A HYDROLOGIC STUDY OF A SMALL SUBURBAN WATERSHED

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ABSTRACT

A 126 acre tract of land in a natural undisturbed state and the adjacent 239.3 acres that made up the watershed, were instrumented in November, 1971, in order to determine the effect of development on the hydrology of the 126 acre tract. Hydrologic quantity and quality data were collected until April, 1975.

The tract, which is located in Tampa, Florida, did not experience the planned extensive development due to financial problems of the developer. Consequently, the anticipated major hydrologic changes did not occur. However, significant alterations to the natural drainage pattern of the property were made and these caused changes in the runoff quality which were documented.

ACKNOWLEDGMENT

The authors wish to express their sincere appreciation to those who gave of their time and talent to make this report possible: Miss Paula Jerkins, Mrs. Sally Hammer, Mr. Robert Moresi, Mr. Tom Roskay, Mr. Charles Palmer, Jr., and many others too numerous to mention, who provided physical labor to install and maintain the structures and instruments, and those in other colleges who contributed their special knowledge for the collection and analysis of chemical and biological data.

Thanks are also extended to the developers who co-operated fully with this study. They showed a genuine interest in the results, whether good or bad, from their point of view. Their property was available without question to the many students who took part during the data collection phase of this study.

1. INTRODUCTION

The purpose of this project was to document the changes in the quality and quantity of stormwater runoff from a watershed which was to be developed from a natural state into a high density apartment complex.

In order to accomplish this, rainfall gages, an evaporation gage, and flow measuring devices were installed within the watershed area, from which daily hydrologic data were obtained. In addition, water quality measurements were taken at the drainage exit of the study area. The parameters measured were dissolved oxygen, pH, carbon dioxide, temperature, hydrogen sulfide, color, turbidity, metaphosphate, orthophosphate, nitrate, nitrite and coliform count.

Shallow aquifer test wells were installed and monitored in order to establish ground water flow directions, ground water storage changes and ground water quality changes.

Initially it was anticipated that the entire watershed being studied would be developed into a relatively high density apartment/townhouse complex. Due to the present slump in the housing industry less than 15% of the watershed was actually developed. The majority of these 64 units are still unoccupied. Therefore, the anticipated extensive quality and quantity changes in storm runoff did not occur. However, unexpected construction activities have caused hydrologic changes which have been documented.

A major change occurred in the watershed during the initial phase of the investigation. A fifty-four inch diameter pipe was installed under the state highway which originally provided the southern hydrologic boundary for the study area. This necessitated an expansion in size of the study area and a relocation of gages. A portion of the region which is drained by use of this pipe consists of a medium density apartment complex. Data pertaining to the quality and quantity of storm runoff passing through this pipe have been obtained. On two occasions water quality measurements were taken at spaced time intervals throughout the storm, and quantities of pollutants per unit area were determined.

During the final year of the study a small shallow lake on the property was greatly enlarged and deepened. The discharge from the study area was then routed by the developer into this lake rather than through the existing natural drainage channel. Water quality changes in the lake during this time have been recorded.

2. DESCRIPTION OF AREA

The watershed chosen for this study is located near latitude 28° 04' north and longitude 82° 23' west on the west central coast of Florida. This is approximately 1.5 miles east of the University of South Florida, as shown on Figure 1.

The climate of the region is basically subtropical characterized by long humid summers and mild winters. It is strongly influenced by winds from the Gulf of Mexico. Variations in day to day maximum temperatures during the summer range from about 72°F to 90°F and during the winter from about 55° to 75°F with average daily temperature of 72°F.

Precipitation is highly variable in frequency distribution, distribution, amount, and intensity, due to frontal storms, local thunderstorms and tropical hurricanes. The normal annual precipitation is approximately 55 inches and is unevenly distributed with more than half falling from June to September.

The Tampa Bay Region is currently experiencing the worst drought in the history of the Tampa weather station. The drought which began in 1961 is still continuing. In Table I the annual rainfall departure from normal and accumulative deficiency for the past fourteen year period is shown.

This extended drought is particularly significant to this study because of the high evapotranspiration in the area. On the average for this region approximately 70% (37-40 inches) of the annual rainfall becomes evapotranspiration, while approximately 27% (15 inches) drains off by way of surface drainage, and the remainder goes into groundwater flow. During extended dry periods, the percentage of surface runoff decreases because of markedly increased surface storage and the evapotranspiration rate remains fairly constant. This causes difficulty in obtaining representative runoff hydrographs and documenting normal lag times.

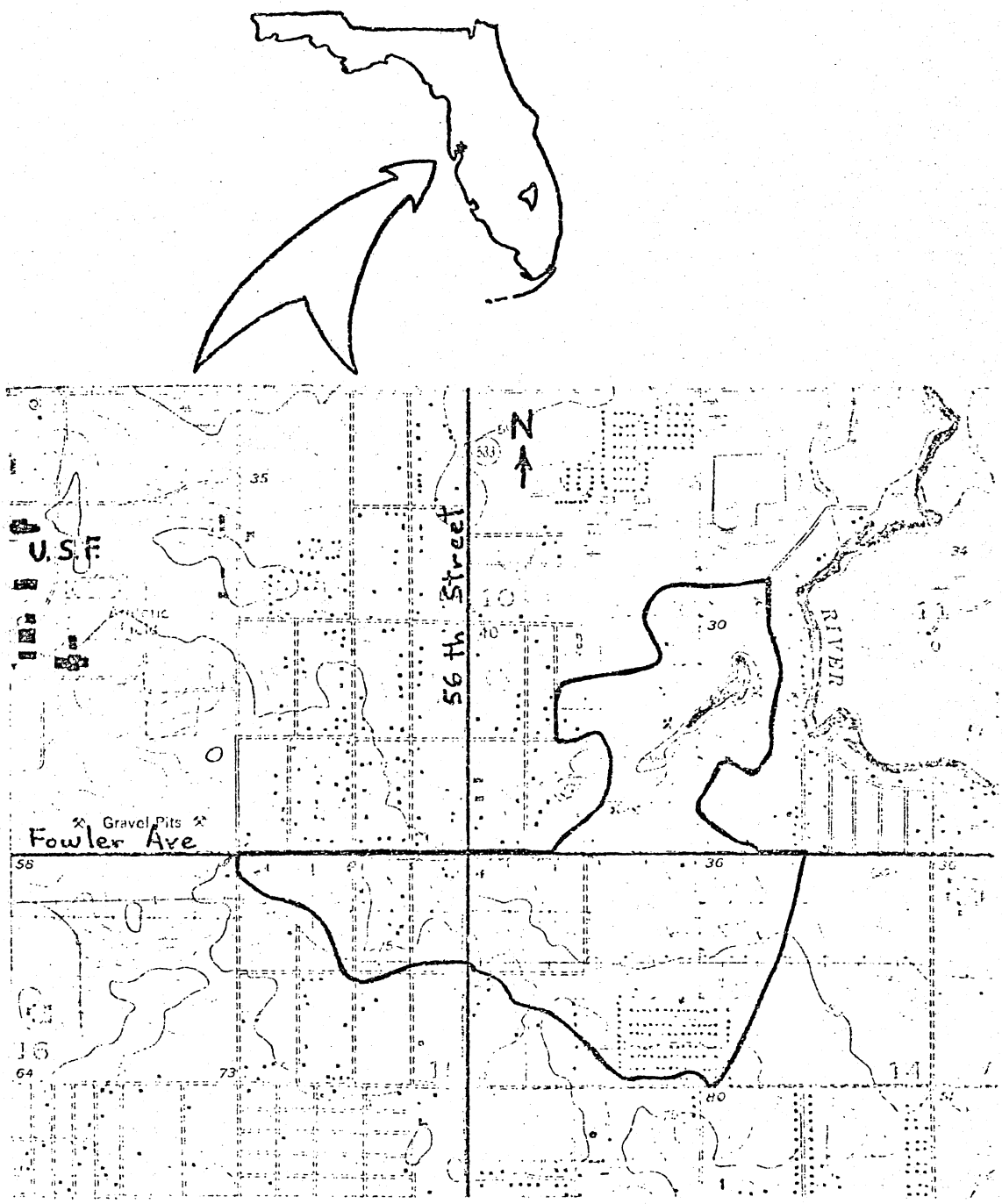


FIGURE 1

WATERSHED LOCATION

TABLE I

Departure from Normal Rainfall for Tampa,Florida
(Based on U.S. Weather Bureau Records)

Year	Departure (inches)	Cumulative (inches)
1961	-16.53	-16.53
1962	- 9.95	-26.48
1963	- 8.15	-34.63
1964	+ 6.35	-28.28
1965	- 8.79	-37.07
1966	-15.52	-52.59
1967	-12.21	-64.80
1968	-12.22	-77.02
1969	+ 2.65	-74.37
1970	-13.30	-87.67
1971	- 5.24	-92.91
1972	- 9.39	-102.30
1973	- 1.86	-104.16
1974	-15.48	-119.64

The study area is underlain by the Floridan aquifer which is made up of limestone and dolomite rocks. The potentiometric pressure of approximately 30 feet above msl is contained by the impervious sediment of the Hawthorne Formation. At an elevation of 20 to 25 feet throughout the area there is a thick clay lense upon which a surface water table is perched.

A map of the watershed is presented in Figure 2. Originally only the 126 acre portion north of Fowler Avenue was to be examined since it was a well defined completely natural state watershed. However, subsequent to the funding of the study and prior to installation of all measuring devices, a 54 inch concrete pipe, which drains 240 acres, was installed under Fowler Avenue. This southern region does contain some developed portions, as indicated in Figure 2. The apartment complex immediately south of the drainage pipe was under construction when the pipe was installed.

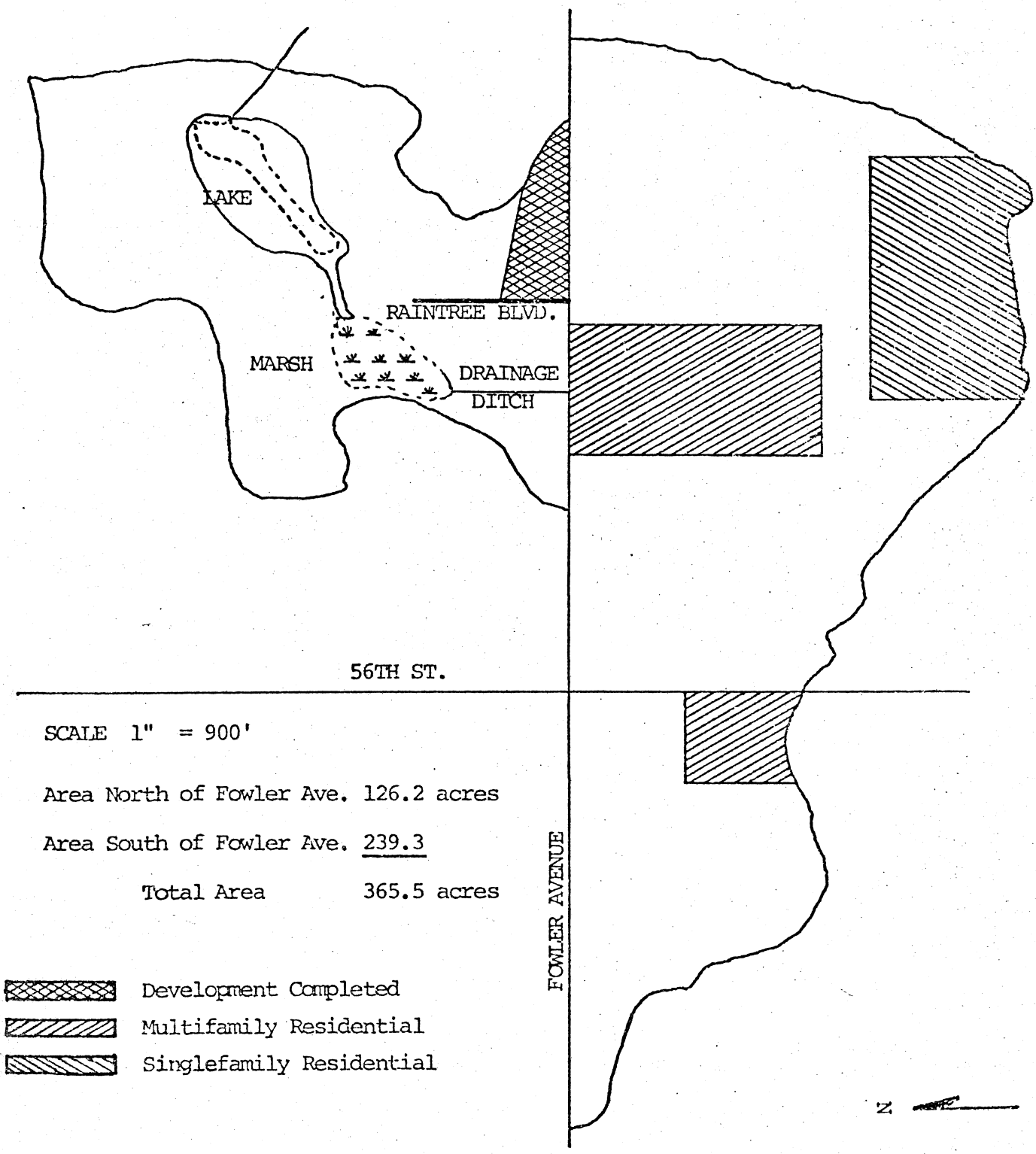


FIGURE 2

STUDY WATERSHED

The topography of the northern portion is quite gentle with ground elevations varying from 25 to 35 feet. On the southern portion, the topographic gradient is much steeper with ground elevations decreasing from 85 feet to 33 feet within 2300 feet.

There was a small natural lake within the 126 acre portion which drained through a natural ditch into the Hillsborough River at times of heavy runoff. The surface area of the lake originally varied from 0.25 acres to 4 acres. The depth of this lake was increased from an average depth of 3 feet to 14 feet deep, while the surface area was increased to approximately 6 acres.

The original condition of the study area is shown in Figures 3, 4, 5 and 6. The study area represented a good cross-section of common undeveloped land in this portion of Florida; grading from hardwoods to pines and palmettos, to marshlands.

The type of construction that was built on the study area watershed can be seen in Figure 7, which shows a condominium under construction in the area north of Fowler Avenue. Figure 8 shows one of the abandoned foundations. The type apartments in the area south of Fowler Avenue and the drainage channel that drains the single family homes, are shown in Figures 9 and 10, respectively.

Figure 3. Hardwood Uplands at Start of Project

Figure 4. Pinewoods at Start of Project

Figure 5. Underbrush at Start of Project

Figure 6. Marsh at Start of Project

Figure 7. Construction of Condominium

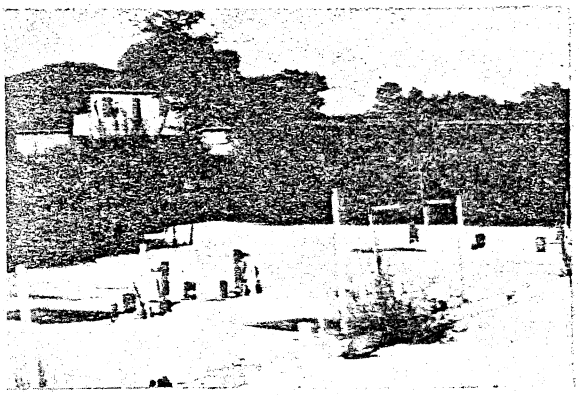


Figure 8. Abandoned Foundation

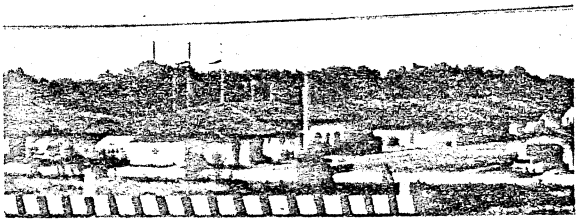


Figure 9. Apartment complex, South of Fowler looking north

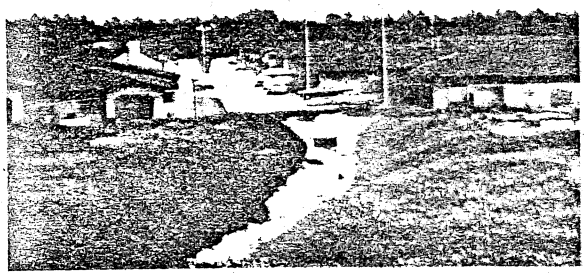


Figure 10. Drainage canal from south edge of watershed

3. INSTRUMENTATION

In order to evaluate the various phases of the hydrologic cycle for the study area, the following equipment was installed on or near the test watershed.

1. a recording rain gage,
2. five nonrecording rain gages,
3. an evaporation pan,
4. a recording evaporation gage,
5. a Parshall flume,
6. a plywood V notch weir,
7. two recording water level gages,
8. two lake stage gages, and
9. seven shallow wells.

The locations of all the rainfall gages and equipment are shown on Figure 11. The recording rain gage, and recording evaporation gage were located on private property adjacent to but outside of the boundary of the watershed for security reasons. They were housed in a wooden box for additional protection. (See Figure 12) A Parshall flume was installed in the drainage ditch into which the 54 inch pipe discharges (See Figures 13, 14, 15). Unfortunately, this process had to be repeated on four additional occasions due to failures of the soft, alluvial sand banks of the ditch. The ditch was not kept clear and by the end of the project had a large crop of aquatic weeds. In June 1972, the Stevens eight day water level recorder was stolen off of the flume and four months of data was therefore not obtained.

A plywood dam with a metal edged V notched weir was built across the stream which drains the lake into the Hillsborough River. This weir was calibrated in place with the use of a large volume portable pump and a portable weir box. A Stevens eight day water level recorder, placed upstream of the weir, recorded the water depth. (See Figures 16 and 17) Three months later, October 1971, the weir was destroyed by vandals. Consequently, it was necessary to build, install and calibrate again.

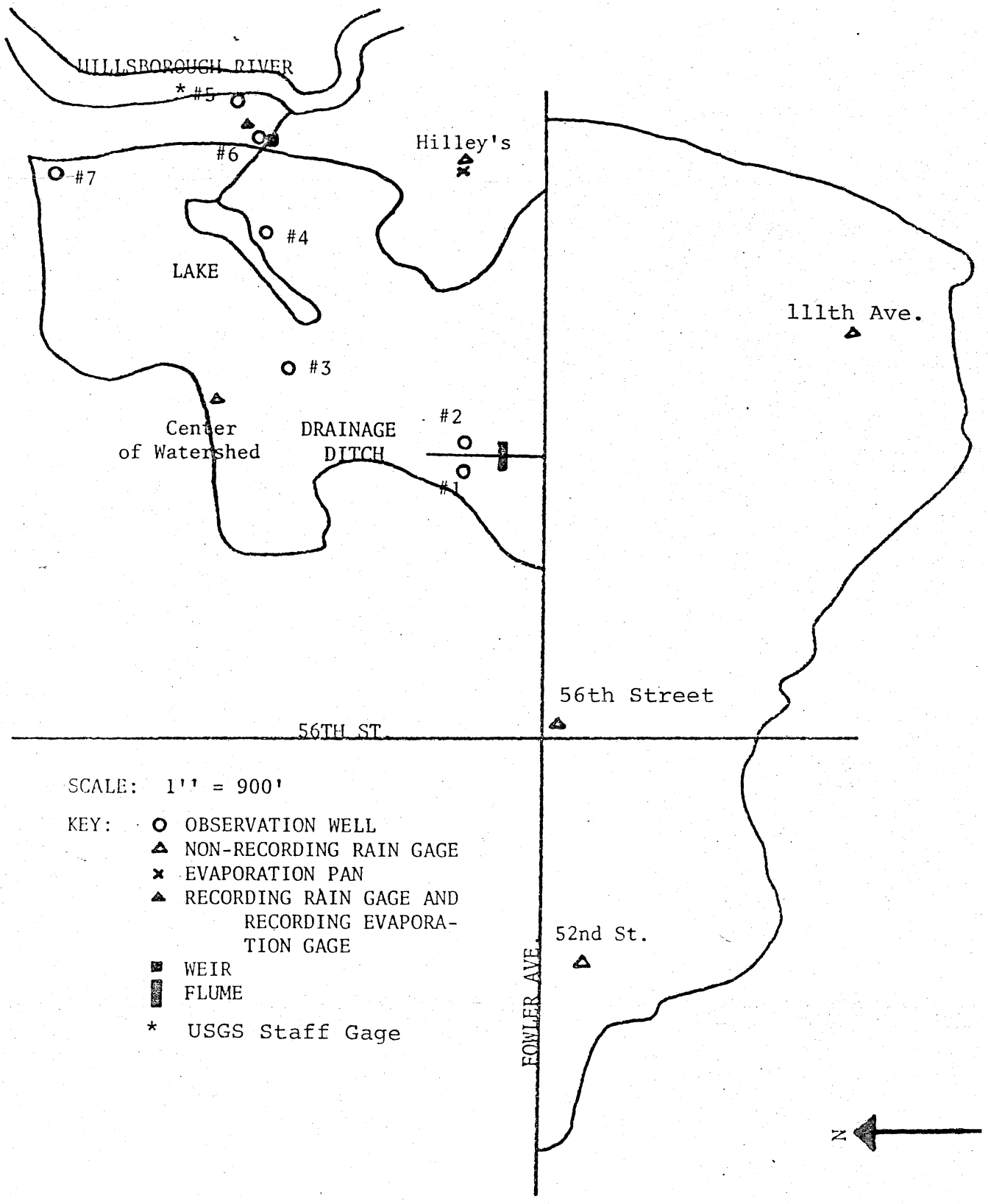


FIGURE 11

INSTRUMENT LOCATIONS IN WATERSHED

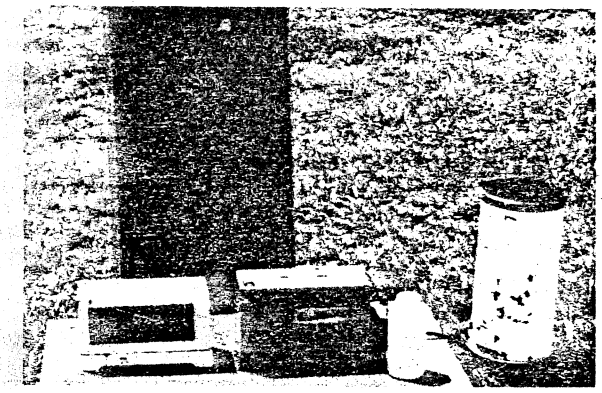


Figure 12. Recording rain and evaporation gages

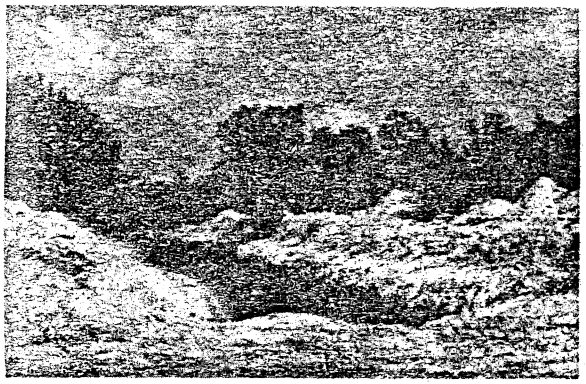


Figure 13. Ditch at start of project

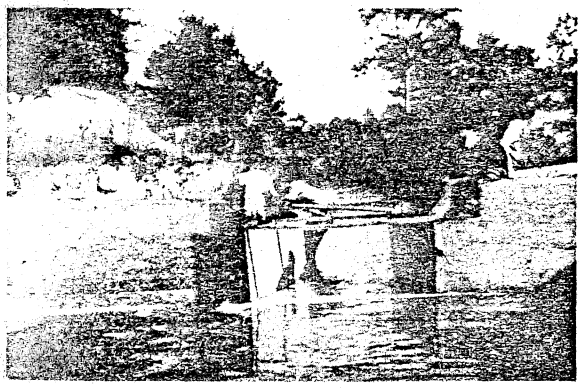


Figure 14. Installing Flume

Figure 15. Flume and ditch condition at completion of project

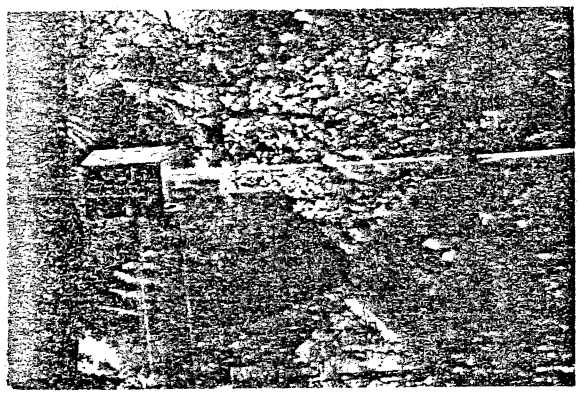


Figure 16. View downstream of V-notch weir

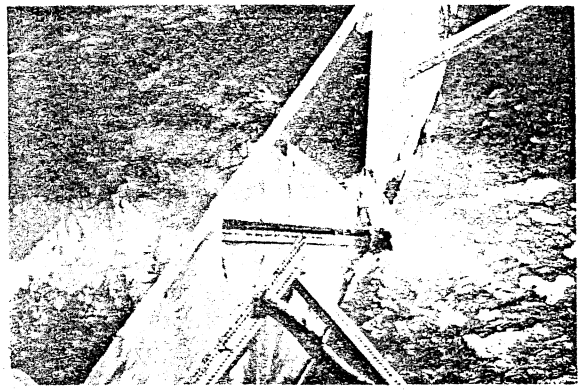


Figure 17. V-notch weir

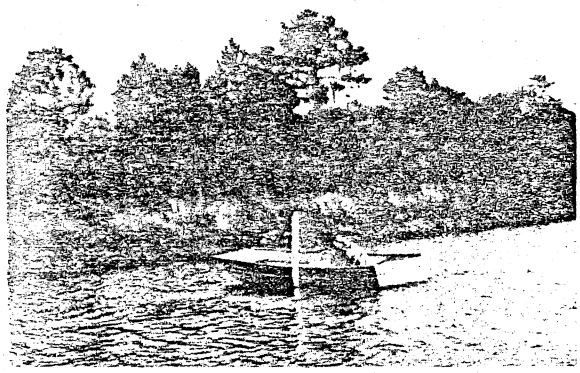


Figure 18. Reading lake staff gage

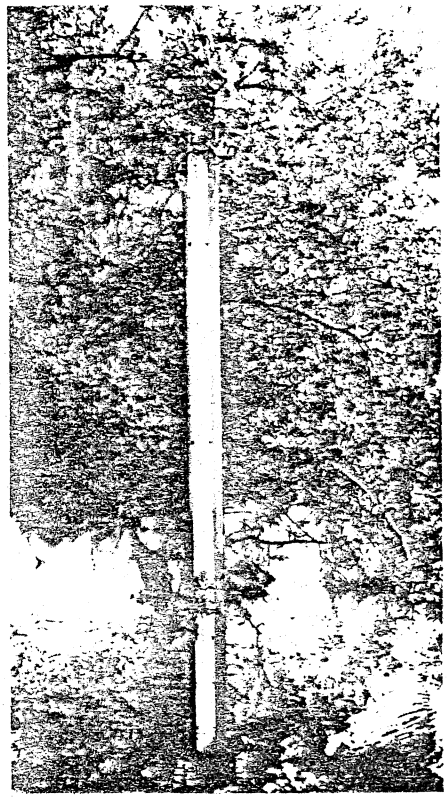


Figure 19. USGS staff gage in Hillsborough River

A standard Class A land pan was built and installed in order to obtain evaporation data. Later, a Weather Measure recording evaporimeter was also installed near the study area; however, it proved quite unsatisfactory. It frequently would not respond when water evaporated from the reservoir, due to the static friction of the linkage connecting the recording pen to the reservoir float. In addition, when a significant rainfall occurred the pen went off the chart and failed to return. It was returned to the manufacturer for servicing but no noticeable improvement occurred.

Originally two staff gages were installed in the lake in order to obtain lake surface elevations. One gage was used when the lake was exceptionally low and the other for normal and high stages. When the lake was deepened to a uniform depth by the developer only one gage was required. (See Figure 18) It was necessary to survey the lake, prepare a contour map, and prepare an elevation-surface area curve three different times (See Figure 20). This was because the area and volume of the original shallow lake were changed two different times.

Seven shallow wells were put down for the purpose of monitoring the perched water table. The holes were drilled with a hydraulic drill rig borrowed from the USF Geology Department. A five inch rotary bit was used to cut through the sand overburden which was washed to the surface by water injected through the A-rod. When the thick impermeable clay layer which underlies the area was reached, the drilling process was stopped and the drill was allowed to rotate and wash out a sump at the bottom of the hole. Following the washing process, the A-rod and bit were removed from the hole and a gravel pack or sand pack was put in the bottom of the sump. Then a three inch, 260 psi, PVC casing with well screen attached, was put into the hole and more gravel added around the screen and casing. Well logs for these are shown in Table II.

The well screen consisted of a twelve inch section of PVC pipe, plugged at one end, with random 1/8 inch wide slots cut into it. The upper end of the pipe was covered with fine 80 x 80 mesh screen.

The elevation of each well was established from a known bench mark.

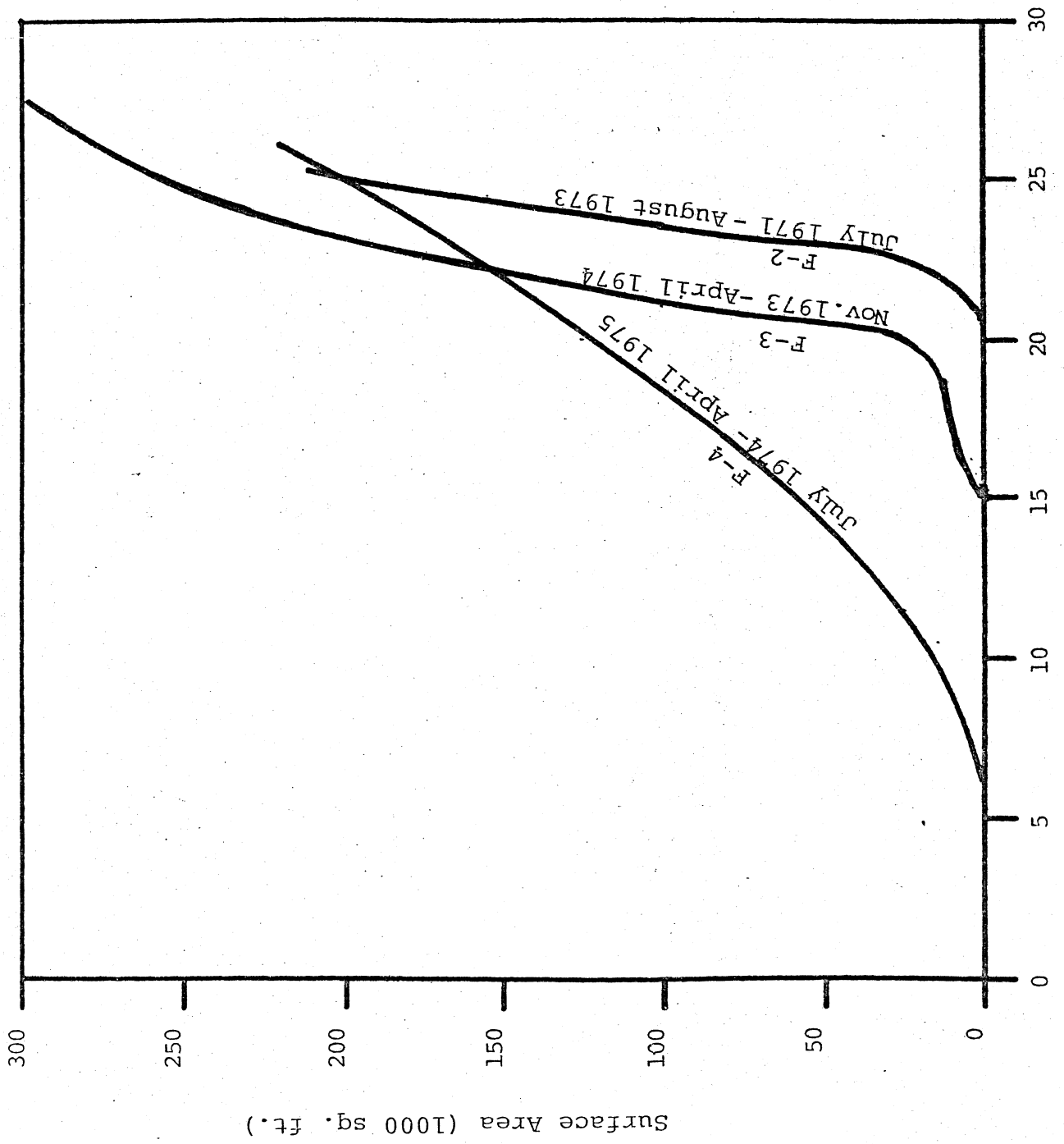

Surface Area (1000 sq. ft.)
300
250
200
150
100
50
0
Lake Level (ft above MSL)
0
5
10
15
20
25
30
July 1971 - August 1973
F-2
Nov. 1973 -April 1974
F-3
July 1974- April 1975
F-4

Figure 20

TABLE II

WELL DATA:

Well #	Location	Well Log	Depth of Hole		Pack
			To Bottom	To Screen	
1	west of ditch	dark brown (organics) for 3 1/2', light brown for next 6 1/2',at 10' very dark sand then at 13' light again, at 14' white with a small clay fraction.	14'	13'	gravel
2	east of ditch	organics for 2' then lighter brown for next 6', light fine sand till 12' where clay was hit.	10'	8 1/2'	gravel
4	lake	organics for 4' then lighter color with clay particles for next 4', at 8' clay.	9 1/2'	8 1/2'	sand
3	center of area	brown sand to 8' very fine, next foot very dark with a small clay fraction.	8 1/2'	7 1/2'	gravel
6	creek	3' of dark brown sand then 2' of lighter sand, at 5' slightly clayey sand to 9' where clay is prominent.	7'	6'	gravel
7	road	organics for first 4' then brown sand for 1', light sand to 9' where clay was hit.	7 1/2'	6 1/2'	gravel
5	river	organics for first 4' then light brown sand next foot, at 5' organics and roots, sand and organics to 10', no clay; from all indications this was an old river channel.	8 1/2'	7 1/2'	gravel

The level of the river was measured by observation of a USGS staff gage. Fortunately, such a gage was located in the Hillsborough River very near the point where water from the study area entered the river. (See Figure 19)

4. DATA COLLECTION

Once a week the recorder charts were changed at the flume, weir, and evaporation gage and readings taken at the lake gage and the evaporation pan. The water levels in the wells were determined biweekly. Daily readings of the nonrecording rain gages were taken each morning.

Water samples were taken weekly from the stream which drained the lake and from the ditch on the downstream end of the 54 inch drainage pipe. The quality parameters determined by use of a Hach Chemical Company DR-EL Test Kit follow:

1. pH
2. Color
3. Hydrogen Sulfide (H_2S)
4. Dissolved Oxygen (O_2)
5. Carbon Dioxide (CO_2)
6. Nitrite (NO_2)
7. Nitrate (NO_3)
8. Metaphosphate (PO_4)
9. Orthophosphate (PO_4)
10. Temperature
11. Turbidity

In addition, Presumptive and Confirmed Coliform Bacteria Tests were conducted on the samples according to procedures described in "Standard Methods for the Examination of Water and Waste Water", 13th Edition.

The samples that were taken at regularly spaced time intervals during two separate storms were rushed to a commercial water quality laboratory to be analyzed. The quality parameters determined according to "Standard Methods" procedures were:

1. Biochemical Oxygen Demand, B.O.D.
2. Chemical Oxygen Demand, C.O.D.
3. Total Oxygen Carbon, T.O.C.
4. Total Kjeldahl Nitrogen
5. Nitrite, NO_2
6. Nitrate, NO_3
7. Carbon Dioxide, CO_2
8. Metaphosphate, Meta-PO_4
9. Orthophosphate, Ortho-PO_4
10. pH
11. Turbidity
12. Suspended Solids
13. Color
14. Aluminum
15. Mercury
16. Iron
17. Lead
18. Zinc
19. Copper
20. Oil and Grease
21. Hydrogen Sulfide, H_2S
22. Coliform Aerogenes Group
23. E-Coli

5. PLANT LIFE SURVEY

In order to establish a record of existing natural vegetation in the watershed prior to urbanization, a plant life survey was conducted on the northern portion of the study area. The transect method, in which a string is stretched in a straight line through the community and each individual plant in contact with it recorded, was applied exclusively. A total of 115 transects were used.

The following parameters were determined:

(1) Species diversity - the number of species and the number of individuals of each species.

(2) Frequency - of occurrence of each species, calculated on the basis of the percentage of occurrence in transects by a given species.

(3) Relative frequency - number of occurrences of one species as a percentage of the total number of occurrences of all species.

(4) Density - the average number of individuals of a species per transect obtained by dividing the total number of individuals of that species in all transects by the total number of transects examined.

(5) Relative density - the number of individuals of one species as a percentage of the total number of individuals of all species.

(6) Abundance - the average number of individuals of a species per transect of occurrence obtained by dividing the total number of individuals of that species by the number of transects in which it occurred.

A very appropriate measure of dominance and relative dominance was also obtained by using a mean basal area of 6 species of trees calculated from 147 measurements and of the herbaceous species arbitrarily taken as 1 cm^2. Dominance is the average basal area of each species and relative dominance is the total basal area of each species as a percentage of the total basal area of all species.

The project area was divided into two subregions based on topographic land features for describing the vege-

tation.

(1) The first of these encompasses the highland portion. The soil encountered here is what Strahler (1969) refers to as red-yellow podzolic, well drained and leached in the soil zone. Vegetation reflects this condition since many plants observed require such edaphic factors. Stratification, considered very important by Richards (1952) was highly variable within this highland area. The upper stratum composed of trees was mainly discontinuous which may have been as a result of "recent" disturbances. Small sectors, however, did contain isolated congruent canopies of either *Quercus virginiana* or *Pinus elliottii* depending on the area being examined.

The middle stratum was better defined since *Serenoa repens* formed a more or less thick and continuous layer. Some of the other representatives of this stratum belonged to *Aquifoliaceae* and *Ericaceae* as well as seedlings from *Ebenaceae*, *Fagaceae* and *Pinaceae*.

Herbaceous plants contained within the lowest of the three strata exhibited the most well defined and continuous layer. This was to be expected, since a large portion of the area had been disturbed in the recent past. Some of the families represented in this stratum were *Compositae*, *Facaceae* and *Gramineae*.

(2) The second portion of the project land examined was the lowland-pond area. The soil here was as described by Strahler (1969), Wisenboden (ground water podzol with 1-half bog soils). This soil supports vegetation that requires moist soil or a body of water for existence. The plants of this area did not exhibit well-pronounced stratification except for the floating aquatics which, however, could not be adequately studied for lack of facilities.

The tallest trees encountered belonged to *Fagaceae*, *Myricaceae*, *Pinaceae* and *Salicaceae*. The canopy was discontinuous allowing ample sunlight for herbaceous plants to flourish. Two small sections, however, did exhibit congruency in its canopy at the pond's east end. One contained *Pinus* members towering to 14 m while the other site supported *Quercus* and *Salix* on the small canal's slopes.

The plant community of this area in its entirety can be best described as a "mixed oak, pine lowland flatwoods". This is probably close to the flatwoods described by Monk and McGinnis (1966), as evidence of recent fire can be detected. The following tree species, though numerically small, registered high on the Importance Value: *Quercus virginiana* (27.60), *Pinus elliottii* (13.75), and *Serenoa repens* (13.926). Since members of the *Gramineae* were abundant throughout, they registered highest in importance value of all the species in this area (93.89). This is to be expected since the exposed sandy soils of the disturbed areas are first colonized by the sand binding members of *Gramineae*.

The complete record of plant life data has been tabulated and is available from the primary investigators, upon request.

Figure 21. String Transect Method

6. SOIL CHARACTERISTICS

Infiltration and disturbed sample permeability tests were performed on the various soil types in the study area. A map showing the various soil types according to the U.S. Department of Agriculture, Soil Conservation Service, is shown in Figure 22 and Table III. The texture of nearly all of the soil in the area is fine sand. In some areas there is a relatively high amount of undecomposed organics which has not been incorporated into the soil zones. Therefore organics play a very small role in the rate of infiltration for this region.

A concentric ring flooding-type infiltrometer was used in the tests. The inner and outer rings were 9 inches and 14 inches in diameter respectively. Measurements were made in accordance with standard procedures.

After the surface infiltration test was completed, a subsurface infiltration test was conducted a few feet from the same site. This consisted of digging a hole below the organic or root zone and performing a test in the same manner as was conducted on the surface.

The infiltration rates thus determined, though higher than normal for soils in this region of Florida, due to the previously mentioned drought, were as expected; 25-50 inches/hour for most sands; 7-20 inches/hour for clays and mucks.

Distributed sample constant head permeability tests were conducted in the laboratory in order to establish the relative differences between the various soil types.

The infiltration data are on file and available upon request, from the primary investigators.

TABLE III

SOILS LEGEND AND CLASSIFICATIONS

SAMPLE	SYMBOL	SOIL CONSERVATION SERVICE DESIGNATION	UNIFIED CLASSIFICATION	AASHO CLASSIFICATION	LAYER DEPTH (inches)
1	Ba	Blanton fine sand, level phase	SP,SP-SM	A-3	0-42+
2	Bb	Blanton fine sand, gently undulating phase	SP,SP-SM	A-3	0-42+
3	Fe[3]	Fresh water swamp-cypress	Variable	Variable	--
4	Ld	Lakeland fine sand, gently undulating phase	SP	A-3	0-60
5	Lh	Leon fine sand	SP	A-3	0-20
6	Me	Mines, pits and dumps	Variable	Variable	0-60
7	Pd	Plummer fine sand	SP,SP-SM	A-3	0-48+
8	Rc	Rutledge fine sand	SP-SM,SM	A-3	0-20
9	Re	Rutledge mucky fine sands	SP,SP-SM	A-3	20-42+
10	Sc	Shallow ponds with grass	Variable	Variable	0-60

7. WATER QUANTITIES

One of the major purposes of this study was to quantitize the hydrologic changes that occur when a subtropical natural watershed is urbanized. Unfortunately, the planned extensive development, which was initially scheduled to begin in January 1972, did not occur. The changes that did occur were minor and gradual, consequently significant changes in storm runoff quantities were not detected.

The 126 acre watershed selected for this study was a separate drainage area within the original 300 acres designated for townhouse/condominium type of development. The original developers experienced financial difficulties and the property exchanged hands two separate times. As of the present, July 1975, only 15% (18.6 acres) of the 126 acre study area has been cleared and had housing foundations poured. Of this portion, only nine acres contain completed condominiums. Thus, only approximately 7% of the 126 acre study area has undergone complete development from a natural state to a curbed and guttered, landscaped condominium complex. (See Figure 2) However, much useful water quantity data was obtained during the study period.

The study site has proven to be a valuable training facility because of its proximity to the University of South Florida. It has been regularly used by water resource engineering students and geology students as a field laboratory to learn how to properly conduct a hydrologic survey.

The drainage pattern of the study area can best be explained by referring to the map in Figure 2. During the early stages of the study a 54 inch concrete pipe which drains a region south of Fowler Avenue was installed under Fowler Avenue. This pipe discharges into the drainage ditch which is contained in the southwest corner of the watershed. Thus, the storm runoff from a 240 acre watershed was unexpectedly introduced into the 126 acre study area.

The elevation of this southern region varies from approximately 85 feet at its southern boundary to 30 feet where it discharges into the 54 inch pipe. This 55 foot change occurs over a distance of less than 3000 feet. Consequently the runoff response time of this region

is quite low and very high velocities are obtained in the alluvial drainage ditch. A typical storm hydrograph for the discharge from the culvert is presented in Figure 23. A Parshall flume and a Stevens water level recorder were used to measure this flow in the ditch.

The water discharges from the northern end of this ditch and flows approximately 1200 feet in sheet flow overland through an intermittently wet region which contains grasses, palmetto bushes and trees. This flow along with the natural runoff from the 126 acre study area drain into what was a small (0.25 acre), shallow (<6 feet) lake. When the lake is full it discharges into a natural drainage ditch which discharges into the Hillsborough River. The lake has been enlarged to the extent that it has not discharged since October 1974.

In order to document the hydrologic changes caused by urbanization, data were collected to perform a water balance for the portion of the study area north of Fowler Avenue. Initial efforts were to independently establish the values of all components of the cycle such as rainfall, groundwater storage changes, groundwater flow, evapotranspiration, etc. However, after the types and quantity of vegetation were established, it was not within the scope of the project to quantitize the transpiration rates of the various plants. Therefore, the decision was made to consider evapotranspiration the unknown in the following hydrologic continuity equation:

$$\text{Rainfall onto 126 acre watershed} + \text{Rainfall runoff from southern area onto watershed} + \text{Sprinkler runoff from southern area onto watershed} - \left(\pm \text{Groundwater Storage Change}\right) - \left(\pm \text{Lake Storage Change}\right) - \text{Volume discharged out of watershed} - \text{Evaporation from Lake} \pm \text{Groundwater Flow} = \text{Evapotranspiration}$$

The obvious unfortunate difficulty of using this equation is that all errors are accumulated into the term that is the unknown and that the least is known about.

A great deal of difficulty was encountered in attempting to quantitize these various components of the hydrologic cycle for an extended period of time, such as a year. At various times equipment has been stolen or

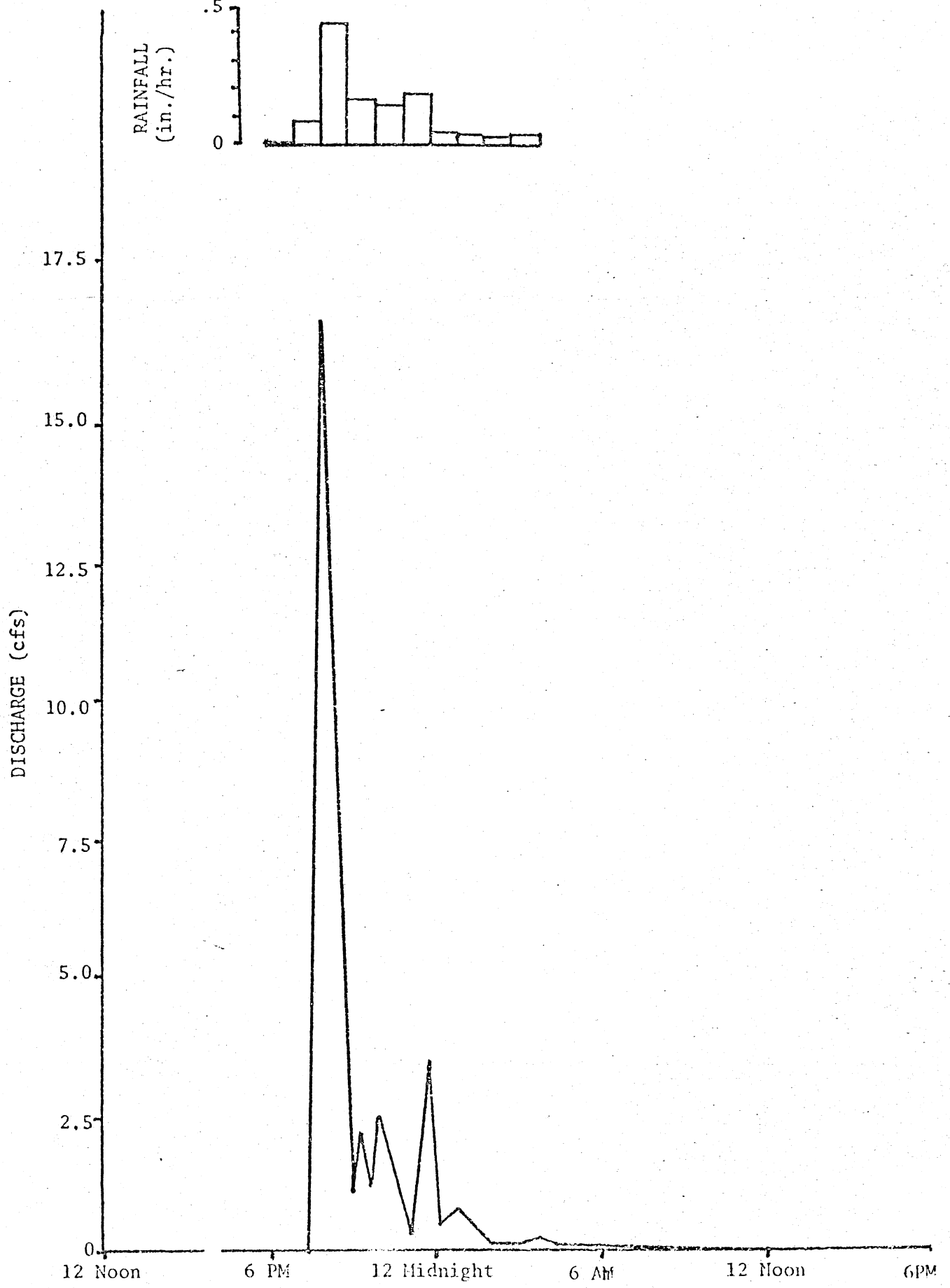


FIGURE 23 HYDROGRAPH

destroyed, rain gages filled by pranksters, the Parshall flume bypassed when the ditch banks caved in, or equipment malfunctions have occurred. Unfortunately, these difficulties occurred at different times and involved various lengths of time to correct. It has been impossible to collect a complete record for a year. Consequently, some missing data techniques had to be used. For example, hydrographs were generated by use of the SCS triangular unit hydrograph technique for the period of time that the recording gage was missing from the Parshall flume. The coefficients used were obtained by generating values from known hydrographs for the area which were obtained when the recording gage was in place. Hydrographs were plotted for each storm but are not included in this report. The typical hydrograph as shown in Figure 23 is an example. Missing rainfall data at a station were determined by the normal-ratio method for the period of record.

A sprinkler system was installed in the apartment complex just upstream of the 54 inch pipe. This resulted in sporadic flows into the Parshall flume which were easily recognized and accounted for.

The groundwater storage changes were established by use of water elevation readings taken in the wells located in the 126 acre area. Figure 11 illustrates the location of the wells with respect to the river. In order to obtain a volume of storage change, the average water level change of wells 1, 2, 3, 4 and 7 was assumed to occur over the 126 acre area minus the area of the lake. A plot of the changes in well water elevations is shown in Figure 24. (The complete record of water elevation changes is available from the primary investigators upon request.) Then taking into account the soil porosity of 30%, and an assumed 70% saturation, the change in groundwater storage was calculated.

Groundwater inflow into the watershed was obtained by determining the hydraulic gradient for the water table by use of the well data and the average permeability for the soils. An average permeability of 152 gpd/ft^2, which was obtained from the soil permeability tests, was used.

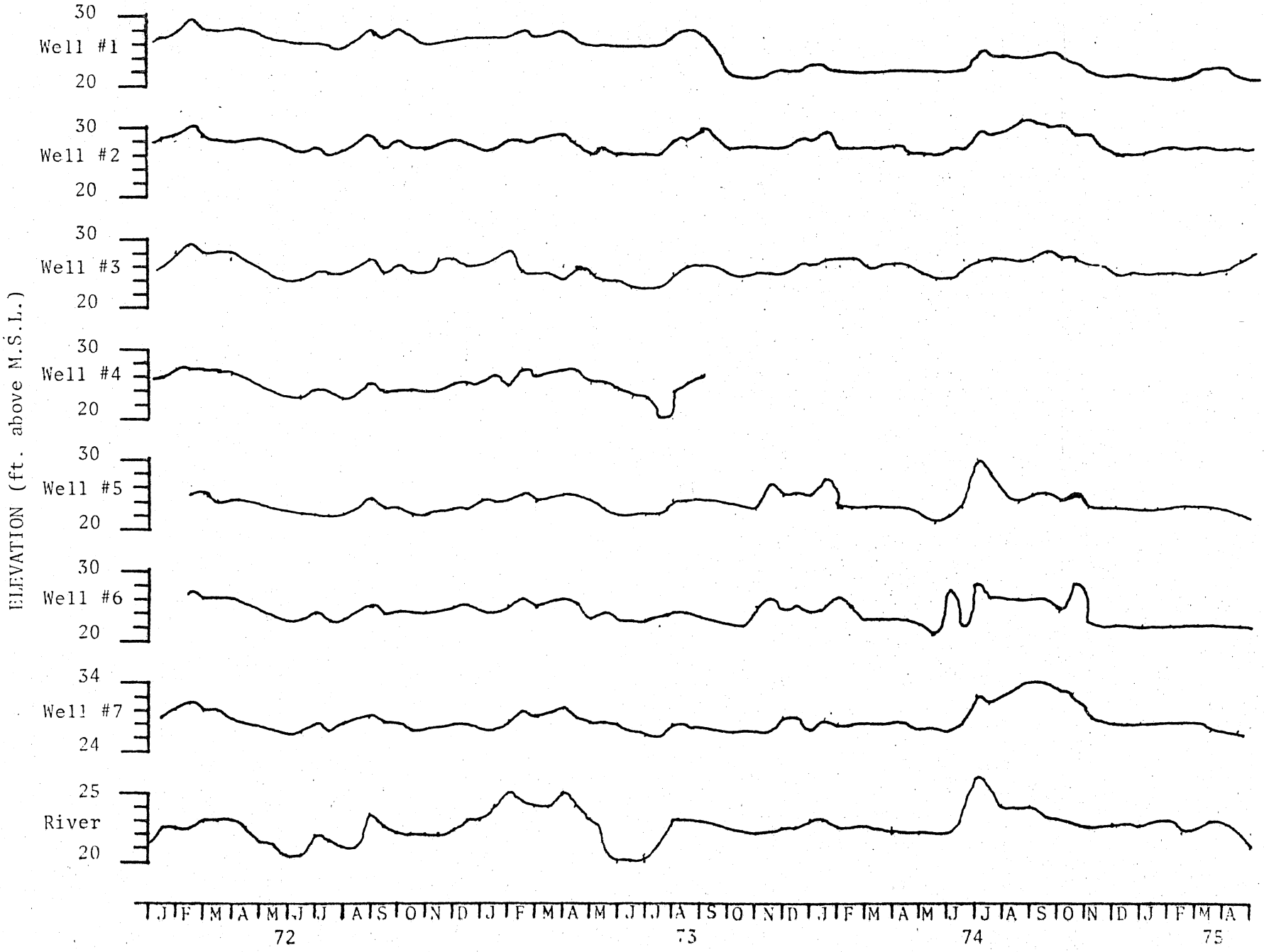

ELEVATION (ft. above M.S.L.)
30
Well #1
20
30
Well #2
20
30
Well #3
20
30
Well #4
20
30
Well #5
20
30
Well #6
20
34
Well #7
24
25
River
20
J J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A
72
73
74
75

FIGURE 24

Rainfall for the watershed was obtained by reading the nonrecording rain gages between 8:00 a.m. and 12:00 noon the day after a rainstorm. At the end of each week, readings from the recording rain gage were added to the data already collected and the average weekly rainfall for the watershed was calculated by the Theissen method. The monthly average rainfall for the study period is shown in Table IV. The complete rainfall record is available from the primary investigators upon request.

A water balance composed of two week periods is shown in Table V. The reader is cautioned that evapotranspiration losses contained in the last column should not be regarded as the correct value for the indicated time period. This is because of the time lag between the occurrence of a significant rainfall and the measurable increase in groundwater storage. For example, a large volume of rainfall occurred during the time period from 6/4/72 to 6/18/72. However, the proportional increase in groundwater storage did not occur until the following period of 6/18/72 to 7/2/72. This large rainfall caused the first term of the hydrologic balance equation to be quite large and resulted in an unrealistic evapotranspiration term of 7.7 inches for the two week period. The large groundwater storage increase in the next period caused a completely impossible evapotranspiration term of -1.2 inches. However, the algebraic sum of these two terms (+7.7 + [-1.2]) is a realistic 6.5 inches for a four week period in June.

Although this tabulating quirk occurred several times, the total evapotranspiration losses for most any 52 week span during the period of record is approximately 50 inches. The increased magnitude of this value over the regionally used value of 40 inches can be attributed to the marsh area which was approximately 20 acres in size during periods of high rainfall and to the phreatophytes surrounding the lake.

Continued.

Month	52nd Street	111th	Hilley	Recording	Center	56th Street	Watershed Average	Tampa Normal	Pan	70% of Pan
Apr.	2.16	2.25	2.26	2.22	1.91	2.06	2.14	2.10	6.60	4.62
May	.33	.56	.34	.40	.34	.37	.41	3.41	7.34	5.14
June	2.18	2.22	2.07	1.83	2.06		2.12	6.49	5.43	3.80
July	8.63	7.38	7.07	6.82	6.94		7.38	8.43	8.32	5.82
Oct.	5.01	4.46	4.82	4.91	5.14	5.09	4.86	2.54	1.41	.99
Nov.	.29	.15	.21	.22	.23	.28	.22	1.79	2.98	2.09
Dec.	7.10	7.21	7.98	7.82	7.75	7.18	7.44	2.19	2.35	1.65
1974										
Jan.	1.53	1.60	1.91	1.74	1.57	1.40	1.60	2.27	3.43	2.40
Feb.	1.11	1.0	1.09	1.11	1.15	1.13	1.09	2.84	2.14	1.49
Mar.	1.06	1.25	1.33	1.32	1.43	1.08	1.25	3.89	2.13	1.49
Apr.	.29	.31	.32	.32	.33	.38	.33	2.10	2.3	1.61
May	2.70	3.09	2.93	3.06	2.64	2.59	2.84	2.41	5.43	3.80
June	16.24	16.71	15.35	15.41	15.58	16.77	16.19	6.49	8.27	5.79
July	8.61	7.02	7.35	7.13	7.00	7.63	7.37	8.43	8.93	6.25
Aug.	7.80	8.89	8.11	8.36	6.97	7.91	8.07	8.00	10.16	7.11
Sept.	9.25	9.46	9.02	6.48	8.62	8.74	8.84	6.35	7.79	5.45
Oct.	0.0	.15	.07	0.0	.10	0.0	.07	2.54	6.97	4.87
Nov.	1.15	1.11	1.25	1.21	1.10	.98	1.11	1.79	6.5	4.55
Dec.	2.10	2.10	2.10	2.08	2.00	2.00	2.06	2.1o	1.25	.87

Continued.

Month	52nd Street	111th	Hilley	Recording	Center	56th Street	Watershed Average	Tampa Normal	Pan	70% of Pan
1975										
Jan.	1.00	.67	.73	.78	.94	1.00	.84	2.21	2.58	1.80
Feb.	1.50	1.61	1.44	1.52	1.51	1.61	1.55	2.86	---	---
Mar.	1.31	1.50	.98	1.11	1.47	.95	1.26	3.89	7.48	5.23
Apr.	1.05	1.29	.98	1.03	1.10	1.02	1.12	2.10	---	---

TABLE V

WATER BALANCE FOR AREA

Period Dates	Rainfall, N * (cu.ft/2 wk)	Inflow Runoff, Flume (cu.ft/2 wk)	Inflow from Lawn-sprinkling (cu.ft/2 wk)	Change in Ground Water Storage (cu.ft/2 wk)	Change in Lake Storage (cu.ft/2 wk)	Lake Evaporation (cu.ft/2 wk)	Weir outflow (cu.ft/2 wk)	Net Ground Water flow (cu.ft/2 wk)	ET Losses (inches)
5-7-72	705,434	317,241	0	- 573,266	6,136	16,451	0	2,089	3.5
5-21-72	187,807	13,093	900	- 573,266	-23,101	12,498	0	2,328	1.7
6-4-72	3,002,712	624,163	0	77,622	16,074	21,877	25,740	668	7.7
6-18-72	164,506	93,085	0	543,355	32,787	19,269	210,600	183	-1.2
7-2-72	675,191	62,101	0	- 458,976	-20,886	10,886	0	890	2.7
7-16-72	511,057.	52,742	0	- 44,148	-16,565	12,505	0	1,900	1.4
7-30-72	1,024,647	476,516	0	597,438	47,045	17,893	140	3,740	1.9
8-13-72	3,452,204	469,028	0	1,534,725	92,489	29,816	560,520	6,637	3.8
8-27-72	240,823	33,444	0	- 922,153	-95,394	16,883	232,380	5,360	2.3
9-10-72	187,087	14,083	0	90,443	-25,249	16,228	0	3,362	0.3
9-24-72	1,180,278	190,616	1,944	347,735	39,097	10,102	0	4,935	2.2
10-8-72	68,441	0	3,744	- 611,434	-28,897	11,842	97,956	3,897	1.3
10-22-72	822,203	313,807	0	46,555	25,727	12,318	0	2,515	2.3
11-5-72	911,089	163,088	3,168	570,262	15,569	8,935	61,704	4,084	0.9
11-19-72	1,061,516	66,955	0	610,547	6,402	8,472	203,256	5,933	0.6
12-3-72	335,052	30,464	0	- 99,132	- 4,095	9,208	0	6,568	1.0

* N indicates flow north of Fowler Avenue

(Continued)

WATER BALANCE FOR AREA

Period Dates	Rainfall,N (cu.ft/2 wk)	Inflow Runoff,Flume (cu.ft/2 wk)	Inflow from Lawn-sprinkling (cu.ft/2 wk)	Change in Ground Water Storage (cu.ft/2 wk)	Change in Lake Storage (cu.ft/2 wk)	Lake Evaporation (cu.ft/2 wk)	Weir outflow (cu.ft/2 wk)	Net Ground Water flow (cu.ft/2 wk)	ET Losses (inches
12-17-72	1,226,277	447,884	0	- 207,755	81	11,733	237,870	4,671	3.6
12-31-72	786,844	81,494	0	- 207,755	15,854	9,444	60,408	1,499	2.2
1-14-73	1,381,165	281,011	5,760	377,352	825	12,059	149,953	1,104	2.5
1-28-73	788,099	113,451	0	794,465	- 91	13,428	159,408	1,975	- .1
2-11-73	437,342	53,280	612	11,306	-21,986	11,642	128,880	1,566	.8
2-25-73	280,038	43,138	0	-399,602	20,370	13,361	0	38	1.5
3-11-73	1,696,191	153,865	16,200	418,338	72,557	19,523	0	- 252	3.0
3-25-73	617,715	68,173	14,688	1,615	-54,645	17,436	378,360	- 135	.8
4-8-73	0	5,438	3,780	-836,676	-28,992	20,886	129,510	- 172	1.6
4-22-73	369,319	97,200	7,020	-1,038,862	-16,154	17,221	0	- 140	3.4
5-6-73	162,438	15,480	61,038	9,311	-14,254	20,799	0	- 161	0.5
5-20-73	280,085	0	40,343	-345,796	-35,934	14,617	0	- 121	1.5
6-3-73	143,411	15,069	44,889	-404,609	-17,019	7,947	0	- 10	1.4
6-17-73	498,094	33,901	9,180	464,333	- 758	4,532	0	301	.2
7-1-73	61,960	8,865	3,278	-750,247	-27,563	3,547	0	769	1.9
7-15-73	2,766,140	264,393	0	1,091,220	102,663	21,171	0	1,704	4.1

(Continued)

WATER BALANCE FOR AREA

Period Dates	Rainfall,N (cu.ft/2 wk)	Inflow Runoff,Flume (cu.ft/2 wk)	Inflow from Lawn-sprinkling (cu.ft/2 wk)	Change in Ground Water Storage (cu.ft/2 wk)	Change in Lake Storage (cu.ft/2 wk)	Lake Evaporation (cu.ft/2 wk)	Weir outflow (cu.ft/2 wk)	Net Ground Water flow (cu.ft/2 wk)	ET Losse: (inche
7-29-73	2,128,237	252,633	0	725,025	9,921	39,654	180,360	2,890	3.2
8-12-73	1,566,719	125,719	0	1,625,180	47,283	28,017	378,144	3,743	-0.8
8-26-73				NO DATA UNTIL					
10-7-73	2,230,829	695,400	0	-724,628	1,960,387	8,156	0	5,782	3.7
10-21-73	67,930	0	1,068	90,451	- 20,601	16,425	1,852	1,345	- .1
11-4-73	100,571	6,120	5,760	429,644	- 9,528	20,186	0	0	- .7
11-18-73	0	0	6,203	218,078	-38,112	18,876	0	0	- .4
12-2-73	1,496,953	519,180	0	790,320	393,575	9,415	1,962	50	1.9
12-16-73	2,064,743	469,592	0	823,680	-125,610	30,284	176,284	1,392	3.7
12-30-73	321,879	121,698	0	- 64,134	7,518	10,676	4,042	3,723	1.1
1-13-74	209,260	24,974	0	-418,521	- 26,852	26,282	0	3,589	1.5
1-27-74	377,062	20,160	0	-244,021	- 48,334	21,044	0	2,923	1.5
2-10-74	255,438	48,597	0	342,568	67,668	20,098	325,473	4,408	-1.0
2-24-74	79,776	0	0	-229,943	- 67,668	5,606	0	8,234	.8
3-10-74	220,263	137,816	2,153	0	0	20,088	0	8,523	.3
3-24-74	297,171	2,156	0	-204,062	-47,643	12,777	46,411	9,087	1.1
4-7-74	142,271	19,193	5,723	-459,015	0	6,594		8,465	1.4
4-21-74	0	0	13,780	-358,917	-821,345	Drained	821,345	6,654	0.9

(Continued)

WATER BALANCE FOR AREA

Period Dates	Rainfall,N (cu.ft/2 wk)	Inflow Runoff,Flume (cu.ft/2 wk)	Inflow from Lawn-sprinkling (cu.ft/2 wk)	Change in Ground Water Storage (cu.ft/2 wk)	Change in Lake Storage (cu.ft/2 wk)	Lake Evaporation (cu.ft/2 wk)	Weir outflow (cu.ft/2 wk)	Net Ground Water flow (cu.ft/2 wk)	ET Losses (inches
5-5-74									
5-19-74	840,633	542,844	0	871,200	551,250	302	0	6,424	-0.1
6-2-74	497,444	48,785	2,310	-155,584	53,759	2,055	0	3,257	1.4
6-16-74	1,327,895	483,493	0	49,821	483,500	43,719	0	3,477	2.8
6-30-74	3,969,561	2,166,344	0	3,406,617	325,250	77,162	325,000	-1,876	4.5
7-14-74	1,061,796	411,500	0	-554,400	125,000	57,096	125,000	207	3.9
7-28-74	1,081,218	214,707	0	-396,000	233,466	52,614	180,423	2,527	2.8
8-11-74	1,840,765	933,410	0	1,425,599	21,633	52,614	58,200	3,880	2.7
8-25-74	1,205,648	671,582	0	105,600	43,263	58,244	21,556	2,527	3.7
9-8-74	1,699,654	833,768	0	-242,325	86,534	61,371	197,800	2,219	5.5
9-22-74	884,675	369,991	0	- 66,000	-194,701	37,929	175,250	4,861	2.9
10-6-74	504,367	202,773	0	-734,800	- 42,389	40,392	0	8,908	3.3
10-20-74	0	0		-1,106,239	-160,280	15,462	0	3,590	2.8
11-3-74	0	0	5,834	- 662,400	-158,440	9,563	0	380	1.8
11-17-74	0	0	4,780	- 753,984	-103,668	22,226	0	403	1.9
12-1-74	525,485	176,832	0	- 635,184	- 85,293	19,431	0	1,000	3.2
	349,061	316,116	0	- 72,072	-13,437	2,670	0	3,515	1.7

(Continued)

WATER BALANCE FOR AREA

Period Dates	Rainfall,N (cu.ft/2 wk)	Inflow Runoff,Flume (cu.ft/2 wk)	Inflow from Lawn-sprinkling (cu.ft/2 wk)	Change in Ground Water Storage (cu.ft/2 wk)	Change in Lake Storage (cu.ft/2 wk)	Lake Evaporation (cu.ft/2 wk)	Weir outflow (cu.ft/2 wk)	Net Ground Water flow (cu.ft/2 wk)	ET Losses (inches)
12-15-74	583,518	0	986	- 33,660	0	10,383	0	6,501	1.4
12-29-74	396,221	291,411	0	- 89,100	- 20,569	17,798	0	6,124	1.8
1-12-75	0	0	0	0	- 11,518	17,798	0	5,242	0.0
1-26-75	104,172	7,500	2,385	158,400	- 1,646	13,251	0	4,795	-0.1
2-9-75	480,949	63,037	0	- 79,200	0	12,038	0	5,615	1.4
2-23-75	102,964	17,120	22,108	+ 79,200	- 25,917	13,570	0	7,950	.2
3-9-75	79,593	23,178	12,173	-237,615	- 17,278	17,279	0	9,087	.8
3-23-75	144,735	176,833	0	+298,542	- 60,473	18,990	0	12,777	.2
4-6-75	214,478	200,094	0	+255,921	-103,668	20,343	0	23,905	.6
4-20-75									

8. WATER QUALITY

During the course of this study, three different aspects of water quality were studied. These were: 1) the change in runoff pollutant concentrations during a storm; 2) the change in groundwater quality in the shallow aquifer; and 3) the change in quality of surface runoff as a result of its passage over the study area.

Quality samples were taken at regular intervals at the entrance to the concrete pipe that passes under Fowler Avenue, during two different storms. The drainage pattern of the watershed is such that all runoff from the area south of Fowler Avenue drains through this pipe. The resulting pollutographs from both storms were quite similar, consequently only one set of data is presented in this report. The hydrograph for the storm of May 19, 1975 is presented in Figure 25 and the pollutographs for the various substances measured are presented in Figures 26 through 36.

The concentrations measured were converted to total pounds of pollutant per time interval and are listed in Table VI. In addition, this table contains the total pounds of each pollutant which was washed off the watershed during the storm and the pounds of substance generated per acre.

The concentrations of eighteen of the twenty-three measured parameters generally decreased with time as anticipated. Carbon dioxide (CO_2) concentrations remained approximately constant while oil and grease concentrations and orthophosphate (Ortho-PO_4) concentrations increased with time. It is felt that the orthophosphate, and the grease and oil concentrations would have reached a peak value and leveled off if the storm had been of a longer duration than fifteen minutes.

Both of the storms, for which data were gathered, were mild and of short duration. More intense storms of longer duration could and probably would produce different pollutographs.

Chemical quality tests were run on groundwater samples which were removed from the surface aquifer wells during July, August and September of 1972 and again in May 1974. (See Table VII). The data show that peak values occurred in dissolved substances when the wells were first dug. Since then, there has been no significant change in groundwater quality. This confirmed expectations.

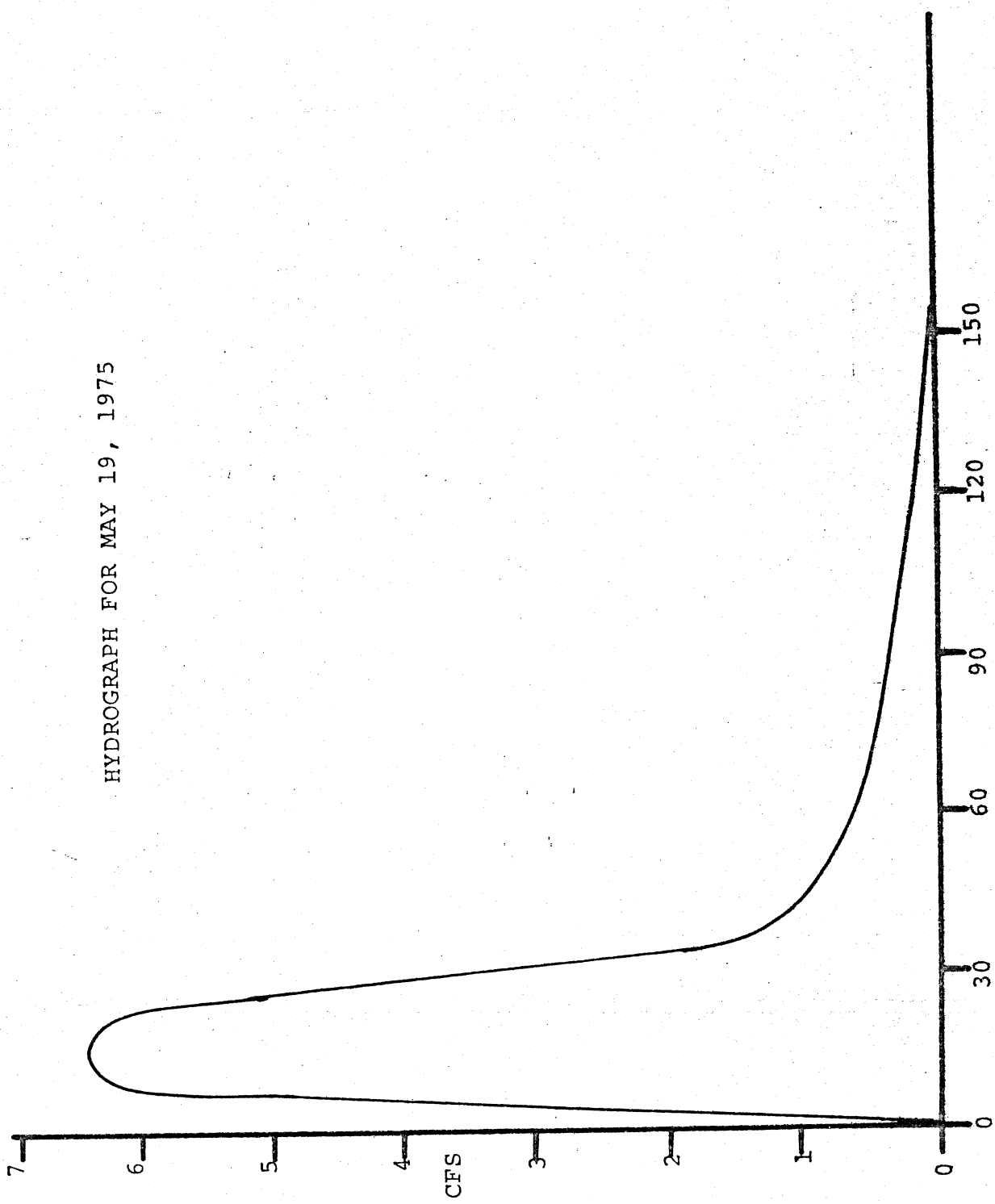
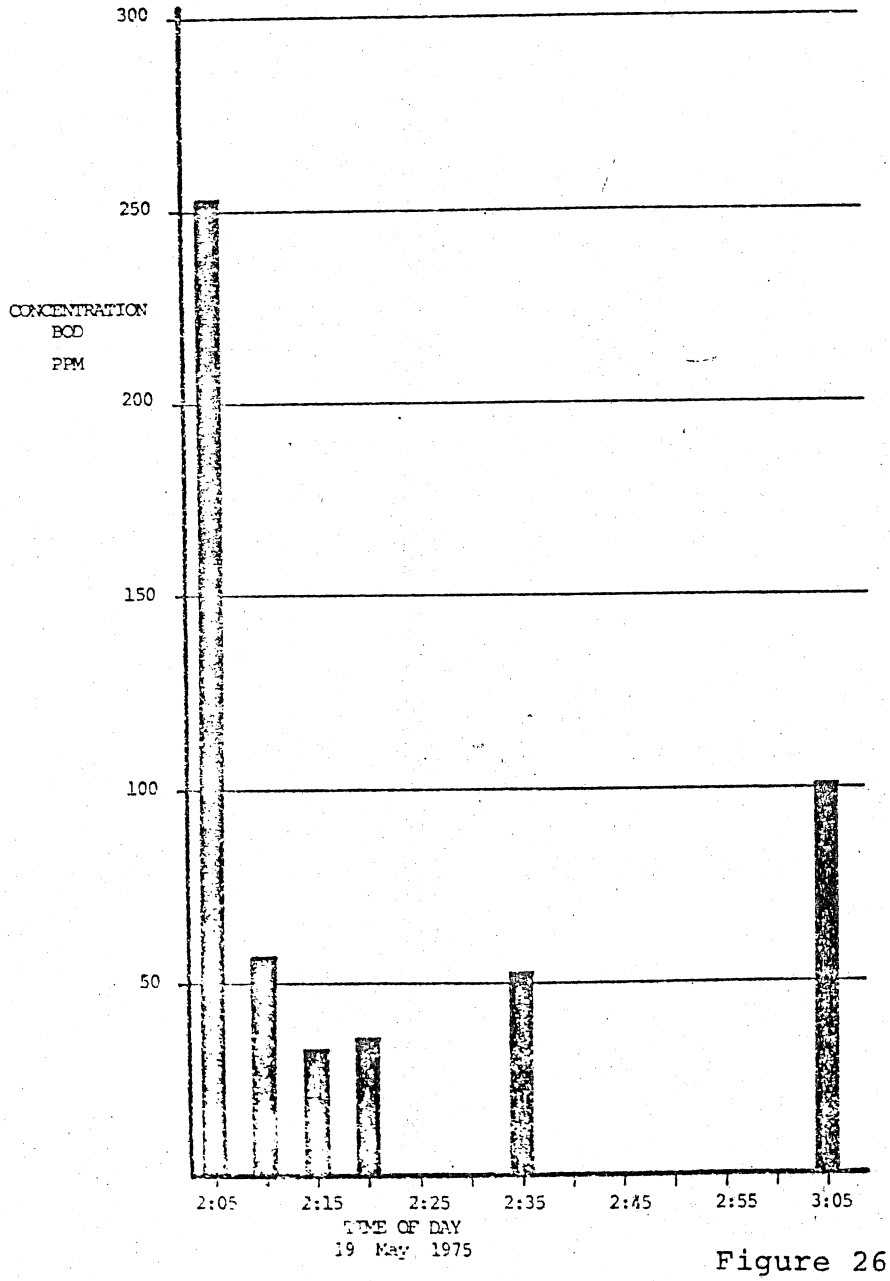

HYDROGRAPH FOR MAY 19, 1975
CFS
0
1
2
3
4
5
6
7
0
30
60
90
120
150
MINUTES

FIGURE 25.



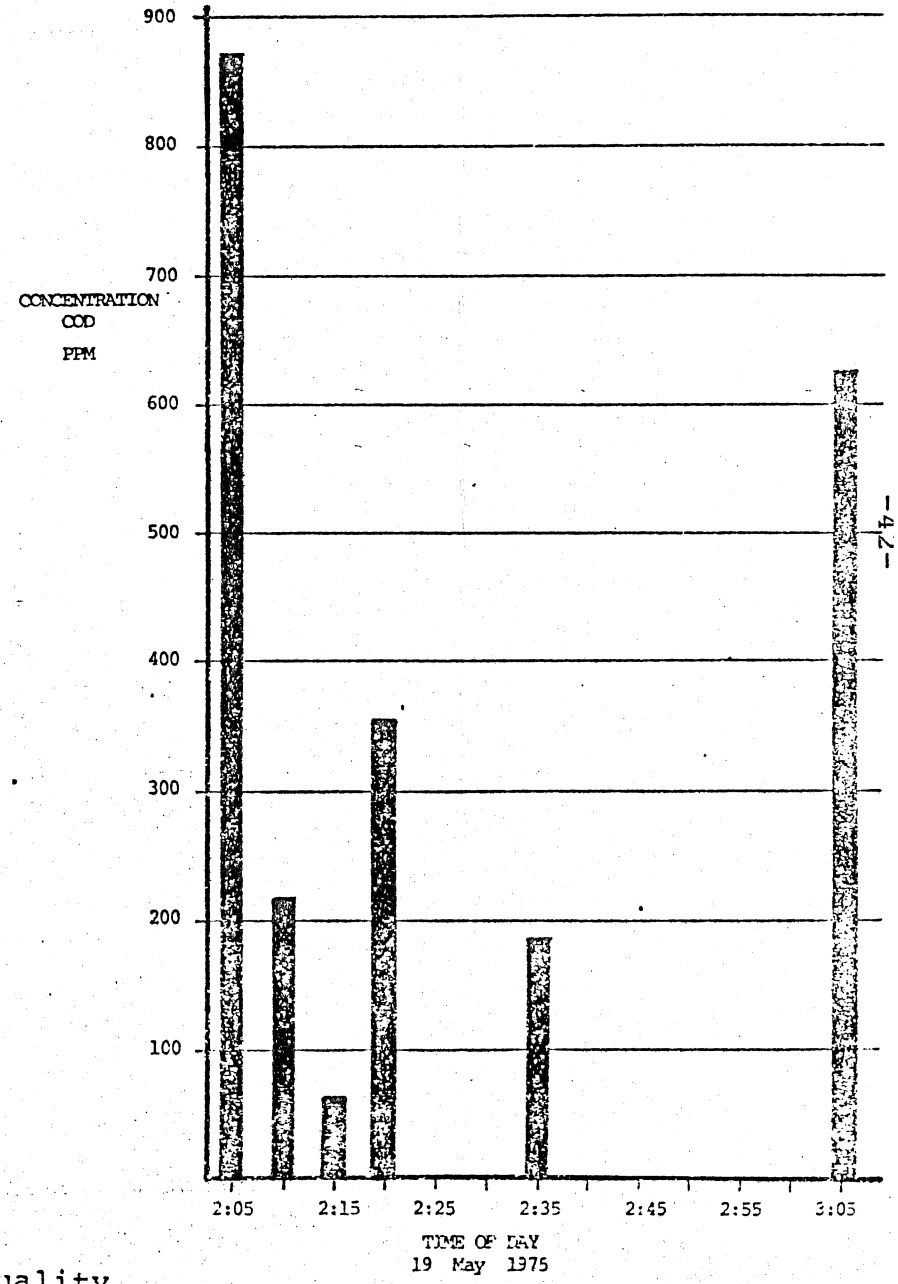
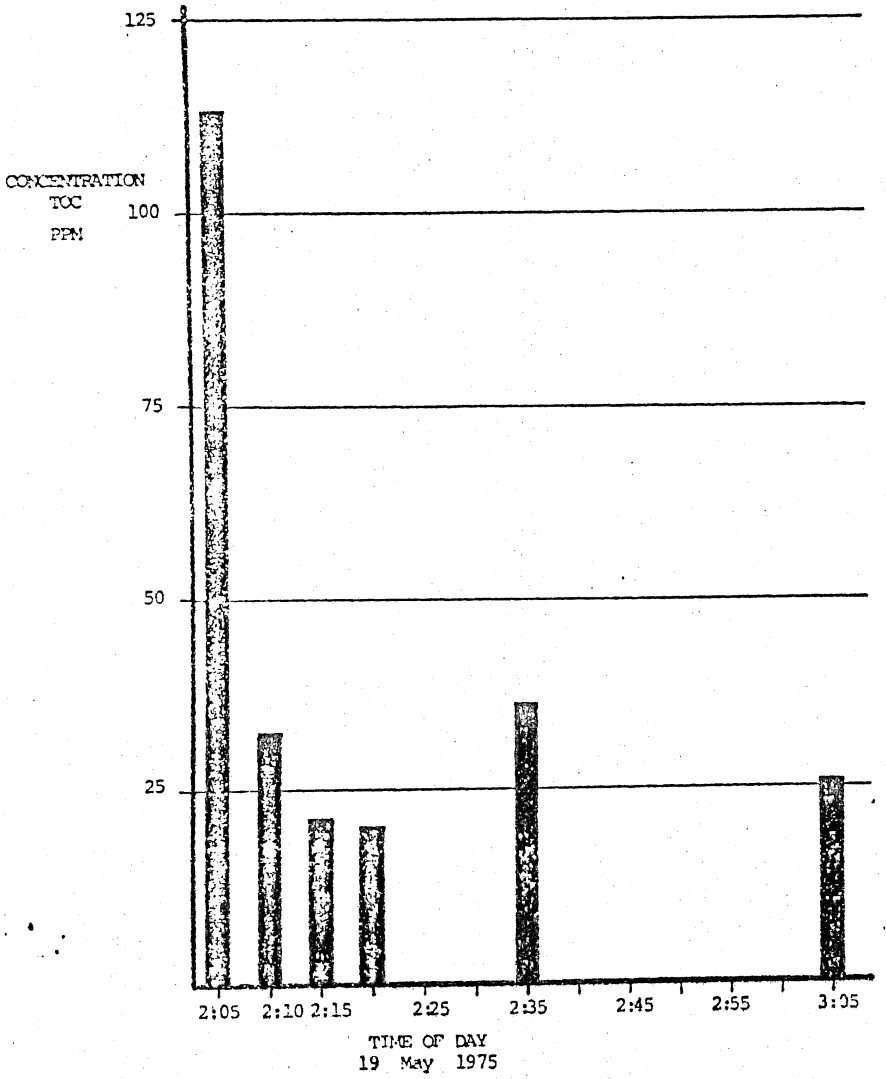


Figure 26 Runoff Quality



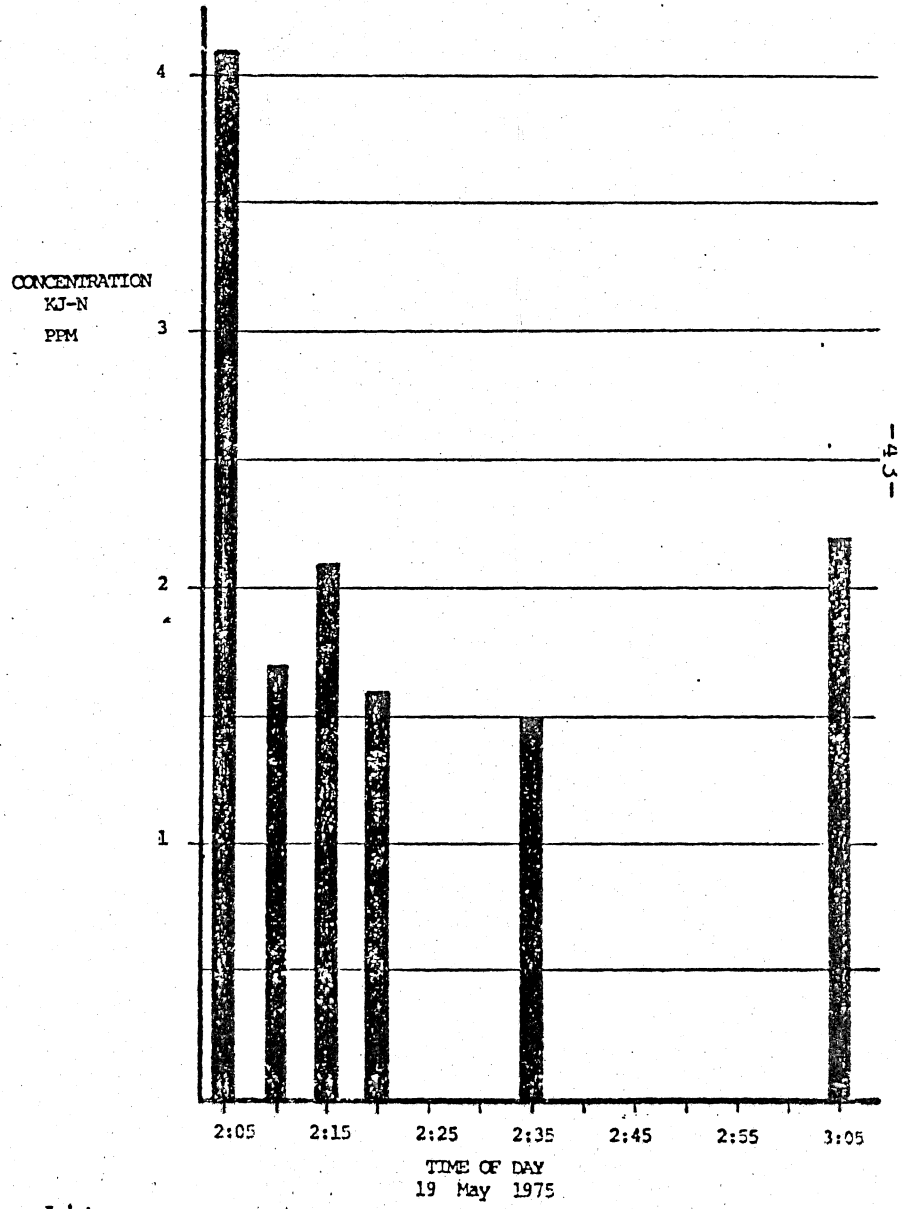
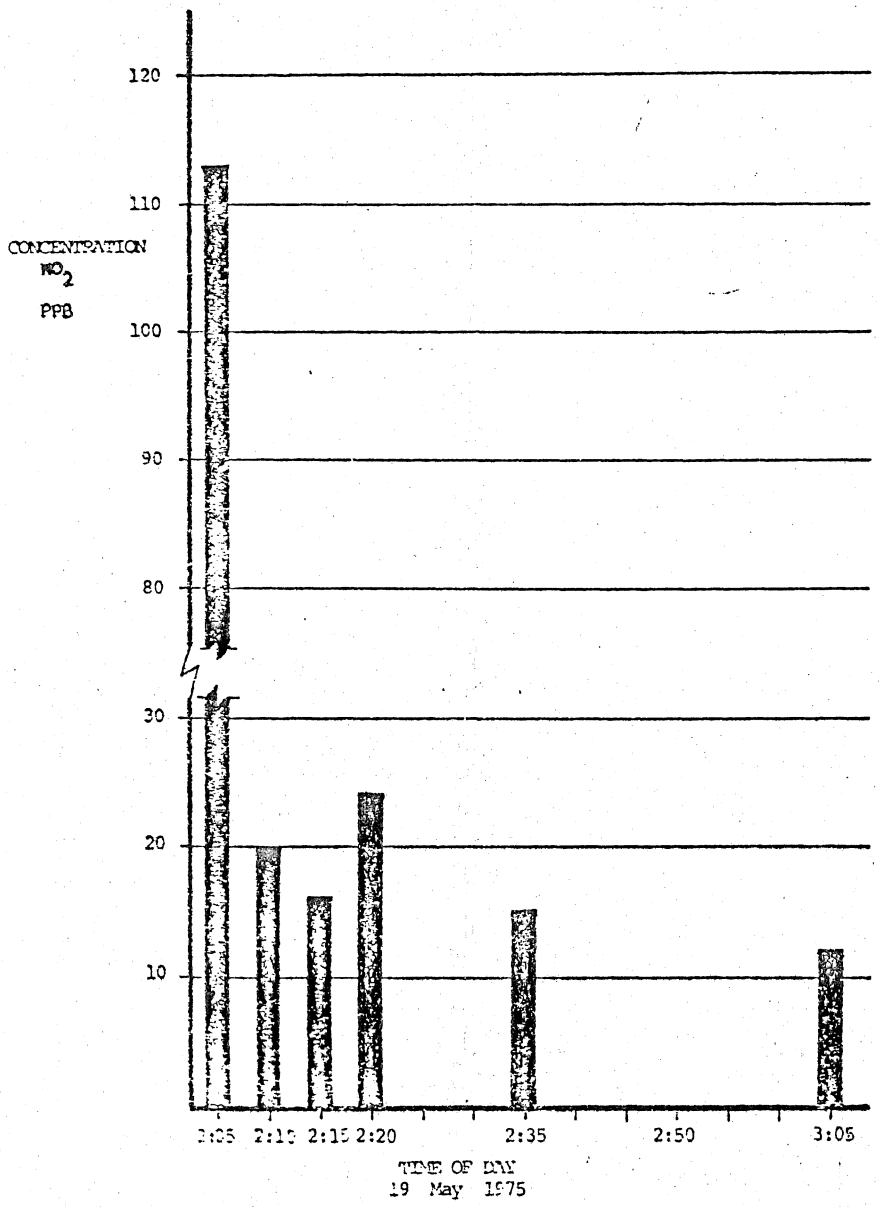


Figure 27 Runoff Quality



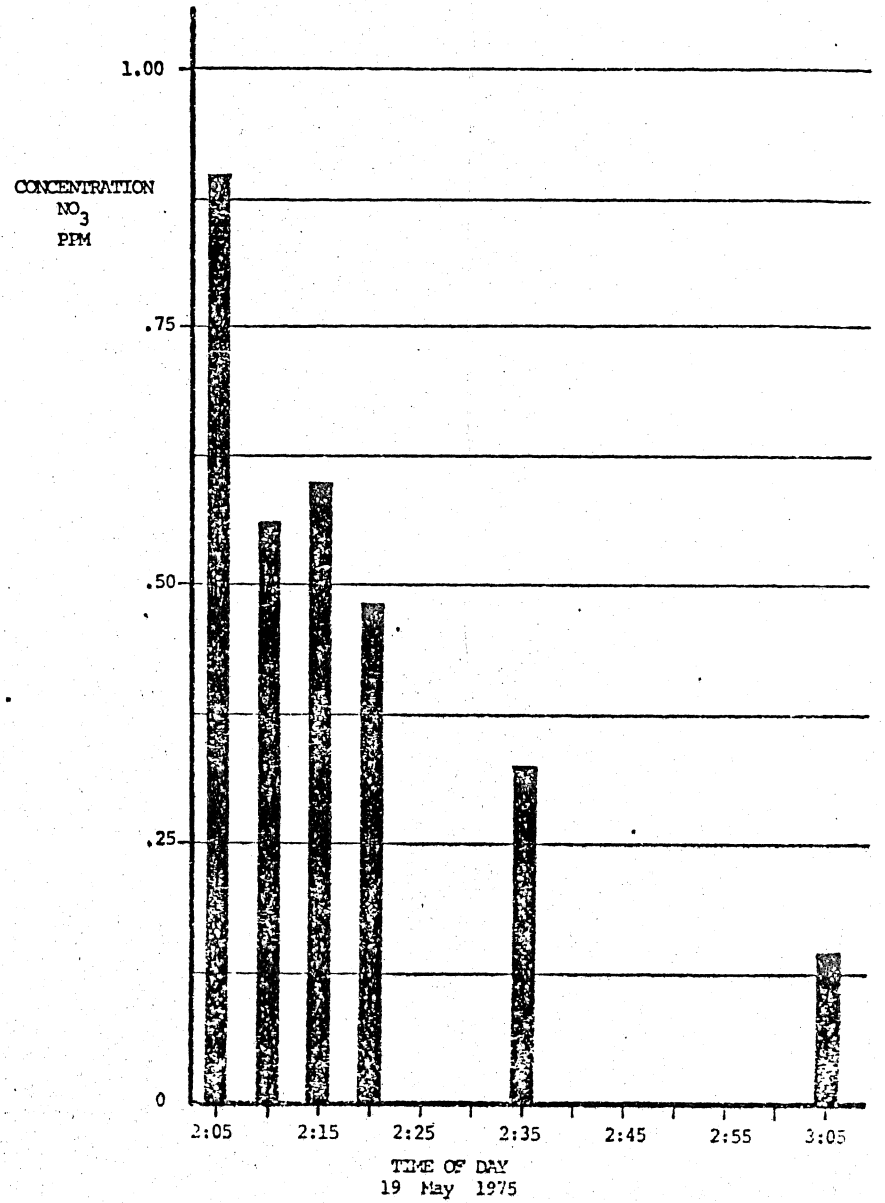
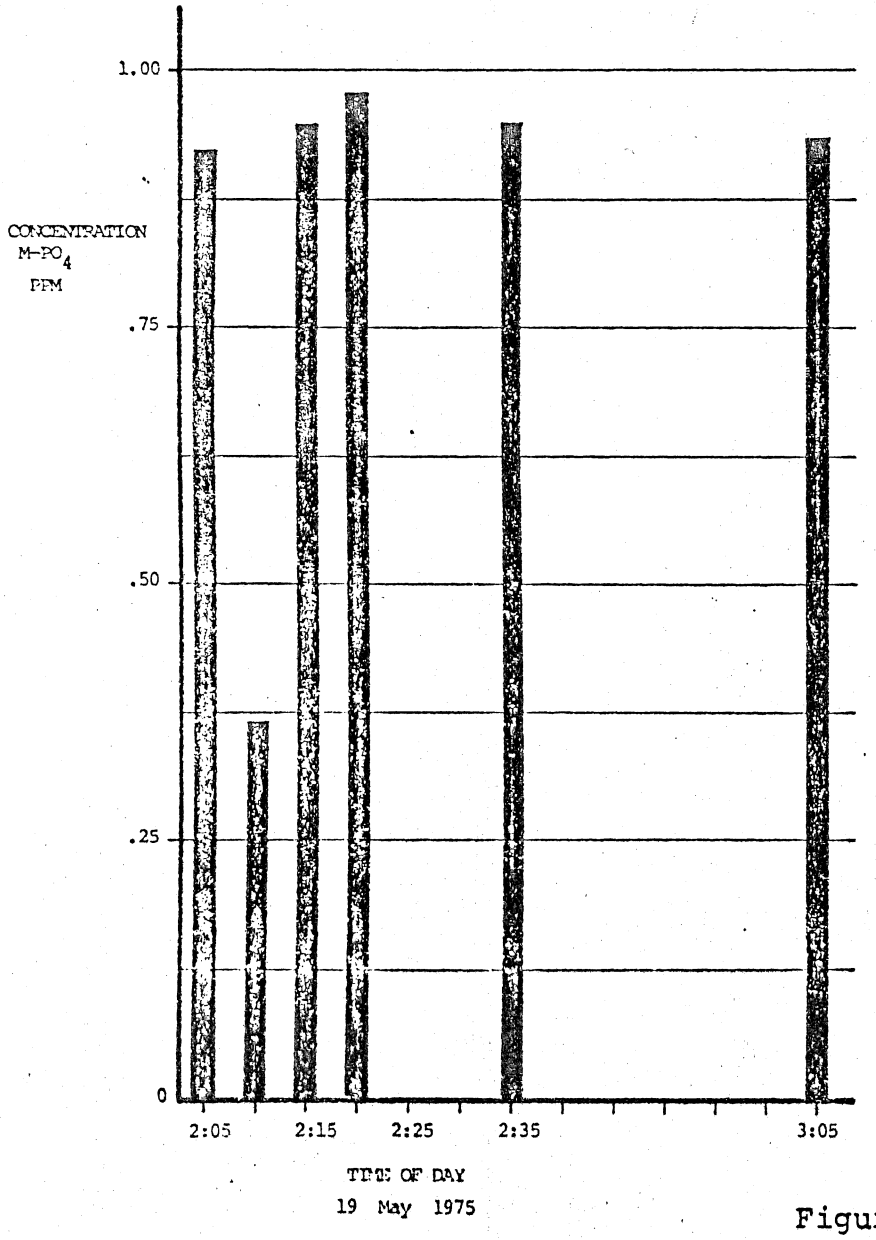


Figure 28 Runoff Quality



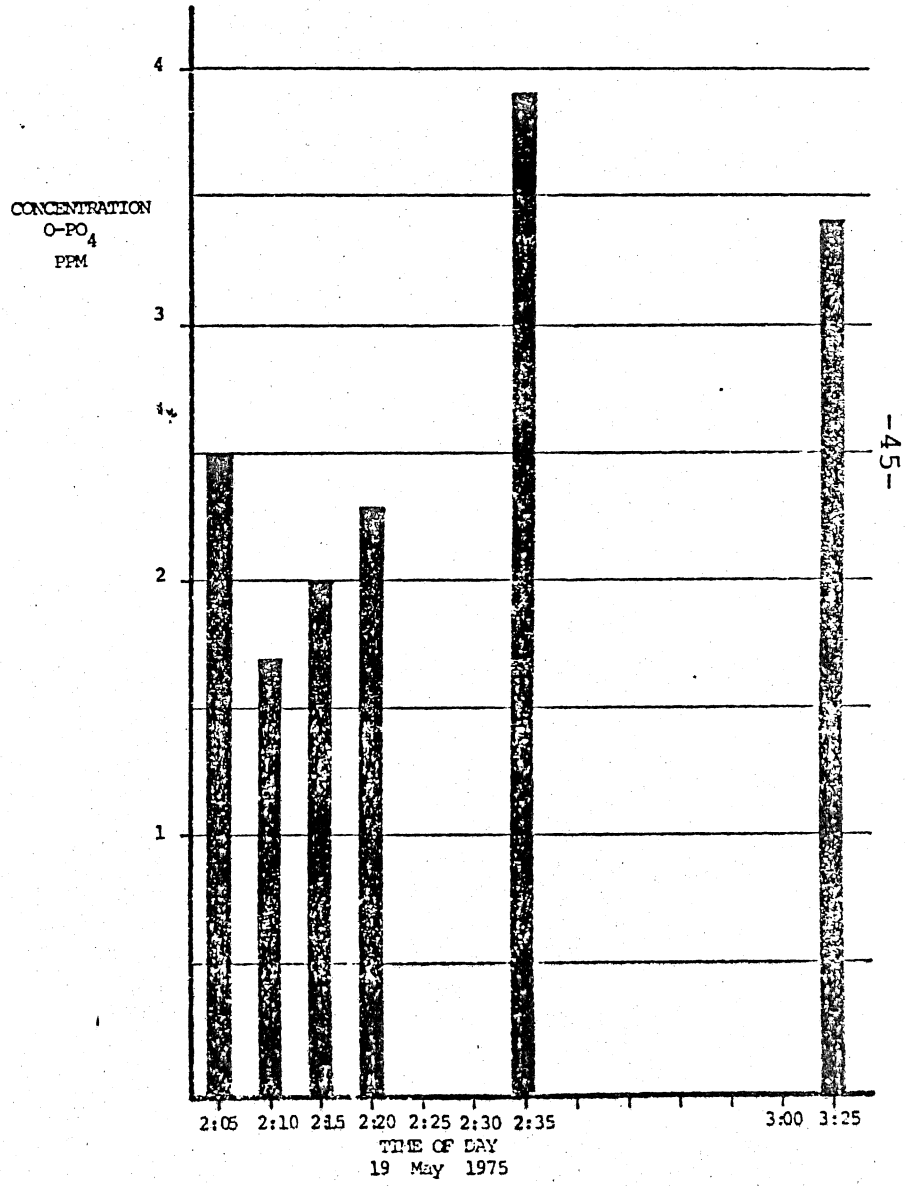
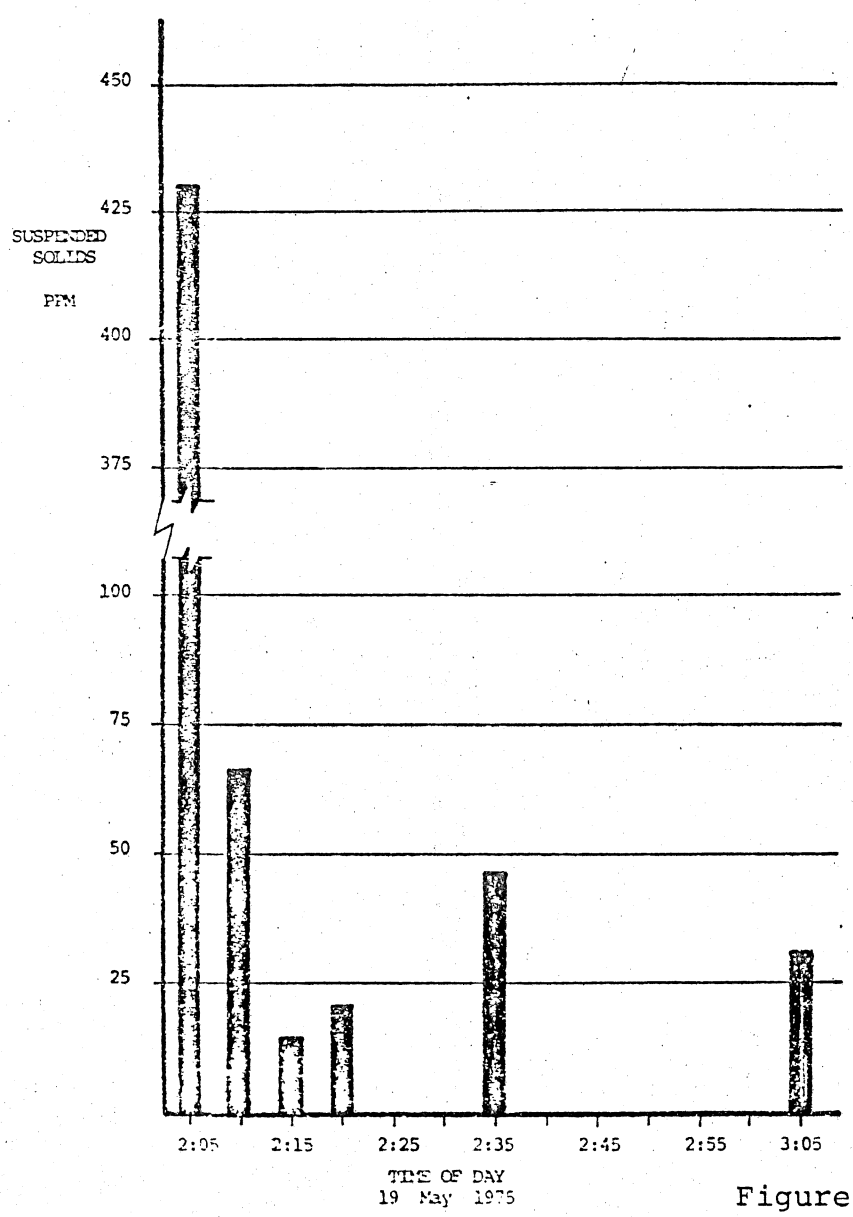


Figure 29 Runoff Quality



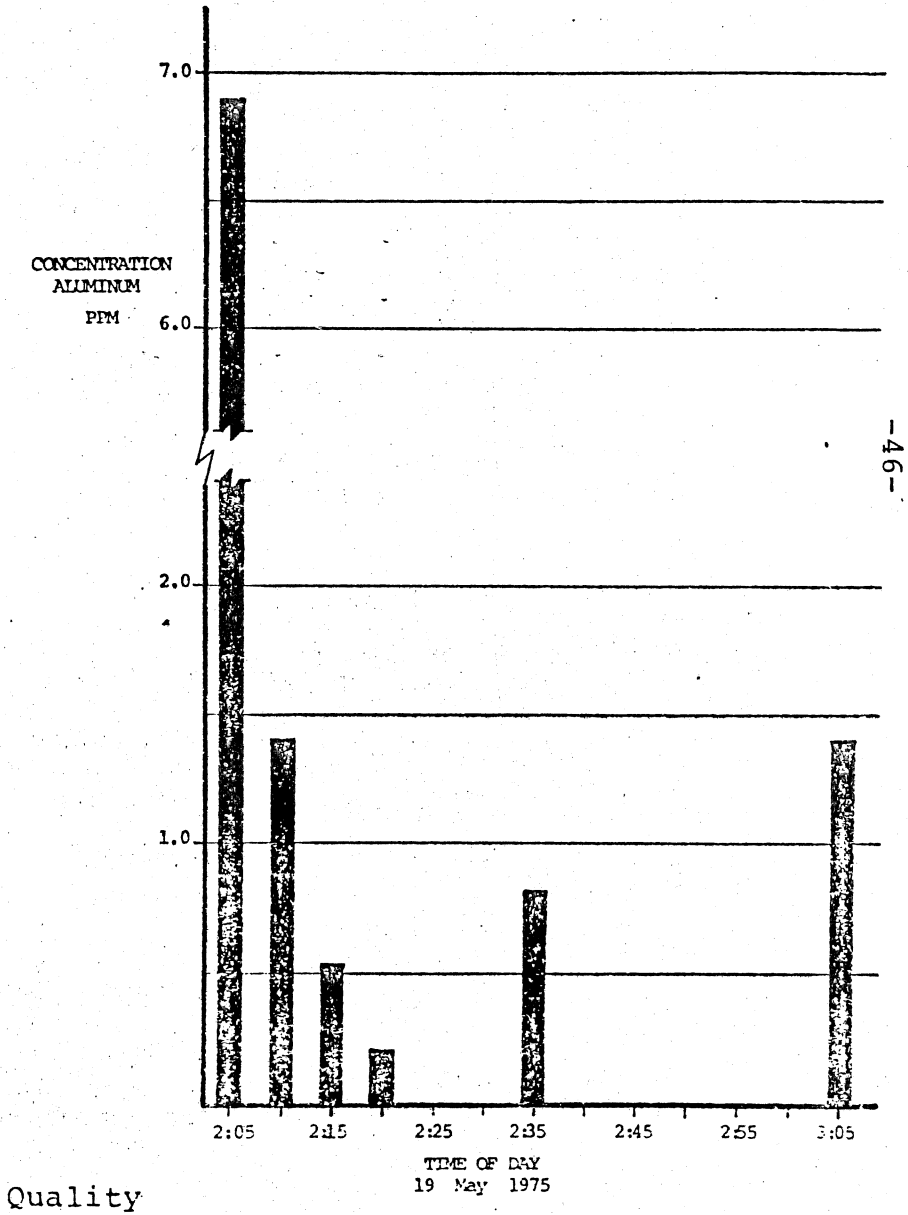
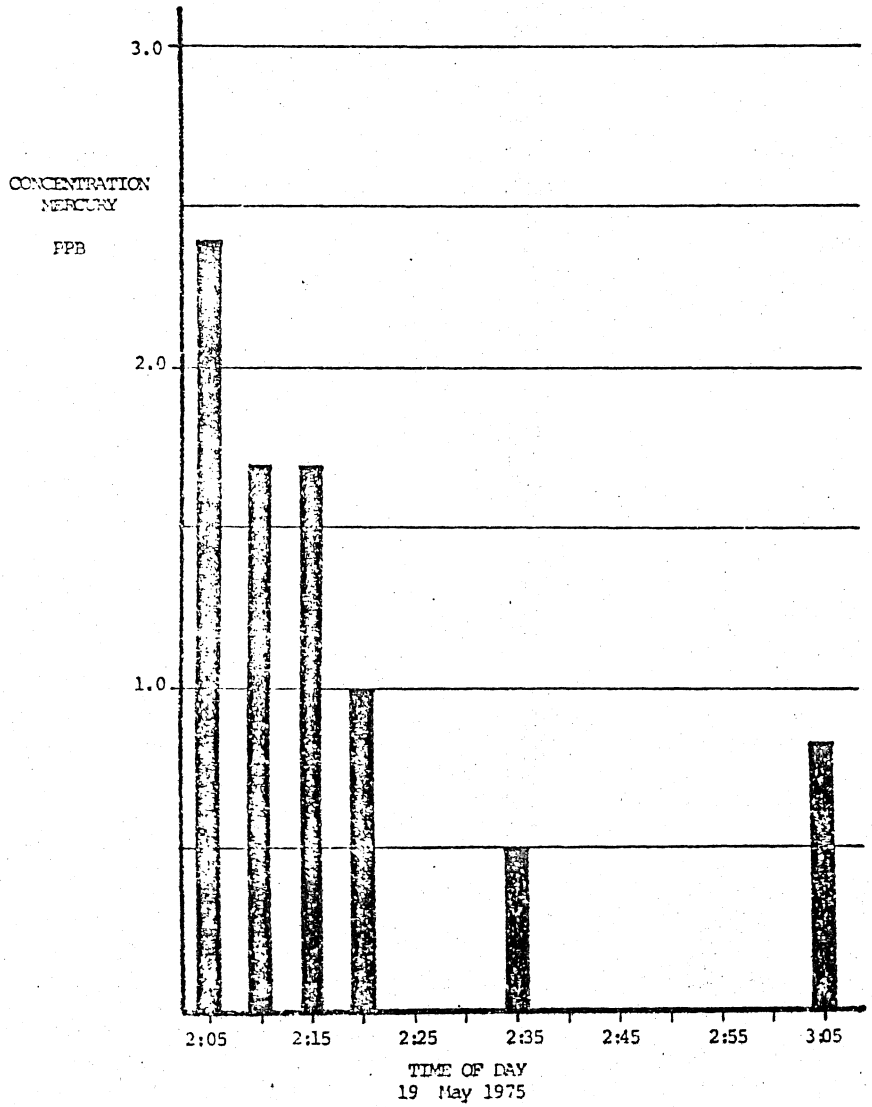


Figure 30 Runoff Quality



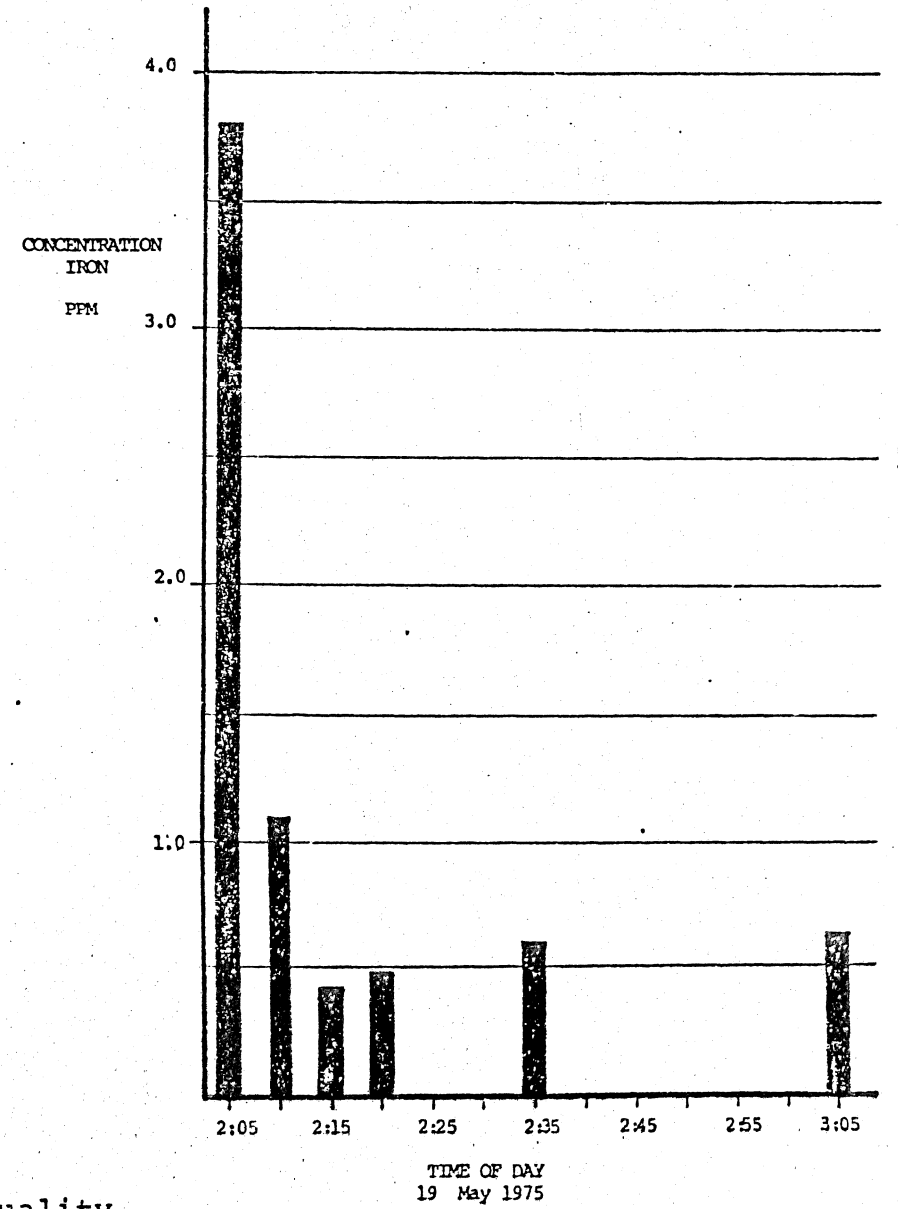
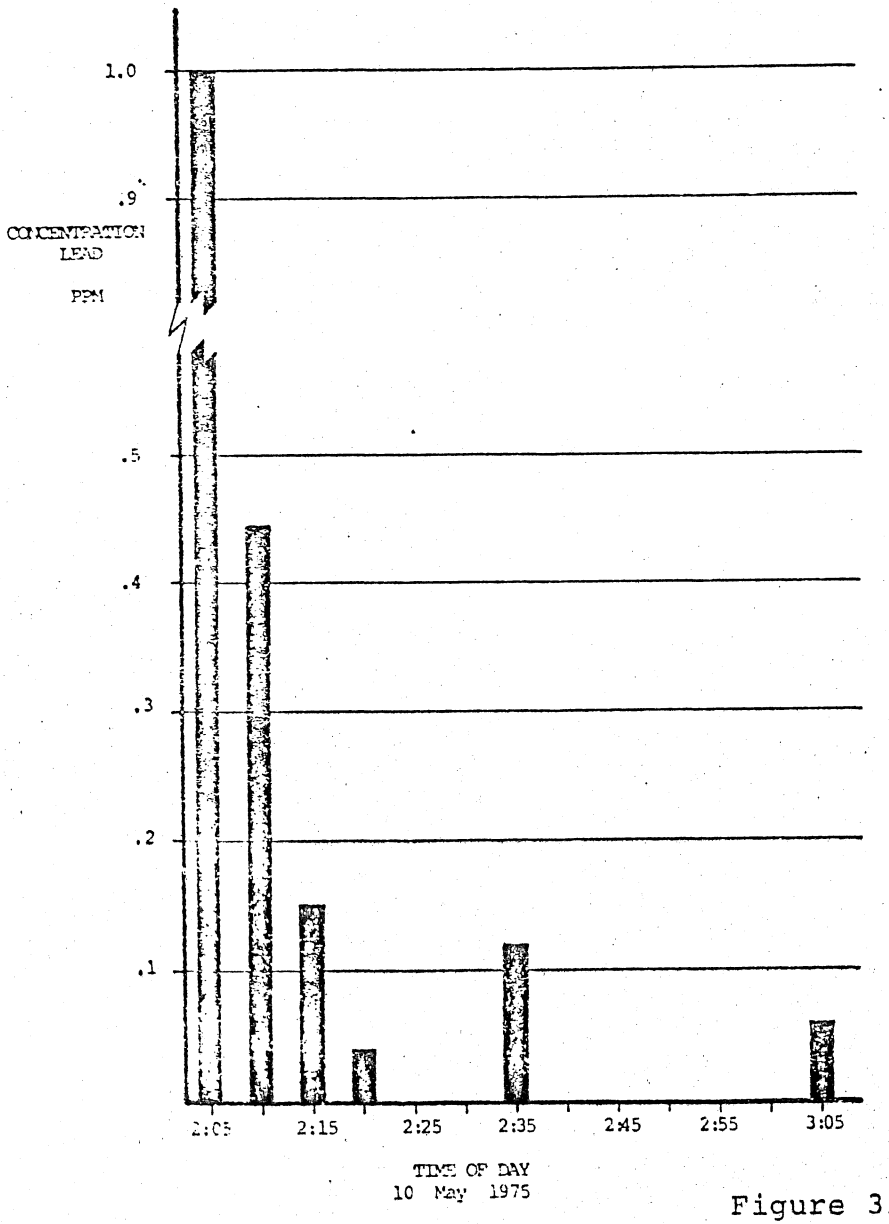


Figure 31 Runoff Quality



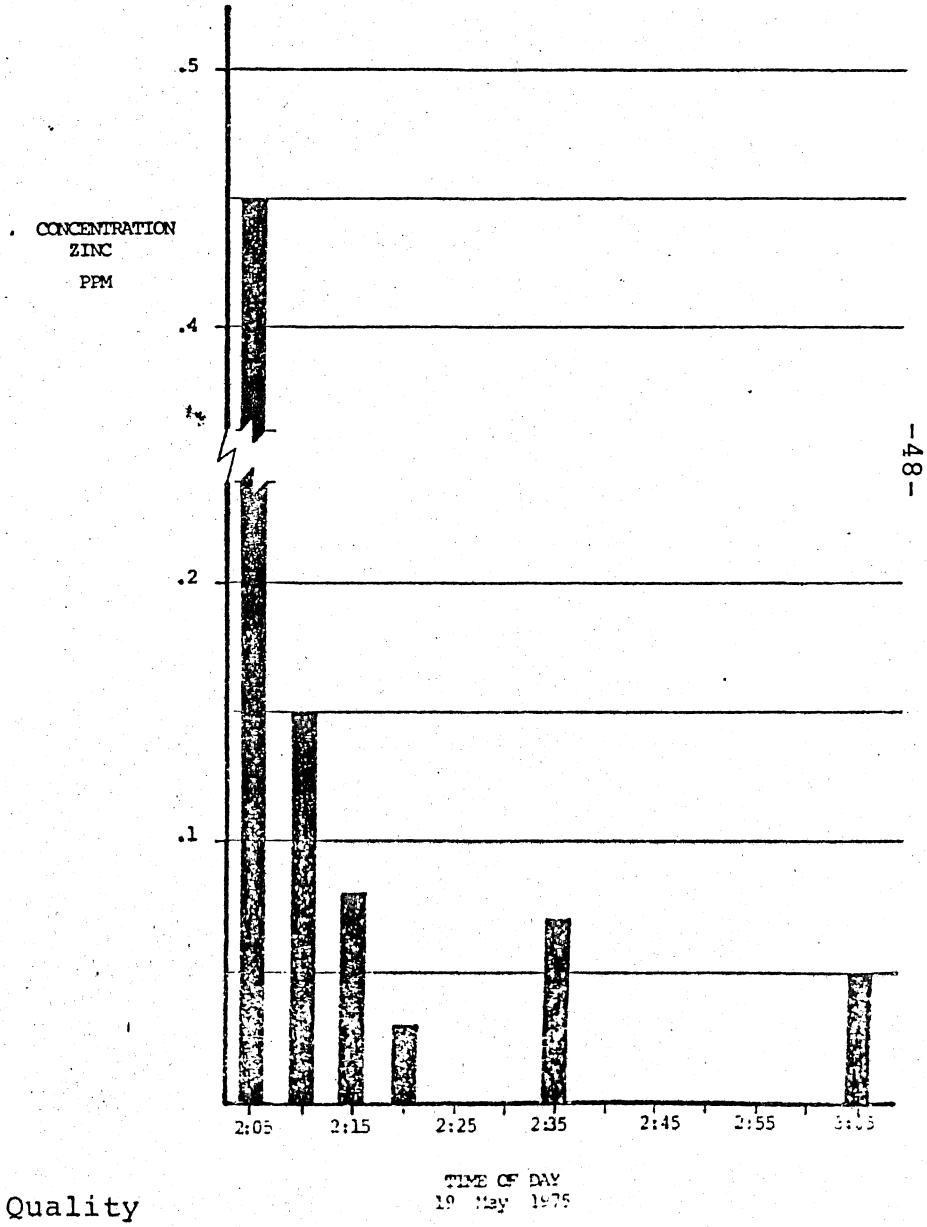
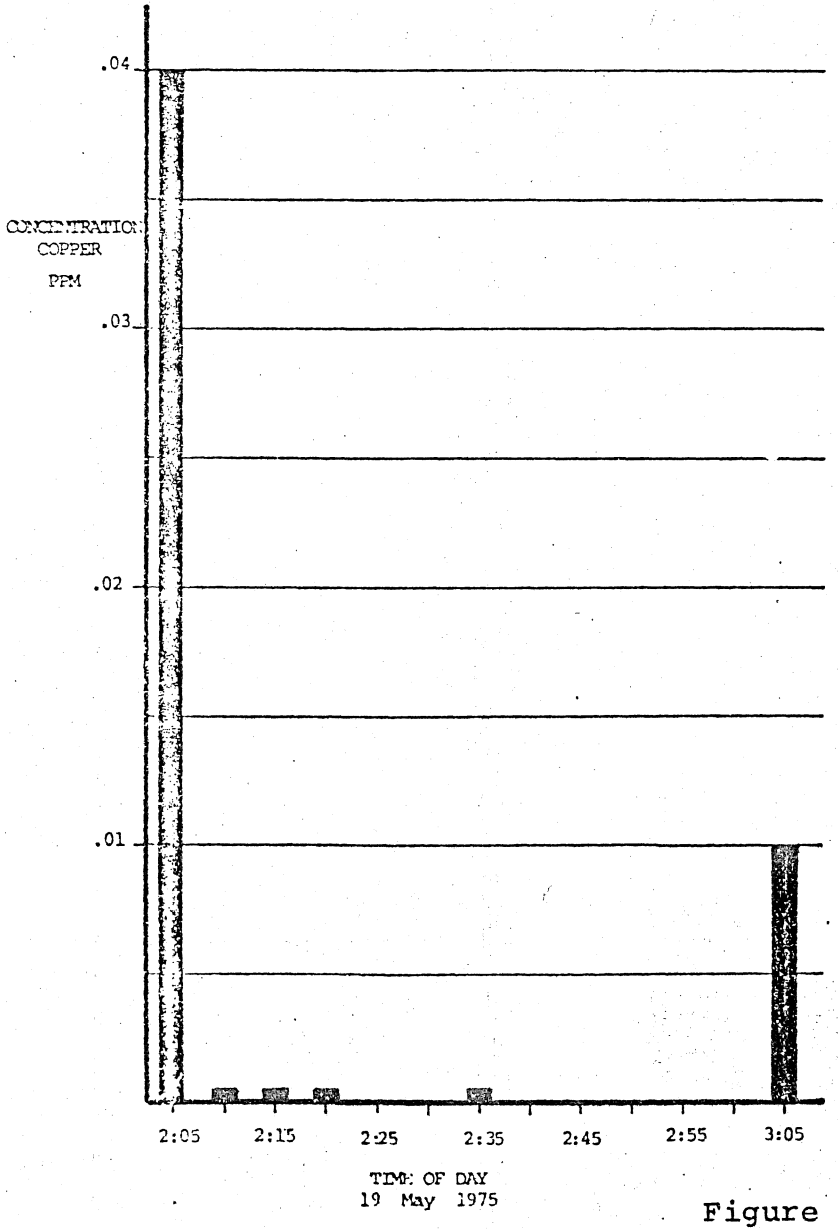


Figure 32 Runoff Quality



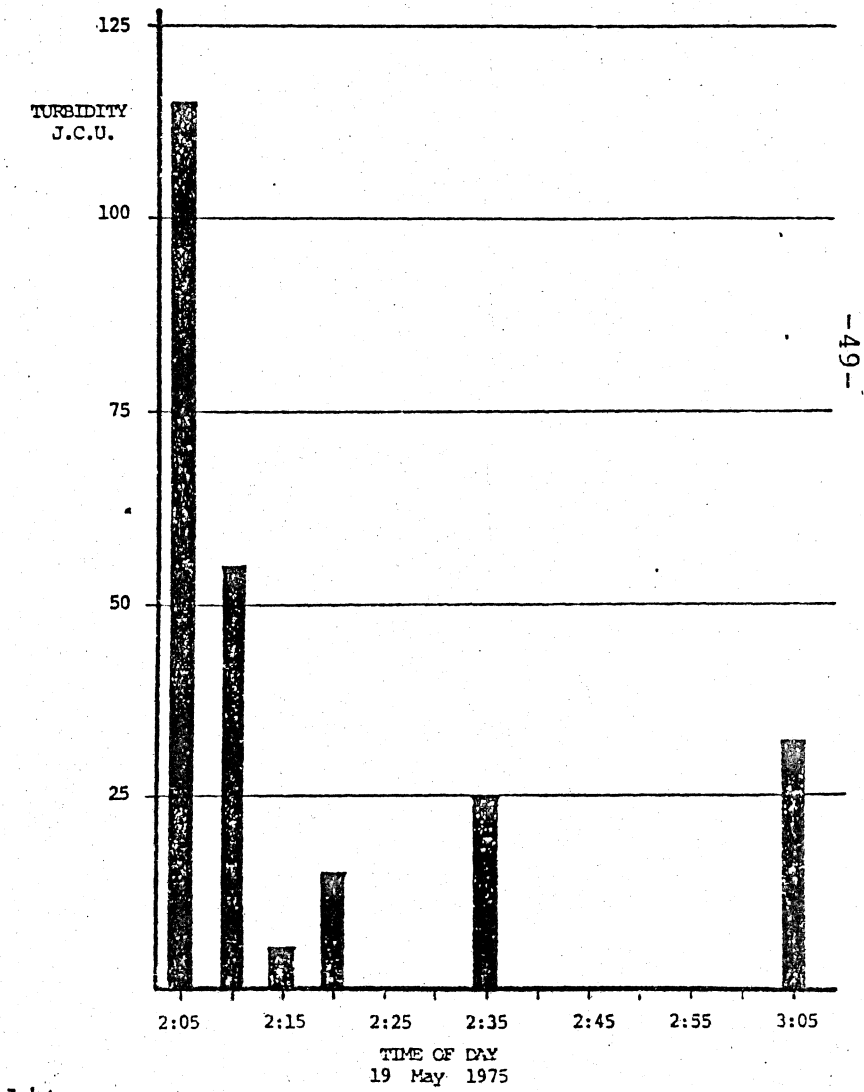
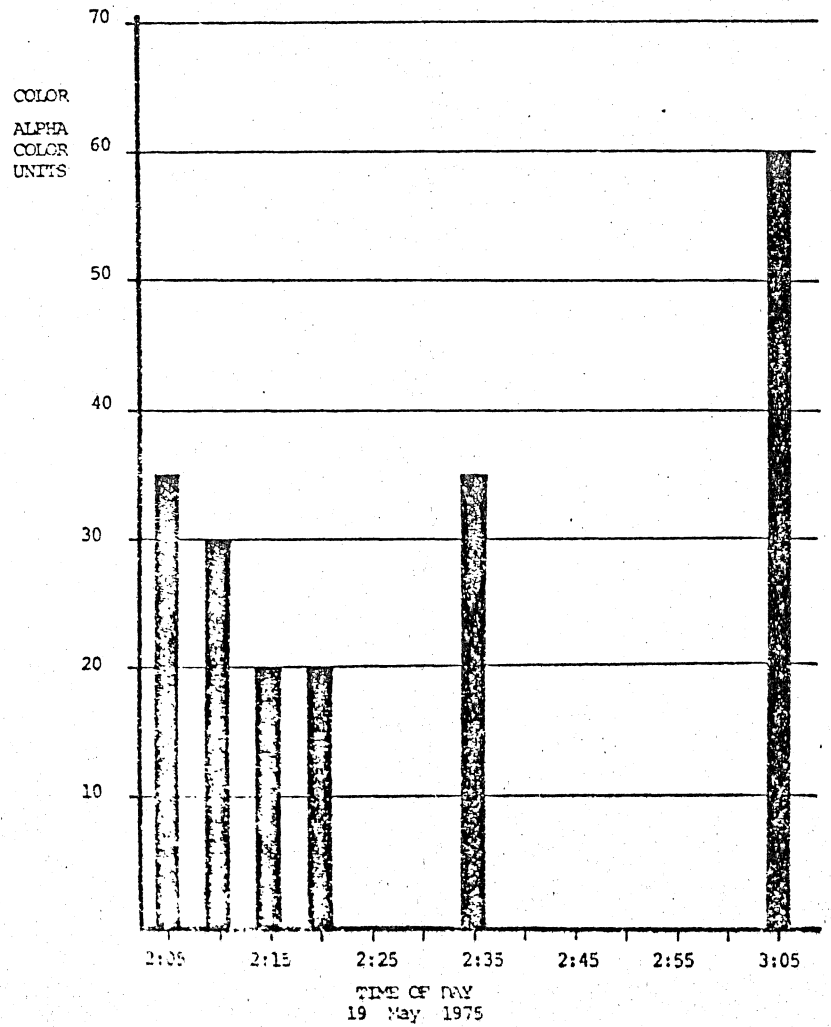


Figure 33 Runoff Quality



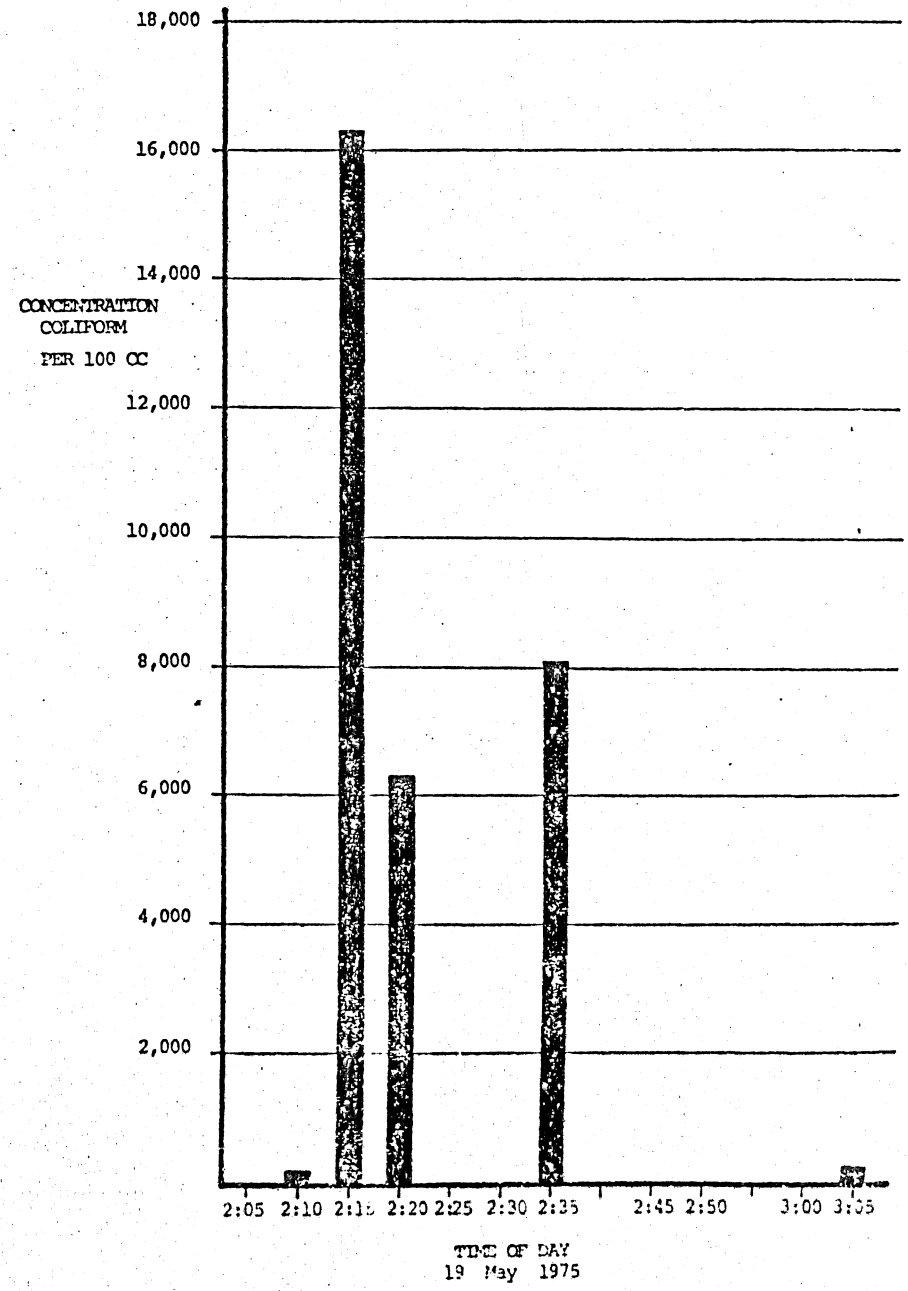
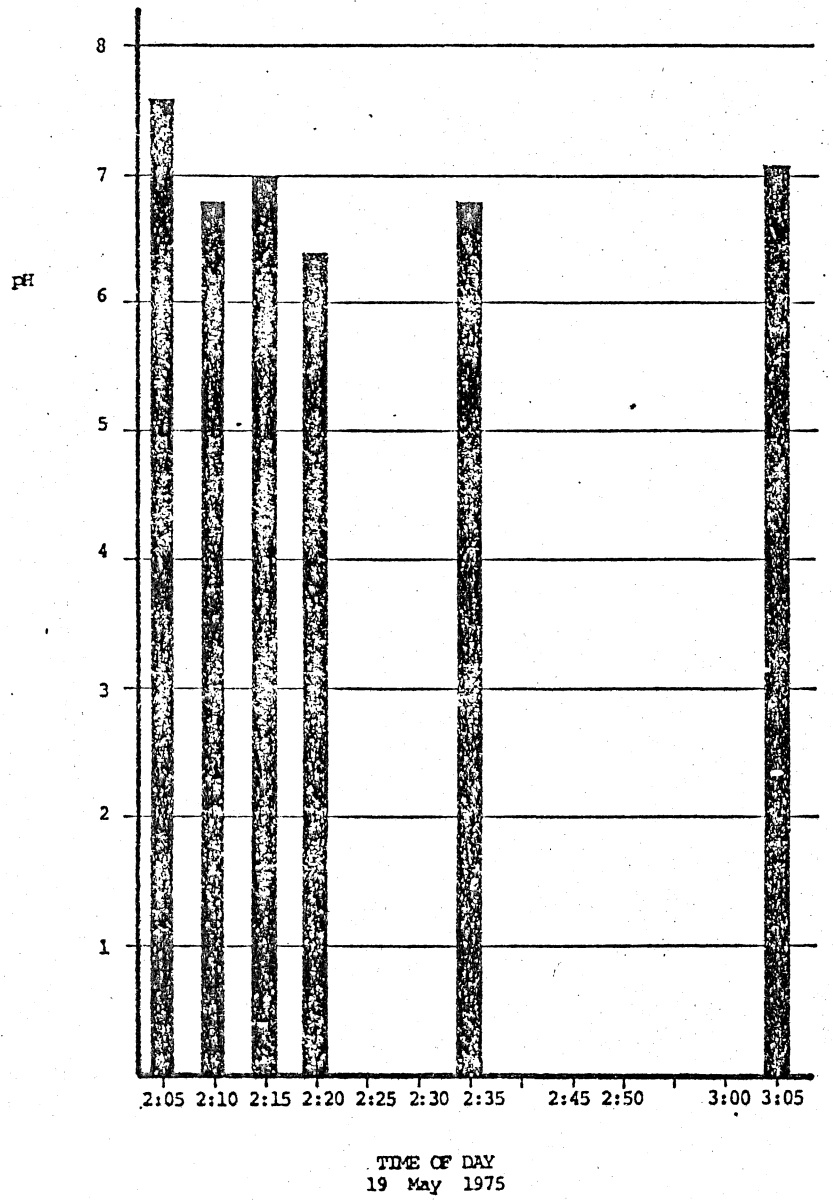


Figure 34 Runoff Quality



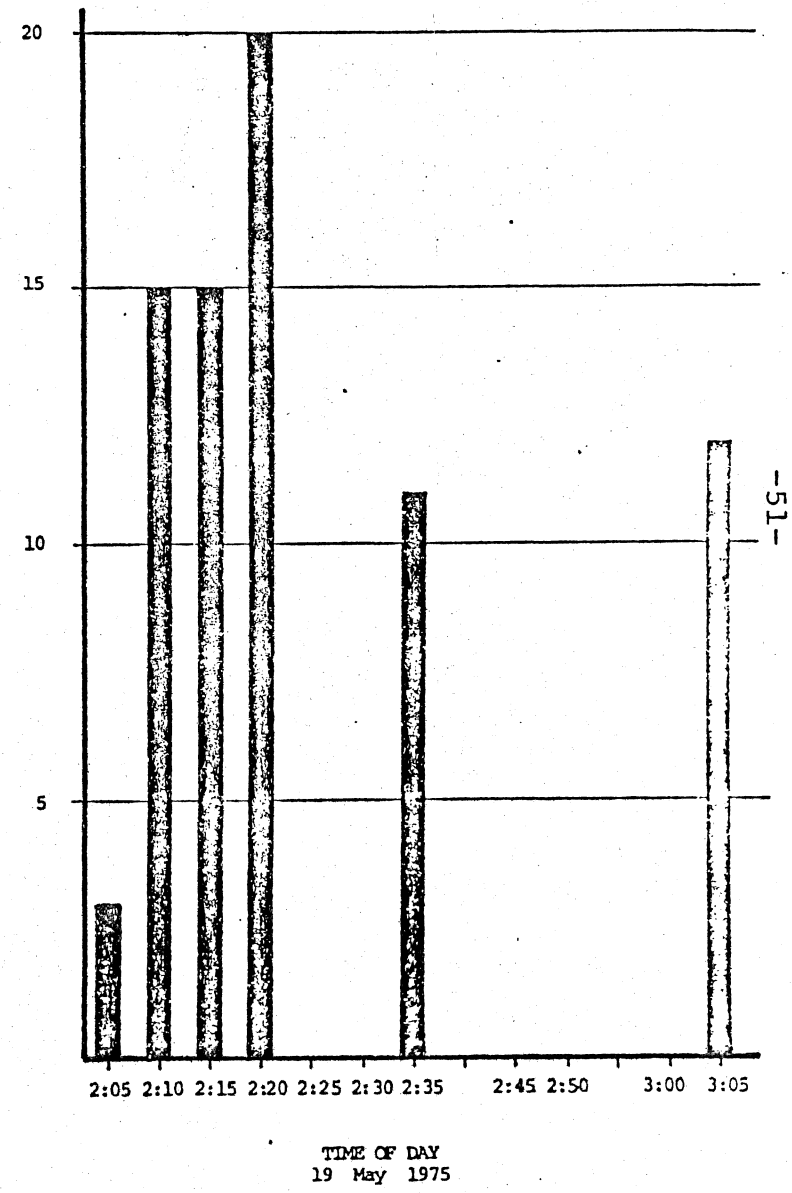


Figure 35 Water Quality

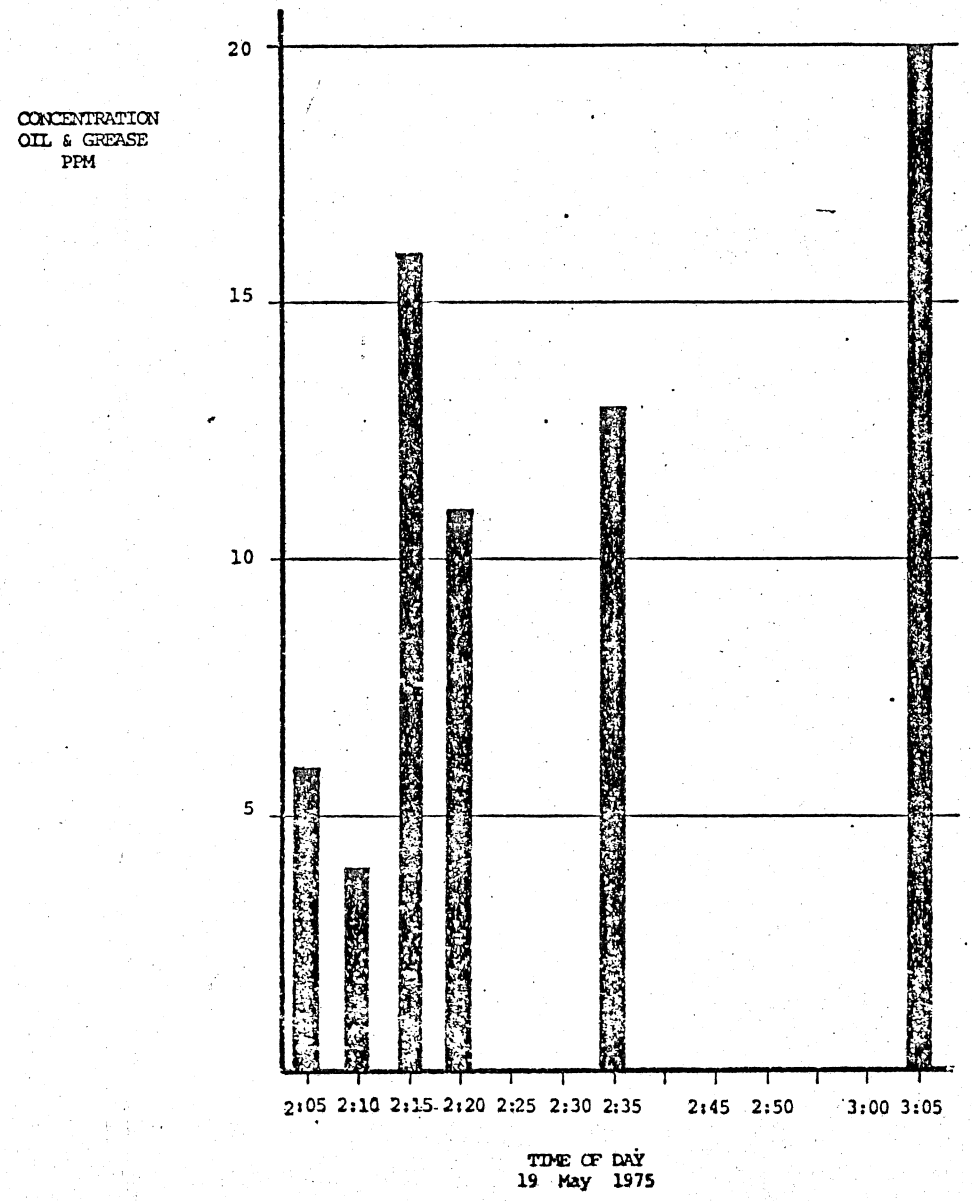


Figure 36 Water Quality

TABLE VI

TOTAL POLLUTANTS ENTERING FROM SOUTH OF FOWLER AVENUE
19 May 1975

Rainfall - .28 inch
Duration - 15 minutes
Values(*)- All values in pounds

	(5min) 2:05	(5min) 2:10	(5min) 2:15	(5min) 2:20	(15min) 2:35	(30min) 3:05	TOTAL	#Per Acre (239.3)
BOD	10.42	5.55	3.37	4.55	11.68	10.06	45.63	.191
COD	35.90	21.11	6.53	42.88	19.99	62.63	189.04	.790
TOC	4.65	3.11	2.24	2.52	7.86	2.59	22.97	.096
TKN	.17	.16	.214	.192	.34	.22	1.30	.0054
NO_2	.0047	.002	.0016	.0028	.0034	.0012	.0057	6.56×10^{-5}
NO_3	.037	.052	.056	.059	.065	.007	.276	1.15×10^{-5}
CO_2	.12	1.46	1.53	2.4	2.47	1.19	9.17	.038
Meta-PO_4	.038	.003	.097	.117	.213	.092	.56	.002
Ortho-PO_4	.10	.017	.204	.275	.88	.339	1.82	.008
SS^2	17.71	6.52	1.53	2.52	10.33	3.19	41.80	.175
Al	.28	.136	.054	.024	.184	.139	.817	.003
Hg	.0001	.00017	.00017	.000012	.00011	.000083	.00065	2.72×10^{-6}
Fe	.16	.11	.043	.057	.135	.064	.569	.0023
Pb	.041	.043	.015	.0048	.027	.006	.137	.0006
Zn	.019	.0146	.0082	.0036	.016	.005	.066	.0003
Cu	.0016	.0002	.0002	.00024	.00045	.001	.00369	.00002
Oil-Grease	.25	.39	1.63	1.32	2.92	1.99	8.5	.036

TOTAL RUNOFF 10,971 ft^3

TABLE VI (Continued)

TOTAL POLLUTANTS ENTERING FROM SOUTH OF FOWLER AVENUE
19 May 1975

Rainfall - .28 inch
Duration - 15 minutes
Values(*)- All values in pounds

	(5min) 2:05	(5min) 2:10	(5min) 2:15	(5min) 2:20	(15min) 2:35	(30min) 3:05	TOTAL	#Per Acre (239.31)
pH	7.6	6.8	7.0	6.4	6.8	7.1		
Turb(JTV)	115	55	5.0	15	25	30		
Color(APHA)	35	30	20	20	30	60		
H_2S	None Found							
Coli-Aerogenes Confirmed -- per 100 cc		200	16300	4300	8100	30		
E.Coli. per 100 cc	--	---	6750	913	415	---		

TABLE VII

CHEMICAL TESTS ON WATER IN WELLS

DATE-WELL	O-PO4 (PPM)	M-PO4 (PPM)	NO3 (PPM)	NO2 (PPM)	CO2 (PPM)	PH	COLOR
7/12/72-1	10.500	5.000	21.100	C.C50	52.000	5.200	0.0
7/24/72-1	1.500	4.000	17.600	0.030	88.000	5.250	420.00
8/ 4/72-1	1.980	0.0	5.200	C.C55	17.000	5.220	510.00
8/16/72-1	1.200	9.500	18.500	C.048	C.0	4.900	500.00
8/23/72-1	0.220	1.130	2.640	C.0	56.000	6.000	485.00
9/ 3/72-1	11.000	4.000	4.400	0.0	84.000	5.500	360.00
9/17/72-1	0.400	0.200	1.400	C.0	76.000	5.700	380.00
7/ 6/72-2	4.500	4.800	2.200	0.066	44.000	4.800	0.0
7/22/72-2	3.300	8.300	24.200	C.041	48.000	5.350	0.0
8/16/72-2	3.200	5.600	24.400	0.250	C.0	0.0	520.00
9/ 3/72-2	0.0	0.0	8.300	C.0	99.000	0.0	0.0
9/18/72-2	5.500	0.0	0.0	0.0	72.000	5.500	0.0
7/ 7/72-3	6.750	0.0	24.200	C.058	6C.000	5.500	0.0
7/14/72-3	2.800	8.200	19.800	C.020	52.000	5.C00	520.C0
8/10/72-3	0.820	1.420	16.700	C.012	44.000	5.850	340.C0
8/16/72-3	0.500	2.190	0.0	0.030	C.0	5.100	422.00
8/24/72-3	C.220	0.650	2.640	C.022	44.000	5.700	280.C0
9/ 3/72-3	2.900	12.100	2.640	0.0	8C.000	6.C00	285.00
9/18/72-3	C.300	0.5C0	0.0	C.0	64.000	6.000	260.C0
7/18/72-4	1.500	1.000	19.800	0.033	17.20C	5.050	0.0

(Continued)

CHEMICAL TESTS ON WATER IN WELLS
(continued)

DATE-WELL	O-PO4 (PPM)	M-PO4 (PPM)	NO3 (PPM)	NO2 (PPM)	CO2 (PPM)	PH	COLOR
8/23/72-4	0.170	0.180	2.700	0.0	0.0	6.500	510.00
9/ 4/72-4	3.300	0.0	0.880	0.0	80.000	6.100	0.0
9/17/72-4	0.300	0.0	2.640	0.0	84.000	6.000	600.00
7/25/72-5	0.750	4.000	17.600	0.033	60.000	5.200	155.00
8/ 2/72-5	1.300	2.000	17.600	0.012	80.000	5.350	165.00
8/17/72-5	5.000	24.500	3.300	0.076	48.000	5.250	175.00
8/24/72-5	0.190	0.110	1.760	0.018	64.000	5.600	105.00
9/18/72-5	5.500	0.300	0.0	0.0	42.000	6.400	80.00
7/11/72-6	4.500	5.000	25.500	0.026	44.000	4.800	380.00
7/28/72-6	2.400	3.400	15.400	0.024	32.000	6.050	280.00
8/23/72-6	0.380	0.0	3.520	0.026	56.000	5.350	490.00
9/ 4/72-6	9.000	0.0	0.900	0.0	48.000	5.050	400.00
9/17/72-6	9.500	0.0	5.720	0.0	28.000		0.0
7/ 9/72-7	5.400	11.500	26.400	0.068	52.000	5.200	0.0
7/15/72-7	2.500	5.500	25.500	0.016	68.000	5.000	210.00
7/27/72-7	1.300	2.200	19.800	0.014	20.000	5.850	240.00
8/ 9/72-7	0.650	1.620	17.600	0.072	40.000	5.350	135.00
8/17/72-7	3.000	0.0	3.500	0.066	44.000	5.050	212.00
8/24/72-7	0.100	0.390	2.600	0.033	80.000	5.250	295.00
9/ 4/72-7	11.000	4.000	0.560	0.0	84.000	5.400	210.00

(Continued)
CHEMICAL TESTS ON WATER IN WELLS
(continued)

DATE-WELL	O-PO4 (PPM)	N-PO4 (PPM)	NO3 (PPM)	NO2 (PPM)	CO2 (PPM)	D-O2 (PPM)	H2S (PPM)	PH	COLOR
9/17/72-7	0.180	0.0	2.810	0.0	60.000	0.0	0.0	5.500	390.00
5/ 3/74-3	2.500	0.400	3.520	0.082	16.000	4.000	0.020	6.650	250.00
5/ 3/74-4	0.300	0.300	4.840	0.099	22.000	7.000	0.020	7.000	240.00
5/ 9/74-5	0.450	0.350	2.640	0.020	4.800	10.000	0.020	7.250	90.00

The ditch, marsh, and lake system in the portion of the watershed north of Fowler Avenue acted much like a water treatment plant in providing settling operations, biological action, and filtration to the runoff from the area south of Fowler Avenue. Therefore, even though the extensive urbanization of the area north of Fowler did not occur, valuable data were gathered which pertain to the natural purification of urban storm runoff.

Major drainage changes were made in this area north of Fowler Avenue during the study period which caused changes in the quality of the effluent leaving the area. When the project started the lake and marsh functioned as a collection basin for the area north of Fowler Avenue and there was no clear separation between the lake and the marsh. The land south of Fowler Avenue was connected to the marsh when the pipe was placed under Fowler Avenue and the drainage ditch was dug. Being a new ditch the walls and bottom were free from vegetation and it drained rapidly into the marsh, so that little or no water remained in the ditch after a rainstorm, except directly downstream of the 54 inch pipe which washed out a large depression. The ditch received no maintenance with the passage of time. It filled with debris and plant life (See Figures 13, 14 and 15). The three times that the flume washed out caused sand that was under the flume or between the wing walls to be transported and deposited further downstream, creating pockets where water would stand for long periods of time. Aquatic weeds grew in these standing waters.

In the summer of 1973 and spring of 1974 the lake was enlarged and the soil which was removed was used to partially fill the marsh making it broader and more shallow. After these enlargements the lake was clearly separate from the marsh, and water backed up in the ditch where it stood 2 or 3 feet deep at all times. At the start of the project biological action on the water borne pollutants took place mainly in the marsh, whereas by the end of the project it took place throughout the entire system. Since water remained in the system longer, nutrients were more fully consumed and suspended solids had more opportunity to precipitate.

There were at least two mechanisms that countered the water quality improvement, rapid development in the area around the study watershed and exposure of fresh soil during the enlargement of the lake. In the period from 1971 to 1975 two apartment complexes and two blocks of retail stores were completed on or adjacent to the study watershed. In the same period the Florida Department of Transportation reported that the average number of vehicles per day on the highways around the projects doubled (for Fowler Avenue east of 56th Street it went from 4075 vehicles per day in 1971 to 10430 vehicles per day in 1974).

The digging and disturbance of the lake and marsh exposed large areas of fresh soil to the leaching of nutrients and increased the silt and suspended solids leaving the lake.

Over the entire test period, there was an expected improvement in the quality of water leaving the watershed when compared with the water entering from south of Fowler Avenue. (See Table VIII) There was a decrease in ortho-phosphate, meta-phosphate, nitrate, dissolved oxygen and pH. These nutrients were consumed during passage over the vegetated area and the decrease in dissolved oxygen indicated that the metabolic regime when averaged over the entire study period was predominantly respiratory. Of even more interest are the yearly water quality averages. (See Table IX) In this table, the changes in the behavior of the ditch, marsh and lake system are apparent. The 1974 figures are of particular interest, since this was the year when major changes were made in the lake and marsh. These changes explain the otherwise unexpected results that occurred in 1974 and 1975. A negative % change in tables VIII and IX indicates a removal or decrease in the water quality parameter as the water flowed through the system.

Ortho-phosphate was removed every year, but there was an increase in the concentration of this nutrient coming in from south of Fowler from 1971 to 1975. This increase can best be seen by comparing the data for 1972 and 1974, both of which cover full years. While the percent change was negative in 1974, there was nearly twice as much ortho-phosphate leaving the lake as in the next highest year. (See Table IX)

Table X shows that there was a large increase in concentrations for most of the samples taken during early 1974, the period when the lake was being enlarged. In June of 1974, the readings returned to normal.

Meta-phosphate decreased while passing through the watershed in every year except 1974 when the lake was drastically disturbed. The concentration entering the system increased with time, so over the period of the study, meta-phosphate discharging from the lake increased. The disturbance of the lake resulted in a sharp increase in meta-phosphate concentration leaving the lake in early 1974. (See Table X) The increase is large enough that the percent change goes positive. Note, that in 1975, the behavior of the system returned to normal. (See Table IX)

TABLE VIII

WATER QUALITY AVERAGES
(Oct. 1971 -May 1975)

	Ortho-PO_4 (ppm)	Meta-PO_4 (ppm)	NO_3 (ppm)	NO_2 (ppm)	CO_2 (ppm)	D.O. (ppm)	Color Units	pH	Turbidity (JTU)	Presumptive Coliform MPN (/100 ml)	Confirmed Coliform MPN (/100 ml)
Ditch Site											
Results	.62	.51	1.87	.03	5.7	8.7	94	7.5	41	8,979	3,835
Number of Samples	99	92	103	104	103	100	101	100	77	95	95
Stream Site											
Results	.43	.43	1.65	.09	9.3	7.3	164	7.0	41	2,394	320
Number of Samples	119	91	109	123	125	123	113	106	104	110	111
% Change $\frac{\text{Stream-Ditch}}{\text{Ditch}} \times 100\%$	-31%	-16%	-12%	+200%	+63%	-16%	+75%	-7%	0%	-73%	-92%

TABLE IX
YEARLY WATER QUALITY AVERAGE

	1971 October - December			1972 January - December			1973 February - May			1974 January - December			1975 January - April		
	Fowler	Lake	%Change	Fowler	Lake	%Change	Fowler	Lake	%Change	Fowler	Lake	%Change	Fowler	Lake	%Change
$O\text{-}PO_4$ ppm	.23	.02	-91%	.42	.29	-30%	.19	.05	-74%	.97	.78	-20%	.73	.42	-42%
$m\text{-}PO_4$ ppm	.17	.06	-64%	.59	.13	-78%	---	.14	---	.64	1.11	+73%	1.14	.55	-52%
NO_3 ppm	0.0	---	---	2.11	2.29	+8%	2.37	2.44	+3%	2.03	.94	-54%	.93	.71	-24%
NO_2 ppm	0.0	---	---	.03	.17	+466%	.09	.08	-11%	.01	.05	+400%	0.0	0.0	---
CO_2 ppm	12.0	22.00	+83	4.88	12.5	+156%	6.10	9.08	+49%	6.1	5.3	-13%	4.5	5.0	+11%
$D\text{-}O_2$ ppm	10.0	3.6	-65%	8.0	4.5	-44%	8.3	7.7	-7%	9.6	10.9	+14%	9.4	10.9	+16%
Color	131	75	-43%	78	102	+31%	67	94	+40%	119	227	+91%	80	200	+150%
pH	7.8	6.0	-23%	8.0	6.3	-21%	7.4	7.0	-5%	7.1	7.5	+6%	7.7	8.0	+4%
Turb.JTV	103.5	19.2	-81%	32.0	41	+28%	---	80	---	60.0	36.0	-40%	13.0	68	+423%
Pres.Coli. MPN	5,240	3,900	-25%	10,160	2,330	-77%	3,460	1,066	-69%	5,240	4,210	-20%	17,240	81	-100%
Conf.Coli. MPN	0	0	0%	2,180	110	-95%	900	170	-81%	2,600	1,160	-55%	14,693	30	-100%

Nitrate concentrations increased in 1972 and 1973 and decreased in 1974 and 1975, while passing through the study area. Again the change took place with the enlargement of the lake. It appears that disturbing the lake bottom caused the lake to behave as a nitrate sink. (See Tables IX and X)

The changes in nitrite and carbon dioxide concentrations indicated that microbial decay of organic matter occurred in the marsh. The negative change in nitrite concentration during 1973 can be explained by the lack of data from June through December. For full years, 1972 and 1974, the change in nitrite was strongly positive. (See Table IX)

Dissolved oxygen and carbon-dioxide values showed the effect of the changing metabolic regime of the system. From 1971 to 1973, carbon-dioxide was released and oxygen consumed, indicating that respiration was overpowering photosynthesis and reaeration. Oxygen became less negative with passing time showing that the green plants were catching up. By 1974, the signs reversed indicating that photosynthesis and reaeration were dominant over respiration. By 1975, both carbon-dioxide and oxygen were positive. (See Table IX)

Color increased while passing through the system due to the leaching of tannic acid and other colored organic materials. (See Table IX)

pH showed a decrease in 1971 to 1973 when respiration was the dominant metabolic regime, indicating the production of acid waste products. In 1974 and 1975 the pH increased, showing that those waste products were being consumed. Notice that oxygen changes changed sign in accord with pH sign changes. (See Table IX)

Turbidity showed no definite pattern but the water was more turbid at the end of the study than at the start. Since there were ample areas for solids to settle out, the turbidity is attributed to colloidal particles and floating organic materials. (See Table IX)

The coliform count show the expected results; as the detention time in the system was increased, due to increased size of the lake, the coliform bacteria died.

By 1975, nearly 100% removal occurred even though the coliform population that entered the system had increased to a high value. This high value at the ditch is attributed to the increase in pet population in the apartment area south of Fowler during the study. (See Table IX)

The complete data for all the water quality tests are presented in Tables X, XI, XII, and XIII.

T LE X

CHEMICAL TESTS ON WATER LEAVING THE LAKE

DATE	C-PO4 (PPM)	M-PO4 (PPM)	NO3 (PPM)	NO2 (PPM)	CO2 (PPM)	D-O2 (PPM)	H2S (PPM)	PH	COLOR	TURB. (JTU)
11- 5-71	0.0					1.5	0.0	5.2	320.	15.
11-20-71	0.0	0.0			28.0	4.0	0.0	6.0	105.	22.
11-29-71	0.02	0.26			22.0	5.0	0.0	6.4	125.	32.
12- 8-71	0.0	0.0			26.0	2.0	0.0	6.0	105.	19.
12-20-71	0.11	0.02			18.0	4.0	0.0	6.4	115.	15.
12-28-71	0.0	0.0			16.0	5.0	0.0	6.4	105.	12.
1-12-72	0.08	0.02			12.0	6.0	0.0	6.5	178.	40.
1-16-72	0.14	0.01			10.0	5.0	0.0	6.4	190.	51.
1-20-72	0.05	0.03			16.0	3.0	0.0	6.3	110.	24.
1-25-72	0.08	0.0			20.0	2.0	0.0	5.8	203.	34.
2- 3-72					24.0	4.0	0.0	6.5	89.	35.
2- 9-72	0.15	0.02			24.0	4.0	0.0	6.3	55.	8.
2-17-72	0.10	0.10	0.61	0.04	10.0	4.0	0.0	6.4	88.	10.
2-23-72	0.30	0.10	0.88	0.00	12.0	2.0	0.0	6.5	90.	30.
3- 3-72	0.50	0.0	2.80	0.03	20.0	2.0	0.0	6.5	75.	17.
3-10-72	0.05	0.50	3.90	0.03	20.0	2.0	0.0	6.5	75.	17.
3-17-72	0.70	0.09	3.40	0.0	18.0	5.2	0.0	5.8	75.	20.
3-22-72	0.60	0.06	4.00	0.0	16.0	6.0	0.0	6.2	80.	20.
3-28-72	0.60	0.0	3.50	0.01	14.0	7.0	0.0	6.1	75.	30.

CHEMICAL TESTS ON WATER LEAVING THE LAKE

(continued)

CATE	C-PO4 (PPM)	M-PO4 (PPM)	NO3 (PPM)	NO2 (PPM)	CO2 (PPM)	D-O2 (PPM)	H2S (PPM)	PH	COLOR	TURB. (JTU)
4- 6-72			2.90	C.00	16.0	6.0	0.1	6.5	60.	12.
4-12-72	0.5	0.2	3.90	0.00	16.0	4.0	0.0	6.1	60.	10.
4-18-72			0.99	0.00	18.0	3.0	0.0	5.9	70.	20.
4-24-72			1.80	0.01	10.0	2.0	0.0	6.6	90.	14.
5- 2-72			2.59	C.01	12.0	4.0	0.0	6.3	100.	10.
5-10-72			2.19	0.01	13.0	3.0	0.0	6.0	110.	10.
5-16-72	0.0	0.14	2.90	0.02	11.0	3.0	0.0	6.1	70.	20.
5-23-72	0.10	0.08	1.99	0.01	14.C	2.0	0.1	6.4	100.	10.
5-30-72	0.18	0.03	1.98	0.02	10.0	2.0	0.0	6.4	100.	12.
6- 6-72	0.02	0.20	1.96	0.04	12.0	5.0	0.0	6.5	100.	20.
6-16-72	0.25	0.25	1.99	0.01	10.0	2.0	0.0	6.2	60.	25.
6-20-72	0.20	0.10	2.44	0.00	30.0	4.0	0.0		85.	20.
6-25-72	0.30	0.09	3.00	0.01	10.0	8.0	0.1	6.7	90.	75.
7- 4-72	0.45	0.0	3.70	0.01	6.0	4.0	0.0	6.7	80.	125.
7-12-72	0.40	0.10	3.88	0.02	8.0	4.0	0.0	6.5	110.	60.
7-17-72	0.60	0.0	3.50	0.0	8.0	5.0	0.1	6.6	70.	55.
7-25-72	0.35	0.15	4.20	0.01	10.0	5.0	0.0	6.9	100.	40.
8- 1-72	0.32	0.60	1.79	0.0C	14.0	0.0	0.0	6.2	70.	60.
8- 8-72	0.27	0.11	0.48	0.00	18.0	7.0	0.0	6.1	75.	80.
8-16-72	0.53	0.16	0.05	0.00	8.0	5.0	0.0	5.6	140.	70.

CHEMICAL TESTS ON WATER LEAVING THE LAKE
(continued)

DATE	O-PO4 (PPM)	M-PO4 (PPM)	NO3 (PPM)	NO2 (PPM)	CO2 (PPM)	D-O2 (PPM)	H2S (PPM)	PH	COLOR	TURB. (JTU)
8-23-72	0.58	0.08	0.99	0.00	12.0	3.0	0.0	6.9	100.	100.
8-30-72	0.60	0.0	3.00	0.00	8.0	5.0	0.0	6.6	120.	60.
9- 5-72	0.40	0.15	2.49	0.00	14.0	3.0	0.0	6.0	120.	30.
9-12-72	0.22	0.20	1.00	0.01	10.0	4.0	0.0	5.9	120.	30.
9-21-72	0.01	0.0	1.50	0.0	16.0	4.0	0.0	6.0	100.	20.
9-28-72	0.20	0.05	2.50	0.0	4.0	4.0	0.0		70.	60.
10- 5-72	0.10	0.10	0.0	1.00	4.0	2.5	0.0			55.
10-12-72	0.10	0.12	1.00	0.0	4.0	7.0	0.0			70.
10-16-72	0.10	0.10	0.0	1.00	5.0	4.0	0.0			55.
10-23-72	0.16	0.07			8.0	5.0	0.0		260.	47.
10-30-72	0.18	0.08			7.0	4.0	0.0			40.
11- 7-72	0.16	0.04	2.00	1.00	7.0	5.0	0.0			80.
11-14-72	0.16	0.06	1.00	1.00	12.0	7.0	0.0			80.
11-21-72	0.14	0.09	1.00	1.00	14.0	10.0	0.0			75.
11-28-72	0.19	0.16	2.50	0.0	10.0	4.0	0.0			20.
12- 5-72	0.70	0.60	4.40	1.00	8.0	10.0	0.0		200.	80.
12-15-72	0.70	0.50	5.00	0.05	17.0	8.0	0.0			70.
12-20-72	0.60	0.20	4.00	1.00	14.0	8.0	0.0			70.
12-29-72	0.04	0.03	2.20	0.0	6.0	8.0	0.0			40.
1-10-73	0.14	0.11	2.50	0.50	10.0	16.0	0.0		100.	80.

CHEMICAL TESTS ON WATER LEAVING THE LAKE
(continued)

DATE	C-PO4 (PPM)	N-PO4 (PPM)	NO3 (PPM)	NO2 (PPM)	CO2 (PPM)	D-O2 (PPM)	H2S (PPM)	PH	COLOR	TURB. (JTU)
1-17-73	0.14	0.14	2.00	0.0	10.0	18.0	0.0		80.	80.
1-23-73	0.12	0.18	2.00	0.0	16.0	14.0	0.0			80.
2-23-73	0.00		2.40	0.0	0.0	6.0	0.0	7.5	82.	
3-12-73	0.00		2.90	0.0	0.0	7.0	0.1	7.0	80.	
4- 1-73	0.04		1.60	0.05	15.0	3.0	0.0	7.0	155.	
4- 7-73	0.20		2.90	0.49	12.0	4.0	0.0	6.5	150.	
4-14-73	0.02		2.60	0.00	0.0	3.0	0.0	7.0	80.	
4-28-73	0.00		3.12	0.05	0.0	9.0	0.0	7.5	76.	
5- 6-73	0.00		2.40	0.0	6.0	6.0	0.0	7.0	82.	
5-15-73	0.01		2.40	0.0	5.0	3.0	0.0	7.2	80.	
5-25-73	0.00		2.40	0.0	18.0	6.0	0.0	6.8	83.	
5-31-73	0.01		2.50	0.00	26.0	5.0	0.0	7.0	84.	
1-12-74	1.62	2.98	3.52	0.0	4.0	22.0	0.0	7.9	155.	53.
1-18-74	1.30	2.10	1.10	0.0	5.6	16.0	0.0	7.7	50.	
1-23-74	1.50	2.20	0.44	0.00	6.0	12.0	0.0	7.8	60.	14.
1-31-74	2.00	0.60	1.14	0.09	4.0	17.0	0.0	8.2	90.	17.
2- 6-74	1.50	1.10	1.32	0.09	3.6		0.0	8.6	45.	6.
2-16-74	1.65	0.56	0.20	0.00	4.8	30.0	0.0	8.4	50.	6.
2-28-74	0.90	1.20	1.10	0.05	4.8	6.0	0.0	8.3	30.	5.
3- 9-74	1.45	1.05	0.44	0.16	4.0	6.0	0.0	8.4	70.	8.

CHEMICAL TESTS ON WATER LEAVING THE LAKE

(continued)

DATE	C-PO4 (PPM)	M-PO4 (PPM)	NO3 (PPM)	NO2 (PPM)	CO2 (PPM)	D-O2 (PPM)	H2S (PPM)	PH	COLOR	TURB. (JTU)
3-24-74	0.95	0.75	3.52	0.49	4.0	11.0	0.0	7.6	140.	50.
3-30-74	1.00	1.40	1.20	0.01	3.2	8.0	0.0	8.6	85.	40.
4- 9-74	0.70	0.80	1.76	0.02	1.6	11.0	0.0	8.8	70.	30.
4-17-74	0.90	1.30	2.00	0.0	3.2	6.0	0.0	8.4	90.	45.
4-24-74	1.50	1.20	0.88	0.0	5.2	5.0	0.0	8.5	70.	15.
5- 9-74	2.20	0.70	1.76	0.0	8.0	3.0	0.0	7.0	100.	18.
6- 7-74	0.85		1.20	0.02	2.0	6.0	0.0	6.8	500.	
6-13-74	0.10		0.30	0.02	6.0	8.0	0.0	6.8	0.	
6-21-74	0.60		0.70	0.01	1.0	4.0	0.0	6.9	0.	
6-25-74	0.47		0.35	0.05	8.0	13.0	0.0	6.6	0.	
7- 2-74	0.70		0.50	0.01	4.5	13.0	0.0	6.9	0.	
7- 9-74	0.80		1.40	0.00	8.0	11.0	0.0	6.9	0.	
7-16-74	0.0		0.0	0.14	0.0	0.0	0.0		0.	
7-16-74	0.65		0.45	0.00	14.0	10.0	0.0	6.8	500.	
7-23-74	0.90		0.95	0.00	12.0	9.0	0.0	6.8	500.	
7-30-74	0.70		1.40	0.95	8.0	0.0	0.0	6.9	500.	
8- 7-74	1.15		1.00	0.00	12.0	13.0	0.0	6.8	500.	
8-13-74	0.25		0.50	0.00	12.0	9.0	0.0	6.5	450.	
8-21-74	0.0		0.30	0.00	8.0	11.0	0.0	6.5	400.	
8-29-74	0.33		0.50	0.00	4.0	11.0	0.0	6.9	500.	

CHEMICAL TESTS ON WATER LEAVING THE LAKE

(continued)

DATE	O-PO4 (PPM)	M-PO4 (PPM)	NO3 (PPM)	NO2 (PPM)	CO2 (PPM)	D-O2 (PPM)	H2S (PPM)	PH	COLOR	TURB. (JTU)
9- 9-74	0.50		0.50	0.00	6.0	9.0	0.0	6.9	475.	
9-16-74	0.20		0.40	0.00	2.0	9.0	0.0	6.5	400.	
9-23-74	0.13		0.60	0.0	2.0	12.0	0.0	6.8	420.	
10-15-74	1.50	0.07	0.60	0.0	2.0	15.0	0.0	8.1	310.	95.
10-22-74	0.17	1.52	0.80	0.0	4.0	12.0	0.0	7.7	320.	70.
10-28-74	0.20	0.95	0.70	0.00	2.0	14.0	0.0	7.9	300.	110.
11- 5-74	0.20	1.60	0.80	0.0	4.0	14.0	0.0	8.0	300.	60.
11-11-74	0.15	1.30	0.30	0.0	4.0	13.0	0.0	7.0	280.	70.
11-19-74	0.30	0.55	0.40	0.0	5.0	13.0	0.0	7.8	360.	0.
11-25-74	0.35	0.70	0.45	0.0	6.0	12.0	0.0	7.5	340.	0.
12- 4-74	0.25	0.65	0.60	0.0	4.0	15.0	0.0	7.7	340.	0.
12-10-74	0.40	0.25	0.40	0.0	4.0	13.0	0.0	7.4	300.	80.
1-13-75	0.45	0.15	0.70	0.0	2.0	11.0	0.0	7.8	290.	75.
2-21-75	0.40	0.20	0.60	0.0	8.0	12.0	0.0	7.6	275.	80.
2-26-75	0.30	0.50	0.90	0.05	4.0	11.0	0.0	7.8	300.	70.
3- 5-75	0.55	0.45	1.10	0.0	8.0	10.0	0.0	8.1	275.	80.
3-12-75	0.30	0.80	0.40	0.0	4.0	13.0	0.0	7.9	260.	75.
3-19-75	0.20	0.45	0.60	0.00	6.0	12.0	0.0	7.8	300.	95.
3-26-75	0.40	0.55	0.80	0.0	6.0	11.0	0.0	7.9	120.	70.
4- 2-75	0.33	0.0	0.90	0.0	4.0	9.0	0.0	8.2	80.	50.

CHEMICAL TESTS ON WATER LEAVING THE LAKE

(continued)

DATE	O-PO4 (PPM)	M-PO4 (PPM)	NO3 (PPM)	NO2 (PPM)	C02 (PPM)	D-02 (PPM)	H2S (PPM)	PH	COLOR	TURB. (JTU)
4- 9-75	0.60	0.45	0.85	0.0	8.0	11.	0.0	7.9	150.	90.
4-29-75	0.70	0.80	0.70	0.0	6.0	13.	0.0	8.2	170.	65.
5- 6-75	0.56	0.84	0.80	0.005	4.0	12.	0.0	8.0	180.	50.
5-13-75	0.40	0.50	0.60	0.0	2.0	10.	0.0	8.9	140.	45.
5-21-75	0.30	0.85	0.45	0.0	4.0	10.	0.0	7.8	120.	50.
5-30-75	0.40	0.55	0.60	0.0	4.0	8.	0.0	8.1	150.	65.

TABLE XI

BACTERIOLOGICAL TESTS ON WATER LEAVING THE LAKE

DATE	TEMPERATURE (C)	PRESUMPTIVE MPN (ORG./100 ML)	CONFIRMED MPN (ORG./100 ML)
10-23-71		3500.0	0.0
11-13-71		5400.0	0.0
11-20-71	22.0	0.0	0.0
11-24-71		2400.0	0.0
11-29-71	19.5	0.0	0.0
12- 8-71	21.5	0.0	0.0
12- 9-71	0.0	9200.0	0.0
12-20-71	21.0	9200.0	0.0
12-28-71	20.0	5400.0	70.0
1-12-72	22.0	5400.0	20.0
1-16-72	18.0	2800.0	230.0
1-20-72	20.5	0.0	0.0
1-25-72	19.0	5400.0	80.0
2- 3-72	19.0	0.0	0.0
2- 9-72	15.4	0.0	0.0
2-23-72		700.0	0.0
3- 3-72		170.0	20.0
3-10-72		80.0	0.0
3-17-72		170.0	40.0
3-22-72		790.0	110.0

BACTERIOLOGICAL TESTS ON WATER LEAVING THE LAKE

(continued)

DATE	TEMPERATURE (C)	PRESUMPTIVE MPN (ORG./100 ML)	CONFIRMED MPN (ORG./100 ML)
3-28-72		110.0	20.0
4- 6-72		1500.0	490.0
4-12-72		170.0	40.0
4-18-72		260.0	20.0
4-24-72		0.0	0.0
5- 2-72		4600.0	80.0
5-10-72		0.0	0.0
5-16-72		3300.0	140.0
5-23-72		3300.0	170.0
5-30-72		390.0	170.0
6- 6-72		1100.0	140.0
6-16-72		4900.0	210.0
6-20-72		35000.0	0.0
6-25-72		7900.0	1100.0
7- 4-72		9200.0	170.0
7-12-72		700.0	170.0
7-17-72		790.0	140.0
8- 1-72		700.0	70.0
8- 8-72		790.0	490.0
8-16-72		220.0	40.0

BACTERIOLOGICAL TESTS ON WATER LEAVING THE LAKE
(continued)

DATE	TEMPERATURE (C)	PRESUMPTIVE MPN (ORG./100 ML)	CONFIRMED MPN (ORG./100 ML)
8-23-72		220.0	80.0
9- 5-72		790.0	490.0
9-12-72		490.0	110.0
9-21-72		16000.0	110.0
9-28-72		920.0	110.0
10- 5-72		350.0	30.0
10-12-72		540.0	80.0
10-16-72		540.0	70.0
10-23-72		110.0	0.0
10-30-72		130.0	30.0
11- 7-72		170.0	30.0
11-14-72		350.0	60.0
11-21-72		280.0	30.0
11-28-72		240.0	20.0
12- 5-72		240.0	20.0
12-15-72		920.0	70.0
12-20-72		540.0	70.0
12-29-72		920.0	50.0
1-10-73		2400.0	140.0
1-17-73		1600.0	60.0

BACTERIOLOGICAL TESTS ON WATER LEAVING THE LAKE
(continued)

DATE	TEMPERATURE (C)	PRESUMPTIVE MPN (ORG./100 ML)	CONFIRMED MPN (ORG./100 ML)
1-23-73	0.0	540.0	30.0
2-16-73	11.0	60.0	40.0
2-23-73	20.0	490.0	170.0
3- 2-73	25.0	20.0	20.0
3-12-73	20.0	170.0	130.0
4- 1-73	21.0	3500.0	490.0
4- 7-73	22.0	790.0	790.0
4-14-73	25.0	490.0	110.0
4-28-73	24.0	1700.0	140.0
5- 6-73	25.0	80.0	20.0
5-15-73	26.0	790.0	140.0
5-25-73	24.0	560.0	120.0
5-31-73	26.0	2800.0	220.0
1-14-74		24000.0	24000.0
1-20-74		920.0	20.0
1-25-74		270.0	20.0
2- 2-74	23.5	1100.0	140.0
2- 8-74	23.0	9200.0	1400.0
2-18-74	21.0	260.0	20.0
3- 2-74	16.5	140.0	40.0

BACTERIOLOGICAL TESTS ON WATER LEAVING THE LAKE
(continued)

DATE	TEMPERATURE (C)	PRESUMPTIVE MPN (ORG./100 ML)	CONFIRMED MPN (ORG./100 ML)
3-11-74	22.5	140.0	10.0
3-26-74	22.0	1400.0	110.0
3-30-74	20.0	9200.0	0.0
4- 9-74	23.0	700.0	0.0
4-19-74	25.0	24000.0	330.0
4-26-74		9200.0	70.0
5-10-74		16000.0	330.0
10-15-74	29.5	0.0	0.0
10-22-74	28.5	20.0	0.0
10-28-74	23.0	50.0	0.0
11- 5-74		50.0	50.0
11-11-74	22.0	0.0	0.0
11-19-74	15.0	80.0	50.0
11-25-74	14.0	100.0	70.0
12- 4-74	15.0	40.0	0.0
12-10-74	18.0	50.0	50.0

BACTERIOLOGICAL TESTS ON WATER LEAVING THE LAKE
(continued)

DATE	TEMPERATURE (C)	PRESUMPTIVE MPN (ORG./100 ML)	CONFIRMED MPN (ORG./100 ML)
1-13-75	16.0	70.0	50.0
2-14-75		0.0	20.0
2-21-75		500.0	50.0
2-26-75		0.0	40.0
3- 5-75		80.0	50.0
3-12-75		60.0	40.0
3-19-75		100.0	80.0
3-26-75		120.0	90.0
4- 2-75		40.0	0.0
4- 9-75		90.0	20.0
4-29-75		0.0	0.0
5- 6-75		40.0	0.0
5-13-75		0.0	0.0
5-21-75		60.0	40.0
5-30-75		60.0	40.0

TABLE XII

CHEMICAL TESTS ON WATER ENTERING FROM SOUTH OF FOWLER AVENUE

DATE	O-PO4 (PPM)	M-PO4 (PPM)	NO3 (PPM)	NO2 (PPM)	CO2 (PPM)	D-O2 (PPM)	H2S (PPM)	PH	COLOR	TURB. (JTU)
11- 5-71	0.0			0.0		8.0	0.0	6.0	300.	25.
11-20-71	0.04	0.09	0.0	0.0	16.0	12.0	0.0	8.3	55.	26.
11-29-71	1.13	0.47	0.0	0.0	8.0	9.0	0.0	8.1	200.	500.
12- 8-71	0.10	0.09	0.0	0.0	4.0	12.0	0.0			47.
12-20-71	0.08	0.11	0.0	0.0	24.0	10.0	0.0	8.3	55.	12.
12-28-71	0.05	0.07	0.0	0.0	8.0	10.0	0.0	8.4	46.	11.
1-12-72						9.0				
1-16-72	0.0	0.0	0.0	0.0	4.0	10.0	0.0	7.4	300.	108.
1-20-72	0.18	0.06	0.0	0.0	12.0	6.0	0.0	7.5	90.	29.
1-25-72	0.18	0.93	0.0	0.0	8.0	9.0	0.0	9.4	71.	12.
2- 3-72			0.0	0.0	4.0	11.0	0.0	8.2	211.	149.
2- 9-72	0.13	0.02	0.0	0.0	4.0	9.0	0.0	8.3	45.	5.
2-17-72	0.90	0.25	0.82	0.05	4.0	4.0	0.0	8.0	60.	10.
2-23-72	0.40	0.10	0.90	0.00	2.0	9.0	0.0	8.5	50.	10.
3- 3-72	0.50	6.00	2.50	0.01	2.0	7.0	0.0	8.6	100.	30.
3-10-72	0.15	0.50	3.60	0.00	2.0	7.0	0.0	8.6	100.	30.
3-17-72	0.69	0.06	5.60	0.00	12.0	8.0	0.0	7.9	50.	20.
3-22-72	0.29	0.07	6.60	0.00	10.0	8.0	0.0	7.4	60.	22.
3-28-72	0.79	0.02	3.10	0.04	8.0	8.0	0.0	8.2	80.	15.
4- 6-72			2.60	0.85	16.0	7.0	0.0	8.2	10.	2.

CHEMICAL TESTS ON WATER ENTERING FROM SOUTH OF FOWLER AVENUE
(continued)

DATE	C-PO4 (PPM)	M-PO4 (PPM)	NO3 (PPM)	NO2 (PPM)	CO2 (PPM)	D-O2 (PPM)	H2S (PPM)	PH	COLOR	TURB. (JTU)
4-12-72	0.30	0.20	1.90	0.00	6.0	5.00	0.0	8.3	20.	5.
4-18-72			0.89	0.00	4.0	8.00	0.1	8.0	10.	5.
4-24-72			1.91	0.01	2.0	8.00	0.0	8.0	60.	15.
5- 2-72			2.30	0.01	1.0	9.00	0.0	8.1	80.	15.
5-10-72			2.09	0.02	0.0	8.00	0.0	8.5	75.	18.
5-16-72	0.28	0.18	2.68	0.01	0.0	9.00	0.0	8.5	20.	10.
5-23-72	0.50	0.07	1.99	0.00	0.0	8.0	0.1	8.9	80.	15.
5-30-72	0.50	0.02	2.00	0.00	2.0	7.0	0.1	8.2	80.	12.
6- 6-72	0.03	0.18	2.66	0.00	1.0	5.0	0.0	7.4	50.	10.
6-16-72	0.32	0.23	4.09	0.00	2.0	7.0	0.1	8.1	15.	36.
6-20-72	0.90	0.05	1.98	0.02	20.0	6.0	0.1		110.	50.
6-25-72	0.24	0.01	3.17	0.03	2.0	10.0	0.1	7.8	55.	40.
7- 4-72	0.35	0.25	3.90	0.0	0.0	6.0	0.0	7.7	60.	40.
7-12-72	0.50	0.25	4.32	0.02	2.0	8.0	0.1	8.0	60.	35.
7-17-72	0.57	0.23	4.50	0.02	0.0	7.0	0.0	7.6	75.	50.
7-25-72	1.10	7.60	3.99	0.01	0.0	10.0	0.1	7.7	60.	20.
8- 1-72	0.40	0.20	1.99	0.00	12.0		0.0	8.3	45.	75.
8- 8-72	0.28	0.16	1.62	0.00	12.0	16.0	0.0	7.1	65.	100.
8-16-72	0.95	0.65	0.09	0.00	6.0	12.0	0.2	8.2	140.	80.
8-23-72	1.00	0.13	0.0	0.0	4.0	8.0	0.0	7.2	100.	95.

CHEMICAL TESTS ON WATER ENTERING FROM SCUTH OF FOWLER AVENUE
(continued)

CATE	O-PO4 (PPM)	M-PO4 (PPM)	NO3 (PPM)	NO2 (FPM)	CO2 (FPM)	D-O2 (PPM)	H2S (FPM)	PH	COLOR	TURB. (JTU)
8-3C-72	0.25	0.60	4.00	0.00	2.0	7.0	0.0	7.4	110.	40.
9- 5-72	0.20	0.50	2.98	C.00	6.C	6.0	0.0	7.9	100.	30.
9-12-72	0.24	0.26	1.09	0.01	8.0	10.0	0.0	7.7	120.	20.
9-21-72	1.10	0.10	2.49	C.01	4.C	7.0	0.0	7.5	80.	10.
9-28-72	0.0	0.15	0.0	0.0	4.0	7.0	0.0			30.
10-12-72	0.0	0.10	0.0	C.0	2.C	5.0	0.0			49.
11- 7-72	0.08	0.05	0.50	0.0	5.0	7.0	0.0			50.
2-23-73	0.04		2.10	C.0	7.C	9.0	0.0	7.5	25.	
3-12-73	0.04		2.80	0.65	9.0	9.0	0.1	7.5	30.	
4- 1-73	1.40		1.50	0.13	1.C	5.0	0.0	8.5	255.	
4- 7-73	0.35		3.10	0.03	1.C	7.0	0.0	7.5	80.	
4-14-73	0.00		2.50	C.00	7.C	9.0	0.0	7.5	26.	
4-28-73	0.00		2.50	0.00	5.0	10.0	0.0	7.5	100.	
5- 6-73	0.00		1.80	0.0	6.C	7.0	0.0	6.5	70.	
5-15-73	0.0		2.50	0.00	7.0	7.0	0.0	7.5	30.	
5-25-73	0.04		2.80	C.08	9.C	10.0	0.0	7.1	26.	
5-31-73	0.00		2.11	0.00	9.0	10.0	0.0	7.C	25.	
1-12-74	0.60	0.40	6.16	C.CC	4.4		0.0	7.7	295.	83.
1-18-74	0.20	0.36	4.84	0.00	4.8	10.0	0.0	7.0	260.	73.
1-23-74	0.30	0.40	1.52	C.C	5.2	9.0	0.0	7.0	260.	70.

CHEMICAL TESTS ON WATER ENTERING FROM SOUTH OF FOWLER AVENUE
(continued)

DATE	O-PO4 (PPM)	M-PO4 (PPM)	NO3 (PPM)	NO2 (PPM)	CO2 (PPM)	D-O2 (PPM)	H2S (PPM)	PH	COLOR	TURB. (JTU)
1-31-74	0.25	0.64	4.84	0.0	5.2		0.0	7.1	277.	78.
2- 6-74	0.30	0.02	4.82	0.CC	4.4		0.0	7.2	285.	77.
2-16-74	0.23	0.14	3.52	C.00	4.C		0.0	6.9	245.	65.
2-28-74	0.20	0.39	4.CO	C.01	3.6	13.0	0.0	7.4	270.	70.
3- 9-74	0.40	0.10	4.40	0.0	3.2	12.0	0.0	7.4	215.	55.
3-24-74	0.25	0.75	5.5C	C.0	3.6	12.0	0.0	6.8	295.	93.
3-31-74	0.30	0.05	4.80	0.0	3.2	9.0	0.0	7.4	260.	135.
4- 9-74	0.30	0.15	5.8C	C.0	4.C	12.0	0.0	7.5	290.	125.
6-13-74	0.80		0.40	0.04	12.C	8.C	0.0	6.6	60.	
6-19-74	0.85		2.2C	C.CC	8.C	11.0	0.0	7.0	50.	
6-26-74	1.20		2.50	0.00	2.C	11.C	0.0	7.1	80.	
7- 2-74	0.45		0.6C	C.C2	4.C	9.0	0.0	6.4	80.	
7- 9-74	0.60		1.10	0.04	5.2	7.0	0.0	6.9	25.	
7-16-74	0.75		0.80	C.00	12.C	11.0	0.0	6.8	18.	
7-23-74	1.20		0.70	0.02	8.C	11.0	0.0	6.8	14.	
7-30-74	0.70		1.4C	C.C1	12.C	9.0	0.0	6.6	18.	
8- 6-74	1.20		1.40	0.18	5.2	14.0	0.0	6.9	10.	
8-13-74	0.55		0.65	C.00	12.C	9.0	0.0	6.5	75.	
8-21-74	0.30		0.40	0.00	6.C	6.0	0.C	6.9	50.	
8-29-74	0.55		0.45	C.C1	8.C	8.0	0.0	6.5	80.	

CHEMICAL TESTS ON WATER ENTERING FROM SOUTH OF FOWLER AVENUE
(continued)

DATE	O-PO4 (PPM)	M-PO4 (PPM)	NO3 (PPM)	NO2 (PPM)	CO2 (PPM)	D-O2 (PPM)	H2S (PPM)	PH	COLOR	TURB. (JTU)
9- 9-74	3.20		1.20	C.00	4.C	5.0	0.0	6.9	50.	
9-16-74	0.35		0.35	0.00	6.0	6.0	0.0	6.5	50.	
9-23-74	0.28		0.30	C.C0	8.C	6.0	0.0	6.9	110.	
10-15-74	3.10	0.70	0.75	0.0	6.0	11.0	0.0	6.9	20.	5.
10-22-74	2.90	0.40	0.60	C.C	6.C	10.0	0.0	8.0	60.	10.
10-28-74	1.50	2.60	0.90	0.0	6.0	12.0	0.0	7.8	20.	5.
11- 5-74	0.28	2.20	1.20	0.01	4.C	10.0	0.0	7.6	60.	10.
11-11-74	7.20	0.24	0.80	0.01	8.0	10.0	0.0	7.2	30.	10.
11-19-74	0.40	0.60	0.40	0.0C	6.C	10.0	0.0	7.7	60.	
11-25-74	0.40	0.50	0.55	0.0	6.0	11.0	0.0	7.6	80.	
12- 4-74	0.55	0.95	0.40	0.0	6.C	7.0	0.0	7.8	80.	
12-10-74	0.60	1.20	0.80	0.00	6.0	10.0	0.0	7.8	45.	15.
1-13-75	0.70	2.50	0.90	C.C0	4.C	16.0	0.0	7.3	30.	10.
2-14-75	1.50	0.40	0.90	0.00	2.0	8.0	0.0	7.3	60.	10.
2-21-75	0.80	0.40	0.75	C.0C	6.C	8.0	0.0	7.4	60.	6.
2-26-75	0.80	0.95	0.90	0.00	2.0	10.0	0.0	7.8	80.	8.
3- 5-75	0.4C	1.10	1.0C	C.C	6.C	8.0	0.0	7.6	120.	5.
3-12-75	0.30	0.90	0.80	0.0	4.0	10.0	0.0	7.4	85.	8.
3-19-75	0.4C	1.15	0.8C	C.CC	4.C	11.0	0.0	7.8	80.	12.
3-26-75	0.90	1.15	1.00	0.0	6.0	7.0	0.0	7.6	70.	80.

CHEMICAL TESTS ON WATER ENTERING FROM SOUTH OF FOWLER AVENUE
(continued)

DATE	O-PO4 (PPM)	M-PO4 (PPM)	NO3 (PPM)	NO2 (PPM)	CO2 (PPM)	D-O2 (PPM)	H2S (PPM)	PH	COLOR	TURB. (JTU)
4- 9-75	1.20	1.50	1.00	0.0	4.0	8.0	0.0	7.9	70.	8.
4-29-75	0.80	1.25	0.90	0.0	0.4	10.0	0.0	7.8	80.	12.
5- 6-75	0.70	1.20	0.75	0.0	6.0	11.0	0.0	7.8	85.	10.
5-13-75	0.85	1.40	0.95	0.0	6.0	12.0	0.0	7.9	120.	7.
5-21-75	0.40	1.30	1.25	0.0	4.0	9.0	0.0	8.1	75.	5.
5-30-75	0.45	0.80	1.10	0.0	8.0	4.0	0.0	7.6	100.	5.

TABLE XIII

BACTERIOLOGICAL TESTS ON WATER ENTERING FROM SOUTH OF FOWLER AVENUE

DATE	TEMPERATURE (C)	PRESUMPTIVE MPN (ORG./100 ML)	CONFIRMED MPN (ORG./100 ML)
10-23-71		24000.0	0.0
11-13-71		9200.0	0.0
11-20-71	22.0	0.0	0.0
11-24-71		4300.0	0.0
11-29-71	23.0	0.0	0.0
12- 8-71	25.0	0.0	0.0
12- 9-71		9200.0	0.0
12-20-71	22.0	3500.0	0.0
12-28-71	21.0	490.0	20.0
1- 4-72		24000.0	5400.0
1-12-72	23.5	16000.0	170.0
1-16-72	18.0	24000.0	24000.0
1-20-72	21.5	0.0	0.0
1-25-72	21.0	24000.0	24000.0
2- 3-72	19.5	0.0	0.0
2- 9-72	22.0	0.0	0.0
2-23-72		220.0	90.0
3- 3-72		35000.0	220.0
3-10-72		790.0	20.0
3-17-72		28000.0	2200.0

BACTERIOLOGICAL TESTS ON WATER ENTERING FROM SOUTH OF FOWLER AVENUE
(continued)

DATE	TEMPERATURE (C)	PRESUMPTIVE MPN (ORG./100 ML)	CONFIRMED MPN (ORG./100 ML)
3-22-72		7900.0	460.0
3-28-72		700.0	40.0
4- 6-72		3500.0	1100.0
4-12-72		1800.0	110.0
4-18-72		1400.0	110.0
4-24-72		2200.0	0.0
5- 2-72		17000.0	3500.0
5-16-72		7900.0	260.0
5-23-72		35000.0	1100.0
5-30-72		4300.0	1400.0
6- 6-72		1100.0	700.0
6-16-72		13000.0	1700.0
6-20-72		35000.0	0.0
7- 4-72		14000.0	330.0
7-12-72		11000.0	950.0
7-17-72		35000.0	1400.0
8- 1-72		1300.0	110.0
8- 8-72		330.0	20.0
8-16-72		790.0	270.0
8-23-72		2200.0	110.0

BACTERIOLOGICAL TESTS ON WATER ENTERING FROM SOUTH OF FOWLER AVENUE
(continued)

DATE	TEMPERATURE (C)	PRESUMPTIVE MPN (ORG./100 ML)	CONFIRMED MPN (ORG./100 ML)
8-30-72		11000.0	1700.0
9- 5-72		330.0	20.0
9-12-72		7900.0	170.0
9-21-72		24000.0	9200.0
9-28-72		920.0	110.0
10-12-72		540.0	110.0
11- 7-72		140.0	30.0
2-16-73	8.0	1100.0	220.0
2-23-73	20.0	230.0	40.0
3- 2-73	22.0	0.0	0.0
3-12-73	21.0	270.0	170.0
4- 1-73	24.0	24000.0	9200.0
4- 7-73	23.0	9200.0	330.0
4-14-73	23.0	330.0	140.0
4-28-73	23.0	1400.0	110.0
5- 6-73	22.0	1400.0	170.0
5-15-73	27.5	1700.0	170.0
5-25-73	26.0	1100.0	90.0
5-31-73		790.0	230.0
1-14-74		20.0	10.0

BACTERIOLOGICAL TESTS ON WATER ENTERING FROM SOUTH OF FOWLER AVENUE
(continued)

DATE	TEMPERATURE (C)	PRESUMPTIVE MPN (ORG./100 ML)	CONFIRMED MPN (ORG./100 ML)
1-20-74		30.0	20.0
1-25-74		20.0	0.0
2- 2-74	23.5	490.0	330.0
2- 6-74	23.0	10.0	0.0
2-18-74	21.0	20.0	20.0
3- 2-74	16.5	50.0	20.0
3- 9-74	22.5	10.0	0.0
2-36-74	22.0	220.0	20.0
3-31-74	20.0	260.0	0.0
4-11-74	23.0	20.0	0.0
4-19-74	25.0	5400.0	170.0
10-15-74	26.0	24000.0	3500.0
10-22-74	26.5	3500.0	3500.0
10-28-74	23.0	0.0	110.0
11- 5-74		3000.0	790.0
11-11-74	20.5	24000.0	24000.0
11-19-74	16.0	5400.0	5400.0
11-25-74	14.0	24000.0	9200.0
12- 4-74	14.0	3500.0	1400.0
12-10-74	16.5	16000.0	3500.0

BACTERIOLOGICAL TESTS ON WATER ENTERING FROM SOUTH OF FOWLER AVENUE (continued)

DATE	TEMPERATURE (C)	PRESUMPTIVE MPN (ORG./100 ML)	CONFIRMED MPN (ORG./100 ML)
1-13-75	15.0	24000.0	24000.0
2-14-75		0.0	10000.0
2-21-75		24000.0	24000.0
2-26-75		9200.0	9200.0
3- 5-75		5400.0	1700.0
3-12-75		9200.0	1100.0
3-19-75		24000.0	24000.0
3-26-75		16000.0	9200.0
4- 2-75		24000.0	16000.0
4- 9-75		24000.0	24000.0
4-29-75		24000.0	24000.0
5- 6-75		2800.0	2800.0
5-13-75		24000.0	2400.0
5-21-75		24000.0	24000.0
5-30-75		24000.0	24000.0

9. SUMMARY

The original purpose of this project was to determine the changes in the quantity and quality of stormwater runoff from a small urbanizing watershed. Unfortunately, the planned development has not yet taken place, thus the anticipated hydrologic changes did not occur. However, valuable data was obtained pertaining to; 1) the changes in runoff quality during a storm, 2) the yearly variation of runoff quality from a partially developed watershed, 3) the lack of change in quality of ground water in the surface aquifer, and 4) the purification of urban runoff by routing it over a natural vegetative system.

In addition, the study confirmed that disturbing marshes or lakes causes a significant increase in suspended solids and nutrient content in runoff, especially phosphates.

The data pertaining to the variation of pollutant concentrations during a storm, indicated a high initial peak during the first minutes of a storm, as expected. Some pollutants did not wash off immediately and caused second peaks or in some cases plateaus.

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