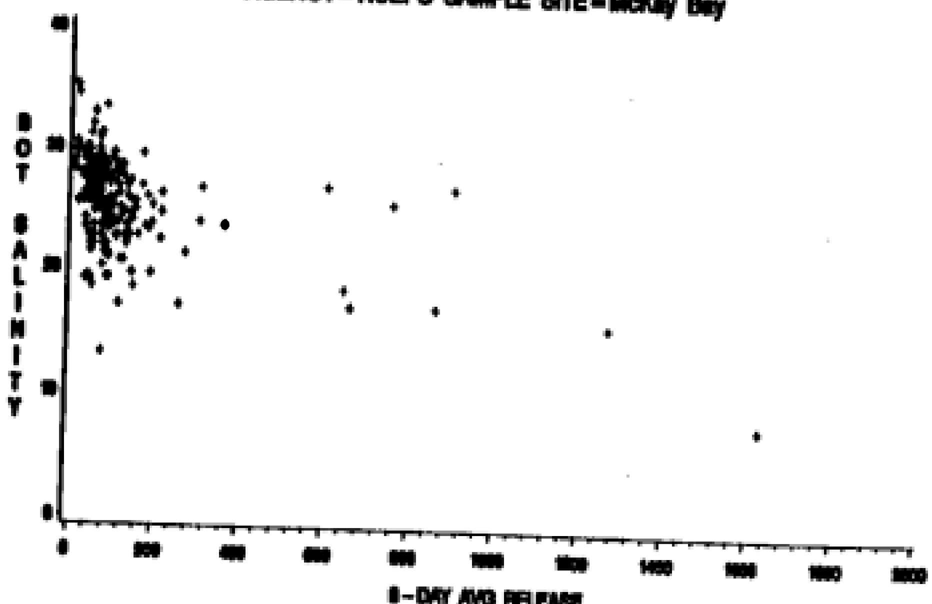

Not shown: 8- ase=7176, salinity=10

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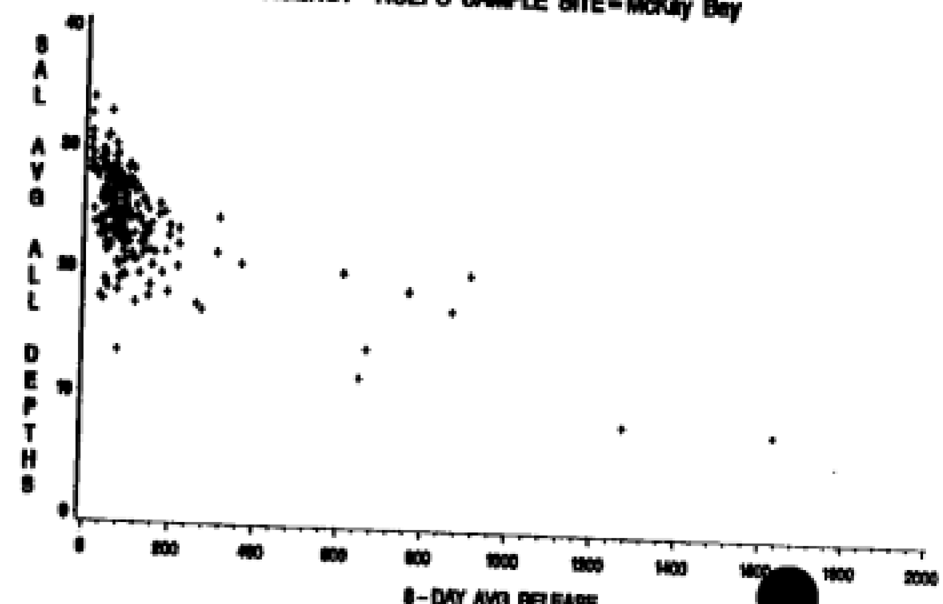
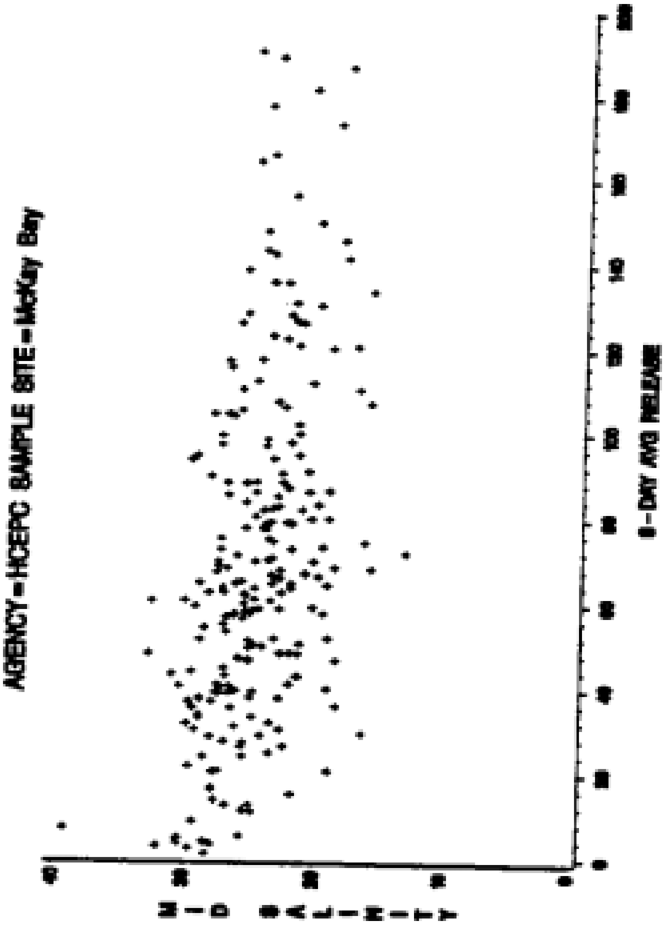


Not shown: 8-day avg release=7176, salinity=7

M1-5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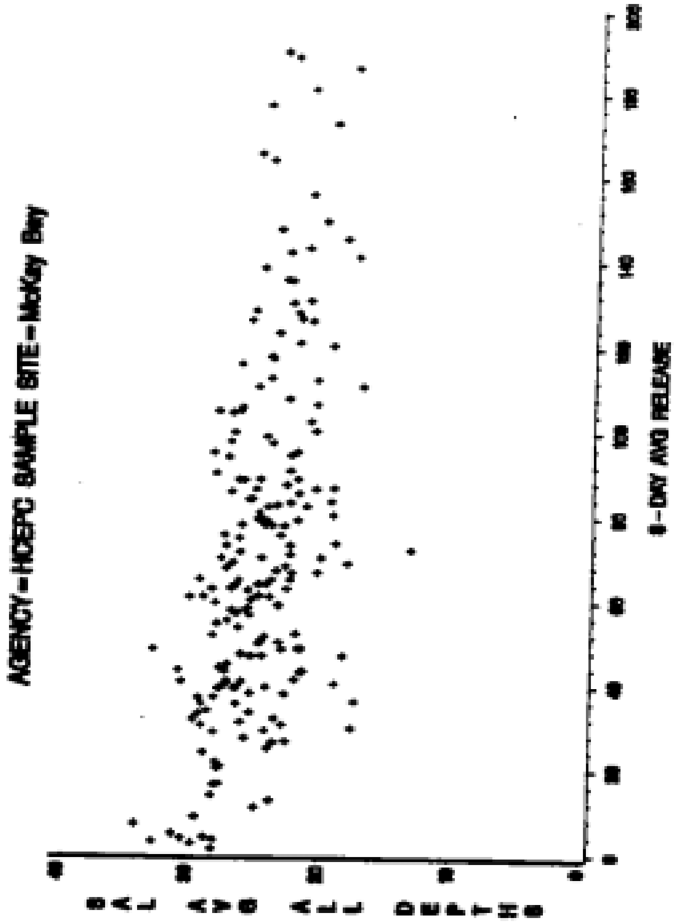
8-DAY AVG RELEASE
MID SALINITY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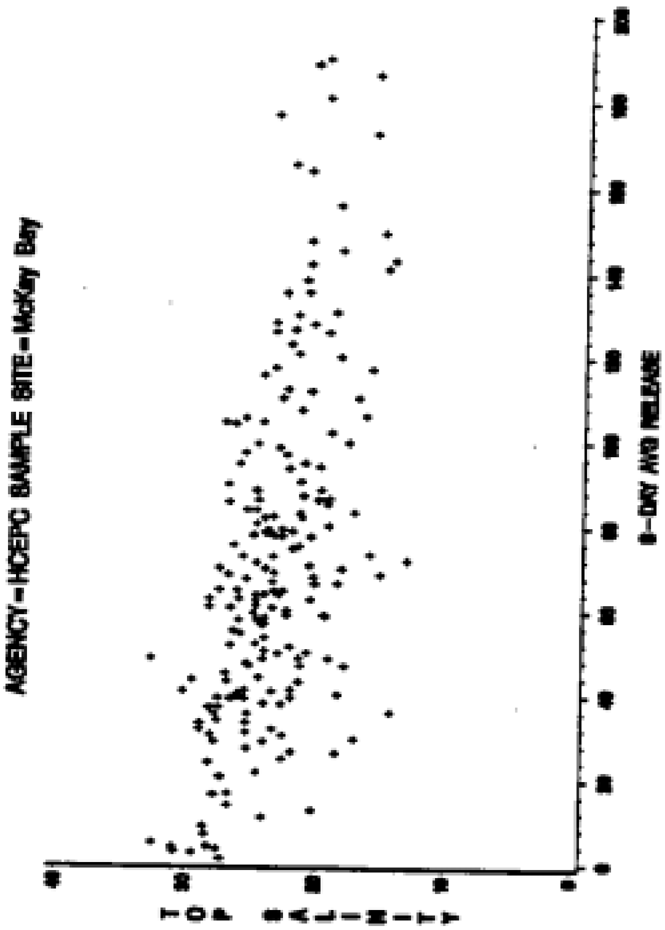
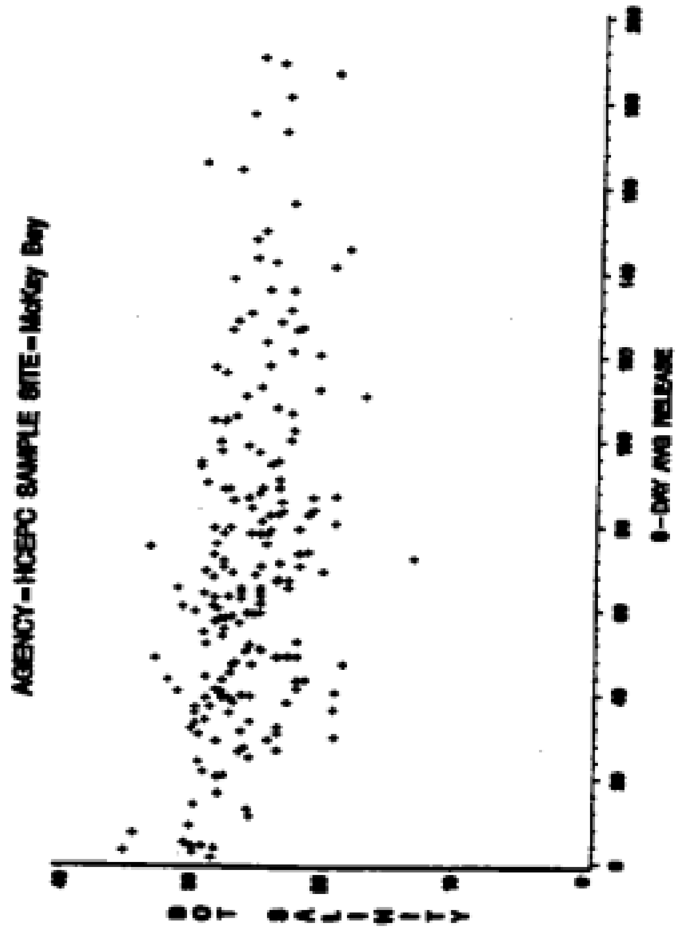
8-DAY AVG RELEASE
SAL AVG ALL DEPTHS


AGENCY=HCEPC SAMPLE SITE=McKay Bay
8-DAY AVG RELEASE
TOP SALINITY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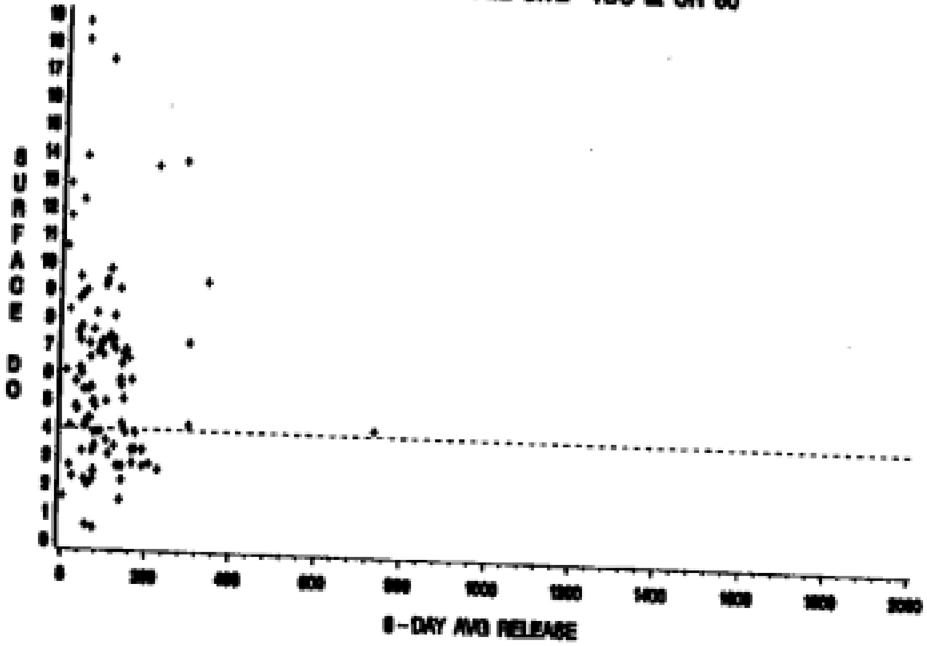
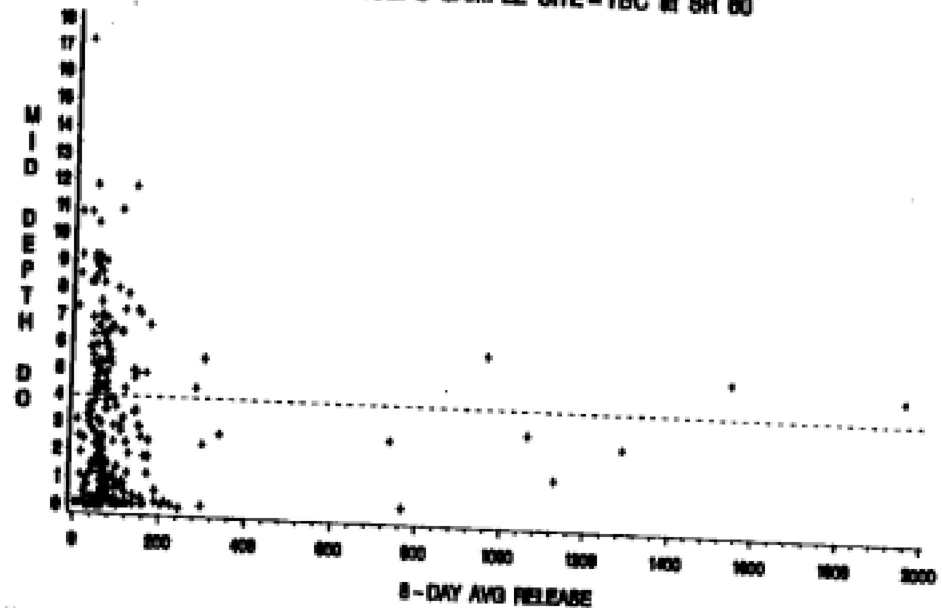
8-DAY AVG RELEASE
BOT SALINITY

AGENCY=HCEPC SAMPLE SITE=TBC at SR 60



AGENCY=HCEPC SAMPLE SITE=TBC at SR 60



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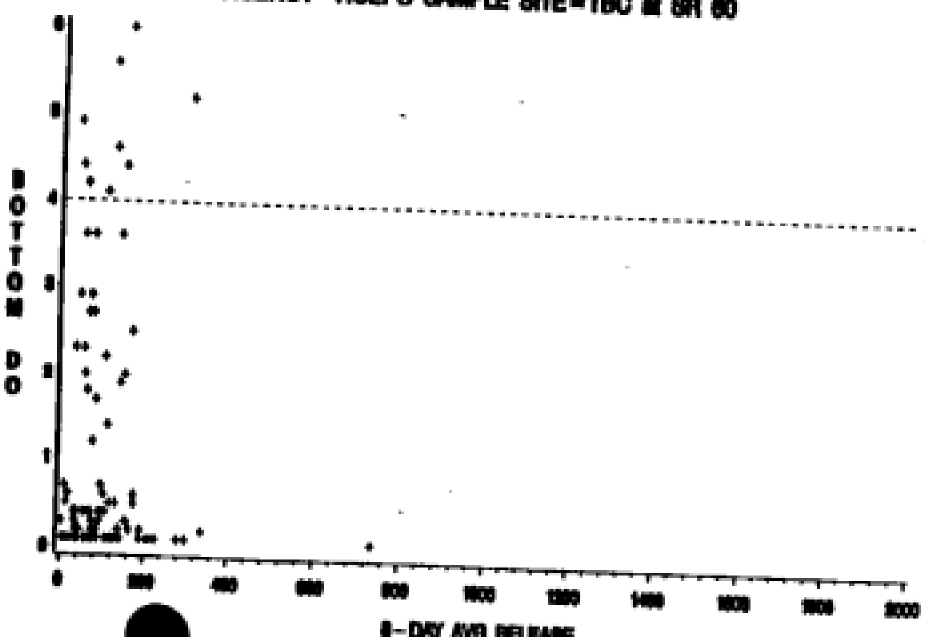

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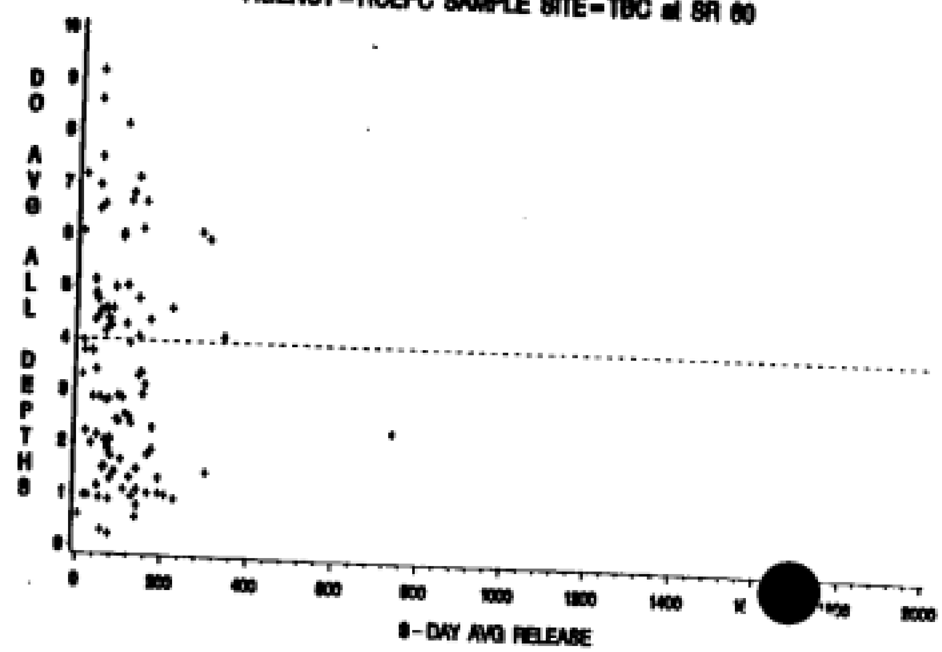

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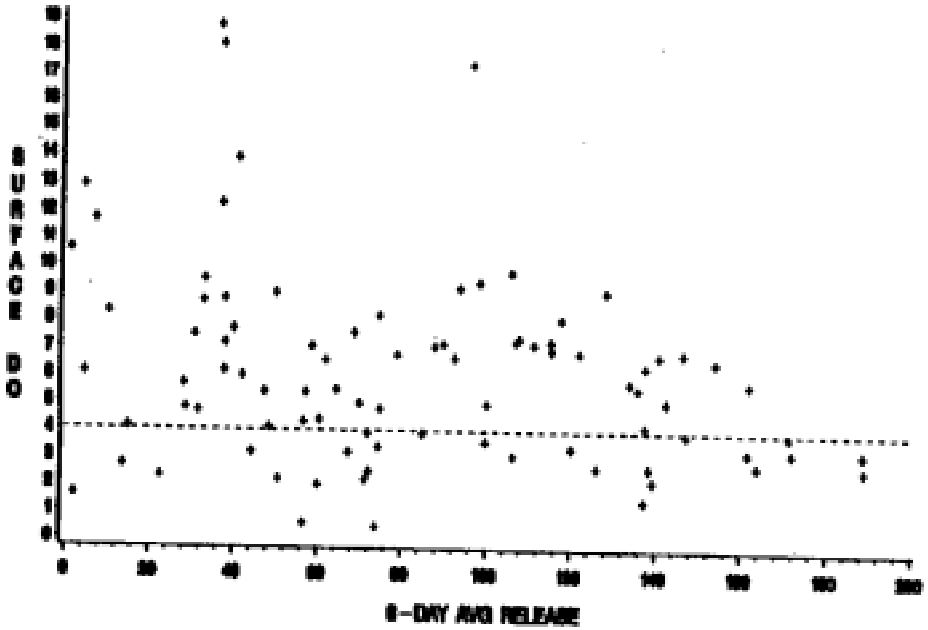

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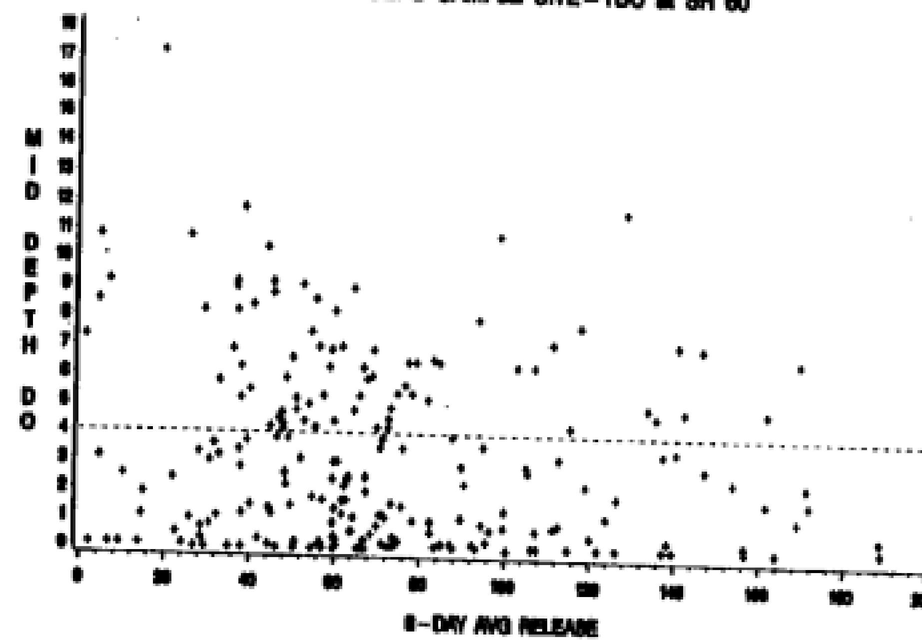

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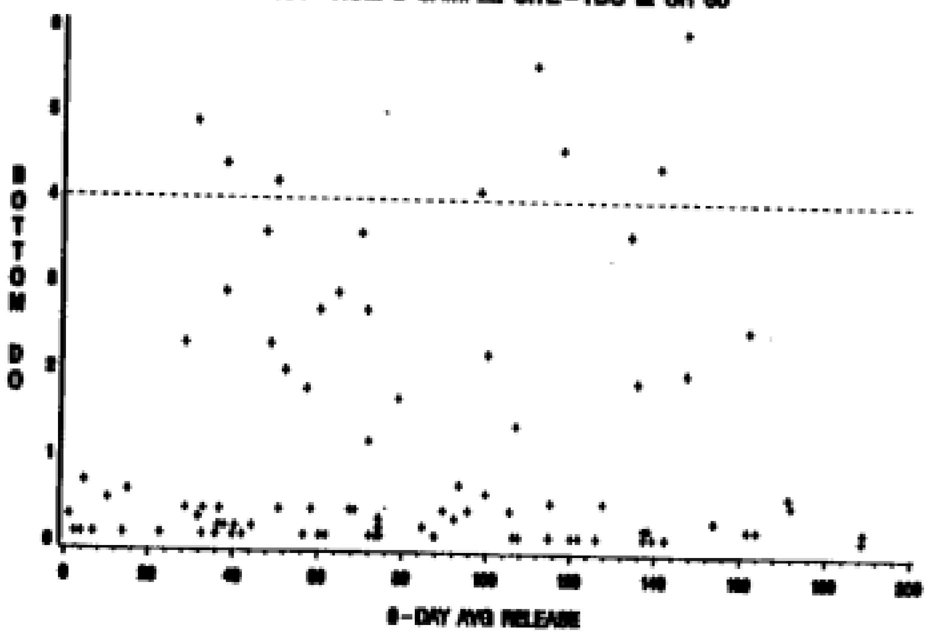

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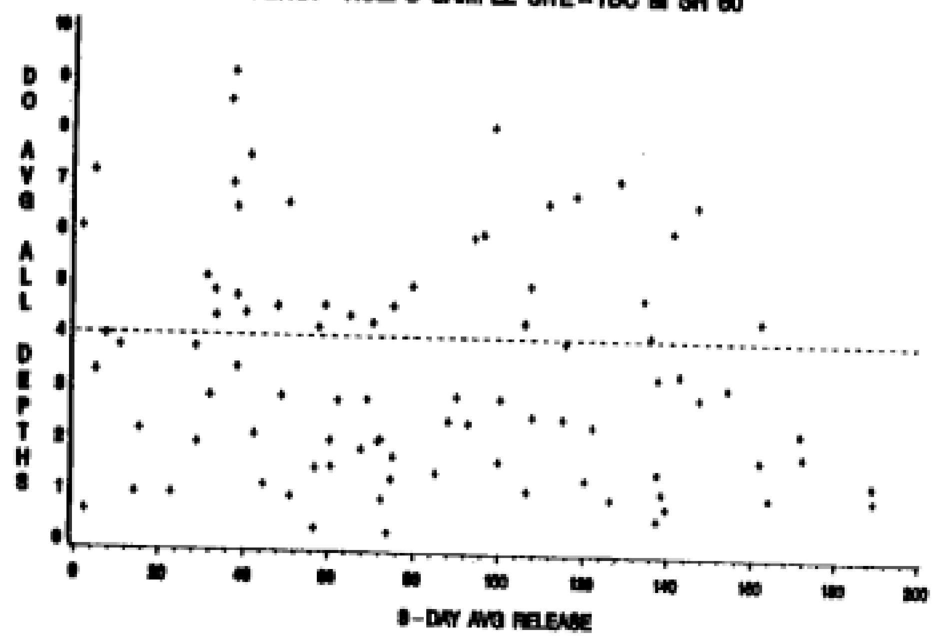
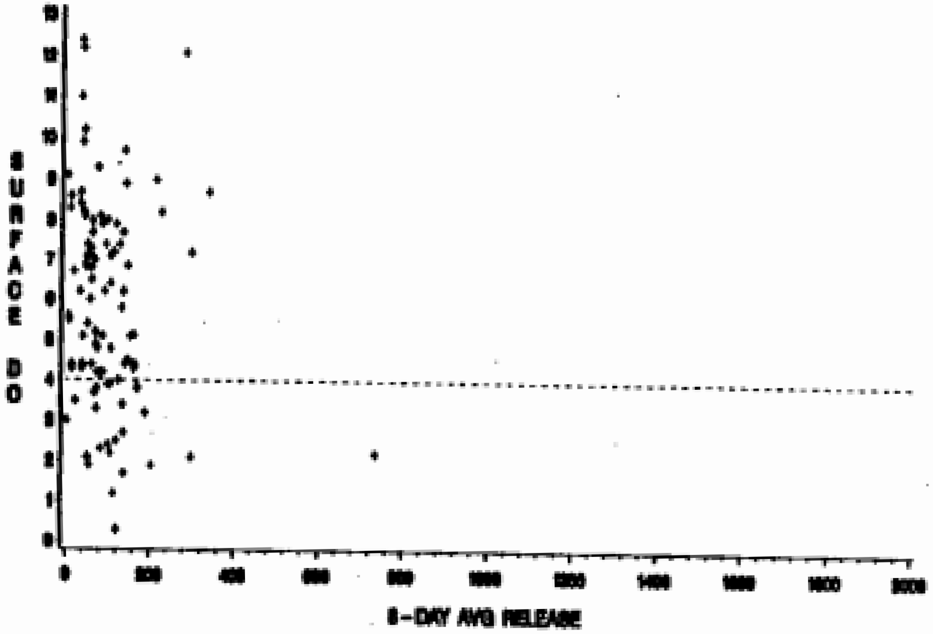
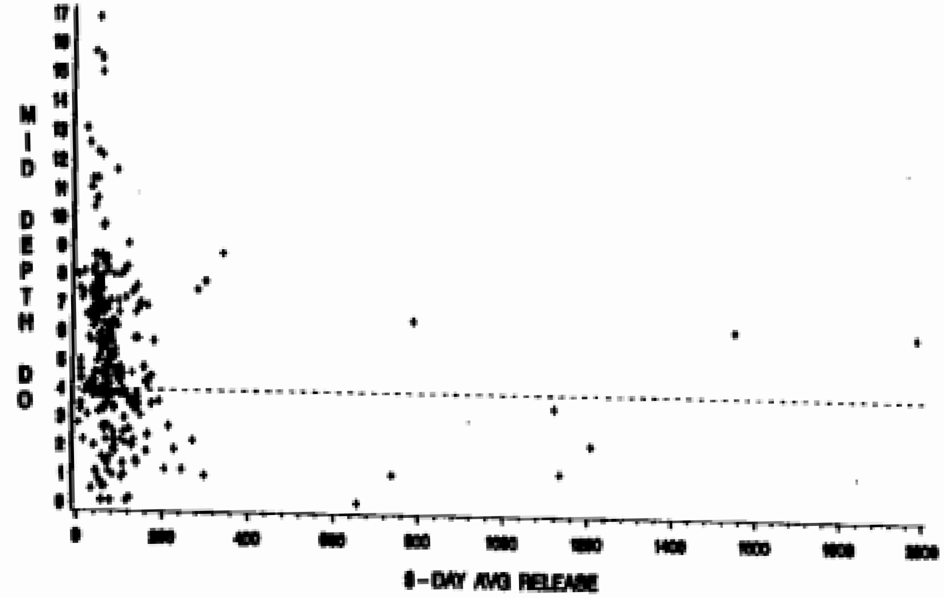


M1-8

AGENCY=HCEPC SAMPLE SITE=TBC at US 41



AGENCY=HCEPC SAMPLE SITE=TBC at US 41



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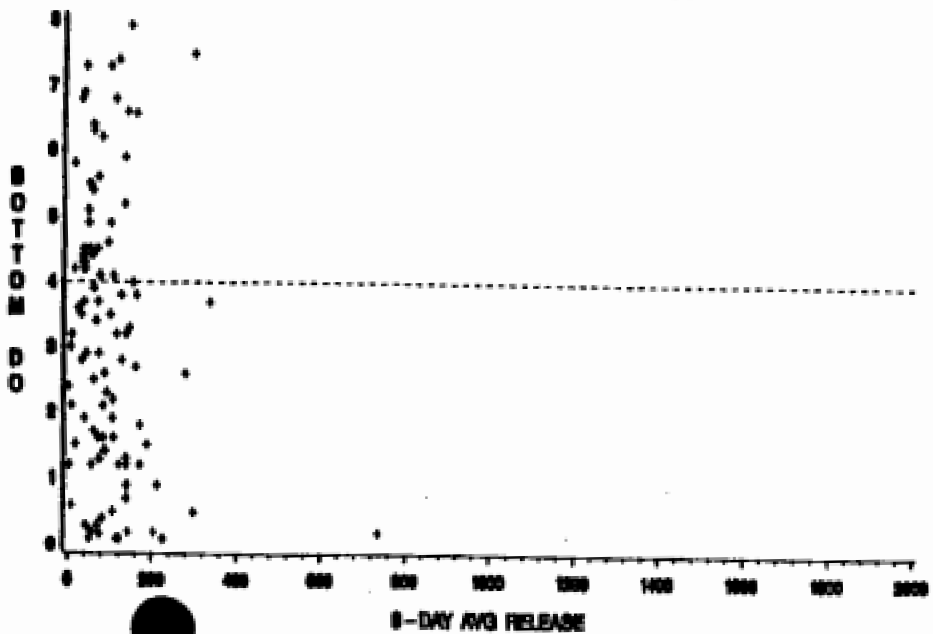
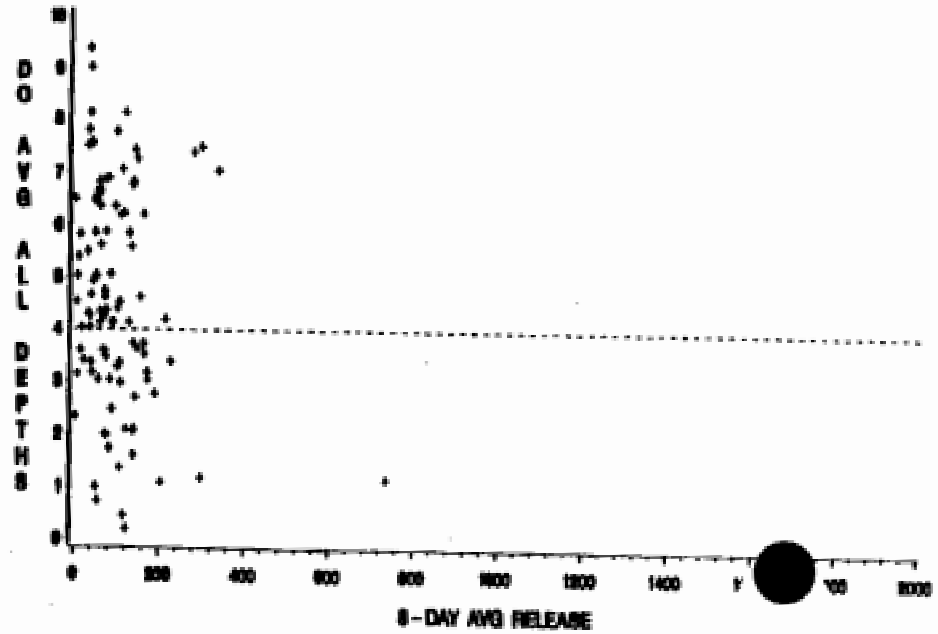
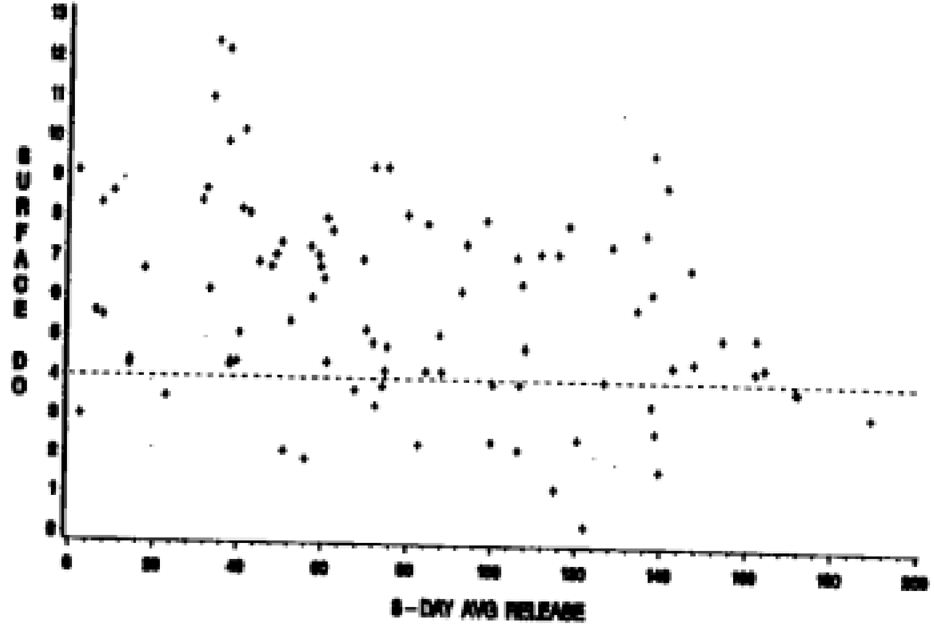
AGENCY=HCEPC SAMPLE SITE=TBC at US 41



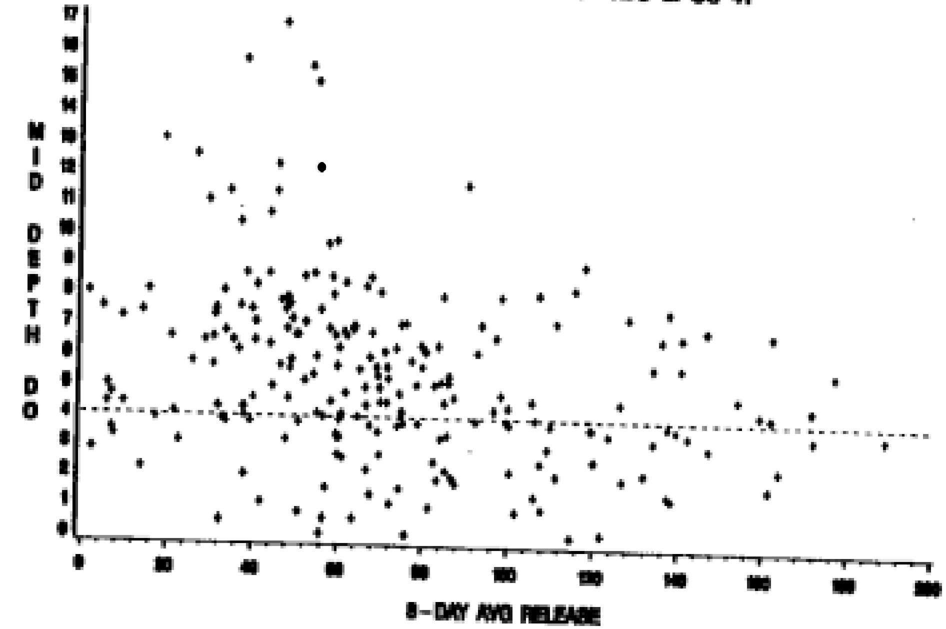
AGENCY=HCEPC SAMPLE SITE=TBC at US 41



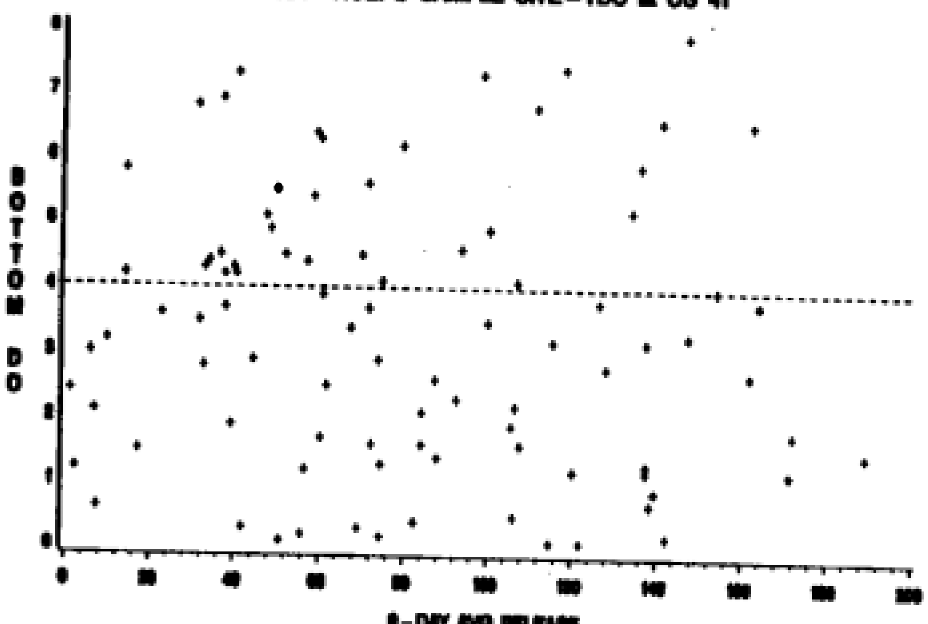
AGENCY=HCEPC SAMPLE SITE=TBC at US 41



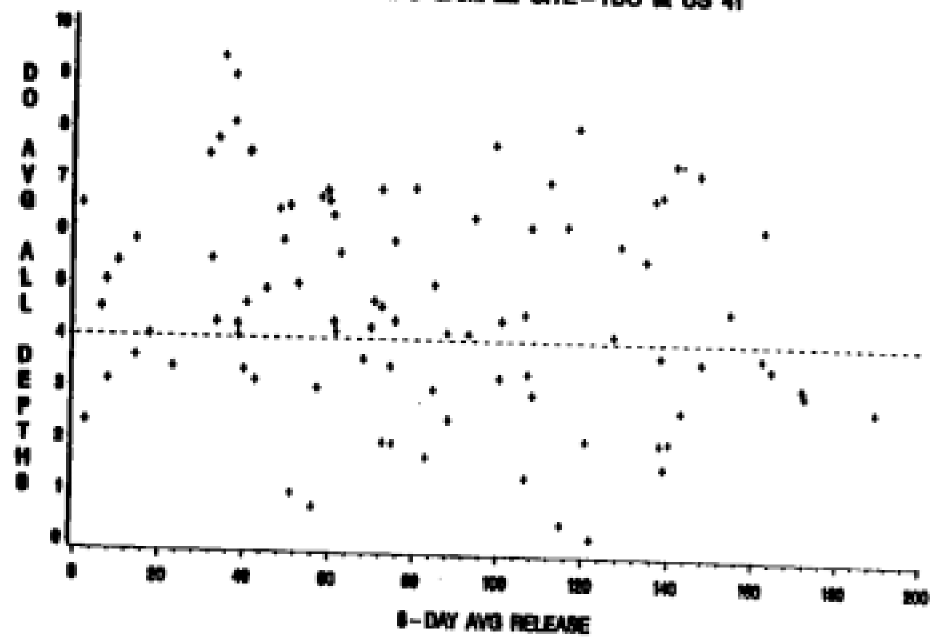
AGENCY=HCEPC SAMPLE SITE=TBC at US 41



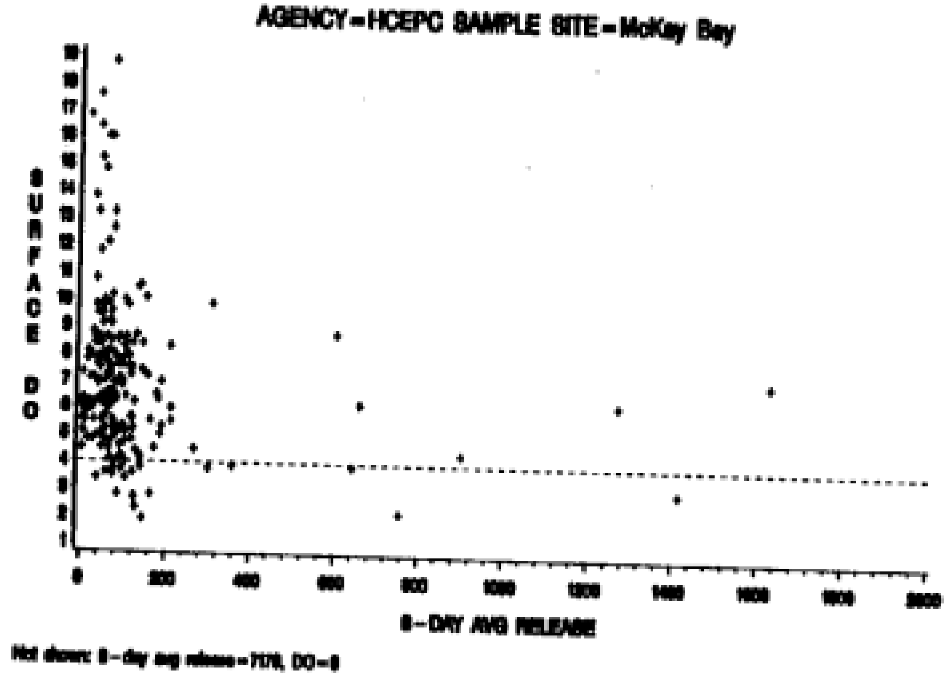
AGENCY=HCEPC SAMPLE SITE=TBC at US 41



AGENCY=HCEPC SAMPLE SITE=TBC at US 41



MI-10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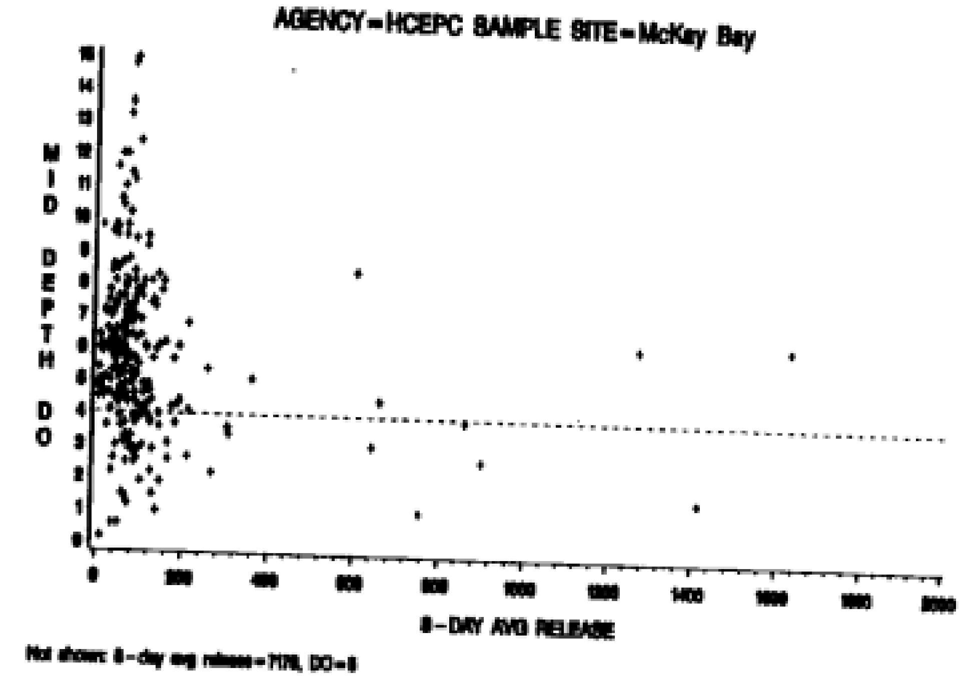
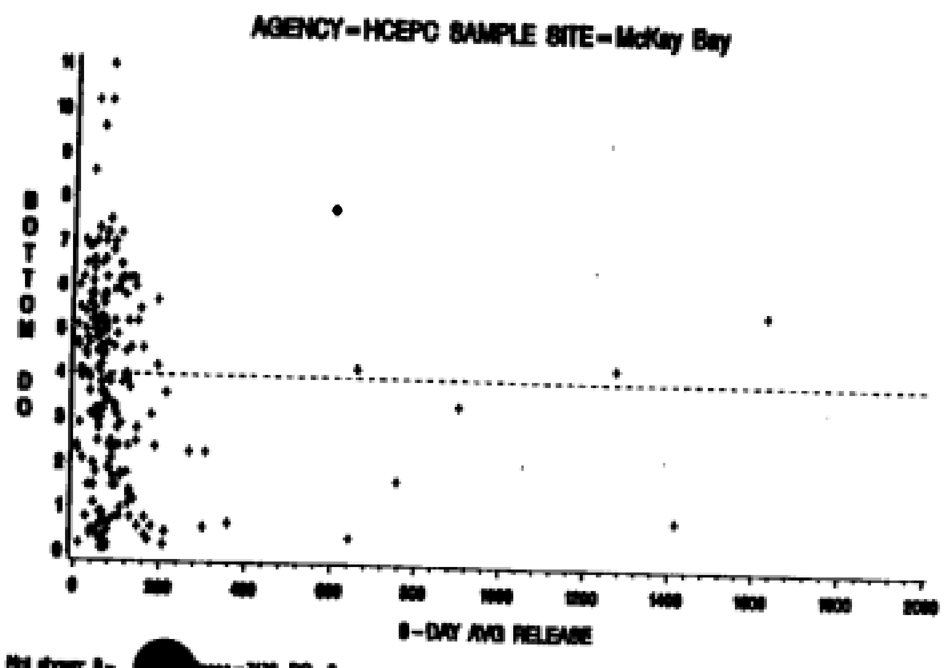
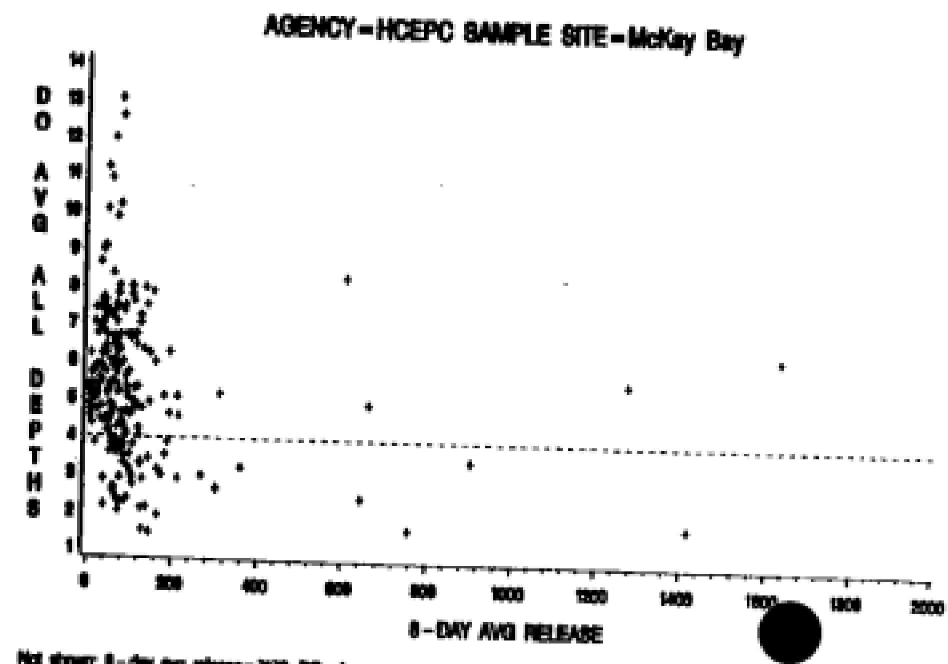
SURFACE DO
8-DAY AVG RELEASE
Not shown: 8-day avg release=7176, DO=8


AGENCY=HCEPC SAMPLE SITE=McKay Bay
MID DEPTH DO
8-DAY AVG RELEASE
Not shown: 8-day avg release=7176, DO=8


AGENCY=HCEPC SAMPLE SITE=McKay Bay
BOTTOM DO
8-DAY AVG RELEASE
Not shown: 8-
-7176, DO=2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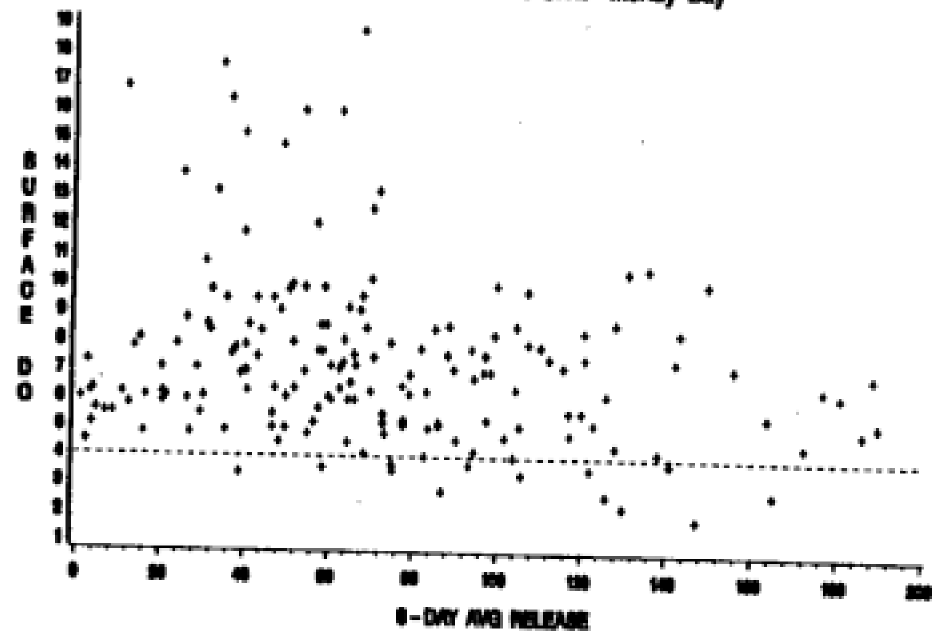
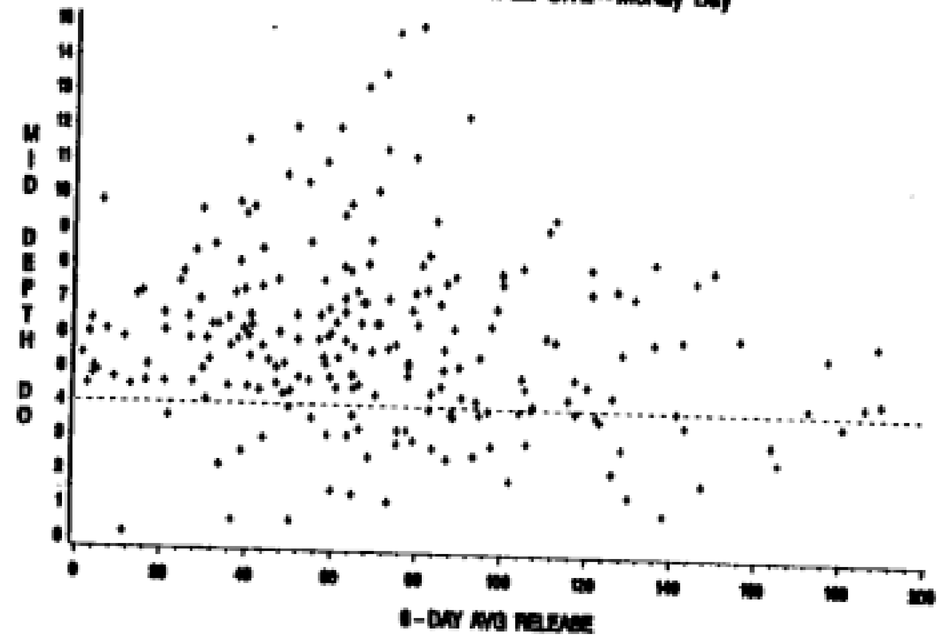
DO AVG ALL DEPTHS
8-DAY AVG RELEASE
Not shown: 8-day avg release=7176, DO=4

MI-11

AGENCY=HCEPC SAMPLE SITE=McKay Bay



AGENCY=HCEPC SAMPLE SITE=McKay Bay



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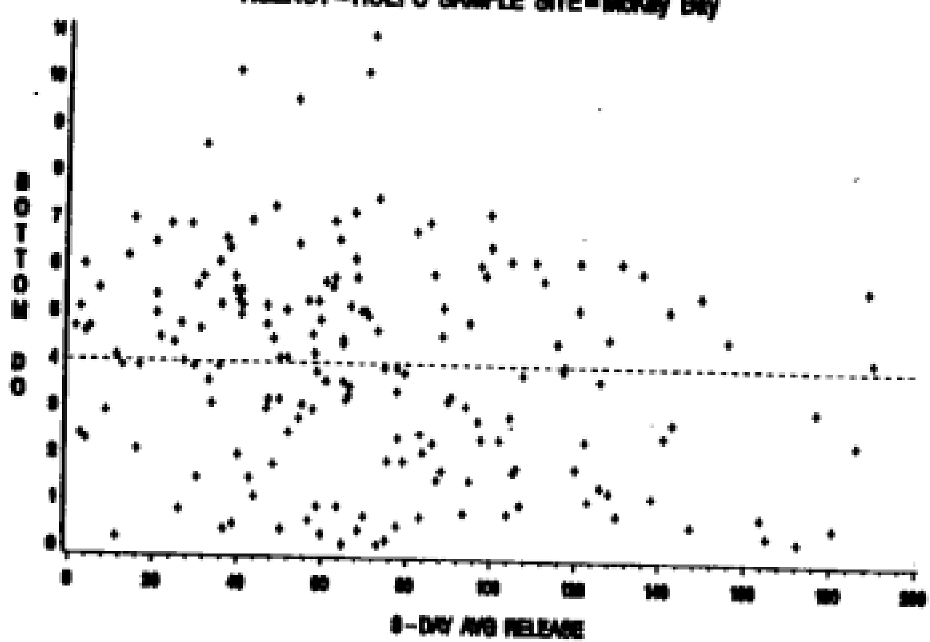
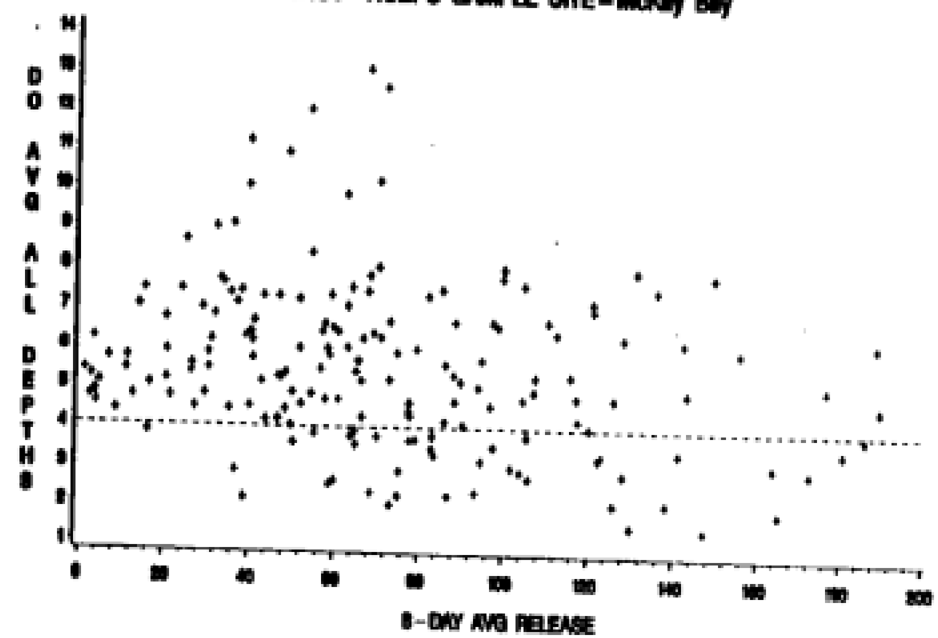


AGENCY=HCEPC SAMPLE SITE=McKay Bay



APPENDIX M-2

Summary statistics for water quality parameters in the Palm River and McKay Bay measured by the HCEPC

Means, standard deviations, medians and number of observations (n) for water quality parameters at HCEPC Station 110 (SR 60) on the Tampa Bypass Canal/Palm River.

	Mean	Std	Median	(N)
pH	7.7	.5	7.6	122
Color (pcu)	23.5	24.1	16	286
Chlorophyll a (ug/l)	31.5	38.9	21.4	253
B.O.D. (mg/l)	4.0	2.2	3.6	286
8-day flow (cfs.)	25.5	17.4	24.5	82
Turbidity (ntu)	7.87	11.2	5	286
N-Total (mg/l)	1.50	.89	1.23	203
NO3-N (mg/l)	.09	.14	.06	109
P-Total (mg/l)	.7	.5	.5	286
P-Ortho (mg/l)	.4	.5	.3	71
Total Coliforms (col./100ml)	1770	7780	200	286
Fecal Coliforms (col./100ml)	453	1476	100	283
Streptococci (col./100ml)	7522	33719	650	68

Means, standard deviations, medians and number of observations (n) for water quality parameters at HCEPC Station 109 (US 41) on the Tampa Bypass Canal/Palm River.

	Mean	**Std**	**Median**	**(N)**
pH	7.6	.3	7.7	122
Color (pcu)	21.0	19.4	15	286
Chlorophyll a (ug/l)	27.9	24.5	20.1	283
B.O.D. (Mg/l)	4.1	2.55	3.4	285
8-day flow (cfs.)	28.2	19.1	26.5	82
Turbidity (ntu)	4.6	2.6	4	286
N-Total (mg/l)	1.47	2.45	1.19	203
NO3-N (mg/l)	.12	.23	.06	109
P-Total (mg/l)	.7	.5	.6	286
P-Ortho (mg/l)	.4	.5	.2	71
Total Coliforms (col./100ml)	2460	8620	300	286
Fecal Coliforms (col./100ml)	1241	6282	100	283
Streptococci (col./100ml)	4207	16030	300	257

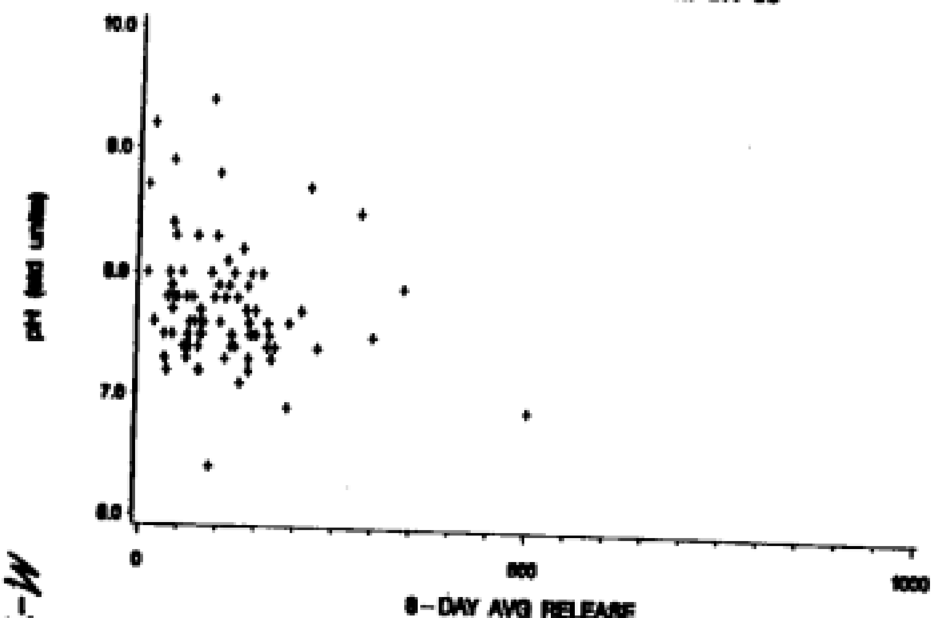
Means, standard deviations, medians and number of observations (n) for water quality parameters at HCEPC Station 58, McKay Bay.

	Mean	Std	Median	(N)
pH	8.0	0.46	7.9	241
color (pcu)	15.2	14.04	12	263
Chlorophyll a (ug/l)	23.6	18.74	17.7	262
B.O.D. (mg/l)	3.2	2.4	2.5	254
8-day flow, cfs	163	564	68	247
Turbidity (ntu)	5.3	3.60	4.0	48
N-Total (mg/l)	0.99	0.40	0.91	176
NO3-N (mg/l)	0.07	0.15	0.03	85
P-Total (mg/l)	0.63	0.38	0.38	263
P-ortho (mg/l)	0.56	0.43	0.34	156
Total Coliforms (col/100 ml)	1254	9927	69	246

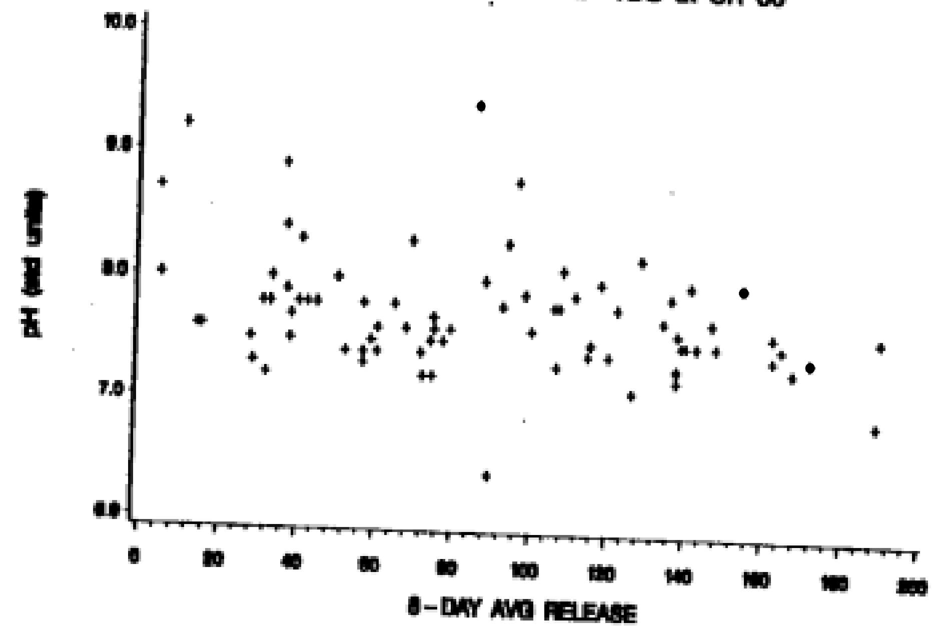
APPENDIX M-3

Plots of water quality parameters measured by the HCEPC in the Palm River vs. discharge from Structure 160 on the Tampa Bypass Canal

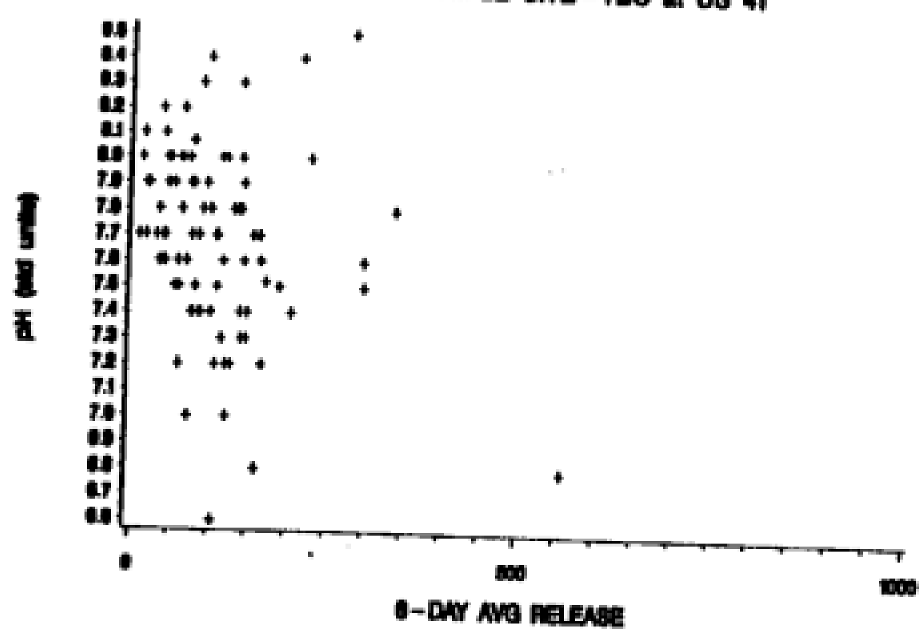
AGENCY=HCEPC SAMPLE SITE=TBC at SR 60



AGENCY=HCEPC SAMPLE SITE=TBC at SR 60



AGENCY=HCEPC SAMPLE SITE=TBC at US 41



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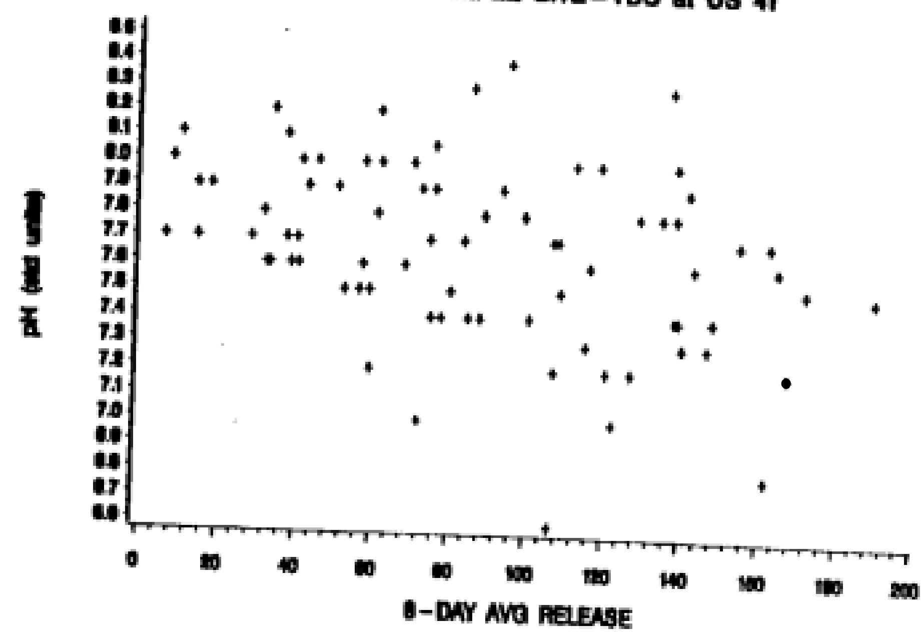

M-3 /

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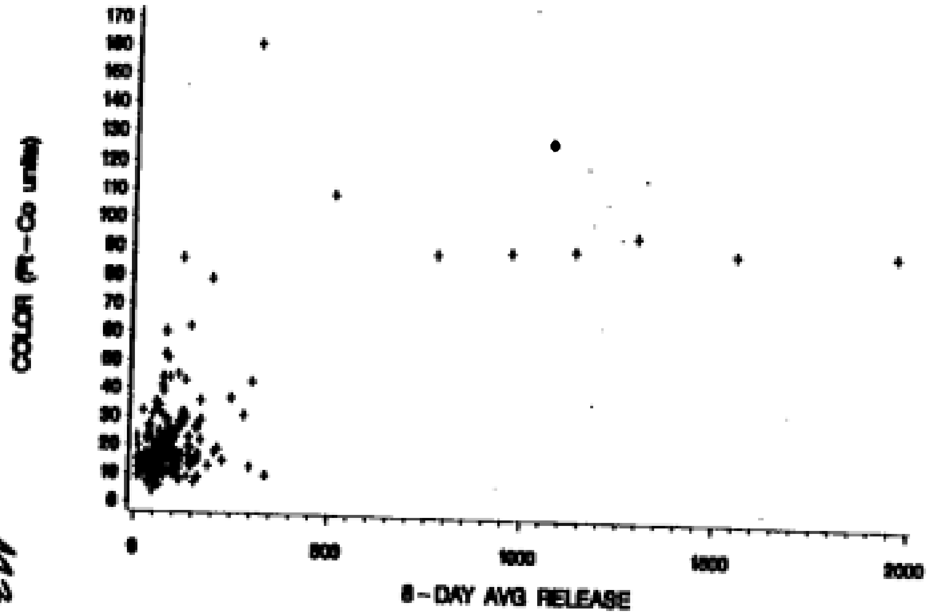
AGENCY=HCEPC SAMPLE SITE=TBC at SR 60



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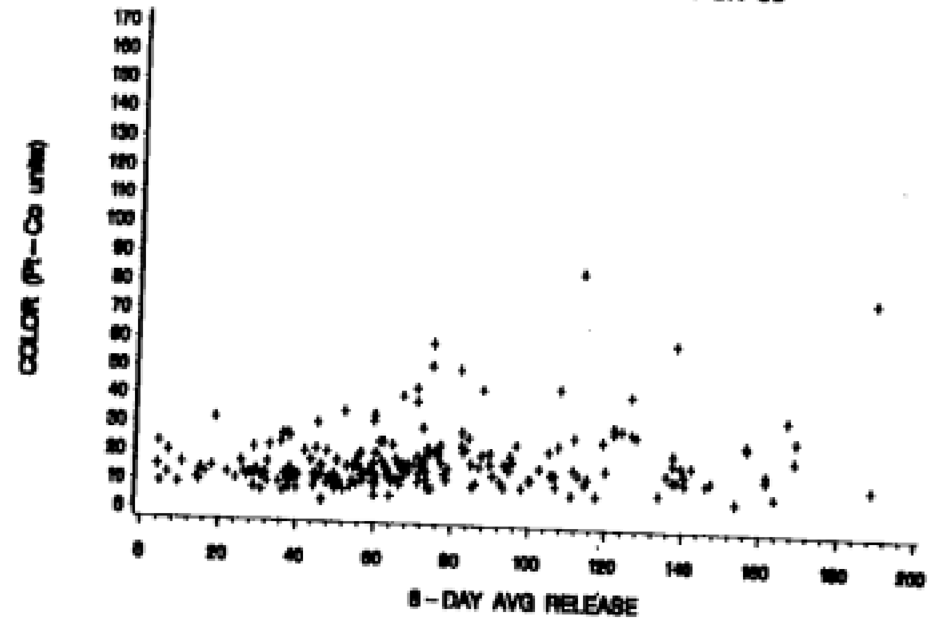
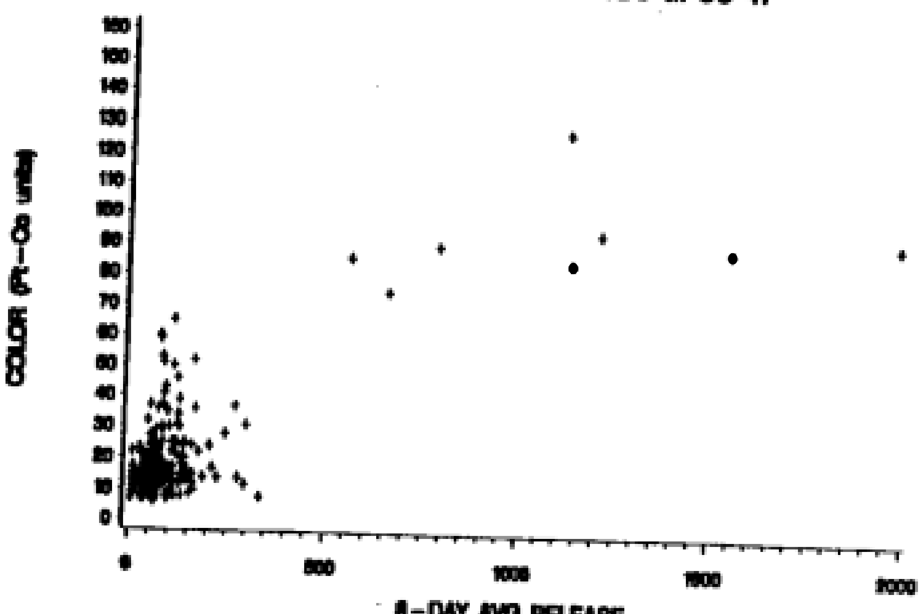
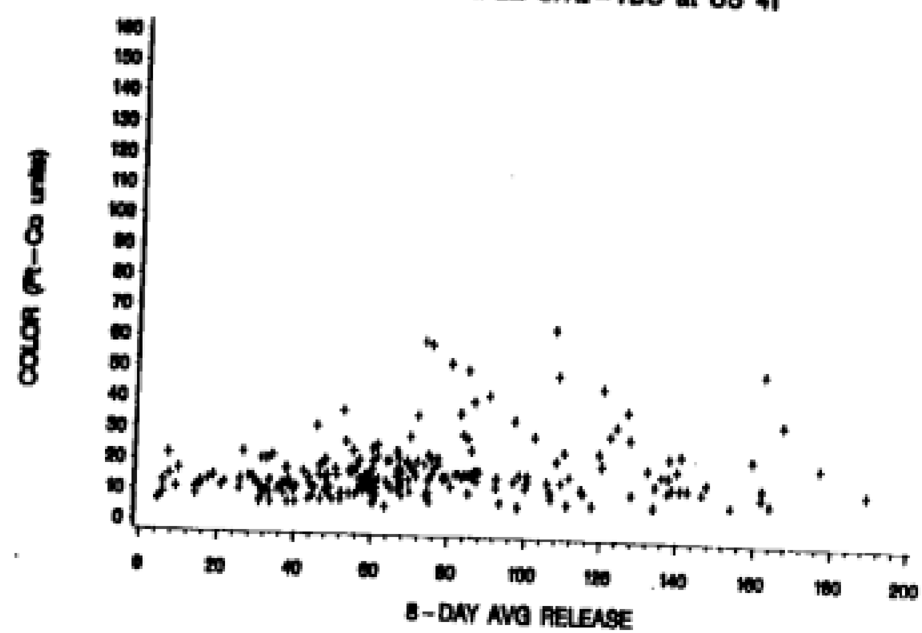


M3-2

AGENCY=HCEPC SAMPLE SITE=TBC at US 41



AGENCY=HCEPC SAMPLE SITE=TBC at US 41



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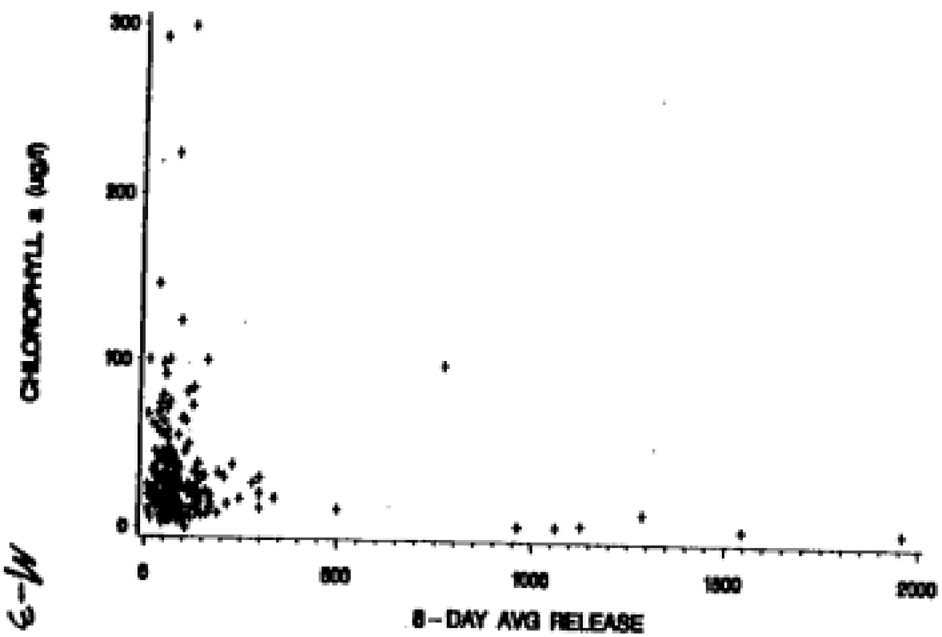

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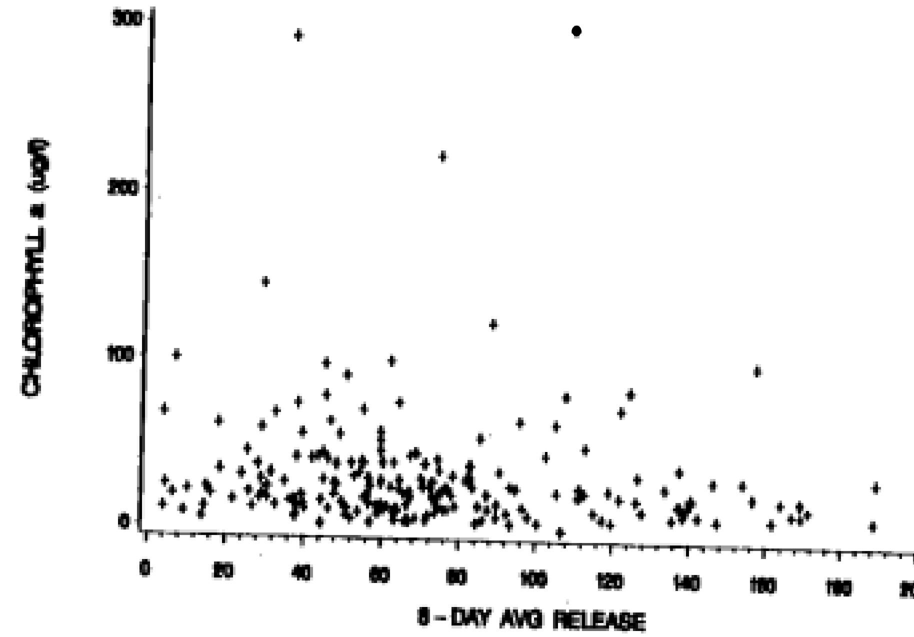

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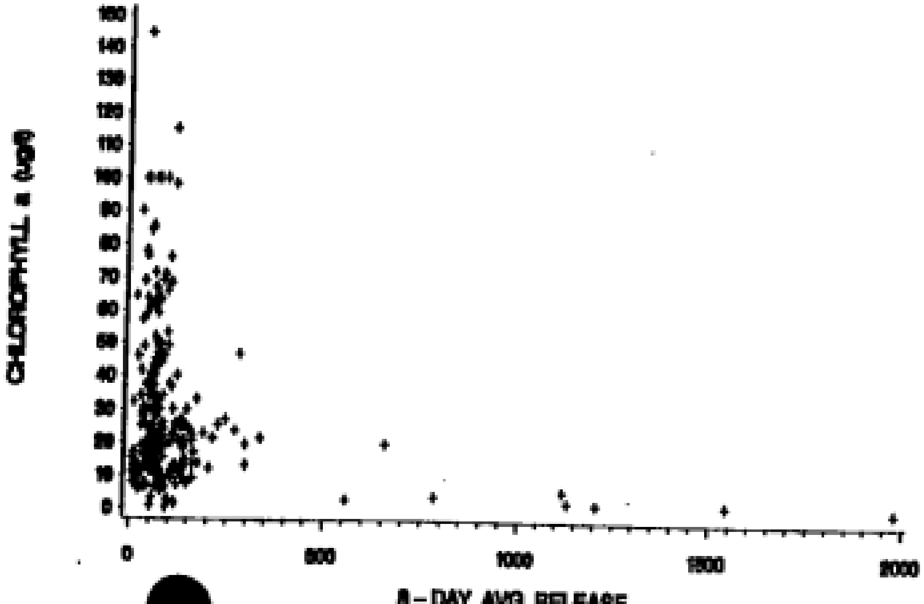

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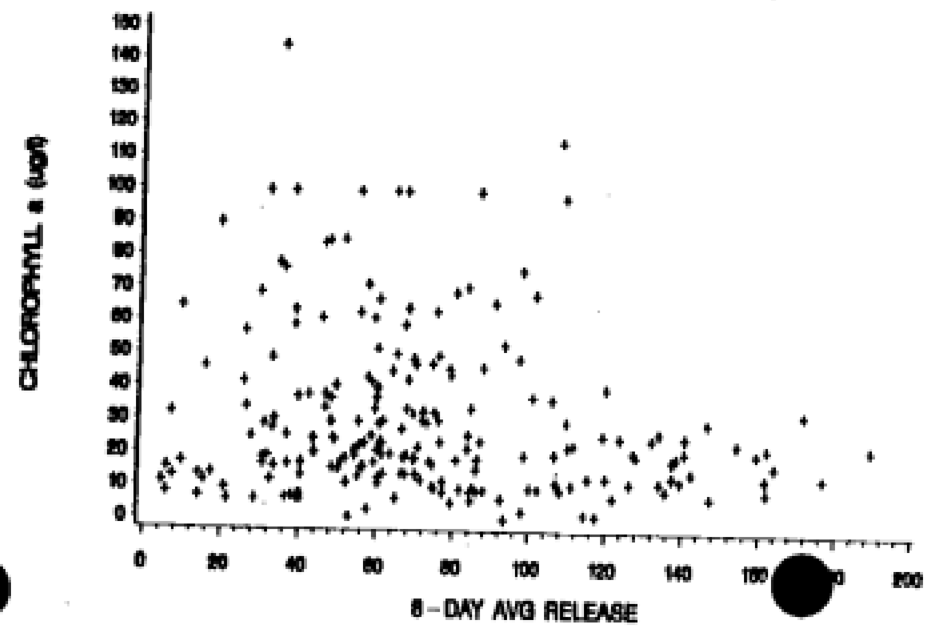
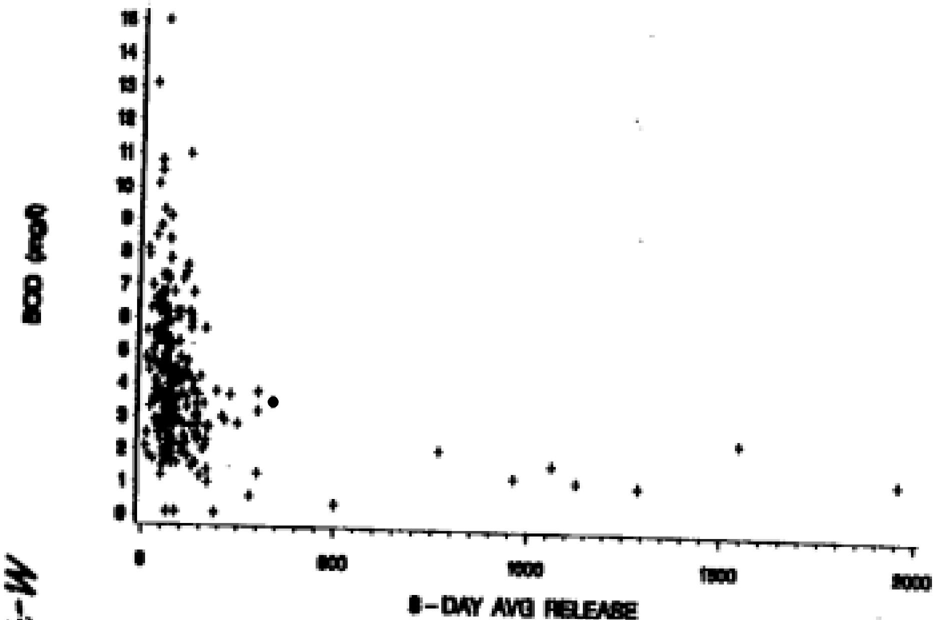


M-3-3

AGENCY=HCEPC SAMPLE SITE=TBC at SR 60



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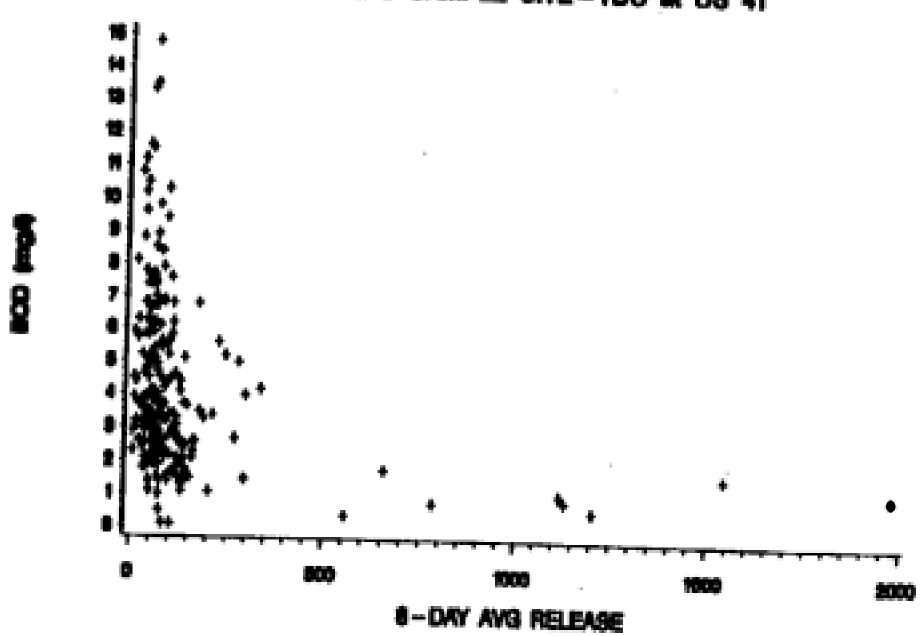
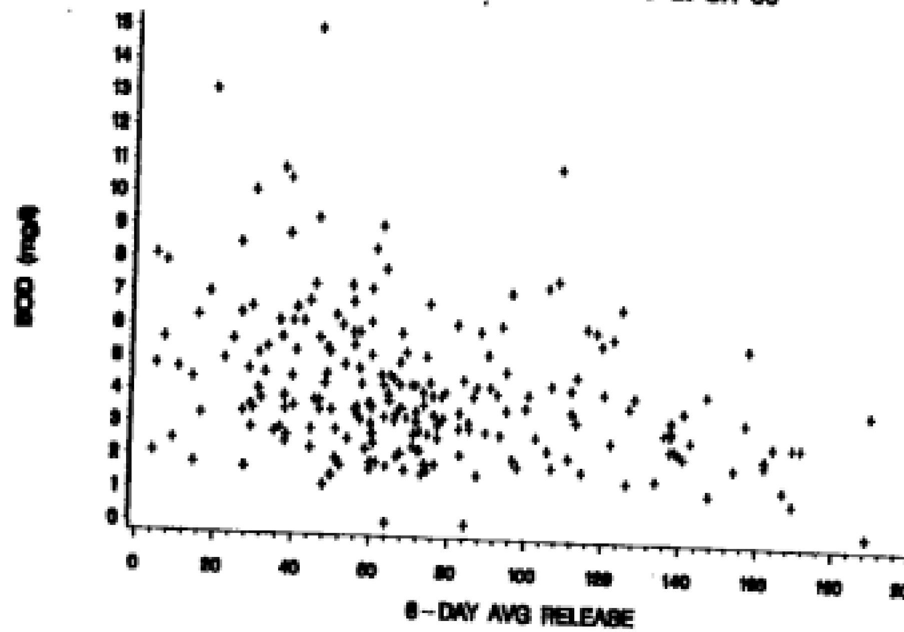


AGENCY=HCEPC SAMPLE SITE=TBC at SR 60



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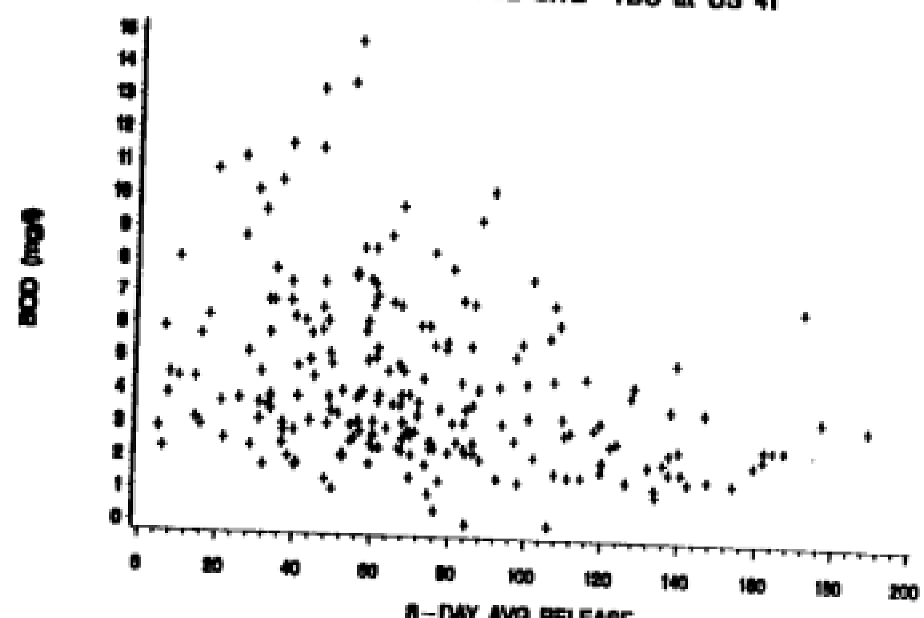

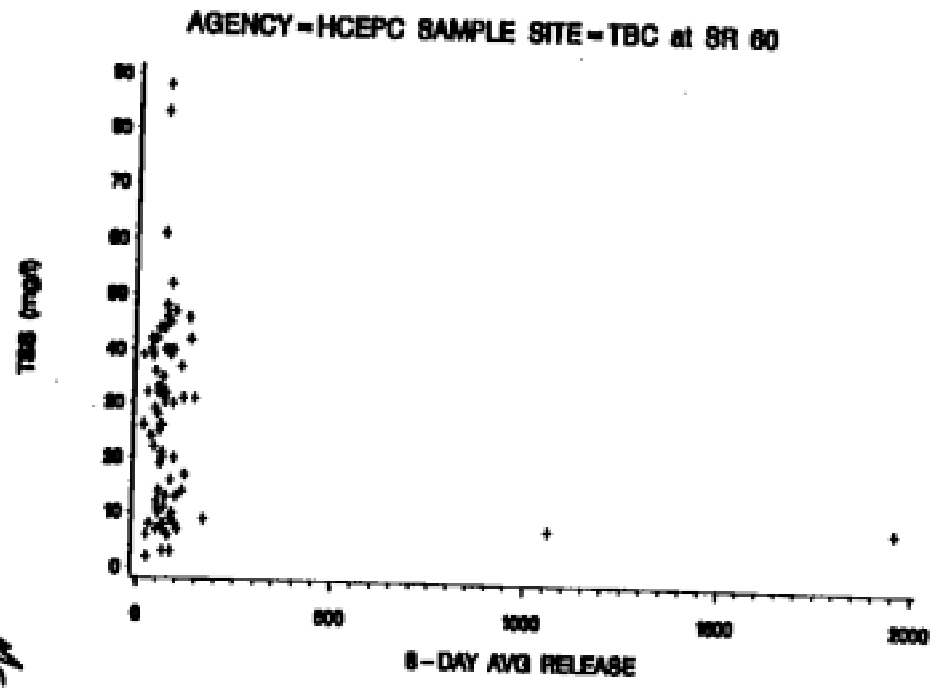
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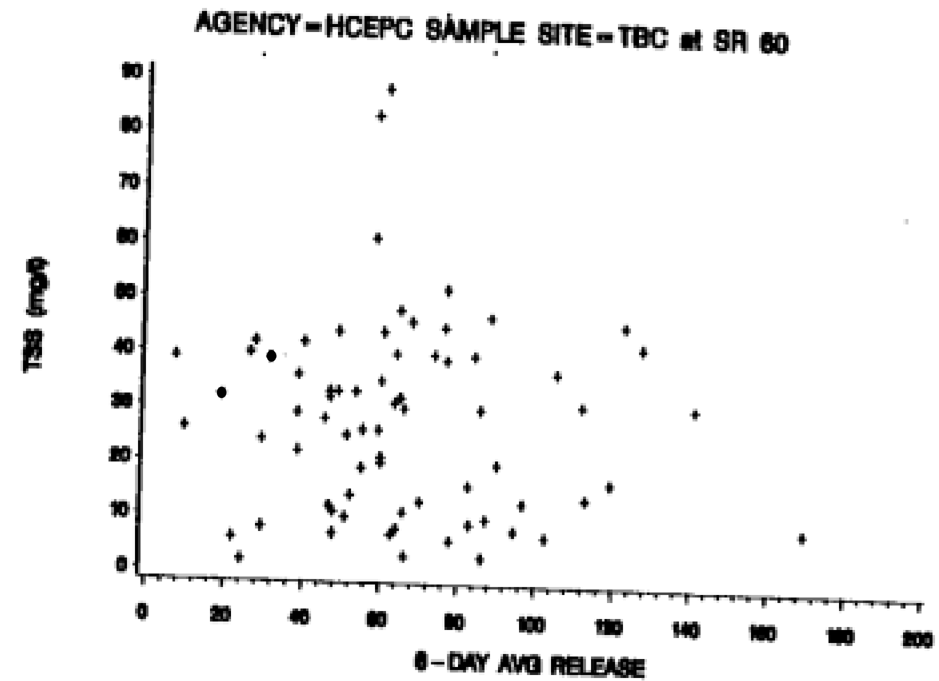
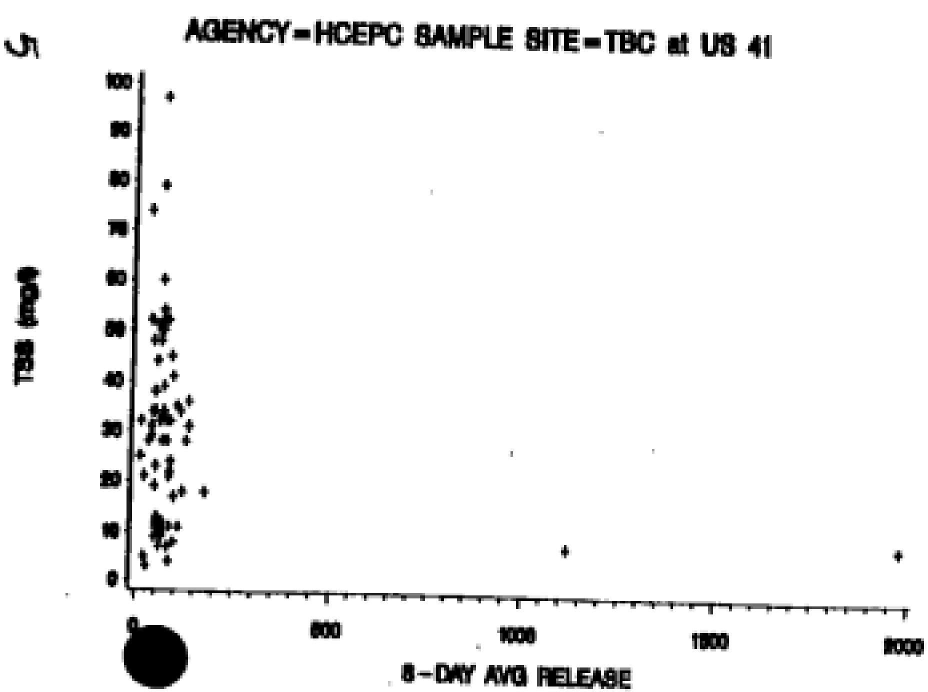
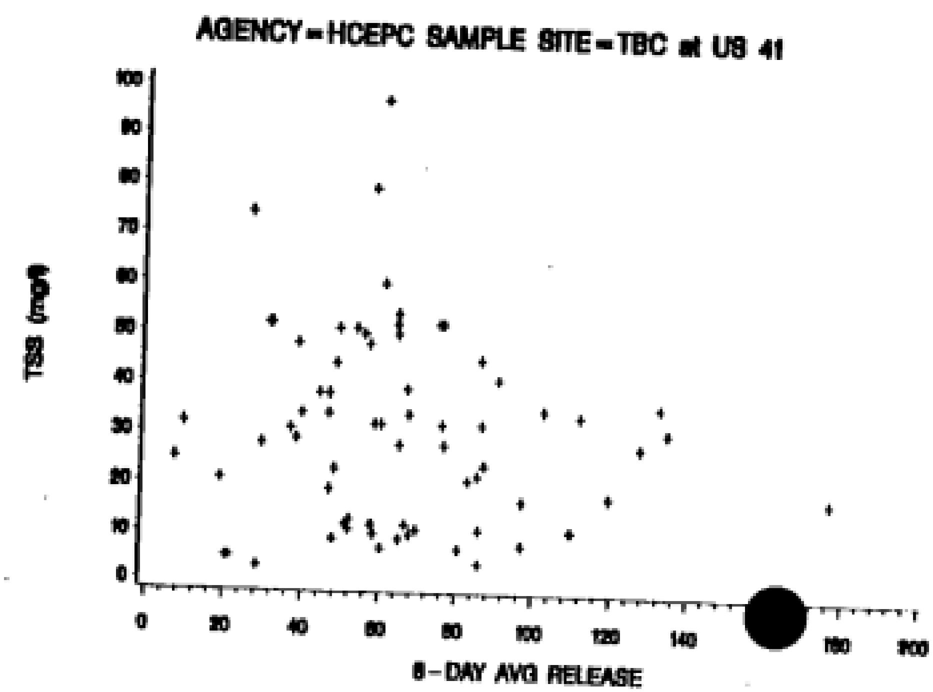
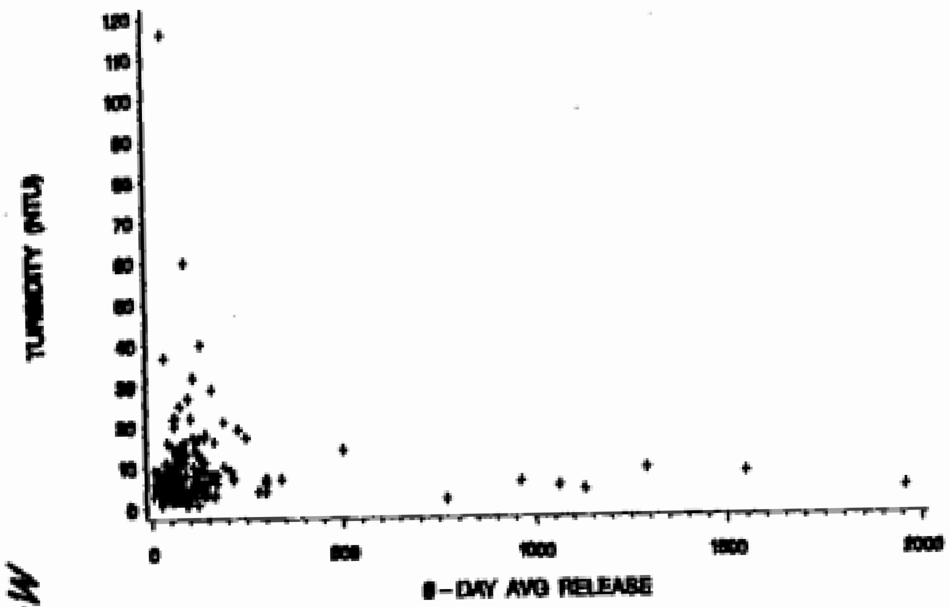
TSS (mg/l)
8-DAY AVG RELEASE


AGENCY=HCEPC SAMPLE SITE=TBC at SR 60
TSS (mg/l)
8-DAY AVG RELEASE


AGENCY=HCEPC SAMPLE SITE=TBC at US 41
TSS (mg/l)
8-DAY AVG RELEASE


AGENCY=HCEPC SAMPLE SITE=TBC at US 41
TSS (mg/l)
8-DAY AVG RELEASE

AGENCY=HCEPC SAMPLE SITE=TBC at SR 60



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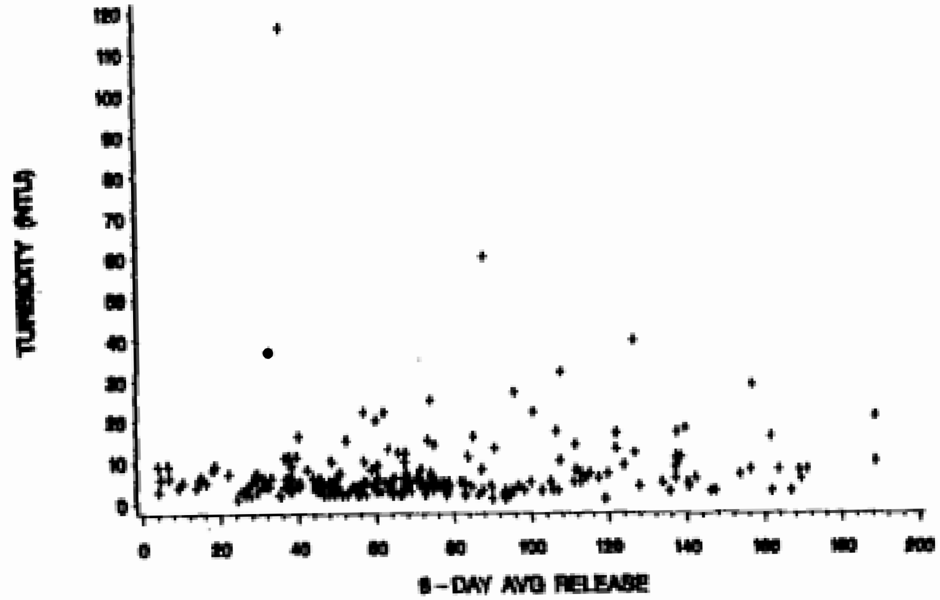

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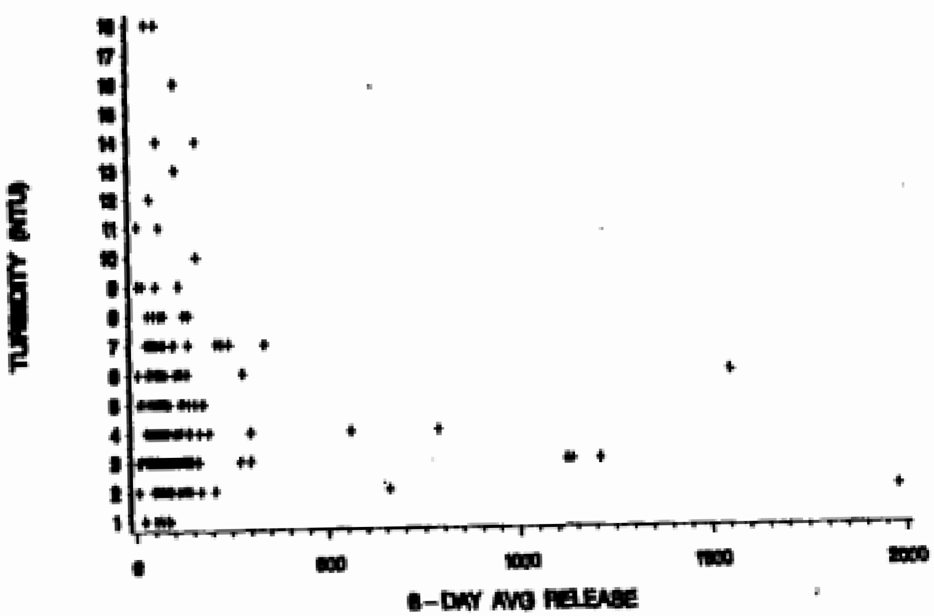

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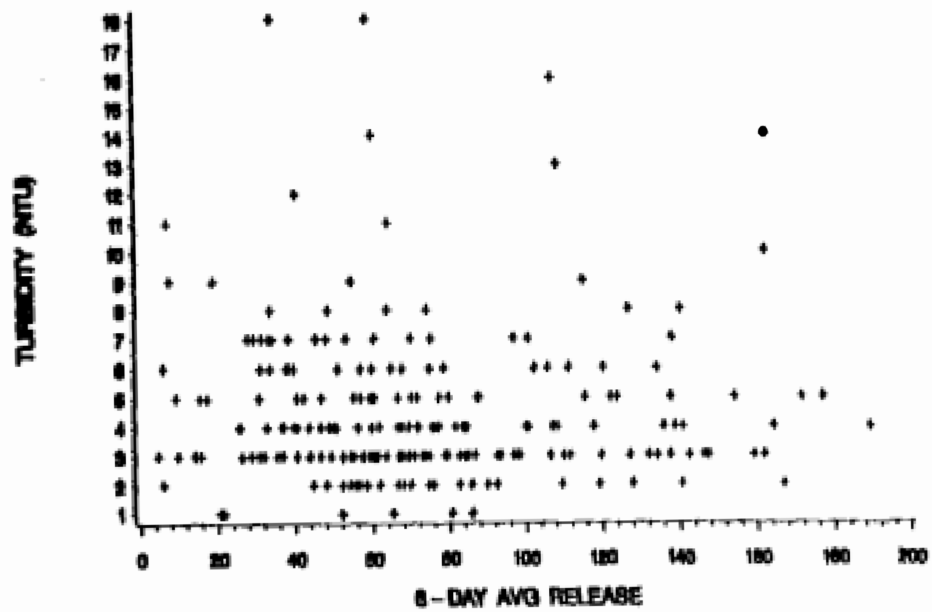

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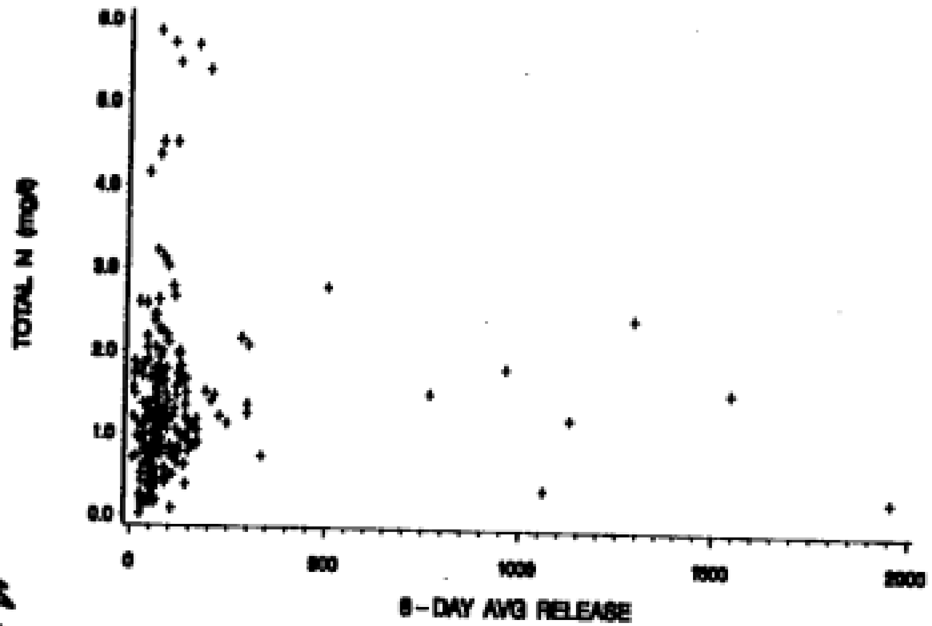

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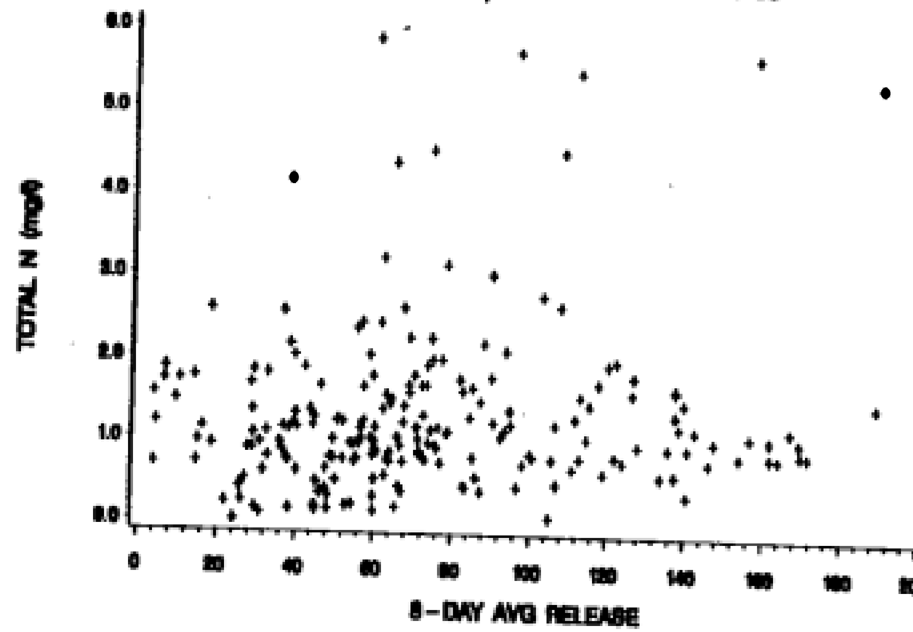

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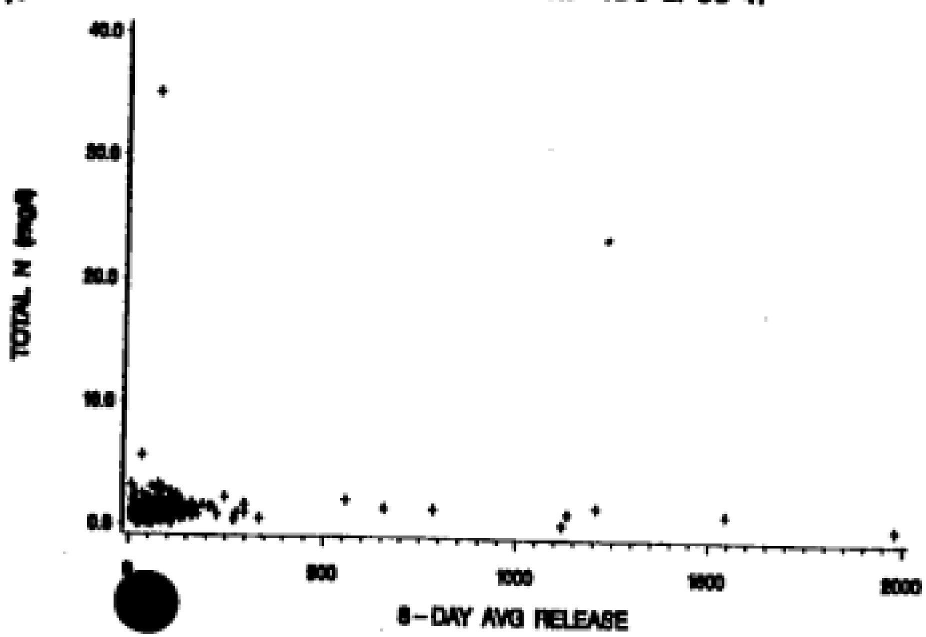

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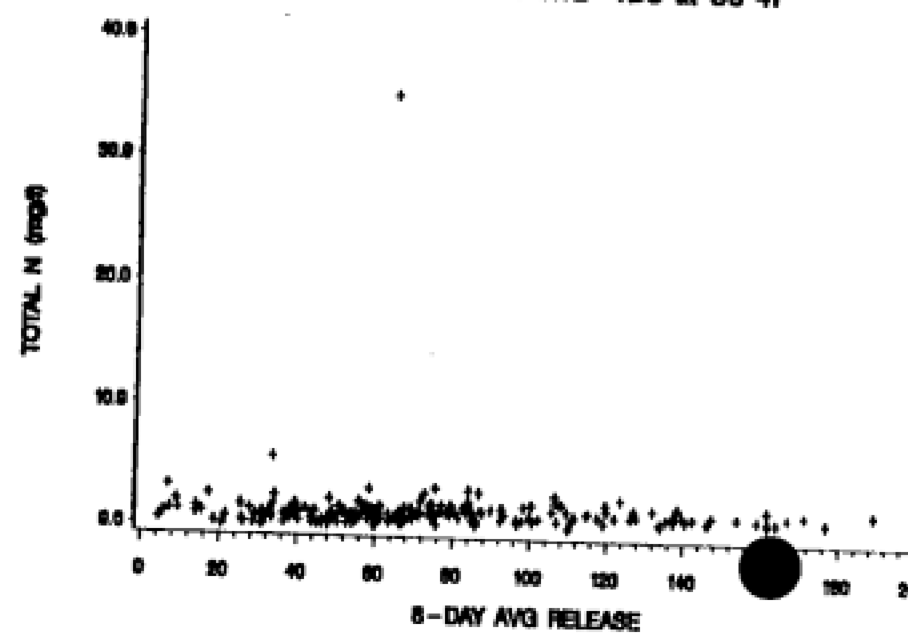

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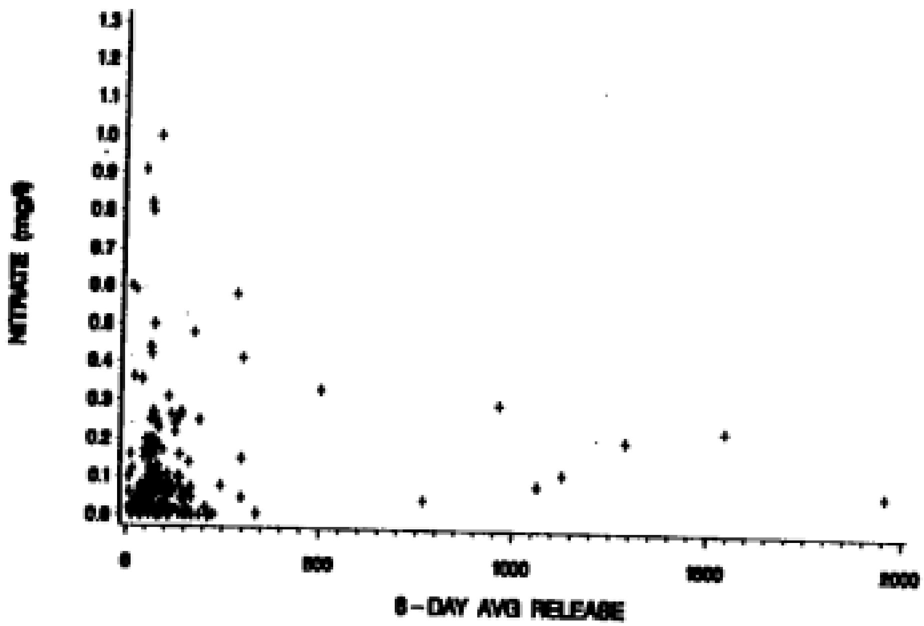

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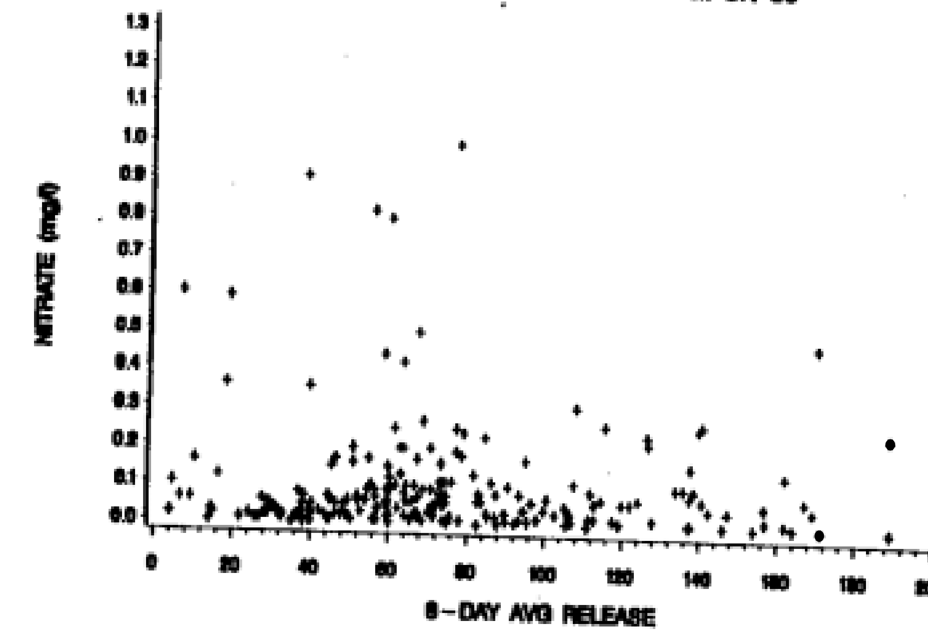

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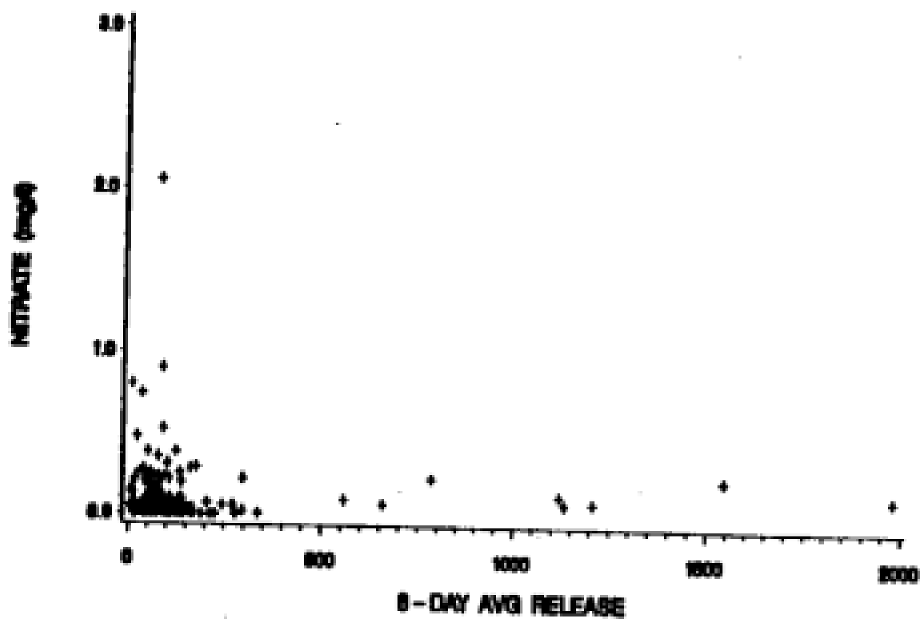
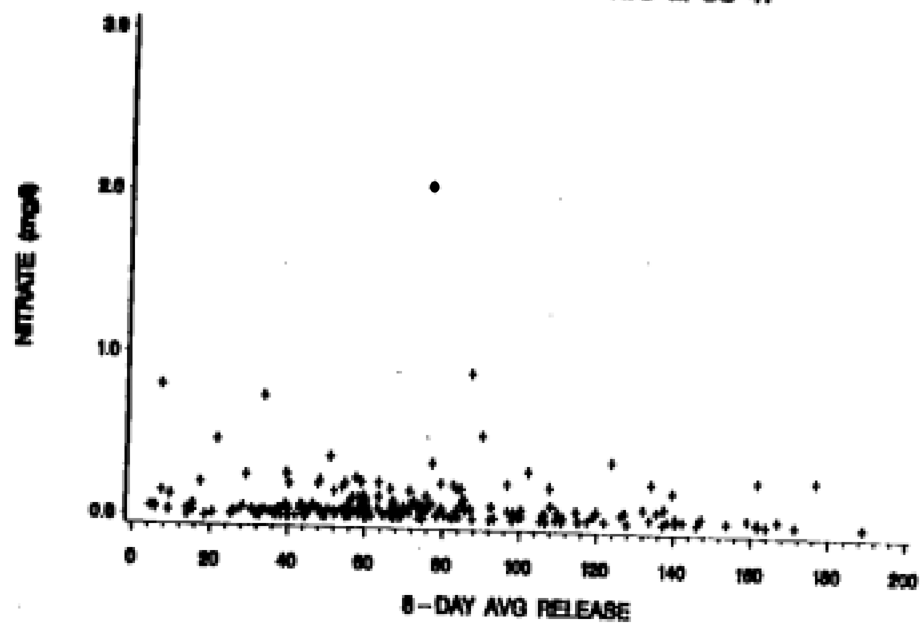
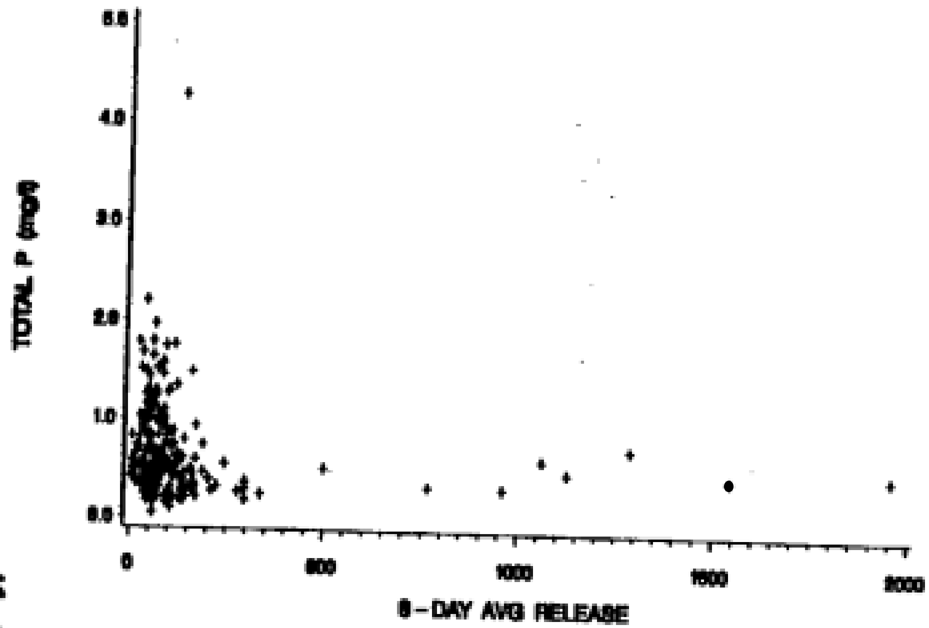


AGENCY=HCEPC SAMPLE SITE=TBC at US 41

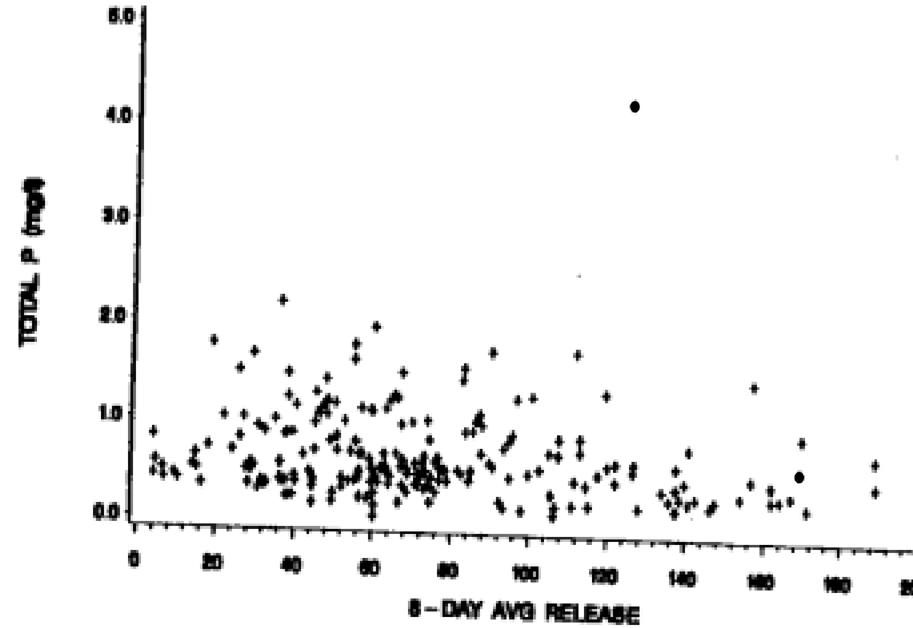


M-3 8

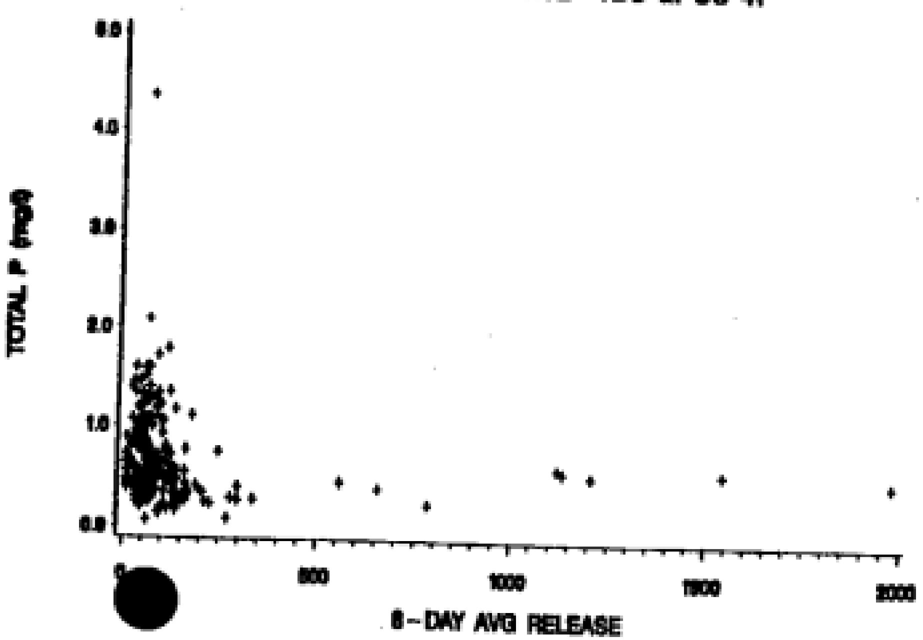
AGENCY=HCEPC SAMPLE SITE=TBC at SR 60



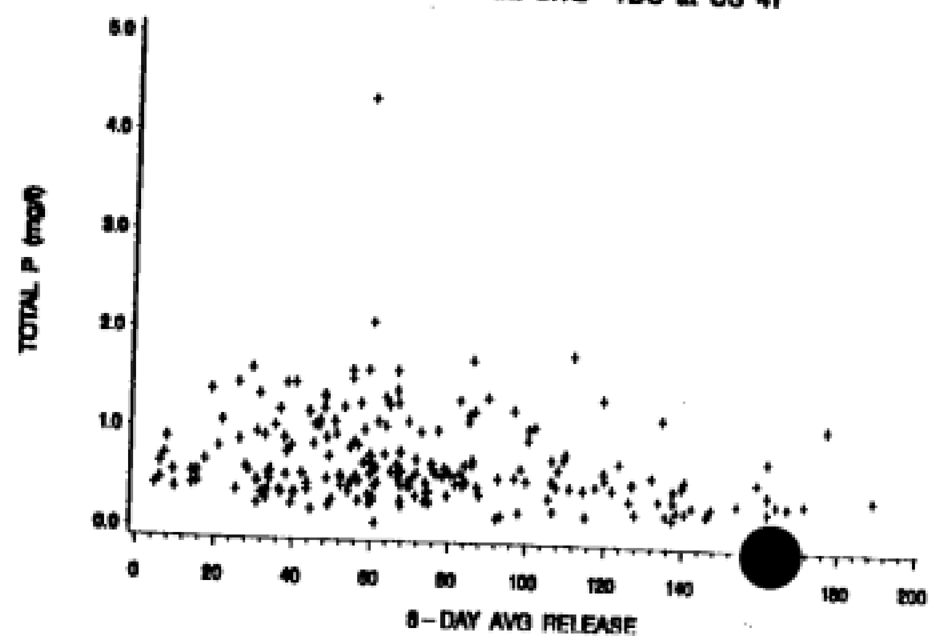
AGENCY=HCEPC SAMPLE SITE=TBC at SR 60



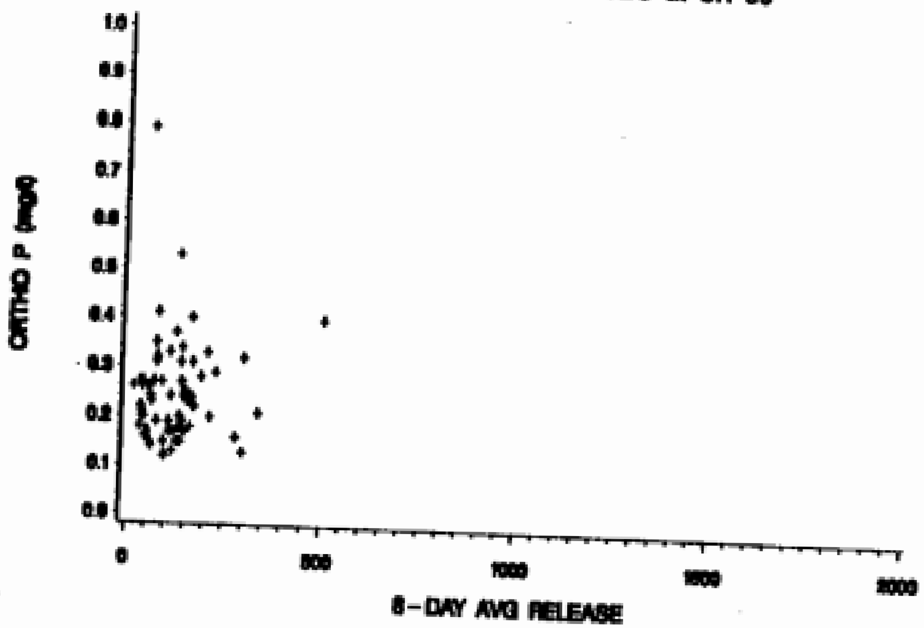
AGENCY=HCEPC SAMPLE SITE=TBC at US 41



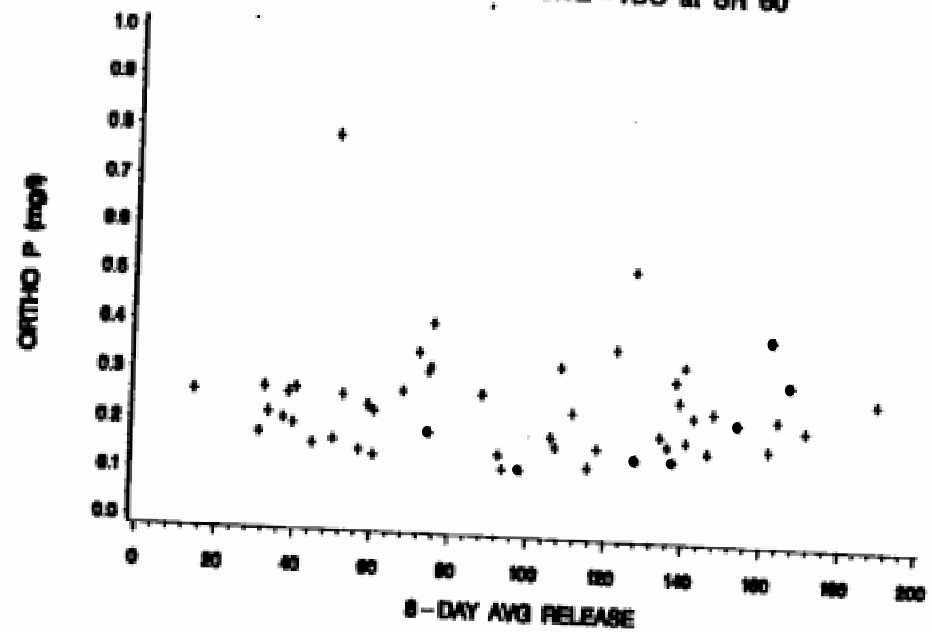
AGENCY=HCEPC SAMPLE SITE=TBC at US 41



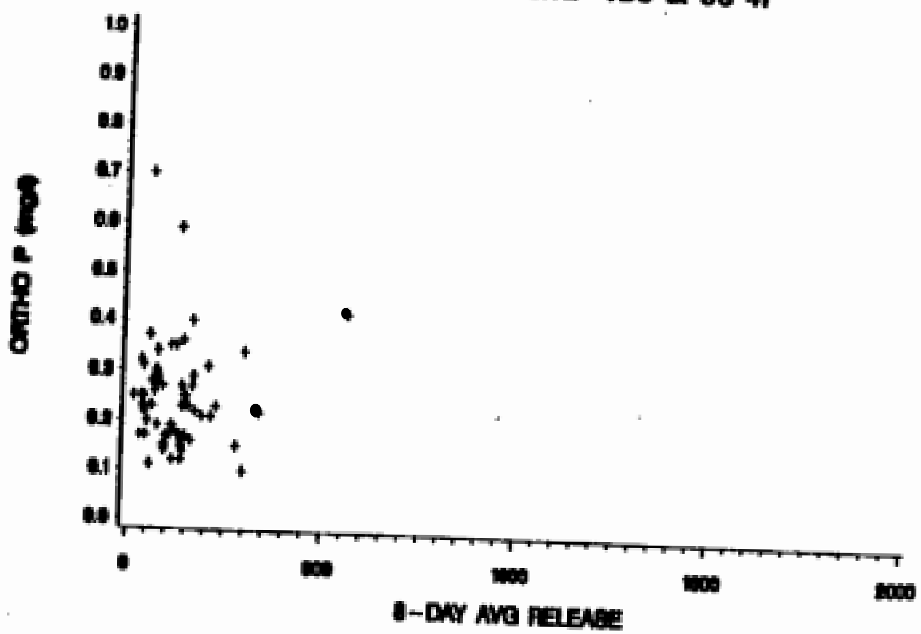
AGENCY=HCEPC SAMPLE SITE=TBC at SR 60



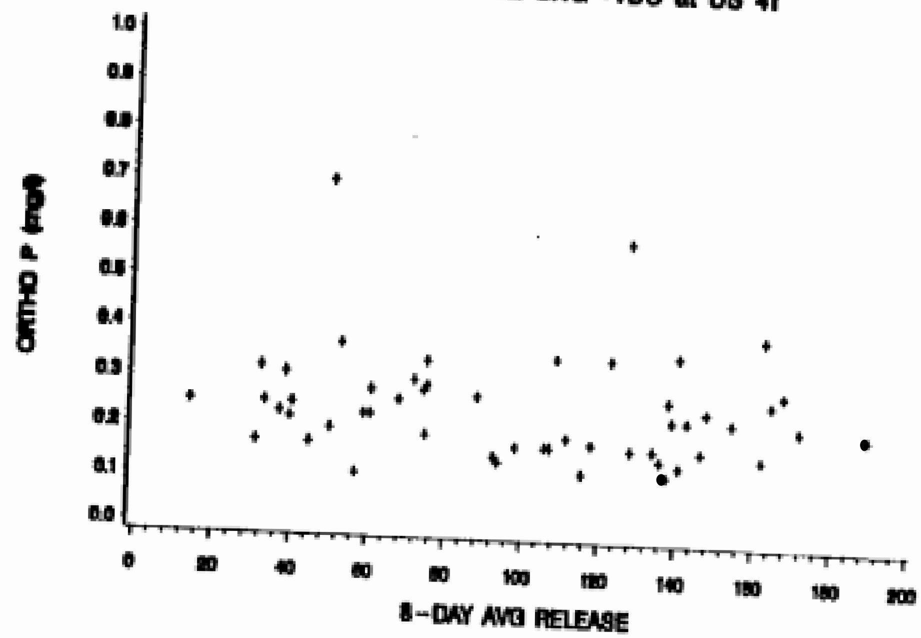
AGENCY=HCEPC SAMPLE SITE=TBC at SR 60



AGENCY=HCEPC SAMPLE SITE=TBC at US 41



AGENCY=HCEPC SAMPLE SITE=TBC at US 41



M-3 10

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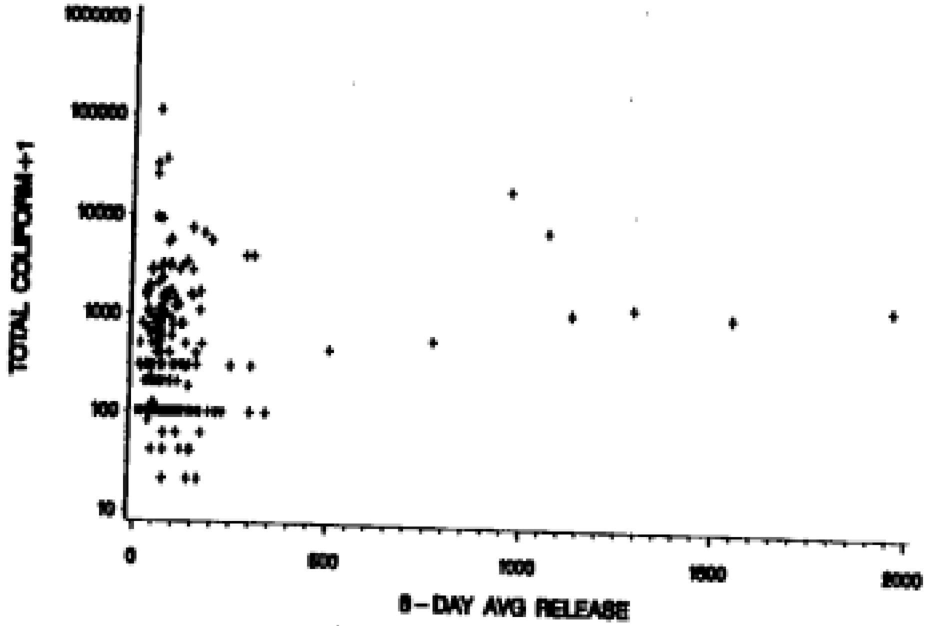
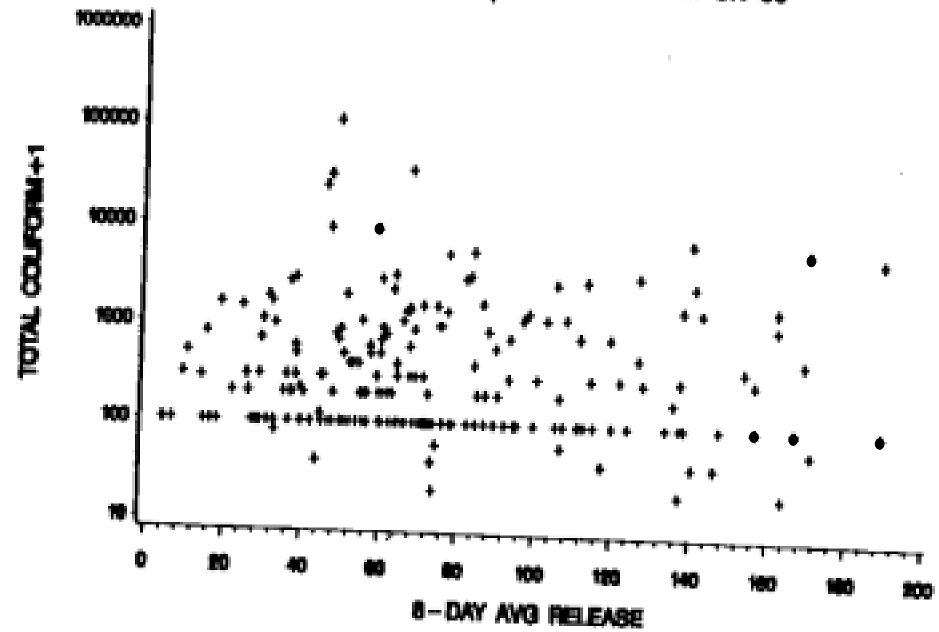


AGENCY=HCEPC SAMPLE SITE=TBC at SR 60



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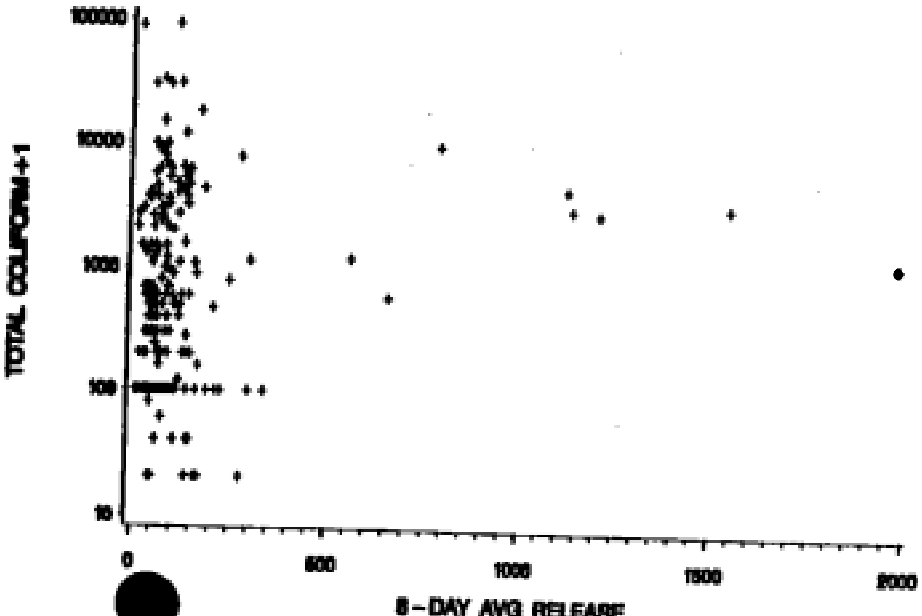
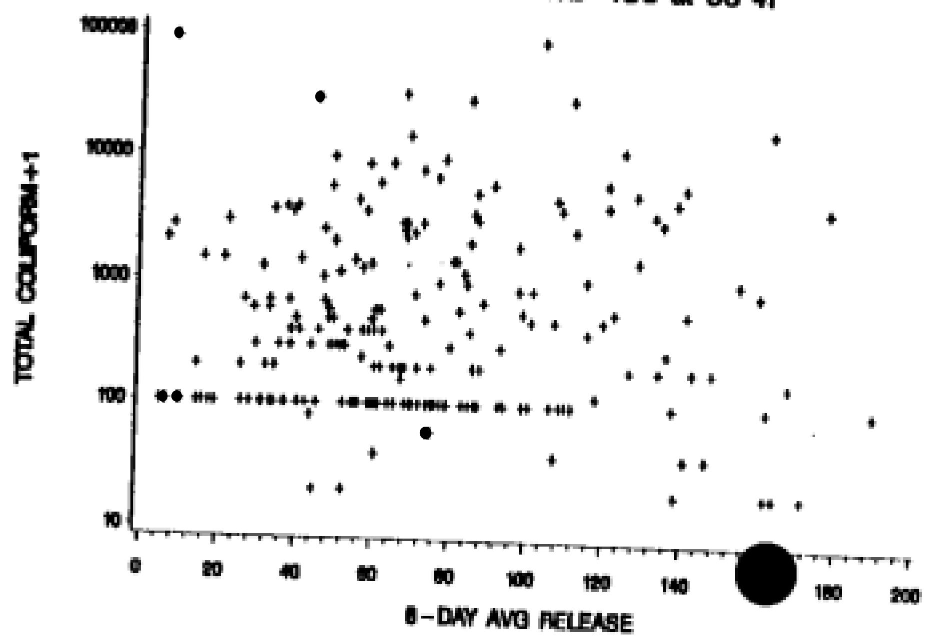
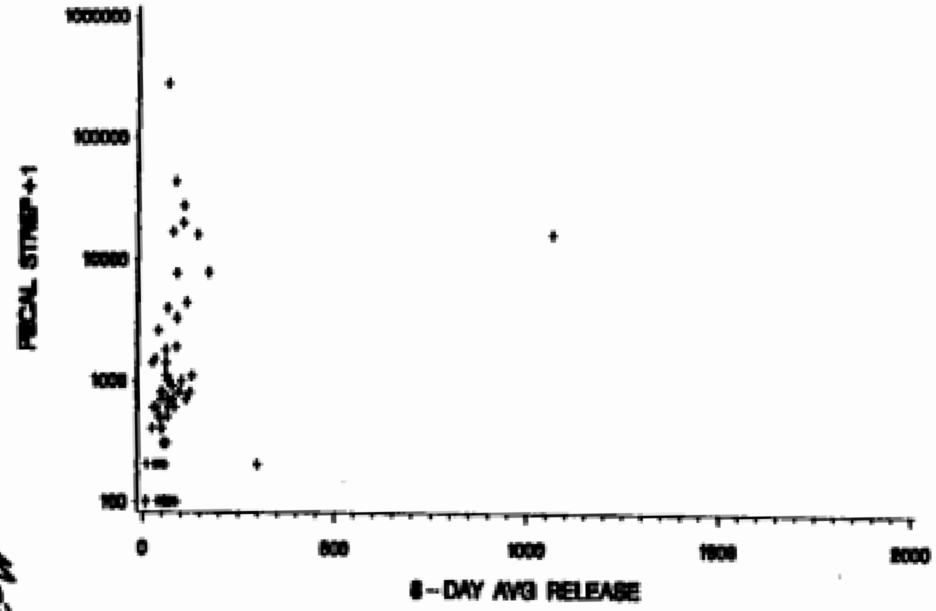


AGENCY=HCEPC SAMPLE SITE=TBC at US 41

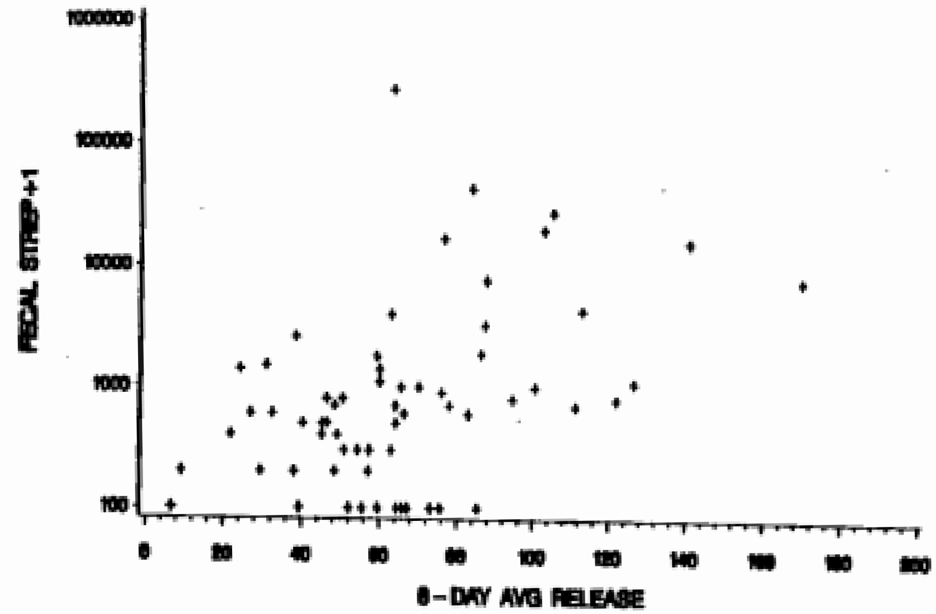


M-3 11

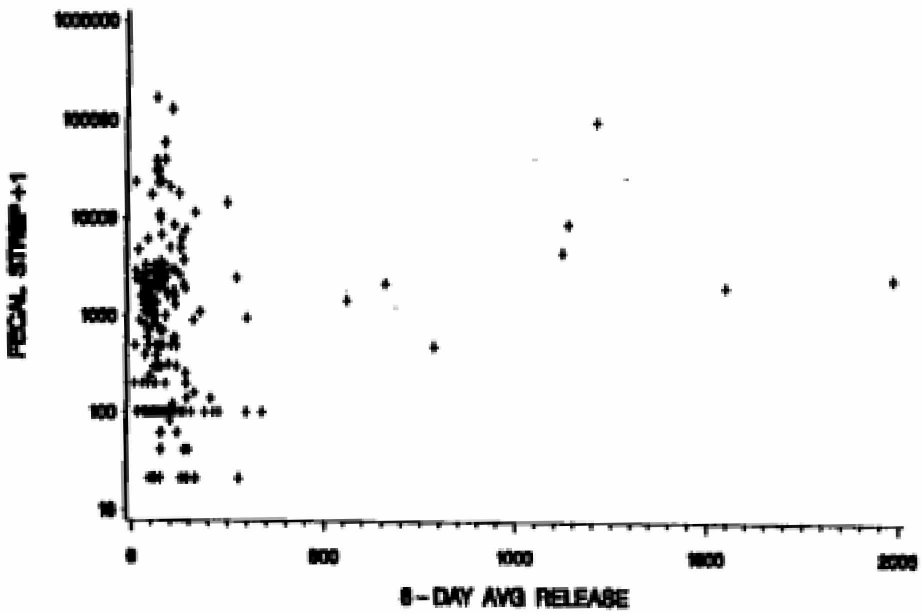
AGENCY=HCEPC SAMPLE SITE=TBC at SR 60



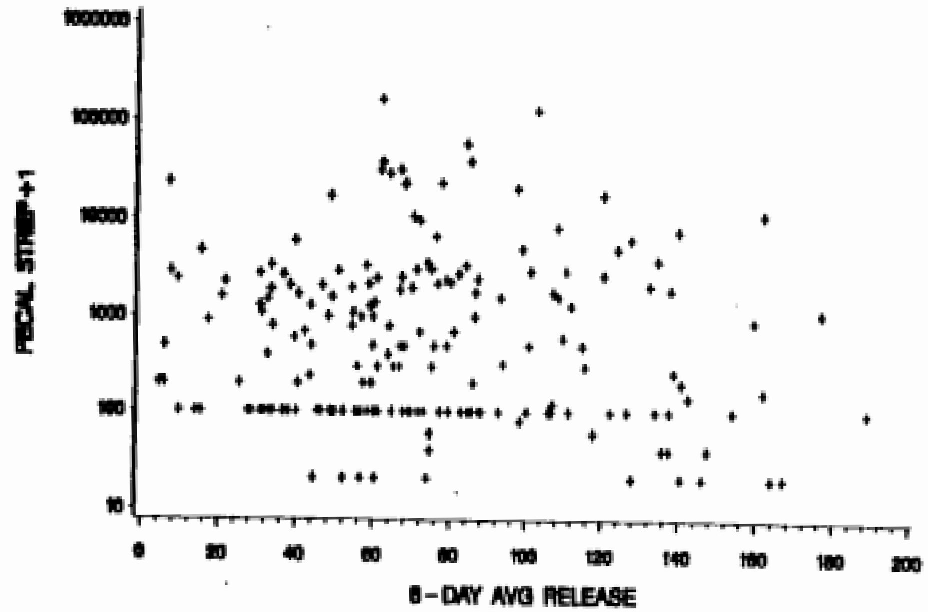
AGENCY=HCEPC SAMPLE SITE=TBC at SR 60



AGENCY=HCEPC SAMPLE SITE=TBC at US 41

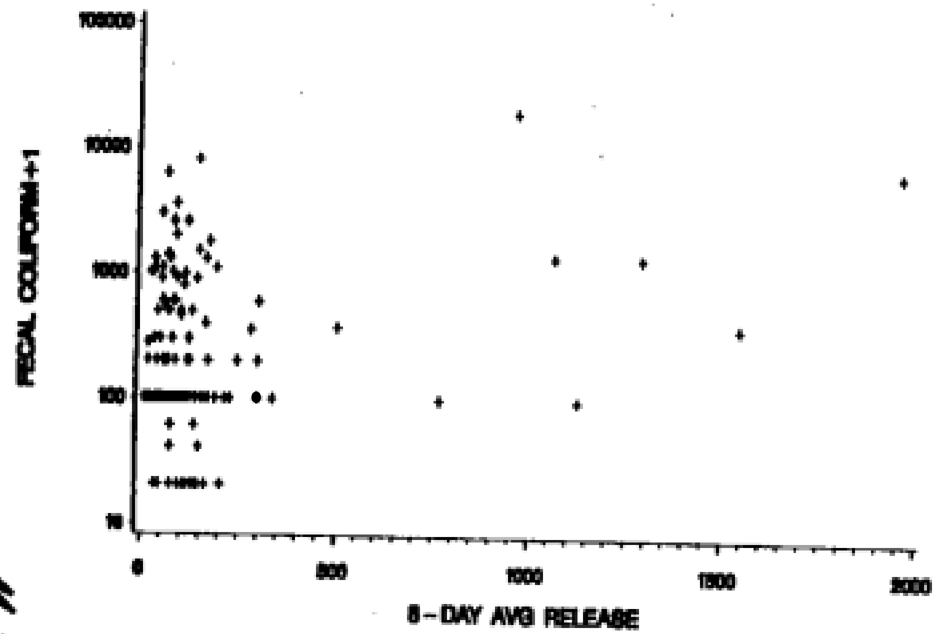


AGENCY=HCEPC SAMPLE SITE=TBC at US 41



M-3 12

AGENCY=HCEPC SAMPLE SITE=TBC at SR 60



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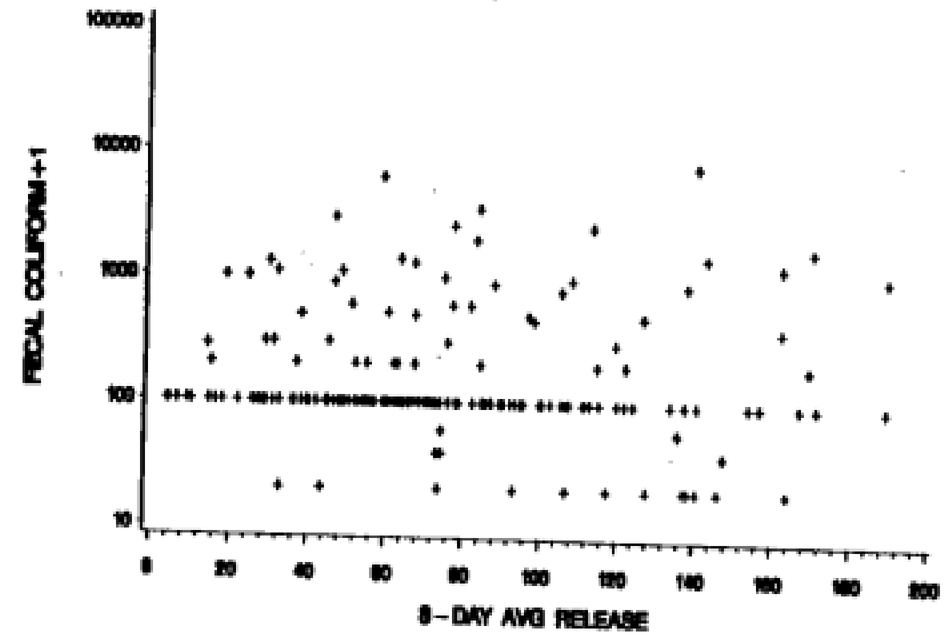
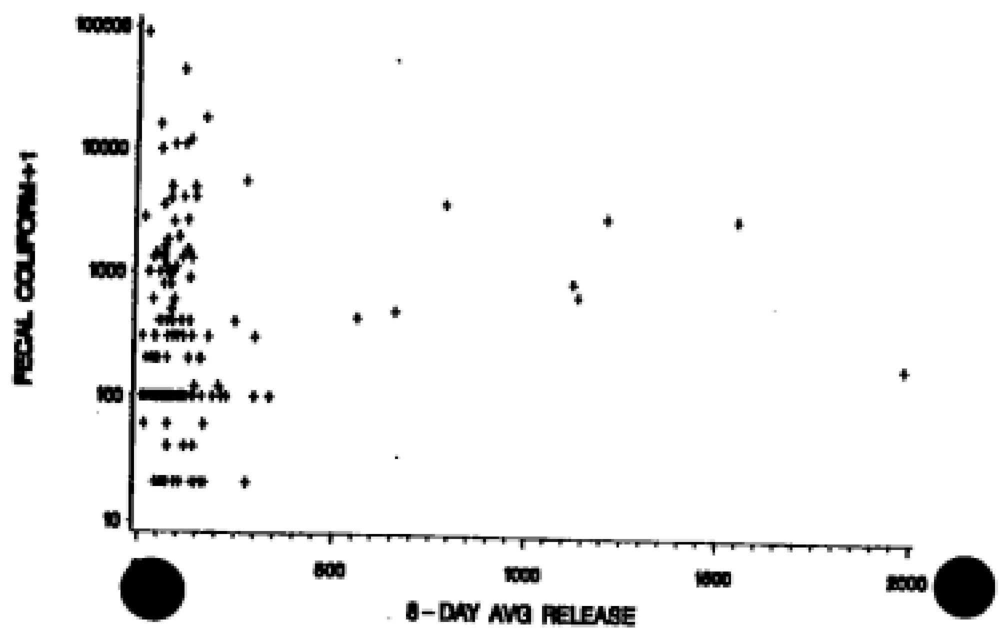
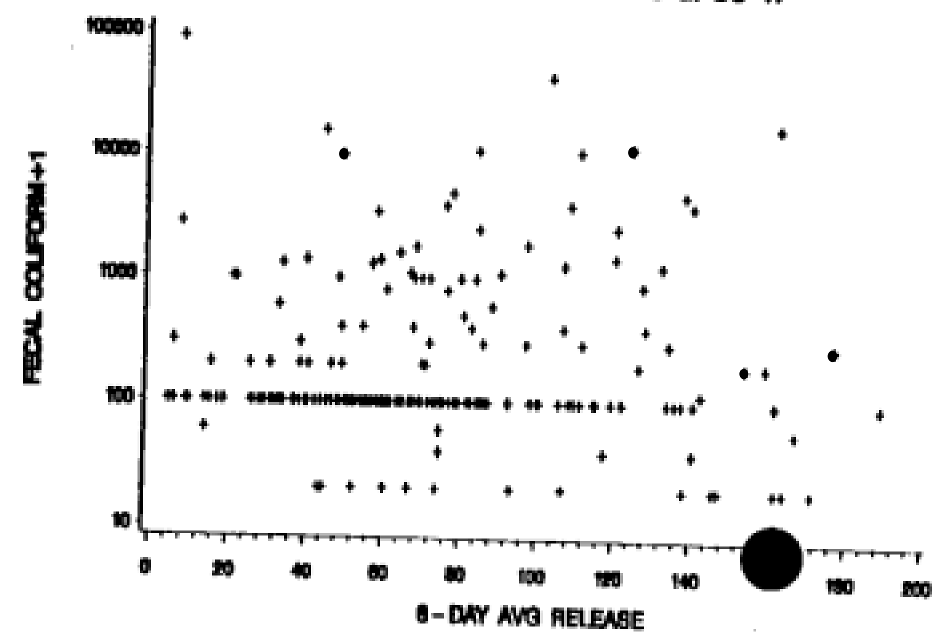
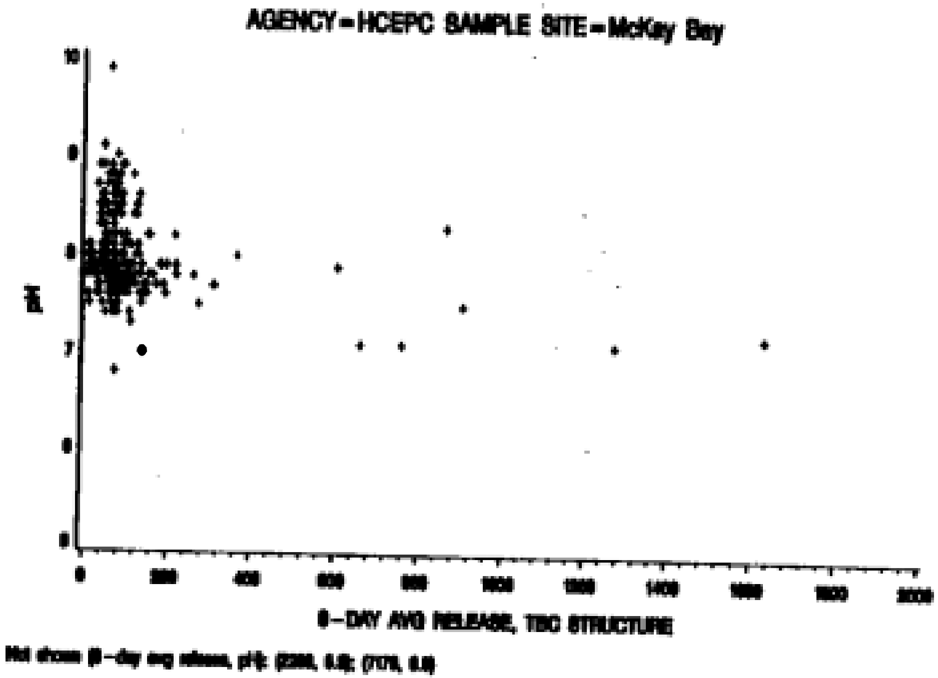


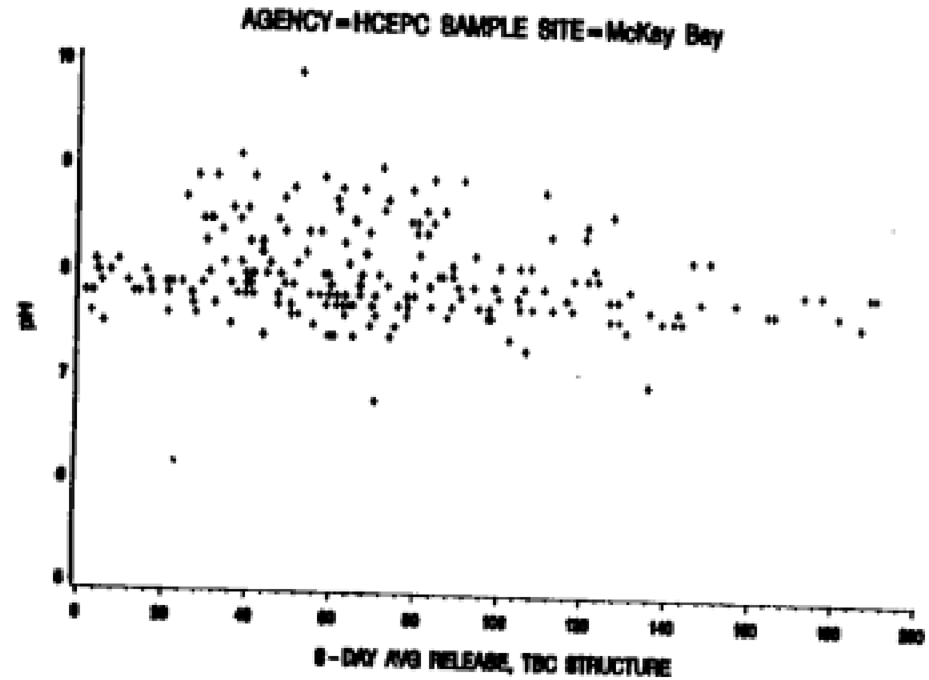
AGENCY=HCEPC SAMPLE SITE=TBC at US 41

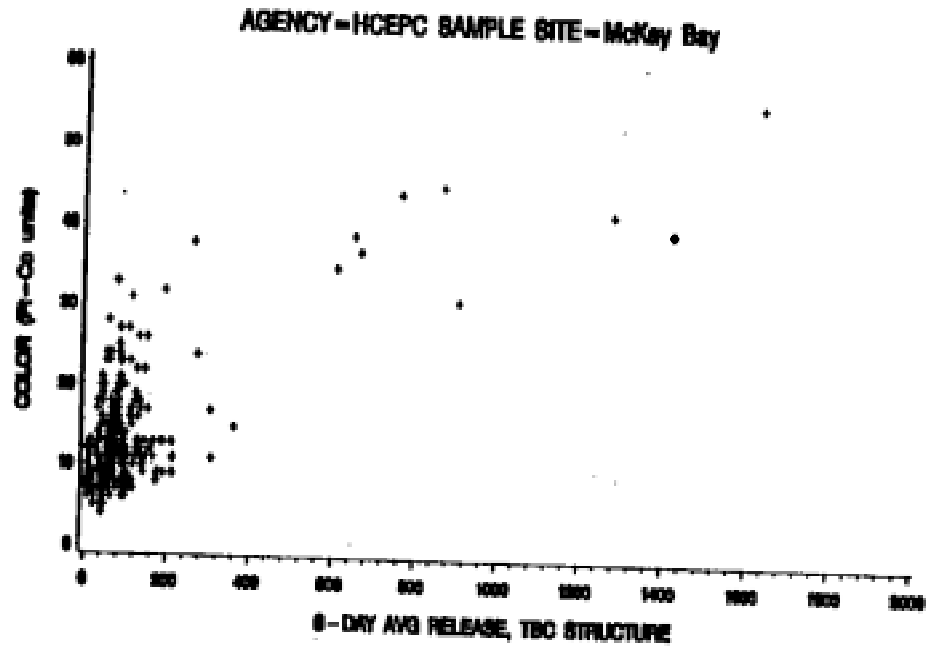


AGENCY=HCEPC SAMPLE SITE=TBC at US 41

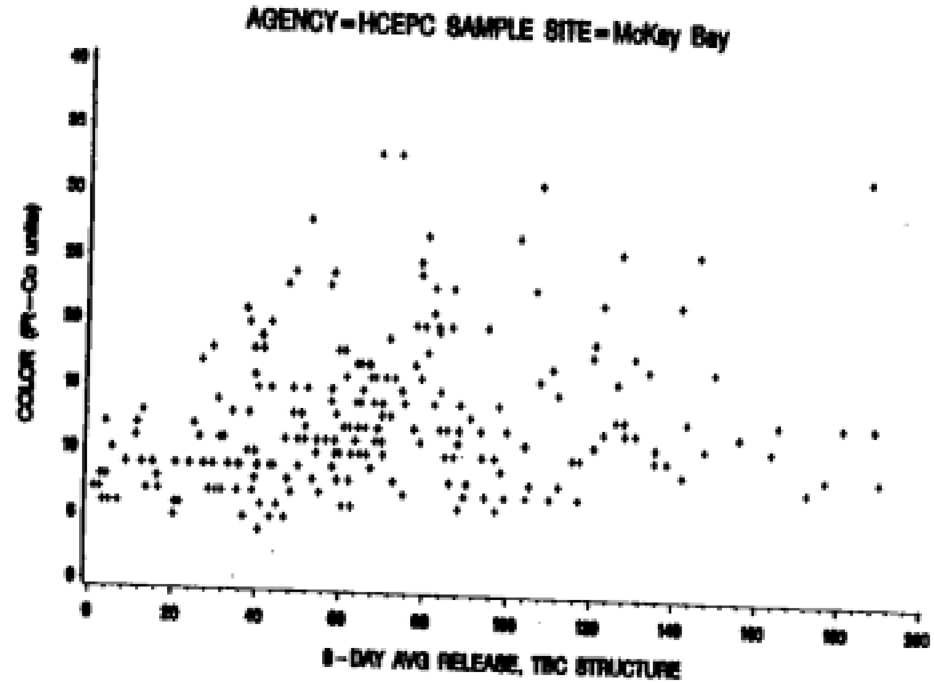


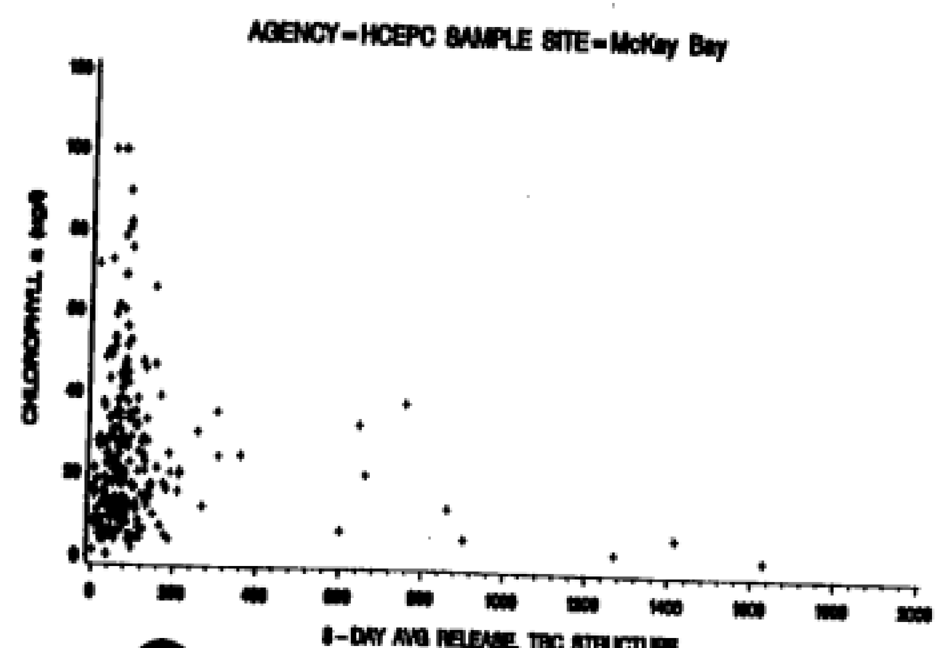

AGENCY=HCEPC SAMPLE SITE=McKay Bay
pH


AGENCY=HCEPC SAMPLE SITE=McKay Bay
pH

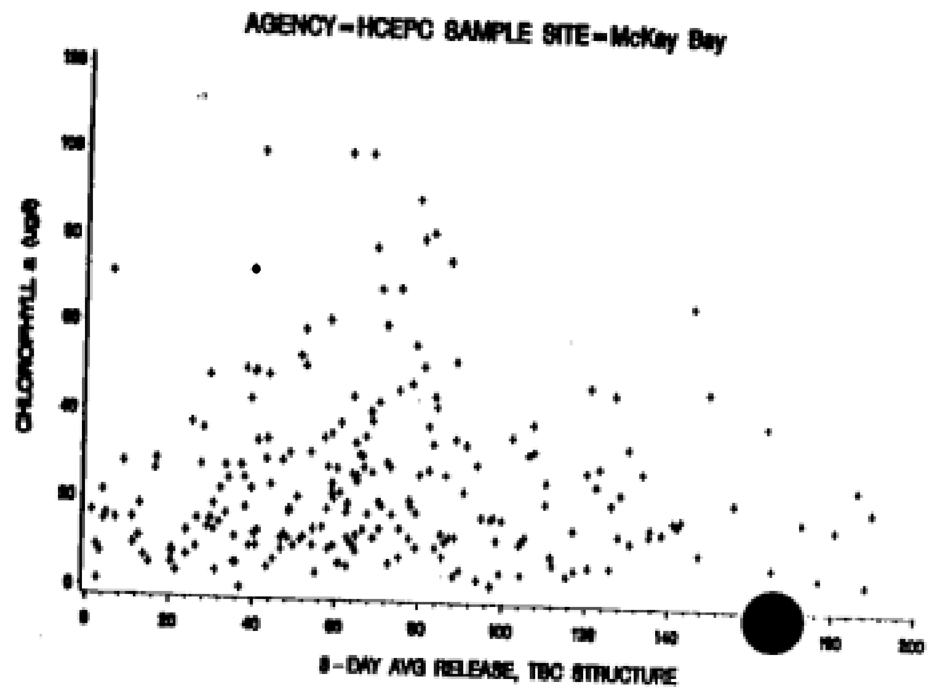


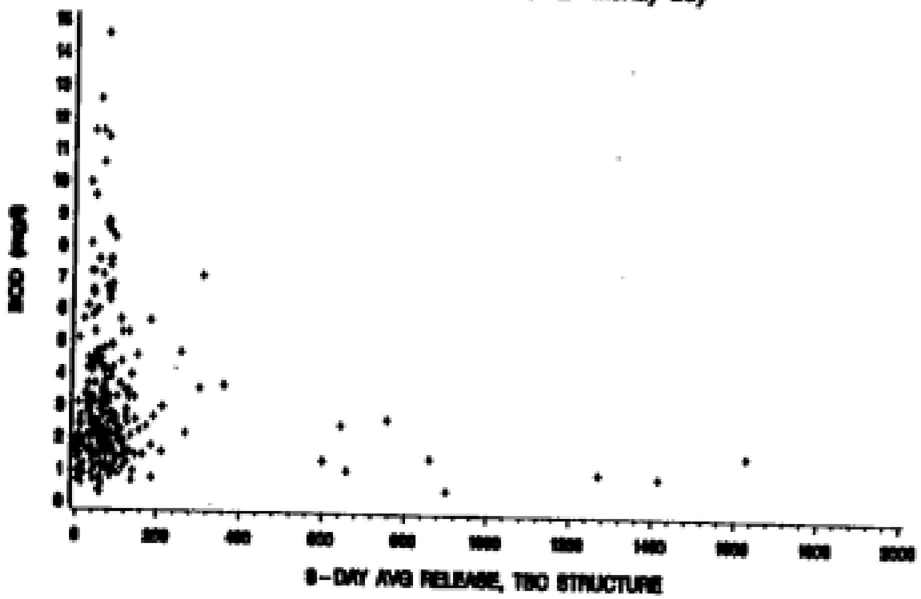
Not shown (8-day avg release, color): ([illegible]); ([illegible]); ([illegible])



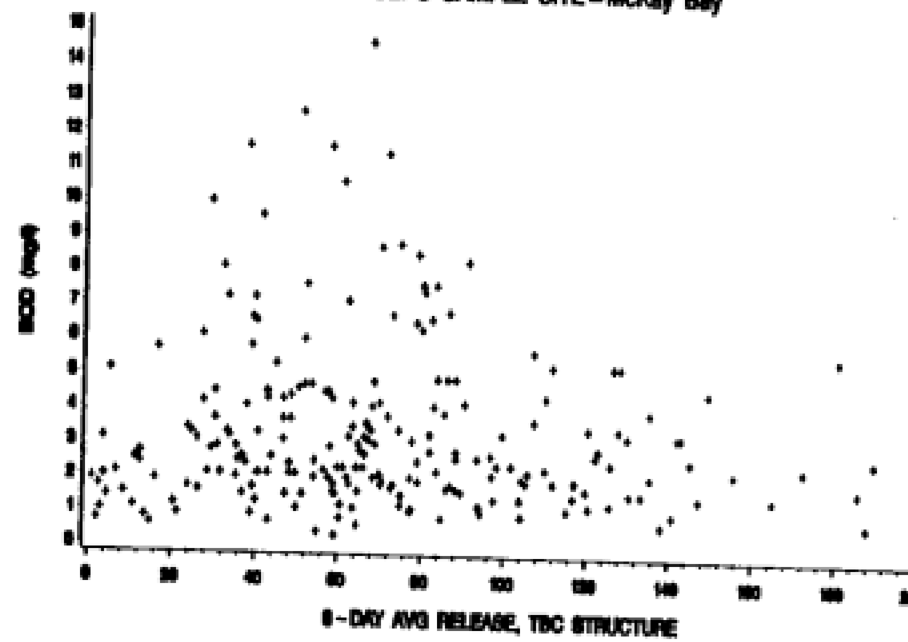


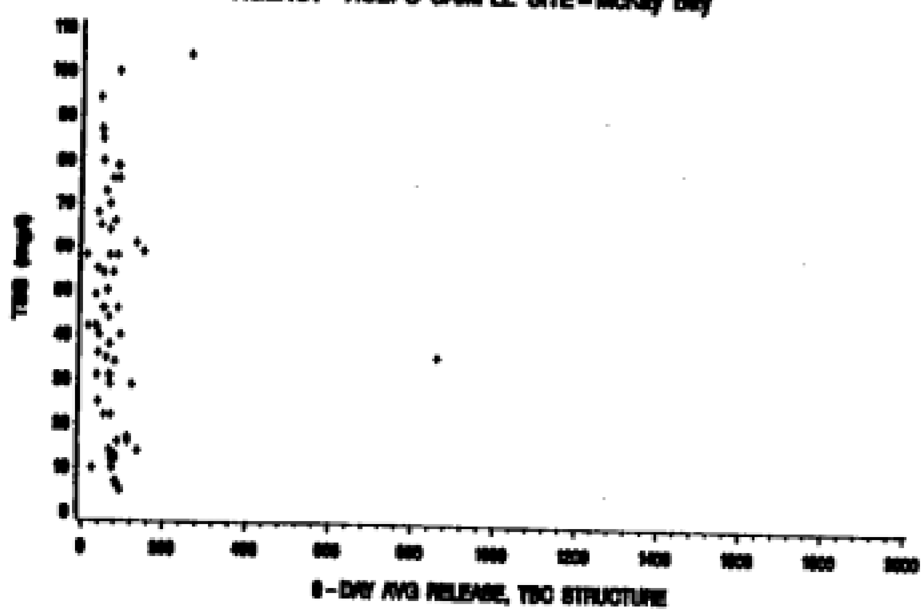
Not shown (8- [illegible] ase, chlorophyll a): ([illegible]); ([illegible]); ([illegible])



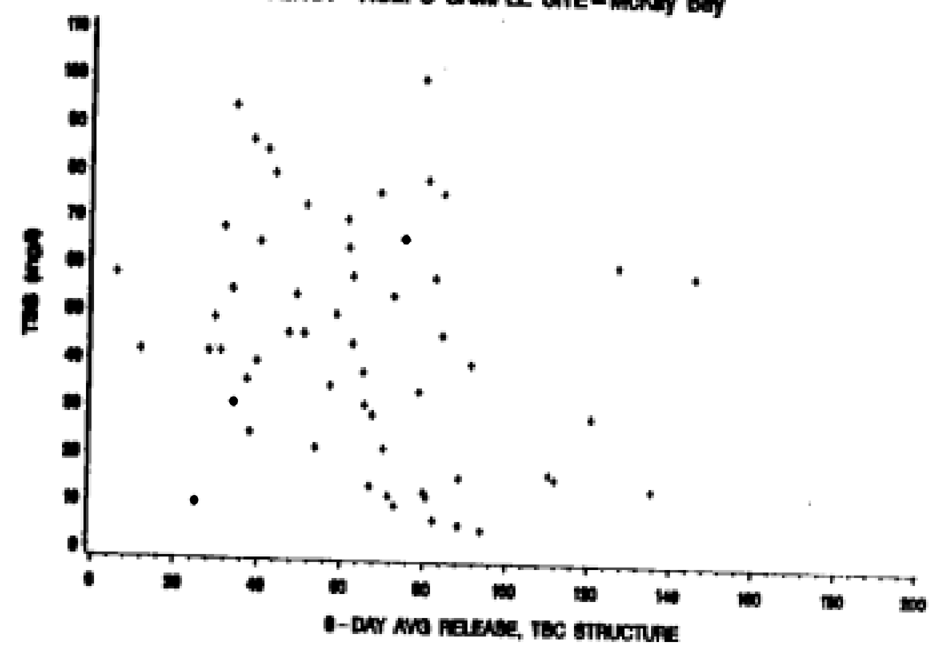


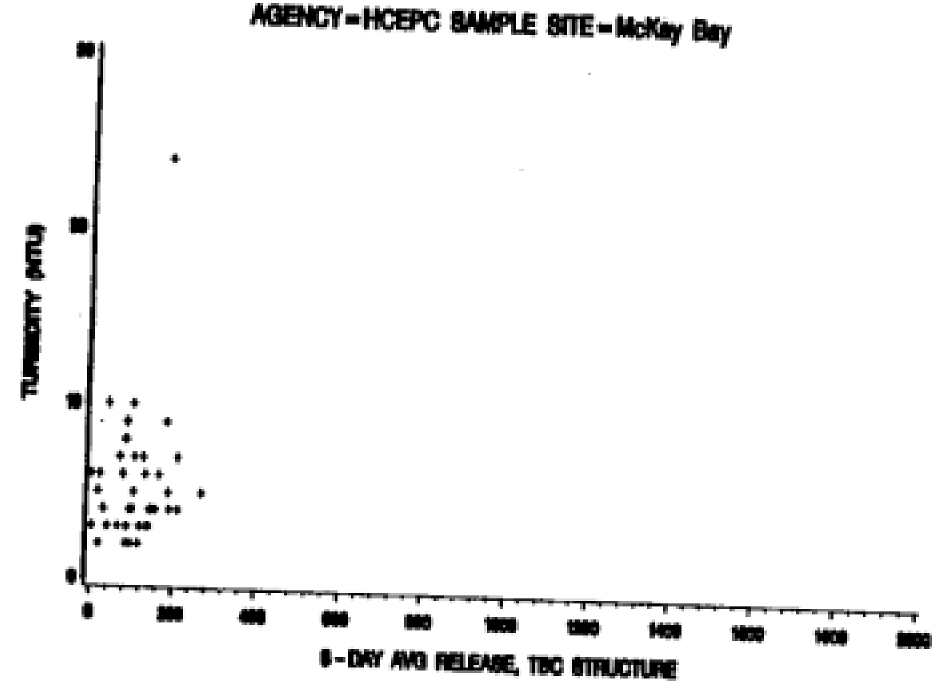
Not shown (8-day avg release, BOD): ([illegible], 2); ([illegible], 2); ([illegible], 1)

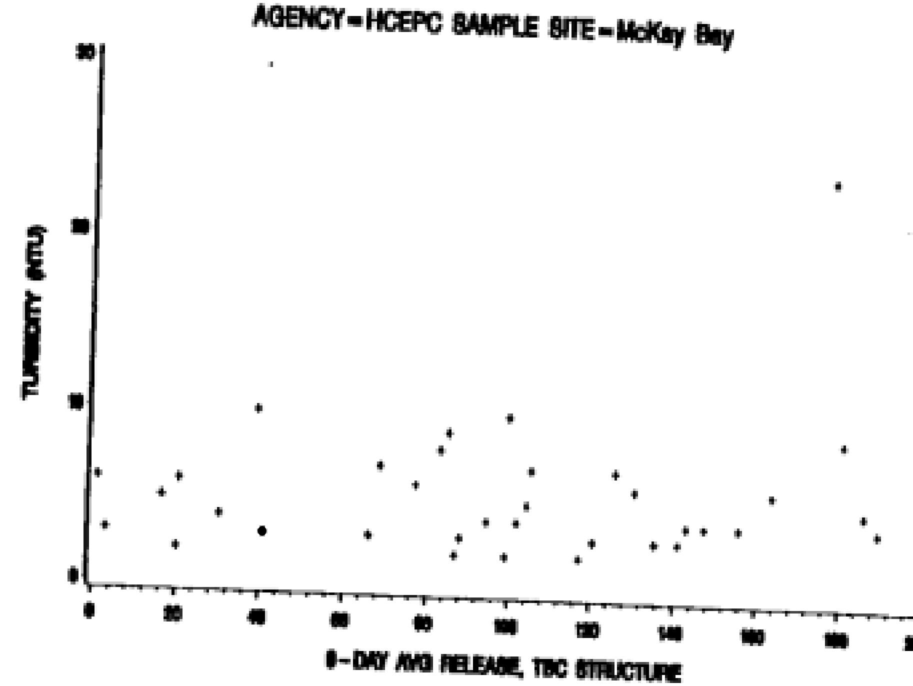


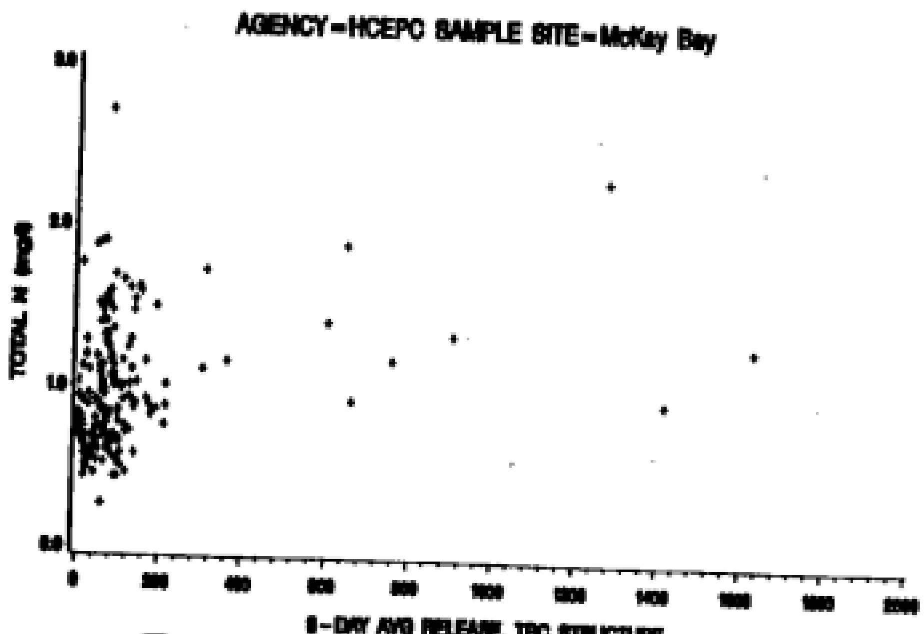


Not shown: 8-day avg release=[illegible], TSS=[illegible]









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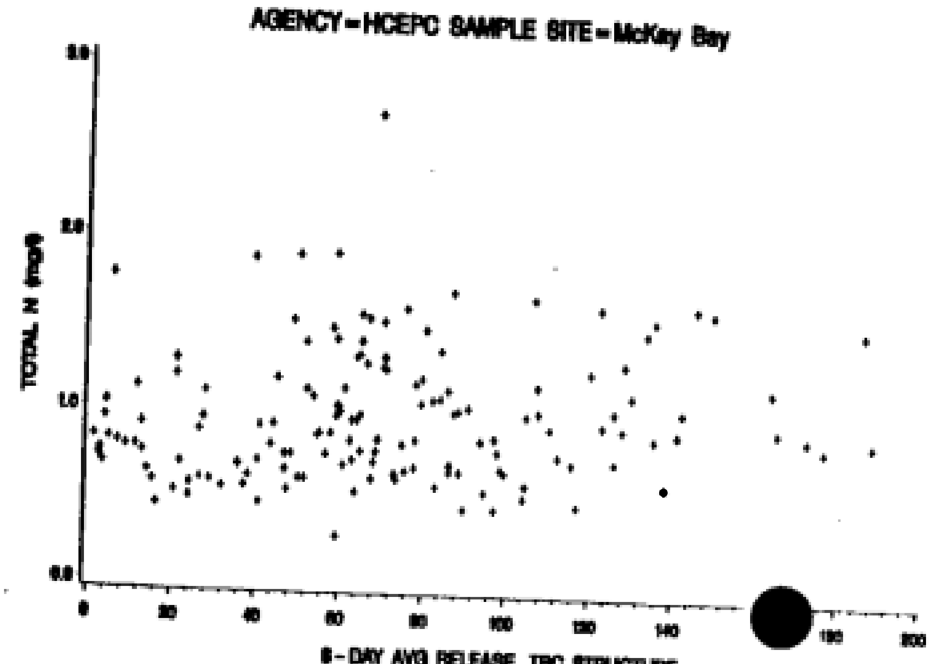
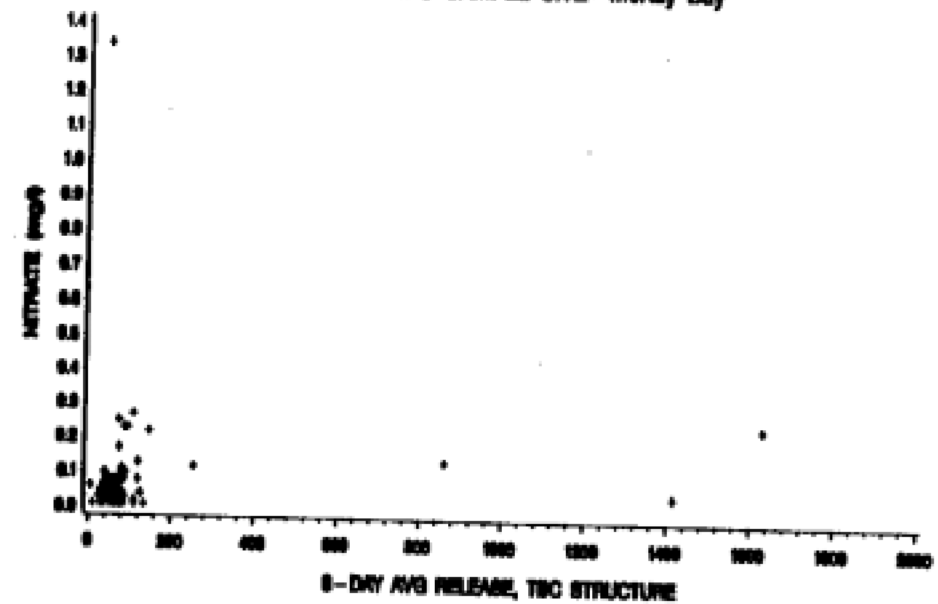
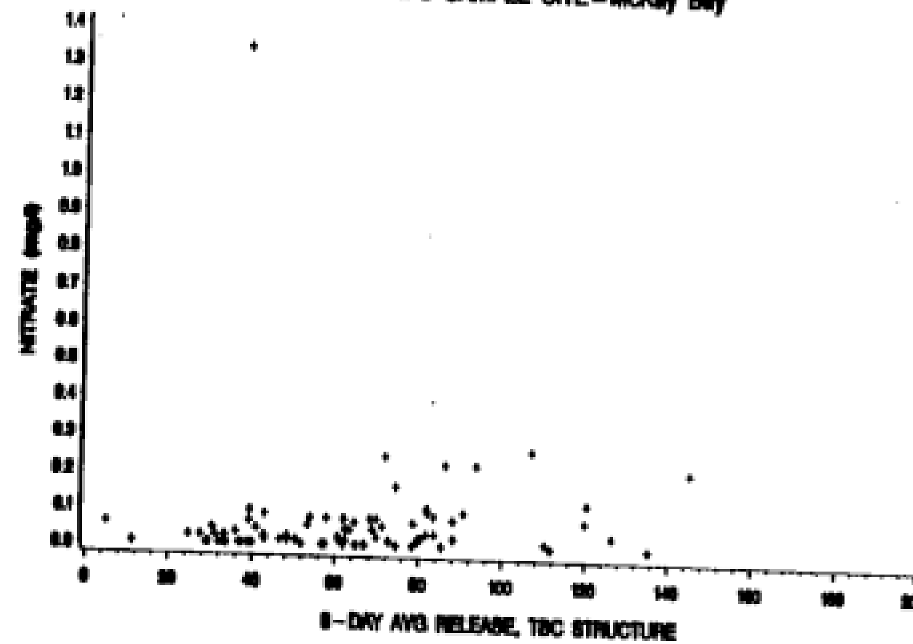


AGENCY=HCEPC SAMPLE SITE=McKay Bay

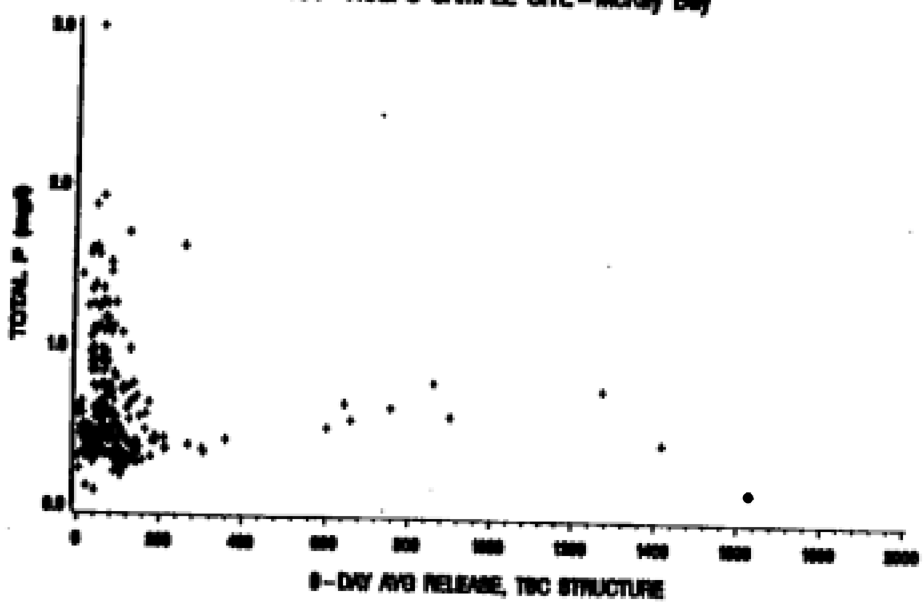


Not shown: 8-day avg release=[illegible], nitrate=[illegible]

AGENCY=HCEPC SAMPLE SITE=McKay Bay

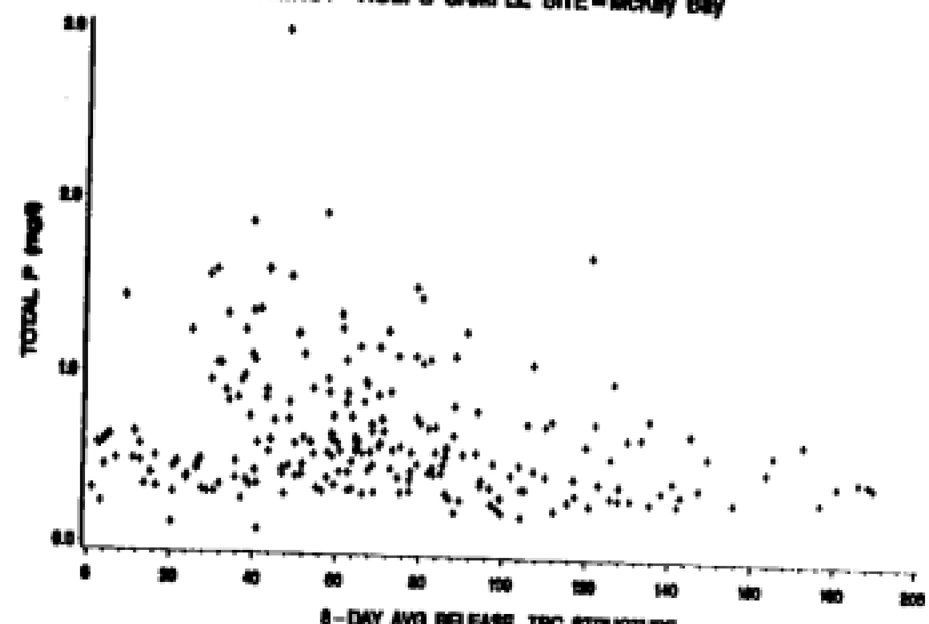


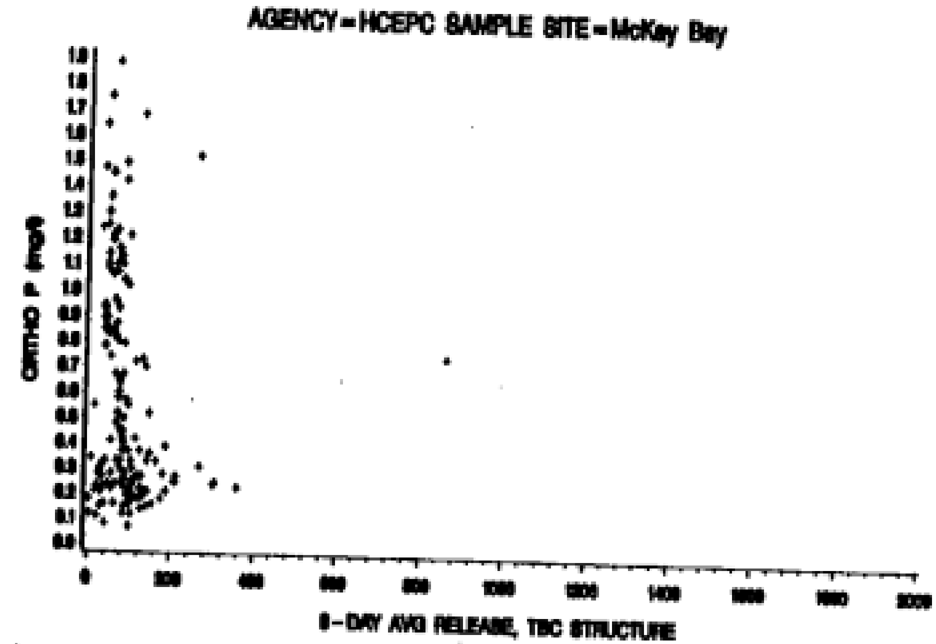
AGENCY=HCEPC SAMPLE SITE=McKay Bay



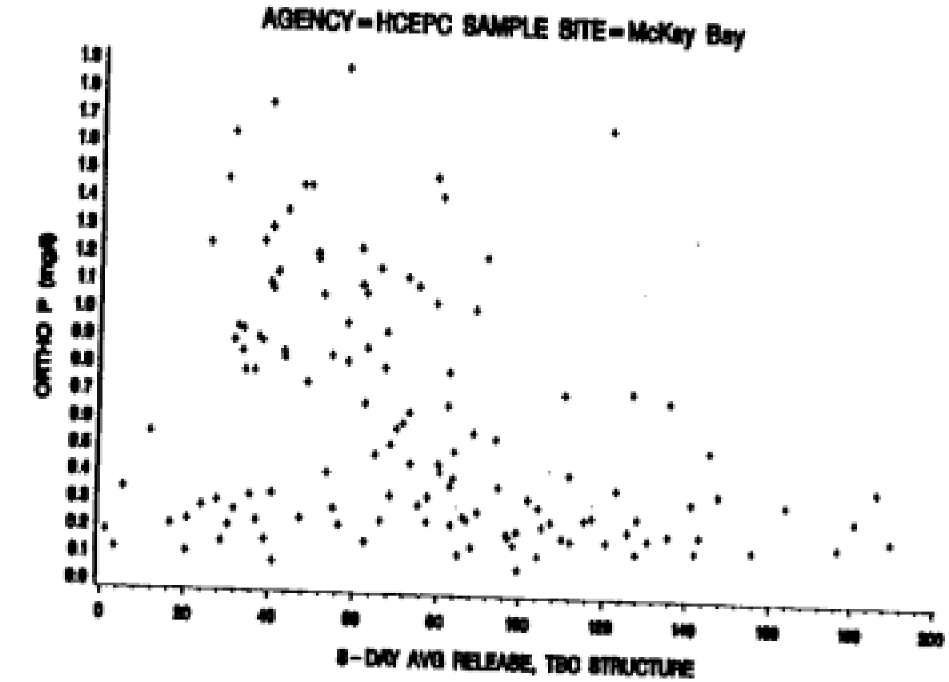
Not shown (8-day avg release, total P): [illegible]

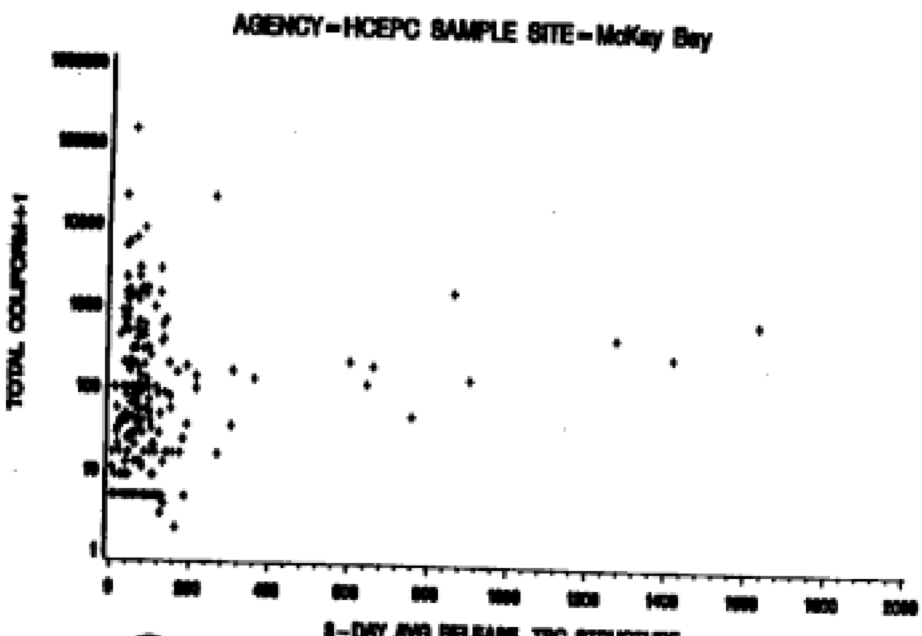
AGENCY=HCEPC SAMPLE SITE=McKay Bay



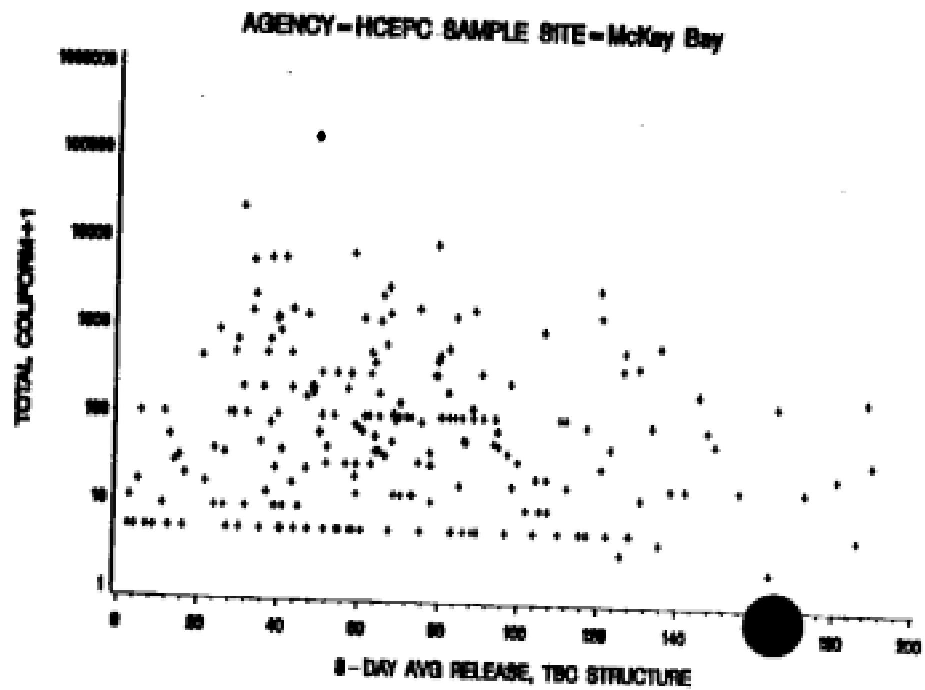


Not shown: 8-day avg release=2300, ortho P=1.1





Not shown (8-[illegible]ase, total coliform): (2300, 1000); (4050, 60); (778, 221)



M3-19

APPENDIX M-4

Results of correlation analysis of water quality parameters in the Palm River measured by the HCEPC with discharge from the Hillsborough River Reservoir

TBC at SR 60

	ALL OBSERVATIONS	
	TBC8	log10(TBC8)
Salinity (top)	-0.37	-0.35
	<0.001	0.001
	97	97
Salinity (mid)	-0.39	-0.37
	<0.001	<0.001
	240	240
Salinity (bottom)	-0.33	-0.41
	0.001	<0.001
	97	97
Salinity (top+mid+bot)	-0.35	-0.33
	<0.001	<0.001
	434	434
Diss. Oxygen (top)	-0.18	-0.25
	0.068	0.010
	102	102
Diss. Oxygen (mid)	0.02	-0.15
	0.766	0.020
	246	246
Diss. Oxygen (bottom)	0.01	0.08
	0.936	0.407
	102	102
Diss. Oxygen (top+mid+bot)	-0.01	-0.13
	0.886	0.007
	450	450
pH	-0.28	-0.38
	0.005	<0.001
	101	101
Turbidity	-0.02	0.01
	0.777	0.853
	252	252
Color	0.73	0.64
	<0.001	<0.001
	252	252
Chlorophyll a	-0.12	-0.15
	0.067	0.023
	239	239
BOD	-0.23	-0.41
	<0.001	<0.001
	252	252

	ALL OBSERVATIONS	
	TBC8	log10(TBC8)
TSS	-0.16	-0.18
	0.170	0.125
	74	74
Nitrate	0.03	0.04
	0.673	0.564
	253	253
Total N	-0.03	0.07
	0.664	0.290
	251	251
Ortho P	0.05	0.01
	0.710	0.964
	60	60
Total P	-0.07	-0.11
	0.303	0.074
	253	253
log10(total coliform)	0.15	0.18
	0.017	0.005
	253	253
log10 (fecal coliform)	0.16	0.19
	0.010	0.002
	250	250
log10 (fecal strep)	0.33	0.45
	0.006	<0.001
	68	68

TBC at US 41

	ALL OBSERVATIONS	
	TBC8	log10(TBC8)
Salinity (top)	-0.41	-0.41
	<0.001	<0.001
	99	99
Salinity (mid)	-0.42	-0.43
	<0.001	<0.001
	242	242
Salinity (bottom)	-0.42	-0.46
	<0.001	<0.001
	99	99
Salinity (top+mid+bot)	-0.39	-0.38
	<0.001	<0.001
	440	440
Diss. Oxygen (top)	-0.21	-0.23
	0.034	0.018
	105	105
Diss. Oxygen (mid)	-0.10	-0.24
	0.122	<0.001
	249	249
Diss. Oxygen (bottom)	-0.17	-0.11
	0.082	0.263
	105	105
Diss. Oxygen (top+mid+bot)	-0.08	-0.20
	0.075	<0.001
	459	459
pH	-0.26	-0.30
	0.009	0.002
	101	101
Turbidity	-0.03	-0.07
	0.667	0.300
	252	252
Color	0.80	0.67
	<0.001	<0.001
	252	252
Chlorophyll a	-0.18	-0.18
	0.004	0.004
	250	250
BOD	-0.21	-0.33
	0.001	<0.001
	251	251

	ALL OBSERVATIONS	
	TBC8	log10(TBC8)
TSS	-0.21	-0.22
	0.077	0.060
	74	74
Nitrate	0.02	-0.01
	0.698	0.872
	253	253
Total N	-0.02	0.00
	0.753	0.959
	251	251
Ortho P	0.03	-0.06
	0.822	0.670
	60	60
Total P	0.06	-0.08
	0.348	0.217
	253	253
log10(total coliform)	0.13	0.12
	0.038	0.053
	253	253
log10 (fecal coliform)	0.13	0.11
	0.043	0.079
	250	250
log10 (fecal strep)	0.15	0.10
	0.023	0.119
	232	232

McKay Bay

	ALL OBSERVATIONS TBC8	ALL OBSERVATIONS log10(TBC8)
Salinity (top)	-0.54 <0.001 217	-0.73 <0.001 217
Salinity (mid)	-0.57 <0.001 246	-0.66 <0.001 246
Salinity (bottom)	-0.35 <0.001 217	-0.54 <0.001 217
Salinity (top+mid+bot)	-0.52 <0.001 217	-0.69 <0.001 217
Diss. Oxygen (top)	-0.10 0.183 194	-0.18 0.013 194
Diss. Oxygen (mid)	-0.08 0.198 238	-0.15 0.024 238
Diss. Oxygen (bottom)	-0.10 0.161 195	-0.21 0.004 195
Diss. Oxygen (top+mid+bot)	-0.10 0.177 194	-0.21 0.003 194
pH	-0.32 <0.001 225	-0.29 <0.001 225
Turbidity	0.16 0.322 38	0.13 0.443 38
color	0.83 <0.001 247	0.63 <0.001 247
Chlorophyll a	-0.15 0.019 246	-0.05 0.411 246
BOD	-0.12 0.071 240	-0.07 0.278 240
TSS	-0.13 0.335 60	-0.16 0.223 60

	ALL OBSERVATIONS TBC8
Nitrate	0.07 0.517 85
Total N	0.25 0.001 165
Ortho P	0.02 0.844 141
Total P	-0.00 0.954 247
log10(coliform)	0.12 0.076 234

APPENDIX N-1

Final recommendations of the Tampa Bay National Estuary Program Minimum Flows Advisory Group for the Lower Hillsborough River and Tampa Bypass Canal.

Tampa Bay National Estuary Program

MEMORANDUM

TO: Dave Moore
Southwest Florida Water Management District

FROM: Richard Eckenrod, Director — Holly Greening, Senior Scientist

DATE: July 10, 1997

CC: Minimum Flow Advisory Group

SUBJECT: Final Minimum Flows Advisory Group Recommendations

On behalf of the Advisory Group, attached are final recommendations of the Hillsborough River and Palm River/Tampa Bypass Canal Minimum Flows Advisory Group, for the District's consideration in preparing minimum flow rules for these systems. The final recommendations include revisions to the draft final recommendations suggested by several Group members.

The Tampa Bay National Estuary Program staff is pleased to have assisted with facilitation of this very competent Advisory Group, and believe that the final recommendations reflect the Group's strong technical review and consensus. If you have questions about the recommendations, please contact us at 893-2765.

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111 7th Avenue South • St. Petersburg, FL 33701 • (813) 893-2765 • FAX (813) 893-2767 • SUNCOM 594-2765

HILLSBOROUGH RIVER AND PALM RIVER/TBC MINIMUM FLOW ADVISORY GROUP

July 10, 1997
Summary recommendations to the Southwest Florida Water Management District

Advisory Group Objectives and Issues
The Southwest Florida Water Management District requested the Tampa Bay National Estuary Program (TBNEP) to convene a technical advisory group to provide recommendations for ecological criteria for setting minimum flows of the Hillsborough and Palm/TBC systems. The Advisory Group was initially convened in October 1996 and met approximately monthly through May 1997. The Group's objective as defined at the initial meeting was subsequently clarified as follows:

> Provide technically sound recommendations to SWFWMD staff for identifying and evaluating the water resources and ecological criteria necessary to establish minimum flows on the Hillsborough River downstream of the dam and on the Palm River/Tampa Bypass Canal downstream of Structure 160.

The Advisory Group was not asked by the District to recommend what would constitute "significantly harmful" withdrawals, as that term is used in Sec. 373.042, Florida Statutes.

The primary issues defined at the initial meeting were:

1. Low-salinity habitats in each of the river systems
2. Low levels of dissolved oxygen (hypoxia)
3. "Truncated" salinity regime on the Palm River/TBC

A Habitat Subcommittee and a Dissolved Oxygen Subcommittee were formed to address these issues. The Advisory Group or its Subcommittees met eleven times between October 16, 1996 and May 27, 1997. A summary of findings and recommendations of the Advisory Group follows. Comments by participants and opposing views (where voiced) are also noted.

Advisory Group Participating Entities
The following entities participated on the Advisory Group and subcommittees.

West Coast Regional Water Supply Authority
Southwest Florida Water Management District
USF Marine Science Department
City of Tampa Water Department
City of Tampa Stormwater Department
City of Tampa Sanitary Sewers

Tampa BayWatch
Palm River Management Committee
EPC of Hillsborough County
U.S. Fish and Wildlife Service
FDEP Florida Marine Research Institute
FDEP Water Standards
U.S. Geological Survey
Florida Game and Freshwater Fish Commission
National Audubon Society Florida Coastal Islands Sanctuary
Manatee County Planning Department
Manatee County Water Department
Concerned citizen
Canoe Escape
NOAA National Marine Fisheries Service
The Planning Commission
Hillsborough River Greenways Task Force
FDEP Hillsborough River Ecosystem Management
Mote Marine Laboratory
ASHORE Civic Group
Hillsborough River Interlocal Planning Board
Technical Advisory Committee to Hillsborough River Board

Summary of Findings

1. In order to offer maximum benefit to the most species of fish, the salinity gradient in a river should be complete (i.e., freshwater to greater than 18 parts per thousand (ppt) of salinity). Many estuarine fish species have abundance peaks at salinities less than 18 ppt, often much less.

2. Numbers of fish species and abundances of fishes in the estuarine reaches of the tributaries in this region tend to be reduced at dissolved oxygen levels less than 4.0 milligrams per liter (mg/l).

3. The Hillsborough River below the dam offers limited opportunity for shoreline vegetative habitat restoration. A visual shoreline survey estimated approximately 4,070 linear feet (3.3 acres) of potentially restorable habitat. The majority of the shoreline is hardened or has very steep banks unsuitable for vegetative habitat creation/restoration.

4. The Palm River/TBC below Structure 160 also offers minimum opportunity for vegetative habitat under its present condition. Maintaining a complete salinity gradient and meeting dissolved oxygen criteria/goals may not be feasible using flow management on the Palm River/TBC. However, the potential for considerable habitat creation exists on publicly-owned lands, but would require major physical alterations of the canal and shoreline.

Several options have been suggested, and the Hillsborough River Basin Board has agreed to act as the local sponsor of a study by the Corps of Engineers examining the feasibility of filling the deep area of the river.

5. The Advisory Group utilized several analytical tools and methods for evaluation of potential effects of various flows on salinity and dissolved oxygen in the Hillsborough River. These tools include the regression-based empirical models (developed by Coastal Environmental), the 2-dimensional, deterministic model (developed by SWFWMD staff), and examination and analysis of salinity and dissolved oxygen data.

However, the Group found that each analytical tool has its limitations that should be recognized when evaluating their results relative to the salinity and dissolved oxygen criteria. Primary limitations of the tools are: 1) very little data on salinity and dissolved oxygen are available for low-flow conditions (between 1 cfs and 30 cfs) at any point along the Hillsborough River downstream of the dam; and 2) although statistically significant regressions were derived for dissolved oxygen and flow at various locations in the river, these regressions generally had low coefficients of determination (r^2 values). The use of these regressions for predictive purposes is not recommended.

Comments from NEP staff and consultant (Coastal Environmental): Due to the deficiency of low-flow data, the NEP staff finds that the empirical model cannot be used to reliably predict salinity levels in the river nor changes in salinity-based habitat due to dam releases when flows are greater than 0 cfs and less than 30 cfs. Similarly, the empirical models cannot be used to reliably predict dissolved oxygen concentrations at fixed stations within the river or to predict the frequency with which specified dissolved oxygen concentrations will be achieved throughout the river.

NEP staff also feels that the advisory group had insufficient opportunity to fully evaluate the reliability of the 2-D model in predicting salinity changes as a function of dam release and Sulfur Spring discharge. NEP staff cautions the District not to rely heavily on the model results until after its performance has been adequately verified, especially for low flow conditions at locations between the dam and Sulfur Spring.

NEP staff recommends that the limitations of these tools and methods should be made clear to policy makers when presenting results and making recommendations. Collection of additional salinity and dissolved oxygen data downstream of the dam at low flow conditions could be valuable for improving the predictive capabilities of the models.

Hillsborough River Recommendations

1. Define ecological criteria or goals for dissolved oxygen concentrations in the Hillsborough River as a minimum of 4.0 mg/l and average of 5.0 mg/l for optimizing fish utilization. If these criteria cannot be feasibly met at all times and in all locations, minimize time and areas in the river where dissolved oxygen is less than 4.0 mg/l.

   Comment: Several members of the Advisory Group expressed concern that "optimizing fish utilization" misrepresented the intent of the statement, and that "enhancing" may be a more appropriate term. Others did not share the same concern.

2. Maintain a salinity gradient from the estuary to the dam ranging from polyhaline (> 18 ppt) to fresh (< 0.5 ppt), to optimize estuarine-dependent fish species utilization.

3. Maintain a freshwater segment below the dam to provide a refuge for freshwater biota.

   Comment: Some members of the Group questioned the ecological value of maintaining freshwater biota below the dam. Although many members agreed that maintaining freshwater biota below the dam could be of value to the ecological integrity of the system, the Group did not reach full consensus on this issue.

4. Evaluate other ecological issues and analytical tools related to freshwater flow management, including impacts on manatees and changes in water quality related to diverting a portion of the Sulfur Springs discharge.

5. Test the reliability of the management tools through a series of controlled releases of freshwater from the reservoir. Commencement of this work should be contingent upon a determination by SWFWMD and the City of Tampa of the need for a controlled release experiment.

   Additional information from the District: The District has initiated new data collection on the river, including three continuous salinity recorders operated by the USGS and periodic boat measurements above Sligh Avenue. These data are being used for additional verification runs of the District's deterministic model.

Palm River/TBC Recommendations

1. Minimum flows on the Palm River/TBC should be set based on existing physical conditions of the water course. However, the minimum flows should be reevaluated once feasibility of filling deep areas of the river downstream of Structure 160, or other habitat creation options, has been established.

APPENDIX N-2

Chronological meeting summary of the Tampa Bay National Estuary Program Minimum Flows Advisory Group for the Lower Hillsborough River and the Tampa Bypass Canal.

Hillsborough River System Minimum Flow Advisory Group
Meeting Summaries
through May, 1997

In October, 1996, The Southwest Florida Water Management District requested that the Tampa Bay National Estuary Program (TBNEP) convene a technical advisory group to provide recommendations for criteria for setting minimum flows of the Hillsborough and Palm/Tampa Bypass Canal systems. The following is a chronological summary of meetings held by the Advisory Group to develop recommendations to the District.

October 16, 1997
The first meeting was held on October 16, 1996, at which the Advisory Group adopted the following objective:

> Provide technically sound recommendations for determining ecological criteria necessary to set minimum flows to protect and restore riverine/estuarine habitats downstream of the Hillsborough River dam and Structure 160 on the Palm River/Tampa Bypass Canal.

Following a background presentation of ecological information available from recently completed studies on the two systems, the Advisory Group defined the following primary issues:

1. Low salinity habitats in each of the river systems
2. Low levels of dissolved oxygen (hypoxia)
3. "Truncated" salinity regime on the Palm River/TBC

December 13, 1996
The second meeting of the Minimum Flow Advisory Group was held on December 13, 1996. The objective of the second meeting was to define the process to be used for each of the issues defined above. TBNEP staff facilitated discussion and agreement by the Advisory Group of the following steps for defining ecological criteria for low-salinity habitat and for dissolved oxygen as follows.

Low-salinity Habitat

1. Assess opportunities for restoring/creating low-salinity habitat (<20 ppt) in the Hillsborough/Palm systems and throughout Hillsborough Bay. Identify the most feasible opportunities. Compare opportunities in the two river systems with overall TBNEP Hillsborough Bay restoration/creation target (68 acres of low-salinity habitat). Consider linear feet of habitat restored in addition to areal extent. Habitat restoration/creation opportunities may include the following:

a. Restore low-salinity regime to existing open water and vegetated habitat.
b. Restore/create vegetated habitat in existing appropriate salinity regime.
c. Restore/create both vegetative habitat and appropriate salinity regime.

Responsible parties:	NEP and Advisory Group
When:	Draft by mid-February
Information Sources:	WAR reports SWFWMD land use maps NEP Habitat Masterplan

2. Define specific goals for Hillsborough River and Palm River/TBC based on Hillsborough Bay-wide most feasible opportunities. Incorporate seasonal salinity regime considerations.

Responsible parties:	SWFWMD and Advisory Group
When:	Mid-February
Information sources:	results of Step 1

3. Identify changes to existing salinity regimes if needed to support goals in these two systems. Simulate unimpounded conditions as a reference.

Responsible parties:	SWFWMD and Advisory Group
When:	March
Information sources:	WAR report, existing data

4. Based on salinity regimes needed to reach habitat goals, calculate appropriate seasonal freshwater flows for each system.

Responsible parties:	SWFWMD
When:	June
Information sources:	Existing models

- **Recommendations from the Advisory Group will be balanced with other considerations in establishing permit conditions for minimum flows pursuant to Florida's Water Policy Rule, including maintenance of freshwater storage and supply.**

The following members of the Advisory Group volunteered to be members of a Habitat Subcommittee, to assist with development of habitat criteria and provide initial review of results.

Habitat Subcommittee of the
Minimum Flows Advisory Group

Ann Schnapf	National Audubon, AWARE
Marjorie Guillory	Tampa Water Department
Tom Cardinale	EPCHC
Ernst Peebles	USF

Jim Beever	FGFWFC
Sid Flannery	SWFWMD
Bob Musser	Tampa Baywatch
Dave Bracciano	WCRWSA
Roger Johansson	City of Tampa
Brandt Henningsen	SWFWMD-SWIM
Bob McMichael	FMRI
Tim McDonald	FMRI
Manny Lopez	SWFWMD
Steve Grabe	EPCHC

Dissolved oxygen

TBNEP staff presented a summary of existing data addressing fish species found in low-salinity habitats and dissolved oxygen preferences (see attached sheet). After discussion of fish species and D.O. requirements or preferences with fisheries scientists on the Advisory Group, the Group adopted the following:

> Provisionally define ecological criteria for dissolved oxygen concentrations as a minimum of 4.0 mg/l and average of 5.0 mg/l, for optimizing fish utilization.

The Advisory Group further agreed to the following process for defining minimum flows associated with reaching adopted dissolved oxygen criteria:

1. Review D.O./flow relationships. Consider location in the river systems (horizontal and vertical), other factors contributing to D.O. concentrations and the relative importance of flows to D.O. concentrations. Quantify D.O./flow relationships for various release options.

   Responsible parties: NEP and Advisory Group
   When: Mid-February
   Information sources: WAR data

2. Determine when, where and under what conditions existing patterns and volumes of discharge meet D.O. criteria.

   Responsible parties: NEP and Advisory Group
   When: Mid-February
   Information sources: WAR data

3. Consider adverse effects of increased freshwater release, including water quality impacts.

   Responsible parties: NEP and Advisory Group
   When: Following results from Steps 1 and 2

Information sources: WAR data

4. If existing discharge does not meet criteria, define options for reaching D.O. requirements. Include flow management from existing structures, other potential sources of freshwater inflow, and other management options for increasing D.O. concentrations. Include combinations of options for reaching criteria.

Responsible parties:	NEP and Advisory Group
When:	Initiate in March
Information sources:	existing knowledge and information

A D.O. Subcommittee was formed to assist with the process and review results.

D.O. Subcommittee of the
Minimum Flows Advisory Group

Tom Cardinale	HCEPC
Sid Flannery	SWFWMD
Marjorie Guillory	City of Tampa
Ernst Peebles	USF
Yvonne Stoker	USGS
Mike Coates	WCRWSA
Bob Musser	Tampa Baywatch
Charles Kovach	FDEP
Gerold Morrison	SWFWMD-SWIM

Tom Cardinale of EPCHC presented recommendations of the Palm River Committee for consideration by this Advisory Group. The Palm River Committee, which has been meeting for almost 10 years, recommends that an option for strong consideration is to fill in the deeper dredged areas immediately downstream of Structure 160, for both anticipated water quality and habitat improvements.

February 3, 1997 Subcommittee meeting summary

Both Subcommittees reviewed data and GIS maps compiled and presented by Coastal Environmental for TBNEP, which consisted of the following:

EPC long-term Water Quality Monitoring

- 3 Stations in Hillsborough River
  - Monthly 1974- Present
  - Physical and chemical parameters

- 3 Stations in Palm River/TBC (one of those above Structure 160)
  - Monthly 1974-Present
  - Physical and chemical parameters

Water and Air Research Special Study

- 10 stations in Hillsborough River
  - Monthly October 1992- September 1994
  - Physical and chemical parameters

- 5 stations in Palm River/TBC (one of those above Structure 160)
  - One station sampled October 1992-September 1994
  - Four stations sampled October 1992-September 1993
  - Physical and chemical parameters

EPC Benthic Studies

- 2 Stations in Hillsborough River (Platt Street and Columbus Drive)
  - Diel dissolved oxygen and other Hydrolab parameters
    - September 1995 and October 1996

- 1 Station in Palm River/TBC
  - Diel dissolved oxygen and other Hydrolab parameters
    - September 1995 and October 1996

GIS Map elements

- SWFWMD 1990 land use/land cover maps
- Public lands from Planning Commission

USGS water quality data

USGS is currently compiling existing data for delivery to TBNEP for inclusion in the analyses. These data will include continuous D.O., temperature and conductivity collected at several locations in the Hillsborough River during the early 1980s, and conductivity and temperature collected at two downstream locations for two years in the early 1990s. Additional continuous data (conductivity and temperature) are currently being collected at one site on the Hillsborough River.

Habitat Subcommittee recommendations

Following review of available data, the Habitat Subcommittee discussed potential analytical and technical methods which would assist with assessing opportunities for restoring/creating low salinity habitat in each of the river systems. The Habitat Subcommittee recommends the following specific steps, and agree that available data can support these steps:

- <u>Develop analytical tools to examine relationships between flow, salinity in the rivers, and amount of habitat exposed to specific salinity ranges at various flows.</u>
  Specifically:
  - Develop an empirical, regression based approach to relate the location of salinity ranges in the rivers to flow, for flows throughout the period of record
  - Using existing land use/habitat maps, photos and a shoreline survey, estimate the amount of existing habitat and potentially restorable habitat exposed to specific salinity ranges and locations of those salinities in the rivers under various flows.

These tools will allow managers to estimate the amount of existing and restorable habitat which would be exposed to a specific salinity under various flow conditions.

The Subcommittee recommended that the analytical tools be capable of providing estimates for the following parameters:

surface area
bottom area
a measure of linear habitat
acreage
volume
shoreline type

Several potential confounding factors were identified, including the following:

sediment type
vertical stratification and anoxic conditions
navigation restrictions
stormwater functions
tidal fluctuations

- <u>Identify resources of concern and salinity preferences for those resources</u>

Several Subcommittee members recommended that the definition of low salinity as 20 ppt be revisited, specifically for fishes. The Subcommittee agreed to examine a set of "representative" species to assist with defining ecologically important salinity ranges in these rivers. FMRI fisheries researchers will be working with TBNEP staff to assist with this element of the process, for review by the Habitat Subcommittee.

After development of the analytical tools in the first step, specific salinities associated with identified resources of concern can be "plugged in" to estimate amount of existing and restorable habitat associated with these salinities under various flow rates.

Dissolved Oxygen Subcommittee

After reviewing existing data, the Subcommittee discussed analytical techniques which the data would support to relate dissolved oxygen to flow, and recommend the following:

- Develop an empirical regression-based approach to relate river flow (as measured at or near the structure) with midday dissolved oxygen measurements within the river.

  Note: much of the available dissolved oxygen data, including the long-term monthly measurements collected by EPC, are collected between mid-morning and mid-afternoon.

- Develop an empirical regression-based approach to relate midday D.O. with minimum D.O. for those data sets which have both measurements. The Subcommittee recognized some risk in applying the regression to time frames outside of the period in which the data were actually collected.

- Using the regression developed in the first step, relate minimum D.O. to flow.

- Determine when, where and under what conditions existing patterns and volumes of discharge meet the minimum target of 4.0 mg/l.

Both Subcommittees recognized that recommendations for the Palm River/TBC regarding both low-salinity habitat and dissolved oxygen may be very different than those for the Hillsborough River.

February 20, 1997

The Habitat and D.O. Subcommittees met jointly to hear and discuss a presentation from FDEP/FMRI concerning available fish habitat and D.O. preference data. Ed Matheson from FMRI presented information collected during extensive fisheries studies on the Little Manatee River (attached table) which indicated salinity preferences for almost 50 species. He summarized his major points as follows:

1). Most of the fish occurring in the estuarine portion of Tampa Bay's tributaries are euryhaline; over their life cycle they may normally travel from full-strength seawater habitats to very low salinity (perhaps even freshwater) habitats.

2) Although the salinity tolerances of these species are broad, they may "prefer" or be attracted to different salinity zones at different times during their life cycle (i.e., peak abundance may occur at different salinities for different life-history stages).

3.) Salinity "preference" is species-specific.

4.) Fish species richness may be highest at salinities greater than 20 ppt, but fish productivity may be highest at much lower salinities (generally lower mesohaline to freshwater).

5). In a Tampa Bay tributary with no water control structures, the Little Manatee River, many estuarine species (including both numerically dominant and economically valuable species) have abundance peaks at salinities less than 20 ppt (often much less).

6.) In the case of truncated salinity gradient, some species that generally occupy lower salinity areas during their early life history will follow the gradient until they encounter the obstacle that is truncating the gradient.

7). In order to offer maximum benefit to the most species of fish, the salinity gradient needs to be complete (i.e., freshwater to polyhaline).

A summary of potential habitat restoration or creation areas along the shoreline as estimated by a visual survey from a boat indicated the following:

- Along the Hillsborough River, the shoreline survey estimated approximately 4,070 linear feet (3.3 acres) of potentially restorable vegetation habitat The majority of the shoreline is hardened or has very steep banks unsuitable for vegetative habitat creation/restoration.

- Along the Palm River/TBC, the shoreline survey identified small areas of existing *Juncus* marsh (less than one acre) on the north side of the river behind an existing berm. The potential for considerable habitat creation exists on publicly-owned lands, but will require major physical alternations.

A summary of potential habitat creation sites identified during this shoreline survey is attached.

The Subcommittees also reviewed preliminary analyses from existing salinity and D.O. data sets collected in the Hillsborough River, and received updates of progress on the development of analytical tools to relate salinity, river mile, D.O. and flow from Tony Janicki (Coastal Environmental, Inc.) and Sid Flannery (SWFWMD).

March 4, 1997
The full Advisory Committee met to revise summaries of the Results, Findings and Recommendations for submittal to SWFWMD staff as follows:

WORKING GROUP RESULTS AND FINDINGS
Hillsborough River

- A visual shoreline survey estimated approximately 4,070 linear feet (3.3 acres) of potentially restorable vegetation habitat. The majority of the shoreline is hardened or has very steep banks unsuitable for vegetative habitat creation/restoration.

- In order to offer maximum benefit to the most species of fish, the salinity gradient in a river needs to be complete (i.e., freshwater to polyhaline). Many estuarine species have abundance peaks at salinities less than 20 ppt, often much less.

- Development of analytical tools and methods to relate flow to dissolved oxygen and salinity in the river is ongoing.

WORKING GROUP RECOMMENDATIONS
Hillsborough River

- Provisionally define ecological criteria for dissolved oxygen concentrations as a minimum of 4.0 mg/l and average of 5.0 mg/l, for optimizing fish utilization. If a minimum D.O. concentration of 4.0 cannot be maintain at all times in all locations, minimize the length of time with D.O. less than 4.0 mg/l.

- Maintain a salinity gradient from river mouth to the dam ranging from polyhaline (>20 ppt) to fresh (0 ppt), to optimize estuarine-dependent fish species utilization. Maintain some portion of the river at salinities less than 10 ppt.

- Maintain a freshwater segment in the upper portion of the river.

Further recommendations:

- Continue development of analytical tools to estimate flow management options to meet dissolved oxygen and salinity criteria as defined for the Hillsborough River.

- Refine DO and salinity gradient criteria (i.e., seasonal or daily fluctuations, depth of measurement, length or volume of optimal salinity ranges, etc.).

- Consider other factors including adequate freshwater flows for manatees.

WORKING GROUP RESULTS AND FINDINGS
Palm River/TBC

- Salinity and DO criteria may not be met using flow management under current conditions.

- A visual shoreline survey identified small areas of existing *Juncus* marsh (less than one acre) on the north side of the river behind an existing berm. The potential for considerable habitat creation exists on publicly-owned lands, but will require major physical alternations.

- Several options for physical alteration, including "shallowing" of the dredged areas of the river and creation of small tributaries along the shoreline, are being considered.

WORKING GROUP RECOMMENDATIONS
Palm River/TBC

The Palm River/TBC has the potential to provide considerable low-salinity and estuarine habitat to the Hillsborough Bay system. Several options have been suggested, and a process to examine the feasibility of filling deep areas of the river has been initiated.

- Minimum flows on the Palm River/TBC should be set based on existing physical conditions of the water course by October 1, 1997. However, the minimum flows will be reevaluated as part of the feasibility of filling deep areas of the river downwatershed of Structure 160, or other habitat creation options.
- Evaluate optimizing existing conditions to address habitat and D.O. criteria/goals.

Ongoing Activities

1. Complete the characterization of existing salinity and dissolved oxygen conditions in the Hillsborough River and Palm River/TBC.
2. Continue development of an empirically-based management tool to predict salinity and dissolved oxygen distributions in the Hillsborough River and Palm River/TBC as a function of flow using recently observed water quality and flow data.
3. Test the reliability of the management tools through a series of controlled releases of freshwater from the Hillsborough River and Palm River/TBC structures. This work will be contingent upon a determination by SWFWMD and the City of Tampa of the need for the controlled release experiment following analyses of prior tasks.
4. Develop a method to estimate environmental benefits of maintaining/restoring various salinity and dissolved oxygen distributions in the Hillsborough River and Palm River/TBC.
5. If existing discharge does not meet criteria, define options for reaching D.O. and salinity gradient goals. Include flow management from existing structures, other potential sources of freshwater flow, and other management options. Include combinations of options for reaching goals.

April 24, 1997
April 30, 1997
May 6, 1997

The next three meetings of the Advisory Group were devoted mainly to examining the results of the statistical model for the Hillsborough and Palm River/TBC developed by Coastal Environmental. Fisheries researchers from FMRI also presented more detailed data analyses of salinity range associations with various species of fish found in Tampa Bay tributaries, and results of a deterministic model (with graphics representing salinity in Hillsborough River under various flow release scenarios) developed by the District were shown. The following attachments received from Coastal Environmental and FDEP FMRI are provided as a summary of the presentations received by the Advisory Group (results of the deterministic model presented by the District are not yet available).

Attachment 1. Map of sampling stations (from Water and Air Research, 1995)

Attachment 2: Hillsborough River results (statistical model developed by Coastal Environmental for TBNEP)

2-1	Cumulative frequency (%) of measured Hillsborough River flow (cfs) from the dam recorded during the WAR sampling period (1991-1993) and during 1985-1993, for flows up to 1000 cfs
2-2	Cumulative frequency (%) of Hillsborough River flow (cfs) from the dam recorded during the WAR sampling period and during 1985-1993, for flows up to 200 cfs.
2-3	Percentile breakdown of release from dam (cfs) and inflow to the Hillsborough Reservoir from upstream (cfs). Information provided by SWFWMD (Sid Flannery).
2-4	Summary of r^2 for regressions of salinity and flow, by station and depth. Regressions used recorded data (flow) from Sulfur Springs and the dam.
2-5	Map of Hillsborough River showing river mile and WAR station locations
2-6	Estimated isohaline locations (surface) for 0 cfs flow from the dam. (NOTE: A flow of 31 cfs (the average flow recorded from the Springs for the WAR study period) is assumed from Sulfur Springs for those areas below the Springs discharge. However, flow on this and the following graphics indicates flow from the dam only.)

2-7 Estimated isohaline locations (surface) for 10 cfs flow from the dam.

2-8 Estimated isohaline locations (surface) for 20 cfs flow from the dam.

2-9 Estimated isohaline locations (surface) for 50 cfs flow from the dam.

2-10 Estimated isohaline locations (1 m depth) for 0 cfs flow from the dam.

2-11 Salinity by flow from the dam at Station 2 (Rowlett Park Drive). Data source: USGS

2-12 Estimated shoreline (in miles) exposed to various salinity ranges (at the surface) for flows up to 200 cfs from the dam.

2-13 Estimated river surface area (in acres) exposed to various salinity ranges (at the surface) for flows up to 200 cfs from the dam.

2-14 Estimated total river miles exposed to various salinity ranges (at the surface) for flows up to 200 cfs from the dam.

2-15 Estimated existing vegetated shoreline habitat (linear feet) exposed to various salinity ranges (at the surface) for flows up to 200 cfs from the dam.

2-16 Table: Changes in habitat (shoreline length, surface area and volume) associated with increased flows from the dam.

2-17 Mid-Day Dissolved Oxygen and flow regression; percent of observations with D.O. less than 1 mg/l. 3-day average flow from the dam. Combined observations from 0m, 1m, 2m, 3m, and bottom depths.

2-18 Mid-day D.O. and flow regression; percent of observations with D.O. less than 2 mg/l. 3-day average flow from the dam. Combined observations from 0m, 1m, 2m, 3 m and bottom depths.

2-19 Mid-day D.O. and flow regression; percent of observations with D.O. less than 3 mg/l. 3-day average flow from the dam. Combined observations from 0m, 1m, 2m, 3m and bottom depths.

2-20 Mid-day D.O. and flow regression; percent of observations with D.O. less than 4 mg/l. 3-day average flow from the dam. Combined observations from 0m, 1m, 2m, 3m, and bottom depths.

2-21 Mid-day D.O. and flow regression; percent of observations with D.O. less than 5 mg/l. 3-day average flow from the dam. Combined observations from 0m, 1m, 2m, 3m, and bottom depths.

Attachment 3 Palm River/Tampa Bypass Canal (statistical model developed by Coastal Environmental for TBNEP)

3-1 Cumularive frequency (%) of measured Palm River/Tampa Bypass Canal flow (cfs) from Structure 160 recorded during the WAR sampling period (1991-1993) and during 1985-1993, for flows up to 1000 cfs

3-2 Cumularive frequency (%) of measured Palm River/Tampa Bypass Canal flow (cfs) from Strucnure 160 recorded during the WAR sampling period and during 1985-1993, for flows up to 200 cfs.

3-3 Summary of r^2 for regressions of salinity and flow, by station and depth. All regressions used recorded data (flow) from Structure 160.

3-4 Cumularive shoreline (miles) by river mile (0 miles is at Structure 160).

3-5 Cumulative surface area (acres) by river mile.

3-6 Table: Changes in habitat (shoreline length and surface area) associated with increased flow from Structure 160.

Attachment 4. Summary of fisheries data provided by FDEP Marine Research Institute (Tim McDonald).

4-1 Map of sampling site locations on the Alafia, Little Manatee and Manatee Rivers, 1994-1996, including boat seine samples and otter trawl samples.

4-2 Distribution of surface and bottom salinities on the Alafia, Little Manatee and Manatee Rivers during sample collections.

4-3 Distribution of surface and bottom dissolved oxygen measurements on the Alafia, Little Manatee and Manatee Rivers during sample collections.

4-4 Salinity classification system used for the FDEP FMRI study.

4-5 Number of samples collected by salinity classification and gear for each river system.

4-6 Density-weighted mean salinities for species collected in ten or more samples.

4-7 Mean and standard deviation of density-weighted salinities for 13 species of estuarine-dependent fishes collected in this study.

Centropomis undecimalis	snook
Diapterus plumerii	striped mojarra
Pogonias cromis	black drum
Elops saurus	ladyfish
Mugil cephalus	black mullet
Archosargus probatocephalus	sheepshead
Lagodon rhomboides	pinfish
Eucinostomus harengulus	tidewater mojarra
Cynoscion nebulosus	spotted seatrout
Sciaenops ocellatus	red drum
Eucinostomus gula	silver jenny
Cynoscion arenarius	sand seatrout

An overall summary of fisheries information provided by FMRI noted that, at all times of the year, some estuarine species are found in the freshwater and oligohaline sections of these Tampa Bay rivers.

[illegible]

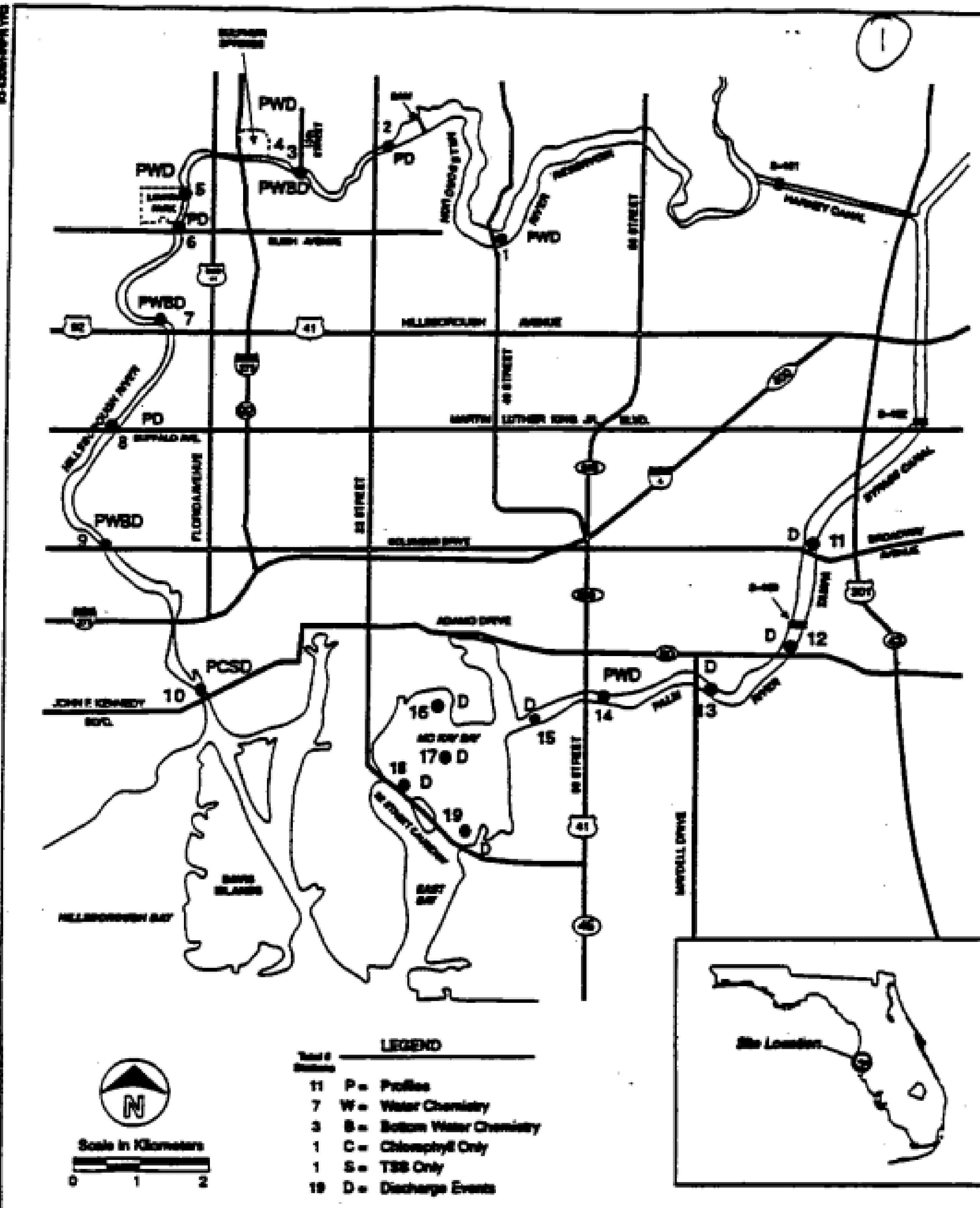
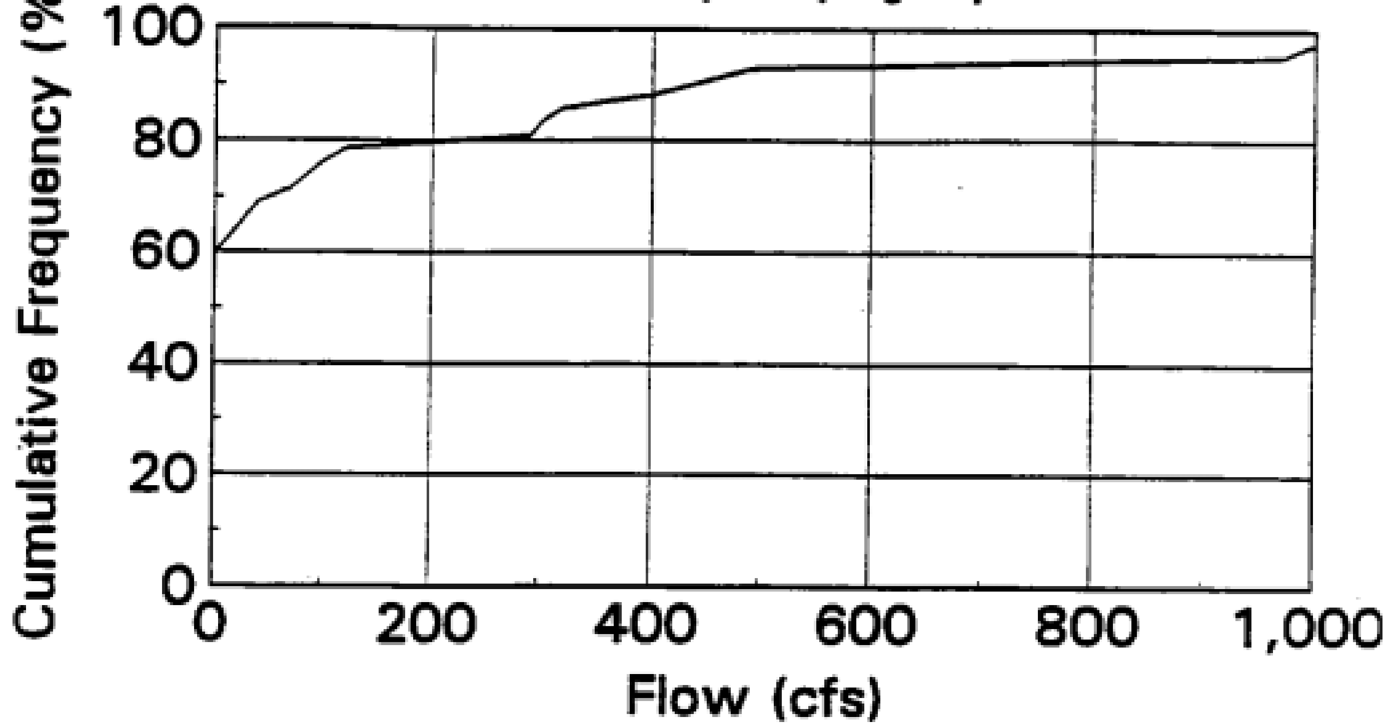
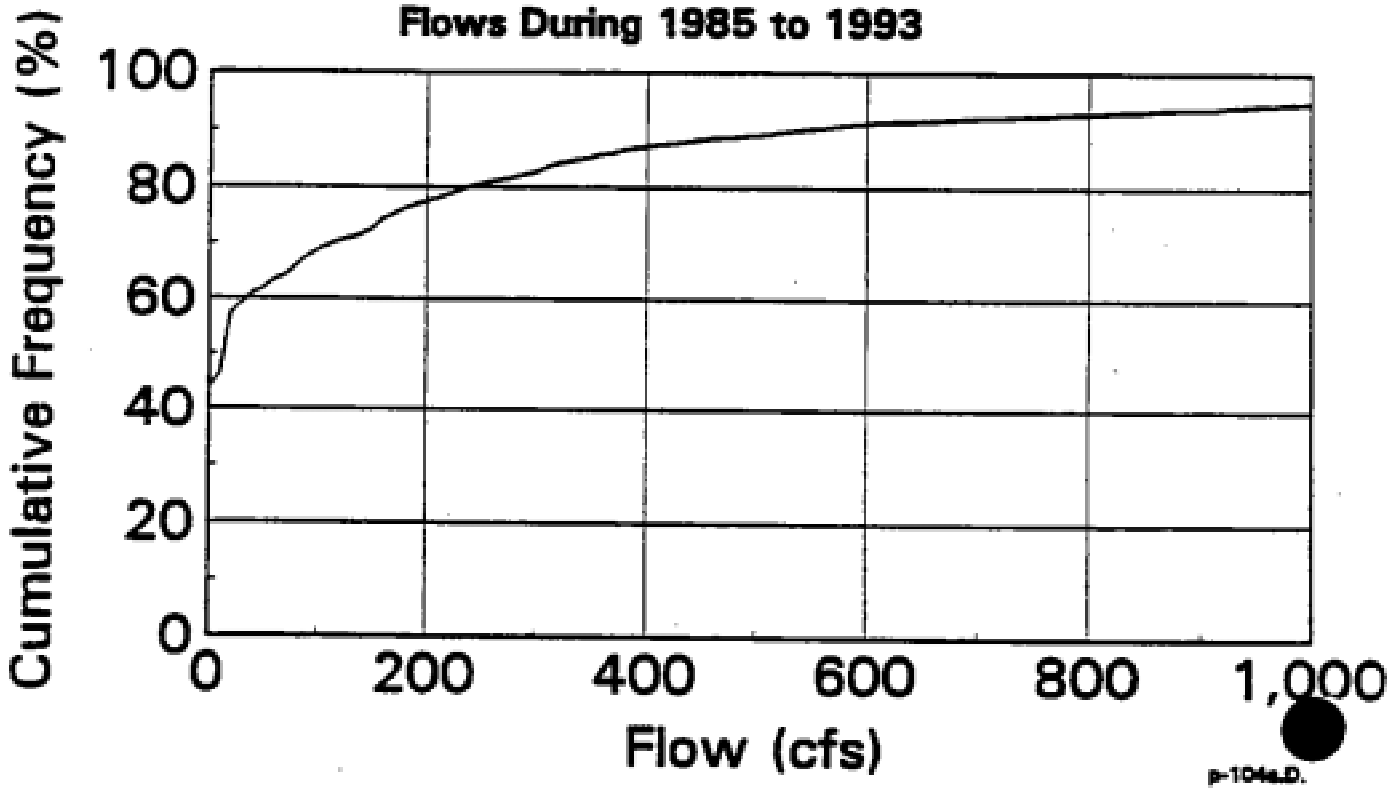


FIGURE 2-3.
Year 3 Sampling Locations

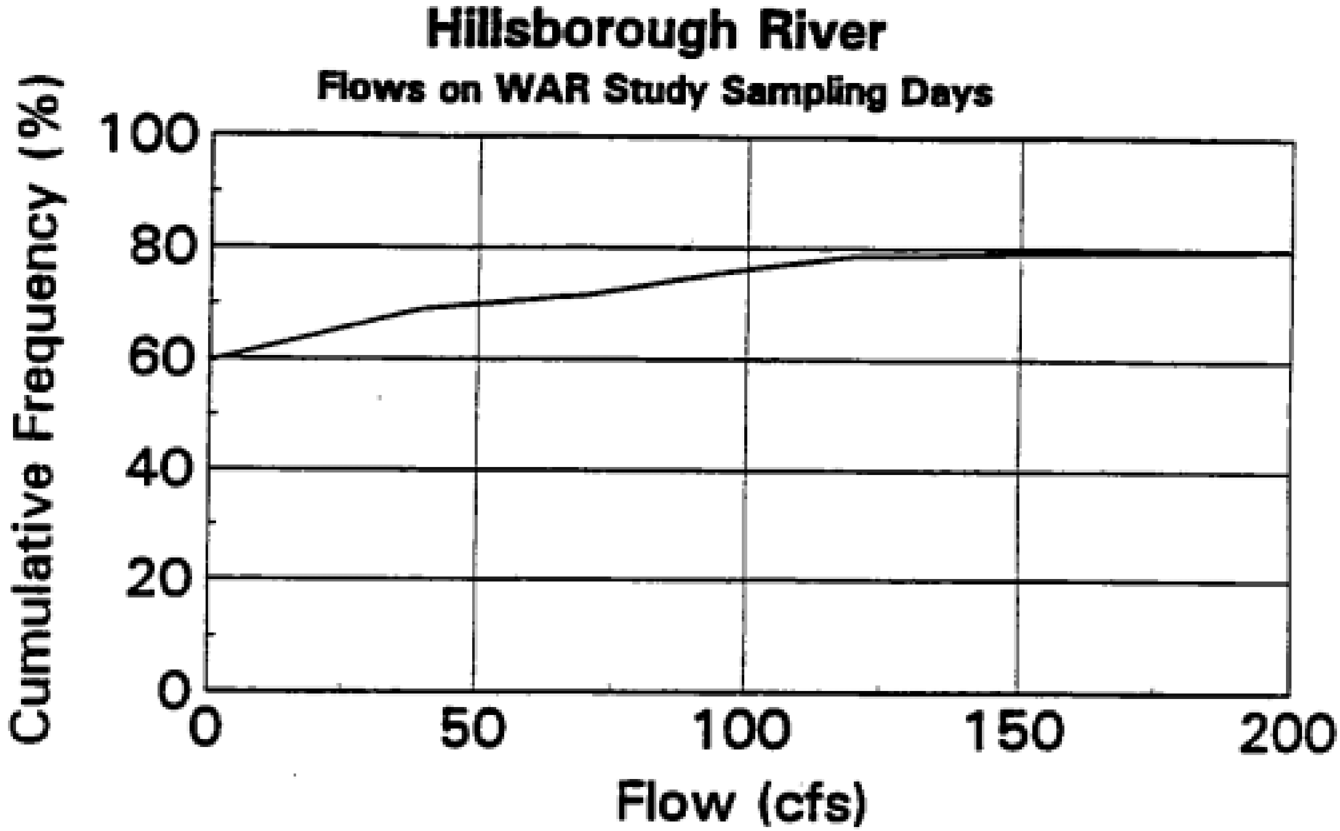
Hillsborough River
Flows on WAR Study Sampling Days

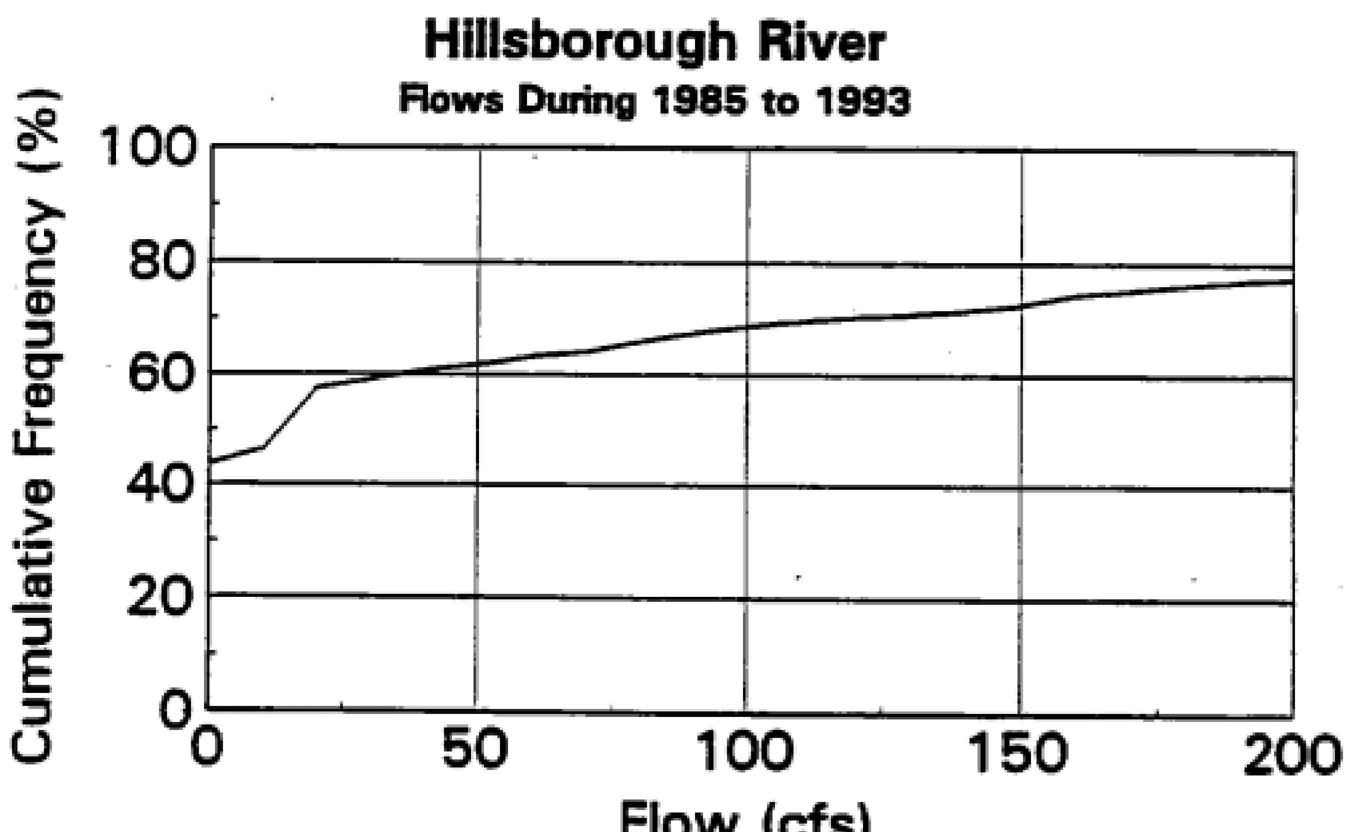


Hillsborough River
Flows During 1985 to 1993



p-104a.D.


Hillsborough River
Flows on WAR Study Sampling Days
Cumulative Frequency (%)
100
80
60
40
20
0
0
50
100
150
200
Flow (cfs)


Hillsborough River
Flows During 1985 to 1993
Cumulative Frequency (%)
100
80
60
40
20
0
0
50
100
150
200
Flow (cfs)

p-104b.DRW

LOWER HILSBOROUGH RIVER FLOW FREQUENCIES
SIX YEARS (1988 - 1994)

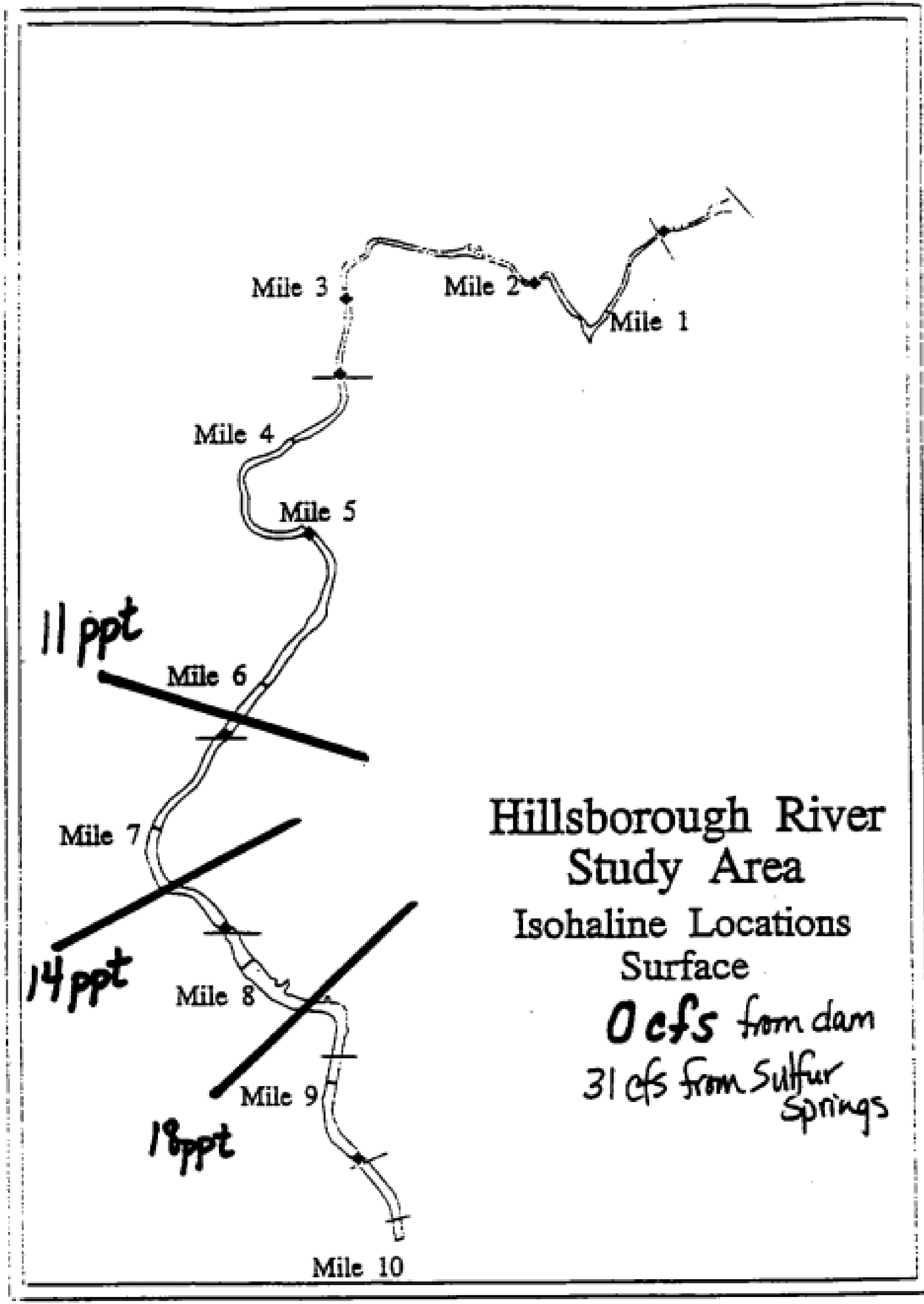
percentile	release	inflow
min	0.1	35
10	0.1	58
20	0.1	69
30	0.2	81
40	0.6	98
50	1	116
60	22	145
70	32	191
80	151	291
90	359	515
100	3830	3119

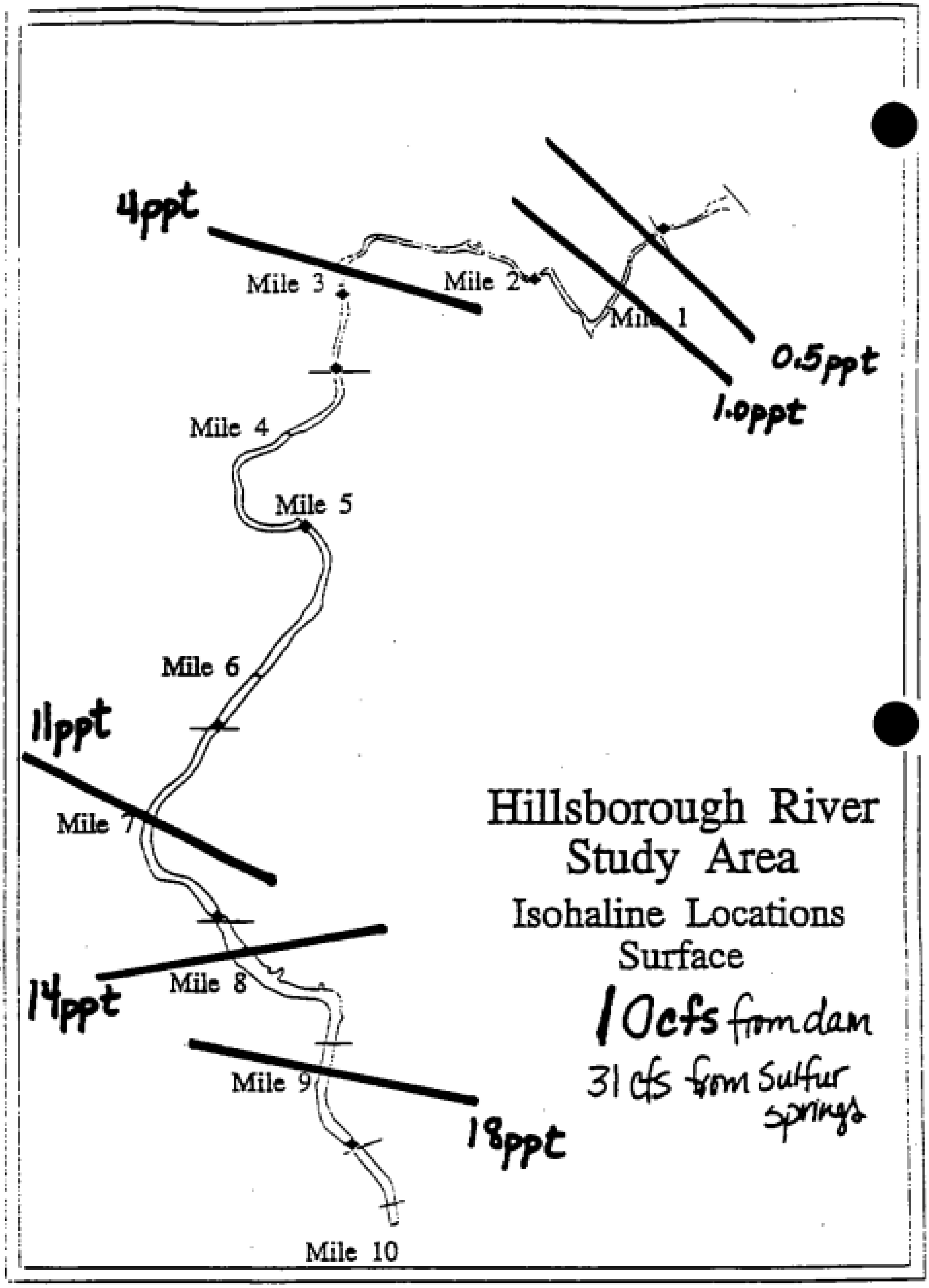
r^2 by Station and Depth

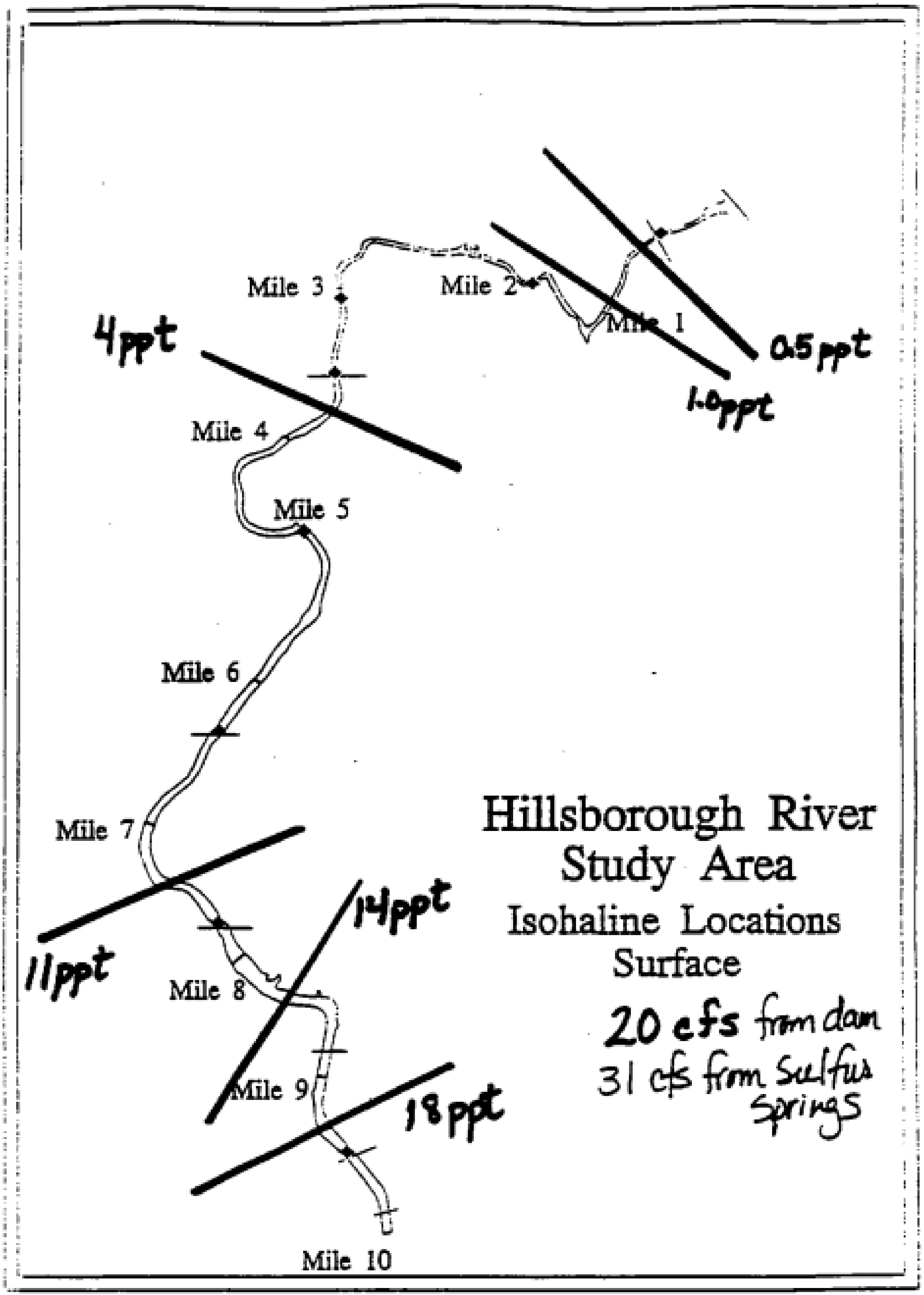
Hillsborough River
Salinity vs. Flow

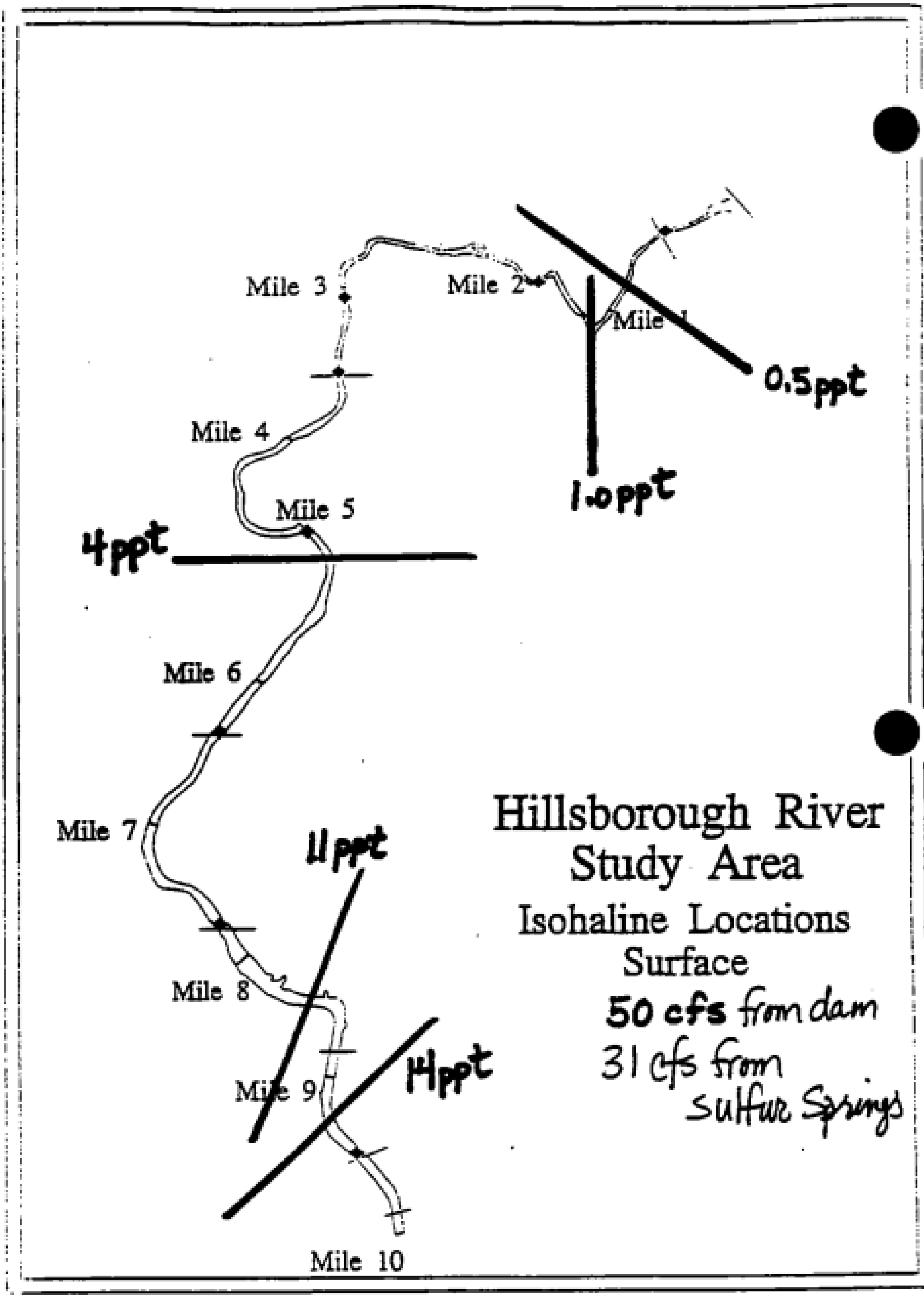
Station	Depth (m)				
	0	1	2	3	Bottom
2	-	-	-	-	-
3	0.72	0.68	0.60	0.57	0.63
5-10	0.87	0.78	0.73	0.83	0.76
	Overall $r^2 = 0.82$				

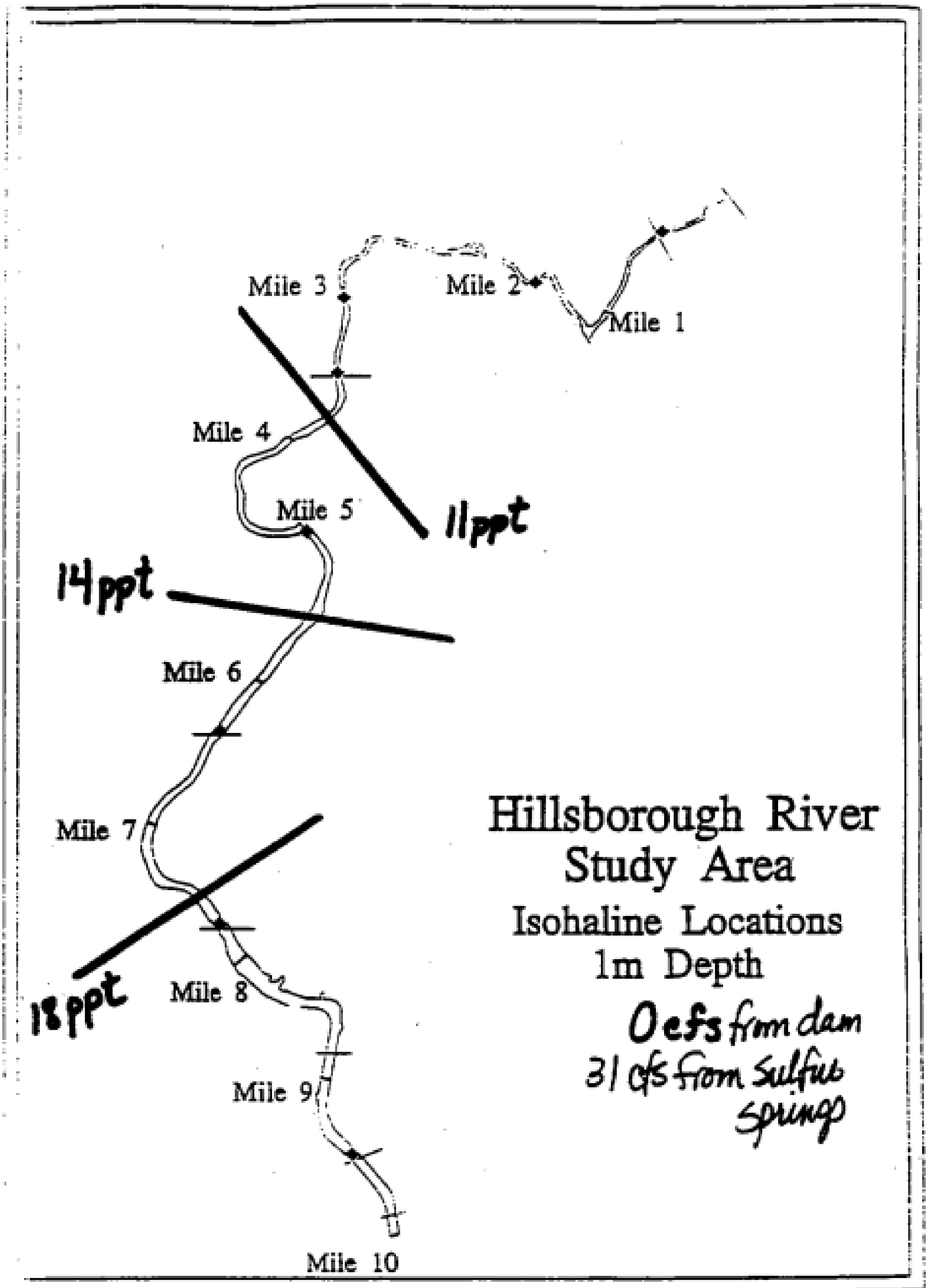
Hillsborough River Study Area
Isohaline Locations
Surface


Mile 1
Mile 2
Mile 3
Mile 4
Mile 5
Mile 6
Mile 7
Mile 8
Mile 9
Mile 10
11 ppt
14 ppt
18 ppt
Hillsborough River
Study Area
Isohaline Locations
Surface
0 cfs from dam
31 cfs from Sulfur Springs


Hillsborough River
Study Area
Isohaline Locations
Surface
10cfs from dam
31 cfs from Sulfur springs
Mile 1
Mile 2
Mile 3
Mile 4
Mile 5
Mile 6
Mile 7
Mile 8
Mile 9
Mile 10
0.5ppt
1.0ppt
4ppt
11ppt
14ppt
18ppt


Mile 1
Mile 2
Mile 3
Mile 4
Mile 5
Mile 6
Mile 7
Mile 8
Mile 9
Mile 10
0.5ppt
1.0ppt
4ppt
11ppt
14ppt
18ppt
Hillsborough River Study Area
Isohaline Locations
Surface
20 cfs from dam
31 cfs from Sulfur Springs

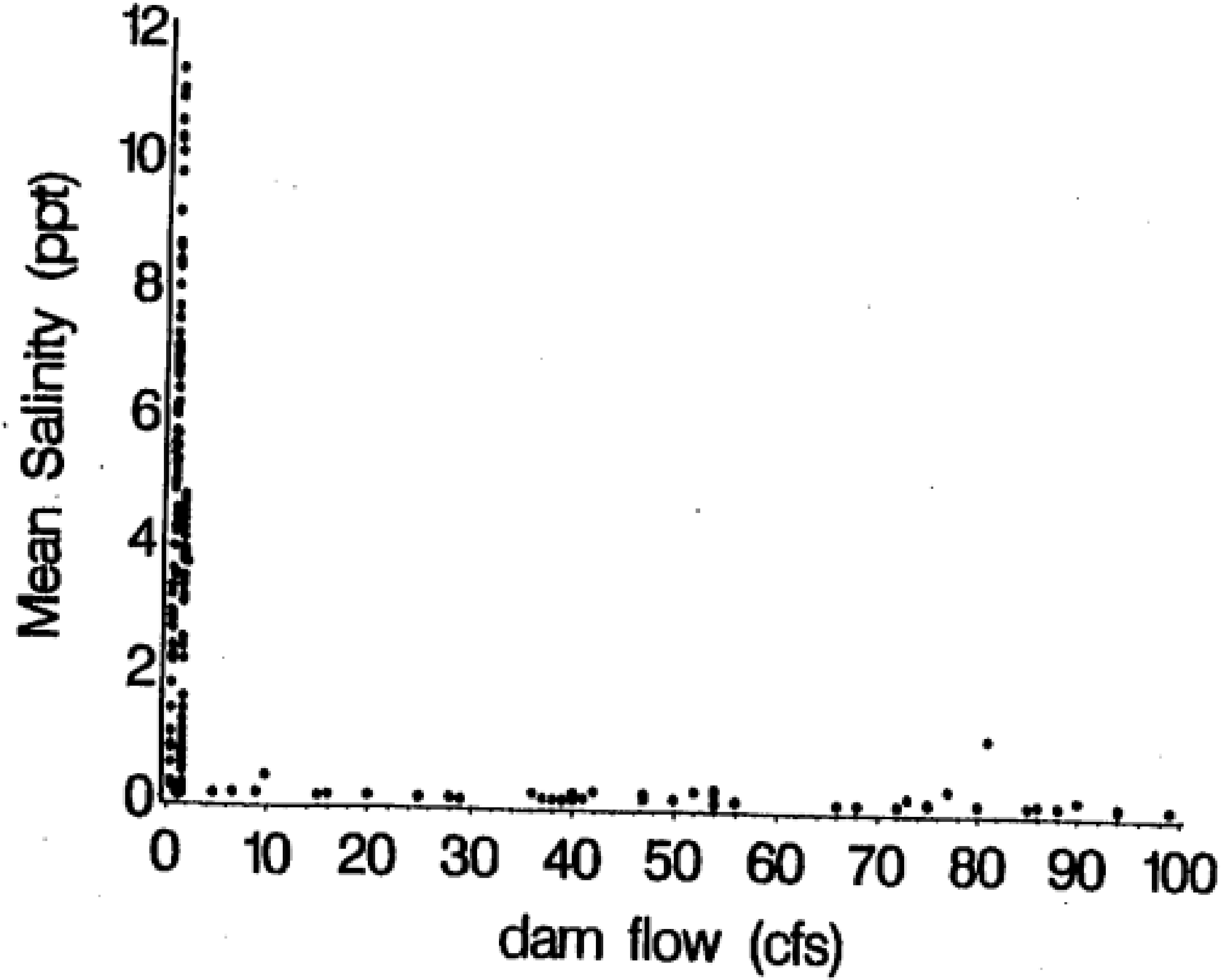

Mile 1
Mile 2
Mile 3
Mile 4
Mile 5
Mile 6
Mile 7
Mile 8
Mile 9
Mile 10
0.5ppt
1.0ppt
4ppt
11ppt
14ppt
Hillsborough River
Study Area
Isohaline Locations
Surface
50 cfs from dam
31 cfs from
sulfur Springs

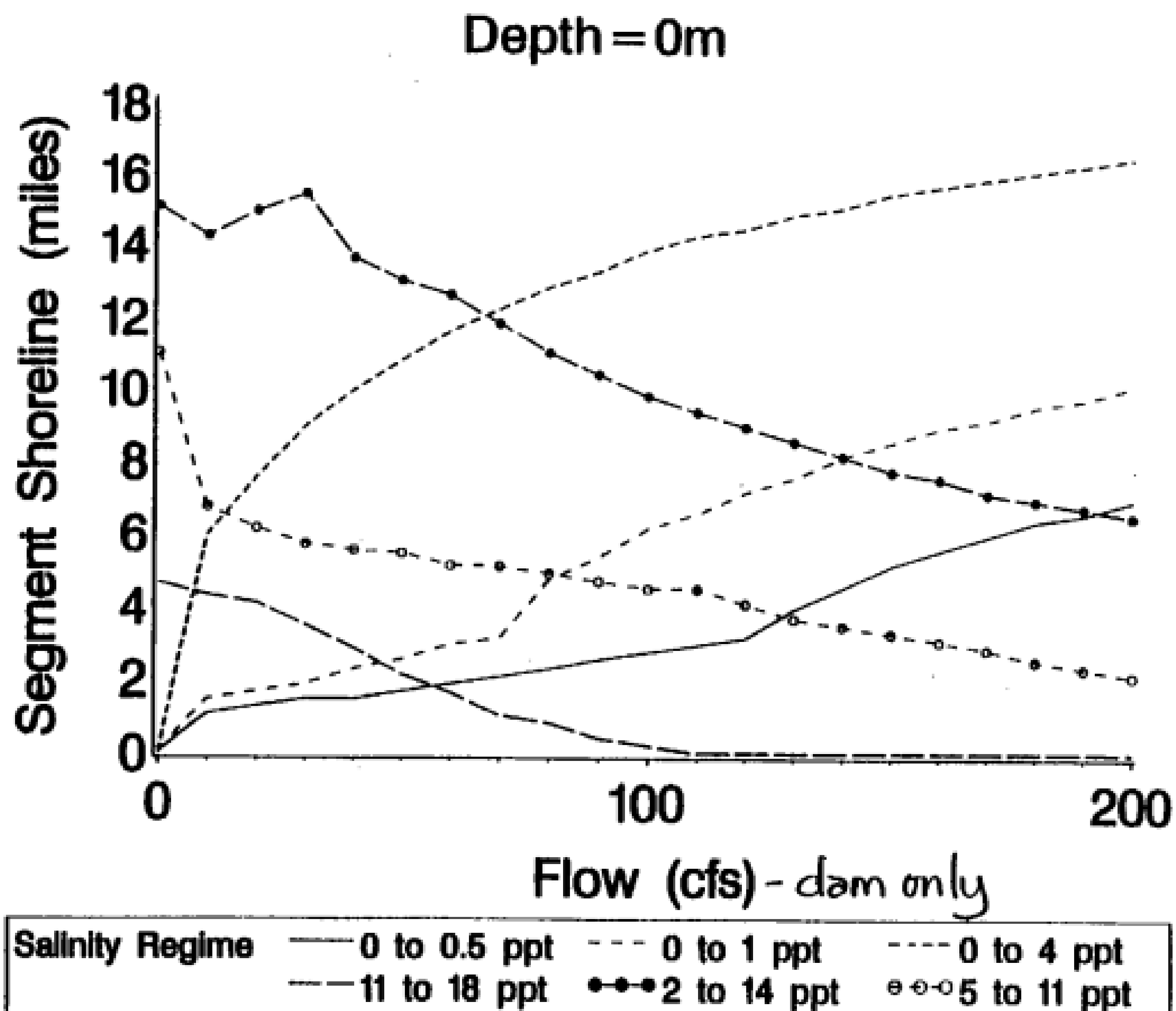


Mile 1
Mile 2
Mile 3
Mile 4
Mile 5
Mile 6
Mile 7
Mile 8
Mile 9
Mile 10
11ppt
14ppt
18ppt
Hillsborough River
Study Area
Isohaline Locations
1m Depth
0 cfs from dam
31 cfs from Sulfur
springs

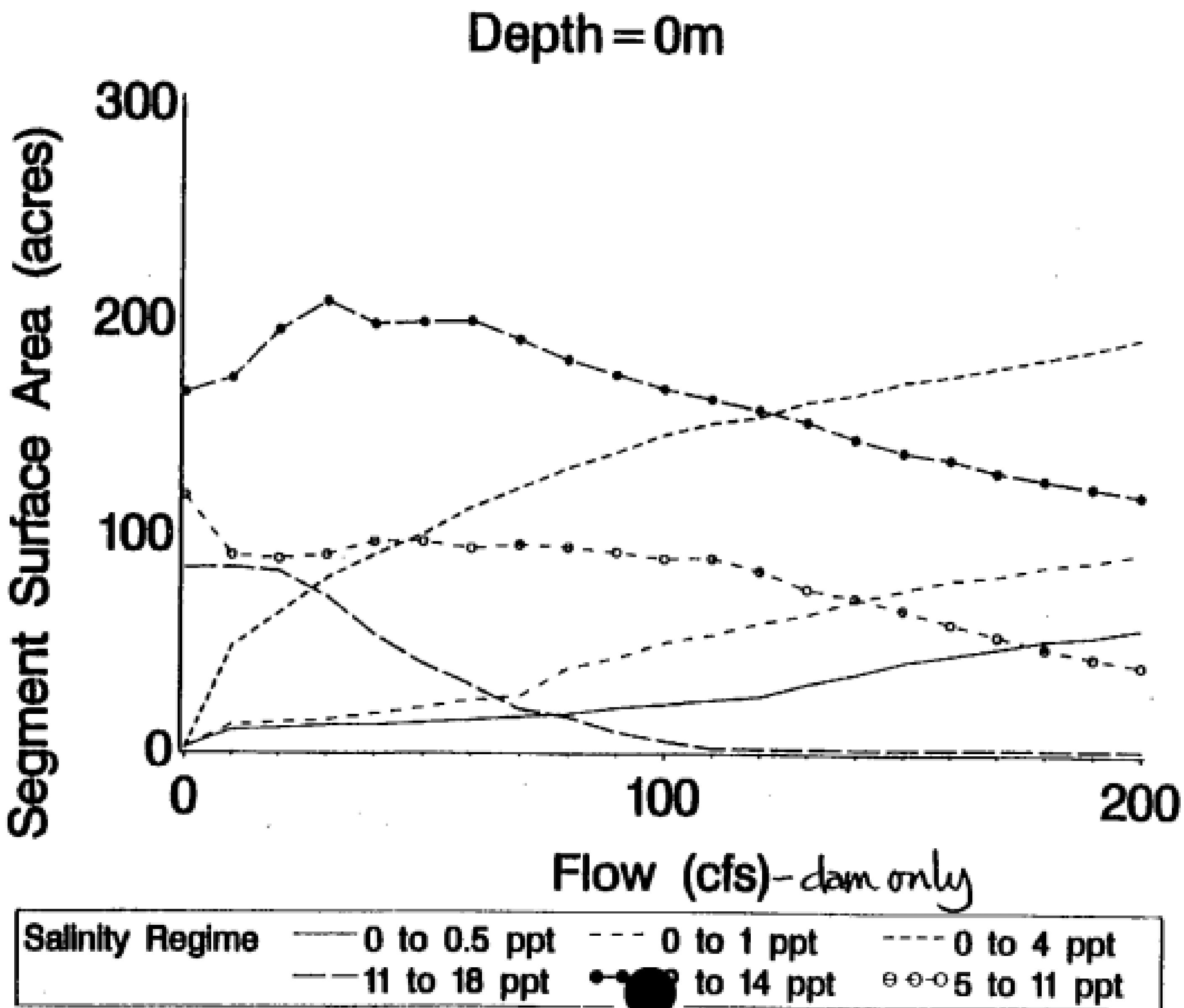
P 5/5 USGS

Subset of data for Damflow <= 100 cfs
STREET=Rowlett Pk. Dr.

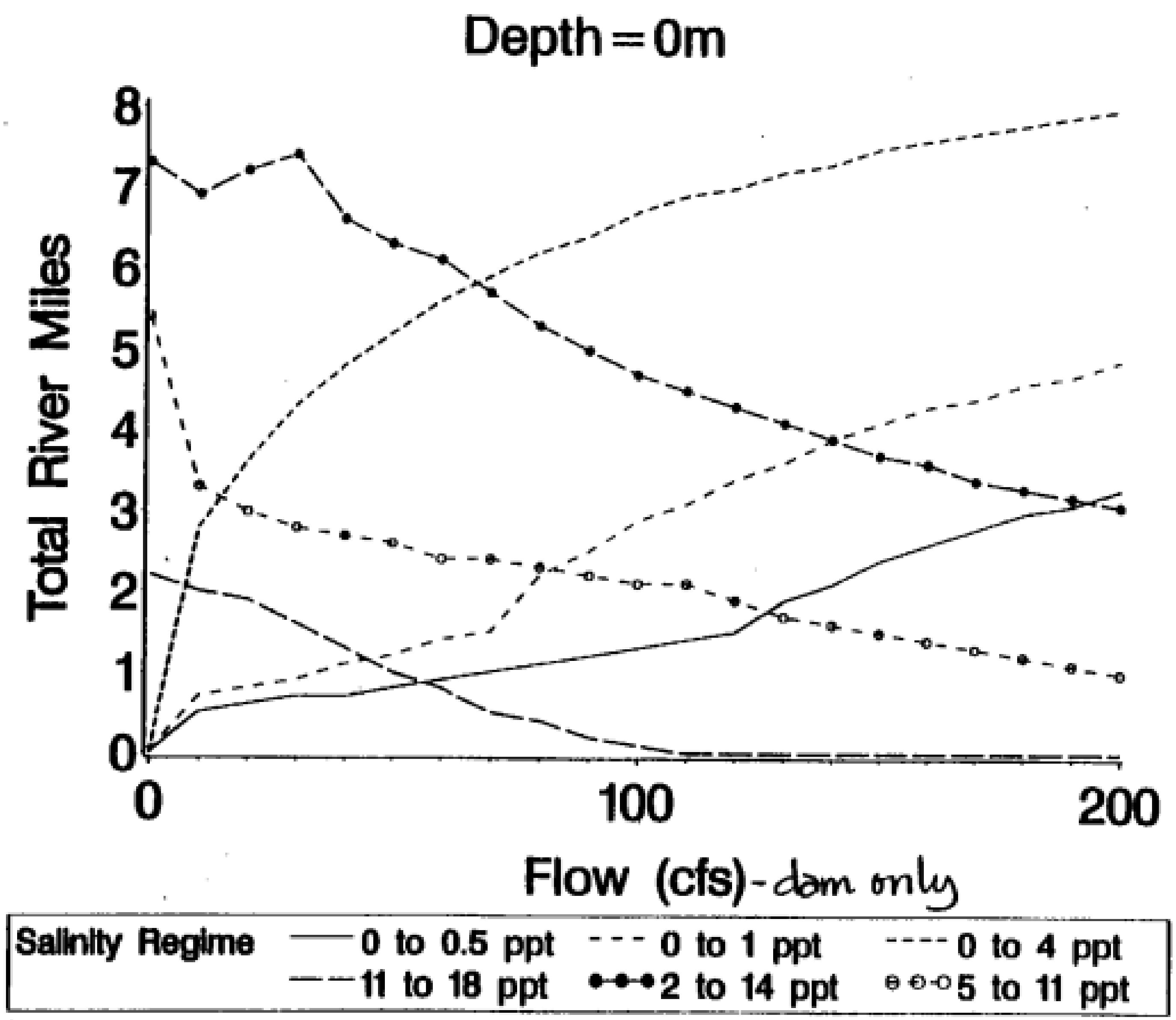



Depth = 0m
Segment Shoreline (miles)
18
16
14
12
10
8
6
4
2
0
0
100
200
Flow (cfs) - dam only
Salinity Regime
0 to 0.5 ppt
0 to 1 ppt
0 to 4 ppt
11 to 18 ppt
2 to 14 ppt
5 to 11 ppt

May 21 1997


Depth = 0m
Segment Surface Area (acres)
300
200
100
0
0
100
200
Flow (cfs)-dam only
Salinity Regime
0 to 0.5 ppt
0 to 1 ppt
0 to 4 ppt
11 to 18 ppt
to 14 ppt
5 to 11 ppt

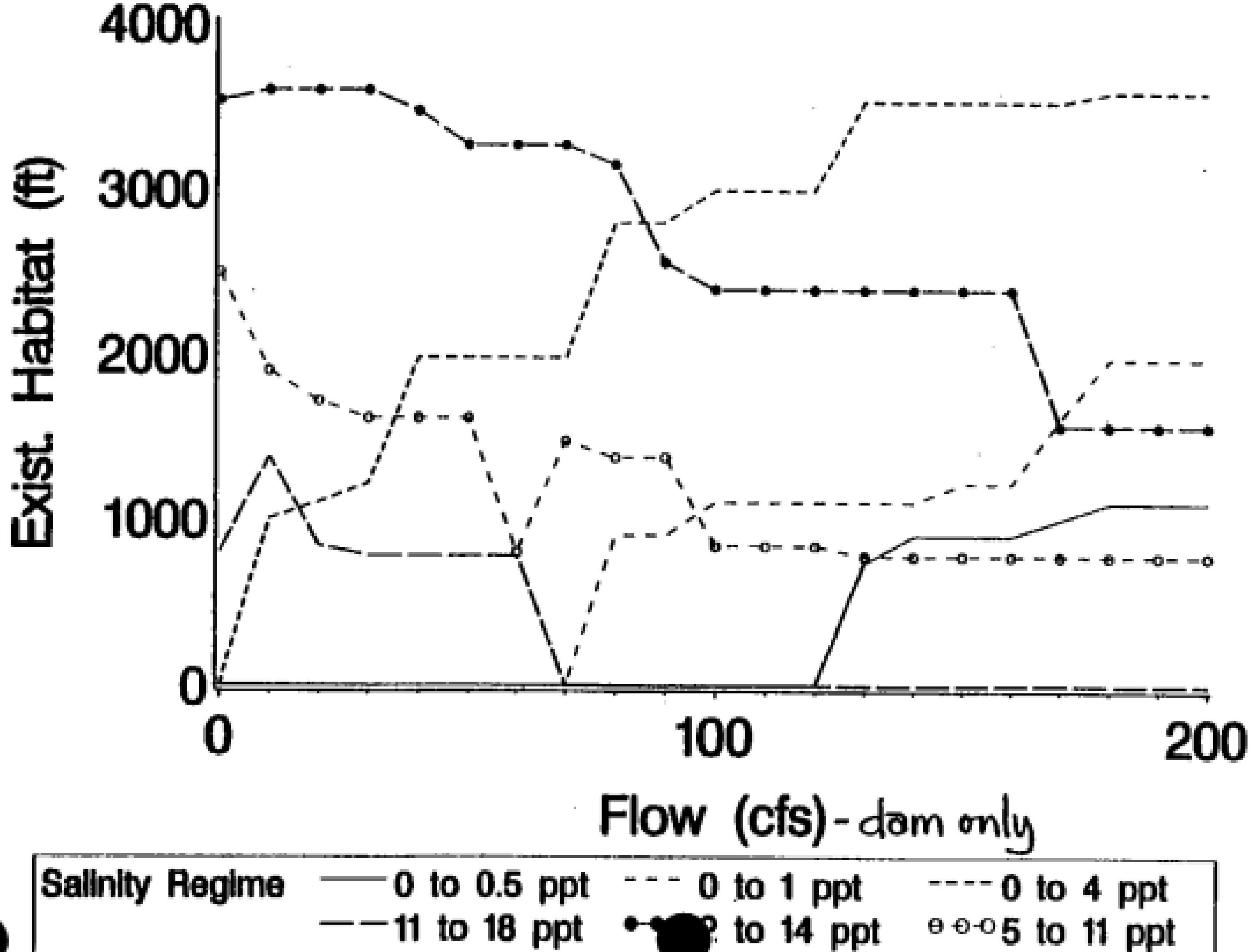
May 21 1997



Depth = 0m
Total River Miles
8
7
6
5
4
3
2
1
0
0
100
200
Flow (cfs) - dam only
Salinity Regime
0 to 0.5 ppt
0 to 1 ppt
0 to 4 ppt
11 to 18 ppt
2 to 14 ppt
5 to 11 ppt

May 21 1997

Depth = 0m



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Hillsborough River
Changes in Habitat Associated With Increased Flow

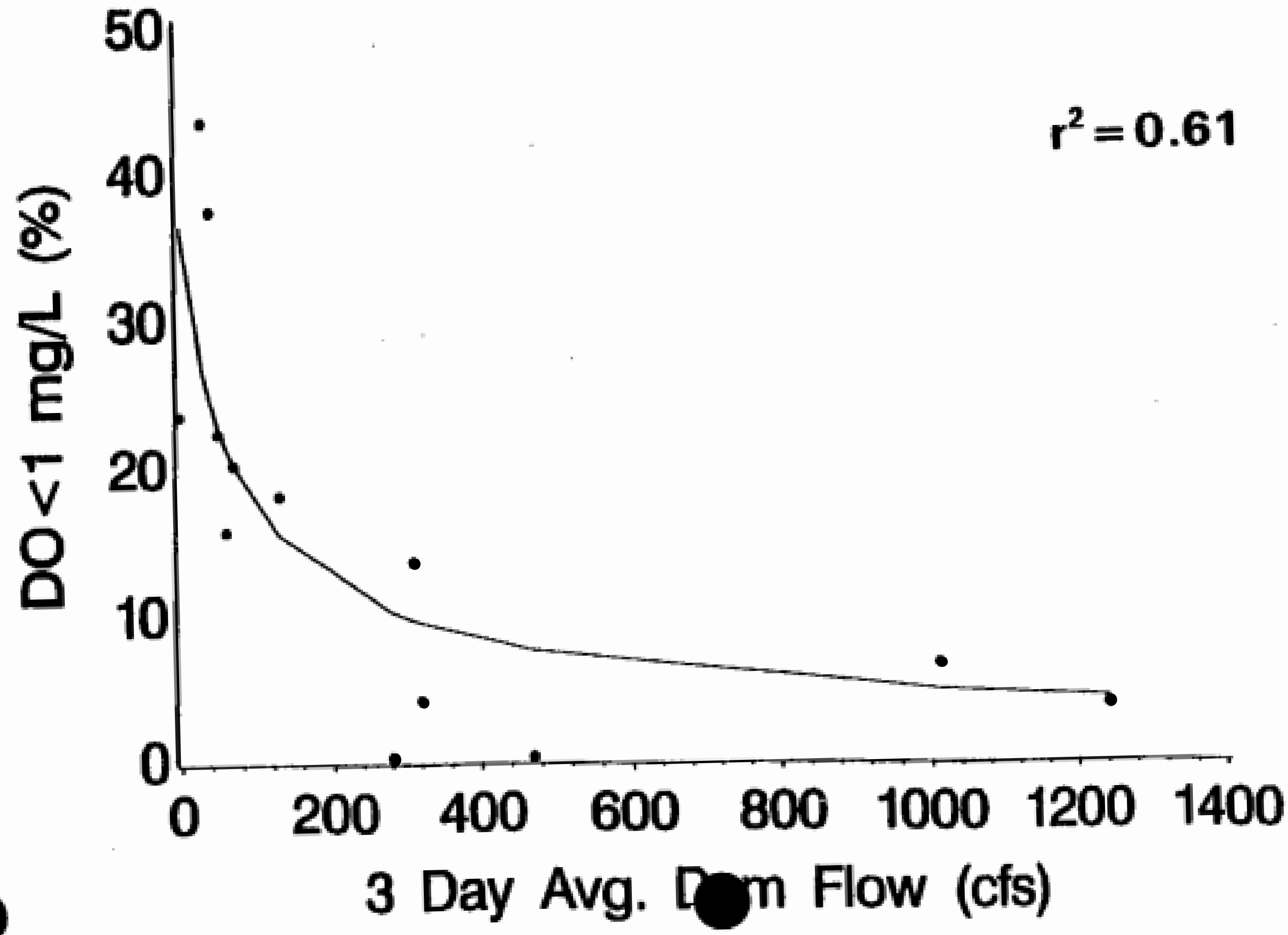
Salinity Range Habitat Type	Baseline Condition (0 Release)	Change from Baselinefor 10 cfs Flow Releases									
		10	20	30	40	50	60	70	80	90	100
0-0.5 ppt											
Shoreline Length (ft)	0	5,513	6,600	7,657	7,657	8,719	9,778	10,846	11,899	13,296	14,385
Surface Area (ac)	0	8	10	11	11	12	14	15	17	19	21
Volume (ac-ft)	0	16	19	21	26	33	36	42	58	66	75
0-1 ppt											
Shoreline Length (ft)	0	7,657	8,719	9,778	11,899	13,296	15,435	16,487	25,012	28,270	32,551
Surface Area (ac)	0	11	12	14	17	19	23	25	37	42	49
Volume (ac-ft)	0	21	28	36	51	61	77	88	123	135	157
0-4 ppt											
Shoreline Length (ft)	0	31,450	39,954	47,351	52,684	57,148	61,430	64,670	67,899	70,158	73,338
Surface Area (ac)	0	47	62	79	89	99	112	121	130	137	145
Volume (ac-ft)	0	114	157	205	287	350	411	469	516	583	625
2-14 ppt											
Shoreline Length (ft)	79,781	-4,386	-668	1,911	-7,741	-10,946	-13,029	-17,237	-21,473	-24,675	-27,874
Surface Area (ac)	164	4	18	26	20	20	21	16	10	5	1
Volume (ac-ft)	649	154	318	421	466	517	566	574	550	538	526
5-11 ppt											
Shoreline Length (ft)	58,227	-22,651	-25,780	-28,077	-28,947	-29,430	-31,134	-31,265	-32,309	-33,426	-34,489
Surface Area (ac)	118	-24	-25	-24	-19	-18	-21	-20	-21	-23	-25
Volume (ac-ft)	376	60	146	171	227	233	230	221	208	214	194
11-18 ppt											
Shoreline Length (ft)	24,529	-1,848	-2,943	-6,179	-9,561	-13,406	-15,970	-19,193	-20,266	-22,374	-23,457
Surface Area (ac)	83	0	-2	-14	-31	-44	-54	-64	-68	-75	-80
Volume (ac-ft)	630	23	27	-14	-91	-117	-172	-221	-265	-313	-339

Note: Salinity response to dam flow between station 2 and dam is consistent (i.e., flow>0 = 0 salinity at station 2)

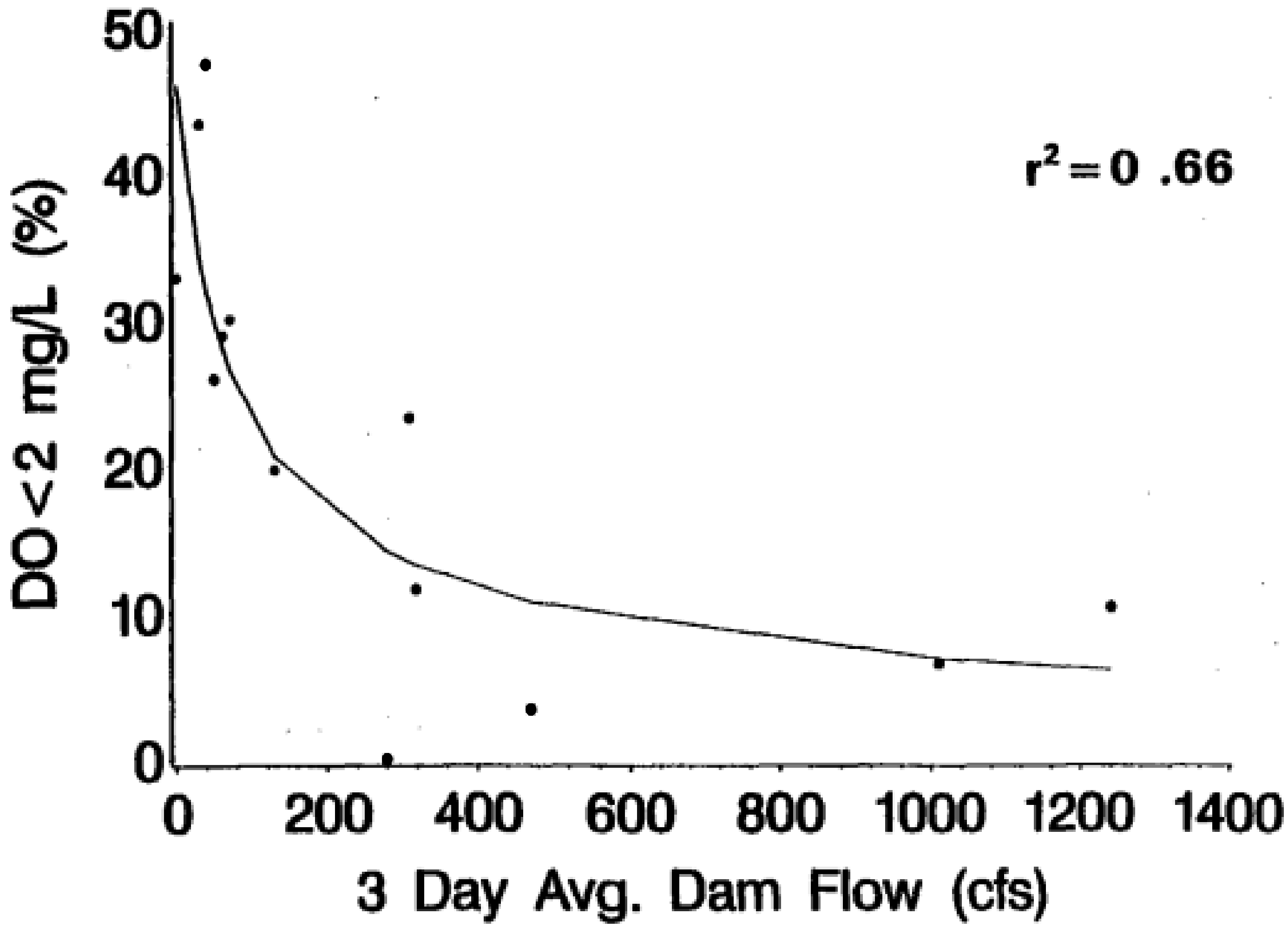
May 21 1997

Mid-Day DO and Flow Model

Observations from 0m, 1m, 2m, 3m, and Bottom

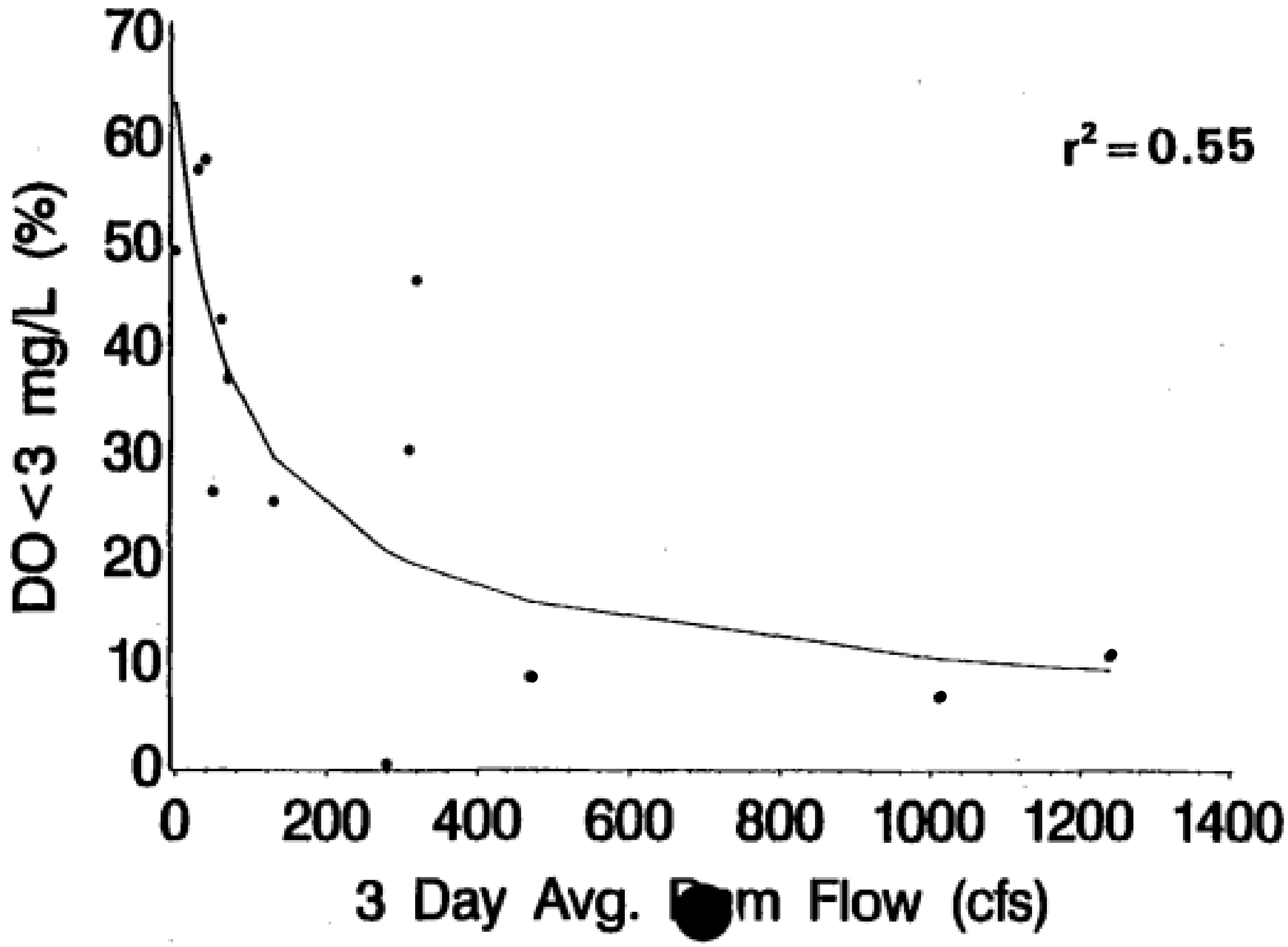


Mid-Day DO and Flow Model
Observations from 0m, 1m, 2m, 3m, and Bottom

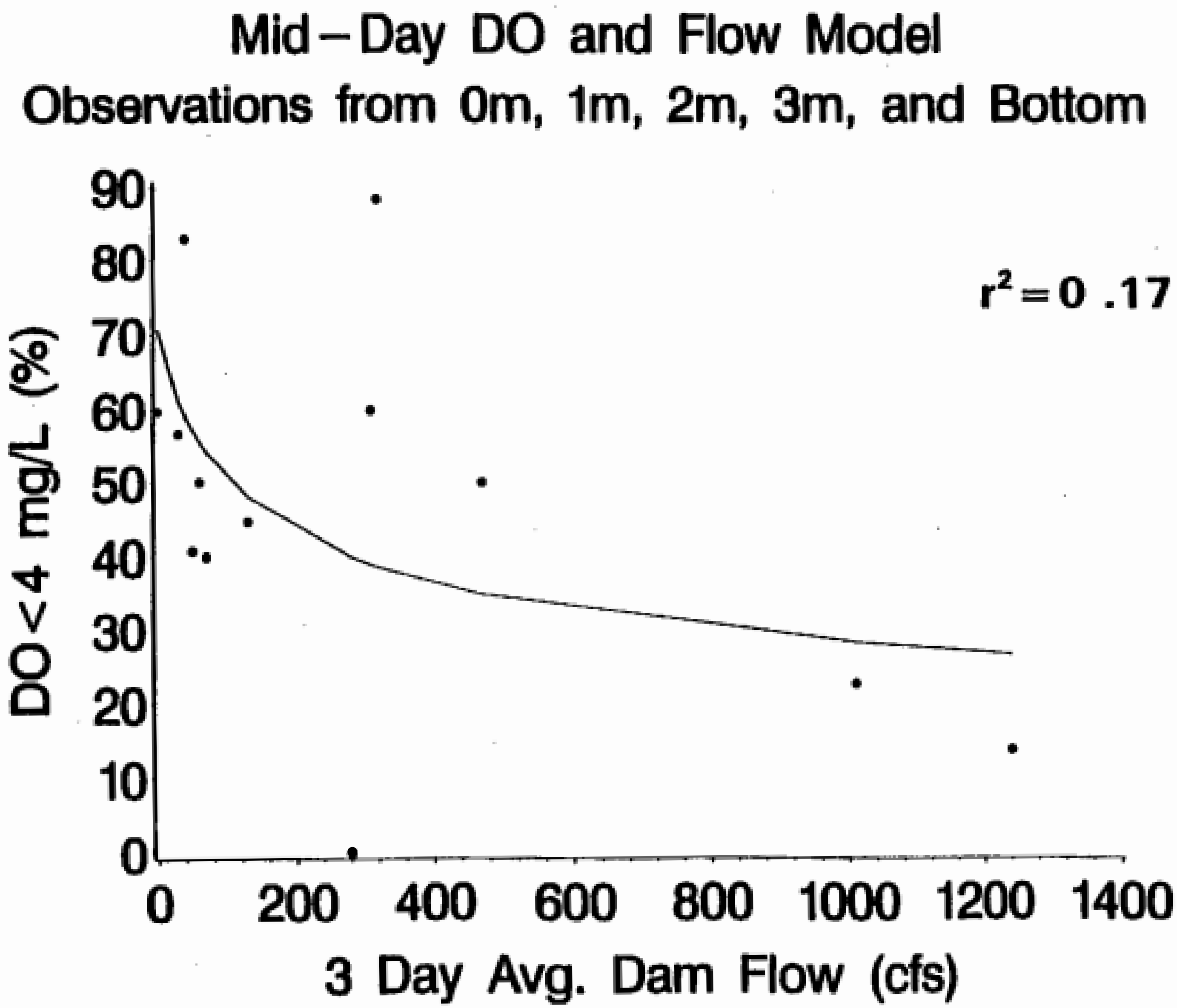


May 21 1997

Mid-Day DO and Flow Model
Observations from 0m, 1m, 2m, 3m, and Bottom



May 21 1997

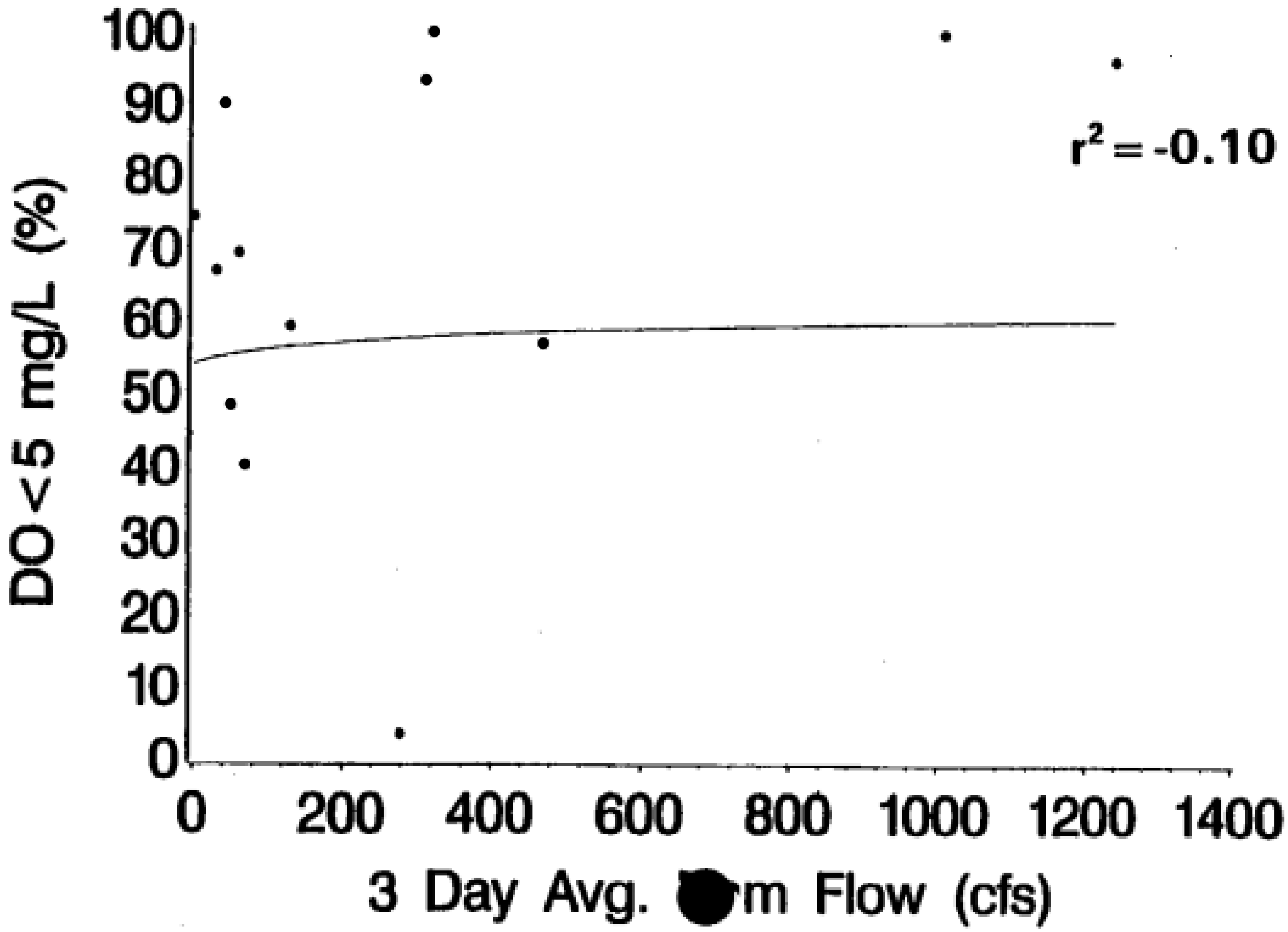


N-2 35

May 21 1997

Mid – Day DO and Flow Model

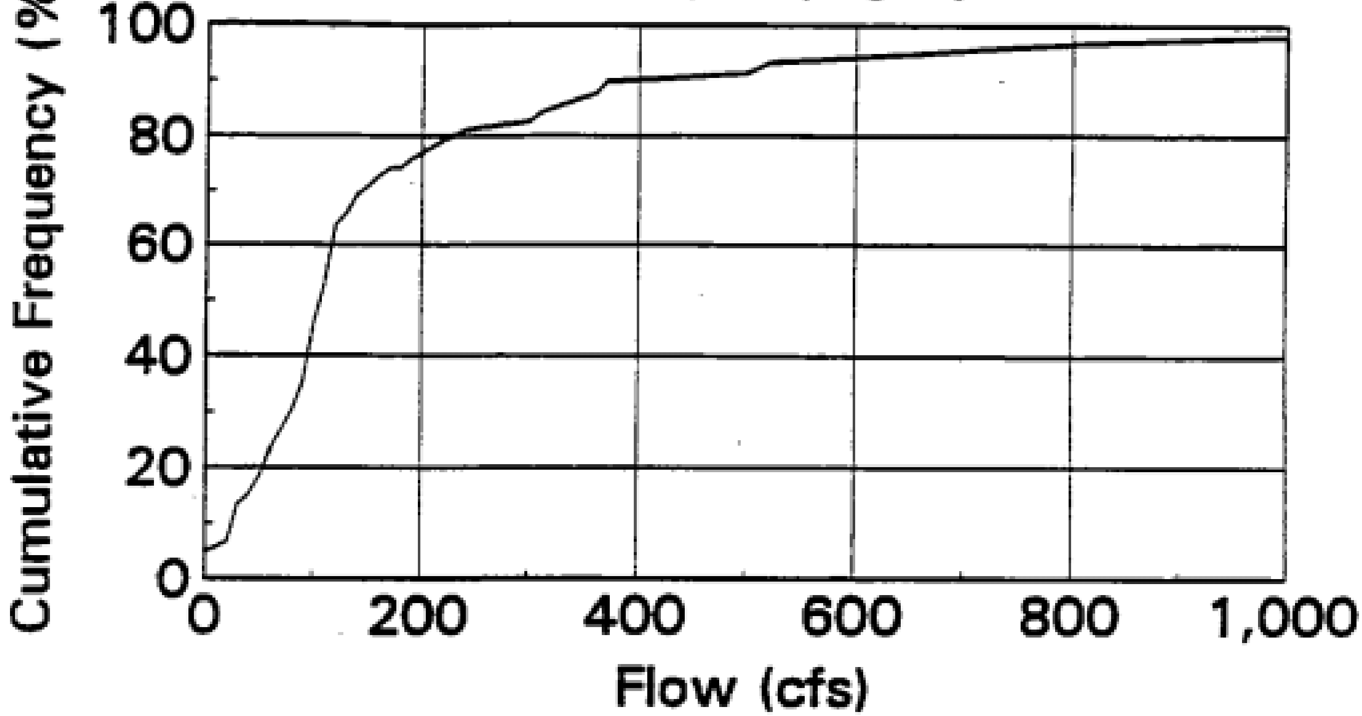
Observations from 0m, 1m, 2m, 3m, and Bottom



May 21, 1997

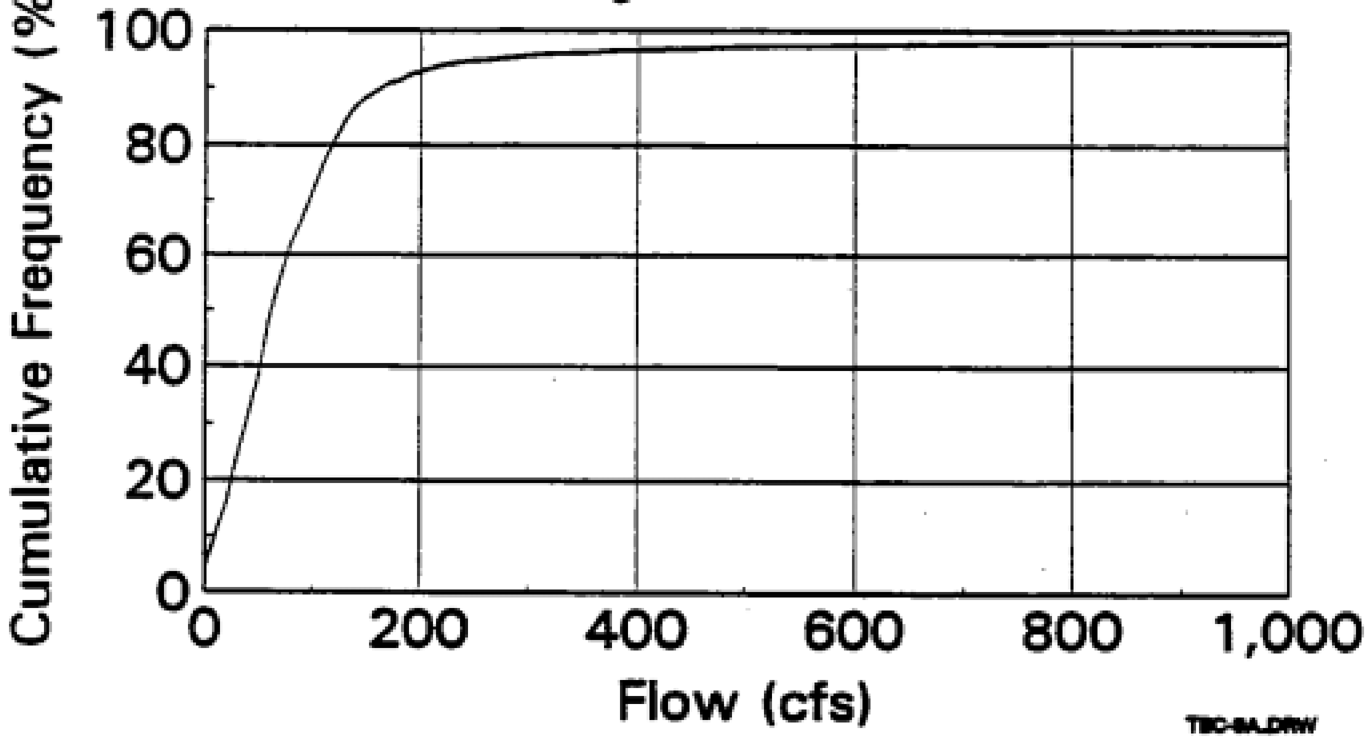
Palm River / Tampa Bypass Canal

Flows on WAR Study Sampling Days

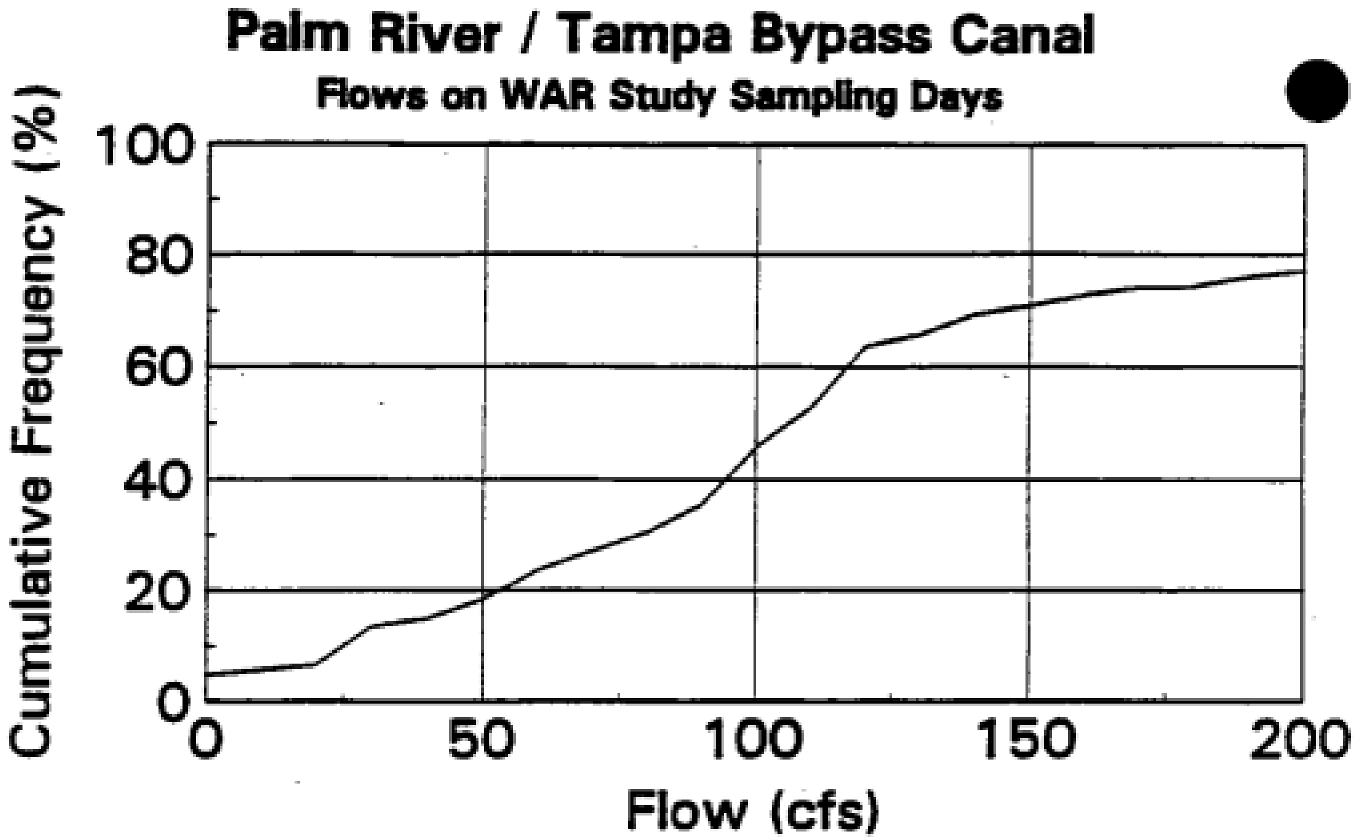


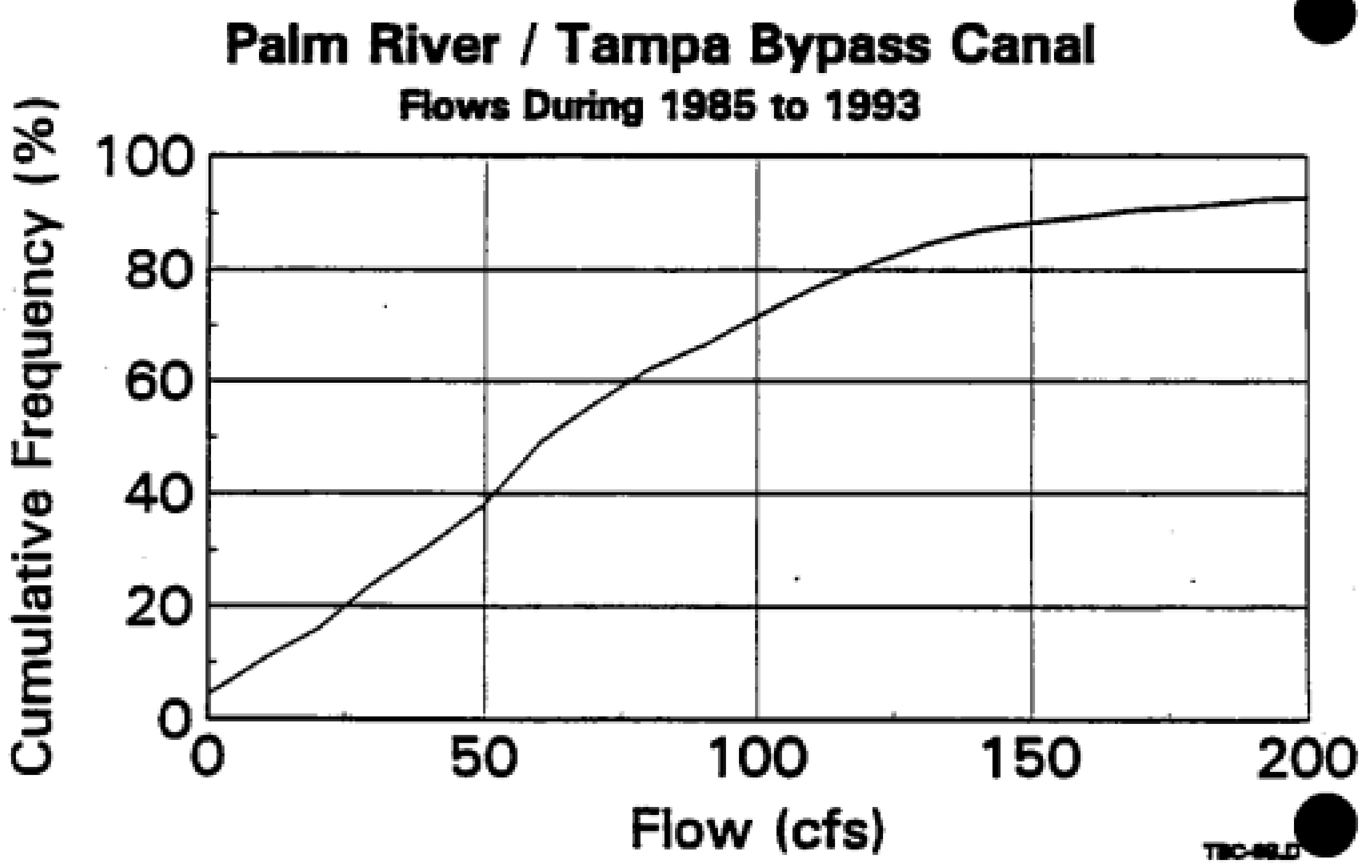
Palm River / Tampa Bypass Canal

Flows During 1985 to 1993



TBC-9A.DRW


Palm River / Tampa Bypass Canal
Flows on WAR Study Sampling Days
Cumulative Frequency (%)
0
20
40
60
80
100
0
50
100
150
200
Flow (cfs)


Palm River / Tampa Bypass Canal
Flows During 1985 to 1993
Cumulative Frequency (%)
0
20
40
60
80
100
0
50
100
150
200
Flow (cfs)

r^2 by Station and Depth

Palm River/Tampa Bypass Canal
Salinity vs. flow

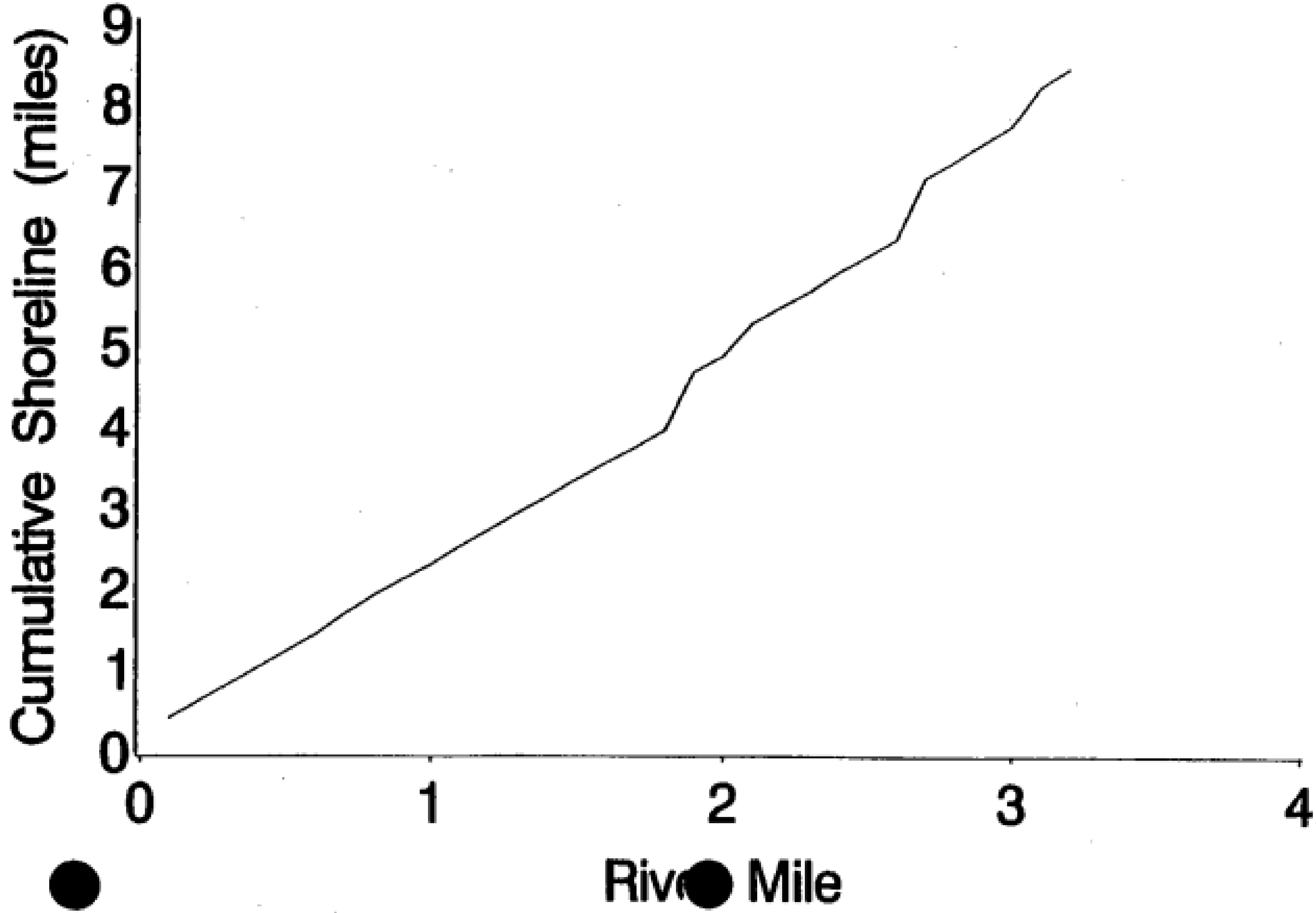
May 21, 1997

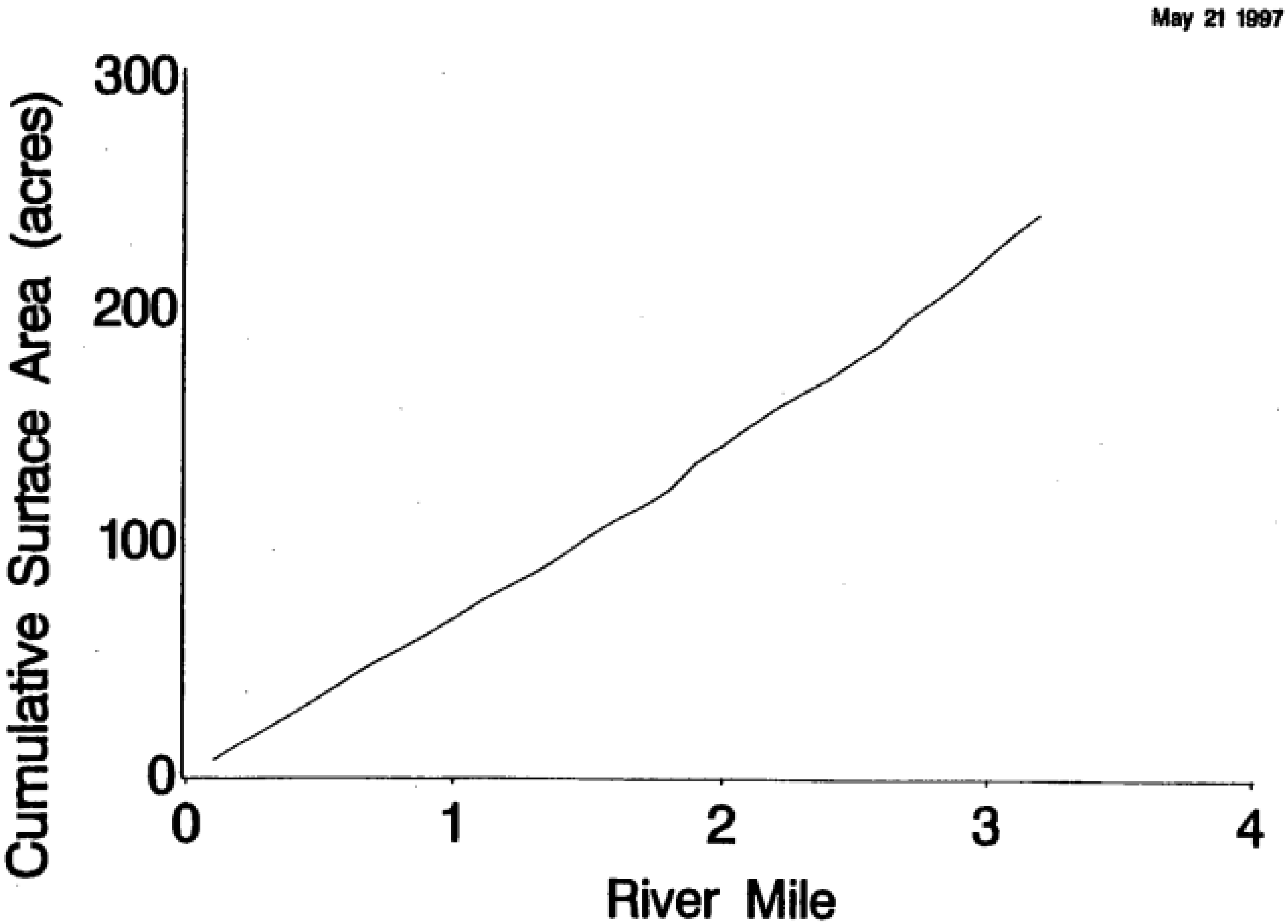
Station	Depth (m)							
	0	**1**	**2**	3	4	5	6	Bottom
12	**0.46**	**0.59**	**0.62**	0.49	0.35	0.12	-	0.12
13	**0.61**	**0.70**	**0.67**	0.51	0.38	0.06	-	0.12
14	**0.74**	**0.72**	**0.60**	0.39	0.31	0.14	0.21	0.20
15	**0.71**	**0.74**	**0.42**	0.29	0.13	0.14	-	0.13

Overall r^2 = 0.69

r2.wpd

May 21 1997




May 21 1997
Cumulative Surface Area (acres)
300
200
100
0
0
1
2
3
4
River Mile

3-5

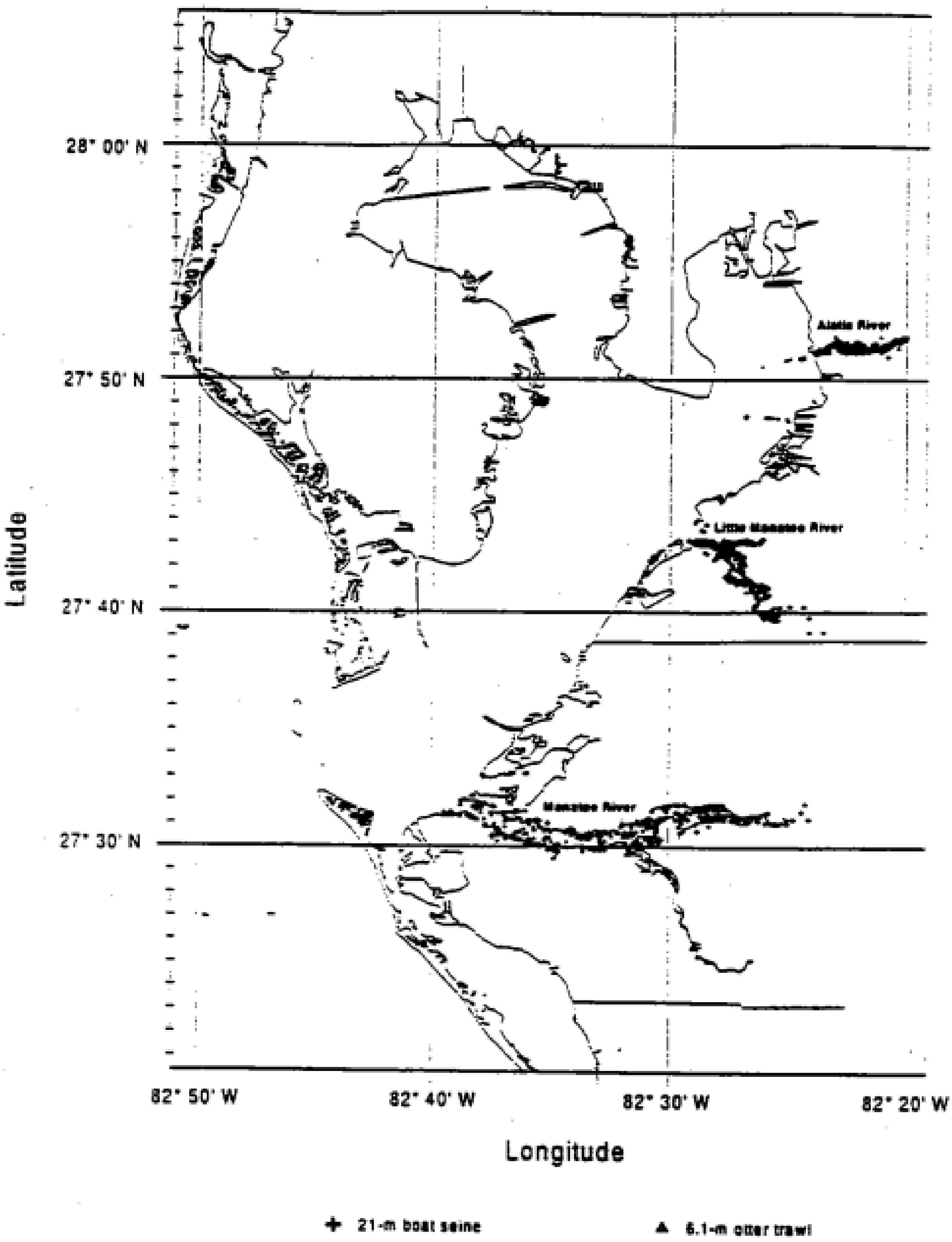
N-2 .41

Palm River / Tampa Bypass Canal
Changes in Habitat Associated With Increased Flow

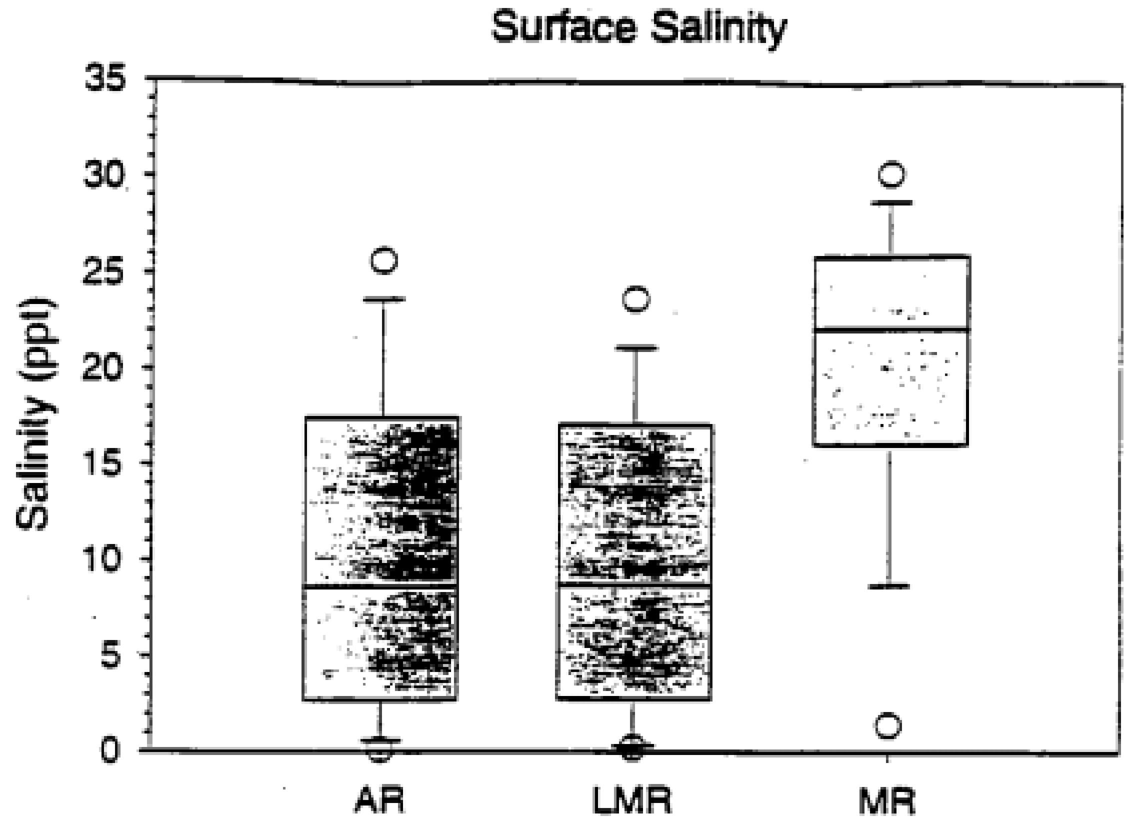
May 21, 1997

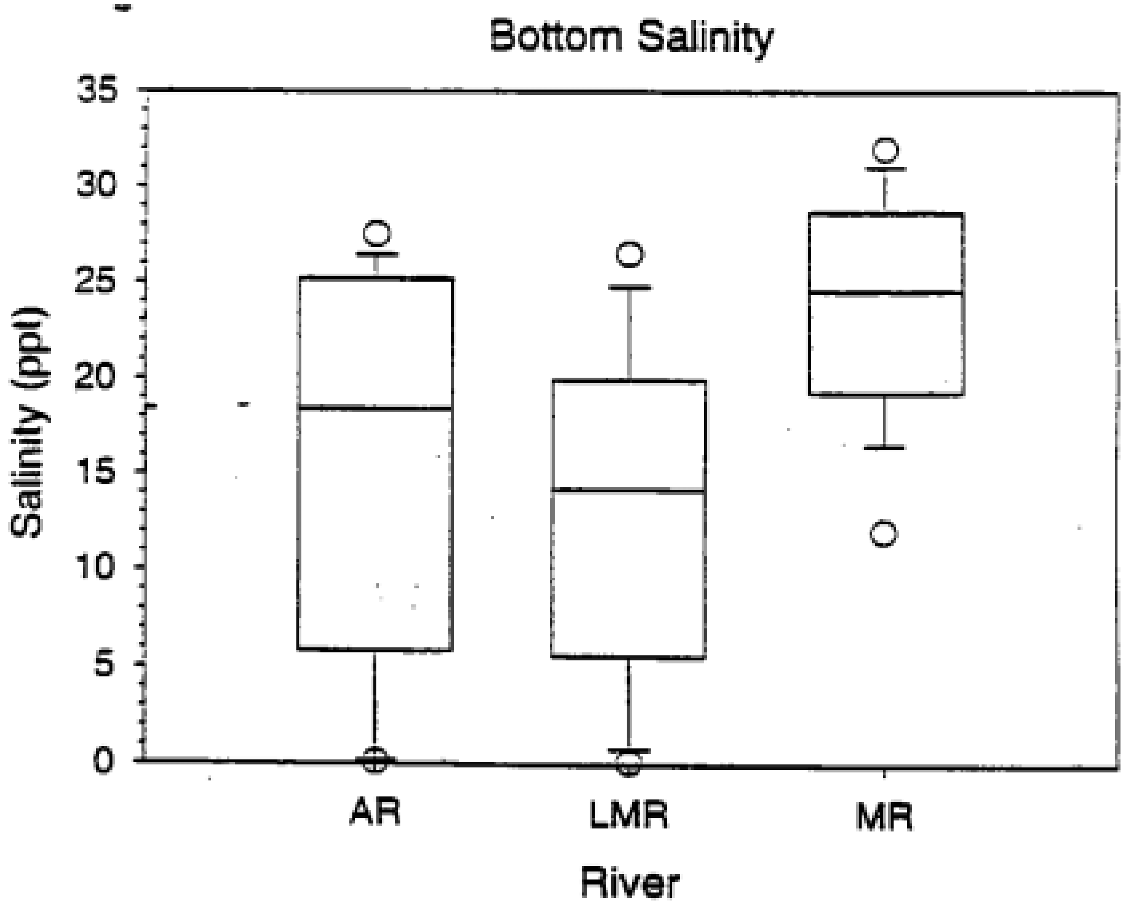
Salinity Range Habitat Type	Baseline Condition (0 Release)	Change from Baseline for 10 cfs Flow Releases						
		10	20	30	40	50	100	200
0-1 ppt (Freshwater)								
Shoreline Length (ft)	0	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Surface Area (ac)	0	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
1-10 ppt								
Shoreline Length (ft)	0	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Surface Area (ac)	0	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
10-20 ppt								
Shoreline Length (ft)	0	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	9,919 (—)	43,508 (—)
Surface Area (ac)	0	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	52 (—)	233 (—)
> 20 ppt								
Shoreline Length (ft)	43,508	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	-9,919 (-22%)	-43,508 (-100%)
Surface Area (ac)	233	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	-52 (-23%)	-233 (-100%)

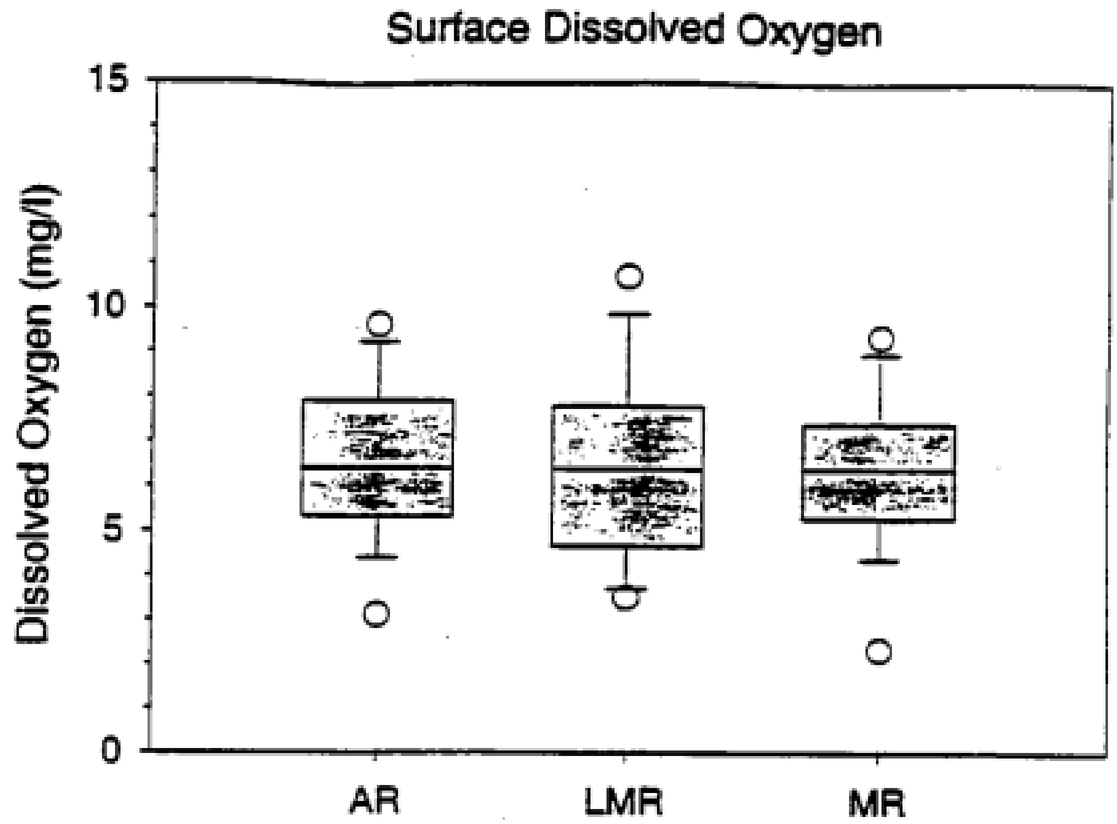
Stratified-Random Sampling sites on the Alafia, Little Manatee and Manatee Rivers, 1994-1996 21-m boat seines and 6.1-m otter trawls only

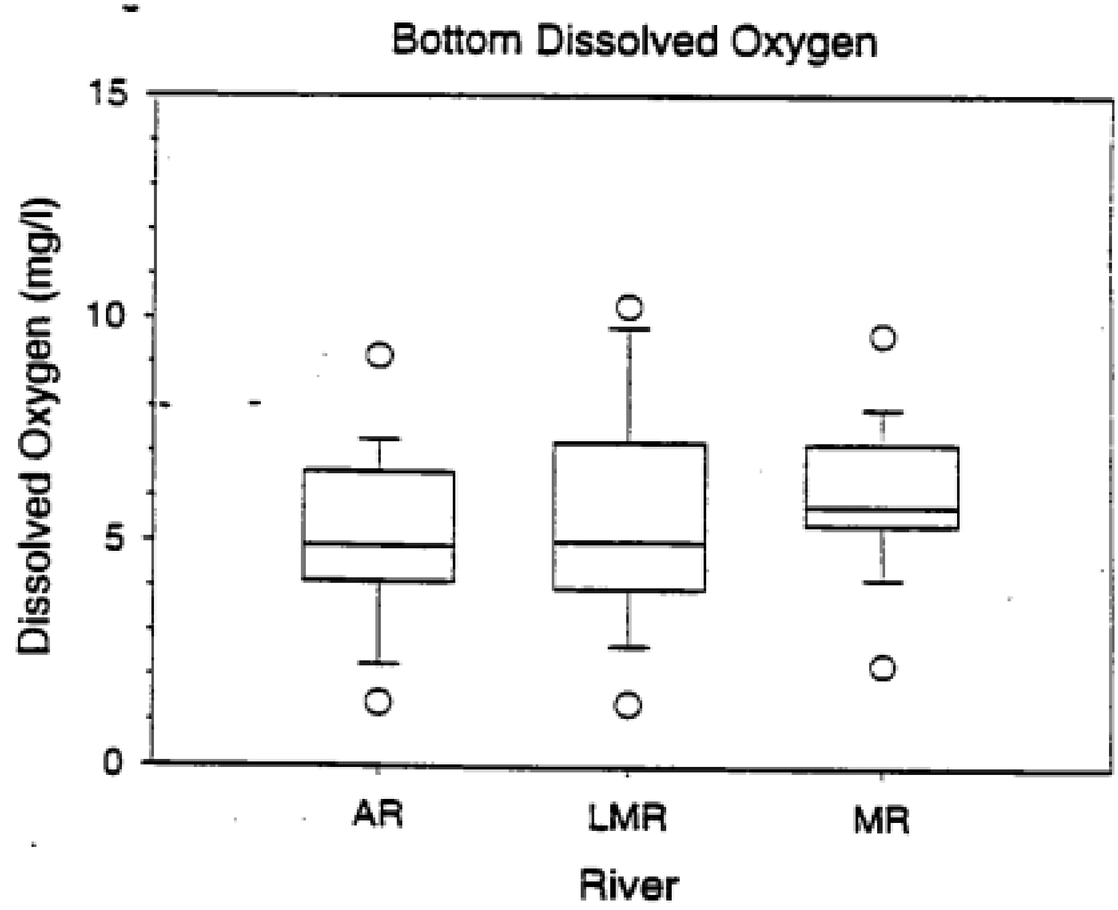


N-2 43


Surface Salinity
Salinity (ppt)
35
30
25
20
15
10
5
0
AR
LMR
MR


Bottom Salinity
Salinity (ppt)
35
30
25
20
15
10
5
0
AR
LMR
MR
River


Surface Dissolved Oxygen
15
10
5
0
Dissolved Oxygen (mg/l)
AR
LMR
MR


Bottom Dissolved Oxygen
15
10
5
0
Dissolved Oxygen (mg/l)
AR
LMR
MR
River

Salinity Classifications

Salinity Range (ppt)	Classification
0.0 - 0.5	Freshwater
0.5 - 5.0	Oligohaline
5.0 - 11.0	Lower Mesohaline
11.0 - 18.0	Upper Mesohaline
>=18.0	Polyhaline

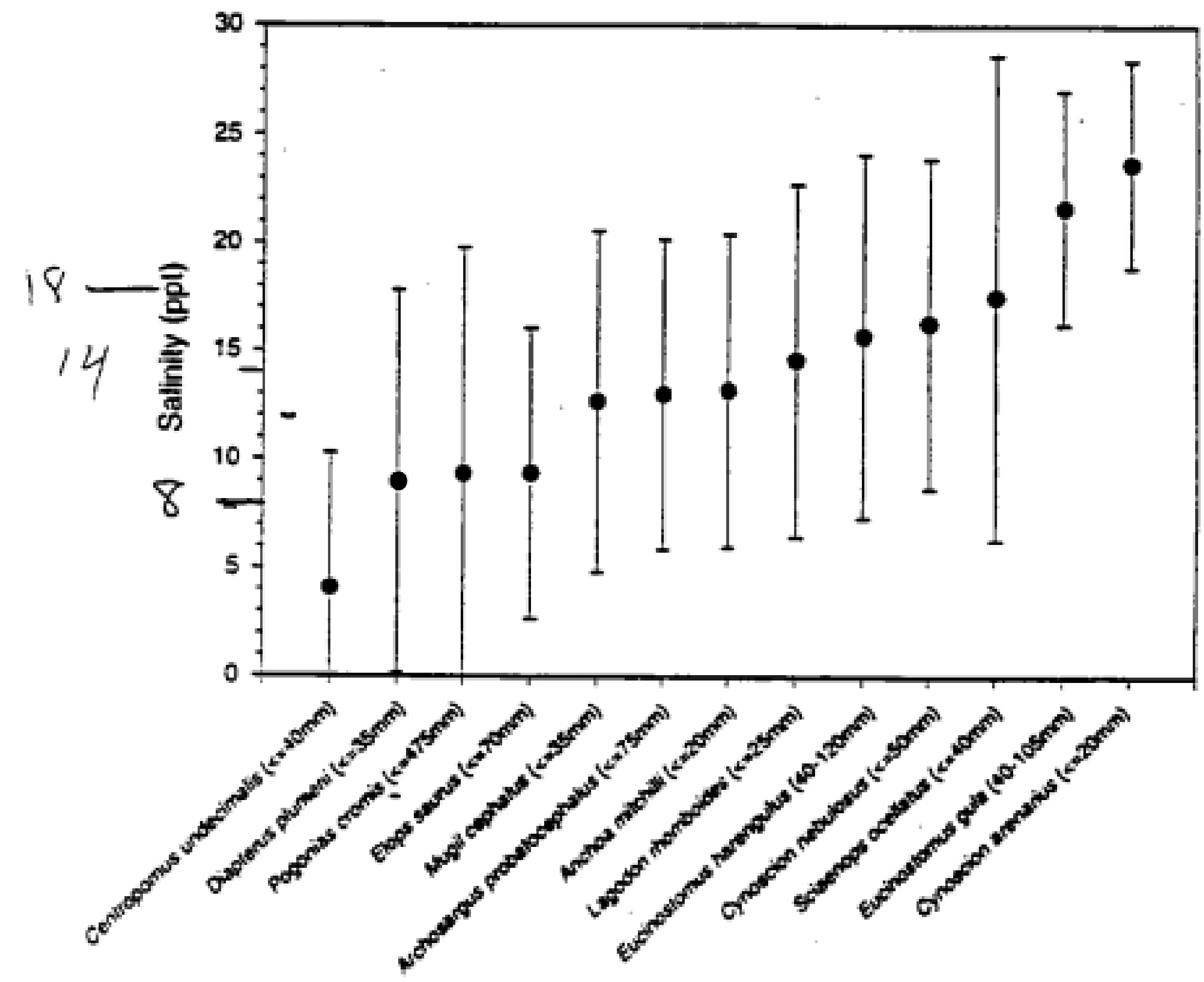
Number of samples collected by salinity classification and gear

	21-m Seines				6.1-m Otter Trawls			
	AR	LMR	MR	Total	AR	LMR	MR	Total
Freshwater	11	29	11	51	10	8	0	18
Oligohaline	46	43	5	94	5	14	2	21
Lower Mesohaline	35	25	17	77	6	15	2	23
Upper Mesohaline	29	34	28	91	12	25	19	56
Polyhaline	31	29	115	175	29	31	86	146
Total	**152**	**160**	**176**	**488**	**62**	**93**	**109**	**264**

Density-Weighted Mean Salinities for species collected in ten or more samples. Species are s[illegible] in order from lowest mean salinity to highest mean salinity.

Species	Lengths Analyzed (mm)	Density-Weighted Salinity Mean	Density-Weighted Salinity Std
Labidesthes sicculus	<= 65	0.11	0.12
Notropis petersoni	<= 55	0.22	0.15
Lepomis macrochirus	<= 165	0.68	1.07
Micropterus salmoides	<= 205	0.99	1.43
Fundulus seminolis	<= 105	1.36	1.92
Opisthonema oglinum	<= 160	1.66	5.95
Gambusia holbrooki	<= 45	1.89	3.29
Heterandria formosa	<= 30	2.60	5.83
Trinectes maculatus	<= 25	3.30	6.27
Centropomus undecimalis	<= 40	4.05	6.24
Diapterus plumieri	<= 35	8.97	8.84
Pogonias cromis	<= 475	9.32	10.45
Elops saurus	<= 70	9.34	6.70
Membras martinica	<= 55	9.73	8.55
Gobiosoma spp.	<= 50	9.77	8.90
Tilapia spp.	<= 295	10.04	6.88
Lepisosteus osseus	<= 1155	10.43	8.39
Lucania parva	<= 50	11.05	12.34
Poecilia latipinna	<= 75	11.95	12.74
Fundulus grandis	<= 105	12.03	7.12
Archosargus probatocephalus	<= 75	12.65	7.86
Brevoortia spp.	<= 35	12.97	5.44
Mugil cephalus	<= 35	12.98	7.14
Anchoa mitchilli	<= 20	13.14	7.21
Microgobius gulosus	<= 75	13.26	8.43
Menidia spp.	<= 110	13.86	9.37
Eucinostomus spp.	<= 75	13.87	7.99
Lagodon rhomboides	<= 25	14.53	8.14
Cyprinodon variegatus	<= 55	14.77	8.12
Callinectes sapidus	<= 30	14.92	8.13
Floridichthys carpio	<= 65	15.47	7.83
Eucinostomus harengulus	40-120	15.64	8.37
Cynoscion nebulosus	<= 50	16.22	7.61
Mugil gyrans	<= 170	16.67	4.19
Syngnathus scovelli	<= 115	16.77	9.62
Arius felis	<= 365	17.10	7.71
Sciaenops ocellatus	<= 40	17.43	11.19
Bathygobius soporator	<= 75	17.89	6.65
Oligoplites saurus	<= 100	18.19	6.68
Penaeus duorarum	<= 45	18.52	7.09
Symphurus plagiusa	<= 70	18.60	8.78
Bairdiella chrysoura	<= 30	19.08	5.86
Bagre marinus	<= 515	19.26	7.23
Harengula jaguana	<= 115	19.53	6.12
Strongylura timucu	<= 425	19.65	6.35
Fundulus majalis	<= 100	19.72	6.93
Gobiesox strumosus	<= 40	19.74	5.61
Chasmodes saburrae	<= 60	19.97	4.44
Lutjanus griseus	<= 215	20.12	7.70
Strongylura marina	<= 420	20.16	5.30
Achirus lineatus	<= 40	20.92	7.28
Gymnura micrura	<= 480	21.20	10.07
Microgobius thalassinus	<= 65	21.53	5.92
Eucinostomus gula	40-105	21.58	5.41
Strongylura notata	<= 380	21.95	5.03
Leiostomus xanthurus	<= 30	22.11	[illegible]
Dasyatis sabina	<= 365	22.33	[illegible]
Opsanus beta	<= 245	22.45	[illegible]
Orthopristis chrysoptera	<= 35	22.67	3.87
Syngnathus louisianae	<= 265	23.14	7.05
Prionotus tribulus	<= 95	23.21	7.13
Chaetodipterus faber	<= 50	23.23	6.09
Anchoa hepsetus	<= 30	23.50	4.43
Menticirrhus saxatilis	<= 190	23.56	5.86
Cynoscion arenarius	<= 20	23.59	4.80
Synodus foetens	<= 75	23.86	3.39
Sphoeroides nephelus	<= 30	24.12	3.80
Prionotus scitulus	<= 55	24.31	6.06
Menticirrhus americanus	<= 25	24.44	3.94
Paralichthys albigutta	<= 310	25.71	3.68
Chilomycterus schoepfi	<= 225	27.86	3.75

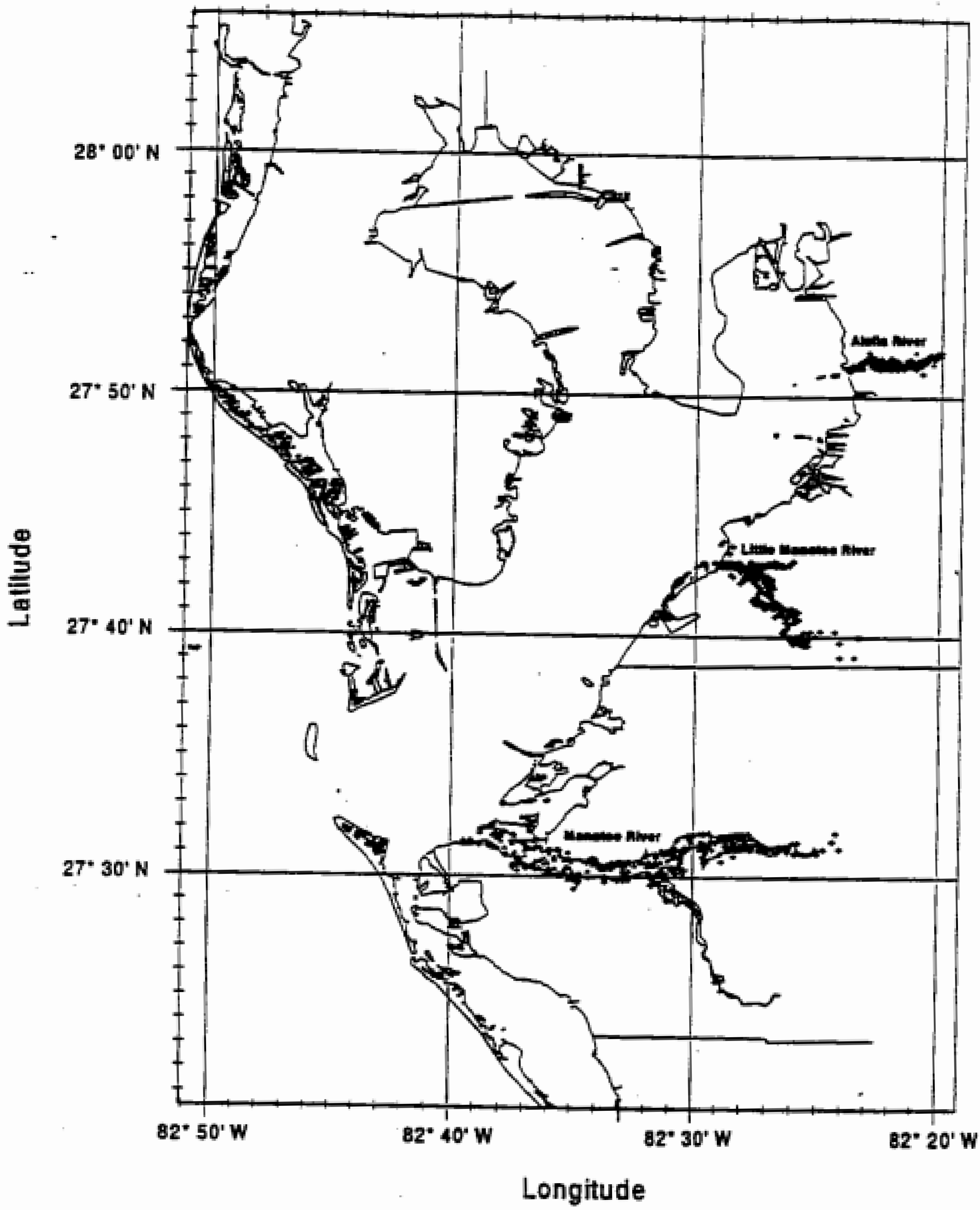
Density-Weighted Salinities



APPENDIX N-4

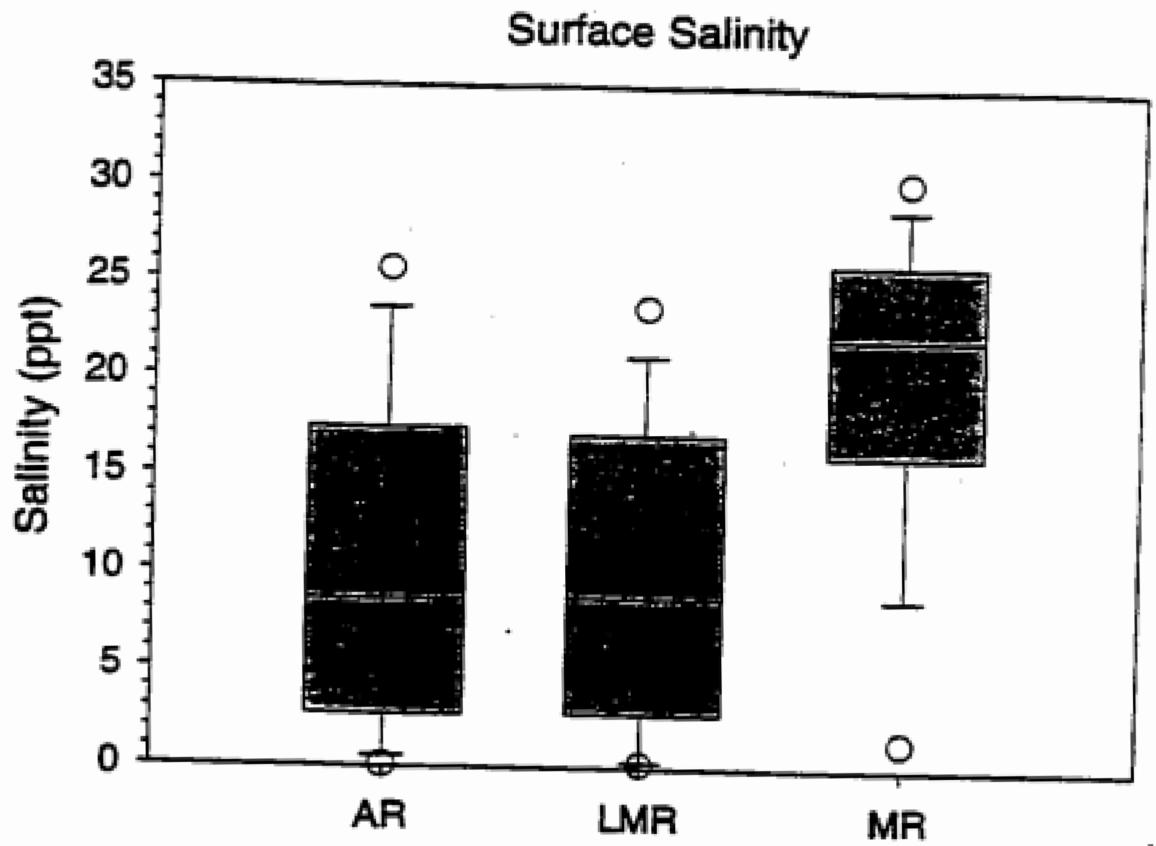
Results of analyses of fish catch data conducted by the Florida Department of Environmental Protection Florida Marine Research Institute.

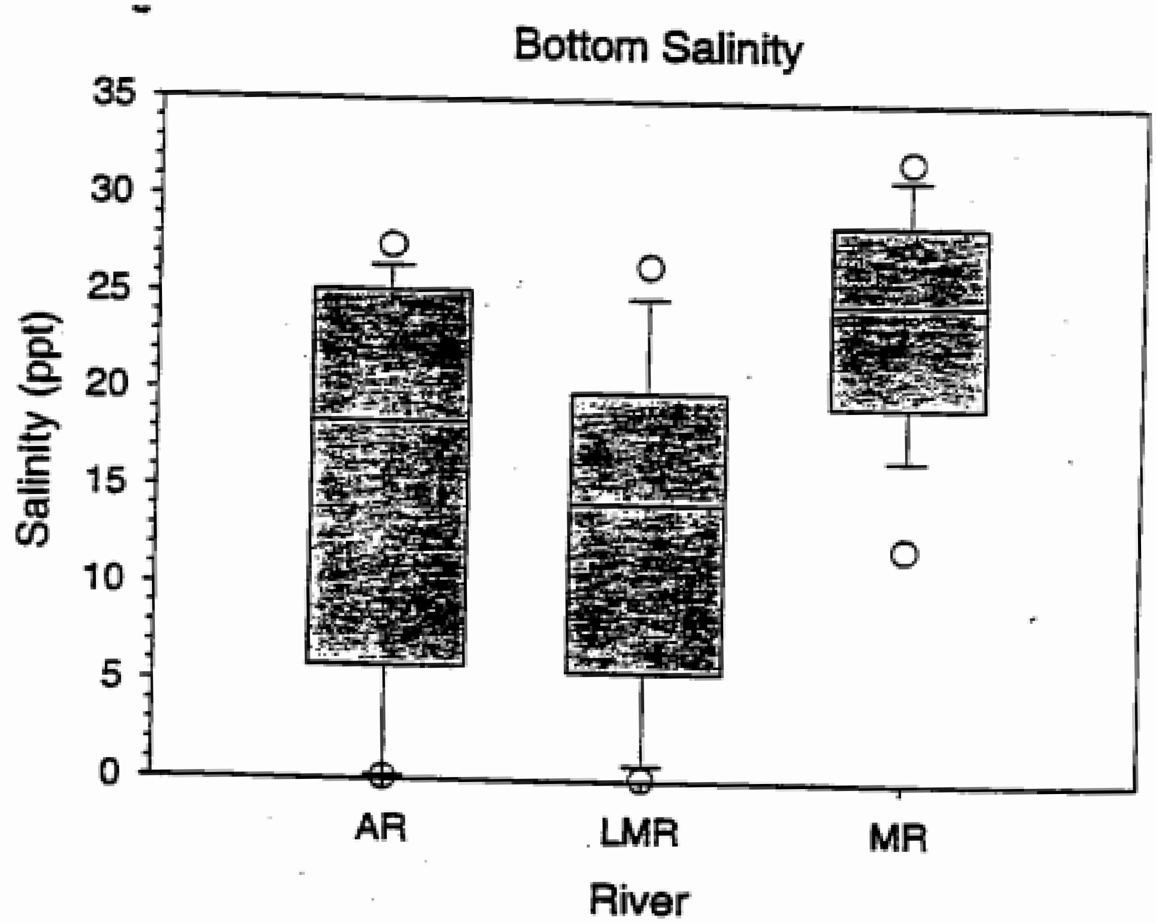
Alafia, Little Manatee and Manatee Rivers, 1994-1996
21-m boat seines and 6.1-m otter trawls only

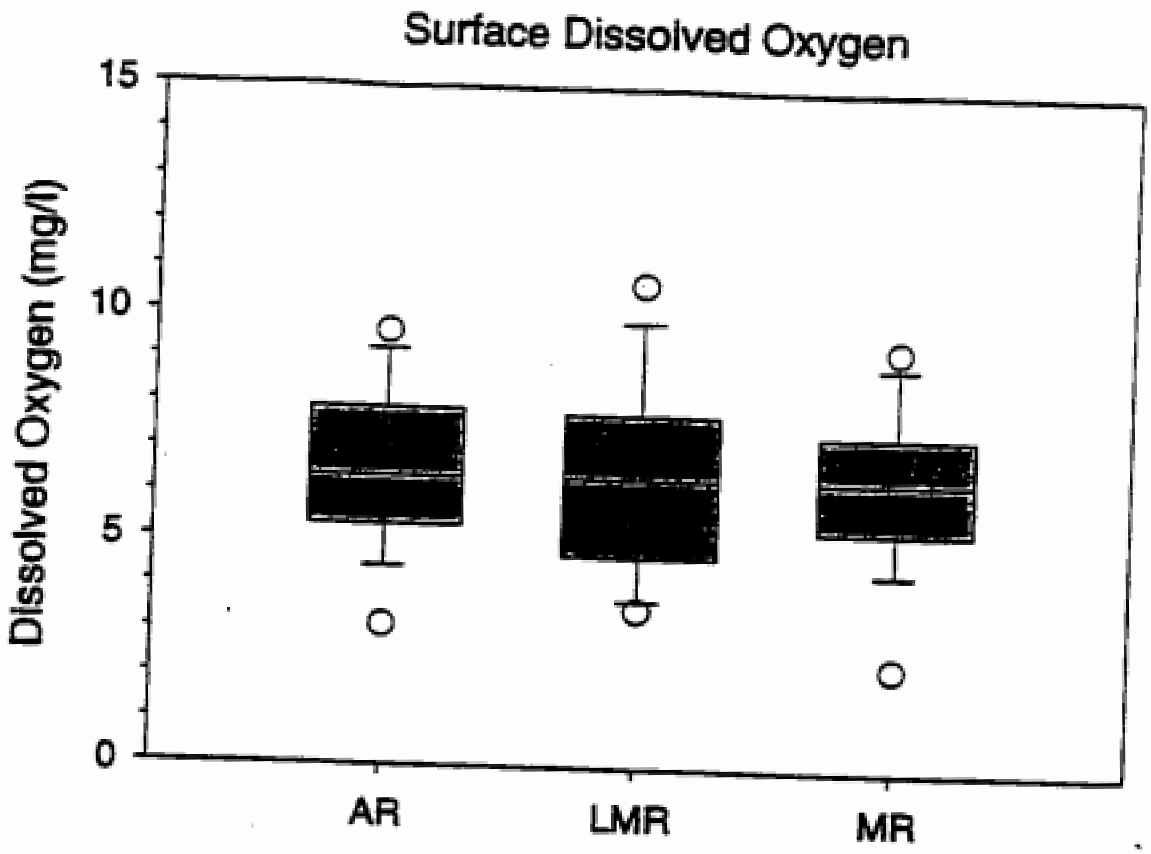


+ 21-m boat seine   ▲ 6.1-m otter trawl

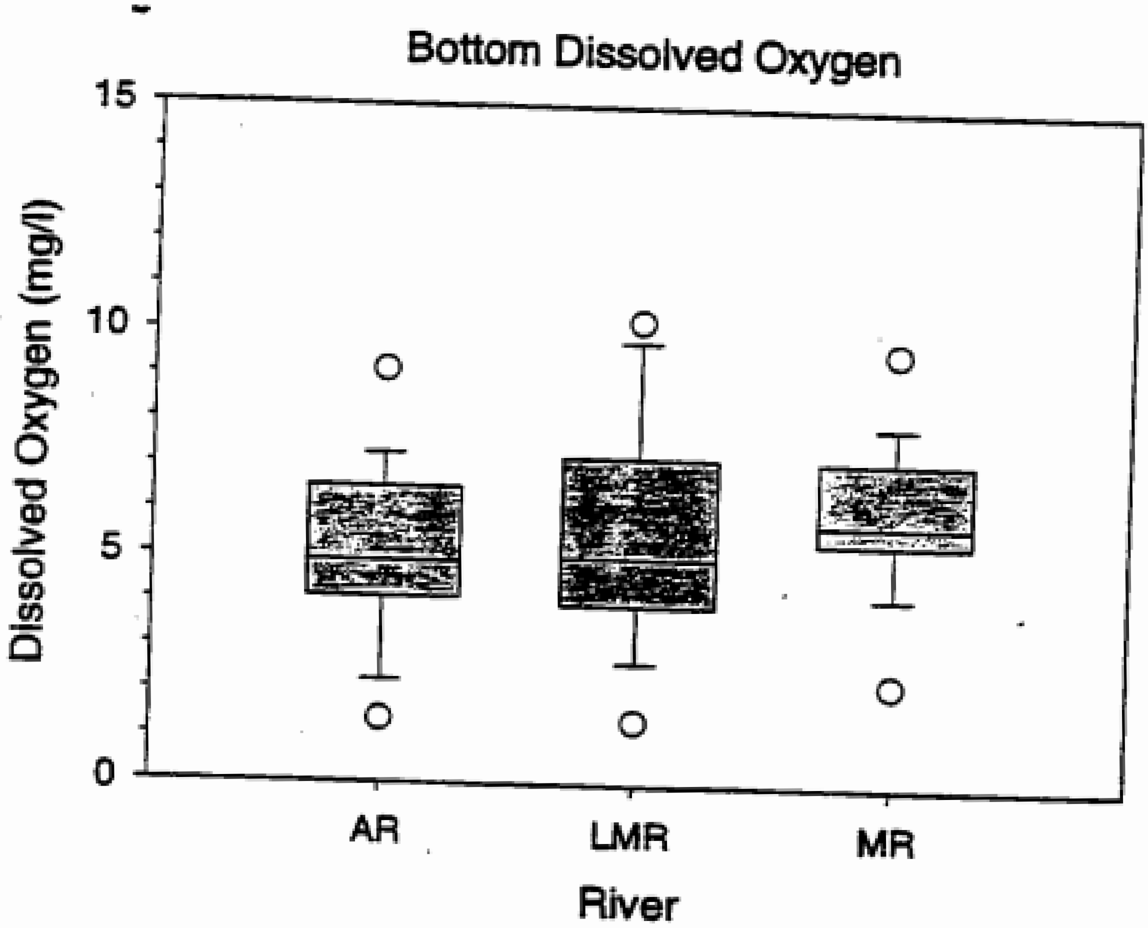
N-4 1


Surface Salinity
Salinity (ppt)
35
30
25
20
15
10
5
0
AR
LMR
MR

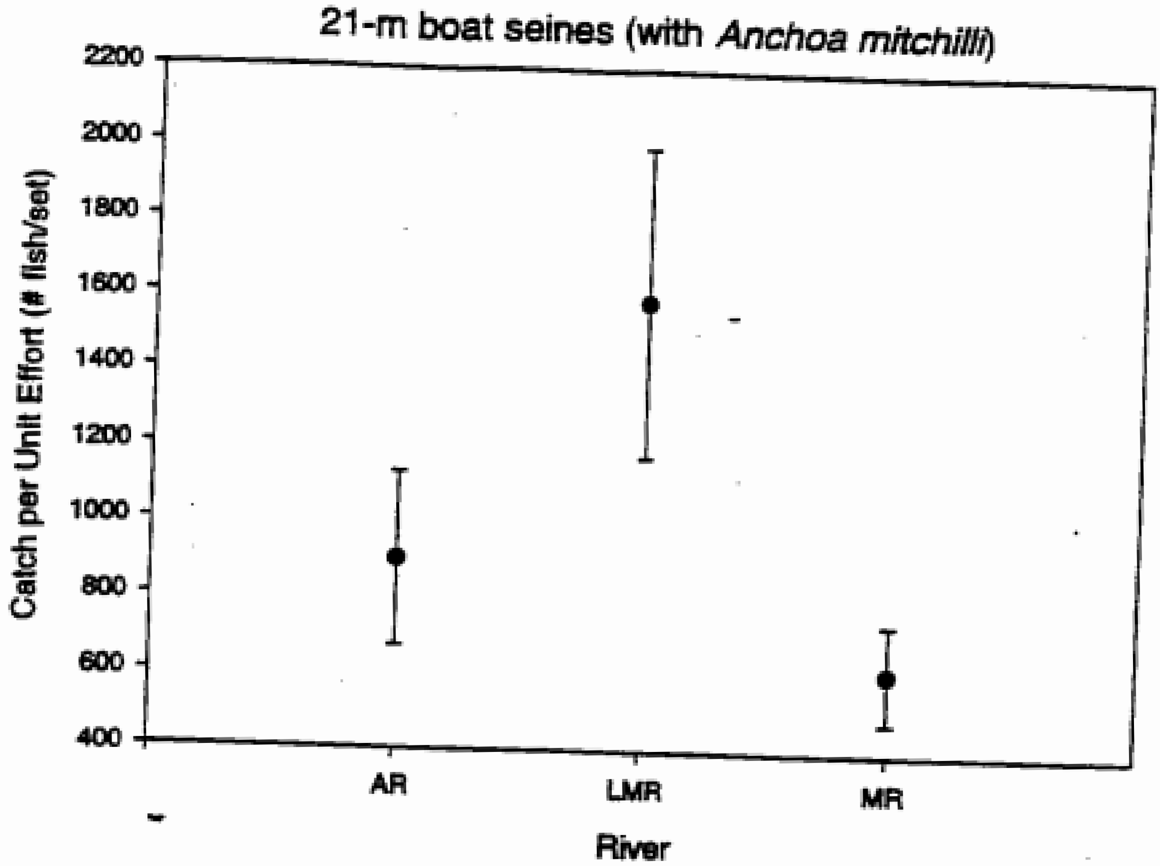

Bottom Salinity
Salinity (ppt)
35
30
25
20
15
10
5
0
AR
LMR
MR
River

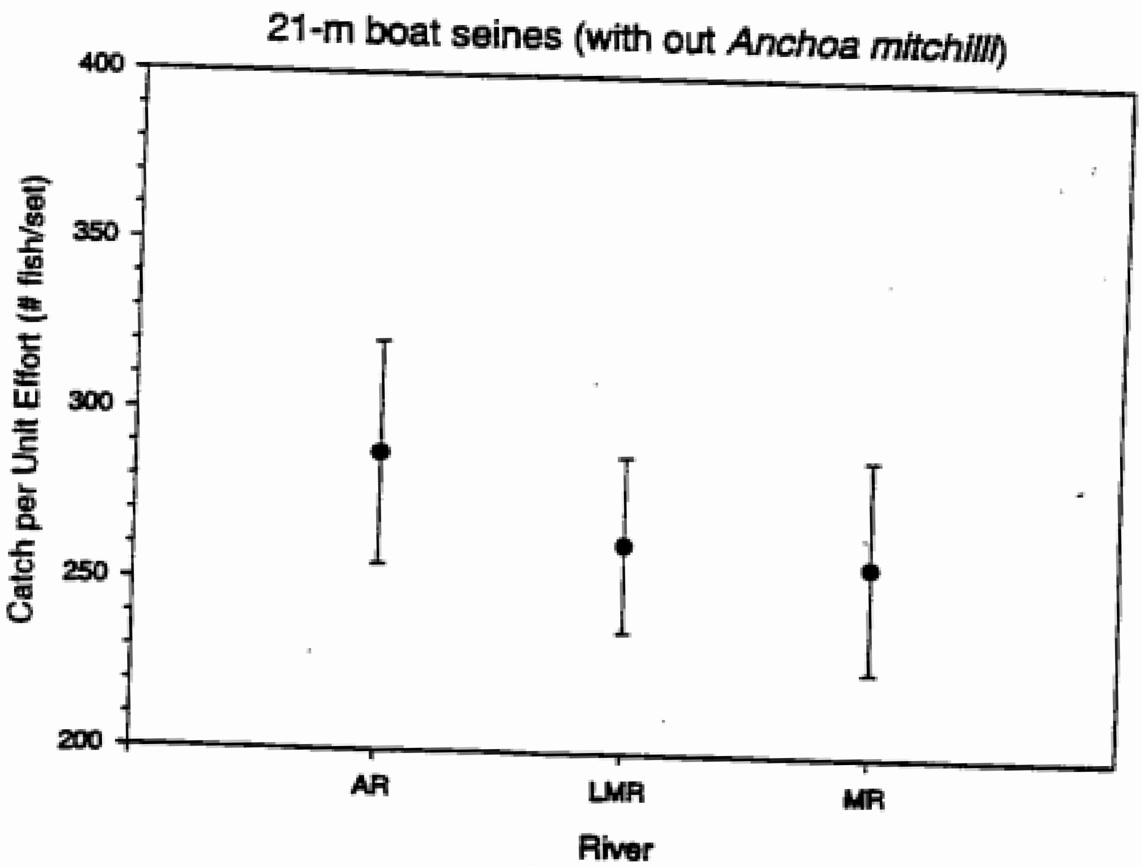


Surface Dissolved Oxygen
15
10
5
0
Dissolved Oxygen (mg/l)
AR
LMR
MR

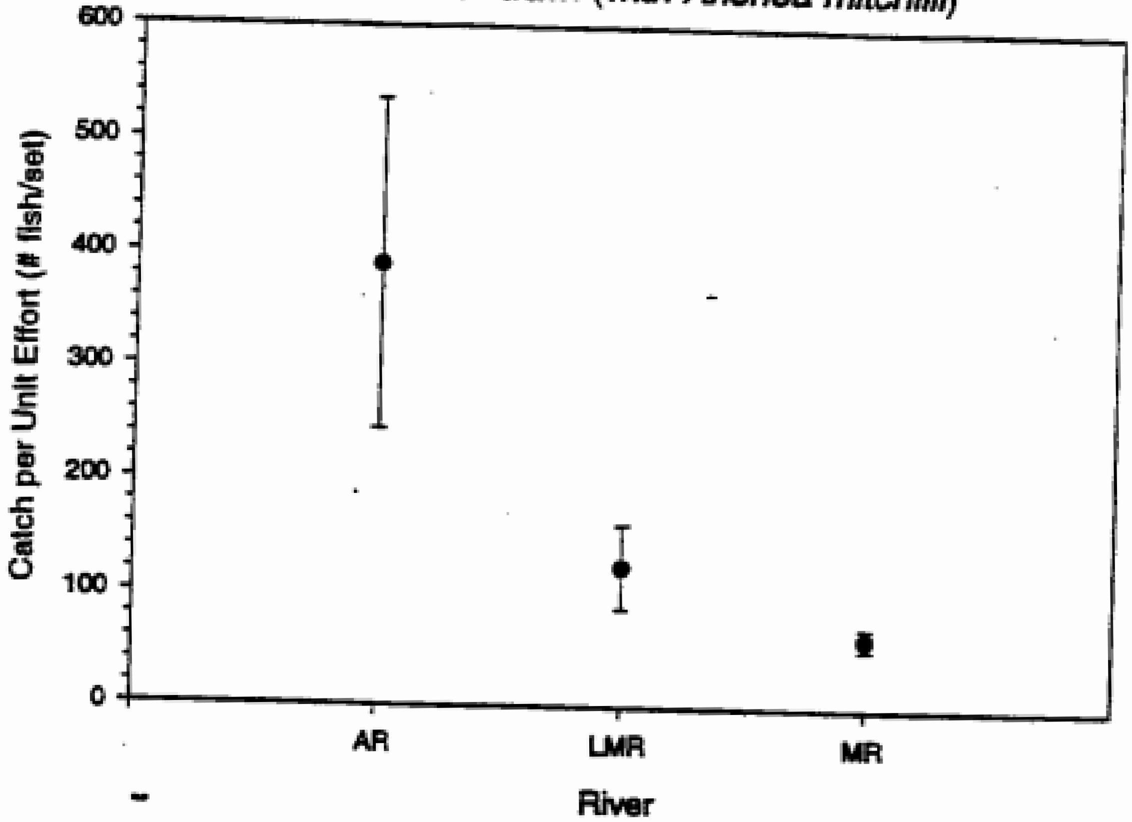


Bottom Dissolved Oxygen
15
10
5
0
Dissolved Oxygen (mg/l)
AR
LMR
MR
River

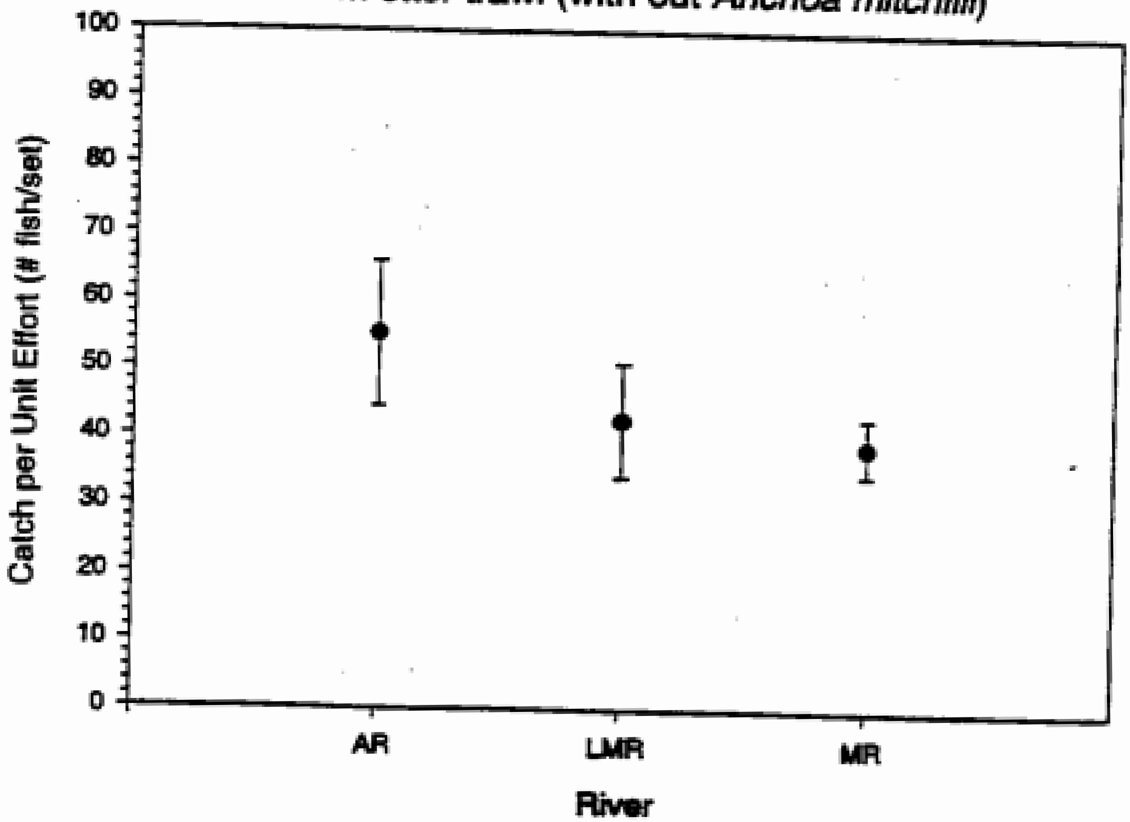

21-m boat seines (with *Anchoa mitchilli*)
2200
2000
1800
1600
1400
1200
1000
800
600
400
Catch per Unit Effort (# fish/set)
AR
LMR
MR
River


21-m boat seines (with out *Anchoa mitchilli*)
400
350
300
250
200
Catch per Unit Effort (# fish/set)
AR
LMR
MR
River

6.1-m otter trawl (with *Anchoa mitchilli*)



6.1-m otter trawl (with out *Anchoa mitchilli*)



Percent Similiarity among the three river systems. AR=Alafia Riv
LMR=Little Manatee River, MR=Manatee River

	AR	**LMR**	**MR**
AR	.	.	.
LMR	83.45	.	.
MR	82.60	71.65	.

Salinity Classifications

Salinity Range (ppt)	Classification
0.0 - 0.5	Freshwater
0.5 - 5.0	Oligohaline
5.0 - 11.0	Lower Mesohaline
11.0 - 18.0	Upper Mesohaline
>=18.0	Polyhaline

Number of samples collected by salinity classification and gear

	21-m Seines				6.1-m Otter Trawls			
	AR	LMR	MR	Total	AR	LMR	MR	Total
Freshwater	11	29	11	51	10	8	0	18
Oligohaline	46	43	5	94	5	14	2	21
Lower Mesohaline	35	25	17	77	6	15	2	23
Upper Mesohaline	29	34	28	91	12	25	19	56
Polyhaline	31	29	115	175	29	31	86	146
Total	**152**	**160**	**176**	**488**	**62**	**93**	**109**	**264**

Table 1. Table listing the mean catch per unit effort (# animals/set) and standard error, by salinity classification for each species collected by 21-m boat set seines during stratified-random sampling in the Alafia, Little Manatee and Manatee Rivers between 1994 and 1996. Salinity classifications are defined as freshwater (0-0.5 ppt), oligohaline (0.5-5 ppt), lower mesohaline (5-11 ppt), upper mesohaline (11-18ppt), polyhaline (>18ppt). The number in parentheses after the salinity classification indicates the number of samples taken within that classification. Shaded species represent species that are of direct commercial and/or recreational importance.

		Freshwater (51)		Oligohaline (94)		Lower Mesohaline (77)		Upper Mesohaline (91)		Polyhaline (176)	
Species	Number	Mean	Stderr	Mean	Stderr	Mean	Stderr	Mean	Stderr	Mean	Stderr
Anchoa mitchilli	371,293	38.25	19.98	116.94	36.57	840.52	306.77	1989.13	716.67	643.54	202.50
Menidia spp.	66,321	113.02	23.94	134.19	30.12	147.77	25.40	102.23	19.09	155.76	27.73
Eucinostomus spp.	8,605	3.94	1.10	17.14	4.93	22.84	8.92	22.20	5.86	17.22	3.70
Lucania parva	6,211	11.84	2.77	30.51	11.19	11.84	4.82	2.03	0.51	9.38	8.16
Gambusia holbrooki	5,723	72.90	24.97	16.11	6.49	4.70	1.86	0.29	0.15	0.59	0.40
Lagodon rhomboides	4,809	0.49	0.18	5.15	1.78	9.78	4.20	11.69	2.16	14.19	2.66
Fundulus majalis	4,387	0.73	0.39	1.69	1.37	4.45	2.03	11.74	6.22	15.69	5.50
Eucinostomus harengulus	4,338	3.08	1.00	6.77	2.24	8.35	3.27	9.63	1.67	11.58	1.80
Trinectes maculatus	2,584	21.76	5.21	8.26	2.07	1.70	0.37	0.86	0.25	2.79	1.13
Sciaenops ocellatus	2,501	1.14	0.74	5.05	1.13	6.39	3.56	4.13	0.99	6.41	3.21
Poecilia latipinna	2,442	17.10	6.52	3.15	1.09	4.06	2.78	1.66	1.07	4.62	3.35
Leiostomus xanthurus	2,137	.	.	7.01	5.81	1.29	0.57	4.13	1.28	5.73	1.61
Bairdiella chrysoura	2,060	0.04	0.03	1.01	0.58	9.55	5.33	7.77	3.40	2.98	1.10
Harengula jaguana	1,636	0.06	0.06	0.10	0.07	4.22	2.98	1.27	0.69	6.75	3.00
Mugil cephalus	1,473	1.16	0.82	1.01	0.98	3.81	2.67	6.53	4.62	2.46	0.82
Eucinostomus gula	1,372	0.04	0.04	0.16	0.12	1.12	0.73	3.37	1.16	5.50	1.09
Fundulus seminolis	1,331	11.80	4.34	7.27	2.53	0.66	0.65	0.01	0.01	0.02	0.01
Cyprinodon variegatus	1,193	0.20	0.13	0.07	0.04	4.42	3.39	6.01	4.93	1.65	1.02
Microgobius gulosus	1,143	2.10	0.60	1.67	0.35	3.13	1.26	2.30	0.75	2.45	0.66
Fundulus grandis	961	1.04	0.81	1.17	0.44	3.32	1.22	3.60	1.50	1.12	0.29
Gobiosoma spp.	911	5.25	1.32	1.18	0.31	2.47	0.76	1.26	0.26	1.30	0.33
Diapterus plumieri	834	3.02	1.42	1.79	0.35	2.61	0.65	1.41	0.52	1.05	0.36
Floridichthys carpio	825	.	.	0.01	0.01	6.13	4.10	0.64	0.39	1.68	0.71
Menticirrhus americanus	761	.	.	0.02	0.02	0.03	0.02	0.21	0.09	4.16	2.35
Penaeus duorarum	671	.	.	0.66	0.26	1.44	0.47	0.95	0.21	2.35	0.51
Notropis petersoni	451	6.69	6.23	0.09	0.09	.	.	.	.	.	.
Labidesthes sicculus	413	6.00	3.70	0.05	0.05	.	.	.	.	.	.
Brevoortia spp.	395	.	.	1.91	1.87	0.04	0.03	1.77	1.54	0.29	0.10

(Continued)

Species	Number	Freshwater (51) Mean	Freshwater (51) Stderr	Oligohaline (94) Mean	Oligohaline (94) Stderr	Lower Mesohaline (77) Mean	Lower Mesohaline (77) Stderr	Upper Mesohaline (91) Mean	Upper Mesohaline (91) Stderr	Polyhaline (175) Mean	Polyhaline (175) Stderr
Cynoscion nebulosus	377	0.02	0.02	0.47	0.16	1.13	0.33	0.90	0.26	0.93	0.25
Oligoplites saurus	347	0.02	0.02	0.20	0.09	0.56	0.20	0.70	0.20	1.26	0.41
Membras martinica	304	1.35	1.33	0.01	0.01	1.96	1.36	0.16	0.11	0.39	0.26
Opisthonema oglinum	272	4.90	3.59	0.06	0.06	0.01	0.01	.	.	0.09	0.06
Callinectes sapidus	255	0.43	0.16	0.30	0.06	0.16	0.05	0.43	0.12	0.88	0.23
Cynoscion arenarius	255	0.04	0.03	0.93	0.40	0.08	0.04	0.23	0.14	0.79	0.44
Tilapia spp.	222	0.16	0.11	0.51	0.39	1.01	0.91	0.01	0.01	0.49	0.30
Strongylura timucu	153	.	.	0.16	0.13	0.03	0.02	0.14	0.07	0.69	0.37
Orthopristis chrysoptera	149	.	.	.	.	.	.	0.24	0.16	0.73	0.26
Centropomus undecimalis	128	0.27	0.11	0.36	0.11	0.35	0.12	0.25	0.08	0.17	0.08
Strongylura notata	124	.	.	0.01	0.01	0.06	0.03	0.20	0.09	0.57	0.18
Archosargus probatocephalus	121	0.16	0.07	0.39	0.09	0.30	0.15	0.35	0.15	0.12	0.05
Achirus lineatus	110	0.02	0.02	.	.	0.21	0.17	0.12	0.05	0.47	0.14
Mugil gyrans	99	.	.	0.03	0.02	0.14	0.13	0.82	0.75	0.06	0.03
Synodus foetens	90	.	.	.	.	.	.	0.04	0.02	0.49	0.10
Notropis maculatus	87	1.71	1.71	.	.	.	.	.	.	.	.
Lepomis macrochirus	80	0.96	0.46	0.33	0.19	.	.	.	.	.	.
Fundulus confluentus	74	1.22	0.83	0.13	0.12	.	.	.	.	.	.
Strongylura spp.	73	0.02	0.02	0.17	0.10	0.08	0.04	0.04	0.02	0.26	0.10
Arius felis	71	.	.	0.06	0.03	0.49	0.38	0.14	0.07	0.08	0.06
Syngnathus scovelli	71	.	.	0.16	0.08	0.13	0.06	0.06	0.03	0.22	0.08
Sphoeroides nephelus	63	.	.	0.01	0.01	.	.	.	.	0.35	0.07
Symphurus plagiusa	58	.	.	0.08	0.05	0.03	0.03	0.06	0.03	0.25	0.10
Prionotus scitulus	52	.	.	.	.	0.01	0.01	0.03	0.03	0.27	0.09
Micropterus salmoides	51	0.24	0.12	0.38	0.21	0.04	0.03	.	.	.	.
Trachinotus falcatus	51	.	.	.	.	.	.	.	.	0.29	0.29
Strongylura marina	49	0.02	0.02	0.01	0.01	0.01	0.01	0.05	0.04	0.23	0.08
Anchoa hepsetus	48	.	.	0.07	0.05	0.09	0.04	0.09	0.08	0.15	0.10
Pogonias cromis	48	.	.	0.01	0.01	.	.	0.02	0.02	0.26	0.18
Heterandria formosa	42	0.57	0.23	0.09	0.05	.	.	.	.	0.03	0.02
Notropis spp.	40	0.78	0.45	.	.	.	.	.	.	.	.
Bathygobius soporator	37	0.02	0.02	.	.	0.06	0.03	0.10	0.04	0.13	0.04
Lucania goodei	36	0.51	0.38	0.10	0.07	.	.	.	.	0.01	0.01

(Continued)

Species	Number	Freshwater (51) Mean	Stderr	Oligohaline (94) Mean	Stderr	Lower Mesohaline (77) Mean	Stderr	Upper Mesohaline (91) Mean	Stderr	Polyhaline (175) Mean	Stderr
Paralichthys albigutta	32	.	.	.	.	.	.	.	.	0.18	0.07
Gobiesox strumosus	28	.	.	.	.	0.01	0.01	0.07	0.03	0.12	0.05
Menticirrhus saxatilis	28	.	.	.	.	0.08	0.08	0.02	0.02	0.12	0.04
Adinia xenica	27	0.02	0.02	0.17	0.10	0.01	0.01	0.10	0.10	.	.
Lepomis spp.	27	0.51	0.37	0.01	0.01	.	.	.	.	.	.
Syngnathus louisianae	27	.	.	0.03	0.02	0.01	0.01	0.03	0.02	0.11	0.03
Fundulus spp.	19	0.06	0.06	0.09	0.06	0.04	0.04	0.05	0.05	.	.
Elops saurus	15	.	.	0.06	0.04	0.01	0.01	0.02	0.02	0.03	0.02
Etropus spp.	10	.	.	.	.	.	.	0.11	0.11	.	.
Lepomis microlophus	10	0.18	0.11	0.01	0.01	.	.	.	.	.	.
Belonesox belizanus	9	.	.	0.04	0.04	0.06	0.06	.	.	.	.
Prionotus tribulus	8	.	.	.	.	.	.	.	.	0.05	0.02
Chasmodes saburrae	7	.	.	.	.	.	.	0.02	0.02	0.03	0.01
Dasyatis sabina	7	.	.	.	.	.	.	0.01	0.01	0.03	0.02
Gymnura micrura	6	.	.	.	.	.	.	.	.	0.03	0.03
Lutjanus griseus	6	.	.	.	.	.	.	0.01	0.01	0.03	0.02
Microgobius thalassinus	6	.	.	.	.	.	.	.	.	0.03	0.03
Caranx hippos	5	.	.	.	.	0.01	0.01	0.02	0.02	0.01	0.01
Chaetodipterus faber	4	.	.	.	.	.	.	0.01	0.01	0.02	0.01
Lepisosteus osseus	4	0.02	0.02	0.02	0.01	.	.	0.01	0.01	.	.
Opsanus beta	4	.	.	.	.	0.01	0.01	0.02	0.02	0.01	0.01
Lepisosteus platyrhincus	3	0.04	0.03	0.01	0.01	.	.	.	.	.	.
Lepomis gulosus	3	0.02	0.02	0.02	0.02	.	.	.	.	.	.
Mugil curema	3	.	.	.	.	0.03	0.02	.	.	0.01	0.01
Rhinoptera bonasus	3	.	.	.	.	0.01	0.01	0.01	0.01	0.01	0.01
Syngnathus floridae	3	.	.	.	.	.	.	.	.	0.02	0.01
Ameiurus catus	2	0.04	0.03	.	.	.	.	.	.	.	.
Hippocampus zosterae	2	.	.	.	.	.	.	.	.	0.01	0.01
Hypostomus spp.	2	.	.	0.02	0.01	.	.	.	.	.	.
Hypsoblennius hentzi	2	.	.	.	.	.	.	.	.	0.01	0.01
Micropterus punctulatus	2	0.02	0.02	.	.	0.01	0.01	.	.	.	.
Sphyraena picudilla	2	.	.	.	.	.	.	.	.	0.01	0.01
Chilomycterus schoepfi	1	.	.	.	.	.	.	.	.	0.01	0.01

(Continued)

Species	Number	Freshwater (51) Mean	Freshwater (51) Stderr	Oligohaline (94) Mean	Oligohaline (94) Stderr	Lower Mesohaline (77) Mean	Lower Mesohaline (77) Stderr	Upper Mesohaline (91) Mean	Upper Mesohaline (91) Stderr	Polyhaline (175) Mean	Polyhaline (175) Stderr
Cichlidae spp.	1	.	.	0.01	0.01	.	.	.	.	.	.
Elopidae spp.	1	.	.	0.01	0.01	.	.	.	.	.	.
Gambusia spp.	1	.	.	.	.	.	.	.	.	0.01	0.01
Hyporhamphus unifasciatus	1	.	.	.	.	.	.	.	.	0.01	0.01
Hypostomus plecostomus	1	0.02	0.02	.	.	.	.	.	.	.	.
Jordanella floridae	1	0.02	0.02	.	.	.	.	.	.	.	.
Lepomis punctatus	1	0.02	0.02	.	.	.	.	.	.	.	.
Micropogonias undulatus	1	.	.	.	.	.	.	.	.	0.01	0.01
Selene vomer	1	.	.	.	.	.	.	.	.	0.01	0.01
Totals	502,131	340.08	48.51	376.67	57.07	1115.78	305.69	2202.77	719.27	932.04	206.07

Table 2. Table listing the mean catch per unit effort (# animals/set) and standard error, by salinity classification for each species collected by 6.1-m otter trawls during stratified-random sampling in the Alafia, Little Manatee and Manatee Rivers between 1994 and 1996. Salinity classifications are defined as freshwater (0-0.5 ppt), oligohaline (0.5-5 ppt), lower mesohaline (5-11 ppt), upper mesohaline (11-18ppt), polyhaline (>18ppt). The number in parentheses after the salinity classification indicates the number of samples taken within that classification. Shaded species represent species that are of direct commercial and/or recreational importance.

Species	Number	Freshwater (18)		Oligohaline (21)		Lower Mesohaline (23)		Upper Mesohaline (56)		Polyhaline (146)	
		Mean	Stderr	Mean	Stderr	Mean	Stderr	Mean	Stderr	Mean	Stderr
Anchoa mitchilli	15,119	2.28	1.47	130.19	73.39	79.13	54.16	38.25	13.89	57.41	18.89
Cynoscion arenarius	1,643	0.39	0.23	2.43	1.66	4.17	2.66	2.66	0.80	8.18	4.25
Trinectes maculatus	1,531	52.00	18.82	5.81	2.21	3.78	1.27	5.20	1.60	0.65	0.17
Menticirrhus americanus	1,408	.	.	3.95	3.71	0.78	0.68	3.34	0.85	7.67	2.64
Penaeus duorarum	1,296	.	.	1.52	0.88	1.52	0.69	8.07	3.31	6.32	1.19
Callinectes sapidus	731	0.72	0.21	1.48	0.85	1.52	0.61	3.25	0.61	3.22	0.44
Arius felis	714	0.72	0.35	2.57	1.36	3.57	2.02	5.21	2.18	1.87	0.73
Eucinostomus gula	693	.	.	.	.	0.04	0.04	0.52	0.23	3.86	0.83
Bairdiella chrysoura	569	.	.	1.71	1.57	0.04	0.04	3.61	2.26	2.26	0.71
Eucinostomus spp.	418	0.11	0.08	1.10	0.77	4.39	3.41	1.09	0.48	1.58	0.73
Prionotus scitulus	247	.	.	0.05	0.05	.	.	0.38	0.38	1.54	0.27
Orthopristis chrysoptera	217	.	.	.	.	.	.	0.75	0.70	1.20	0.34
Symphurus plagiusa	206	.	.	0.76	0.71	.	.	1.34	0.53	0.80	0.22
Leiostomus xanthurus	174	0.06	0.06	1.00	0.86	1.35	1.26	0.02	0.02	0.82	0.25
Eucinostomus harengulus	170	0.83	0.45	0.48	0.30	0.26	0.22	1.05	0.36	0.55	0.15
Chaetodipterus faber	154	.	.	0.10	0.10	.	.	0.48	0.20	0.86	0.38
Lagodon rhomboides	148	.	.	0.43	0.22	1.87	1.28	0.39	0.21	0.51	0.11
Dasyatis sabina	147	.	.	0.62	0.37	0.17	0.08	0.21	0.06	0.81	0.14
Microgobius gulosus	136	0.28	0.19	0.95	0.59	0.46	0.24	0.41	0.12	0.53	0.12
Sciaenops ocellatus	117	1.39	1.27	1.95	1.07	1.39	1.06	0.11	0.05	0.09	0.05
Gobiosoma spp.	93	0.17	0.12	0.81	0.36	0.43	0.22	0.23	0.06	0.34	0.10
Microgobius thalassinus	91	.	.	0.05	0.05	.	.	0.71	0.42	0.34	0.09
Pogonias cromis	84	.	.	3.82	3.32	0.13	0.10	0.09	0.09	.	.
Achirus lineatus	61	.	.	0.29	0.21	.	.	0.13	0.05	0.33	0.10
Archosargus probatocephalus	56	0.22	0.10	0.36	0.18	0.43	0.26	0.18	0.08	0.16	0.05
Synodus foetens	55	.	.	.	.	0.04	0.04	0.07	0.04	0.34	0.07
Anchoa hepsetus	49	.	.	.	.	.	.	.	.	0.34	0.19
Paralichthys albigutta	46	.	.	.	.	.	.	0.05	0.04	0.29	0.06

(Continued)

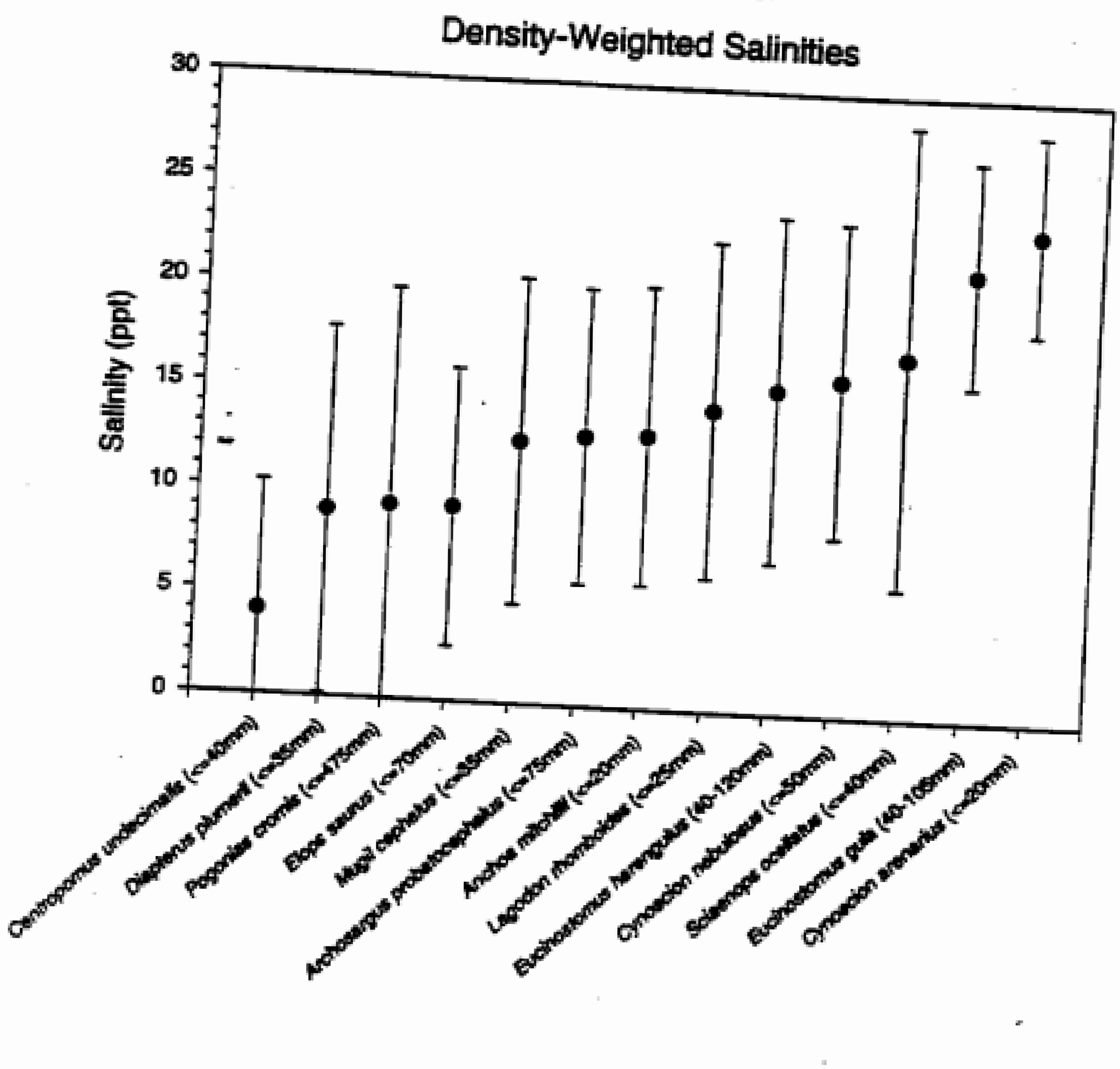
Species	Number	Freshwater (18)		Oligohaline (21)		Lower Mesohaline (23)		Upper Mesohaline (56)		Polyhaline (146)	
		Mean	Stderr	Mean	Stderr	Mean	Stderr	Mean	Stderr	Mean	Stderr
Diapterus plumieri	40	0.39	0.23	1.00	0.54	0.17	0.14	0.13	0.11	0.01	0.01
Chilomycterus schoepfi	39	.	.	.	.	.	.	0.02	0.02	0.26	0.07
Cynoscion nebulosus	39	.	.	0.19	0.15	0.09	0.06	0.13	0.06	0.18	0.07
Chloroscombrus chrysurus	36	.	.	0.38	0.38	.	.	0.34	0.34	0.06	0.03
Syngnathus louisianae	31	.	.	.	.	0.04	0.04	0.07	0.03	0.18	0.05
Menticirrhus spp.	27	.	.	.	.	.	.	0.07	0.04	0.16	0.13
Opsanus beta	26	.	.	.	.	.	.	0.04	0.03	0.16	0.05
Prionotus tribulus	26	.	.	0.05	0.05	0.04	0.04	0.07	0.03	0.14	0.05
Sphoeroides nephelus	26	.	.	.	.	.	.	0.04	0.03	0.16	0.06
Bagre marinus	25	0.06	0.06	0.05	0.05	0.09	0.06	0.18	0.16	0.08	0.04
Gobiesox strumosus	25	.	.	.	.	0.22	0.18	0.07	0.04	0.11	0.05
Ictalurus punctatus	24	1.28	0.98	0.05	0.05	.	.	.	.	.	.
Menticirrhus saxatilis	23	.	.	.	.	.	.	.	.	0.16	0.11
Syngnathus scovelli	19	.	.	0.10	0.10	0.13	0.10	0.09	0.04	0.06	0.03
Gymnura micrura	16	.	.	0.19	0.19	.	.	0.02	0.02	0.06	0.02
Etropus crossotus	12	.	.	.	.	.	.	.	.	0.06	0.03
Dasyatis say	10	.	.	.	.	.	.	.	.	0.07	0.03
Menippe mercenaria	9	.	.	.	.	.	.	.	.	0.06	0.04
Lepisosteus osseus	8	0.06	0.06	.	.	0.09	0.09	0.05	0.03	0.01	0.01
Menidia spp.	7	.	.	0.05	0.05	0.13	0.13	0.02	0.02	0.01	0.01
Ameiurus catus	6	0.22	0.17	0.10	0.07	.	.	.	.	.	.
Lactophrys quadricornis	6	.	.	.	.	.	.	.	.	0.04	0.02
Lutjanus griseus	6	.	.	.	.	.	.	0.05	0.04	0.02	0.01
Opisthonema oglinum	6	.	.	0.05	0.05	0.17	0.17	.	.	0.01	0.01
Harengula jaguana	4	.	.	.	.	.	.	.	.	0.03	0.02
Monacanthus hispidus	4	.	.	.	.	.	.	.	.	0.03	0.02
Urophycis floridana	4	.	.	.	.	.	.	.	.	0.03	0.02
Centropomus undecimalis	3	.	.	0.14	0.10	.	.	.	.	.	.
Micropogonias undulatus	3	.	.	.	.	.	.	.	.	0.02	0.02
Rhinoptera bonasus	3	.	.	.	.	.	.	.	.	0.02	0.01
Selene vomer	3	.	.	.	.	.	.	.	.	0.02	0.02
Chasmodes saburrae	2	.	.	.	.	.	.	0.02	0.02	0.01	0.01
Gunterichthys longipenis	2	.	.	.	.	.	.	0.04	0.03	.	.

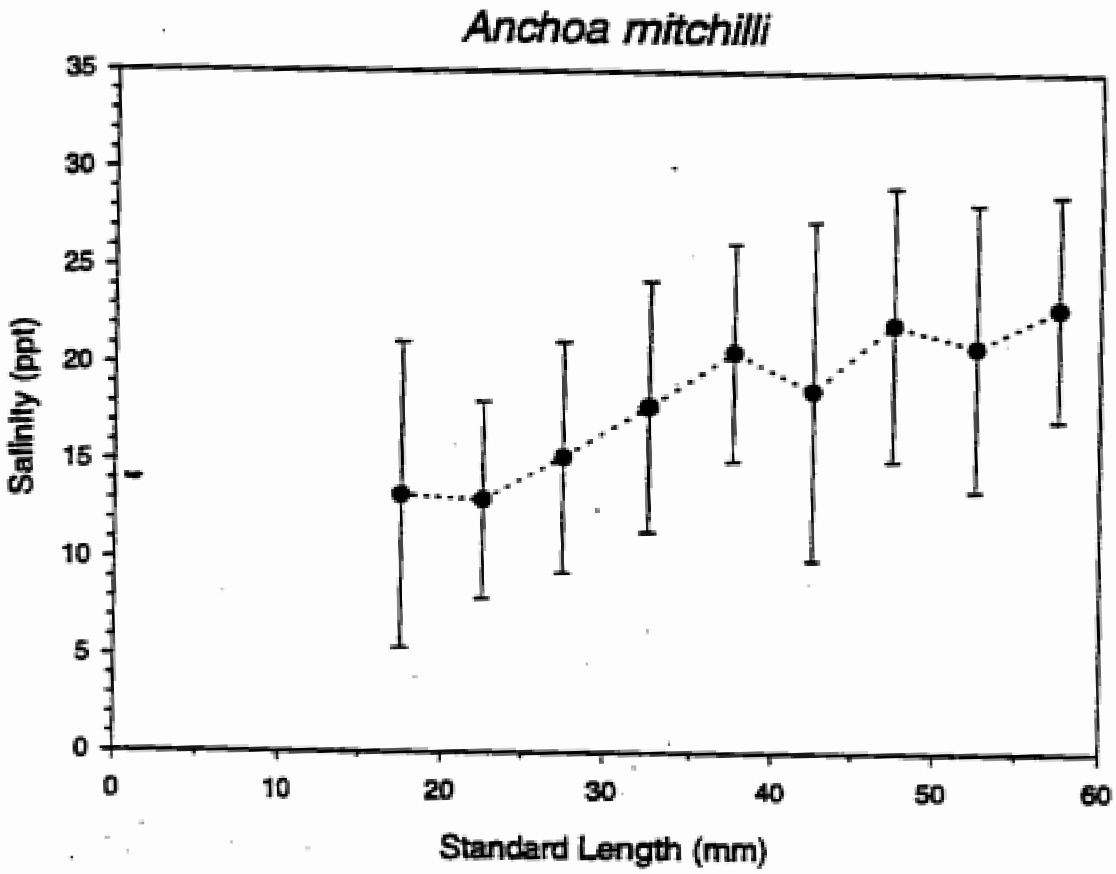
(Continued)

Species	Number	Freshwater (18)		Oligohaline (21)		Lower Mesohaline (23)		Upper Mesohaline (56)		Polyhaline (146)	
		Mean	Stderr	Mean	Stderr	Mean	Stderr	Mean	Stderr	Mean	Stderr
Ictalurus spp.	2	.	.	0.10	0.07	.	.	.	.	.	.
Lucania parva	2	0.06	0.06	0.05	0.05	.	.	.	.	.	.
Lutjanus synagris	2	.	.	.	.	.	.	.	.	0.01	0.01
Menippe spp.	2	.	.	.	.	.	.	.	.	0.01	0.01
Notropis spp.	2	.	.	.	.	.	.	.	.	0.01	0.01
Aluterus schoepfi	1	.	.	.	.	.	.	.	.	0.01	0.01
Ameiurus nebulosus	1	0.06	0.06	.	.	.	.	.	.	.	.
Ancylopsetta quadrocellata	1	.	.	.	.	.	.	.	.	.	.
Bathygobius soporator	1	.	.	.	.	.	.	.	.	0.01	0.01
Blenniidae spp.	1	.	.	.	.	.	.	.	.	0.01	0.01
Brevoortia spp.	1	.	.	.	.	.	.	0.02	0.02	.	.
Carangidae spp.	1	.	.	.	.	.	.	.	.	0.01	0.01
Clupeidae spp.	1	.	.	.	.	.	.	.	.	0.01	0.01
Hippocampus zosterae	1	.	.	.	.	.	.	.	.	0.01	0.01
Lepisosteus platyrhincus	1	.	.	.	.	.	.	.	.	0.01	0.01
Microgobius spp.	1	.	.	.	.	.	.	.	.	0.01	0.01
Mugil cephalus	1	.	.	.	.	.	.	0.02	0.02	.	.
Rachycentron canadum	1	.	.	.	.	.	.	.	.	0.01	0.01
Sphoeroides spengleri	1	.	.	.	.	.	.	.	.	0.01	0.01
Strongylura timucu	1	.	.	.	.	.	.	.	.	0.01	0.01
Totals	26,820	61.28	18.68	164.71	73.30	106.74	55.07	79.27	14.45	105.24	21.96

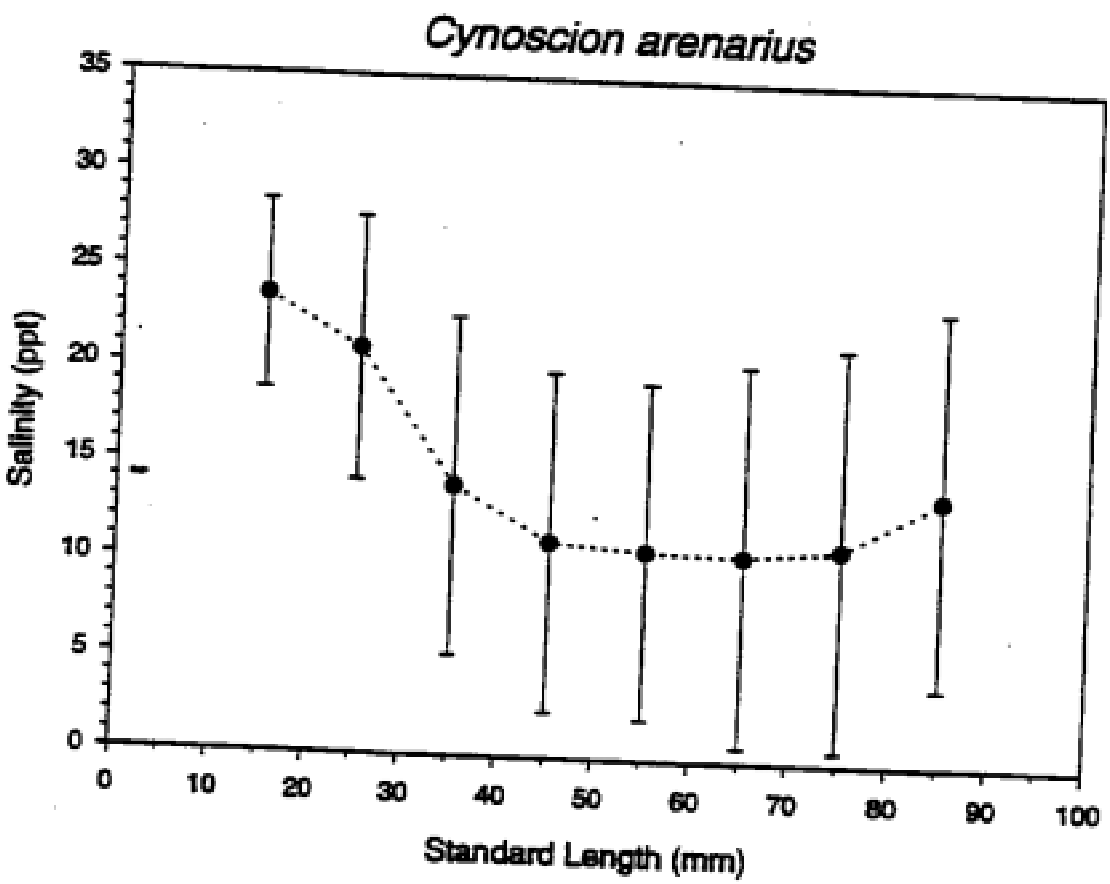
Density-Weighted Mean Salinities for species collected in ten or more samples. Species are in order from lowest mean salinity to highest mean salinity.

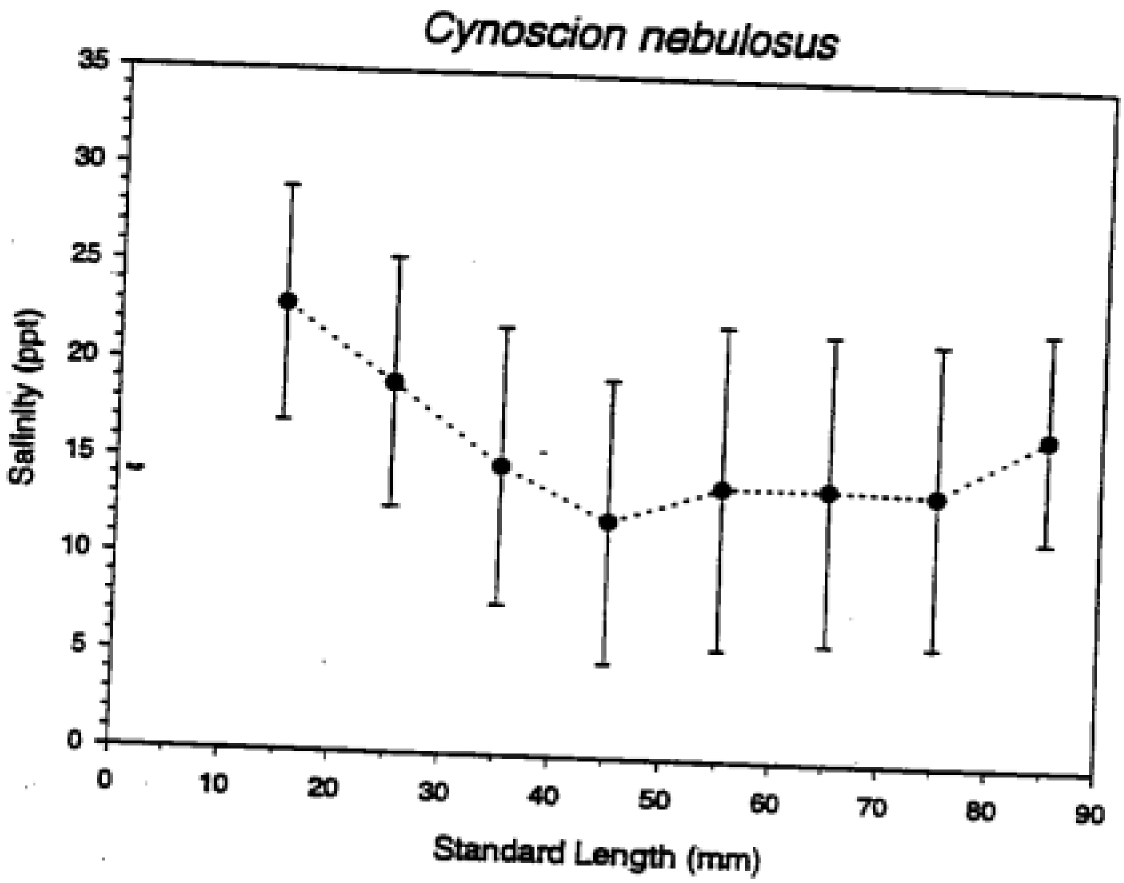
Species	Lengths Analyzed (mm)	Density-Weighted Salinity Mean	Density-Weighted Salinity Std
Labidesthes sicculus	<= 65	0.11	0.12
Notropis petersoni	<= 55	0.22	0.15
Lepomis macrochirus	<= 165	0.68	1.07
Micropterus salmoides	<= 205	0.99	1.43
Fundulus seminolis	<= 105	1.36	1.92
Opisthonema oglinum	<= 160	1.66	5.95
Gambusia holbrooki	<= 45	1.69	3.29
Heterandria formosa	<= 30	2.60	5.83
Trinectes maculatus	<= 25	3.30	6.27
Centropomus undecimalis	<= 40	4.06	6.24
Diapterus plumieri	<= 35	8.97	8.84
Pogonias cromis	<= 475	9.32	10.45
Elops saurus	<= 70	9.34	6.70
Membras martinica	<= 55	9.73	8.55
Gobiosoma spp.	<= 50	9.77	8.90
Tilapia spp.	<= 295	10.04	8.88
Lepisosteus osseus	<= 1155	10.43	8.39
Lucania parva	<= 50	11.06	12.34
Poecilia latipinna	<= 75	11.95	12.74
Fundulus grandis	<= 105	12.03	7.12
Archosargus probatocephalus	<= 75	12.65	7.86
Brevoortia spp.	<= 35	12.97	5.44
Mugil cephalus	<= 35	12.98	7.14
Anchoa mitchilli	<= 20	13.14	7.21
Microgobius gulosus	<= 75	13.26	8.43
Menidia spp.	<= 110	13.66	9.37
Eucinostomus spp.	<= 75	13.87	7.99
Lagodon rhomboides	<= 25	14.53	8.14
Cyprinodon variegatus	<= 55	14.77	6.12
Callinectes sapidus	<= 30	14.92	8.13
Floridichthys carpio	<= 65	15.47	7.63
Eucinostomus harengulus	40-120	15.64	8.37
Cynoscion nebulosus	<= 50	16.22	7.61
Mugil gyrans	<= 170	16.67	4.19
Syngnathus scovelli	<= 115	16.77	9.62
Arius felis	<= 365	17.10	7.71
Sciaenops ocellatus	<= 40	17.43	11.19
Bathygobius soporator	<= 75	17.89	6.65
Oligoplites saurus	<= 100	18.19	6.68
Penaeus duorarum	<= 45	18.52	7.09
Symphurus plagiusa	<= 70	18.60	8.78
Bairdiella chrysoura	<= 30	19.06	5.86
Bagre marinus	<= 515	19.26	7.23
Harengula jaguana	<= 115	19.53	6.12
Strongylura timucu	<= 425	19.65	6.35
Fundulus majalis	<= 100	19.72	6.93
Gobiesox strumosus	<= 40	19.74	5.61
Chasmodes saburrae	<= 60	19.97	4.44
Lutjanus griseus	<= 215	20.12	7.70
Strongylura marina	<= 420	20.16	5.30
Achirus lineatus	<= 40	20.92	7.28
Gymnura micrura	<= 480	21.20	10.07
Microgobius thalassinus	<= 65	21.53	5.92
Eucinostomus gula	40-105	21.56	5.41
Strongylura notata	<= 380	21.95	[illegible]
Leiostomus xanthurus	<= 30	22.11	[illegible]
Dasyatis sabina	<= 365	22.33	[illegible]
Opsanus beta	<= 245	22.45	4.84
Orthopristis chrysoptera	<= 35	22.57	3.87
Syngnathus louisianae	<= 265	23.14	7.05
Prionotus tribulus	<= 85	23.21	7.13
Chaetodipterus faber	<= 50	23.23	6.09
Anchoa hepsetus	<= 30	23.50	4.43
Menticirrhus saxatilis	<= 190	23.56	5.86
Cynoscion arenarius	<= 20	23.59	4.80
Synodus foetens	<= 75	23.86	3.39
Sphoeroides nephelus	<= 30	24.12	3.80
Prionotus scitulus	<= 55	24.31	6.08
Menticirrhus americanus	<= 25	24.44	3.94
Paralichthys albigutta	<= 310	25.71	3.68
Chilomycterus schoepfi	<= 225	27.86	3.75


Density-Weighted Salinities
Salinity (ppt)
0
5
10
15
20
25
30
Centropomus undecimalis (<=40mm)
Diapterus plumieri (<=35mm)
Pogonias cromis (<=475mm)
Elops saurus (<=70mm)
Mugil cephalus (<=85mm)
Archosargus probatocephalus (<=75mm)
Anchoa mitchilli (<=20mm)
Lagodon rhomboides (<=25mm)
Eucinostomus harengulus (40-120mm)
Cynoscion nebulosus (<=50mm)
Sciaenops ocellatus (<=40mm)
Eucinostomus gula (40-105mm)
Cynoscion arenarius (<=20mm)

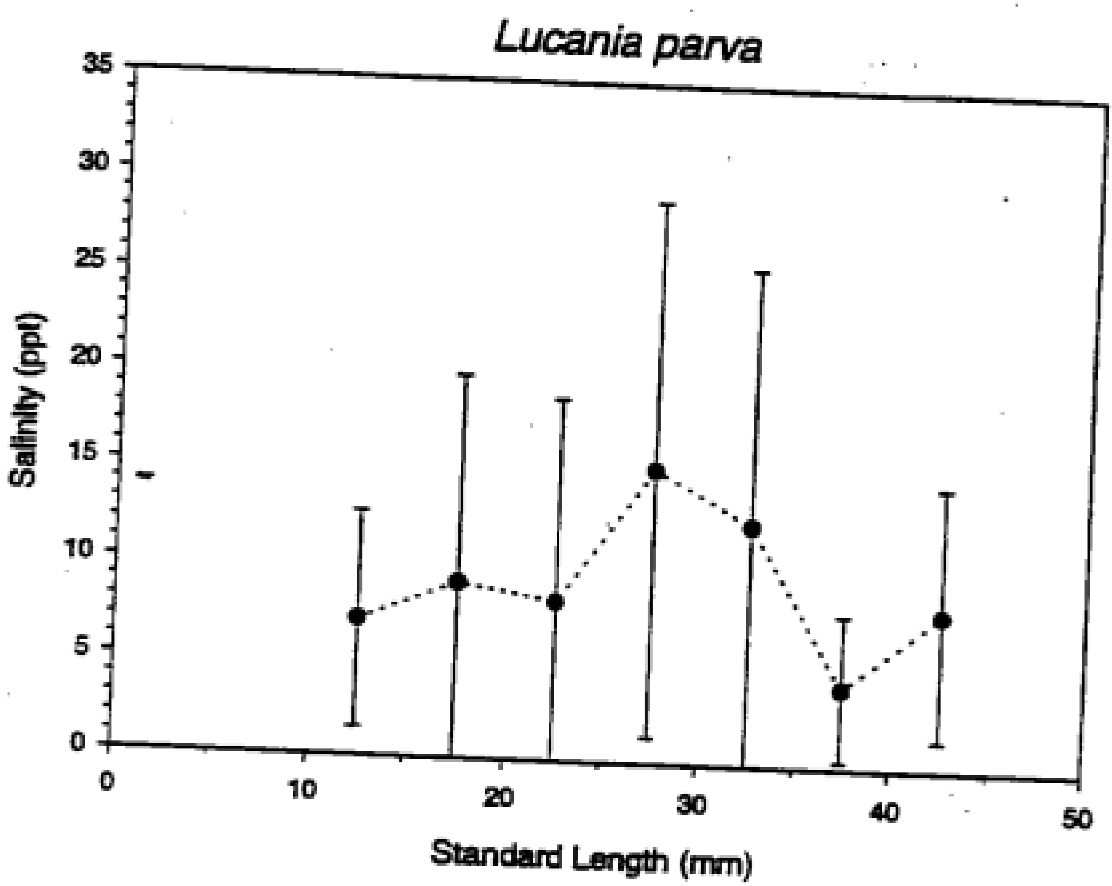


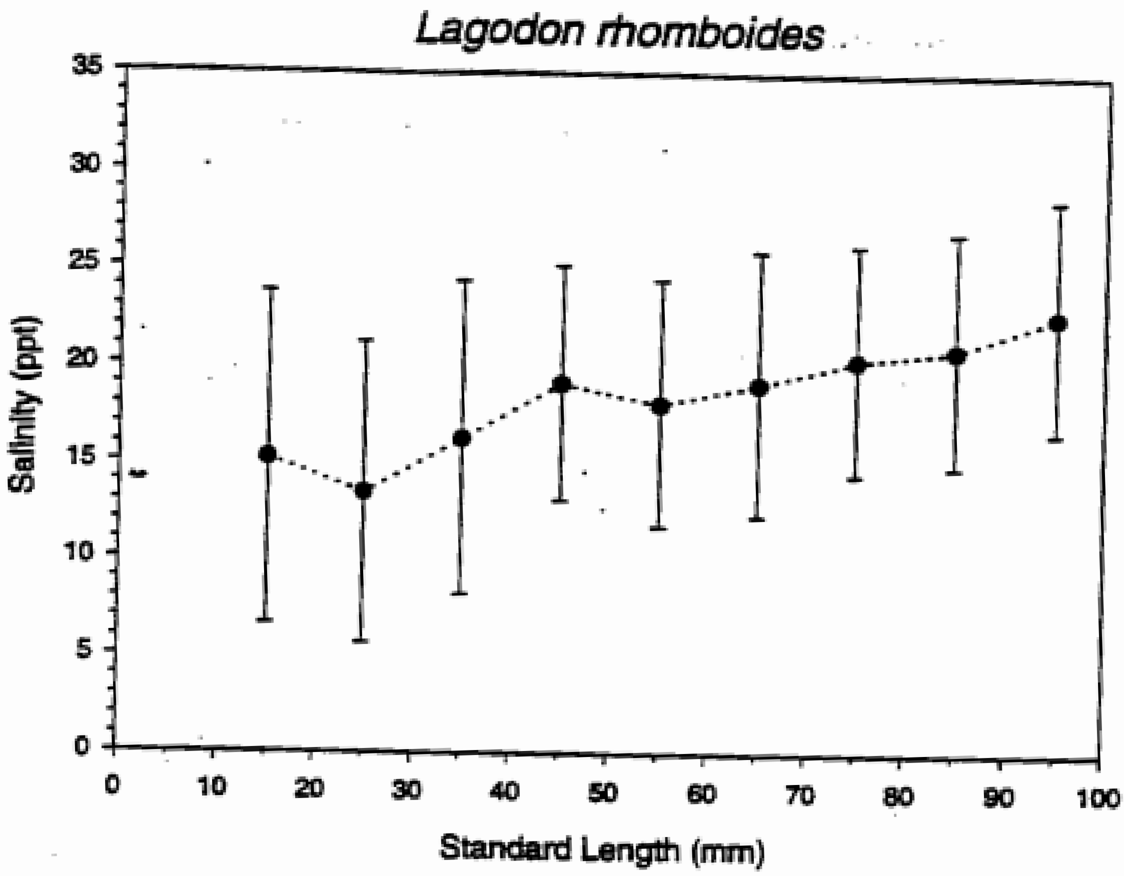
Anchoa mitchilli
Salinity (ppt)
Standard Length (mm)
0
5
10
15
20
25
30
35
0
10
20
30
40
50
60


Cynoscion arenarius
Salinity (ppt)
Standard Length (mm)
0
5
10
15
20
25
30
35
0
10
20
30
40
50
60
70
80
90
100



Cynoscion nebulosus
Salinity (ppt)
0
5
10
15
20
25
30
35
0
10
20
30
40
50
60
70
80
90
Standard Length (mm)


Lucania parva
Salinity (ppt)
0
5
10
15
20
25
30
35
0
10
20
30
40
50
Standard Length (mm)


Lagodon rhomboides
Salinity (ppt)
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
Standard Length (mm)

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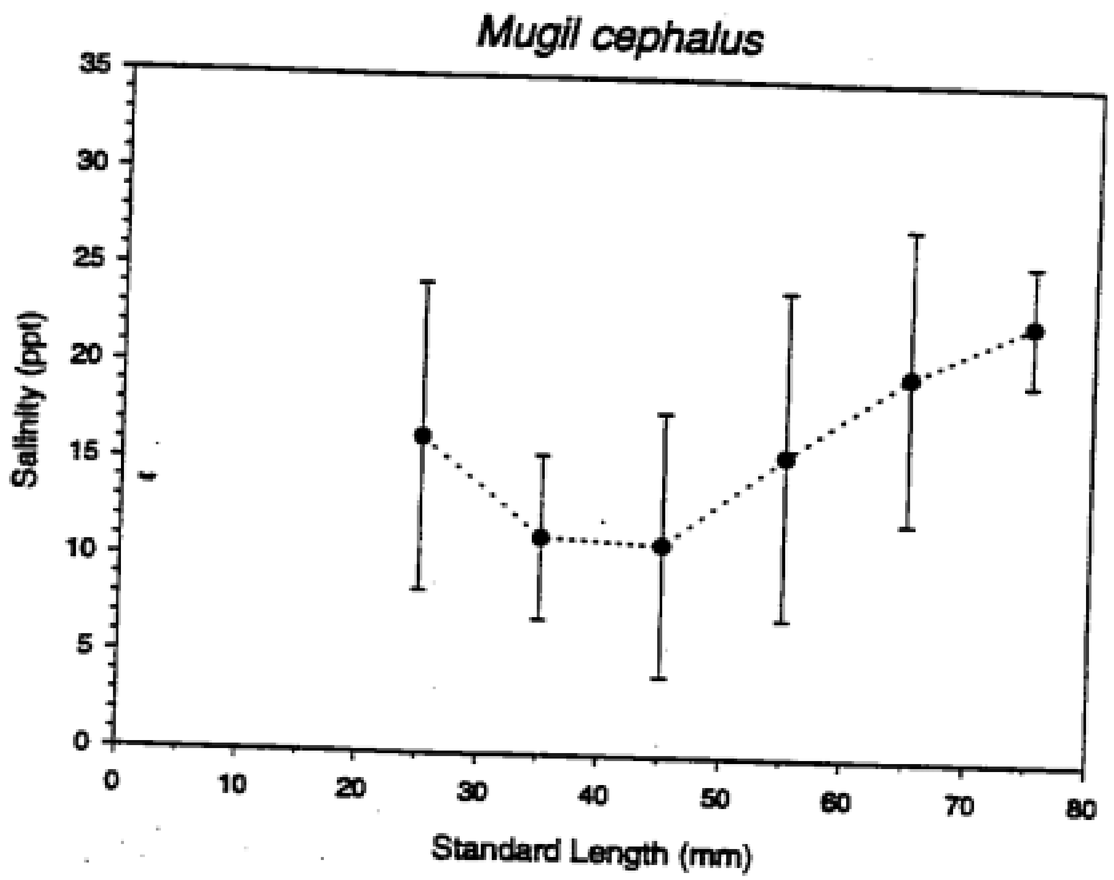
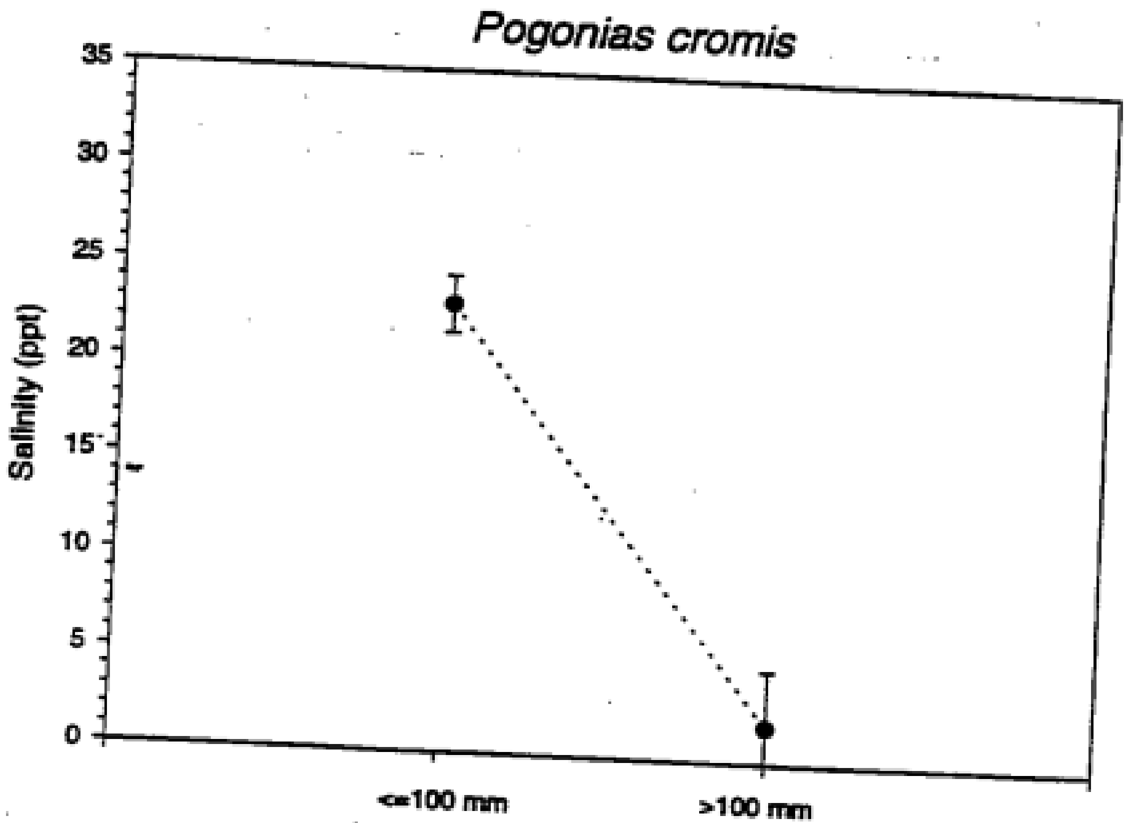
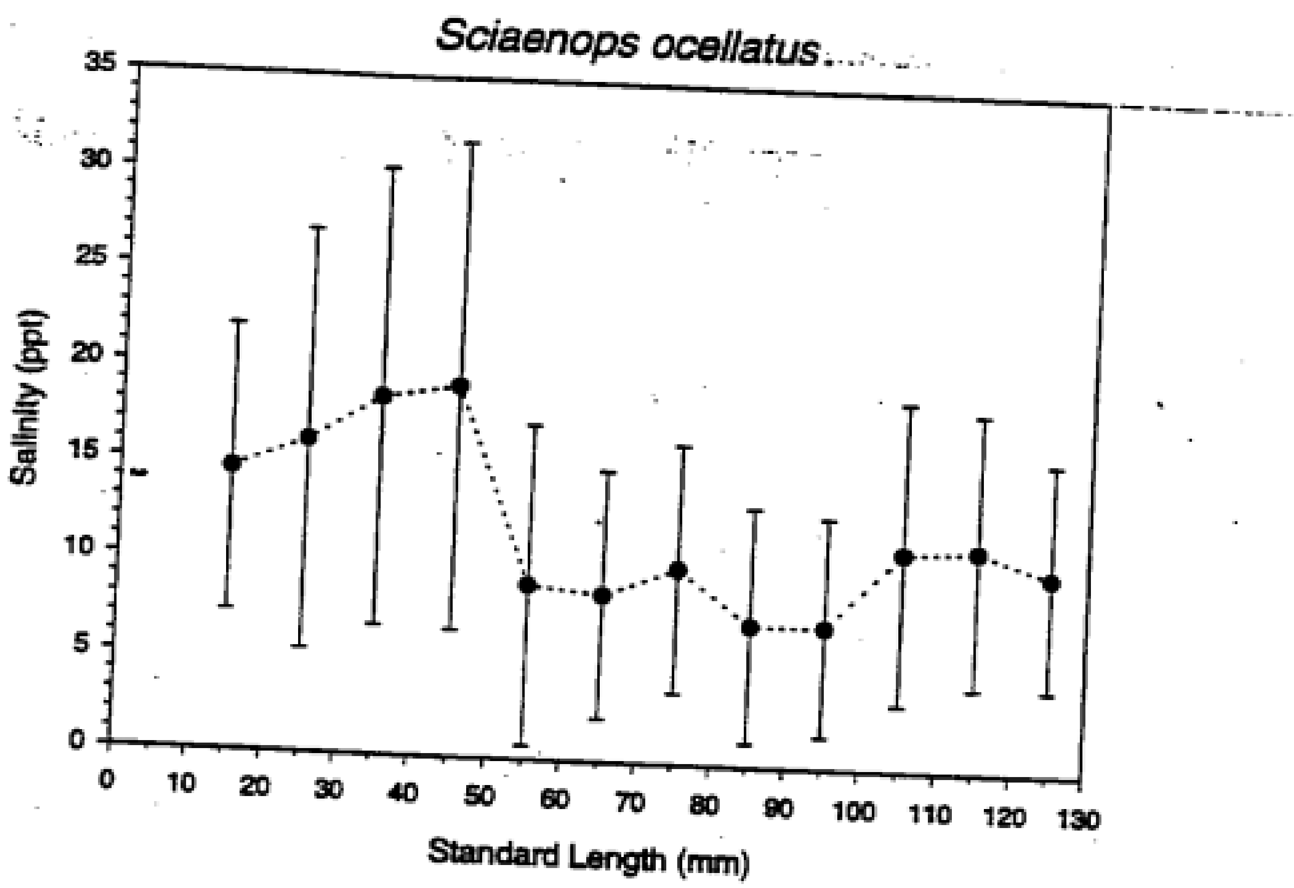


Mugil cephalus
Salinity (ppt)
0
5
10
15
20
25
30
35
0
10
20
30
40
50
60
70
80
Standard Length (mm)



Pogonias cromis
Salinity (ppt)
35
30
25
20
15
10
5
0
<=100 mm
>100 mm



Sciaenops ocellatus
Salinity (ppt)
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
Standard Length (mm)

Number of samples collected by shoreline classification

	AR	LMR	MR	Total
Unveg	6	8	11	25
Emmergent	67	86	90	243
Overhanging	59	56	39	154
Hardened	20	14	36	70
Total	**152**	**164**	**176**	**492**

Table 3. Table listing the mean catch per unit effort (# animals/set) and standard error, by shore vegetation classification for each species collected by 21-m boat set seines during stratified-random sampling in the Alafia, Little Manatee and Manatee Rivers between 1994 and 1996. The number in parentheses after the shore vegetation classification indicates the number of samples taken within that classification. Shaded species represent species that are of direct commercial and/or recreational importance.

Species	Number	Unvegetated (25) Mean	Stderr	Emmergent (243) Mean	Stderr	Overhanging (154) Mean	Stderr	Hardened (70) Mean	Stderr
Anchoa mitchilli	373,266	219.92	145.07	1060.40	291.44	345.38	142.23	647.60	377.19
Menidia spp.	66,423	165.04	51.13	133.88	20.06	141.71	22.28	113.46	24.03
Eucinostomus spp.	8,762	3.12	1.27	21.67	4.16	10.63	2.16	25.43	7.27
Lucania parva	6,246	15.24	5.40	11.12	6.01	19.91	7.03	1.43	0.44
Gambusia holbrooki	5,971	65.36	35.59	8.90	2.95	16.17	6.94	1.27	1.06
Lagodon rhomboides	4,820	2.76	1.82	10.76	1.95	9.57	1.69	9.47	4.56
Eucinostomus harengulus	4,417	11.40	8.69	9.14	1.42	8.34	1.14	8.97	2.92
Fundulus majalis	4,390	12.16	4.43	13.96	4.57	4.31	1.36	0.43	0.25
Trinectes maculatus	2,595	6.64	3.15	2.45	0.69	11.67	2.27	0.73	0.28
Sciaenops ocellatus	2,548	3.92	2.24	6.03	2.35	2.67	0.56	6.19	3.80
Poecilia latipinna	2,506	5.16	2.47	4.93	2.67	7.19	2.98	1.07	0.55
Leiostomus xanthurus	2,137	6.64	7.24	3.82	0.96	6.80	3.59	1.34	0.63
Bairdiella chrysoura	2,061	1.88	1.76	4.63	1.81	3.85	1.78	4.57	2.79
Harengula jaguana	1,673	0.72	0.72	4.83	2.16	0.67	0.37	5.41	3.19
Eucinostomus gula	1,514	0.52	0.35	3.59	0.70	1.31	0.66	6.10	2.02
Mugil cephalus	1,474	15.68	6.43	1.34	0.56	4.51	2.76	0.81	0.74
Fundulus seminolis	1,331	16.68	6.62	1.82	0.74	2.58	1.09	0.97	0.57
Cyprinodon variegatus	1,197	2.04	1.18	4.16	2.24	0.84	0.39	0.10	0.05
Microgobius gulosus	1,144	1.44	0.59	1.56	0.30	2.76	0.73	4.36	2.11
Fundulus grandis	1,010	6.24	3.86	1.95	0.54	2.08	0.59	0.87	0.39
Gobiosoma spp.	911	1.84	0.92	1.55	0.30	2.03	0.44	2.50	0.81
Diapterus plumieri	636	2.48	1.05	1.07	0.28	2.70	0.56	1.44	0.59
Floridichthys carpio	625	1.64	1.39	2.58	1.37	0.59	0.34	0.96	0.62
Menticirrhus americanus	751	0.12	0.09	2.73	1.69	0.44	0.26	0.24	0.13
Penaeus duorarum	671	0.16	0.12	1.06	0.22	1.41	0.40	2.79	0.86
Notropis petersoni	451	.	.	1.28	1.24	0.91	0.72	0.11	0.11
Labidesthes sicculus	413	5.92	5.92	0.13	0.11	1.62	0.60	.	
Brevoortia spp.	395	.	.	0.76	0.56	1.32	1.14	0.10	0.08
Cynoscion nebulosus	380	0.52	0.48	0.77	0.15	0.60	0.12	1.27	0.57

(Continued)

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Species	Number	Unvegetate (25)		Emmergent (243)		Overhanging (154)		Hardened (70)	
		Mean	Stderr	Mean	Stderr	Mean	Stderr	Mean	Stderr
Oligoplites saurus	348	0.56	0.36	0.79	0.27	0.36	0.09	1.23	0.52
Membras martinica	304	2.72	2.72	0.08	0.04	0.91	0.57	1.09	1.09
Opisthonema oglinum	272	.	.	0.22	0.17	1.38	1.17	0.09	0.09
Callinectes sapidus	256	0.60	0.34	0.34	0.08	0.51	0.09	1.14	0.53
Cynoscion arenarius	255	.	.	0.37	0.16	1.01	0.60	0.14	0.06
Tilapia spp.	222	0.12	0.12	0.14	0.08	0.73	0.39	1.03	1.00
Strongylura timucu	156	.	.	0.27	0.12	0.65	0.39	0.07	0.04
Orthopristis chrysoptera	149	.	.	0.62	0.21	0.10	0.06	0.10	0.09
Centropomus undecimalis	134	0.32	0.21	0.24	0.06	0.32	0.08	0.26	0.13
Strongylura notata	125	0.08	0.08	0.32	0.12	0.05	0.02	0.53	0.18
Archosargus probatocephalus	123	0.20	0.16	0.09	0.02	0.42	0.06	0.46	0.23
Achirus lineatus	112	0.04	0.04	0.36	0.11	0.03	0.01	0.29	0.14
Mugil gyrans	99	.	.	0.08	0.05	0.48	0.44	0.07	0.04
Synodus foetens	90	0.04	0.04	0.27	0.06	0.10	0.04	0.13	0.05
Notropis maculatus	87	.	.	.	.	0.66	0.56	.	.
Lepomis macrochirus	80	.	.	0.03	0.03	0.47	0.19	.	.
Fundulus confluentus	74	1.00	0.70	0.00	0.00	0.31	0.26	.	.
Strongylura spp.	73	0.36	0.32	0.19	0.07	0.10	0.04	0.04	0.02
Arius felis	71	0.04	0.04	0.15	0.12	0.20	0.10	0.04	0.04
Syngnathus scovelli	71	0.20	0.08	0.15	0.04	0.13	0.05	0.13	0.05
Sphoeroides nephelus	65	0.08	0.06	0.19	0.05	0.02	0.01	0.19	0.08
Symphurus plagiusa	56	.	.	0.16	0.07	0.08	0.04	0.06	0.03
Prionotus scitulus	52	.	.	0.15	0.06	0.10	0.06	0.01	0.01
Micropterus salmoides	51	0.08	0.06	0.05	0.03	0.24	0.12	.	.
Trachinotus falcatus	51	.	.	0.21	0.21	[illegible]	[illegible]	.	.
Anchoa hepsetus	49	0.20	0.20	0.07	0.03	0.01	0.01	0.36	0.24
Strongylura marina	49	0.20	0.20	0.07	0.04	0.16	0.07	0.07	0.05
Pogonias cromis	48	.	.	0.18	0.15	0.03	0.01	.	.
Heterandria formosa	42	0.32	0.32	0.08	0.04	0.10	0.04	.	.
Notropis spp.	40	0.32	0.32	0.03	0.03	0.18	0.13	.	.
Bathygobius soporator	39	.	.	0.12	0.03	0.03	0.01	0.09	0.03
Lucania goodei	36	.	.	0.10	0.08	0.06	0.05	.	.
Paralichthys albigutta	32	0.04	0.04	0.12	0.06	.	.	0.03	[illegible]

(Continued)

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Species	Number	Unvegetate (25)		Emmergent (243)		Overhanging (154)		Hardened (70)	
		Mean	Stderr	Mean	Stderr	Mean	Stderr	Mean	Stderr
Gobiesox strumosus	28	.	.	0.06	0.03	0.06	0.02	0.07	0.05
Menticirrhus saxatilis	28	.	.	0.10	0.04	.	.	0.04	0.02
Adinia xenica	27	.	.	0.05	0.04	0.09	0.06	0.03	0.02
Lepomis spp.	27	.	.	0.00	0.00	0.17	0.12	.	.
Syngnathus louisianae	27	.	.	0.07	0.02	0.04	0.02	0.06	0.03
Fundulus spp.	19	.	.	0.06	0.03	0.05	0.03	.	.
Elops saurus	15	.	.	0.02	0.01	0.06	0.03	0.01	0.01
Etropus spp.	10	.	.	0.04	0.04	.	.	.	.
Lepomis microlophus	10	.	.	.	.	0.06	0.04	.	.
Belonesox belizanus	9	.	.	.	.	0.03	0.03	0.07	0.07
Prionotus tribulus	8	.	.	0.01	0.01	0.02	0.01	0.04	0.03
Chasmodes saburrae	7	.	.	0.01	0.01	.	.	0.07	0.03
Dasyatis sabina	7	.	.	0.01	0.01	0.03	0.02	0.01	0.01
Gymnura micrura	6	.	.	.	.	.	.	0.09	0.09
Lutjanus griseus	6	.	.	0.02	0.01	0.01	0.01	.	.
Microgobius thalassinus	6	.	.	.	.	.	.	0.09	0.07
Caranx hippos	5	.	.	0.02	0.01	.	.	.	.
Mugil curema	5	0.04	0.04	0.01	0.01	0.01	0.01	.	.
Chaetodipterus faber	4	0.04	0.04	0.00	0.00	.	.	0.03	0.03
Lepisosteus osseus	4	.	.	0.01	0.01	0.01	0.01	.	.
Opsanus beta	4	.	.	0.00	0.00	0.01	0.01	0.03	0.02
Lepisosteus platyrhincus	3	.	.	0.00	0.00	0.01	0.01	.	.
Lepomis gulosus	3	.	.	0.01	0.01	.	.	.	.
Rhinoptera bonasus	3	.	.	0.01	0.01	0.01	0.01	.	.
Syngnathus floridae	3	.	.	0.01	0.01	0.01	0.01	.	.
Ameiurus catus	2	.	.	0.00	0.00	0.01	0.01	.	.
Hippocampus zosterae	2	.	.	0.01	0.01	.	.	.	.
Hypostomus spp.	2	0.04	0.04	.	.	0.01	0.01	.	.
Hypsoblennius hentzi	2	.	.	0.00	0.00	.	.	0.01	0.01
Micropterus punctulatus	2	.	.	0.01	0.01	.	.	.	.
Sphyraena picudilla	2	.	.	0.01	0.01	.	.	.	.
Chilomycterus schoepfi	1	.	.	0.00	0.00	.	.	.	.
Cichlasoma octofasciatum	1	.	.	0.00	0.00	.	.	.	.

(Continued)

Species	Number	Unvegetate (25)		Emmergent (243)		Overhanging (154)		Hardened (70)	
		Mean	Stderr	Mean	Stderr	Mean	Stderr	Mean	Stderr
Cichlidae spp.	1	.	.	.	.	0.01	0.01	.	.
Elopidae spp.	1	.	.	.	.	0.01	0.01	.	.
Gambusia spp.	1	.	.	.	.	0.01	0.01	.	.
Hyporhamphus unifasciatus	1	.	.	0.00	0.00	.	.	.	.
Hypostomus plecostomus	1	.	.	.	.	0.01	0.01	.	.
Jordanella floridae	1	.	.	.	.	0.01	0.01	.	.
Lepomis punctatus	1	.	.	.	.	0.01	0.01	.	.
Micropogonias undulatus	1	.	.	0.00	0.00	.	.	.	.
Selene vomer	1	.	.	0.00	0.00	.	.	.	.
Totals	505,132	575.48	208.20	1319.42	293.07	622.77	146.10	1060.29	374.09

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APPENDIX P-2

MEMORANDUM (July 14, 1997, Revised August 4, 1997)

July 14, 1997 (Revised August 4, 1997)

MEMORANDUM

TO: File, HRTBC Minimum Flows and Levels

FROM: Michael H. Beach, Professional Engineer, Resource Evaluation

SUBJECT: Regression modeling of lower pool of TBC

PURPOSE: Investigate relationship of rainfall to flow from the TBC lower pool via structure S-160.

BACKGROUND & ASSUMPTIONS:

1. January 22 to May 1, 1997 structure S-162 was closed; all flow out of the lower pool via S-160 was assumed to be from lower pool sources (i.e. rainfall, runoff, evaporation, seepage).
2. The pool stage decline for the period from February 17 through February 19 and the subsequent stage recovery through February 29 appears to be anomalous. Terry Rigsby of Operations can find no record of any activity at structure S-160 for the period although it appears as if there was a discharge for the two days of stage decline.
3. Ground-water level data for S-160 well (USGS) are missing for the period February 21 through March 11, 1997 and were estimated.

METHOD: Linear regression models were fitted to the data for the period that S-162 was closed. All models related likely parameters to the dependent variable flow at structure S-160 for the model period, January 22, 1997 through April 30, 1997. The models tested the statistical significance of parameters rainfall, ground-water levels, evaporation, pumping from the middle pool, and head differences between ground-water and the lower pool stage. All data were daily values. The regression was carried out on my personal computer using Quattro Pro V6.0. MINFLOW\HRTBC\LOWRPOOL.WB2 is the Quattro file containing the models.

MODELS: The models, by model number, incorporated the following parameters:

1. Rainfall (no lags), head difference (middle pool well TBC 2E-SMC and lower pool stage), evaporation, change in volume.
2. Same as Model 1 except head difference term used and average of the middle pool well and the USGS well S-160 as the ground-water level. The well S-160 is a Floridan aquifer well located near the structure of the same name.
3. Rainfall and three (3) lags of rainfall. Lags were daily;
4. Rainfall and two (2) lags of rainfall;
5. Rainfall, two lags and the head difference of Model 2;
6. Rainfall, two lags and evaporation;

7. Rainfall, two lags and the change in volume (storage) term;
8. Rainfall and four (4) lags;
9. Rainfall, four lags of rainfall and pumping from the middle pool;
10. Rainfall, three lags and pumping from the middle pool.
11. Rainfall, two lags and pumping from the middle pool.

RESULTS:
The results indicate that discharge at S-160, independent of any inflows at S-162, is principally the result of rainfall. However, discharges are also affected by pumping of water from the middle pool of the TBC to the City of Tampa reservoir on the Hillsborough River. The best fit was achieved with Model 10 and the results are plotted in the Figure of predicted and observed flows versus time. The R^2 term for Model 10 is 0.898. The significance of the third rainfall lag was marginal. In Model 11, the third lag was dropped and the R2 was 0.891. Model 10 results are given in the following table:

Parameter	Coefficient	t Statistic	P-Value
Rainfall (inches)	14.94	17.84	0
1st Lag, Rainfall (in)	10.69	12.88	0
2nd Lag, Rainfall (in)	8.347	10.00	1.11E-16
3rd Lag, Rainfall (in)	2.130	2.391	0.0187
Pumping (Mgd)	-0.0872	-4.286	4.33E-05
Intercept (cfs)	3.265	5.886	5.79E-08

The intercept indicates that without pumping or rainfall within the past few days, the flow over S-160 would be about three cfs. Pumping from the middle pool would decrease flow from the lower pool 0.09 cfs/Mgd pumped from the middle pool. This means that pumping 40 Mgd from the middle pool will likely reduce discharge over S-160 by some 3.5 cfs (about 2.3 Mgd).

The model has been formulated on a rather short period of record. The high rainfall of the rainy season was not included. However, the model does simulate reasonably well the short period of data associated with the dry winter months. The model appears to be an appropriate tool to estimate that portion of discharge due to rainfall from the lower pool of the TBC as well as the lower pool discharge to middle pool pumping relationship.

Attached are several figures of the results and some tables summarizing the results of this exercise.

MODEL 10 Model w/3 lags and middle pool pumping.

Regression Statistics *Regression Statistics*

Multiple R	0.94745
R Square	0.897661
Adjusted R Square	0.892038
Standard Error	2.271039
Observations	97

Analysis of Variance

	df	Sum of S	Mean Sq	F	Significance F
Regression	5	4116.812	823.3624	159.64	1.86E-43
Residual	91	469.3434	5.15762		
Total	96	4586.155			

0%

	Coefficie	Standard	t Statistic	P-value	Lower 95	Upper 95.
Intercept	3.264575	0.554836	5.885973	5.79E-08	2.162858	4.366291
x1, Rainfall	14.93836	0.837267	17.84182	0	13.27523	16.60149
x2, 1st Lag	10.69446	0.829797	12.88804	0	9.046169	12.34275
x3, 2nd Lag	8.34706	0.834926	9.99737	1.11E-16	6.688583	10.00554
x4, 3rd Lag	2.13048	0.891009	2.391087	0.018749	0.3606	3.90036
x5, Pumping, Midpool	-0.08716	0.020338	-4.28554	4.33E-05	-0.12756	-0.04676

LOWER POOL MODELS

MODEL 11 Model w/2 lags and middle pool pumping.

Regression Statistics

Multiple R	0.94405
R Square	0.891231
Adjusted R Square	0.886502
Standard Error	2.328535
Observations	97

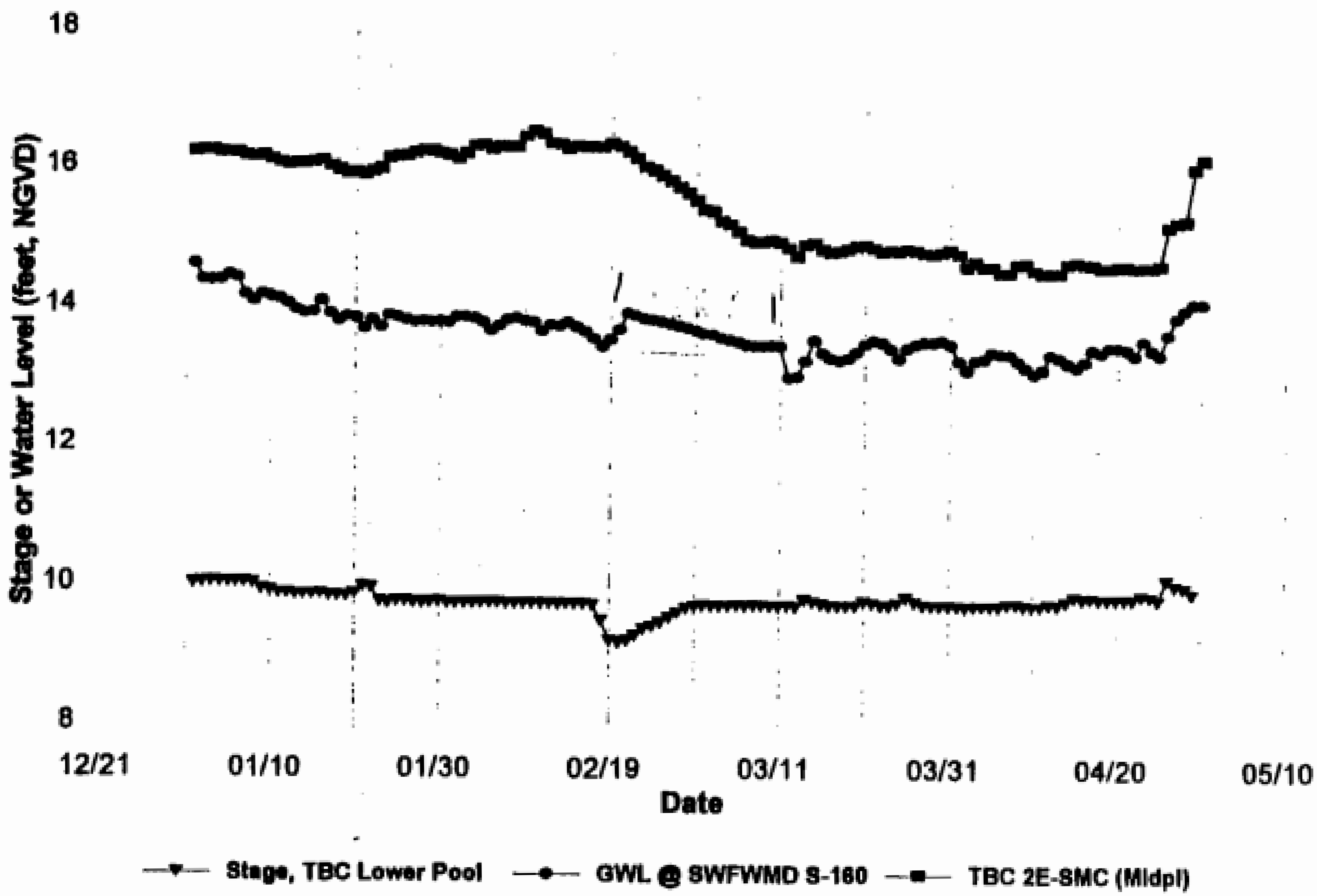
Analysis of Variance

	df	*Sum of S*	*Mean Sq*	*F*	*Significance F*
Regression	4	4087.324	1021.831	188.4575	2.01E-43
Residual	92	498.8311	5.422077		
Total	96	4586.155			

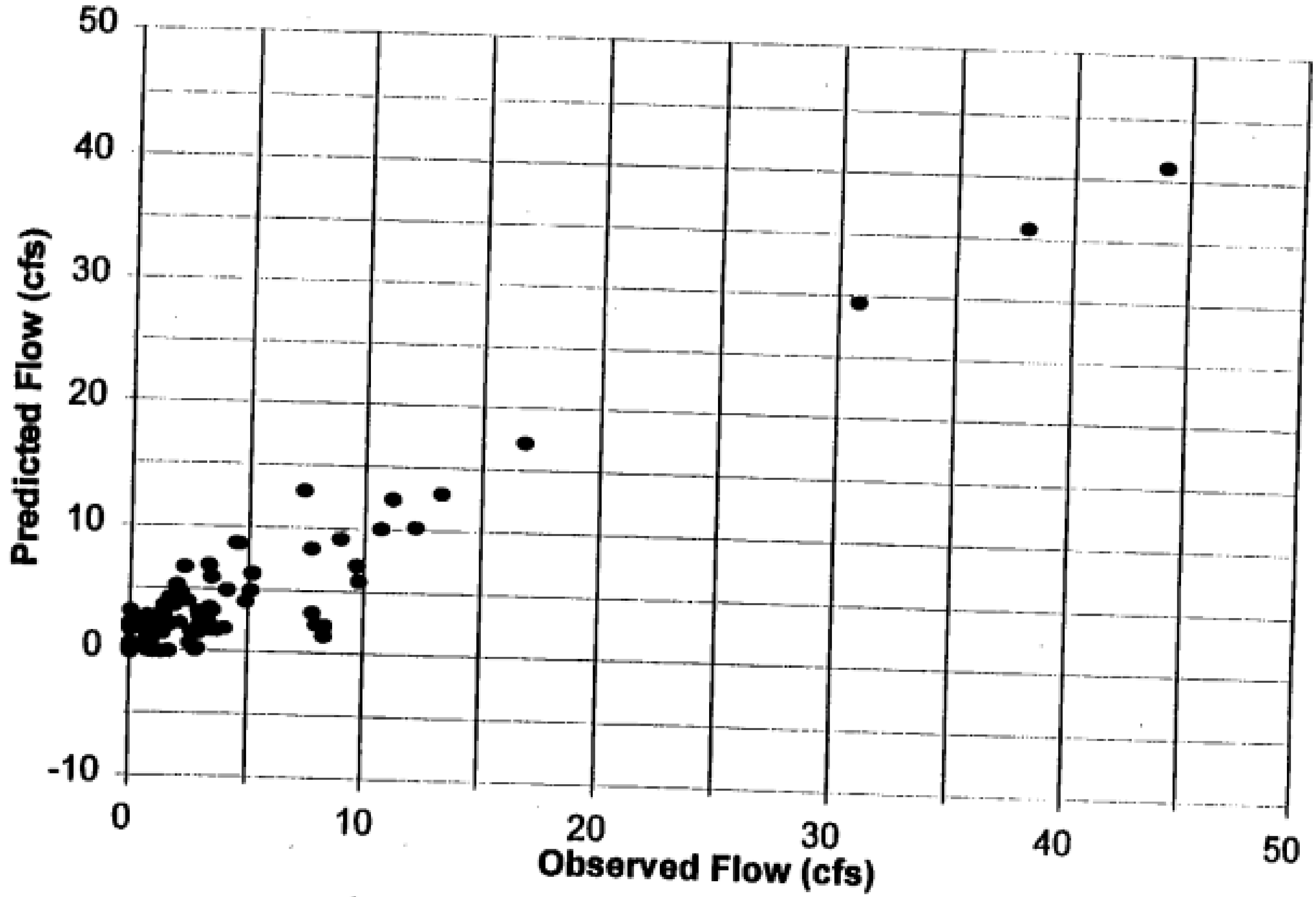
	Coefficie	*Standard*	*t Statistic*	*P-value*	*Lower 95*	*Upper 95.00%*
Intercept	3.634826	0.546066	6.65639	1.74E-09	2.550293	4.71936
x1, Rainfall	15.25484	0.847669	17.99623	0	13.5713	16.93839
x2, 1st Lag, Rain	11.0358	0.83812	13.16732	0	9.371222	12.70038
x3, 2nd Lag, Rain	8.148883	0.851835	9.566268	1.22E-15	6.457065	9.840701
x4, Pumping	-0.09865	0.020262	-4.86883	4.41E-06	-0.13889	-0.05841

Water Levels : 1997

Lower Pool and Well at S-160



Model 10: Predicted vs Observed Data



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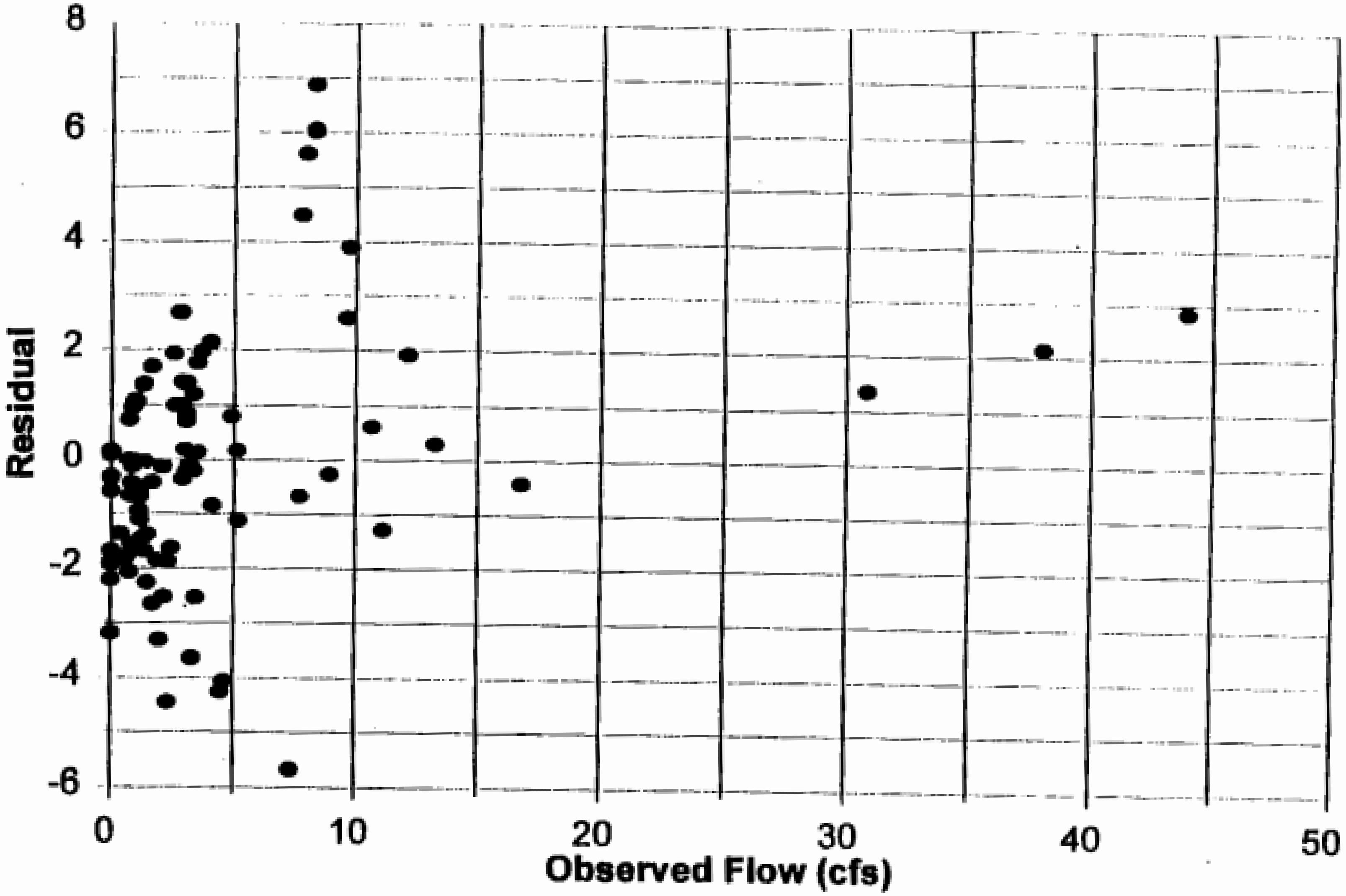
Model 10: Residual vs Observed Data



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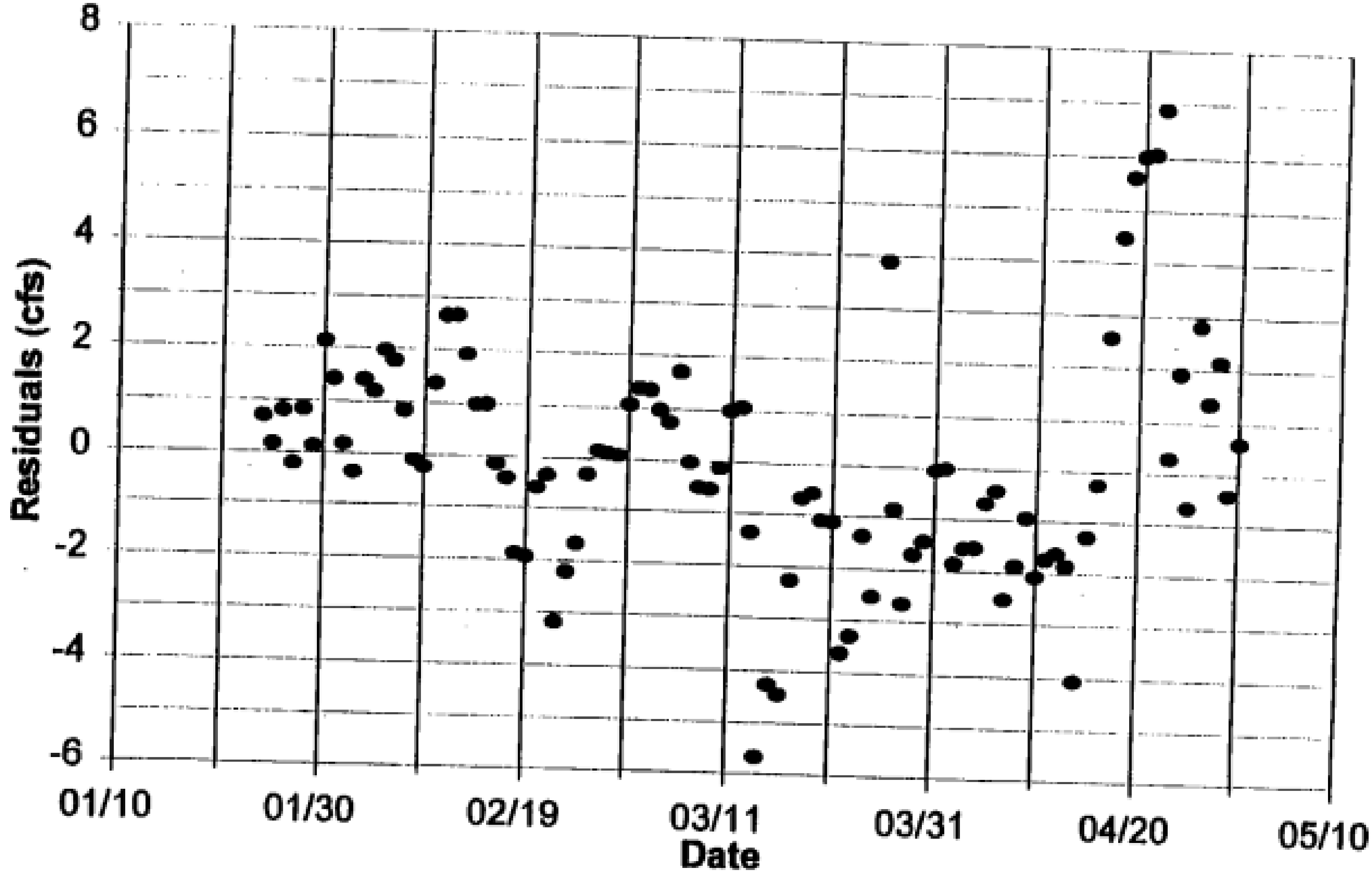
Model 10: Residuals versus Time



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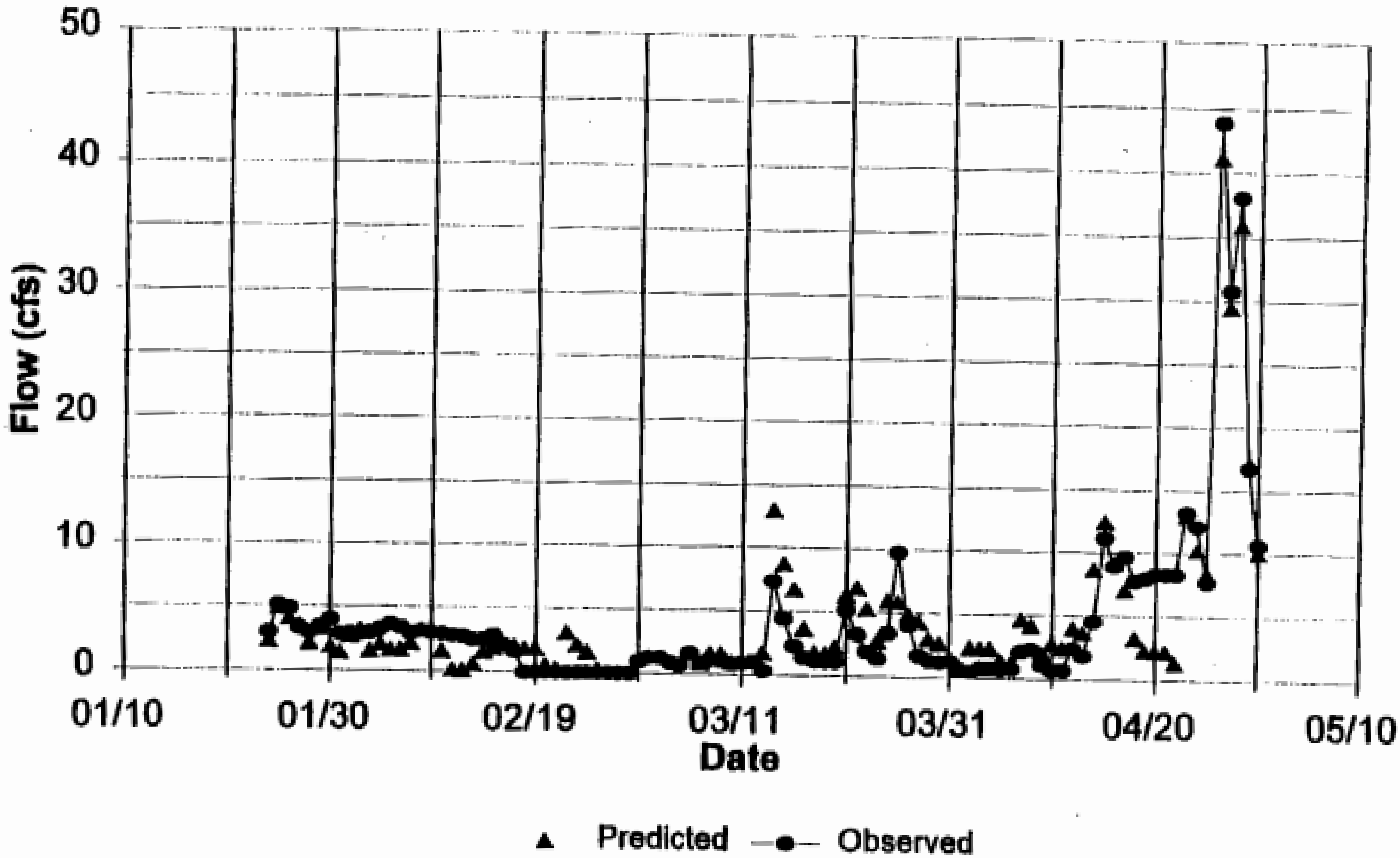
Model 10: Flow versus Time
Predicted and Observed



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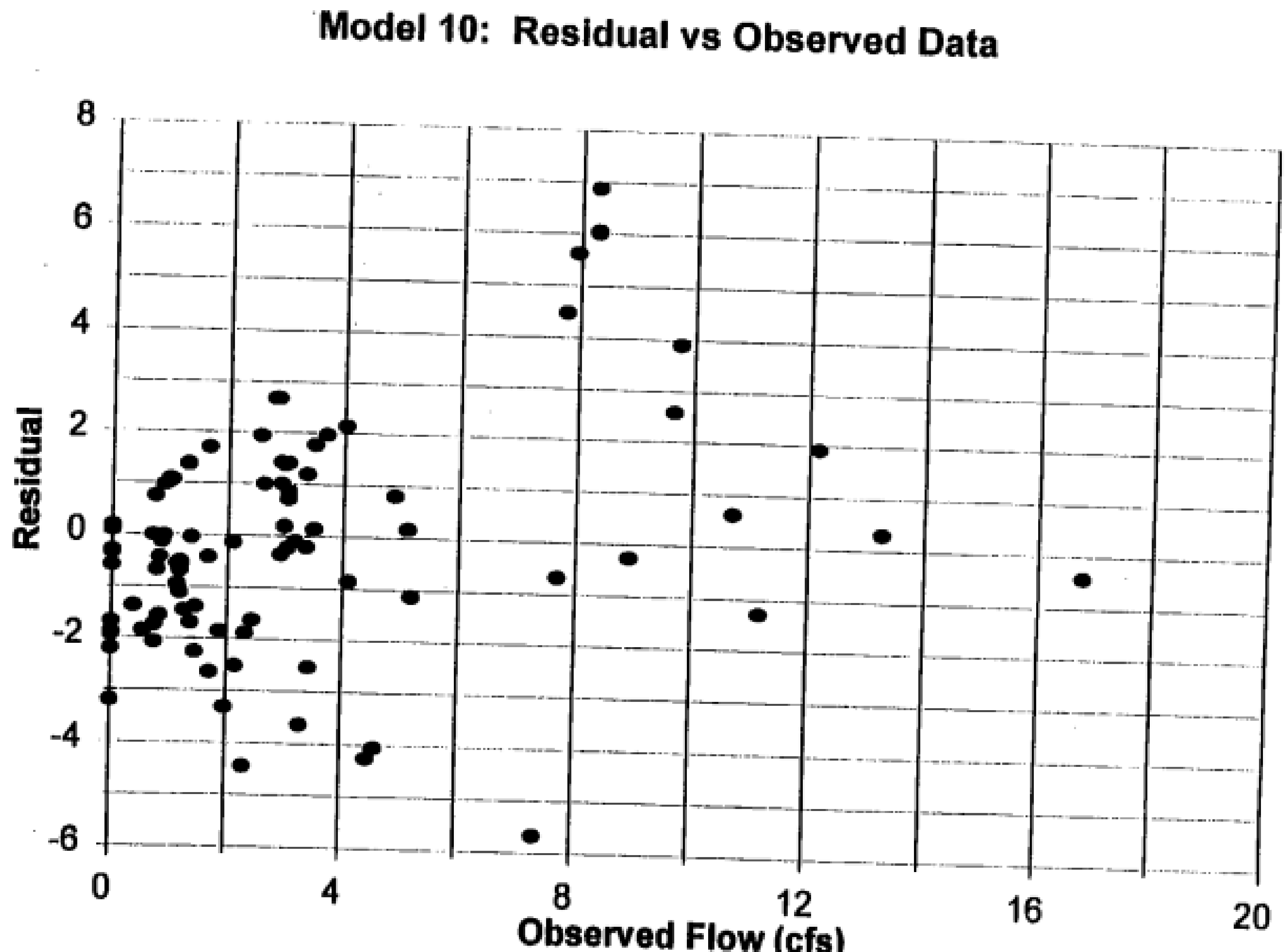
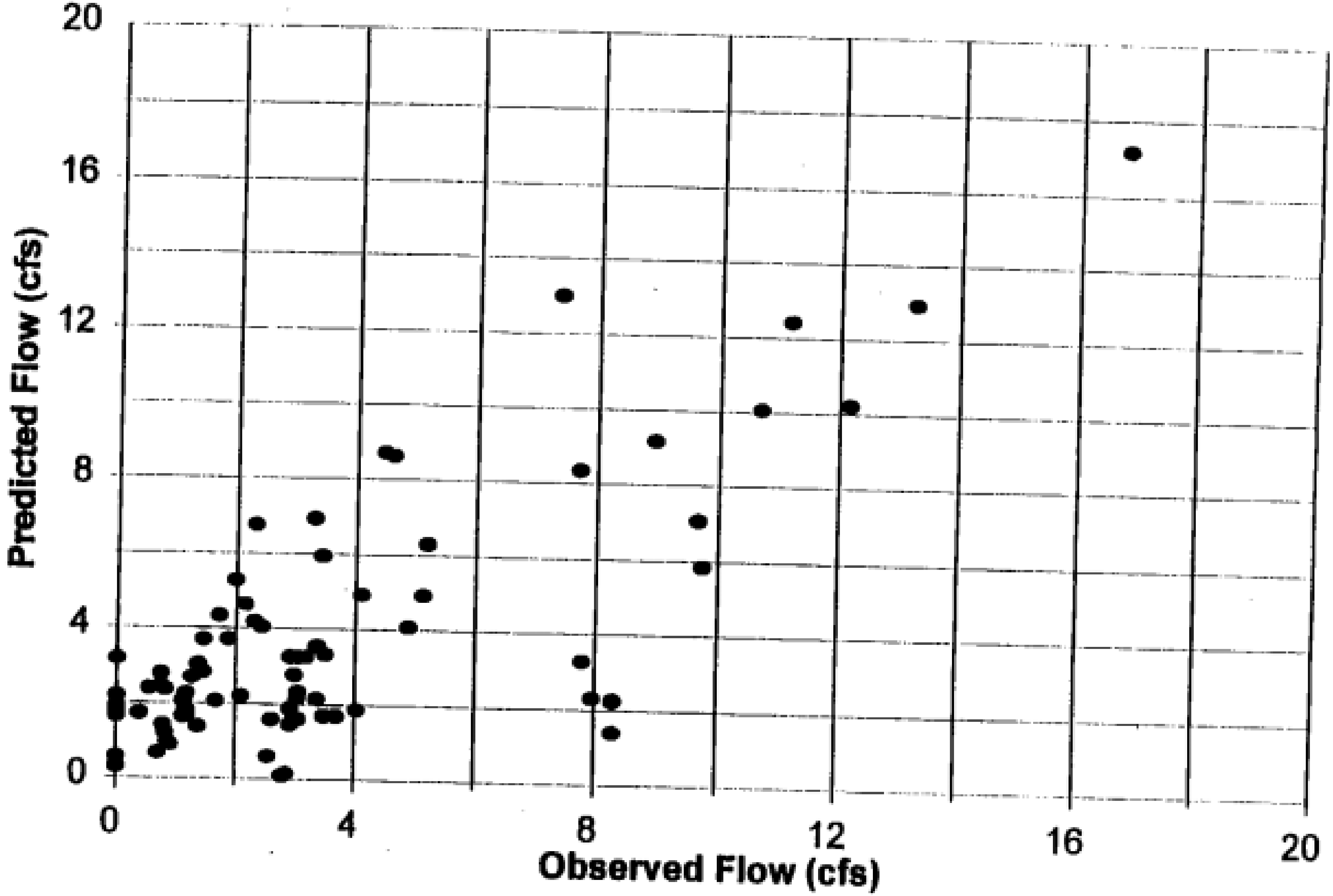

Model 10: Residual vs Observed Data
Residual
8
6
4
2
0
-2
-4
-6
0
4
8
12
16
20
Observed Flow (cfs)

P-2 10

Model 10: Predicted vs Observed Data



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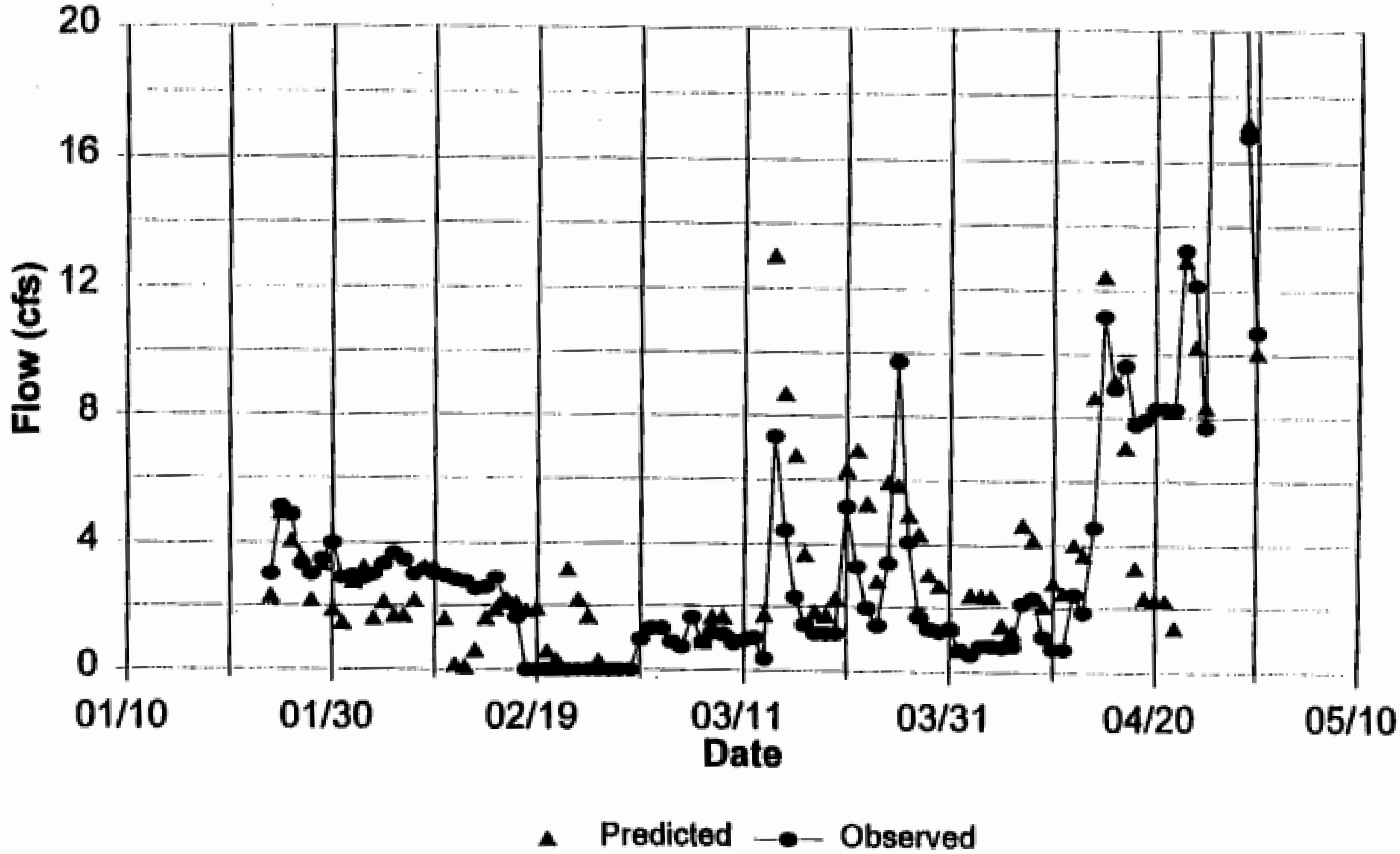
Model 10: Flow versus Time

Predicted and Observed



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APPENDIX P-3

MEMORANDUM (September 9, 1997)

September 9, 1997

\minflow\hrtbc\TBCMIDPL.MEM

MEMORANDUM

TO: File, HRTBC Minimum Flows and Levels

FROM: Michael H. Beach, Professional Engineer, Resource Evaluation MHB

SUBJECT: TBC middle pool regression modeling (1/22/97-4/30/97)

PURPOSE: Investigate relationship of TBC middle pool stage to rainfall, pumping, and ground-water levels when S-162 is closed.

BACKGROUND & ASSUMPTIONS:

1. The TBC middle pool system is that portion of the Tampa Bypass Canal (TBC) downstream of structure S-159, located north of Harney Road, and upstream of structure S-162, located north of Martin Luther King Boulevard. A spur of the middle pool, the Harney Canal, extends one mile west from the main channel to structure S-161. The Harney canal connects the TBC with the City of Tampa's reservoir on the Hillsborough River.

2. The objective of the analysis was to estimate inflows to the middle pool using available data. The principal inflows being investigated were seepage from the ground-water system and runoff. The District would like to carry out yield analysis on the middle pool which requires estimates of inflows for the period of interest.

3. The City of Tampa pumps water from the TBC into the reservoir at structure S-161 during periods of low flow in Hillsborough River. There are two pumps at the structure, each capable of pumping about 20 million gallons per day (Mgd). Either one, or both, may be operated at the same time. Pumping quantities are recorded daily.

4. The investigation period was January 22 through April 30, 1997. During this period structure S-162 was closed allowing no discharge from the middle pool. Divers released sawdust upstream of S-162 below the water surface to reduce flow around the structure gates. There was no other surface discharge from the system for the period. The only outflows were pumping and evaporation. Structures S-159 and S-161 are rarely opened and were closed for the duration of this analysis.

METHOD:

Linear regression models were fitted to the data for the period that S-162 was closed. The models related likely parameters to the dependent variable based on terms from a generalized water budget. The form of the water budget was

$$\text{Change in Canal Volume, dVol} = \text{Inflow} - \text{Outflow}, \quad (1)$$

which was expanded to

dVol = Rainfall + Runoff + Seepage - Discharges - Evaporation - Pumping. (2)

Rainfall represents direct rainfall to the middle pool. The only major outflow for the period was pumping. Surface water discharge was zero and evaporation had been shown to be insignificant in an earlier model of the TBC lower pool. In the early models, the dependent variable was change in volume in the pool plus pumping. Since pumping was part of the dependent variable and there were no other outflows, the right side of the equation would be the total inflows, principally seepage, rainfall and runoff. The quantification of total inflows would be required to construct a yield model of the middle pool. In some later models, the change in volume variable was the sole dependent variable and pumping was the sole dependent variable in one model.

DATA:
All data except withdrawals were available from the District's Water Management Data Base (WMDB). Withdrawal data were available from the District's Regulatory Data Base (RDB) except the most recent data which were obtained directly from the City of Tampa. The time step for the modeling was one day.

Stage data for the middle pool ~~was~~ were available at two locations, S-161 and S-162. Values from these sites were in feet and were averaged for use in the models. Volume and change in volume were calculated from a stage-volume relationship described in the published code of the "Lower Hillsborough Flood Detention Area and Tampa Bypass Canal Flood Routing Model", by H.T. Nguyen (page 92, April 1986, SWFWMD).

Daily pumping data were converted to millions of gallons (Mgal). Daily rainfall data collected at structures S-161 and S-162 were averaged for use in the models and the units were inches. Evaporation data, used in one model, were available from an evapotranspiration site at Dover, about eight miles away. Daily pan evaporation data were in inches and incorporated unchanged from the WMDB.

Seepage was assumed to be a function of one or several head differences from the middle pool stage. Stage data from the City of Tampa reservoir and the lower pool of the TBC as well as ground level data from a nearby well were used to set head differences. The head differences are discussed below.

MODELS:
The regression modeling was carried out on my personal computer using Quattro Pro V6.0 Advanced Regression Analysis function. The Quattro file containing the models is minflow\lrtbc\MIDLPOOL.WB2. There were 20 models developed in the course of the analysis.

There were no explicit data for surface water runoff into the middle pool. It was assumed that rainfall could account for most of the runoff by using one or more lags of rainfall. Although this method will not account for rainfall duration, intensity, frequency, or antecedant conditions, it can provide a reasonable estimate for runoff due to most rainfall events. It is acknowledged that short duration or low intensity rainfall events may produce little or no runoff. Similary, rainfall after long dry spells will produce little runoff initially.

Three head difference parameters were tested. Head difference A was the daily difference of the ground water level minus the middle pool stage. Head difference B was the daily difference of the Hillsborough River reservoir on the upstream side of S-161 minus the stage on the downstream side of S-161. Head difference C was the daily difference of the middle pool stage minus the lower pool stage. The latter difference was assumed to be an outflow from the middle pool.

Head difference A was included in some models to account for general ground-water seepage into the middle pool. The ground-water level for head difference A was from well TBC 2E-SMC. This well is located about two hundred yards east and slightly upstream of S-162. The data set from this well was the only set with no gaps in the period. Additionally, water level values were usually close to the average obtained from area well water levels. A graph of well water levels (Figure 1) shows little variation between five area wells. Head difference B was included in some models to account for a reported seepage from the Hillsborough River reservoir to the TBC at S-161 on the Harney Canal. Head difference C was included in some models because previous modeling of the lower pool had shown a relation between pumping from the middle pool and lower pool stages. Head differences A and B were assumed to produce inflows to the system. The differences were set up so that the middle pool stage would be subtracted from the ground-water level and the Hillsborough River stage, as they were always higher than the middle pool stage and should cause water to flow into the middle pool. Head difference C was assumed to produce flow out of the system because the lower pool was always lower than the middle pool, so the lower pool stage was subtracted from the middle pool stage.

One other parameter included in some of the models was a release from ground-water storage term, dh/dt. This term was assumed to account for the release of ground water from storage into the middle pool. Since a decline in head would release flow from the ground water to inflow into the TBC, the term was set up as the ground water level at TBC 2E-SMC on the previous day minus the ground-water level on the current day.

A summary of the regression models evaluated is shown in the Table 1.

Table 1: Summary of modeling results.

MODEL	Adj R^2	VARIABLES									
		HEAD DIFFERENCE			RAINFALL & LAGS						
		A	B	C	Rain	1st	2nd	dh/dt	Pump	Evap	Vol
1	0.16	S			S						
2	0.43	X			S	S					
3	0.44	X			S	S	X				
4	0.47		S		S	S					
5	+										
6	0.45				S	S					
7	0.51	S	S		S	S					
8*	0.66				S	S					S
9	0.54	X	X	S	S	S				X	
10	0.52		S	S	S	S					
11*	0.83	S			S	S		S	S		
12	+										
13*	0.82				S	S		S	S		
14	0.44				S	S		X			
15	0.46		S		S	S		X			
16	0.43	X			S	S		X			
17*	0.80				S	S			S		
18*	0.62		S		S	S		S	S		
19	0.54	S	X	S	S	S					
20	0.54	S		X	S	S					

* Change in TBC middle pool volume is dependent variable, except Model 5 where pumping is the dependent variable.
X- Variable of model is not statistically significant, α=0.05.
S - Variable of model is statistically significant.
+Models 5 and 12 were not rerun after revisions to the data set. They were not viable prior to the revisions and were not expected to improve after the revisions.

RESULTS:
The models for which change in volume was the sole dependent variable (Models 11, 13, and 17) had distinctly higher adjusted R^2 values than when change in volume and pumping were combined. Models 11, 13, and 17 had very similar adjusted R^2 values: 0.83, 0.82 and 0.80 respectively. The simplest of these models was Model 17 where pumping, rainfall and one lag of rainfall were the independent variables. Model 11 was the same as Model 17 with the addition of head difference A and the ground-water storage term, dh/dt. The Model 11 t-statistics were -2.2 for head difference A and -2.7 for dh/dt, indicating that these parameters were only marginally significant. In Model 13, only the dh/dt term was included with the parameters of Model 17. The t-statistic for daily head change increased to -3.3 but the overall R^2 decreased from that of Model 11. Because the adjusted R for these models was very similar, and the t-statistics for the added parameters were marginal, Model 17 was selected as the better model.

The Model 17 estimated changes in volume, dVol, compare well with the observed changes in volume (Figure 2). Estimated changes in TBC volume versus observed changes in volume are shown in Figure 3. The residuals for Model 17 versus time are shown in Figure 4.

The resulting regression equation for Model 17 is

$$\textbf{Volume Change} = 14.08 + 12.63\textbf{Rainfall}_t + 16.48\textbf{Rainfall}_{t-1} - 0.718\textbf{Pumping}_t \qquad (3)$$

where rainfall is measured in inches and pumping and volume change in million gallons (Mgal). The subscript t indicates the current day and t-1 the first lag. Table 2 lists the t-statistics and the probability that the parameter is zero. Additional summary statistics for Model 17 are shown in Table 3.

TABLE 2: The regression results for Model 17.

Parameter	Coefficient	t Statistic	P-Value
Rainfall (inches)	12.63	6.955	4.29E-10
1st Lag, Rainfall (in)	16.48	9.093	1.32E-14
Pumping (Mgd)	-0.7181	-13.03	0
Intercept (cfs)	14.08	9.608	9.99E-16

A sustainable yield in the absence of rainfall can be derived from the model. If there is no change in volume, on a daily basis then

$$\textbf{Pumping} = 14.08\ \textbf{Mgal}/0.718 = 19.6\ \textbf{Mgal}. \qquad (4)$$

Note that seepage as a function of head difference does not appear explicitly in the resulting regression equation. It can be derived from the water budget equation (2) as follows:

$$\text{Volume Change} + \text{Pumping} = \text{Seepage} + \text{Rainfall}. \qquad (5)$$

If there is no rainfall or runoff, then seepage equals the change in volume and the amount pumped. If volume change is replaced by the regression equation with no rainfall, then

$$\textbf{Seepage} = 14.08 + 0.282\ \textbf{Pumping}. \qquad (6)$$

Probably the constant in the regression equation reflects a loss for evaporation from the middle pool. Some later work indicated that this was about a million gallons per day. So the seepage component may be slightly higher than indicated here.

Finally, the direct rainfall and runoff terms of the water budget are approximated by the rainfall and first rainfall lag term of the regression equation.

CONCLUSION:

A reasonable regression model was developed to explain the relation between changes in volume of the TBC middle pool as a function of rainfall and pumping. The models were developed from data for the period January 22, 1997 through April 30, 1997. At that time there was no surface water discharge through Structure 162 of the middle pool. The only outflow was pumping from the middle pool to the City of Tampa's in-stream reservoir on the Hillsborough River. The best model indicates that a sustained yield of the middle pool in the absence of rainfall would be about 20 Mgd. The model shows that seepage to maintain that yield is equivalent to a constant 14.08 Mgd with additional quantities from drawdown induced by pumping.

The model may not be applicable over longer time periods. The rainfall events here were of relatively small magnitude. Larger and more frequent rainfall events may affect runoff and ground-water levels differently. However, the sustainable yield derived here is probably an absolute minimum. To test the model against larger flows, a simulation of the period from October 1993 through September 1995 will be carried out and the results reported separately.

Attachments: Table (1) and Graphs (4)

Table 3

MODEL 17 **dS (TBC Vol) = a + b*Pumping + c*Rainfall + d*1st Lag of Rainfall**

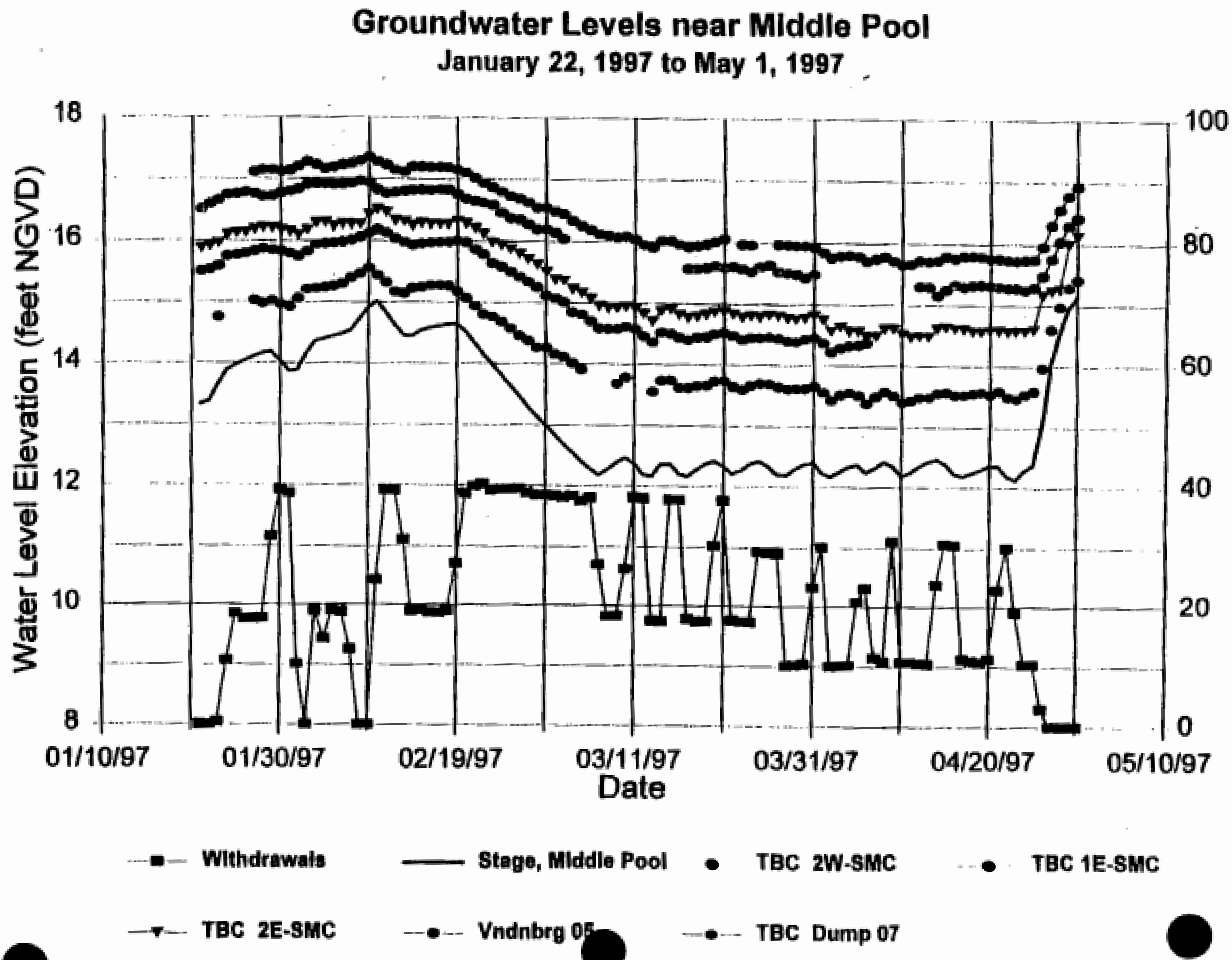
Regression Statistics

Multiple R	0.89897
R Square	0.808148
Adjusted R Square	0.801959
Standard Error	6.356134
Observations	97

Analysis of Variance

	df	*Sum of S*	*Mean Sq*	*F*	*Significance F*
Regression	3	15826.78	5275.592	130.5826	3.18E-33
Residual	93	3757.24	40.40043		
Total	96	19584.02			

	Coefficie	*Standard*	*t Statistic*	*P-value*	*Lower 95*	*Upper 95.00%*
Intercept	14.08111	1.465606	9.607705	9.99E-16	11.17071	16.99152
x1, Pumping	-0.7181	0.05509	-13.0349	0	-0.8275	-0.6087
x2, Rainfall	12.62676	1.815476	6.955069	4.29E-10	9.021587	16.23194
x3, 1st Lag, Rainfall	16.4757	1.811796	9.093572	1.32E-14	12.87783	20.07357



Groundwater Levels near Middle Pool
January 22, 1997 to May 1, 1997
18
16
14
12
10
8
Water Level Elevation (feet NGVD)
100
80
60
40
20
0
Withdrawals (Mgd)
01/10/97
01/30/97
02/19/97
03/11/97
03/31/97
04/20/97
05/10/97
Date
Withdrawals
Stage, Middle Pool
TBC 2W-SMC
TBC 1E-SMC
TBC 2E-SMC
Vndnbrg 05
TBC Dump 07

Figur.

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Model 17: Estimated & Obs dVolume

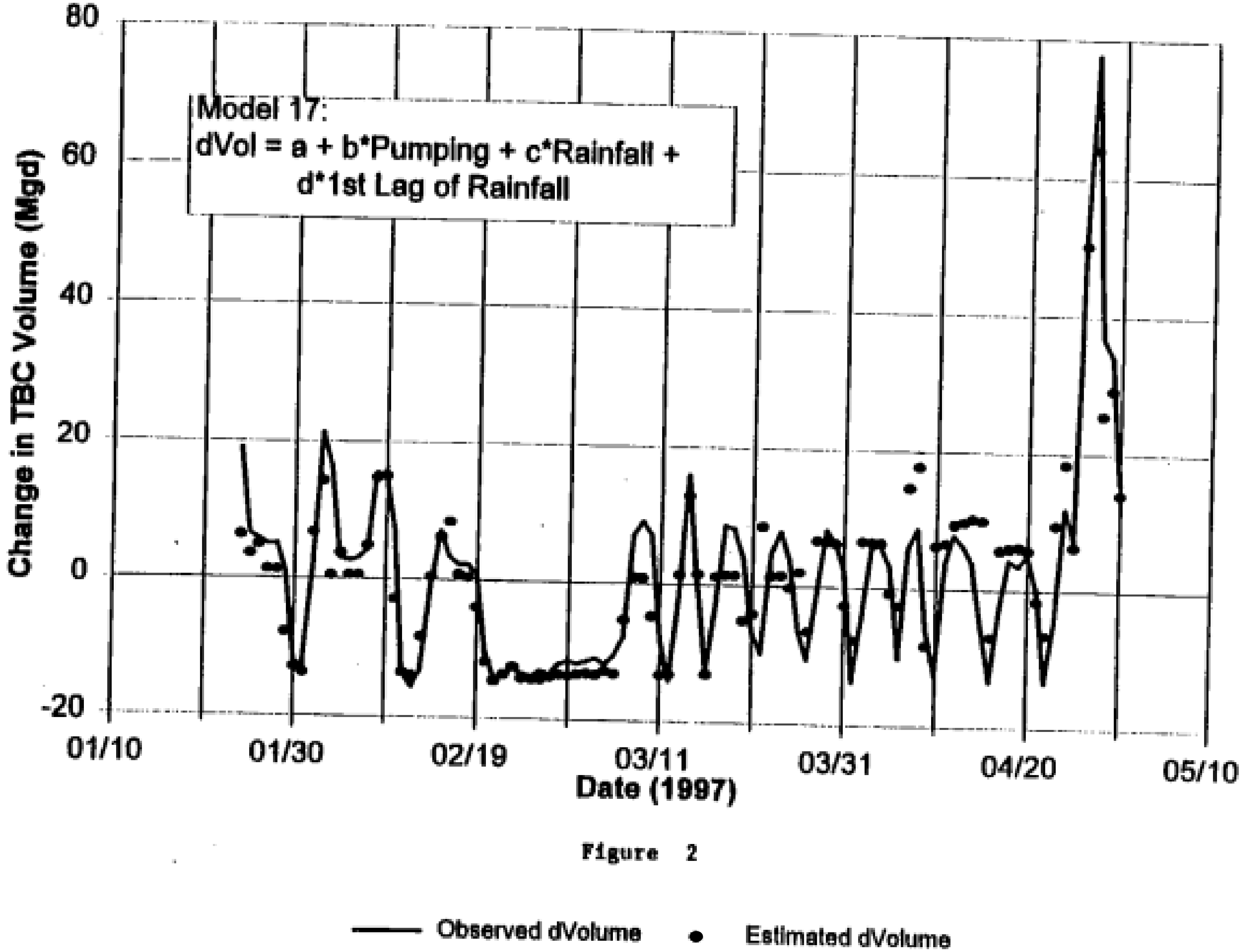

Figure 2

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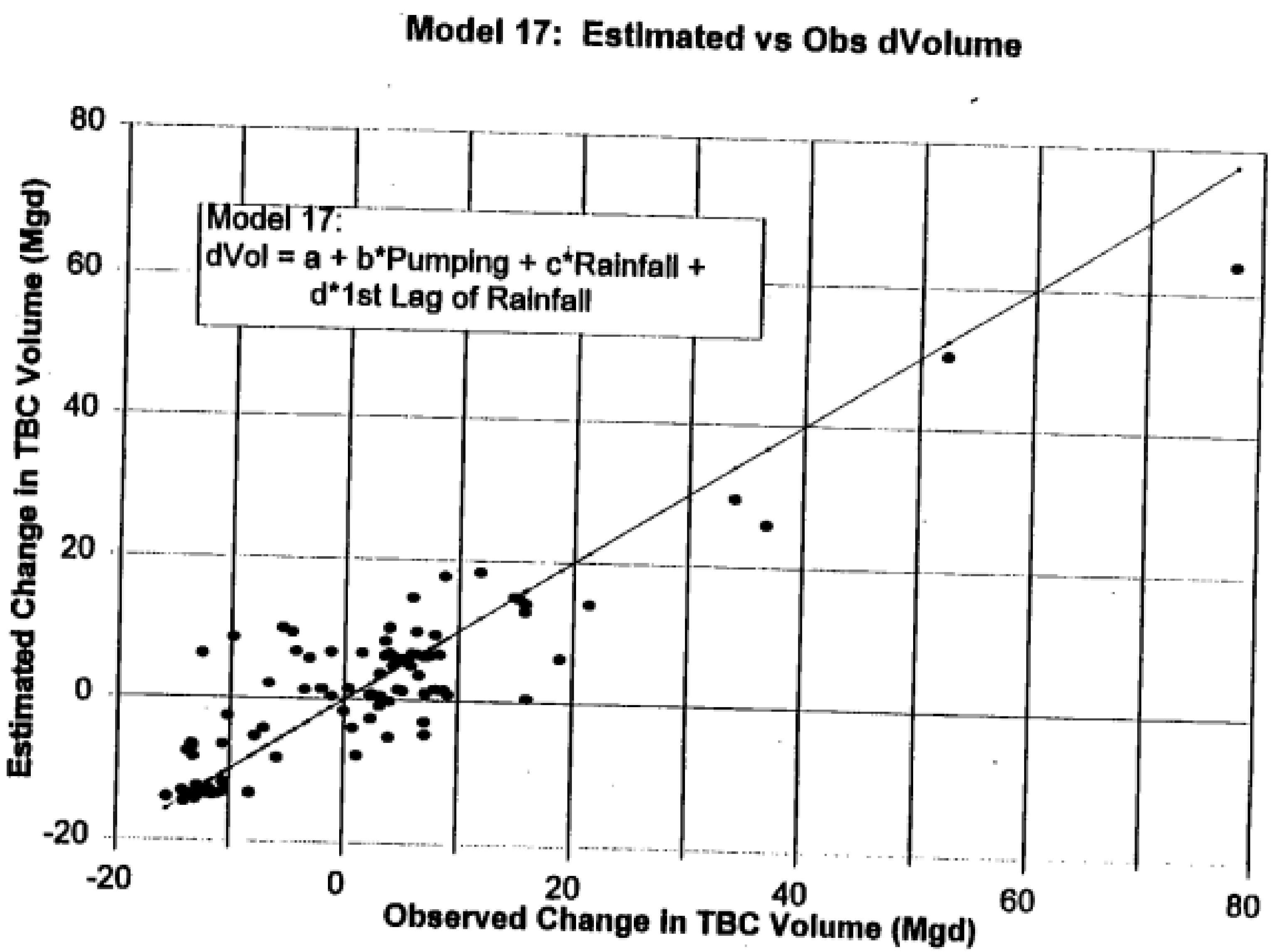

Figure 3

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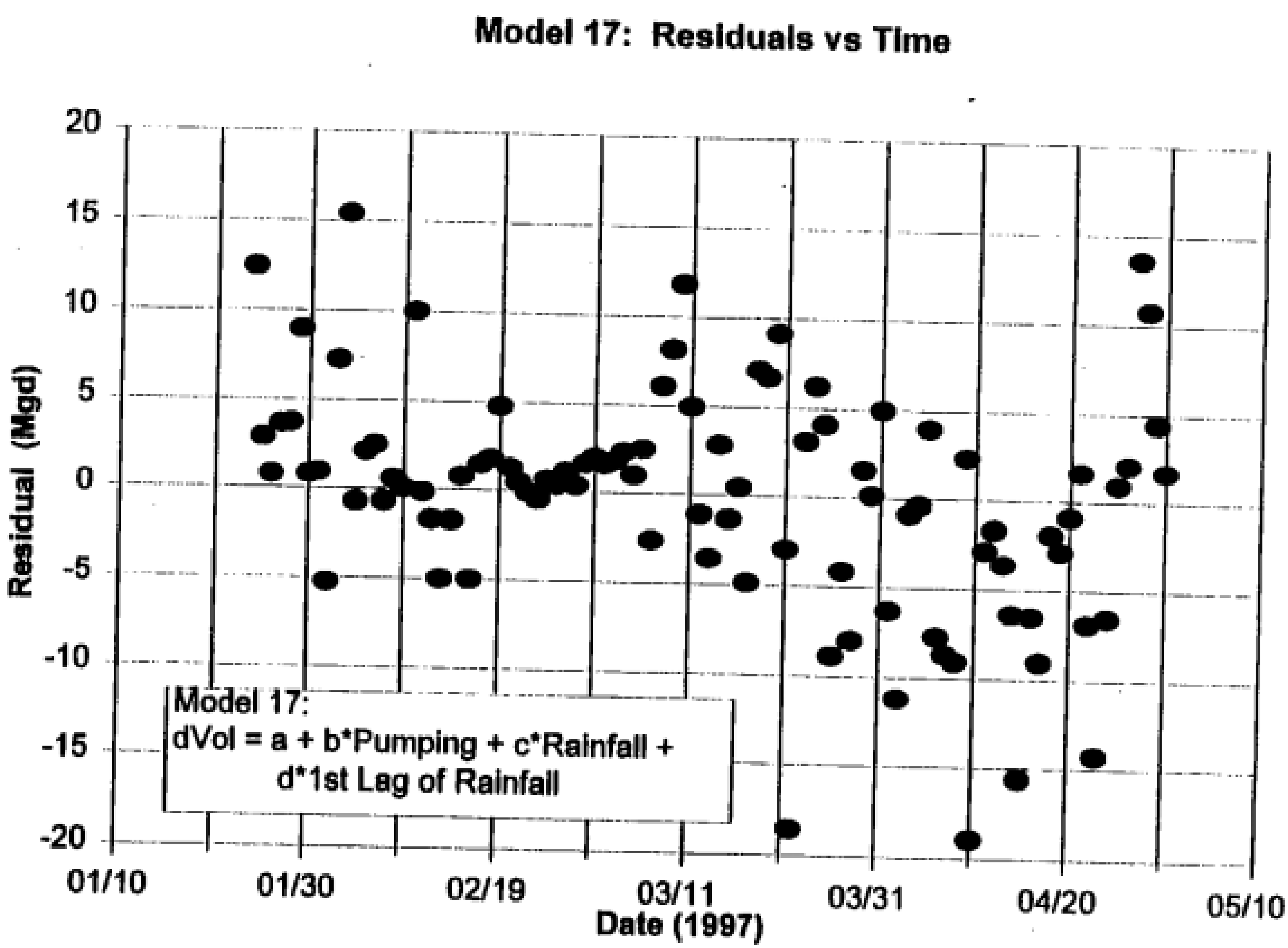

Figure 4

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APPENDIX P-4

MEMORANDUM (October 30, 1997 DRAFT)

October 30, 1997 **DRAFT** \minflow\hrtbc\TBCMPL2.MEM

MEMORANDUM

TO: File, HRTBC Minimum Flows and Levels

FROM: Michael H. Beach, Professional Engineer, Resource Evaluation

SUBJECT: <u>TBC middle pool water budget and regression modeling (10/1/93-9/19/94)</u>

PURPOSE: Investigate relationship of TBC middle pool stage to rainfall, pumping, and ground-water levels during an annual rainfall cycle.

BACKGROUND & ASSUMPTIONS:

1. The TBC middle pool is that portion of the Tampa Bypass Canal (TBC) downstream of structure S-159, located north of Harney Road, and upstream of structure S-162, located north of Martin Luther King Boulevard (Figure 1). A spur of the middle pool, the Harney Canal, extends one mile west from the main channel to structure S-161. The Harney canal connects the TBC with the City of Tampa's reservoir on the Hillsborough River.

2. The objective of the analysis was to estimate inflows to the middle pool using available data. The principal inflows being investigated were seepage from the ground-water system and runoff. The original purpose of the work was to generate a multi-year set of inflows to the middle pool. The inflows would be used to do yield analysis on the middle pool.

3. The original proposed investigation period was 1989 through 1996. However, large gaps in the data reduced the period to water years 1994 and 1995 (October 1, 1993 through September 30, 1995). Although the reduced study period would preclude generating sufficient data for yield analysis, the study would serve as check of previous work which covered shorter time periods.

4. The City of Tampa withdraws water from the TBC to supplement the Hillsborough River reservoir. These withdrawals occur at structure S-161 during low flow periods in the river. There are two pumps at the structure, each capable of pumping about 20 million gallons per day (Mgd). Either one, or both, may be operated at the same time. Pumping quantities are recorded daily by the City of Tampa Water Supply Department.

METHOD:

Water budget and regression models were fitted to the data for the periods October 1, 1993 through September 19, 1994 (Water Year 1994) and October 1, 1994 through September 30, 1995 (Water Year 1995). The approach used regression analysis to estimate seepage and runoff data from other parameters. The method was similar to a previously performed study of this water body for the period 1/22/97 through 4/30/97 (see Memorandum, To: File, HRTBC Minimum Flows and Levels, September 9, 1997), when rainfall was minimal during the period and the middle pool outlet structure, S-162, was closed.

modeling). HdDiffA was the daily difference of the reference ground water level minus the middle pool stage. Head difference A was included in the models to account for shallow Floridan aquifer seepage into the middle pool. The daily-average water level between the shallow Floridan aquifer well SWFWMD West Vandenburg AP and the well TBC-03 Pasture provided the daily reference ground-water level.

Direct evaporation from the middle pool was shown to be insignificant in the earlier model of the TBC lower pool. It can be shown that middle pool evaporation averages about one million gallons per day.

The time step for the modeling was one day.

RESULTS:

The regression modeling computation was done with the Quattro Pro V6.0 Advanced Regression Analysis feature. The Quattro file minflow\hrtbc\TBCMPL2.WB2. contains the models and resides on the author's personal computer. Nine models developed in the course of the analysis. A summary of the regression models evaluated is shown in Table 1.

Table 1: Summary of modeling results.

MODEL	Adj R^2	VARIABLES					
		Pump (t)	Pumping (t-1)	RAINFALL & LAGS			HdDiffA
				Rain	1st	2nd	
A	0.82	S	-	S	S	-	S
B	0.44	S	-	S	S	-	S
C	0.44	S	-	S	S	X	S
D	0.80	S	-	S	S	-	-
E	0.30	S	-	S	S	-	-
F	0.48	S	-	S	S	-	S
G	0.84	S	S	S	S	S	S
H	0.82	S	-	S	S	S	S
I	0.83	S	S	S	S	-	S

X- Variable of model is not statistically significant, α=0.05.
S - Variable of model is statistically significant.
Models A, D, G, H and I are water year 1994; models B, C and E are water year 1995.
Model F is calendar year 1996.

Models A, D, G, H, and I were developed from the water year 1994 data. Models B, C, and E were developed from the water year 1995 data. Model F was based on the calendar year 1996 data. Only the models for the water year 1994 exhibited reasonable results which probably indicates some problems with the data for the other periods.

The most reasonable model was Model A. The estimated and observed sum of the discharge plus change in volume is shown in Figure 3. The coefficient of determination, R^2, was very similar for all the 1994 water year models. Model D is very similar to Model A, but lacks the HdDiffA term. As a result, Model D poorly tracks the base flow of the system (Figure 4). Models G, H, and I attempted to improve Model A by adding a lag of pumping and

The form of the water budget was

Change in canal volume, dVol = Inflow - Outflow, (1)

which was expanded to

dVol = Rainfall + Runoff + Seepage - Discharge - Evaporation - Pumping. (2)

Rainfall represents direct rainfall to the middle pool. Discharge is the outflow through structure S-162. For purposes of regression modeling, discharge was moved to the left-hand side of the equation and dVol plus discharge became the dependent variable. Rainfall and runoff were replaced by rainfall and one or more lags of rainfall. Seepage was related to the head difference between the middle pool stage and a reference ground-water level. The general form for regression was

$$\text{dVol} + \text{Discharge} = a_0 + a_1\text{Pumping} + a_2\text{Head Difference} + a_3\text{Evaporation} + a_4\text{Rainfall} + a_5\text{-}a_n\text{(Rainfall lags)}. \quad (3)$$

DATA:
Most data except withdrawals and S-162 discharge were available from the District's Water Management data base (WMDB). Withdrawal data were available from the District's Regulatory data base (RDB). Discharge from the middle pool through structure S-162 was not explicitly available in the database.

The upstream structures S-161 and S-159 are operated (opened) during major storm events. However, neither the middle pool inflows through these structures nor the gate settings are maintained in the database. The gate operation records have been maintained by the District Operations department in the past but the records are incomplete. Even if the record of operations was complete, the flow equations for these structures have never been calibrated. The missing data prevents multi-year simulation of the middle pool, but some single years are possible.

Volume and change in volume were calculated from a stage-volume relationship described in the report "Lower Hillsborough Flood Detention Area and Tampa Bypass Canal Flood Routing Model", by H.T. Nguyen (page 92, April 1986, SWFWMD). Middle pool stage data was available for structure locations S-161 downstream and S-162 upstream. Daily values from these two sites were averaged for use in the models.

Daily middle pool discharge values through S-162 were derived from other data. Discharge from the lower pool through S-160 consists of inflows from the middle pool at S-162 and flow generated from the lower pool area. Flow through S-162 was calculated as the difference between flow through S-160 and flow generated from the lower pool area. Daily flows through S-160 are available in the WMDB. A regression model (Memorandum, To: File, HRTBC Minimum Flows and Levels, July 14, 1997 (Revised August 4, 1997)) estimated the flow generated from only the lower pool area. The lower pool model was based on the time period January 22, 1997 through April 30, 1997 when structure S-162 was closed (i.e. no discharge into the lower pool).

Daily withdrawals from the TBC by the City of Tampa were obtained from the RDB and were converted to millions of gallons (Mgal). Daily rainfall data from rain gages at structures S-161 and S-162 was obtained from the WMDB. The data was averaged by days to get a daily rainfall for the TBC middle pool and the area contributing to runoff. Daily rainfall data was in inches.

Seepage was assumed to be a function of head difference between the average ground-water levels near the canal and the middle pool stage. Daily ground-water level records for the period of interest were available from three shallow Floridan aquifer wells. Water levels in these three wells were closely linked to water levels in the middle pool of the TBC (Figure 2).

The SWFWMD West Vandenburg AP well is located along the main branch of the middle pool, about 2,000 feet south of the Harney canal, and west of the Vandenburg air port. The well has a reported depth of 37 feet, below land surface, but the casing depth is unrecorded. Land surface at the site is 18.0 feet NGVD. The TBC-03 Pasture well is located about 600 feet east of the canal and about 1,500 feet southeast of Harney Road. This well is 100 feet deep and cased to 37 feet below land surface. Land surface is 36.2 feet NGVD. Daily water levels for a third well, Eureka Springs Deep, were available but not used. This Floridan aquifer well is located about 2,200 feet from the TBC. Locations for these wells appear in Figure 1.

MODELS:

Initial models attempted to simulate the period from 1990 through 1996. The period is characterized by a number of short term, poorly documented inflows as discussed above. Smaller time periods were selected to work around the inflow data difficulty. After reviewing the data, two periods were chosen for simulation: October 1, 1993 through September 19, 1994 and October 1, 1994 through September 30, 1995. The interval between these periods was characterized by a large storm event in which both S-161 and S-159 were operated to divert flow to the TBC.

Surface water runoff into the middle pool was not available from the WMDB. It was assumed that runoff could be estimated in the models from rainfall and one or more daily lags of rainfall. The daily average values from the two sites at S-161 and S-162 were used in the models. Rainfall was entered in inches. This method can provide a reasonable runoff estimate due to most rainfall events, but it will tend to overestimate runoff for low rainfall conditions in which little or no runoff occurs.

The seepage variable was referred to as head difference A (HdDiffA). The term was consistent with its use in the Spring 1997 model (1/22/97 through 4/30/97 middle pool rainfall. All three of these models had slightly better R^2 values and all terms were statistically significant. However, the additional complexity was not warranted by so slight an improvement.

The Model A residuals are plotted versus time in Figure 5. They appear to be uniformly distributed about zero. The median was calculated as 0.202, the mean as −0.0002 and the standard deviation as 14.0.

The resulting expression for Model A is

$$\mathbf{dVol + Discharge = 38.9 - 1.75Pumping + 9.20HdDiffA + 17.4Rainfall_t + 35.8Rainfall_{t-1}}, \quad (4)$$

where volume change, discharge and pumping are in million gallons (Mgal). Rainfall is measured in inches and head difference is in feet. The subscript t indicates the current day and t-1 the first lag. Table 2 lists the t-statistics and the probability that the parameter is zero for Model A. Regression statistics for all the models are attached.

TABLE 2: The regression results for Model A.

Parameter (units)	Coefficient	t Statistic	P-Value
Intercept (Mgd)	38.9	8.76	1.11E-16
Pumping (Mgd)	-1.75	-28.7	0
Head Difference A (ft)	9.20	5.67	3.02E-08
Rainfall (in)	17.4	7.59	2.81E-13
1st Lag, Rainfall (in)	35.8	15.4	0

The direct rainfall and runoff terms of the water budget are approximated by the rainfall and first rainfall lag term of the regression equation.

A relationship for seepage in the absence of rainfall can be derived from the model. Equation (2), the water budget, can be rearranged and related to the right hand side of the expression for Model A.

$$\mathbf{Rainfall + Runoff + Seepage - Pumping = 38.9 + 9.3HdDiffA - 1.75Pumping + 17.4Rainfall_t + 35.8Rainfall_{t-1}}. \quad (5)$$

If there is no rainfall and runoff, seepage can be related to HdDiffA and pumping as

$$\mathbf{Seepage = 38.9 + 9.3HdDiffA - 0.75Pumping}. \quad (6)$$

If this expression for seepage is substituted into the water budget equation, a yield estimate for the 1994 water year can be made. Assume that discharge and dVol are zero and HdDiffA is two feet. Also, assume that rainfall is zero indicating no runoff or direct rainfall inflows. Solving this for pumping suggests a yield of 32.7 Mgd for the 1994 water year.

The constant in the regression equation (4) reflects a loss for evaporation from the middle pool. A review of available data suggests that evaporation was about a million gallons per day. So the seepage component may be a little higher than indicated here.

DISCUSSION

The Model A dependent variable estimates (discharge plus change in volume) tend to regularly under estimate the observed values (Figure 6) when the observed values are greater than 75 million gallons. Reference to Figure 3 will show that dependent variable values greater than 75 million gallons occur only when there are large spikes in the data. The spikes are due to large rainfall events as seen by the large number during the June through September period. The underestimates are due to the averaging nature of the regression process.

Comparison with the Spring 1997 Middle Pool Model

Water Year 1994 (Model A) model was similar to the Spring 1997 middle pool model which was developed for the period 1/22/97 through 4/30/97 (see Memorandum, To: File, HRTBC Minimum Flows and Levels, September 9, 1997). However, the differences are notable. Some of the differences may derive from the different time spans on which each model was based: a year and a full rain cycle for the Water Year 1994 model versus the Spring dry season for the Spring 1997 model. Also, the Spring 1997 model dependent variable was only change in volume (dVol) because structure S-162 was closed to prevent any discharge.

One notable difference is the inclusion of the HdDiffA term in the Water Year 1994 model. Several head difference terms were tried in the Spring 1997 model but none proved to be strongly significant statistically. Spring 1997 withdrawals from the canal were either 20 or 40 million gallons per day everyday except 8 of the 99 days when they were zero, so canal and ground-water levels were strongly correlated to pumping. In the 1994 water year models, pumping occurred less than 30 percent of the year and the head difference term accounts for the baseflow.

Seepage in the Spring 1997 model was generally smaller than the 1994 water year model. When pumping is 40 Mgd in each model, seepage is similar: 25.4 Mgd in Spring 1997 and 27.5 in 1994 water year when HdDiffA was assumed to be 2.0 feet. As pumping is reduced the estimates diverge: seepage decreases in the Spring 1997 model and increases in the Water Year 1994 model. The Spring 1997 model is incapable of generating the 50 to 70 cfs base flows of the 1994 data set. However, the negative sign on the pumping in the seepage expression is puzzling. It might be expected that seepage would be increased by pumping as occurred in the Spring 1997 model. It is possible that the negative pumping is a limit on seepage or may reflect some error in the discharge data. It is unclear from this analysis.

Monthly Water Budgets

Monthly water budgets were developed and the percent error calculated based on this work (Table 3). The error term was sum of the inflows minus the outflows minus the change in volume. Inflows were direct rainfall, ground-water seepage and surface water flows. Direct rainfall was calculated as rainfall times the middle pool average area. Ground-water seepage was calculated from Equation 6. Surface water runoff was calculated from the rainfall terms in the regression equation with direct rainfall subtracted. Outflows were evaporation, withdrawals for public supply and discharge at S-162. Withdrawals and discharge were taken directly from the model data. Evaporation was based on 0.81 times daily pan evaporation rates at the Dover ET station and the average surface area. Evaporation from the middle pool surface averaged 0.84 Mg/d.

Residence Times Estimates

Residence times for flows through the middle pool were calculated for the 1994 water year period. The median residence time was 17.5 days, while the minimum was 12 days and the maximum 29 days.

Residence times were calculated by dividing the average monthly pool volume by the total monthly discharge. Average monthly pool volume was based on the average stage for the period. Monthly discharge was the sum of the daily flows through S-162. As the S-162 flows had been estimated as described above, the monthly water budget errors may be relevant. The monthly residence times are shown in Table 4 with the error estimate from the monthly water budgets. Note that the lowest and two highest residence times were characterized by the largest water budget error. Still, the longest residence times belonged to April and May, typically two of the driest months, and the shortest times were associated with July and August, two of the wettest months. From this, the residence times appeared to be reasonable.

Table 4: Monthly estimates of residence times in the TBC middle pool, Water Year 1994. Time is in days and error is water budget error in percent.

MONTH	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
TIME	14	17	19	16	18	19	26	29	19	12	13	15
ERROR	-6.9	0.2	-2.4	-7.3	1.3	-4.9	14.7	13.4	5.3	-15.3	-0.6	11.8

CONCLUSION:

A water budget model was developed to explain the relation between changes in volume of the TBC middle pool as a function of rainfall and pumping. The model produced an expression for seepage and estimated TBC middle pool yield of 32.7 Mgd for the 1994 water year. The derived seepage was generally greater than the seepage derived from the Spring 1997 model. Water budgets based on this analysis were produced for each month of the 1994 water year. Residence times for flow through the TBC middle pool were found to be between ten and thirty days.

Attachments: Tables (1) and Figures (6)

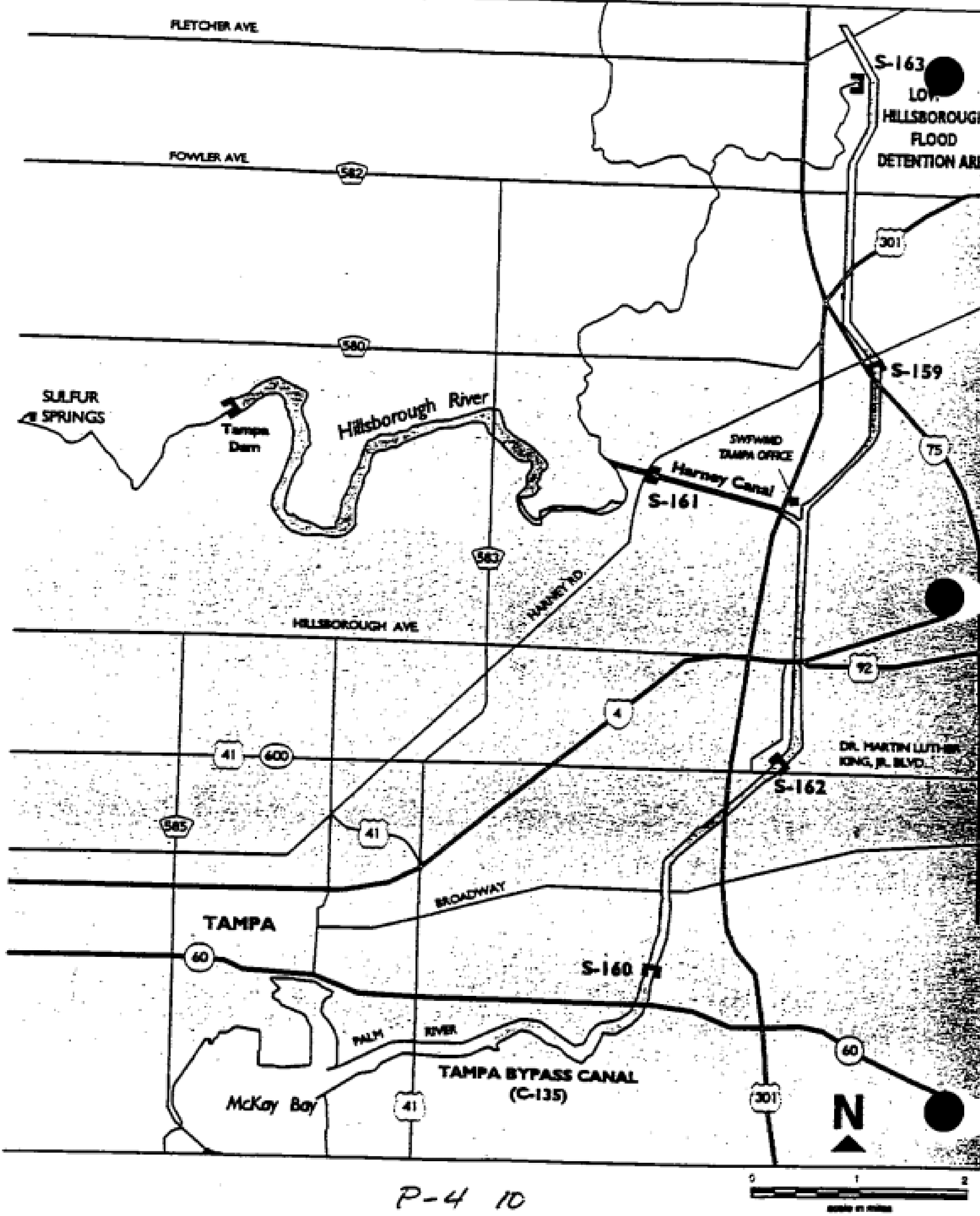
WATER BUDGET

WATER YEAR 1994 (10/1/93 - 9/19/94)

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
INFLOW	Mgal	2269	2009	1766	2033	1726	1539	1423	1300	1925	2448	2566	1655
OUTFLOW	Mgal	2426	2012	1808	2185	1709	1742	1189	1179	1703	2837	2591	1454
dVOL	Mgal	5.3	-7.9	0.8	3	-5.7	-122	42.3	-45.7	126	14.7	-8.4	17
ERROR	Mgal	-162.3	4.9	-42.8	-155	22.7	-81	191.7	166.7	96	-403.7	-16.6	184
% ERROR	N/A	-6.9%	0.2%	-2.4%	-7.3%	1.3%	-4.9%	14.7%	13.4%	5.3%	-16.3%	-0.6%	11.8%
RAINFALL	Inches	2.88	0.36	1.33	2.96	0.55	0.63	3.45	1.48	9.97	10	8.47	4.91

Error = Inflow - Outflow - dVol; % Error = Error / Mean of absolute values of Inflow and Outflow

Configuration of the Tampa Bypass Canal and Hillsborough River Reservoir



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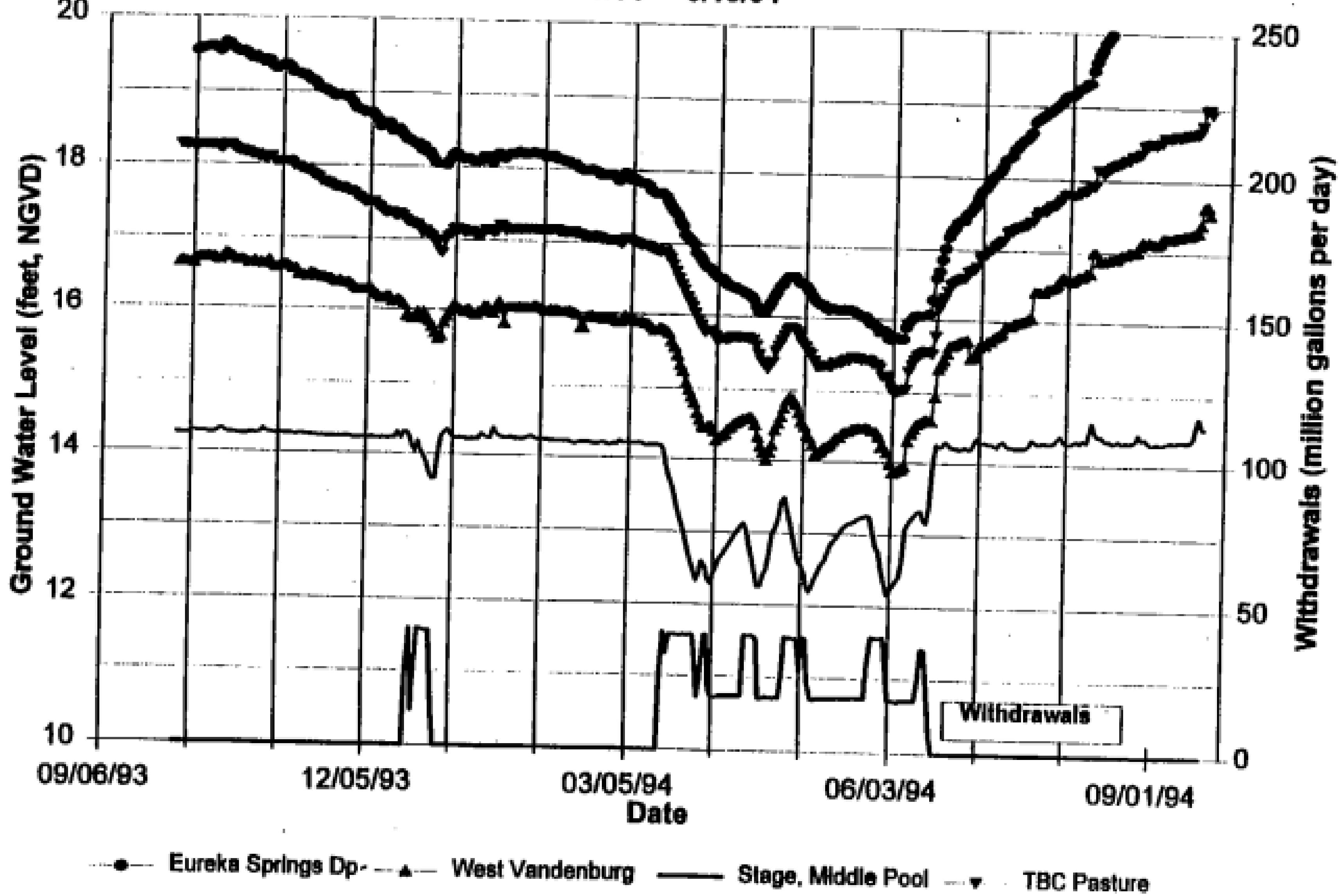
Ground Water Levels
10/1/93 - 9/19/94



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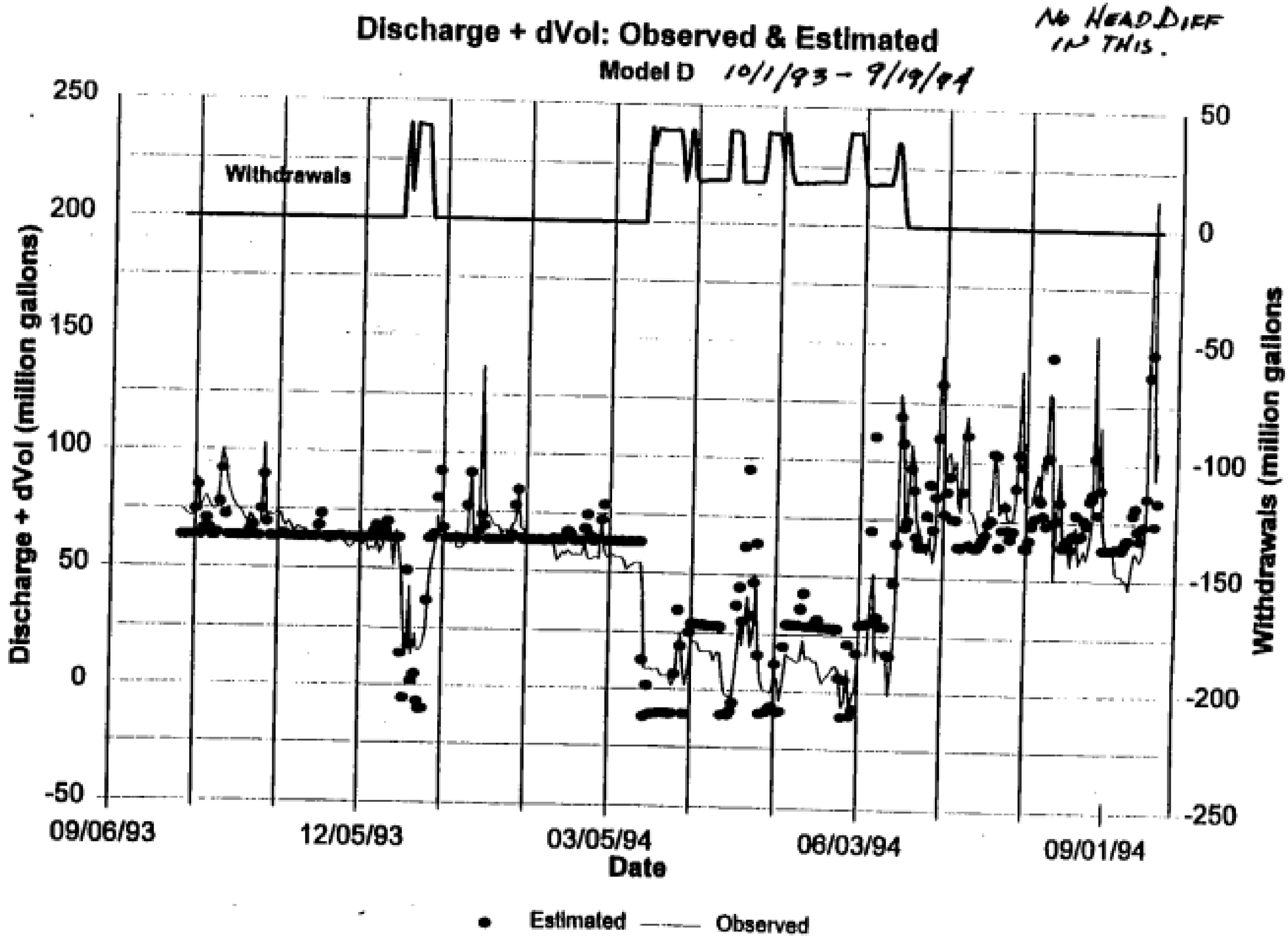

Discharge + dVol: Observed & Estimated
Model D 10/1/93 - 9/19/94
No HEAD DIFF IN THIS.
Withdrawals
Discharge + dVol (million gallons)
250
200
150
100
50
0
-50
Withdrawals (million gallons)
50
0
-50
-100
-150
-200
-250
09/06/93
12/05/93
03/05/94
06/03/94
09/01/94
Date
Estimated
Observed

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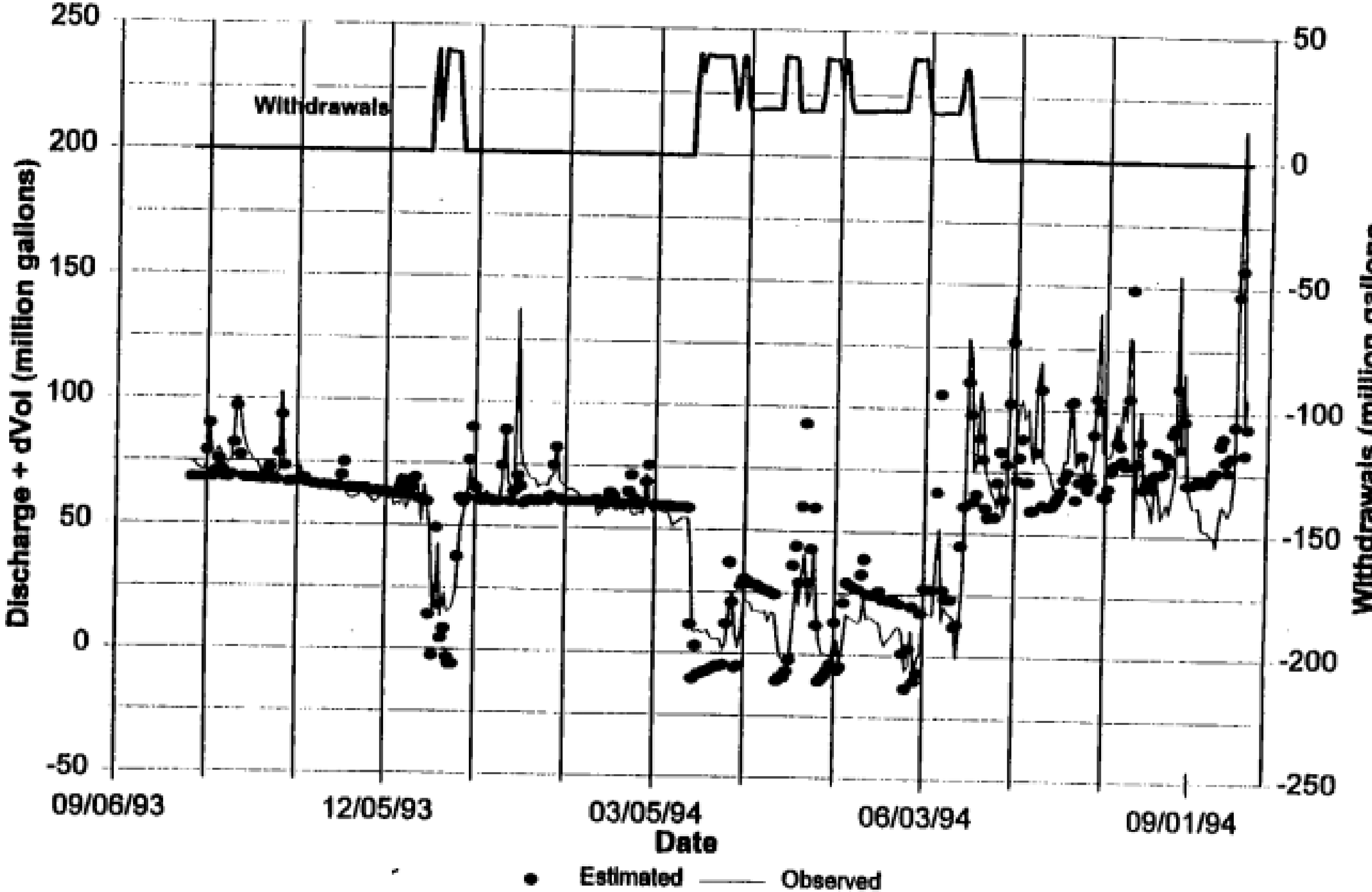
Discharge + dVol: Observed & Estimated

Model A: 10/1/93 - 9/19/94



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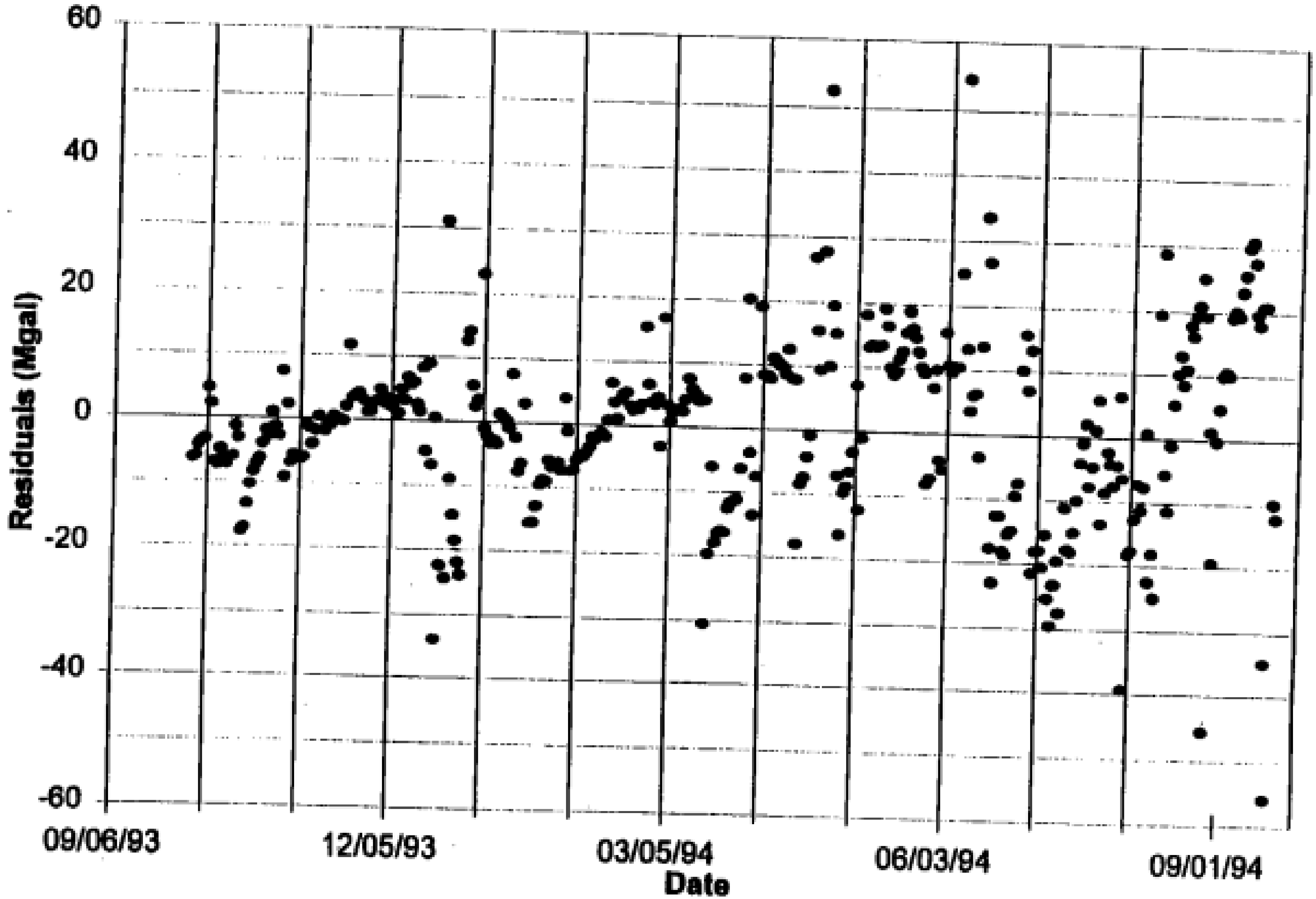
Residuals, Estimated - Observed

Model A: 10/1/93 - 9/19/94



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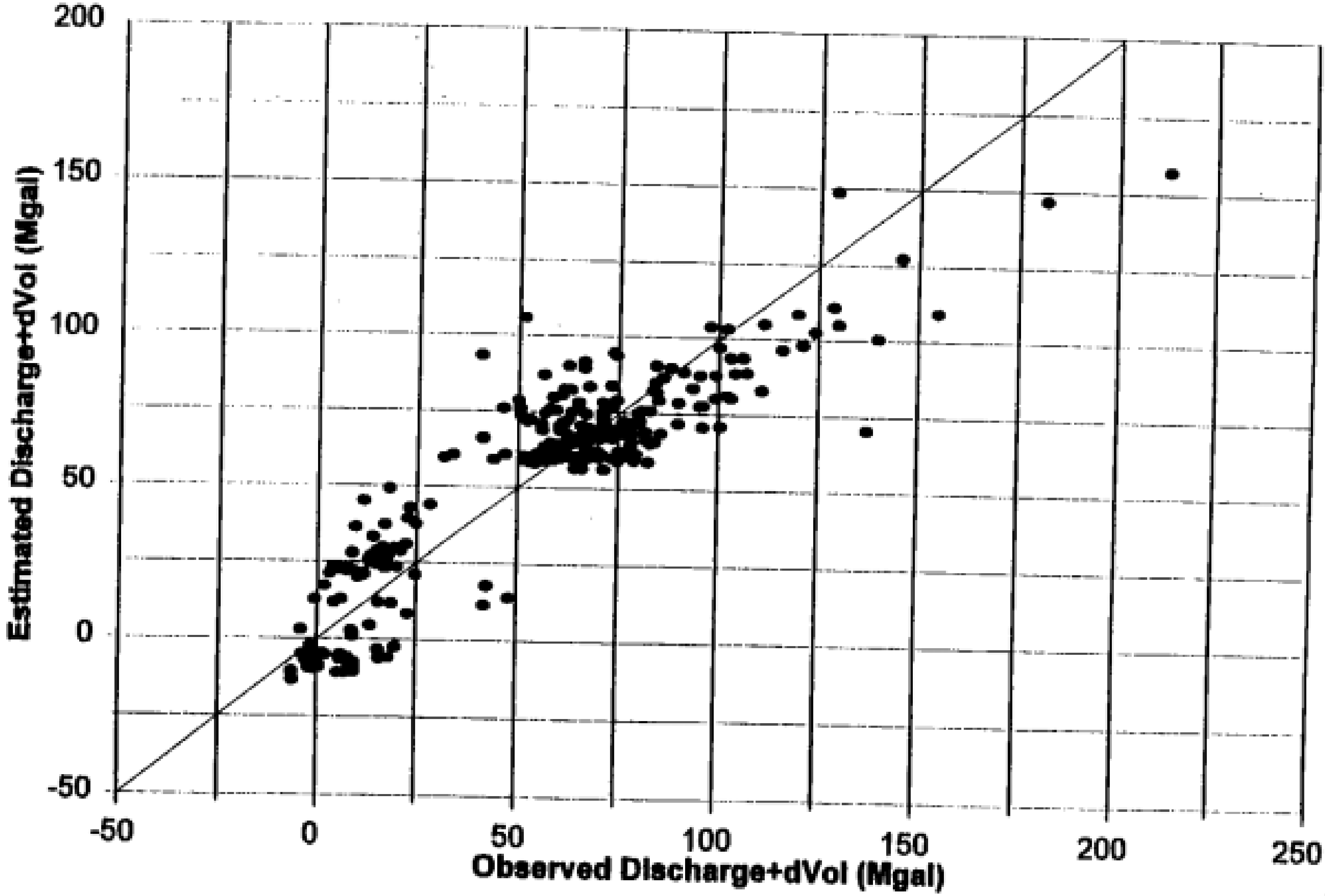
Discharge+dVol: Estimated vs Observed

Model A: 10/1/93 - 9/19/94



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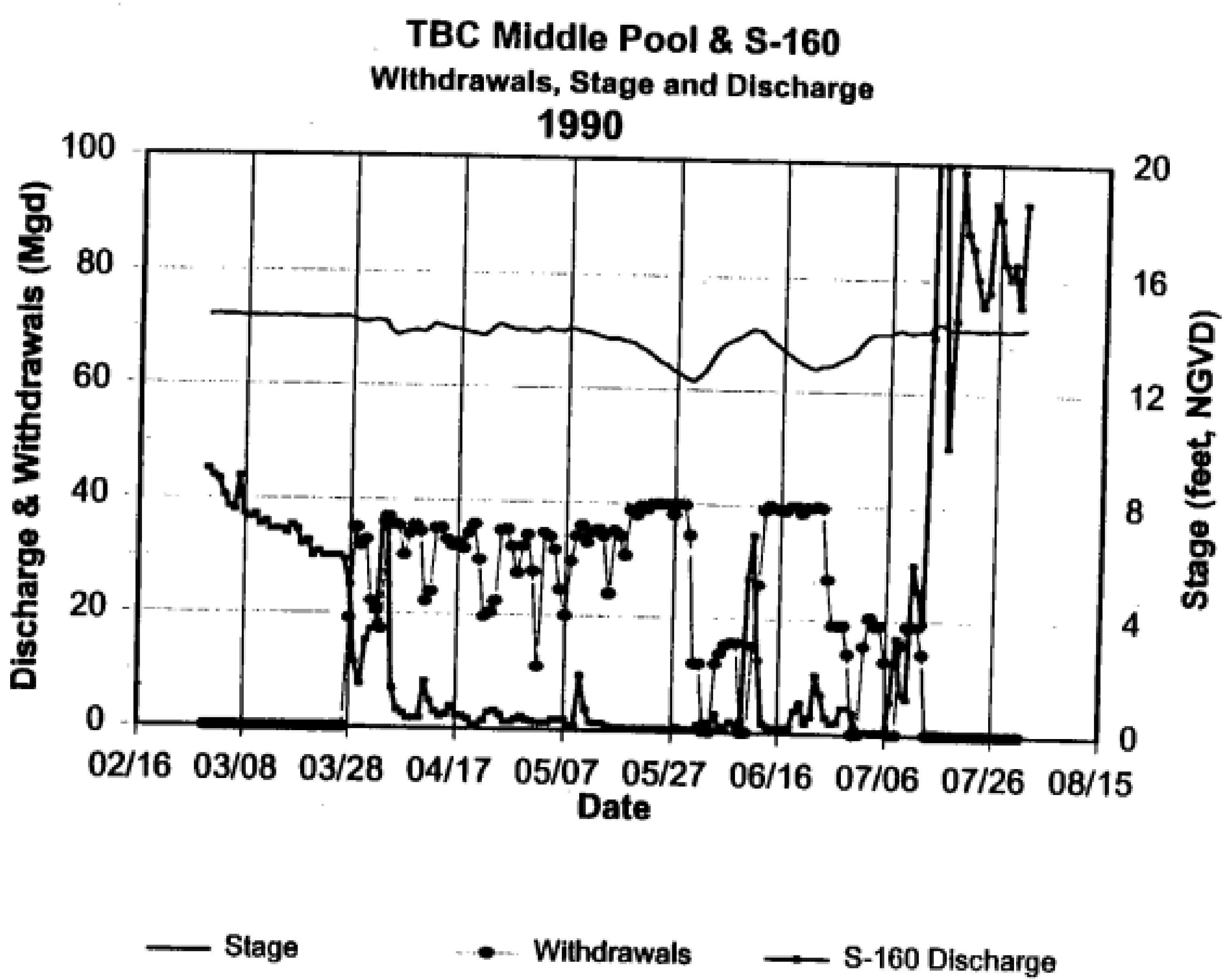
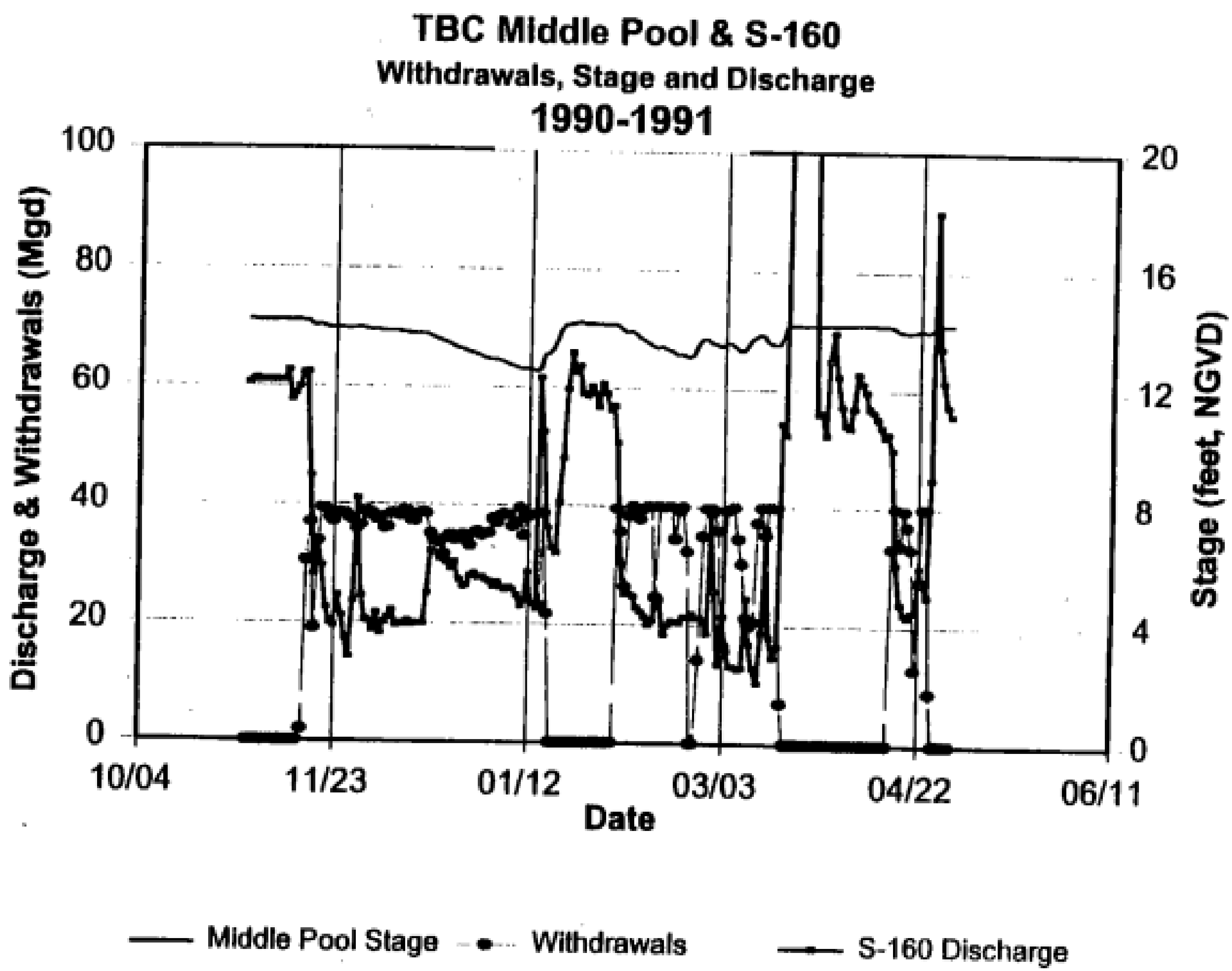
APPENDIX P-5

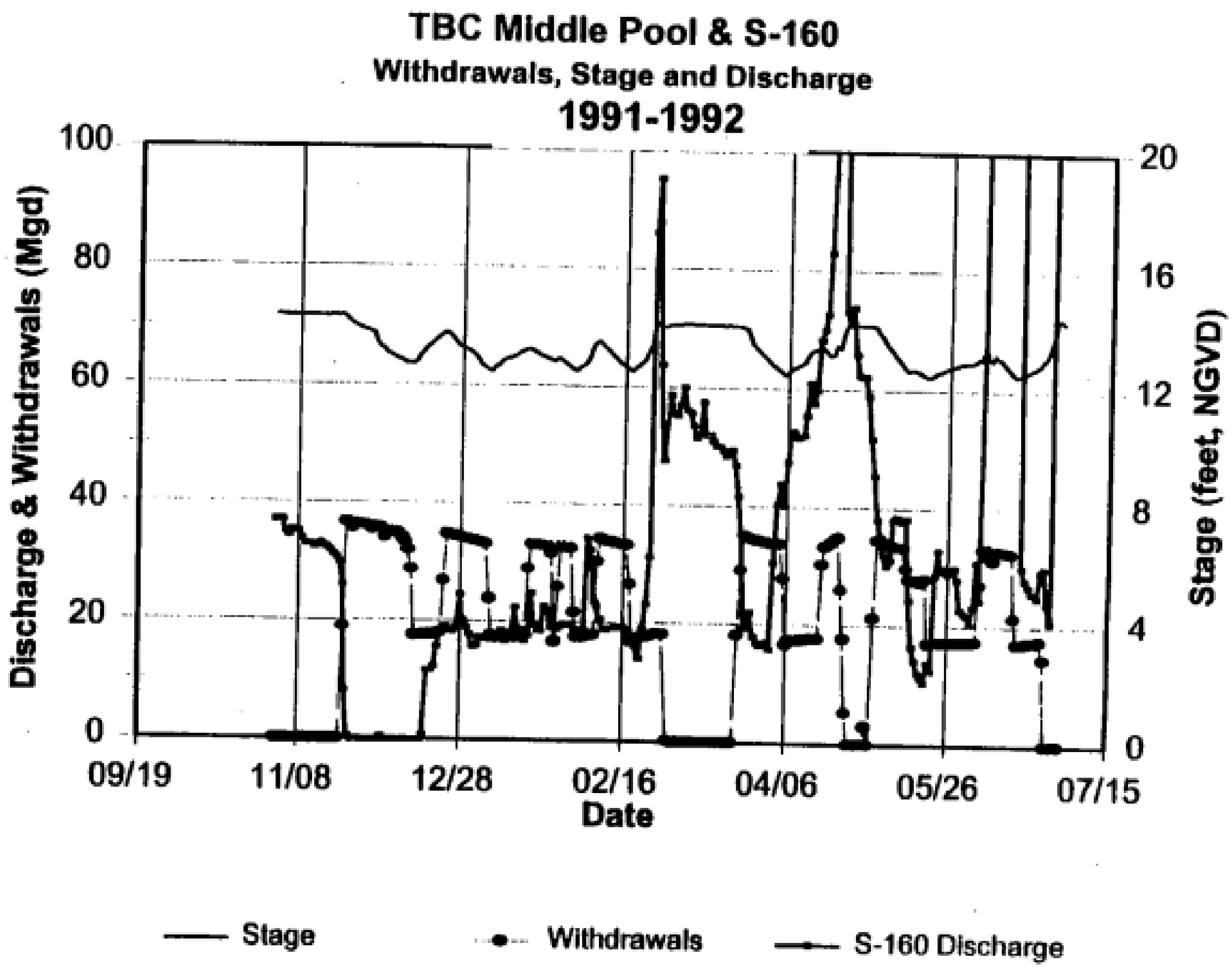
Time Series Graphs of Discharge at S-160, Augmentation Withdrawals from the TBC Middle Pool and Stage of the Middle Pool


TBC Middle Pool & S-160
Withdrawals, Stage and Discharge
1990
Discharge & Withdrawals (Mgd)
100
80
60
40
20
0
Stage (feet, NGVD)
20
16
12
8
4
0
02/16
03/08
03/28
04/17
05/07
05/27
06/16
07/06
07/26
08/15
Date
Stage
Withdrawals
S-160 Discharge

P5-1

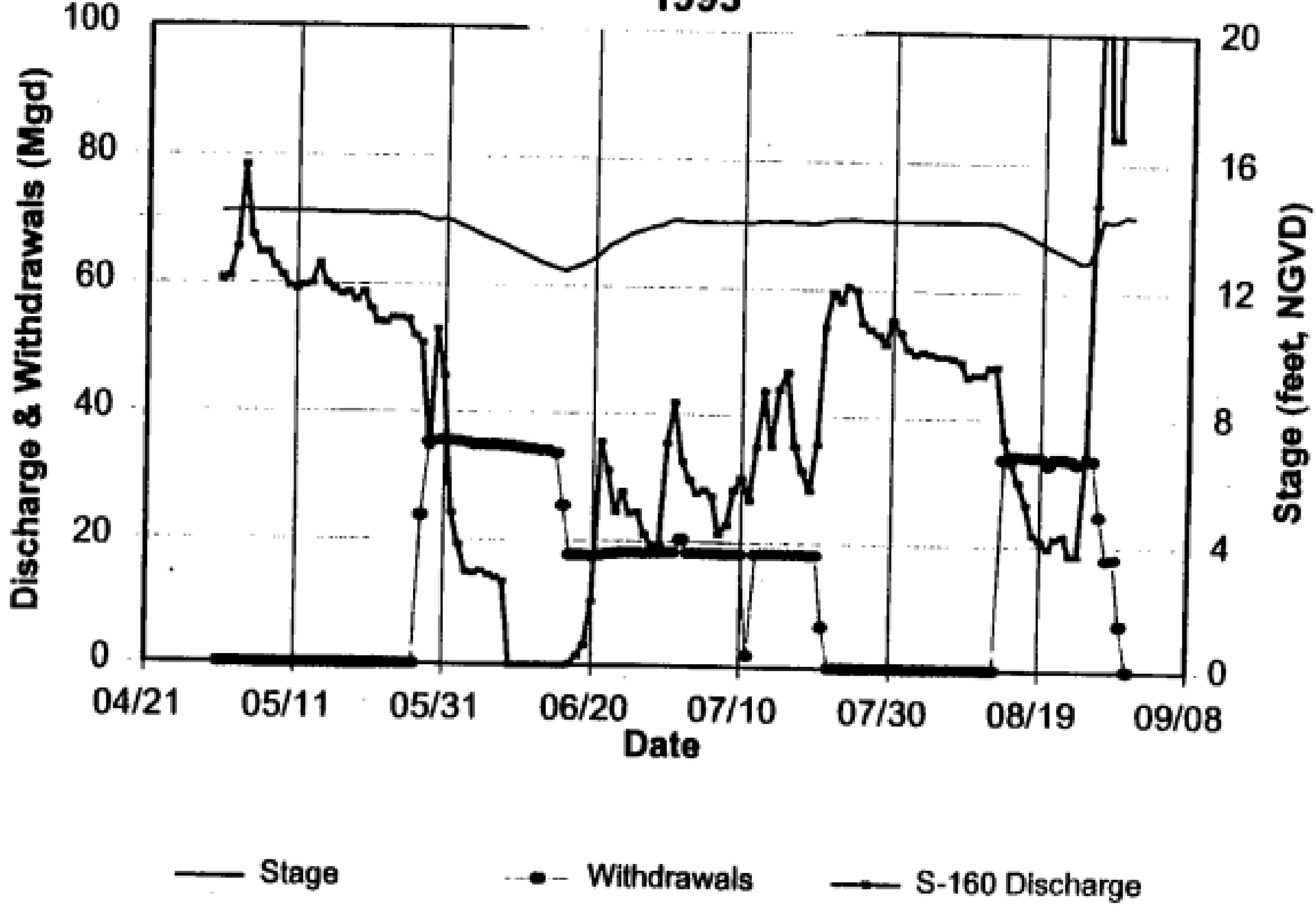

TBC Middle Pool & S-160
Withdrawals, Stage and Discharge
1990-1991
Discharge & Withdrawals (Mgd)
100
80
60
40
20
0
Stage (feet, NGVD)
20
16
12
8
4
0
10/04
11/23
01/12
03/03
04/22
06/11
Date
Middle Pool Stage
Withdrawals
S-160 Discharge

P5-2


TBC Middle Pool & S-160
Withdrawals, Stage and Discharge
1991-1992
Discharge & Withdrawals (Mgd)
100
80
60
40
20
0
Stage (feet, NGVD)
20
16
12
8
4
0
09/19
11/08
12/28
02/16
04/06
05/26
07/15
Date
Stage
Withdrawals
S-160 Discharge

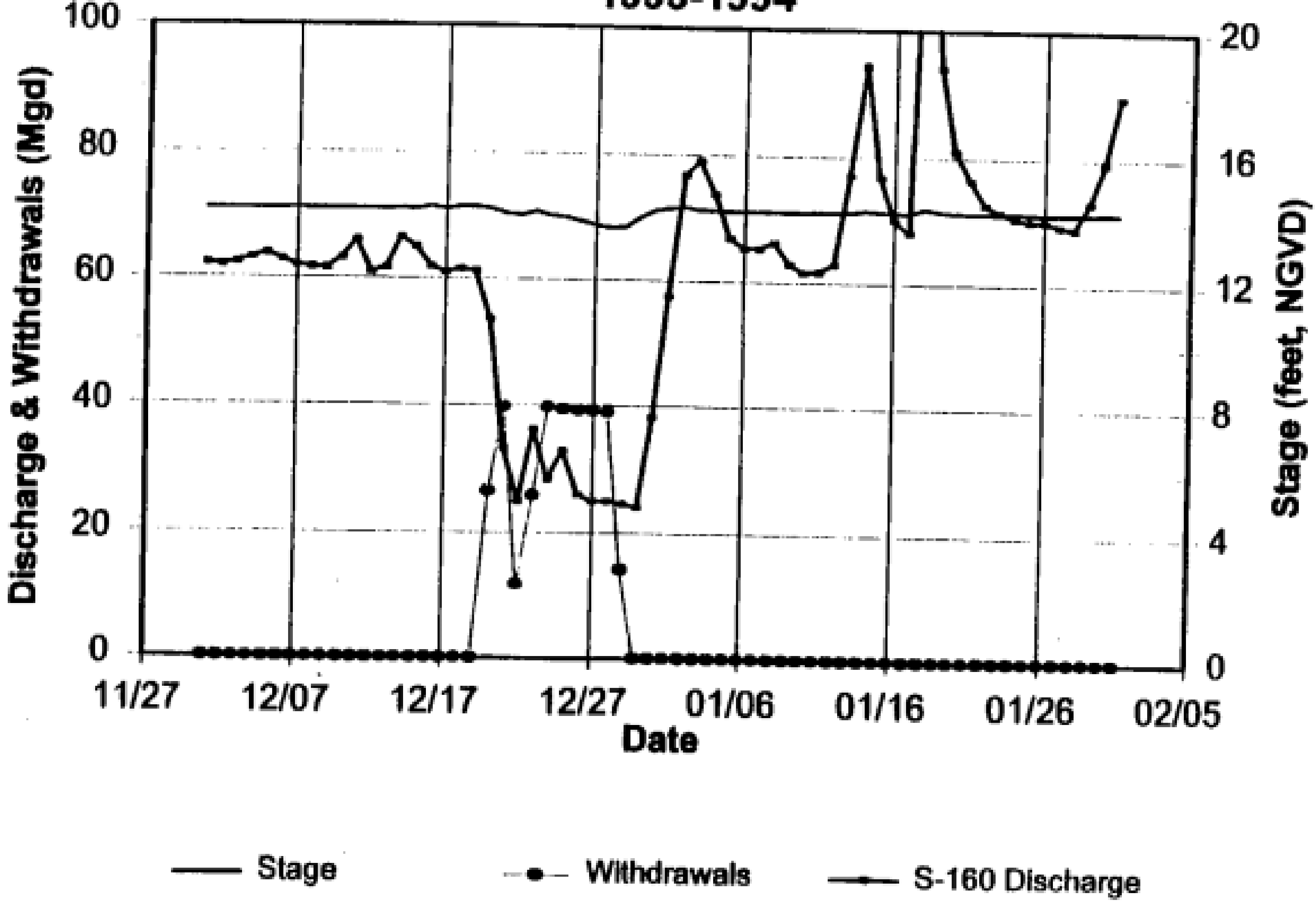
P5-3

TBC Middle Pool & S-160
Withdrawals, Stage and Discharge
1993

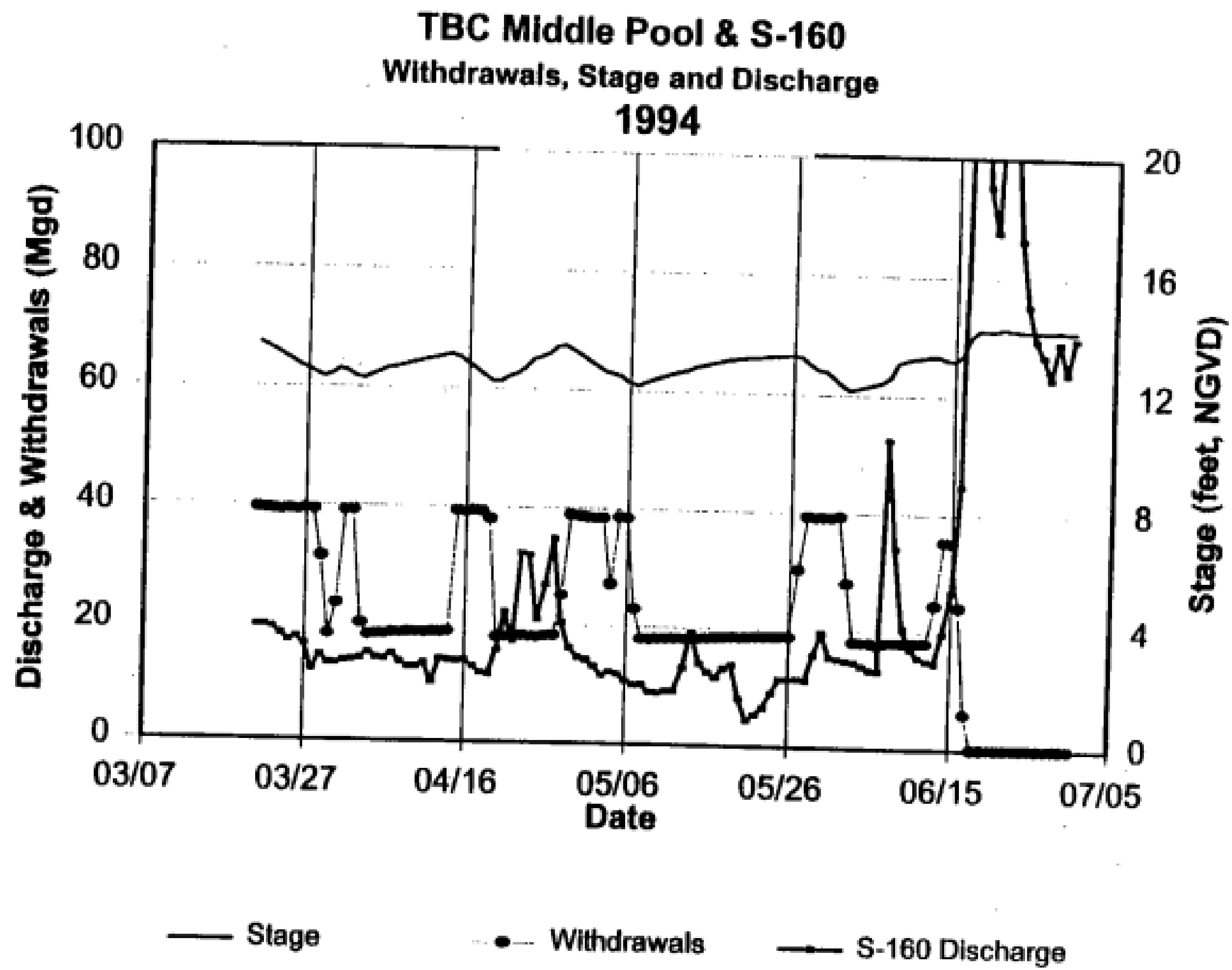


P5-4

TBC Middle Pool & S-160
Withdrawals, Stage and Discharge
1993-1994

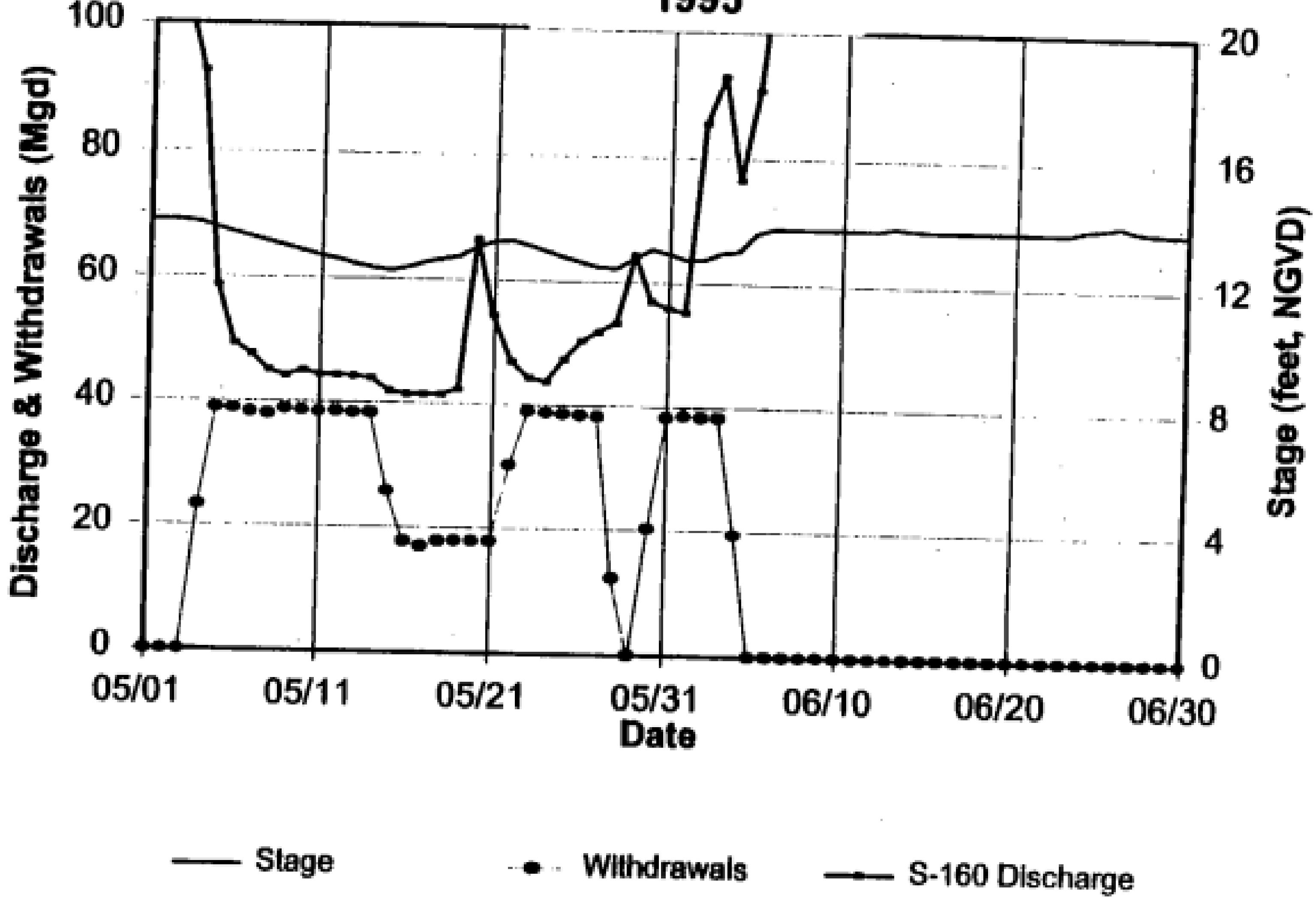


PS- 5

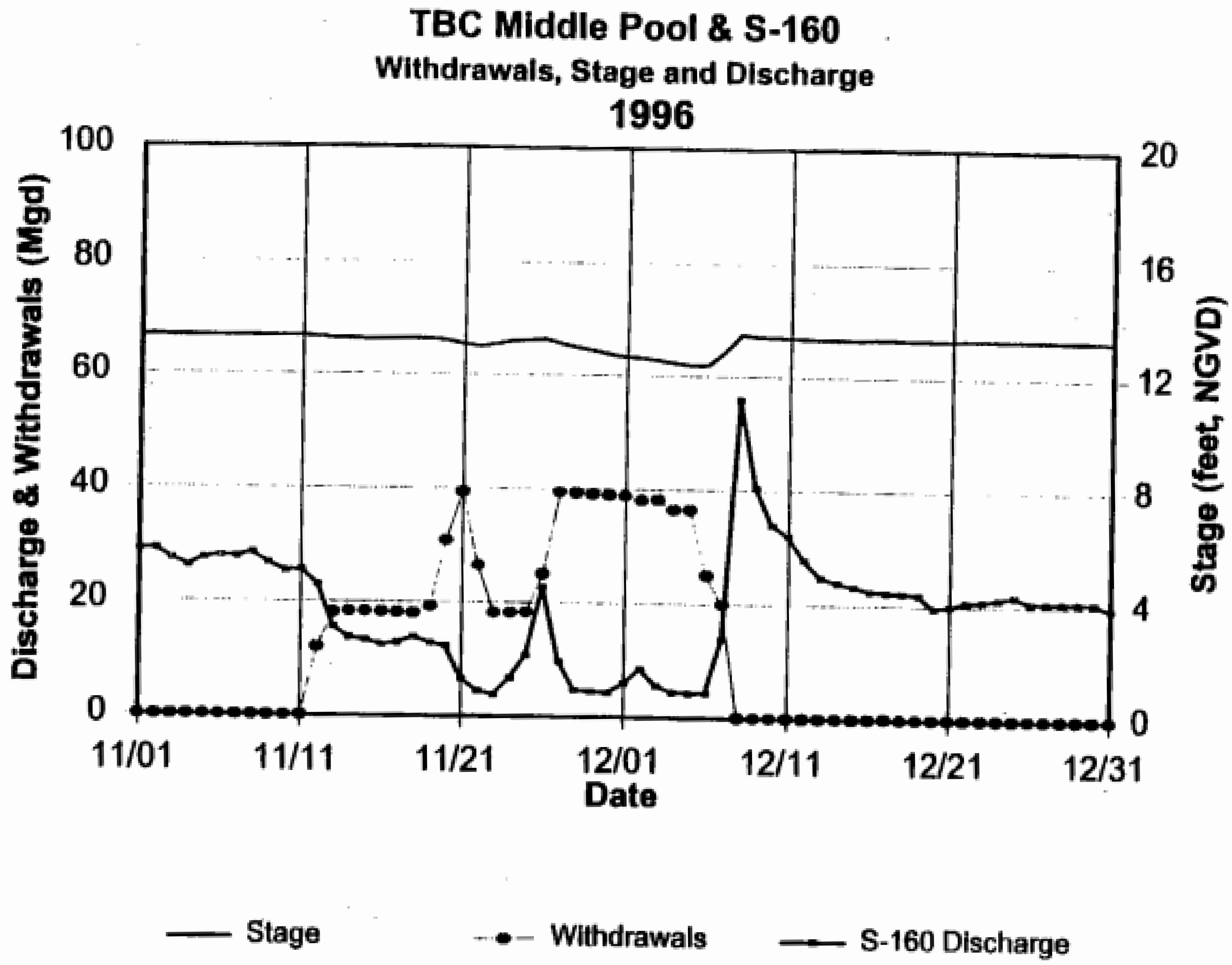

TBC Middle Pool & S-160
Withdrawals, Stage and Discharge
1994
Discharge & Withdrawals (Mgd)
100
80
60
40
20
0
Stage (feet, NGVD)
20
16
12
8
4
0
03/07
03/27
04/16
05/06
05/26
06/15
07/05
Date
Stage
Withdrawals
S-160 Discharge

P5-6

TBC Middle Pool & S-160
Withdrawals, Stage and Discharge
1995



PS-7


TBC Middle Pool & S-160
Withdrawals, Stage and Discharge
1996
Discharge & Withdrawals (Mgd)
100
80
60
40
20
0
Stage (feet, NGVD)
20
16
12
8
4
0
11/01
11/11
11/21
12/01
12/11
12/21
12/31
Date
Stage
Withdrawals
S-160 Discharge

P5-8