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SEPTEMBER, 1978

THE ROLE OF STREAMS IN POLLUTION DILUTION AND DISPERSION

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16. Abstract

This report is the culmination of a brief study conducted to gather information necessary to evaluate the progressive streamflow water quality decrement by means of multiple correlation and regression techniques. The streamflow along Rock Creek from the city of Sulphur, Oklahoma to Arbuckle Lake in Murray County, Oklahoma has been selected as the study area since the water quality in this region is considered substandard as set forth by the Oklahoma Water Resources Board.

1. determine the existing water quality of Rock Creek at Sulphur, Oklahoma and to measure the water quality at selected points along the stream.
2. develop mathematical models of water quality parameters at three sites along Rock Creek and to obtain a relation between the different physical and chemical characteristics associated with the degree of pollution in the streams.
3. determine the pollution decrement as a function of distance downstream from the city of Sulphur area.

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Water quality, pollution

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CHAPTER 1

INTRODUCTION

The University of Oklahoma, School of Civil Engineering and Environmental Science conducted a related study on Rock Creek from June 1976 to July 1977 (1).* Twenty-one sampling sites were chosen, see figure 1, in Rock Creek and seven on the Arbuckle Reservoir, see figure 2. Conclusions were as follows:

The water quality of Rock Creek through the city of Sulphur and the Platt section of the Chickasaw National Recreation Area is below the standards established by the Oklahoma Water Resources Board for the designated beneficial uses of the stream. Sources of pollution along this stream segment include runoff from cattle, swine, feeding lots and holding pens, waste discharge from an upstream O.G.& E. plant, runoff from city streets and inadvertant discharges from poorly maintained inadequate waste collection systems from the City of Sulphur. As a result of these sources of pollution the nutrient concentrations and fecal coliform levels were determined to be unacceptable. The fecal coliform levels from all sampling sites on Rock Creek above and through the Chickasaw Recreation Area were usually much greater than the established standard of 200/100 ml. as a geometric mean determined by the membrane filter procedure.

The standard for nutrients was violated as determined by chemical analysis and visual observation. The standards limit the total phosphorus and the nitrogen/phosphorus ratio to concentrations which prevent

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*Numbers in parentheses refer to References.

eutrophication problems. These concentrations were exceeded resulting in observable algal blooms and concomitant water quality problems downstream in the Lake of the Arbuckles.

The water quality of Travertine Creek, a tributary of Rock Creek, is higher than that of Rock Creek since the sustained flow for Travertine Creek emerges within the boundary of the recreation area and therefore is not subjected to pollution from urban and industrial activities. It remains relatively unpolluted except for the impact of the recreational activities within the Chickasaw National Recreation Area. During periods of high recreational use however, a noticeable increase in the number of total fecal coliforms was observed below the swimming areas. A direct relation between the number of swimmers and the fecal coliform count was observed.

The sub-basin of Guy Sandy and Buckhorn Creeks, small tributaries of Rock Creek, in general produced a higher quality water than that of the Rock Creek sub-basin. However, the potential for a significant contribution of nutrient loading from agricultural activities has been demonstrated by virtue of the great percentage of potential land use for that activity.

The Lake of the Arbuckles is now and has been for several years a highly eutrophied lake. The water sources supplying the lake have been demonstrated to be a factor in the nutrient enrichment of the lake. Water quality studies of the lake indicate nutrient concentrations adequate to support algal blooms, determined by measuring the variation in dissolved oxygen profiles and by visual observation.

Data from this previous study has been utilized in addition to water quality samples taken specifically for this report in order to provide more valid results.

CHAPTER 2

DESCRIPTION OF THE WATERSHED AREA

The Rock Creek watershed covers an area of approximately 170 square miles in the central part of Murray County, the south part of Garvin County and the southwestern part of Pontotoc County. This study covered a basin area of 12.1 square miles, see figure 1, that is, that reach of Rock Creek upstream from the Lake of the Arbuckles, the city of Sulphur and the Chickasaw National Recreation Area.

Sulphur, Oklahoma is the Murray County seat and has an estimated population of 5600. The present source of the city's drinking water is seven untreated water wells. Future needs will be met by using water from the Lake of the Arbuckles. The City has an extended aeration sewage treatment plant that discharges into the Washita River.

The Chickasaw National Recreational Area is located in the foothills of the Arbuckle Mountains. It covers approximately 910 acres of woodlands and grass covered hills. In addition to containing a wide range of native vegetation, birds and animals (the western part is a bison range), the park provides opportunities for picnicking, camping, hiking, swimming or wading.

The park area contains two major waterways, Rock Creek (a tributary of the Washita River) and Travertine Creek which is fed by two freshwater springs. The majority of these are sulfur springs but three are bromide springs.

According to USDA soil survey maps the major soils in the watershed area are Denton clay loam, Gilson gravelly loam and Gilson soil material (rough broken land).

Denton clay loam is the most important arable soil in the County. It is fairly dark heavy prairie soil developed from limestone and interbedded calcareous shales. Denton clay loam, deep phase, has a gently rolling relief and is well drained. It is moderately fertile and is particularly suited for farm production. This soil is susceptible to erosion because the fine granules of the dried surface soil are moved easily by running water.

Denton stony loam is somewhat similar to Denton clay loam but is more shallow and contains considerable amounts of stone. It cannot be cultivated because of the abundance of limestone gravel and broken relief but is widely used for pasture purposes.

Gilson gravelly loam is light colored forested soil which is developed from limestone conglomerate. The material is very loose and erosion is severe on unprotected cultivated soil. It is associated in most places with Gilson soil material and the relief is rolling or gently rolling principally in the breaks of Guy Sandy Creek southwest of Sulphur.

Gilson soil material (rough broken land) is similar to Gilson gravelly loam but occurs on steep slopes or low hills. It is unsuited for crop growing and most of the land is covered with post oak, blackjack, oak, elm, etc.

Figure 3 shows the generalized soil map of the area.

Beneficial Uses and Water Quality of Rock Creek

A major use of the water in the Chickasaw National Recreation Area is devoted to recreational activities. There are many public swimming areas and during the summer thousands of people camp, swim and picnic along the streams.

Water quality is used to describe the nature of water in terms of its components and it is determined by the stream's beneficial uses. Rock Creek has been designated as follows:

Code	Beneficial Use
A	Public and private water supplies.
C_1	Fish and wildlife propagation.
D	Agriculture (including livestock watering and irrigation).
F_1	Industrial and municipal cooling water.
F_2	Receiving, transporting and/or assimilation of adequately treated waste.
G_1	Recreation, primary body contact (includes recreational uses where the human body may come into direct contact with the water to the point of complete body submergence).
I	Aesthetics.

The quality of water in a stream or reservoir determines its uses and effects on the environment. According to the beneficial use categories for Rock Creek as listed in the Oklahoma Water Quality Standards, the following water quality criteria have been established.

Bacteria: Bacteria of the fecal coliform group shall not exceed a monthly geometric mean of 200/100 ml. as determined by the membrane filter procedure and on a minimum of not less than five samples for any 30-day period. Nor shall more than 10% of the total samples during any 30-day period exceed 400/100 ml.

Dissolved Oxygen (DO): The dissolved oxygen concentration shall not be less than 5 mg/l. for all warm waters.

pH: The pH shall be between 6.5 and 8.5. pH values below 6.5 and above 8.5 must not be due to waste discharge.

Turbidity: Turbidity of other than natural origin shall be restricted in warm water streams to 50 Jackson Units.

Temperature: During any month of the year heat shall not be added to any stream in excess of the amount that will raise the temperature of the water more than five degrees Fahrenheit. In lakes, the temperature of the epilimnion shall not be raised more than three degrees Fahrenheit above what existed before the addition of heat of artificial origin.

Nutrients: The total phosphorous concentration and nitrogen/phosphorus ratio shall be limited to prevent eutrophication problems.

Toxic Substances: Toxic substances shall not be present in such quantities as to cause the waters to be toxic to human, animal, plant and aquatic life nor detrimental to any beneficial use including continued ingestion by livestock or continued use for irrigation. For aquatic life, using bioassay techniques, the toxic limit shall not exceed 1/10 of the 96-hour median tolerance limit for the most sensitive species common to the stream.

Hydrological Description of Rock Creek

The basin area is located in the hydrologic portion of the state drained by the Lower Washita River beginning on the western border of Grady County and sloping generally southeast.

This area is primarily agricultural with short winters and long hot summers. There is some erosive action in the area and in the past there has been a normal amount of flood damage. Flood control and improved land management practices have generally contributed to a solution of these problems. There is some irrigation and there would be more if water were available.

The climatology of the Rock Creek basin area is a warm continental climate. Major weather disturbances develop over the region when the prevailing warm moisture-laden air driven from the Gulf of Mexico conflicts with the cool drier air arriving from the West coast and Canada. Rainfall is adequate about 53% of the time while droughts of severe to extreme intensity are present about 11% of the time. The occasional dry periods or untimely distribution of precipitation usually causes hardships since less than one percent of the croplands are irrigated.

The long warm summers provide many hot days which are eased by the presence of relatively low humidity prevailing southerly winds and occasional rain showers or thunderstorms. However, drought conditions are greatly intensified during the extreme hot periods when brisk hot winds out of the southwest accompany the high daytime temperatures. The cooling trend of fall usually begins with the secondary maximums of precipitation in September. Winter is the driest season and is usually mild and of short duration. The stronger outbreaks of cold and snow conditions last only a few days and the severe "northers" occur very infrequently. The 30-year mean temperature is about 63 degrees Fahrenheit, the mean January temperature is about 40 degrees Fahrenheit while July means are about 83 degrees Fahrenheit. Extreme temperatures at Sulphur, Oklahoma since 1892 have been recorded as -15 degrees Fahrenheit minimum and 120 degrees Fahrenheit maximum. Mean annual precipitation is about 36 inches per year resulting in an average annual runoff of five to 10 inches per year. The average surface wind speed is about 13 miles per hour. Actually less than two percent of the winds exceed 25 miles per hour and nearly 50% of the observations are reported as calm. The area is subject to tornado activity, and although rare, do produce winds of up to 100 miles per hour. Some hail activity is noted but it is a rarity. The mean monthly relative humidity ranges from about 46% to 80%. The climatologic rainfall from 1917-1977 published by the State Water Development Board is in part assembled from the National Weather Service and Park records and is listed in Table 1.

The base flows in Travertine Creek and Rock Creek are primarily fed from the springs in the park. The springs in the park are directly associated with ground water recharge which in turn is directly related to precipitation in the area.

Base flow in Travertine Creek originates from basically two sources, Buffalo and Antelope springs. Peak flows are a result of surface runoff that enters the creek from rainfall. The drainage area of the Travertine Creek basin is small and the runoff coefficient is estimated to be less than 10%. After a significant rainstorm the hydrograph runoff peaks recede rapidly.

Travertine Creek is an important tributary to Rock Creek and is one of the three main sources of water for the Lake of the Arbuckles reservoir which is only a few miles downstream. Rock Creek has a larger drainage area than does Travertine Creek and also exhibits a greater surface flow.

The groundwater status in the area of the park has gradually deteriorated from a strong to weak or non-existent artesian condition. Prior to the period of this research effort Buffalo and Antelope springs ceased to flow on nine different occasions. As determined by Harp and Laguros (2), the same aquifer that supplies water to the city of Sulphur well field also supplies Buffalo and Antelope springs. Thus except on isolated occasions the city wells flow continually under artesian conditions and at night overflow into Travertine Creek while supply exceeds demand. Artesian conditions exist north of the park boundary for several miles, exactly how far has not yet been determined. The fresh groundwater is derived from the Arbuckle formation while the mineralized springs originate in the Simpson formation which is shallow and has less artesian pressure. In fact, the mineralized springs have for all practical purposes ceased to flow under artesian conditions and the public springs in the park are pumped so that the park patrons can have access to the famous sulphur water of reputed medicinal value. The groundwater supply from Buffalo and Antelope springs to Travertine Creek will cease to exist if "mining" of the aquifer continues.

CHAPTER 3

SOURCES OF POLLUTION

POINT SOURCE

There are several point sources of discharge as listed below.

1. Cooling tower blowdown water from O.G.&E., the Arbuckle electric generating plant. The source of supply for the cooling water make up is from a highly mineralized aquifer and would account for the high concentrations of Cl and TDS measured in the discharge water. Also associated with this discharge is a high COD concentration with a mean value of 50.9 mg/l. which contributes significantly to the COD loading of Rock Creek.

2. Livestock holding pens where cattle and hogs are held for the weekly auctions. An artesian well flows freely through the pens and discharges over the creek bank directly into Rock Creek. An increase from 18.6 mg/l. to 30.2 mg/l. in COD before and after the discharge was observed in a past study. There was also an increase in the bacterial population of the stream.

3. Broken sewer lines running parallel to Rock Creek several hundred yards upstream from Sandy Beach. Several inverted siphons pass under Rock Creek and are in a poor state of repair with much leakage and communication with the water in the stream.

4. Manholes associated with inverted siphons crossing Rock Creek in a number of places. Sometimes these manholes were observed overflowing directly into the stream.

5. A storm sewer drainage culvert discharging into Travertine Creek.

This culvert collects storm and other runoff from the streets and yards in that area of Sulphur and discharges it into Travertine Creek.

NON-POINT SOURCES

There are several dispersed sources of pollution from agriculture and forest lands to urban runoff. In farm areas, fertilizer is currently being applied at the annual rate of 200 pounds of 10N-20P-10K fertilizer per acre. Increasingly more of the agricultural activities in Murray County are turning to beef and dairy production with 21 dairy and poultry farms in the watershed area. The dairy farms range in size from 40 to 80 head of cattle per farm while the poultry population ranges from 8,000 to 10,000 hens per house.

Another non-point source of pollution is the recreational activity in the park. The effects on water quality from the recreational uses of an area depends on whether or not the activity comes in direct contact with the water. The major effect from direct water contact activities is an increase in bacterial contamination.

CHAPTER 4

MATHEMATICAL MODELING OF NATURAL SYSTEMS

Any natural body of water may be viewed as a system consisting of complex interacting subsystems each with its own set of physical characteristics (3). From an engineering point of view, the system may be best described in a mathematical framework such that for each of the physical characteristics there may be written a mathematical statement which bears a one-to-one correspondence to it.

As with any system, the natural water body responds in a variety of ways depending on the nature of the inputs and forcing functions. The responses of the system are the spatial and temporal distributions which affect water quality. The inputs to which the quality of the system responds may be divided into two categories. First, there are a number of natural inputs such as rainfall, solar radiation, runoff, and winds which in conjunction with surface and ground characteristics of the basin determine the background quality of the water. Second, the system is subjected to a variety of man-made effects such as waste water discharge, water diversions and runoff from urban and land developments.

The relationship between the quality of water and the contiguous environment is essentially the domain of mathematical modeling. The use of a mathematical representation of water quality has its roots in the early models of dissolved oxygen constructed by Streeter and Phelps (4) to analyze the effects of waste discharge on the water quality of the Ohio River. A mathematical model is simply an analytical abstraction of the real world. As such, it does not pretend to incorporate all phenomena but rather abstracts only those portions of the real world that are relevant to the problem under consideration.

In the case of water quality the purpose of the model is to reproduce in time and space the distribution of a substance due to the inputs described above. The model may be employed to analyze past data, assess present conditions and project future needs.

Multiple regression and correlation analysis is believed to be the most powerful technique, at least for the purposes of this study, that can be utilized to define the water quality of Rock Creek. The general form of the model equation is as follows:

$$Y = A_0 + A_1f_1(t) + A_2f_2(t) + \dots + A_kf_k(t)$$

where,

Y = dependent variable (such as DO or fecal coliforms)

$f_i(t)$ = independent variable in various functional forms.

For a simple linear trend:

$$Y = A_0 + A_1f_1(t).$$

Computer programs can be prepared to handle this general case. The user merely specifies the particular model equation that he wishes to investigate. The various functional forms can be programmed and coded for ease of specification.

In 1956 Churchill and Buckingham (5) proposed this method of analysis based on the multiple correlation of all the principal factors producing and controlling the extent of the oxygen sag below a source of pollution. Times of water travel determinations are not necessary. Long-term BOD determinations are not required since BOD constants K_1 and K_2 and ultimate carbonaceous BOD_L are not used in the analysis.

A number of factors operate concurrently in a stream below a source of pollution to produce an oxygen deficiency in the river. The basic procedure simultaneously correlates these factors statistically with the measured decrease, or drop, in oxygen concentration from the pollution source to the low point of the oxygen sag. The factors used must be readily measurable in quantitative units. When pollution is discharged into a reasonably well aerated stream the factors which affect the extent of the oxygen sag and which are also quantitatively observable are BOD, stream temperature and stream discharge.

Churchill and Buckingham (5) believe that these controlling factors can be correlated by relating the observed values of the so called independent variables with the observed values of the dependent variable, DO drop, resulting in an equation that can be used with confidence to predict the extent of the DO drop for various assumed values of the independent variables.

In general Churchill (5) has found from the results of 24 stream surveys and stream sampling procedures at appropriate points, that a good correlation exists between BOD, DO, temperature and stream flow. In other words, he found that the dissolved oxygen sag occurring in a stream depends upon only three variables: BOD, temperature and flow. By using the least-squares method, the line of regression can be computed so that for any desired BOD loading the dissolved oxygen sag can be predicted. This method eliminates the often questionable and always cumbersome procedure of determining times of flow between stations and resulting stream reaction rates (K_1, K_2 and K_3).

Numerow (6) found that a good correlation exists in the Churchill and Buckingham method if each sample is observed under maximum and minimum conditions of each of the three stream variables: stream flow, BOD and temperature. Only a minimum number of samples is required to produce practical results.

The simplest type of multiple correlation is expressed by the linear equation:

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3$$

where,

Y = dependent variable, DO drop, in mg/l.

x_1 = 5 day BOD, in ppm.

x_2 = water temperature in ^{0}C.

x_3 = stream discharge factor in ft^3/sec.

a, b_1, b_2, b_3 = constants derived from actual data.

MULTIPLE CORRELATION THEORY

It is beyond the scope of this report to explain or discuss the general equation of the form:

$$Y = a + \Sigma b_i x_i$$

However, there are several computer programs that can be used to produce results as well as the reliability of those results. For the purposes of this study the following parameters will be utilized in insuring that all mathematical models obtained are statistically valid.

Coefficient of determination (R^2) is a measure of the explained variation over the total variation. R^2 values range from 0 to 1 with a value of 1 representing the situation where all variation has been explained.

F-statistic (F) is a measure of the explained variance over the unexplained variance. At a confidence level of 95%, the value obtained for a

6 - 10 sample size can be considered significant if over 6. For a sample greater than 10, the F-statistic must have a value of 5 or greater to be considered significant.

Standard Error of Forecast (SEF) defines a confidence interval around forecasts based on the regression line. Normally a 95% confidence interval is used and this test will allow a 95% certainty that an actual value will be within ±2 standard errors of forecast around the forecasted value.

Mathematical expressions for the above parameters are contained in Table 2.

CHAPTER 5

MATHEMATICAL MODELS OBTAINED

This study was divided into two phases. The first phase dealt with the development of mathematical models with data already available. The second phase dealt with the sampling and development of the final mathematical models.

Three sampling stations, 7, 14 and 18 (Figure 1) were chosen to explain the general behavior of Rock Creek. Mathematical models for DO, fecal coliform, organic nitrogen and total phosphorus were obtained for each one of the three stations with data already available. Table 3 shows the data utilized to develop the models.

In the second phase, data was obtained to develop models for DO, organic nitrogen and total phosphorus and this data is summarized in Table 4.

From the data contained in Tables 3 and 4, models were developed at the three sampling stations. Each model with its statistical analysis for validity is shown below.

PHASE 1

MATHEMATICAL MODELS AT STATION 7

Dissolved Oxygen
$y_1 = 8.1 + 22.2 \ln x_1 - 5.4 \ln x_2 - 0.06 x_3$
$F = 0$
$R^2 = 1.0$
SEF = 0

y_1 = Dissolved Oxygen, mg/l.
x_1 = Flow, cfs.
x_2 = Temperature, degrees C.
x_3 = COD, mg/l.
F = F-statistic
R^2 = Coefficient of Determination
SEF = Standard Error of Forecast

Fecal Coliform
$y_2 = -0.4776 - 0.0128 x_2 + 0.0701 x_3$
$F = 5.7$
$R^2 = 0.91$
SEF= 1.215

y_2 = Fecal Coliform 1000/100 ml.

Organic Nitrogen

y_3 = Organic Nitrogen, mg/l.

$y_3 = -0.782 + 0.276x_1 + 0.066x_3$
$F = 4.7$
$R^2 = 0.9$
$SEF = 6.0$

Total Phosphorus

y_4 = Total Phosphorus

$y_4 = -0.091 - 0.095x_1 - 0.012x_3$
$F = 0$
$R^2 = 1.0$
$SEF = 0$

MATHEMATICAL MODELS AT STATION 14

Dissolved Oxygen
$y_1 = 12.71 - 0.27\ln x_1 - 0.81\ln x_2 - 0.05x_3$
$F = 3.1$
$R^2 = 0.9$
$SEF = 0.38$

Fecal Coliform
$y_2 = -28.567 + 17.91x_1 - 1.08x_2 + 0.09x_3$
$F = 23.3$
$R^2 = 0.99$
$SEF = 3.64$

Organic Nitrogen
$y_3 = 6.25 - 2.34x_1$
$F = 27.3$
$R^2 = 0.96$
$SEF = 0.156$

Total Phosphorus
$y_4 = -0.808 + 0.274x_1 + 0.011x_3$
$F = 1991.9$
$R^2 = 0.999$
$SEF = 0.0099$

MATHEMATICAL MODELS AT STATION 18

Dissolved Oxygen
$y_1 = 14.7 + 2.3\ln x_1 - 2.97\ln x_2 - 0.04x_3$
$F = 6.69$
$R^2 = 0.87$
$SEF = 1.2$

Fecal Coliform
$y_2 = -15.01 + 2.98x_1 - 0.20x_2 + 0.31x_3$
$F = 12.5$
$R^2 = 0.96$
$SEF = 4.12$

Organic Nitrogen
$y_3 = -0.396 + 0.086x_1 + 0.024x_3$
$F = 0.77$
$R^2 = 0.6$
SEF= 0.78

Total Phosphorus
$y_4 = -0.624 + 0.138x_1$
$F = 71.1$
$R^2 = 0.98$
SEF= 0.015

PHASE 2

MATHEMATICAL MODELS AT STATION 7

Dissolved Oxygen
$y_1 = 8.26 + 19.79\ln x_1 - 4.83\ln x_2 - 0.053x_3$ (1)
$F = 29.9$
$R^2 = 0.95$
SEF= 0.28

Organic Nitrogen
$y_3 = -0.848 + 0.33x_1 + 0.06x_3$ (2)
$F = 63.6$
$R^2 = 0.96$
SEF= 0.19

Total Phosphorus
$y_4 = -0.09 + 0.046x_1 + 0.002x_3$ (3)
$F = 14.9$
$R^2 = 0.88$
SEF= 0.018

MATHEMATICAL MODELS AT STATION 14

Dissolved Oxygen
$y_1 = 13.16 - 0.37\ln x_1 - 0.90\ln x_2 - 0.055x_3$ (4)
$F = 16.1$
$R^2 = 0.94$
SEF= 0.23

Organic Nitrogen
$y_3 = 5.95 - 2.217x_1$ (5)
$F = 103.3$
$R^2 = 0.96$
SEF= 0.094

Total Phosphorus
$y_4 = -0.848 + 0.304x_1 + 0.009x_2$ (6)
$F = 176.5$
$R^2 = 0.988$
SEF= 0.035

MATHEMATICAL MODELS AT STATION 18

Dissolved Oxygen

$y_1 = -3.31 + 10.74\ln x_1 - 1.71\ln x_2 - 0.027x_3$ (7)

$F = 7.44$

$R^2 = 0.788$

$SEF = 0.95$

Organic Nitrogen

$y_3 = -0.205 + 0.048x_1$

$F = 5.1$

$R^2 = 0.819$

$SEF = 0.35$

Total Phosphorus

$y_4 = -0.517 + 0.113x_1 + 0.0005x_2$ (9)

$F = 23.9$

$R^2 = 0.92$

$SEF = 0.035$

SAG CURVE MODEL
BETWEEN STATIONS (7+14) and 18

$\Delta y_1 = -5.54 + 1.52x_1 - 0.09x_2 - 0.025x_3$ (10)

$F = 5.02$

$R^2 = 0.83$

$SEF = 0.70$

CHAPTER 6

DISCUSSION OF RESULTS

MODELS AT STATION 7

Equation 1 shows that flow has a positive effect on the oxygen content in water. This effect can be explained since flow increments cause turbulent conditions in the stream so that oxygen is transferred to the liquid in a greater amount due to surface film disruption and film renovation.

Temperature and COD increment concentrations adversely affect the DO content in the stream. It is evident that an increase in temperature decreases the ability of liquids to hold dissolved gases. COD is a measure of the strength of a waste in terms of the total quantity of oxygen required for oxidation to carbon dioxide and water so that an increase in COD will tend to decrease the dissolved oxygen content in the water.

Values of R^2 and F-statistic show that the data utilized has a good statistical correlation and the low standard error of forecast indicates that this equation will give very accurate results.

Equation 2 shows that an increase in flow and/or COD concentration will increase the organic nitrogen concentration in the stream.

Values of R^2, F-statistic and SEF, indicate good statistical correlation and assure that the predictions will be sound.

Equation 3 shows that an increase in flow and/or COD concentration will increase the total phosphorus concentration.

Eighty-eight percent of the total variation is explained by the values of COD and flow utilized to obtain the mathematical model. The SEF value shows a low error of forecasting therefore the model is an accurate one.

MODELS AT STATION 14

Equation 4 shows that an increase in the values of flow, temperature and COD will cause a reduction on the DO in the stream. This negative effect of the flow may be explained by the point and non-point sources of pollution existing upstream of the station, which causes an increase in the natural flow and hence septic conditions.

The values of R^2, F-statistic and SEF show that the equation obtained is statistically safe to use.

Equation 5 shows that an increase in the stream flow causes a decrease in the concentration of organic nitrogen, therefore, the flow has a diluting effect on the stream.

The values of R^2, F-statistic and SEF show that equation 5 is statistically safe to use.

Equation 6 shows that an increase in the stream flow and COD values will cause an increase in the total phosphorus content.

The values of R^2, F-statistic and SEF show that equation 6 is statistically safe to use.

MODELS AT STATION 18

Equation 7 shows that flow, temperature and COD cause the same effects as those of station 7. It indicates that water coming from the Travertine Creek has a high beneficial influence on the water quality of Rock Creek.

The value of R^2 is a little low, but it is still statistically good. The values of F and SEF show that the use of the equation is statistically good.

Equation 8 shows that an increase in flow causes an increase in the organic nitrogen concentration in the stream.

The value of R^2 is a little low, but it is still statistically good. The value of F shows that the equation does not show significance at the 95% of confidence level.

Equation 9 shows that an increase in flow and/or COD concentration will cause an increase in the content of total phosphorus.

The values of R^2, F-statistic and SEF show that the equation obtained is statistically safe to use.

SAG CURVE MODEL

Equation 10 shows that an increase in flow at station 18 will increase the value of the oxygen difference between stations 7 and 14, and station 18. Temperature and COD increase will cause a negative effect.

The value of F shows that the equation does not show significance at the 95% confidence level.

DISCUSSION ON WATER QUALITIES FOUND

COD VALUES

In general, station 7 (Travertine Creek) shows a better quality of COD values with a mean of 19.4 mg/l than does station 14 (mean 28.2) or station 18 (mean 28.9), as shown in Figure 4. This pattern was established in a previous study.

These high values show that there are sources of pollution reaching the stream. Unfortunately, this study was not concerned with the location of these sources.

DO VALUES

Figure 5 shows the values of DO found in the three sampled stations. Station 7 had the lowest mean concentration followed by station 14 and 18. These values do not mean a high pollution of the creek. Moreover, the mean value of DO at station 14 does not represent the water quality of that stream, since during the last sampling (April 15) a great amount of small algae was observed there with the result that a high value of DO was recorded.

The most important observation is that DO content increases as flow goes downstream due to natural reaeration given as a result of an oversaturation of DO in the water. This oversaturation of DO escapes to the atmosphere as soon as the flow becomes laminar.

ORGANIC NITROGEN

Figure 6 shows the values of organic nitrogen found in the three stations. It can be observed that station 7 shows the highest values of this parameter. This suggests a source of pollution just upstream of this station.

The low values observed in station 14 do not appear to be reasonable due to the high COD values, although it may be possible that the sources of pollution upstream from station 7 are far enough away in order for organic nitrogen to be converted to NH_3, NO_2 or NO_3.

TOTAL PHOSPHORUS

Figure 7 shows the concentration of phosphorus found in the three stations. Station 14 has the highest phosphorus content and station 7 shows the lowest values.

Nevertheless, concentrations of phosphorus found at stations 14 and 18 are sufficient to support the accelerated growth of algae and other aquatic plants in places where water is impounded, such as the Arbuckle Lake. Evidence of high concentrations of nutrients was observed at station 14 during the last sampling and this fact was further evidenced by the high DO concentrations found.

CHAPTER 7

SUMMARY AND CONCLUSIONS

The water quality of Rock Creek in the three selected stations is below the standards set forth by the Oklahoma Water Resources Board for the designated beneficial uses of that stream.

Local inflows reaching the stream have different impacts on water quality parameters as can be seen in the mathematical models obtained.

Modeling of the stream is demonstrated to be statistically accurate and simulation of different conditions can be made with a reasonable degree of confidence and reliability.

High concentrations of phosphorus is a main concern as shown in this study, however this may be unique for this stream at this time. Nitrogen concentrations are well below the applicable standards. More research is recommended to fully understand all of the input-output relationships that might exist in general streams of Oklahoma, and other states.

CHAPTER 8

RECOMMENDATIONS

A more detailed study should be developed to take into account other variables that might significantly affect the water quality of the stream, such as number of visitors, length of stay, etc.

A better model for coliforms could be obtained since this is the main pollutant that affects the closing of recreational areas.

This modeling technique can be applied to other streams in order to develop general models. Once the model is obtained, different simulations can then be analyzed resulting in a better understanding of the water system and its ecological relationships with the physical surroundings.

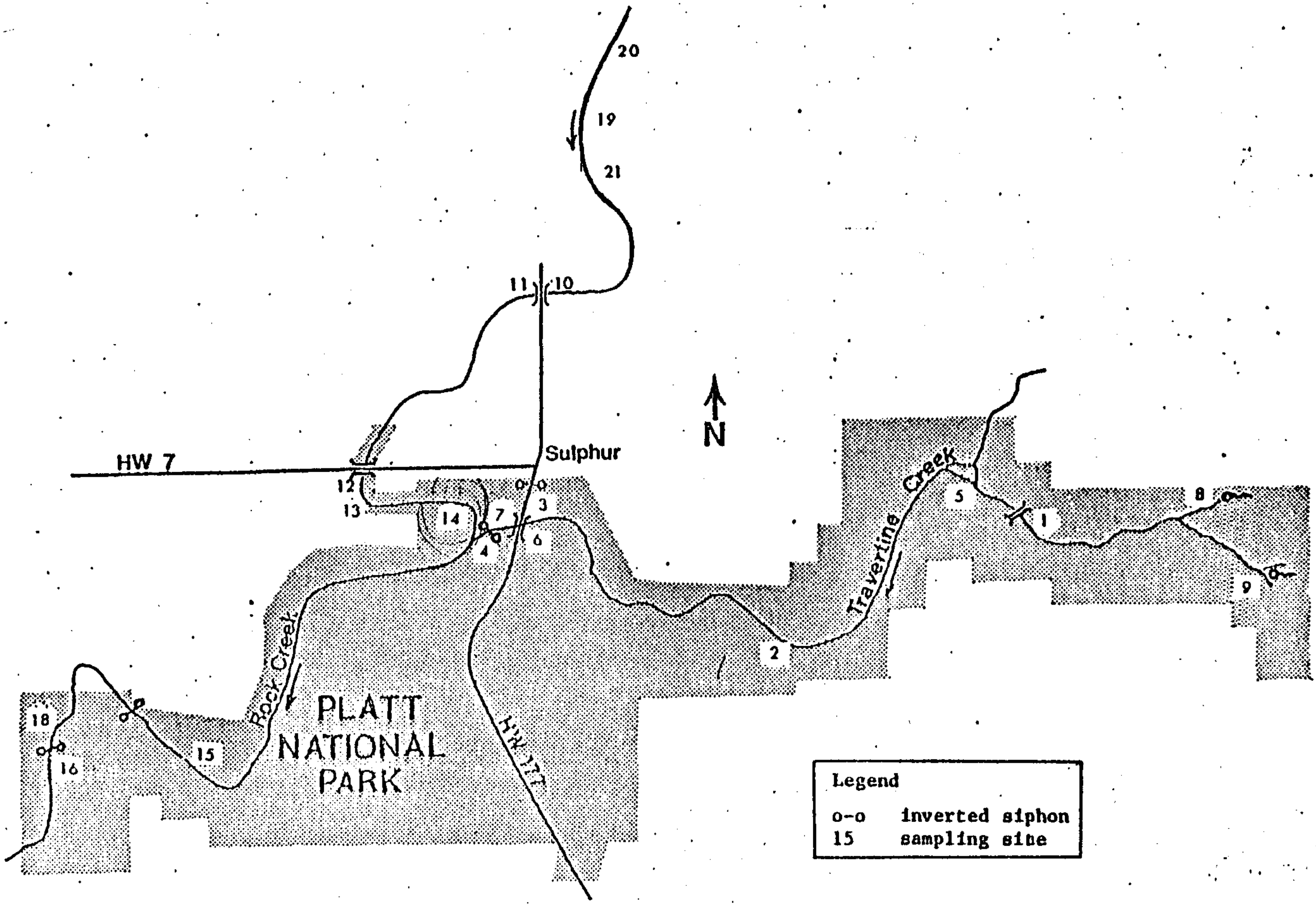


Figure 1
SAMPLING SITES--ROCK CREEK--CHICKASAW NATIONAL RECREATION AREA

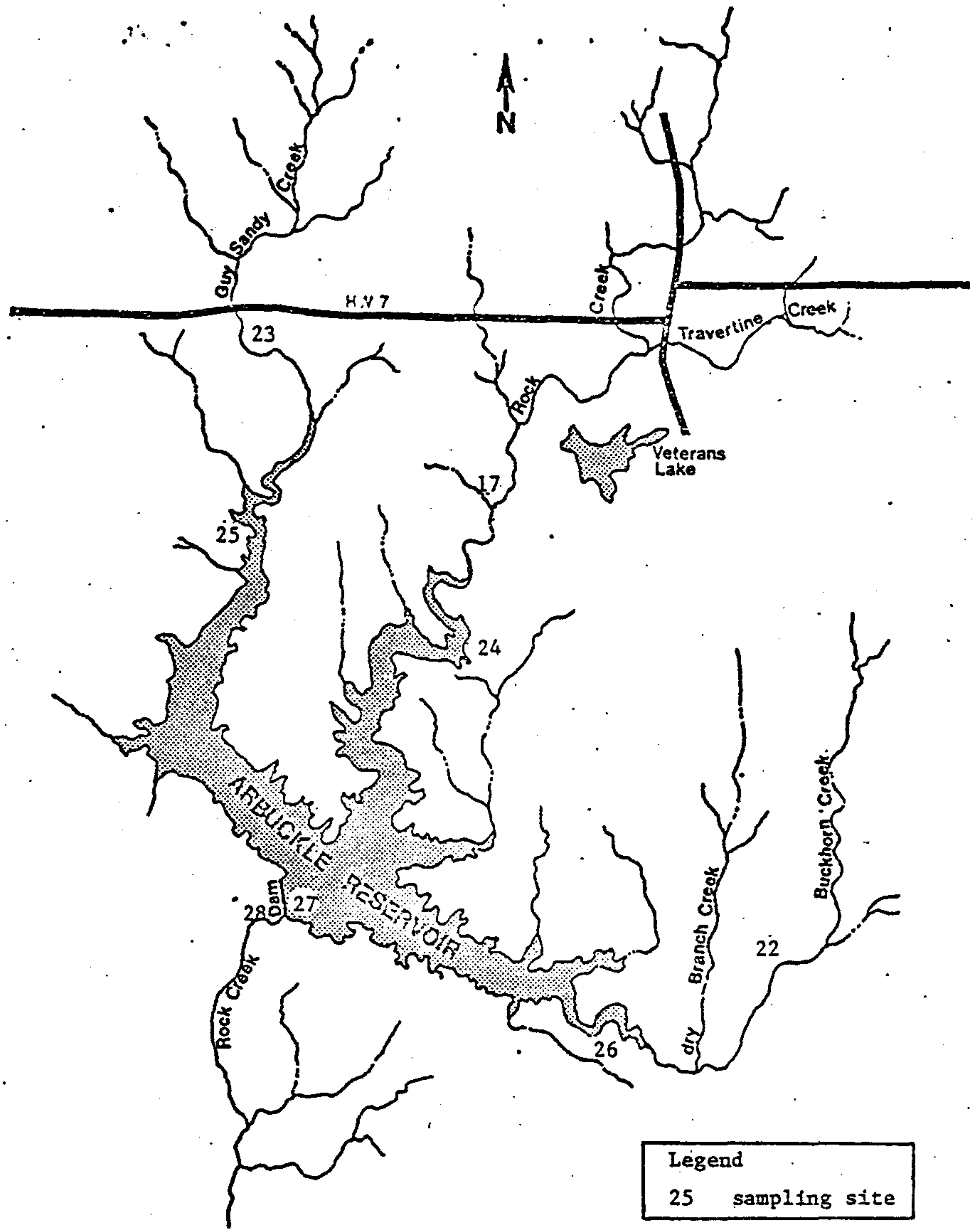


Figure 2

SAMPLING SITES—ARBUCKLE RESERVOIR—CHICKASAW NATIONAL RECREATION AREA

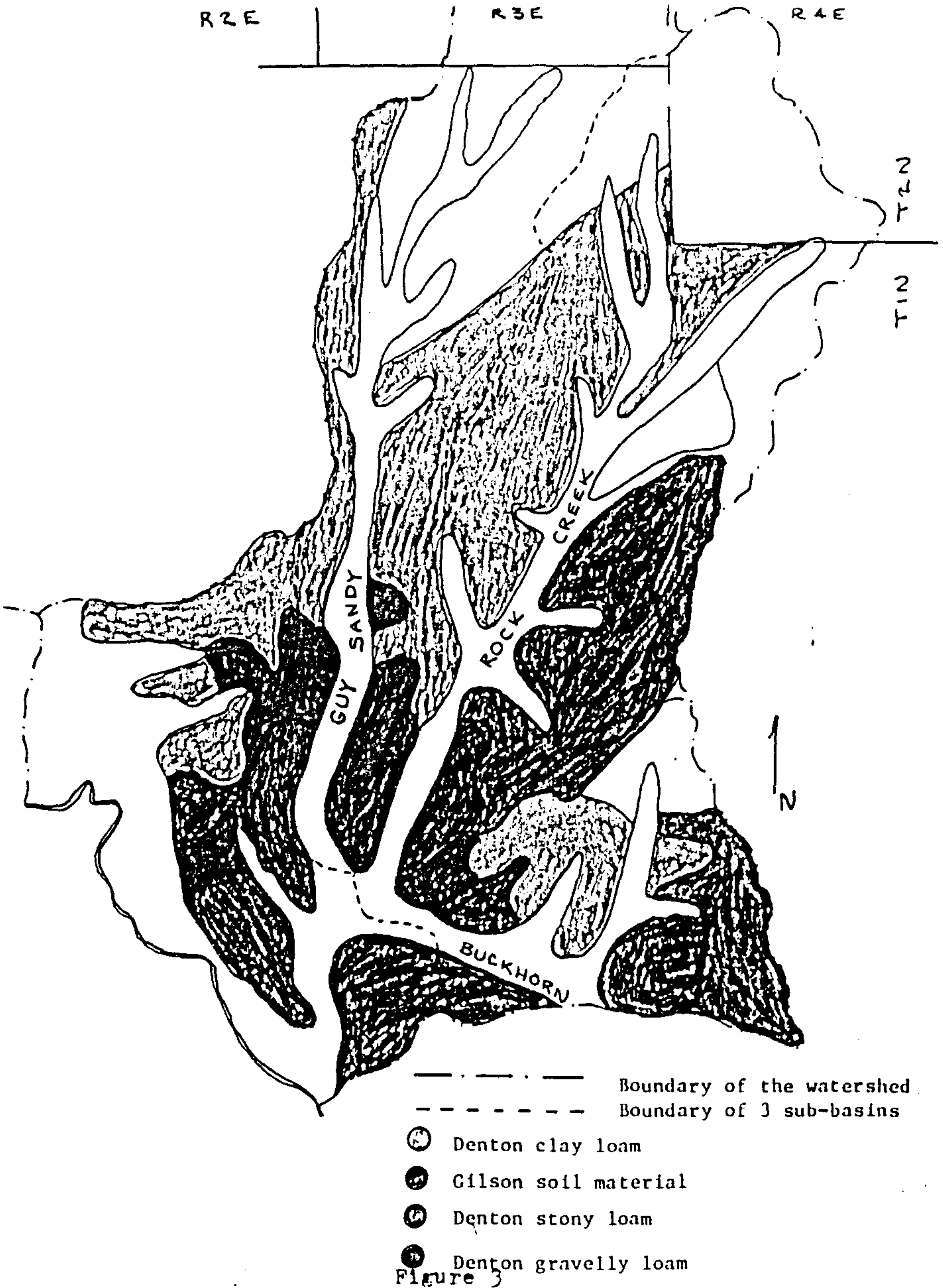
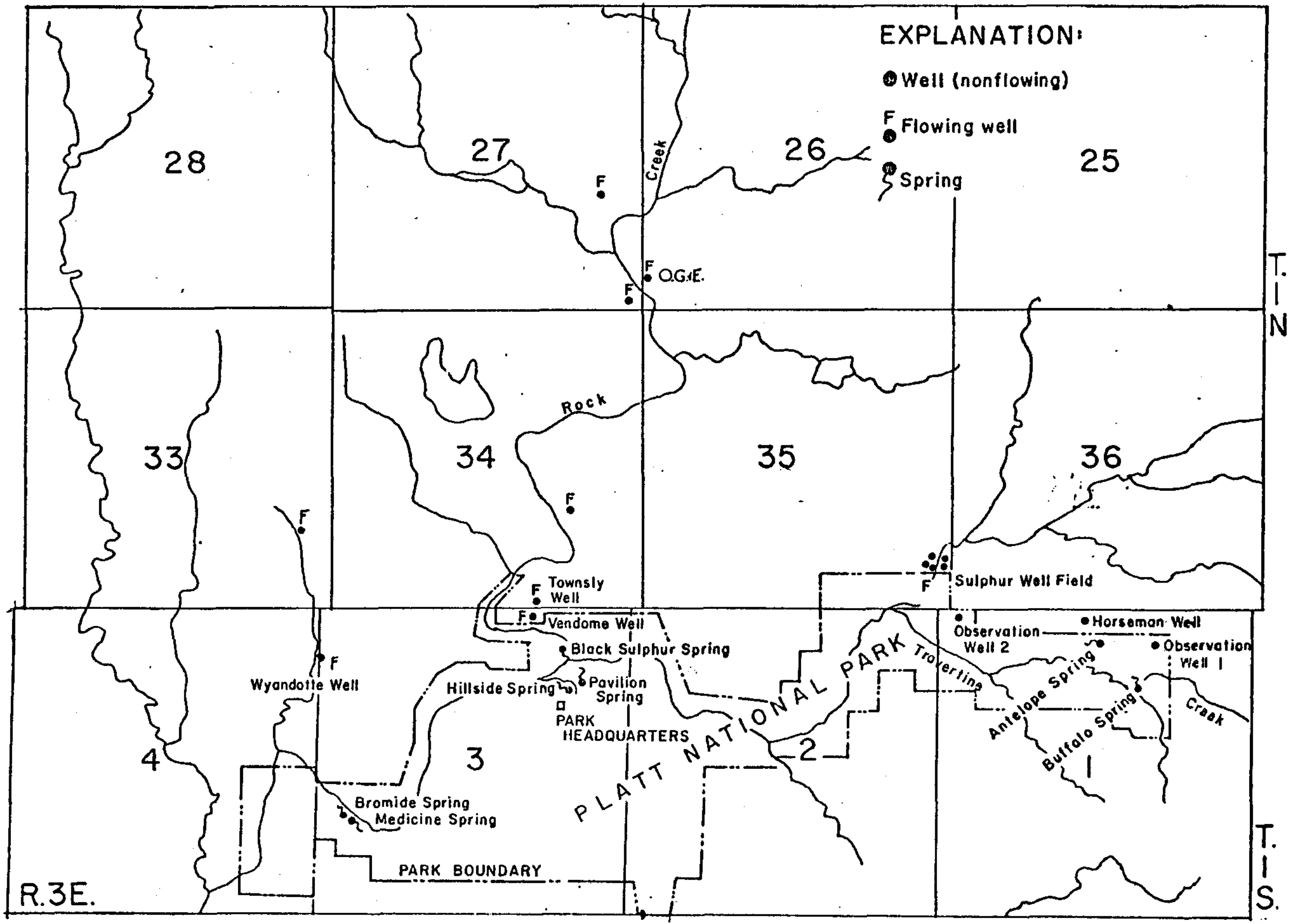


Figure 3

GENERALIZED SOILS MAP OF THE ROCK CREEK WATERSHED.

Figure 4a



Platt National Park Area—Selected Wells and Springs

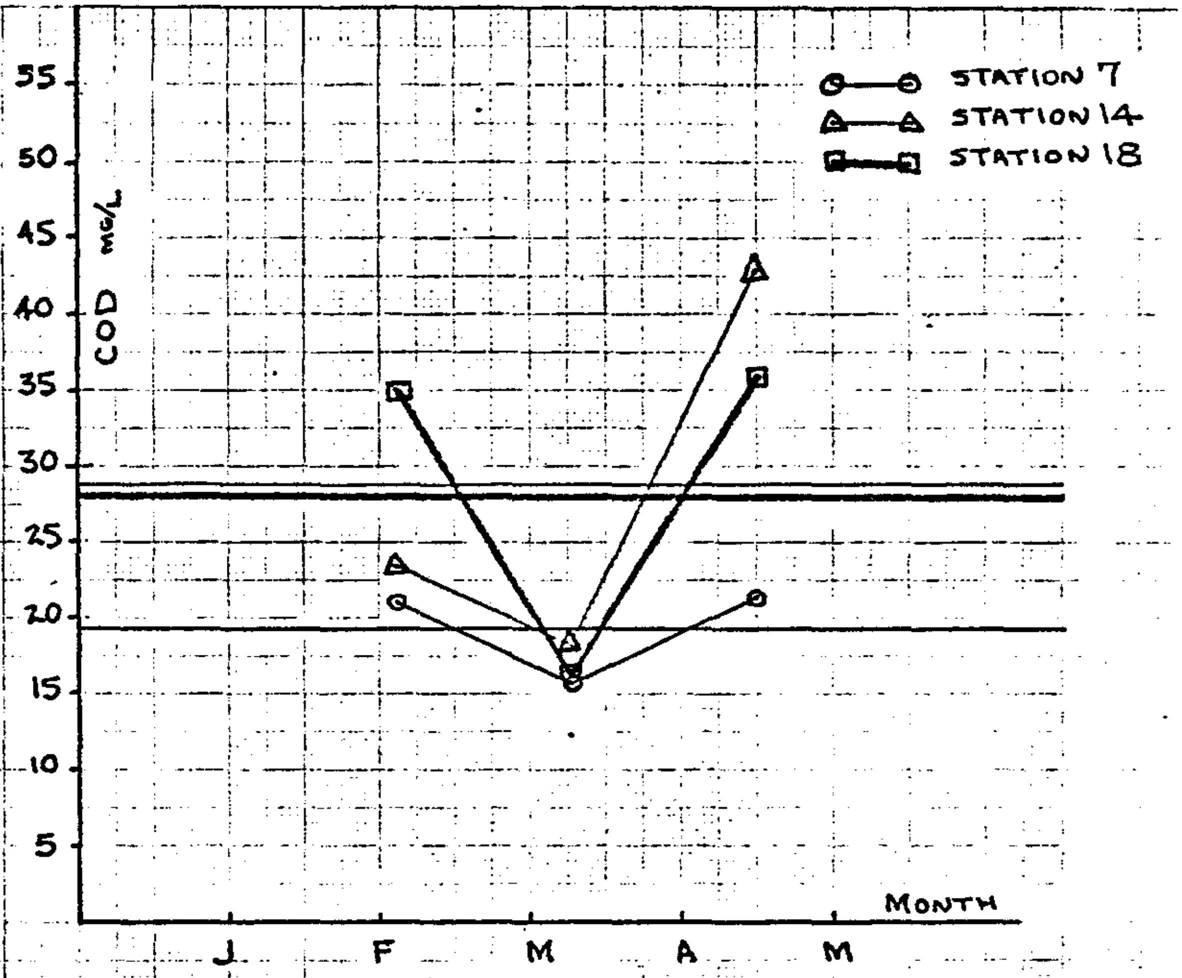


Figure 4
COD CONCENTRATIONS AND MEAN VALUES AT STATIONS 7, 14 AND 18.

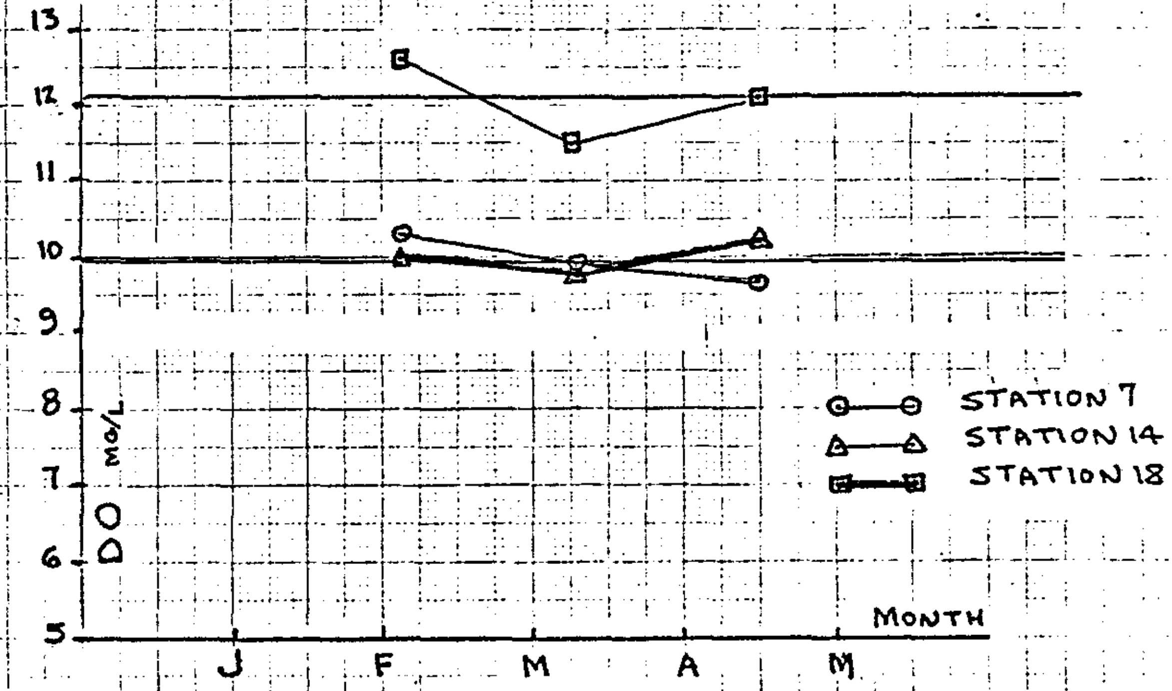


Figure 5
DO CONCENTRATIONS AND MEAN VALUES AT STATIONS 7, 14 AND 18.

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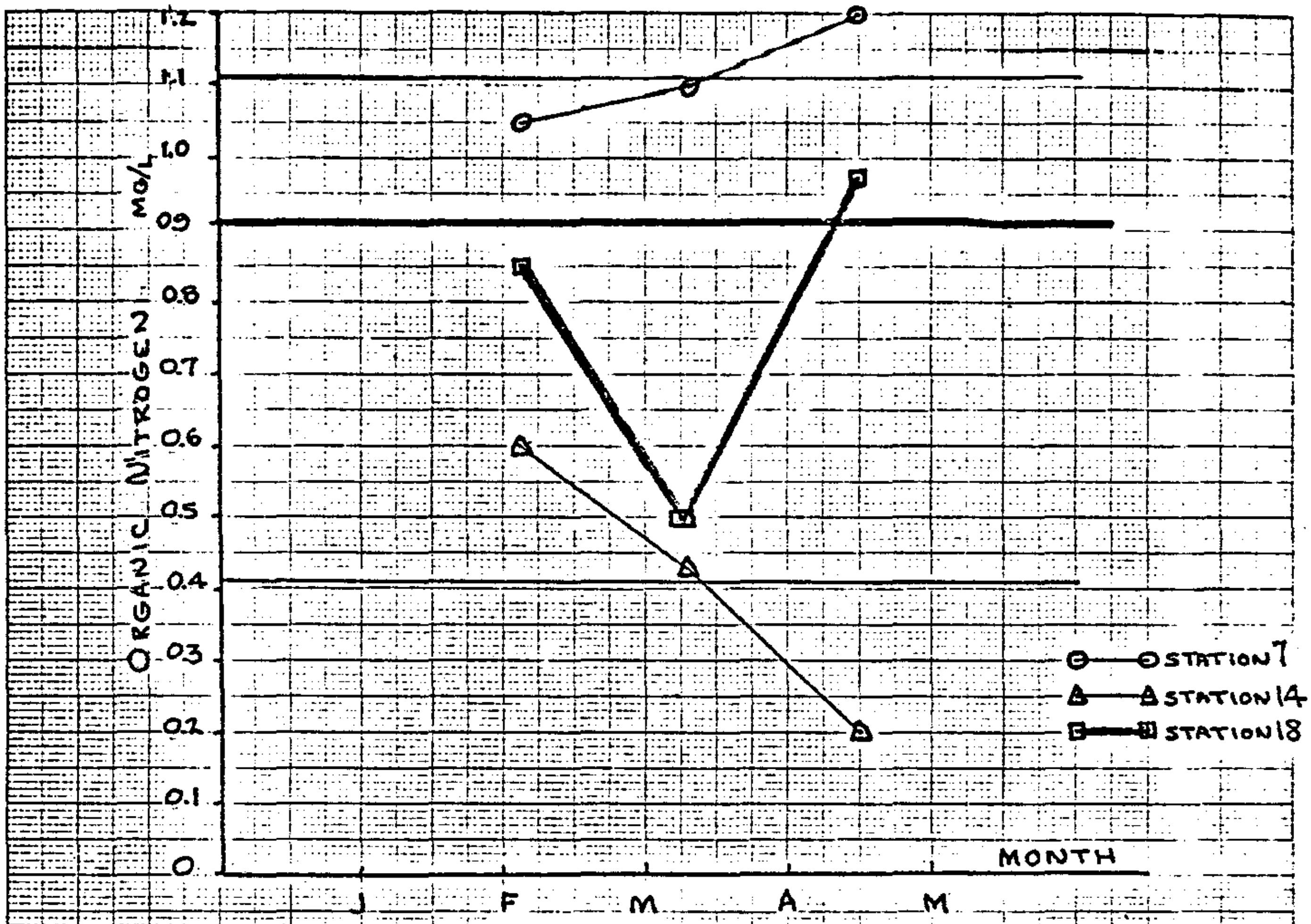

Figure 6
ORGANIC NITROGEN CONCENTRATIONS AND MEAN VALUES AT STATIONS 7, 14 AND 18.

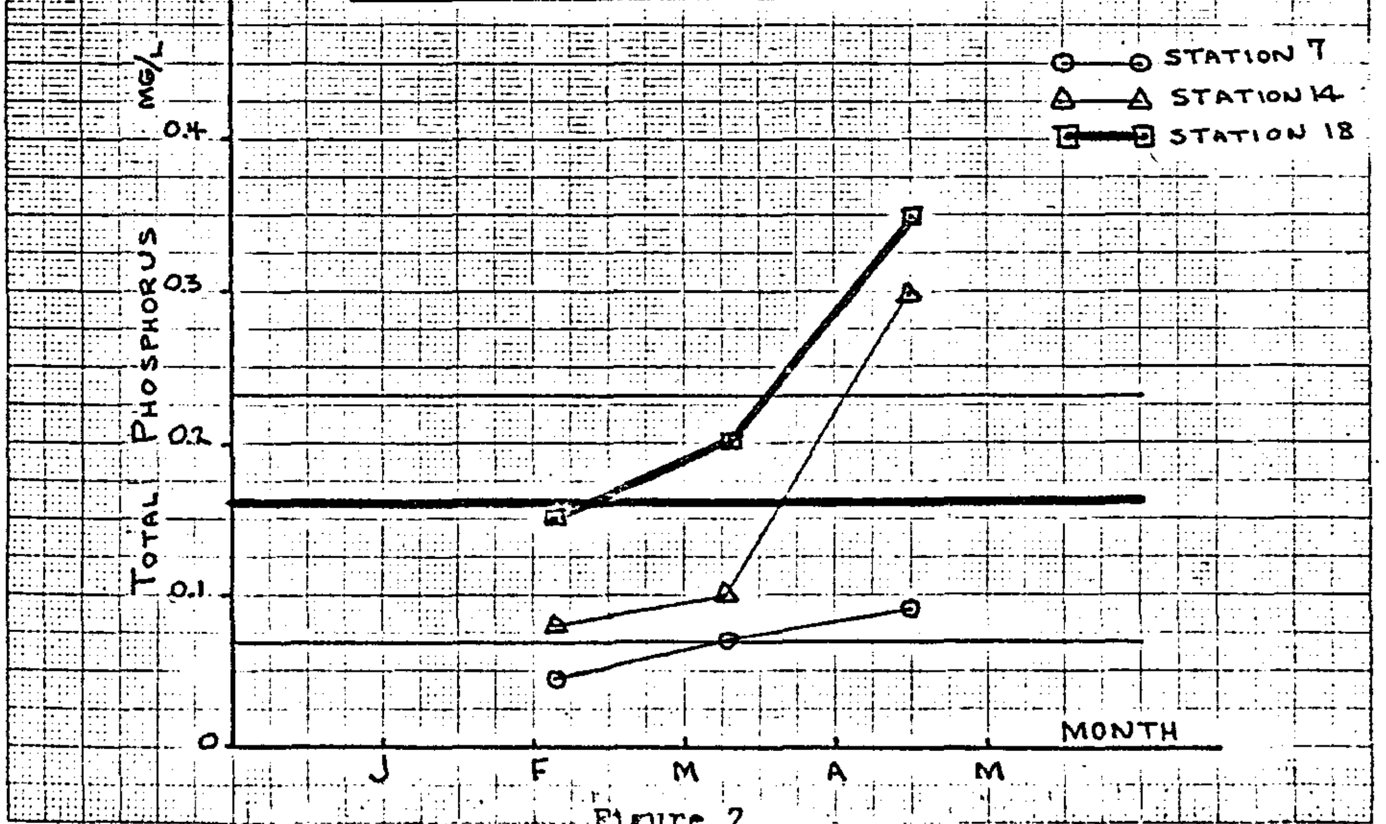

Figure 7
TOTAL PHOSPHORUS CONCENTRATIONS AND MEAN VALUES AT STATIONS 7, 14 AND 18.

10 Millimeters to the Centimeter

Table 1

PRECIPITATION RECORDS.

Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Ann'l
*1917		.80	.17	4.68	2.28	3.04	3.12	2.15	3.09	T	1.72	T	
*1918	.62								4.15	4.37	2.56	3.92	
1919	1.21	2.39	2.18	3.40	5.35	3.67	3.81	7.24	.79	8.04	3.86	1.10	43.04
1920	2.65	.14	1.45	3.22	6.08	4.88	1.64	2.15	5.38	5.64	1.18	1.48	35.89
1921	1.66	2.17	4.91	4.27	2.80	8.00	3.90	2.83	.78	.05	1.11	1.06	33.54
1922	1.40	1.36	3.09	8.31	6.08	1.11	2.58	.79	.04	2.33	4.50	.40	31.99
1923	2.51	1.28	1.80	5.30	8.88	3.87	T	2.51	6.54	10.75	2.81	4.26	50.51
1924	.89	.79	3.42	5.88	3.10	3.63	.35	.72	1.98	.14	.49	2.85	24.24
1925	.99	.78	.08	2.19	4.83	.02	2.95	1.32	5.08	3.63	1.48	.32	23.67
1926	3.47	.72	2.56	2.56	4.40	3.17	6.19	8.28	5.84	5.39	.66	3.31	46.55
1927	4.78	2.97	1.95	9.99	.76	6.44	7.70	2.93	5.00	3.19	.77	3.65	50.13
1928	3.30	2.99	1.10	7.86	3.20	9.77	4.97	3.06	.76	3.55	2.68	1.74	44.98
1929	2.04	1.22	3.52	1.67	10.46	2.49	1.84	.14	5.05	6.76	2.36	2.78	40.53
1930	2.10	2.76	1.23	3.73	7.99	2.57	1.18	3.42	1.73	2.47	4.02	2.34	35.54
1931	.35	7.20	4.30	2.02	1.83	1.63	2.95	.72	.14	6.22	6.03	1.44	34.83
1932	7.33	3.41	1.73	3.71	2.11	4.06	1.48	1.76	.44	2.54	.22	9.30	38.09
1933	2.50	2.02	4.40	2.25	13.78	.54	2.22	5.95	4.96	.46	1.82	1.44	42.34
1934	2.40	2.72	3.80	2.97	3.00	2.81	.00	.87	6.38	1.06	5.98	.48	32.47
1935	1.89	.85	5.38	4.31	12.54	7.48	2.34	4.14	5.45	3.84	3.09	3.05	54.36
1936	.43	.40	1.61	1.07	8.38	.60	2.52	T	12.68	3.56	.30	1.62	33.17
1937	2.47	.18	4.06	3.68	2.22	2.79	4.63	4.38	.05	3.27	2.10	2.93	32.76
1938	2.60	9.55	4.61	2.35	6.05	4.83	2.57	1.43	2.44	.50	2.80	.68	40.41
1939	3.07	1.73	1.96	2.78	2.70	4.35	1.26	2.67	.59	2.91	2.28	1.20	27.50
1940	.45	2.87	T	6.82	9.33	6.58	6.83	2.47	.22	3.28	6.67	2.87	48.39
1941	2.88	3.18	.47	6.89	4.62	7.71	1.06	6.63	4.02	14.89	1.59	1.58	55.52
1942	.46	2.30	1.70	10.62	4.28	8.18	.77	4.76	3.68	5.41	2.24	2.53	46.93
1943	.15	.74	3.14	4.23	7.81	2.73	1.21	T	1.21	1.63	.12	3.87	26.84
1944	2.78	4.76	2.63	2.75	5.86	2.54	3.12	2.77	.85	4.44	3.82	2.65	38.97
1945	1.70	4.44	9.76	8.61	1.41	10.99	4.58	6.13	11.13	.78	.72	.08	60.33
1946	6.42	3.66	4.01	2.83	5.66	3.43	.84	6.71	2.72	.14	6.80	8.42	51.64
1947	.32	.34	1.21	9.04	8.04	4.28	1.57	1.13	3.33	1.61	2.87	2.70	39.34
1948	.98	4.19	2.51	.70	7.59	6.64	3.62	1.32	.12	.78	.48	1.27	30.20
1949	5.97	2.69	3.38	2.13	6.14	4.90	.58	2.75	6.28	4.54	.00	1.48	40.84
1950	3.02	1.86	.35	2.03	6.44	3.39	5.91	7.94	2.48	.71	.22	.10	34.45
1951	1.14	3.61	1.35	1.43	5.88	6.87	5.54	2.92	1.78	3.15	1.84	.31	35.82
1952	.31	1.23	3.33	4.72	4.86	.50	2.85	.90	.10	.03	4.47	1.45	24.75
1953	.55	.97	3.14	4.36	4.51	2.28	7.72	1.44	1.16	5.15	2.22	1.05	34.55
1954	1.49	.55	.93	5.45	8.21	4.34	.15	.83	.36	5.72	.36	3.08	31.47
1955	1.47	2.18	2.45	1.81	4.77	1.79	2.09	1.08	7.37	.21	.02	.40	25.64
1956	1.47	2.14	.39	2.89	4.81	1.55	1.43	1.39	.04	3.73	3.93	3.15	26.92
1957	2.13	2.09	4.37	9.14	13.24	6.09	2.34	1.68	11.41	2.25	4.86	1.46	61.06
1958	2.44	.51	4.15	2.06	4.85	3.52	4.30	1.91	.78	.33	1.94	.86	27.65
1959	.45	.79	3.36	2.74	4.45	2.87	3.04	2.07	1.81	8.96	2.50	2.77	35.81
1960	2.74	3.08	2.10	2.76	6.98	1.84	3.59	3.16	5.33	4.38	.20	4.95	41.11

Table 1

PRECIPITATION RECORDS. (continued)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Ann'l
1961	.10	2.00	3.62	.92	3.75	3.41	3.70	.64	6.87	3.72	3.20	1.74	33.67
1962	.34	.35	2.55	2.97	1.91	8.91	4.13	1.19	4.69	4.85	2.75	1.79	36.43
1963	.07	.04	5.02	3.22	.81	.56	2.28	1.99	1.77	.04	2.29	1.45	19.54
1964	.96	1.59	2.89	1.79	8.52	.98	.70	4.98	6.33	.47	6.70	.72	36.63
1965	2.14	1.55	1.65	2.60	5.90	1.69	1.58	2.48	2.04	1.95	.83	1.32	25.73
1966	1.26	1.87	1.26	5.09	.71	2.18	4.65	5.36	2.04	1.86	.94	.69	27.91
1967	.34	.80	1.05	8.17	6.68	6.73	3.89	.20	5.81	5.37	.79	2.13	41.96
1968	4.13	1.27	3.82	2.35	9.47	4.02	5.75	.97	4.43	2.87	5.73	2.04	46.85
1969	1.25	2.97	2.55	5.21	5.05	3.30	1.74	1.61	2.65	7.92	.51	3.47	38.23
1970	.18	1.74	3.90	4.97	2.26	4.82	1.68	.80	11.73	16.43	.79	.77	50.07
1971	1.89	1.15	.68	2.76	2.83	2.63	4.05	4.92	2.79	6.62	.57	5.46	36.35
1972	.36	.56	.61	3.95	4.05	2.39	1.41	3.56	2.52	7.69	3.87	.88	31.85
1973	3.01	3.00	6.44	6.04	2.72	8.12	3.94	.99	10.90	4.89	8.02	.86	58.93
1974	.90	1.76	1.45	4.91	3.64	3.47	2.10	5.49	8.65	7.10	2.48	1.53	43.48
1975	1.98	4.26	4.71	3.05	6.85	2.43	4.73	1.98	3.55	1.24	2.05	1.50	38.33
1976	.07	.29	3.70	3.88	7.78	1.33	1.90	1.18	1.36	4.71	.90	1.57	28.67
*1977	1.91	1.39	6.39	3.51	5.29	2.41							
Average	2.14	2.11	2.84	4.18	5.34	3.97	2.93	2.67	3.63	3.87	2.43	2.10	38.50

* Records Incomplete

Note: (Data furnished by the Oklahoma Water Resources Board and Platt National Park)

TABLE 2

STATISTICAL PARAMETER EXPRESSIONS AND DEFINITIONS

PARAMETER	EXPRESSION	DEFINITIONS
Coefficient Of Determination	$R^2 = \frac{\Sigma(y_c - \bar{y})^2}{\Sigma(y - y)^2}$	y_c = value forecasted $\bar{y}$ = mean value y = actual value
F-statistic	$F = \frac{\Sigma(y_c - \bar{y})^2 / k - 1}{\Sigma(y - \bar{y})^2 / n - k}$ or $F = \frac{R^2/(k - 1)}{(1 - R^2)/(n - k)}$	k = number of variables n = number of data utilized R^2 = coefficient of determination

TABLE 3

STREAM DATA FROM PREVIOUS STUDY (JUNE 1976-JULY 1977)

Station	Date	Flow cfs.	Temp. °C.	COD. mg/l.	DO. mg/l.	Coli. $\frac{10^3}{100ml}$.	Organic Nitrogen mg/l.	Total Phosphorus mg/l.
7	10/30/76	2.35	13.0	79.0	8.6	5.20	-	-
	11/14/76	1.98	-	7.9	-	-	0.00	0.00
	1/21/77	2.01	9.0	5.7	11.4	0.26	0.42	0.03
	4/01/77	2.22	14.0	28.3	9.9	0.28	1.73	-
	6/13/77	2.19	23.0	9.8	8.0	0.20	-	-
	7/01/77	3.04	-	10.4	-	-	0.73	0.07
14	10/30/76	3.30	11.0	122.4	8.3	29.5	-	-
	11/14/76	2.62	-	14.0	11.0	-	0.084	0.06
	1/21/77	2.78	5.5	51.7	8.4	126.0	-	0.80
	4/01/77	2.26	14.0	20.0	9.1	0.6	1.077	0.04
	6/13/77	3.58	29.0	26.5	8.2	7.0	-	-
	7/01/77	2.15	-	36.0	-	-	0.730	0.07
18	10/30/76	5.78	11.0	93.8	8.1	29.6	-	-
	11/14/76	4.69	-	19.8	-	-	0.0	0.020
	1/21/77	5.98	5.0	17.2	12.6	2.6	-	0.195
	4/01/77	4.97	15.0	16.7	9.5	0.6	1.032	-
	6/13/77	6.19	27.0	14.6	9.5	0.5	-	-
	7/01/77	5.51	-	64.0	-	-	1.64	0.150

TABLE 4

STREAM DATA FROM PRESENT STUDY (FEB. 1978-MARCH 1978)

Station	Date	Flow cfs.	Temp. °C.	COD. mg/l.	DO. mg/l.	Coli. 10^3	Organic Nitrogen mg/l.	Total Phosphorus mg/l.
7	2/04/78	2.15	11.0	21.0	10.3		1.05	0.045
	3/08/78	2.78	15.0	15.7	9.9		1.10	0.070
	4/15/78	2.56	22.0	46.5	9.5		2.75	0.130
	4/15/78	2.36	20.0	21.4	9.7		1.20	0.090
14	2/04/78	2.38	6.0	23.5	10.0		0.60	0.080
	3/08/78	2.50	10.0	18.2	9.8		0.43	0.100
	4/15/78	2.62	24.0	42.9	10.2		0.20	0.300
18	2/04/78	5.89	6.5	35.0	12.6		0.85	0.150
	3/08/78	6.48	15.0	16.0	11.5		0.50	0.200
	4/15/78	7.14	23.0	46.5	11.6		1.25	0.280
	4/15/78	7.09	25.0	35.8	12.2		0.97	0.35

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