EVALUATION OF PHOSPHORUS STANDARDS FOR THE BALD EAGLE CREEK AND SPRING CREEK WATERSHEDS: STREAM RESPONSE STUDIES

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ABSTRACT

Point source effluent limits of 0.13 mg/L total soluble phosphorus (TSP) have been established for the Bald Eagle Creek and Spring Creek watersheds. A study was conducted to evaluate the effectiveness of these standards for discharges to Spring Creek and to develop a rational method for setting phosphorus effluent limits based on in-stream primary productivity and dissolved oxygen variations in the stream.

Using field derived measurements on in-stream plant photosynthesis and respiration, empirical formulae were developed to relate ecosystem primary productivity to daily solar radiation and in-stream concentrations of total soluble phosphorus; to relate photosynthesis-respiration ratios to solar radiation.

Subsequent use of these relationships in conjunction with a dissolved oxygen mass balance model, DIURNAL characterized the impact of exogenous inputs of phosphorus on the dissolved oxygen resources of the receiving stream.

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LIST OF SYMBOLS AND ABBREVIATIONS

BS	Benner Spring Fish Hatchery
BSTP	Bellefonte Sewage Treatment Plant
C	Concentration of dissolved oxygen
CBOD	Carbonaceous biochemical oxygen demand
C_s	Saturation value of dissolved oxygen concentration
$D_{(X)}$	DO Deficit at distance X
Do	Initial DO Deficit
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
FP	Fishermans Paradise - Lower Spring Fish Hatchery
H	Depth
K_a	Reaeration coefficient
K_d	Carbonaceous biochemcial oxygen demand removal rate
K_n	Nitrogenous biochemical oxygen demand removal rate
K_s	Half-saturation constant for phosphorus uptake by aquatic mcacrophytes
Lglys	Langlies
L_o	Ultimate Carbonaceous Biochemical Oxygen Demand
MGD	Millions Gallons per Day
NBOD	Nitrogenous Biochemical Oxygen Demand
P_g	Gross photosynthesis
P_m	Maximum gross photosynthetic oxygen production
Q	Flow
Rp	Plant Respiration
RSTP	Rockview Sewage Treatment Plant
SR	Solar Radiation

LIST OF SYMBOLS AND ABBREVIATIONS (continued)

TOT	Time of Travel
TSP	Total Soluble Phosphorus
UAJA	University Area Joint Authority
V	Velocity
σ	Standard Deviation

CHAPTER 1. INTRODUCTION

Purpose/Goals

Point source effluent limits of 0.13 mg/L total soluble phosphorus (TSP) have been established for the Bald Eagle Creek and Spring Creek watersheds in order to improve the trophic status of Spring Creek and the Foster Joseph Sayers Reservoir. Survey data taken in 1973, under conditions of no phosphorus removal in the watershed, indicate the reservoir's trophic condition to be eutrophic (EPA NES, 1975).

Independent studies on the watersheds have characterized the extent of aquatic plant growth in Spring Creek above the Bellefonte discharge, its effect on stream dissolved oxygen (McDonnell, 1970; McDonnell, 1982a), and the general in-stream water quality (PaDER, 1980). These studies suggest that some degree of phosphorus removal is required to improve the aquatic ecosystem.

An evaluation of the EPA Sayers (Blanchard) Reservoir survey has raised a number of issues relating to the necessity of the current high levels of phosphorus removal in the watershed and the implementation strategy used to achieve these removals. Specific questions pertain to effluent phosphorus limits and the need for a year-round program of high level phosphorus removal (McDonnell, 1982b).

This study, then, is in direct response to the above raised issues, and to the impetus of a 208 Facilities Planning Grant for the Borough of Bellefonte. As part of Phase I of the grant, the study addresses the phosphorus removal concerns and their relationship to the stream water quality as well as the trophic status of the reservoir. Specifically, the objectives of this study are to:

1. Characterize the fate of phosphorus and its effect on the trophic status of the Sayers Reservoir as it responds to the influence of watershed discharges, non-point source inputs, and a variable volume environment;

2. Calibrate a lake water quality model for the reservoir, in this case, the Water Quality Analysis and Simulation Program (WASP) as supported by the EPA is used;

3. Assess the impact of various phosphorus removal scenarios on the existing and predicted water quality and trophic status of the reservoir;

4. Characterize the current levels of primary production and aquatic plant respiration existing in stream segments below the Bellefonte and University Area Joint Authority (UAJA) discharges;

5. Evaluate the effect of various phosphorus removal scenarios for these discharges on the existing and predicted productivity and dissolved oxygen economy of these segments.

The stream response studies (Objectives 4-5) are described in this report and the lake response studies (Objectives 1-3) are described in a companion volume.

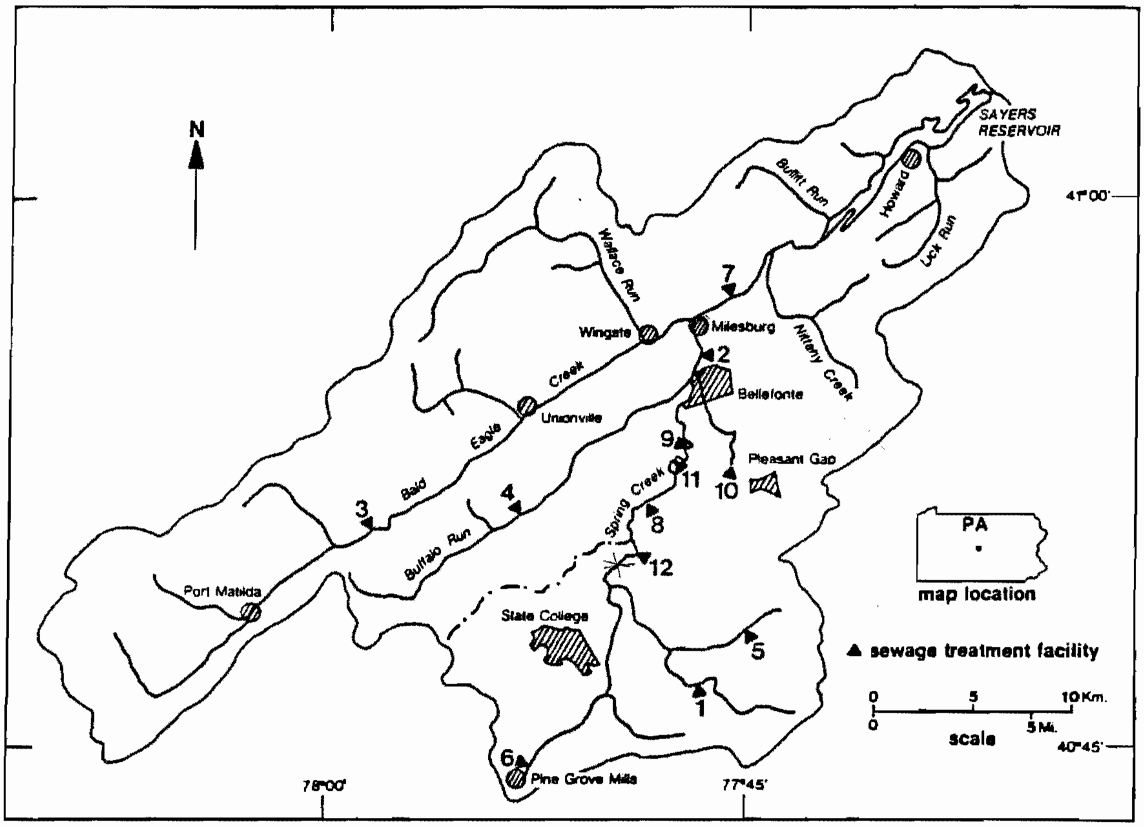
CHAPTER 2. SITE DESCRIPTION

Watershed Location

Spring Creek is a shallow, headwater stream that drains approximately 143 square miles of land in Centre County, Pennsylvania. The stream water has a high alkalinity (200 mg/L as $CaCO_3$) with moderate temperatures due to the dominance of limestone and dolomite bedrock in the area. Spring Creek originates about 2 miles above Oak Hall, flows northward and passes through Lemont, Bellefonte, and finally through Milesburg where it empties into Bald Eagle Creek. Agriculture is the predominant land use in the watershed. Figure 2.1 shows the location of the Bald Eagle and Spring Creek watersheds.

Watershed Discharges

Twelve point sources in the watershed are currently active phosphorus dischargers. These include the two largest, the University Area Joint Authority (UAJA) and Bellefonte, with permitted flows of 3.84 and 1.75 MGD, respectively. Also included are three Pennsylvania Fish Commission Hatcheries: Benner Spring (PFCB), Lower Spring (PFCL), and Pleasant Gap (PFCP). The hatcheries are all located on sites which contain one or more springs as a water source. Consequently, the hydraulic load from these hatcheries is significant. In fact, they supply over 79% of the water discharged from point sources in the watershed. A fourth hatchery, Upper Spring is not currently in use. The Rockview State Penitentiary, Ferguson Municipal Authority, and Mid-Centre Wastewater Treatment Plant have permitted flows of 0.125, 0.125, and 0.250 MGD, respectively. Four smaller trailer courts were also included in this study: Continental Courts, Country Club Estates, Almar Acres, and Coble's Trailer Park. The Penn State University Wastewater Treatment Plant is in the Spring Creek watershed but the effluent from the plant is currently being sprayed onto agricultural land and therefore is not included in this study. Figure 2.1 shows the location and permitted flows of each of these 12 point source discharges in the watershed.



Site #	Point Source Discharge	1985 Permit Flow (MGD)
1	Almar Acres	0.010
2	Bellefonte	1.750
3	Coble's Trailer Park	0.020
4	Continental Courts	0.050
5	Country Club Estates	0.035
6	Ferguson Municipal Authority	0.125
7	Mid-Centre Authority	0.500
8	PFC - Benner Spring Hatchery	7.400
9	PFC - Lower Spring Hatchery	6.480
10	PFC - Pleasant Gap Hatchery	5.930
11	Rockview State Penitentiary	0.250
12	University Area Joint Authority	3.840

Figure 2.1 Bald Eagle and Spring Creek Watersheds

CHAPTER 3. MATERIALS AND METHODS

Survey Procedure

Survey Description

During the summer of 1985, two reaches of Spring Creek were surveyed to determine the primary productivity and existing water quality in the stream system. The first reach that was surveyed extended from the UAJA Wastewater Treatment Plant to the Logan Branch confluence with Spring Creek. This reach is referred to as the UAJA reach. The second reach, the Bellefonte reach, extended from the BSTP outfall to the West Penn Power company in Milesburg (2,200 feet above the Bald Eagle Creek confluence).

The survey period extended from June 1 to August 15, 1985. During this period, stream flow and time of travel data were collected for both reaches. Also, three recording dissolved oxygen (DO) meters were used to monitor D.O. and temperature at specified locations. On July 17 and July 25, extensive survey work was completed on the UAJA and Bellefonte reaches respectively. On these days, pre-dawn and mid-afternoon profile data were collected including D.O., temperature and water quality data. Stream flows and time of travel were determined for these days.

UAJA Reach

The UAJA reach extends from UAJA to just above the Logan Branch confluence with Spring Creek. Four of the five major dischargers on Spring Creek are located in this segment including UAJA, BS, RSTP and FP. In order to survey this reach of stream, it was broken into five segments. The sampling stations were established such that a sample was taken above each discharge point and at least three sampling stations were located between the discharges. For the segment between BS and RSTP, only one sampling location was established because access to the stream was denied by the officials of the State Correctional Institution at Rockview for security reasons. USGS gage number 01546500 is located at water quality Station 10. Water quality stations, gaging stations, and mile points are given in Table 3.1 for each of the five segments.

Bellefonte Reach

The Bellefonte reach extends from the BSTP to the West Penn Power Plant. The only point source discharge that enters this reach is the Bellefonte STP. The reach is only 1.26 miles long, but it had to be broken into two segments. The first segment extends from the point of complete mixing (Station 4) to the dam that divides the reach. The second segment starts at the base of the dam and goes to the West Penn Power Plant. USGS gage Number 01547100 is located at the beginning of the second segment. Eight water quality stations and three gaging stations were established in the reach as shown in Table 3.2.

Table 3.1: Water Quality and Gaging Stations for the UAJA Reach

Segment	Water Quality Station	Gaging Station	Mile Point
	1		-0.05
	UAJA		0.00
		1	0.05
I	2		0.36
	3a	2	1.21
II	3b		1.22
	4		2.43
III	BS		2.434
		3	2.44
	5		2.57
	Rockview, 6a		3.74
IV	6b		3.93
	7	5	5.04
	8		6.47
V	FP		6.474
		6	6.48
	9		6.93
	10		7.53
	11	7	8.79
	12	8	9.33
	13	9	10.29

Table 3.2: Water Quality and Gaging Stations for the Bellefonte Reach

Segment	Water Quality Station	Gaging Station	Mile Point
	1		-0.05
	BSTP		0.00
	3M*	1	0.21
	3P**		0.21
	4		0.48
	5	2	0.59
	6		0.67
	7		0.82
	8	3	1.26

* Water samples were taken in the middle of the stream channel at this station.

** Water samples were taken in the plume of the discharge from the BSTP at this station.

Stream Hydraulics

Staff Gages

Nine staff gages were established in the UAJA reach, and three staff gages were established in the Bellefonte reach. The locations of the staff gages were chosen to coincide with stream flow measurement locations so that stage discharge curves could be developed for all gaging locations. The staff gages consisted of surveying tape mounted to a furring strip and firmly installed in the stream.

Stream Flows

Stream flows were determined for both reaches using a Gurley No. 625 Pygmy Current Meter. Nine gaging stations were established for the UAJA reach. Three gaging locations were established in a previous study during the summer of 1984 for the Bellefonte reach, and the same locations were used for flow measurements in 1985. In-stream flow data and data obtained from the USGS gages were used to establish flows for the stream for the given survey days.

Several criteria were used to establish stream flow measurement locations. A cross-section was chosen that was fairly uniform and free from attached macrophytes and algae. Also, the cross section was chosen so that there were no large rocks obstructing the flow. Site accessibility also was taken into consideration.

In order to evaluate the stream flow at a specific site, the cross section was broken into small intervals. Velocities were taken at 2-3 foot intervals (depending upon total width) with the flow meter. The six-tenth-depth method was used to determine the position of the flow meter while measuring the velocity (United States Department of the Interior, 1967). Depth values were recorded at each point where velocity measurements were taken. With the width and depth of each interval, incremental flows could be calculated. The sum of the incremental flows is the total flow at the specific location.

Time of Travel

The intended procedure to develop a travel time vs. stream flow relationship was to perform dye trace studies for a given reach at different flow regimes. To accomplish this task, the dye trace studies were completed by introducing uranine, a fluorescent green dye, into the stream at the beginning of the segment and recording the time it took for the dye to pass through the reach. The time of travel (TOT) commonly is taken to be the time required for 1/2 of the dye to pass through the reach. To obtain the needed information, 60 mL samples were taken at 1-2 minute intervals, at the end of the reach. Samples were taken until no sign of the dye could be detected. The samples then were taken to the laboratory where they were analyzed for fluorescence using a Turner Model 111 Fluorometer. The fluorescence of each sample, compared to a blank, was recorded, and a plot of fluorescence versus time was prepared for each dye trace study. The center of mass under the curve was determined, and the corresponding time was taken to be the TOT for that particular reach.

Travel times also were calculated on a volumetric basis. The calculated travel times compared very well with the leading edge travel times recorded for the BOD dye trace and therefore were used. Using this method, the TOT values were calculated for July 17th survey day on the UAJA reach and the July 25th survey for the Bellefonte reach. Since stream flow was determined for all gaging stations on all the mentioned days, average velocities for each reach could be estimated.

Water Quality Analysis

Sample Collection and Preservation

Water quality samples were collected at each sampling station and at the point source discharges for both the pre-dawn and afternoon profile runs. In addition to the pre-dawn and afternoon samples, two additional samples were collected at each point source discharge. Two and one-half liters of water were collected in polyethylene sampling bottles. The samples were stored in an iced cooler, and after each run, the samples were taken directly to the Water Analysis laboratory at the Environmental Resources Research Institute for immediate analysis.

Analytical Tests and Procedures

A list of tests, along with the methods of analysis, is given in Table 3.3.

Dissolved Oxygen and Temperature

Three recording YSI Model 56 Dissolved Oxygen (D.O.) and temperature meters were available for use during the survey period. For the UAJA survey, the meters were located at Stations 2,3 and between 3 and 4. D.O. and temperature data were collected at all 13 stations and other strategic locations six times over the 24-hour survey period on the 17th. Similar data were collected for the Bellefonte survey, with the meters located at Stations 4,6, and 8. Again D.O. and temperature data were collected at all sampling stations 10 separate times over the 24-hour survey period.

The grab sample D.O. and temperature measurements were used to formulate diurnal curves at the designated sampling station. The values at each station were plotted against time and a curve was fitted through the data points using the Fourier series formulation:

$$y=A_0 + A_1\cos(\pi/12*t) + B_1\sin(\pi/12*t) + A_2\cos(\pi/6*t) + B_2\sin(\pi/6*t) \quad (1)$$

This procedure allowed D.O. values to be determined for each hour of the day. The temperatures also were determined for each hour using an interpolation procedure.

Table 3.3: Summary of Analytical Tests and Procedures

Parameter	Detection Limit (mg/L)	Methodology (Reference)*	Equipment
Alkalinity	0.05	EPA Tritrimetric 310.1	Fisher Titrimeter II
BOD	2.00	EPA Probe 405.1	YSI 54A Meter, YSI 5420-Probe
Chloride	0.2	Potentrometric-Silver Chloride	Aminco Cotlove Chloride Titrator
Dissolved Oxygen	0.1	EPA Membrane Electrode 360.1	YSI 54A Meter, YSI 5420-Probe
Nitrogen - Ammonia	0.005	EPA Phenate Method 350.1	Technicon AA II
Nitrogen - Nitrate	0.005	EPA Cadmium Reduction 353.2	Technicon AA II
Nitrogen - Nitrite	0.005	EPA Colorimetric 353.2	Technicon AA II
Nitrogen - Total Kjeldahl	0.1	EPA Colorimetric 352.2	Technicon AA II
Orthophosphate	0.001	EPA Colorimetric 365.2	Baush & Lomb Spec 2000
Phosphorus - Total	0.001	EPA Colorimetric 365.2	Baush & Lomb Spec 2000
pH	N.A.	EPA Electrometric 150.1	Orion Ionalyzer 901
Temperature	N.A.	EPA Thermometric 170.1	Precision Thermometer

* EPA - 600/4-79-020 Methods for Chemical Analysis of Water and Wastes. March 1979

BOD Dye Trace

A BOD dye trace study was performed on July 2-3 for the UAJA reach and on July 23 for the Bellefonte reach in an attempt to estimate the BOD deoxygenation rate for each reach. Uranine was injected at each discharge and the time was recorded. As the leading edge of the dye approached the specified sampling stations, a water sample was collected and the time was recorded. Sampling stations were set up so that at least three sites were located in each reach. The only exception to this protocol was in the reach between Benner Spring Fish Hatchery and Rockview STP discharge.

After each sample was collected, it was stored in an iced cooler until all samples were collected for the day. The samples were then taken back to the Water Lab where inhibited and noninhibited 20-day BOD tests were run in duplicate for each sample. Also, BOD series tests were run for all complete mix points (Stations 2,5,6,9). Nitrogen species tests, including TKN, NO_3-N, NO_2-N, and NH_4-N, were run on each sample.

CHAPTER 4. HYDRAULIC CONSIDERATIONS

Drought Flow Analysis

An extensive drought flow analysis was performed for Spring Creek on data collected at the Axemann gage (01546500) and the Milesburg gage (01547100) to determine low flow values for the UAJA and Bellefonte reaches. The current flow regime that is used to develop water quality standards is the seven-day-average low flow value, occurring between May and October, that has a 90 percent probability of exceedence. In other words, there is a 10 percent probability that the seven-day-average low flow will be less than the given value. This particular flow value is identified as the $Q_{(7-10)}$. Besides a $Q_{(7-10)}$ value for May thru October, a $Q_{(1-10)}$, $Q_{(7-10)}$, and $Q_{(30-10)}$ was determined for each month of the year and for the May thru October period.

A statistical analysis employing a Log-Pearson Type III distribution was performed using a modified version of a flood frequency analysis computer program that was written by Dr. Gert Aron, Professor of Civil Engineering at The Pennsylvania State University. Table 4.1 shows the results of the drought flow analysis for both the Axemann and Milesburg gages for the three averaging periods.

Hydraulic Geometry

In order to make projections of water quality impacts on a particular stream at some critical low flow period, the velocity, depth, and width must be estimated at the given flow regime. Three empirical relationships have been developed (Leopold and Maddox, 1953) to relate velocity, depth, and width to flow. The equations take the following forms: $V=aQ^n$; $H=bQ^m$; and $W=cQ_f$ where V=velocity, H=depth, W=width, Q=flow, a,b,c=constants for the stream in question, and n,m,f = coefficients defining the basic relationships.

Flow versus velocity, depth, and width relationships were developed for the UAJA reach using in-stream measurements at the gaging stations. The reach was broken into four segments. Table 4.2 summarizes the coefficients and exponents calculated for the velocity, depth, and width for the respective segments.

The Bellefonte reach was broken up into two segments--stations 4-6 above the dam as one segment and Stations 7-8 below the dam as the second segment. Since a USGS gage was located at Station 7, data from the gage was used to develop Q versus V,H, and W relationships. The hydraulic characteristics above the dam differ significantly from those below the dam, so the relationships were derived from in-stream measurements. There was a limited data base for this segment; therefore, average Q,V,H, and W values from 1984 and 1985 were used. Table 4.3 gives the results for the coefficients and exponents for the Q,V,H, and W relationships for the two Bellefonte segments.

Table 4.1: Drought Flow Analysis Results for Axemann and Milesburg Gages (Flow in cfs Units)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	May/Oct
Axemann Gage:													
1-day	30	33	46	64	55	44	35	31	29	29	28	27	27
7-day	32	37	55	69	59	46	37	33	31	30	30	29	30
30-day	39	53	85	91	70	54	42	37	33	32	32	33	31
Milesburg Gage:													
1-day	113	121	122	128	142	135	114	105	98	96	106	114	96
7-day	116	131	135	159	145	144	119	110	106	101	107	119	98
30-day	120	132	133	137	174	156	137	124	114	104	119	124	110

Table 4.2: Summary of Coefficients and Exponents for UAJA Segments

Stations	Gage # Used	n	V coeff	V exp	H coeff	H exp	W coeff	W exp
1-3	1,2	10	0.04	0.75	0.53	0.25	48.2	0.0
3-6	3	5	0.08	0.69	0.52	0.19	24.0	0.12
6-8	5	7	0.11	0.59	0.44	0.27	21.0	0.14
9-13	6,8,7	14	0.14	0.54	0.34	0.27	18.8	0.21

Table 4.3: Summary of Coefficients and Exponents for Bellefonte Segments

Stations	n	V coeff	V exp	H coeff	H exp	W coeff	W exp
4-6	2	0.30	0.25	0.06	0.69	52.2	0.06
7-8	48	0.15	0.43	0.13	0.50	48.8	0.07

CHAPTER 5. DISSOLVED OXYGEN BUDGET

The distribution of dissolved oxygen in a stream is determined by spatial and temporal relationships between the sources and sinks of D.O. In order to define the dissolved oxygen at a particular time, the sources and sinks must be estimated and added together.

The mass balance equation for the dissolved oxygen distribution in a stream is given by the following equation:

$$dC/dt = -QdC/Adx + K_a(C_s-C) + P_{(x,t)} - K_dL_{(X)} - K_nN_{(X)} - S_{(X)} - R_{p(X)} \quad (2)$$

where $\frac{-QdC}{Adx}$ = advective flux term; K_a = Reaeration coefficient; C_s=Saturation value of dissolved oxygen; C=Concentration of dissolved oxygen; $P_{(X,t)}$=Photosynthetic oxygen source; Kd=Deoxygenation coefficient; $L_{(X)}$=Concentration of carbonaceous BOD; K_n=Deoxygenation rate due to nitrification; $N_{(X)}$=Concentration of nitrogenous BOD; $S_{(X)}$=Benthal respiration sink; $R_{p(X)}$=Plant respiration sink.

A water quality model entitled DIURNAL has been adapted for microcomputer use at Penn State based on the method of oxygen balance proposed by O'Connor and DiToro in 1970.

Atmospheric Reaeration

The rate of reaeration is a difficult parameter to measure in the field; however, many empirical formulas are available to estimate K_a. The most commonly used formulas are based on stream velocity and depth. Three of the common formulas have been developed by Owens et al. (1964), O'Connor and Dobbins (1956), and Churchill et al. (1962). Each formula has been found to be more accurate within a certain depth-velocity range. With a given velocity and depth, a protocol provided by Covar (Covar, 1976) can be used to determine which empirical formula is appropriate for a specific situation.

Odum has suggested a technique to estimate K_a using in-stream measurements of dissolved oxygen variation. The following mass balance equation is solved using a finite difference approach:

$$dC/dt = P - R_c + K_a(C_s-C) \quad (3)$$

in equation 3, R_c is a community respiration term that includes CBOD, NBOD, and SOD. Since productivity is assumed to be zero at night, the equation consists of two unknowns, K_a and R_c, which can be solved by using measurements taken at two different sampling sites, one at the beginning and one at the end of a particular stream segment.

Reaeration rates were determined using the Odum approach and the Owens formula (as dictated by the Covar protocol). A comparison of the K_a results indicated that the empirical formula developed by Owens compared favorably with the Odum values estimated from field data. The Owens formula takes the form:

$$K_{a(20)} = 21.7 \times \frac{(V)^{0.67}}{(H)^{1.85}} \quad (4)$$

in which K_a=reaeration rate, day^{-1}, base e; V=velocity, feet/second; and H=depth in feet.

The Owens formula was used in all segments as the method for determination of the reaeration rate.

Benthal Respiration

The benthal respiration sink, or the sediment oxygen demand, is an oxygen demand exerted by the sediments that are deposited on the stream bottom. Although measurements were not obtained during the 1985 survey, in-stream SOD measurements were obtained from Slab Cabin Run and Spring Creek in 1980 (Wright). The Slab Cabin Run SOD values, which were assumed to be indicative of a stream reach below a STP discharge in the watershed, were used to determine the SOD rates in the segments I, II, III at UAJA and the entire Bellefonte reach. Segments IV and V in the UAJA reach were assumed to exert no SOD since visual observation of these reaches revealed little, if any, sediment deposition.

The average SOD rates obtained from the Slab Cabin data were modified for temperature using a theta value of 1.065 as proposed by McDonnell and Hall (1969). Table 5.1 is a list of the SOD rates that were measured in 1980 and 1983.

Carbonaceous BOD

Inhibited and uninhibited BOD_5 and BOD_{20} tests were run at all sampling locations during a BOD dye trace study to determine an in-stream deoxygenation rate; however, in the final DIURNAL analysis an empirically derived K_d rate was used. The differences in the BOD measurements at the respective stations were extremely small (within measurement error); therefore, measured in-stream deoxygenation gradients were questionable. K_d rates were obtained from an empirical equation which was derived from in-stream data (Wright and McDonnell, 1979) (EPA, 1985). The equation takes the form:

$$K_d = 10.3Q^{-0.49} \quad (5)$$

where K_d is the deoxygenation rate (day^{-1}, base e) and Q is stream flow in cfs.

Other empirical relationships relate K_d to the wetted perimeter and the hydraulic radius; however, for the DIURNAL runs, the formula relating K_d to flow was used to determine the deoxygenation rate. In the analysis, the BOD term is assumed to be first order. The UAJA reach was treated in this manner; however, the Bellefonte reach was treated as

Table 5.1: Benthic Demand Data from Slab Cabin Run, 1980 and 1983

Uptake at T gm/m^2/hr	Temp. oC	Uptake at 20 oC gm/m^2/hr	Uptake at 20 oC gm/m^2/day
0.192	14.30	0.275	6.60
0.171	19.00	0.182	4.37
0.065	15.75	0.085	2.04
0.094	19.90	0.095	2.28
0.108	16.10	0.138	3.31
0.190	19.10	0.201	4.82
0.093	18.60	0.102	2.45
0.099	17.00	0.120	2.88
0.086	17.90	0.098	2.35
0.097	18.50	0.107	2.57
0.066	17.00	0.080	1.92
0.262	22.40	0.225	5.41
0.131	23.50	0.105	2.52
0.173	21.40	0.159	3.81
0.084	20.20	0.083	1.98
0.145	15.30	0.195	4.69
0.104	17.40	0.123	2.94
		X =	3.35
		sigma =	1.37
		n =	17.00

zero order since the BOD_{20} values measure throughout the segment were constant.

Nitrogenous BOD

In both the UAJA and Bellefonte reaches, no significant nitrification was observed. Inhibited and uninhibited ultimate BOD tests were run at all sampling stations and the plotted results clearly showed that there was no nitrification in either system. A summary of the uninhibited and inhibited BOD data is given in Tables A.1, A.2, A.3, A.4 and A.5 of Appendix A for all of the stations in the UAJA and Bellefonte reaches. The nitrogen species water quality data supported the BOD results. From the water quality data, a small amount of nitrification may be occurring below the Rockview STP, but the distance that is affected is very short and most likely it does not have a significant effect on the system since a 3.4 ft. dam below the discharge acts as an aeration device for the water.

Gross Productivity and Plant Respiration

The current method used to determine Pg and Rp in macrophyte dominated systems is to measure the DO fluctuations, assign values to the other sources and sinks of DO, and adjust the DO mass balance equation (eqn.2) by calibration with Pg and Rp. The resulting Pg and Rp values are representative values for a given set of environmental conditions. As the solar radiation and TSP changes over days and years, the Pg and Rp values will also change. Using the above method of Pg and Rp determination, it would be impossible to predict the consequences of phosphorus removal on the dissolved oxygen budget of a stream system from synoptic survey data. Therefore, one of the main purposes of this study was to develop empirical relationships that relate Pg and Rp to solar radiation and in-stream phosphorus concentrations. Once these relationships have been developed, Pg and Rp values can be obtained for any given set of environmental conditions, and subsequently inserted into the dissolved oxygen mass balance equation for the computation of predicted oxygen profiles. Comparison of predicted with observed values for specific surveys then can be made.

Dam Response

In both the UAJA reach and the Bellefonte reach, there were dams that affected the DO concentration in the stream. The UAJA reach had two dams--one at Station 3 and one at Station 6. At Bellefonte, there is one dam between Station 6 and Station 7 that is 13 feet high. In all cases, DO either is added or lost from the system after the dam depending upon water temperature and DO saturation values. The DIURNAL program will not accommodate this type of discontinuity. As a consequence, the UAJA reach was partitioned into five segments and the DIURNAL program was balanced for each separate segment.

To accommodate DO changes derived from dam reaeration for Q_{7-10} scenarios, an average deficit ratio, r, was determined for each individual dam. From the DO measurements obtained on the July 17^{th} and 25^{th} survey, the r value was calculated by the equation:

$$r = \frac{Ca - Cs}{Cb - Cs} \quad \text{...} \quad (6)$$

where

r = deficit ratio; Ca = DO concentration above falls, Cb = DO concentration below falls; Cs = DO saturation value.

The r values were screened according to several criteria which were used to exclude data points (Butt and Evans, 1983). These criteria include: 1) negative values for the expression (r-1); 2) r values that are excessive (>4.0), and 3) observations that fall too close to saturation ± 1.0 mg/L DO).

An r value was calculated for each acceptable DO reading, and an arithmetic mean r value was obtained. Average r values for each dam are summarized in Table 5.2. No discernible effect of temperature on dam reaeration capacity was observed over the range of stream temperatures that were monitored.

Table 5.2: Summary of Deficit Ratios for Different Dams

Falls	Height (ft.)	n	r_{avg}	σ_r	T_{avg} °C	σ_T °C
Station 3	1.9	8	1.13	0.10	16.4	1.4
Station 6	3.4	5	1.66	0.10	18.5	2.3
Bellefonte 85	13.0	24	2.21	0.14	14.6	1.2
Bellefonte 84	13.0	24	2.26	0.08	15.0	1.5

Chapter 6. PRIMARY PRODUCTION AND PLANT RESPIRATION

In order to verify a water quality model for a system that is controlled by photosynthesis and respiration, a stream system would need to be observed over a wide range of nutrient concentrations, solar radiation, and temperature. This observation is not possible with the conventional calibration/verification protocols currently used for stream synoptic surveys (EPA, 1985). To accommodate this need, empirical relationships were developed from past studies on the Spring Creek watershed using estimates of Pg and Rp observed over a broad spectrum of environmental conditions. Seven separate data sets were used to develop the empirical relationships. Table 6.1 lists the past surveys in the watershed. Three surveys have been conducted on Upper Spring Creek in 1966, 1980, and 1983/84. Although the phosphorus concentrations in this reach of stream are very low since there are no significant point source discharges in the reach, there is still significant plant growth. Therefore, Upper Spring Creek is considered to represent background production levels in the watershed. Two surveys have been completed on Slab Cabin Run. Since the University treatment plant discharged into Slab Cabin in the past, the phosphorus levels during the 1980 survey are relatively high. In the 1983-84 survey, after the Penn State STP started their spray irrigation program, the phosphorus levels were at an intermediate level. Phosphorus levels were high for the two surveys on Lower Spring Creek in 1966.

The development of the empirical equations involved the analysis of three different system responses. First, a seasonal response in Pg was analyzed to determine peak production periods in the watershed. Second, primary productivity was observed as a function of solar radiation and total soluble in-stream phosphorus. Finally, the photosynthesis to respiration ratio, as affected by solar radiation, was characterized for the watershed so that plant respiration values could be estimated from primary productivity measurements.

Seasonal Response of Primary Productivity

The monthly variation of primary productivity was characterized using the Fourier series equation:

$$Pg=A_0+A_1\cos(\pi/12*t)+B_1\sin(\pi/12*t)+A_2\cos(\pi/6*t)+B_2\sin(\pi/6*t) \quad (7)$$

Coefficients estimated for each data set are given in Table 6.2. Table 6.3 lists $P_{g(annual)}$, $P_{g(max)}$, $P_{g(average)}$, and average in-stream TSP concentrations monitored for the respective reaches. Peak productivities ranged from 18.9 to 26.1 $gm/m^2/day$ for the phosphorus enriched reaches and from 12.0 to 15.5 $gm/m^2/day$ for the background reach. Winter productivities ranged from 2.5 to 5.1 $gm/m^2/day$.

Table B.1 in Appendix B is a summary of the average monthly Pg values that were used to develop the annual productivity plots shown in Figures 6.1, 6.2, 6.3, 6.4, 6.5, and 6.6. Examination of the plots indicates that the peak production period occurs in June and July. Therefore, only data from June and July were used to develop subsequent empirical relationships.

Table 6.1: Data Sets Used in Development of Pg vs. TSP and SR Relation

	System	Date	Source
1	Upper Spring Creek	1966	McDonnell
2	Lower Spring Creek (7-9)	1966	McDonnell
3	Lower Spring Creek (9-10)	1966	McDonnell
4	Upper Spring Creek	1980	Wright
5	Slab Cabin Run	1980	Wright
6	Upper Spring Creek	1983/84	Davis
7	Slab Cabin Run	1983/84	Davis

Table 6.2: Summary of Estimated Fourier Series Coefficients

Data Set.	System	Ao	A1	A2	B1	B2
1	Upper Spring Creek	6.468	-3.543	-0.433	-0.222	-0.295
2	Lower Spring Creek (7-9)	11.8	-6.532	-0.659	5.556	-1.53
3	Lower Spring Creek (9-10)	10.265	-1.262	-1.566	6.811	0.036
4	Upper Spring Creek	6.468	-3.543	-0.433	-0.222	-0.295
5	Slab Cabin Run	10.817	-8.78	3.613	-0.252	-0.106
6	Upper Spring Creek	7.195	-5.901	1.64	-0.202	-0.246
7	Slab Cabin Run	9.343	-7.444	0.909	3.62	-0.754

Table 6.3: Summary of Seasonal Pg Responses

Data Set	$P_{g(annual)}$ (gm/m^2/yr)	$P_{g(max)}$ (gm/m^2/day)	$P_{g(avg)}$ (gm/m^2/day)	Avg. TSP (mg/L)
1	2268	9.60	6.30	0.019
2	4200	21.88	12.48	0.802
3	3660	18.40	11.07	0.764
4	2268	9.60	6.30	0.008
5	3750	23.21	11.27	0.641
6	2400	14.74	7.38	0.016
7	3174	18.70	9.90	0.115

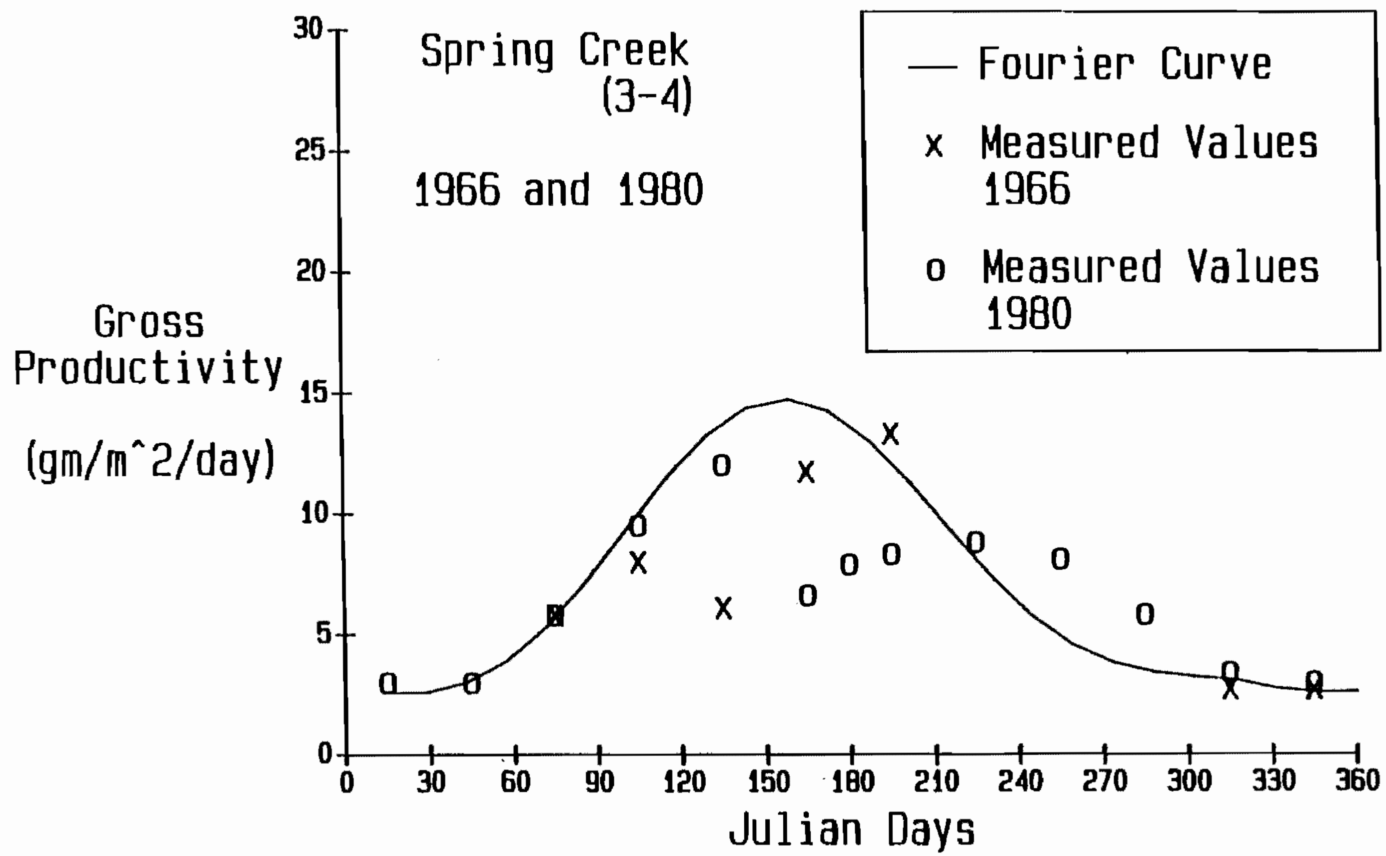


Figure 6.1: Annual Productivity Curve for Upper Spring Creek in 1966 and 1980

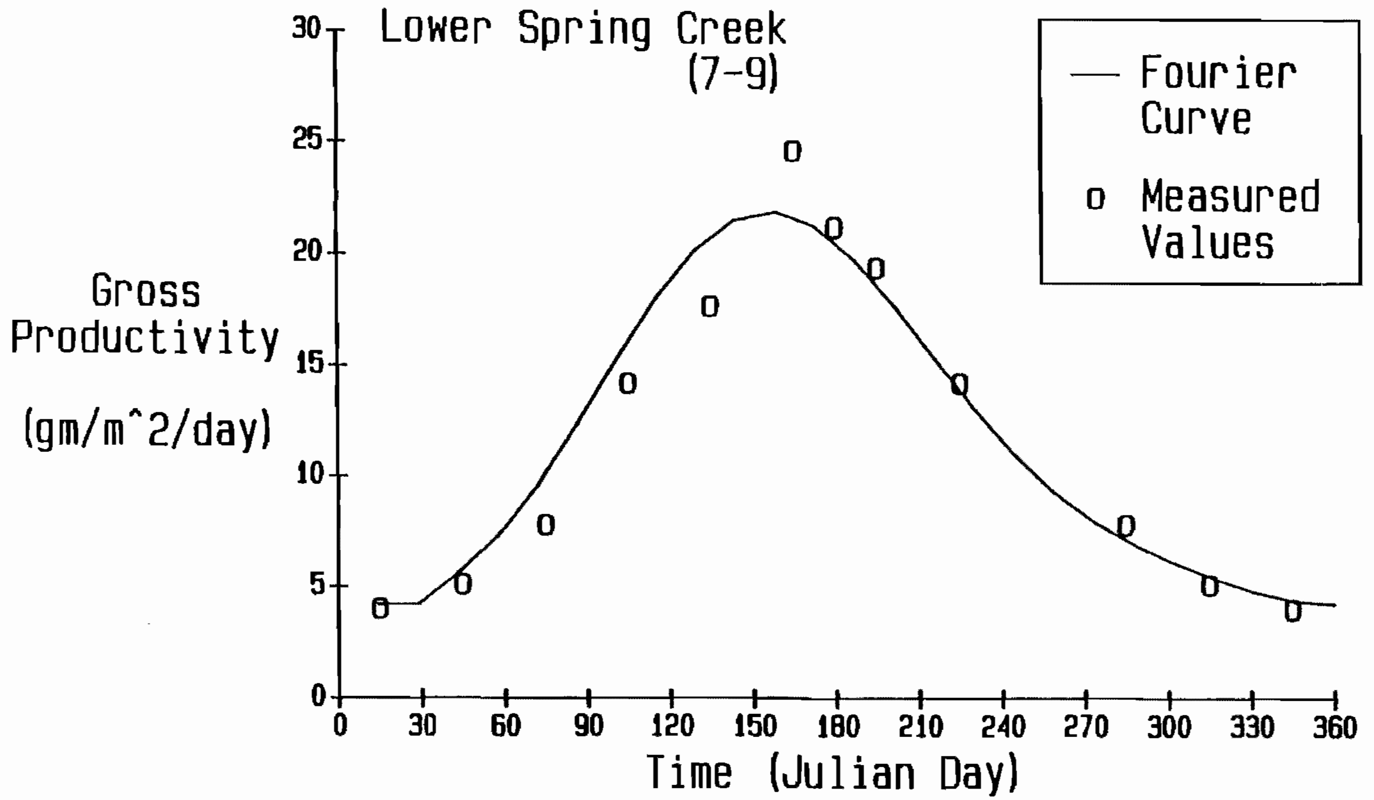


Figure 6.2: Annual Productivity Curve for Lower Spring Creek (7-9) in 1966

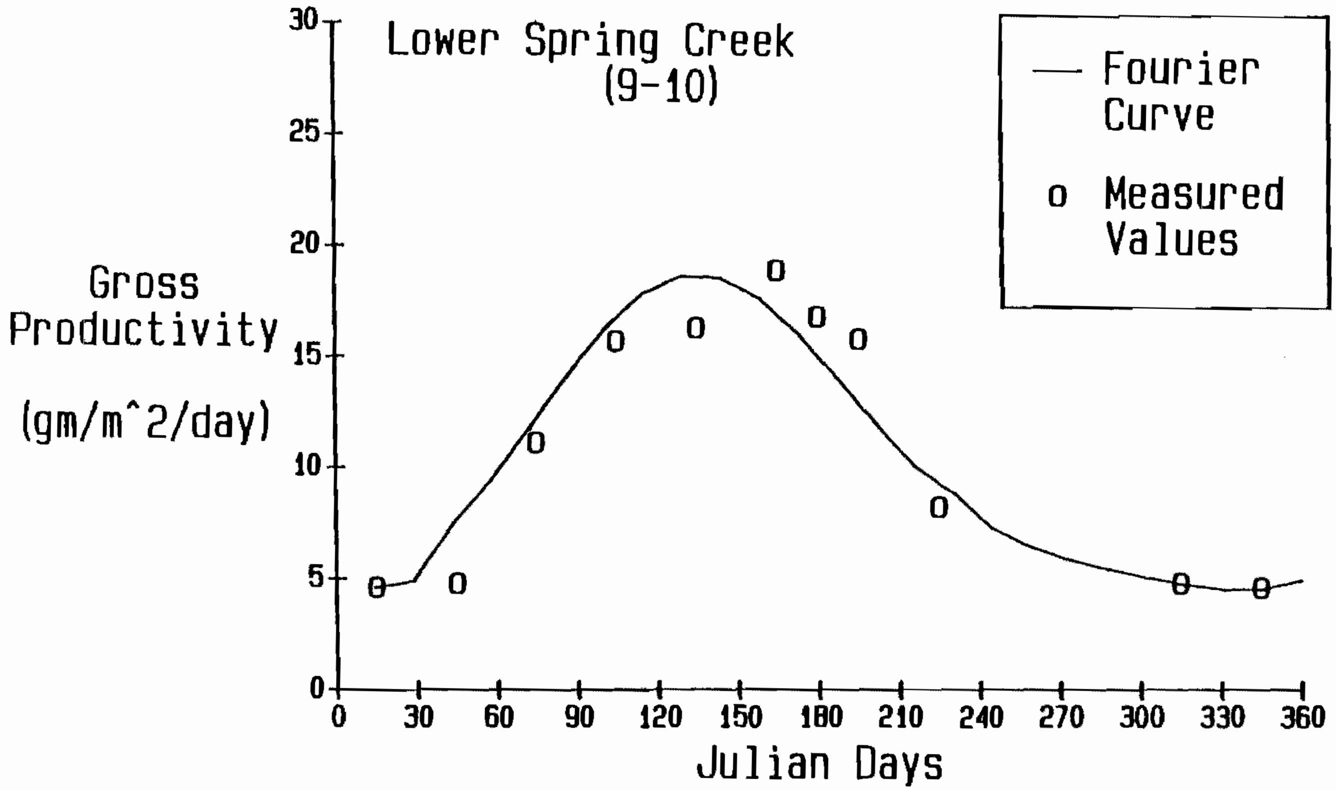


Figure 6.3: Annual Productivity Curve for Lower Spring Creek (9-10) in 1966

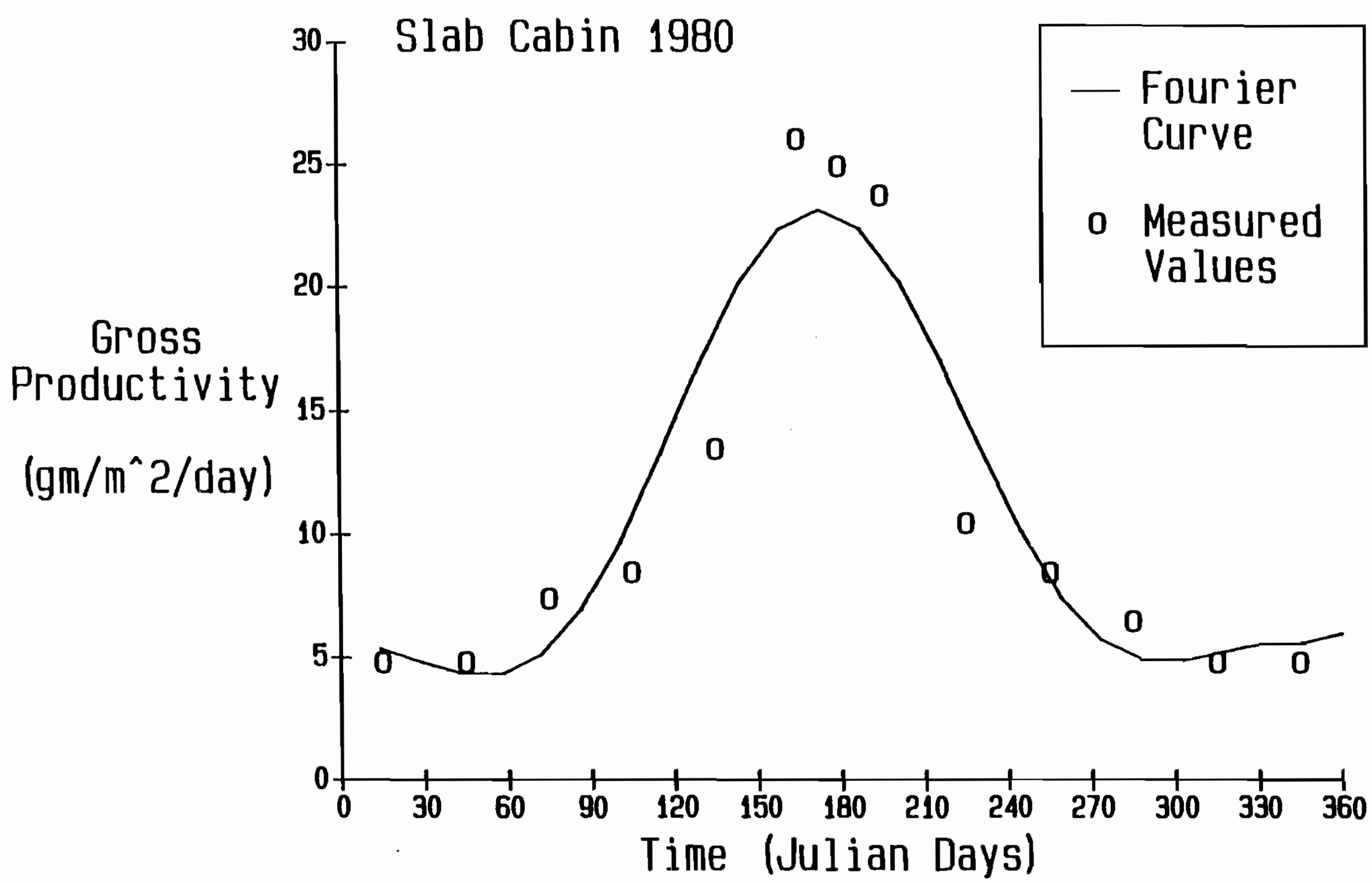


Figure 6.4: Annual Productivity Curve for Slab Cabin Run in 1980

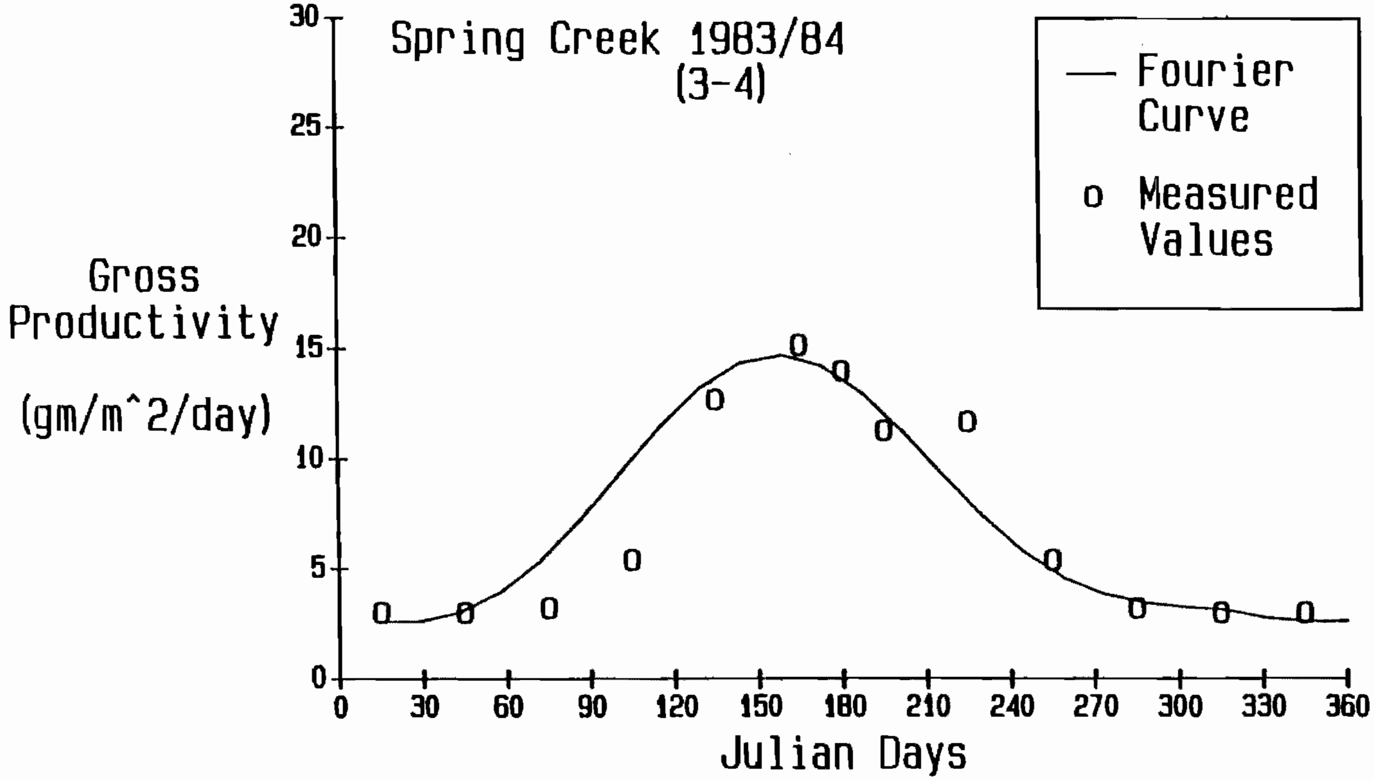


Figure 6.5: Annual Productivity Curve for Upper Spring Creek in 1983/84

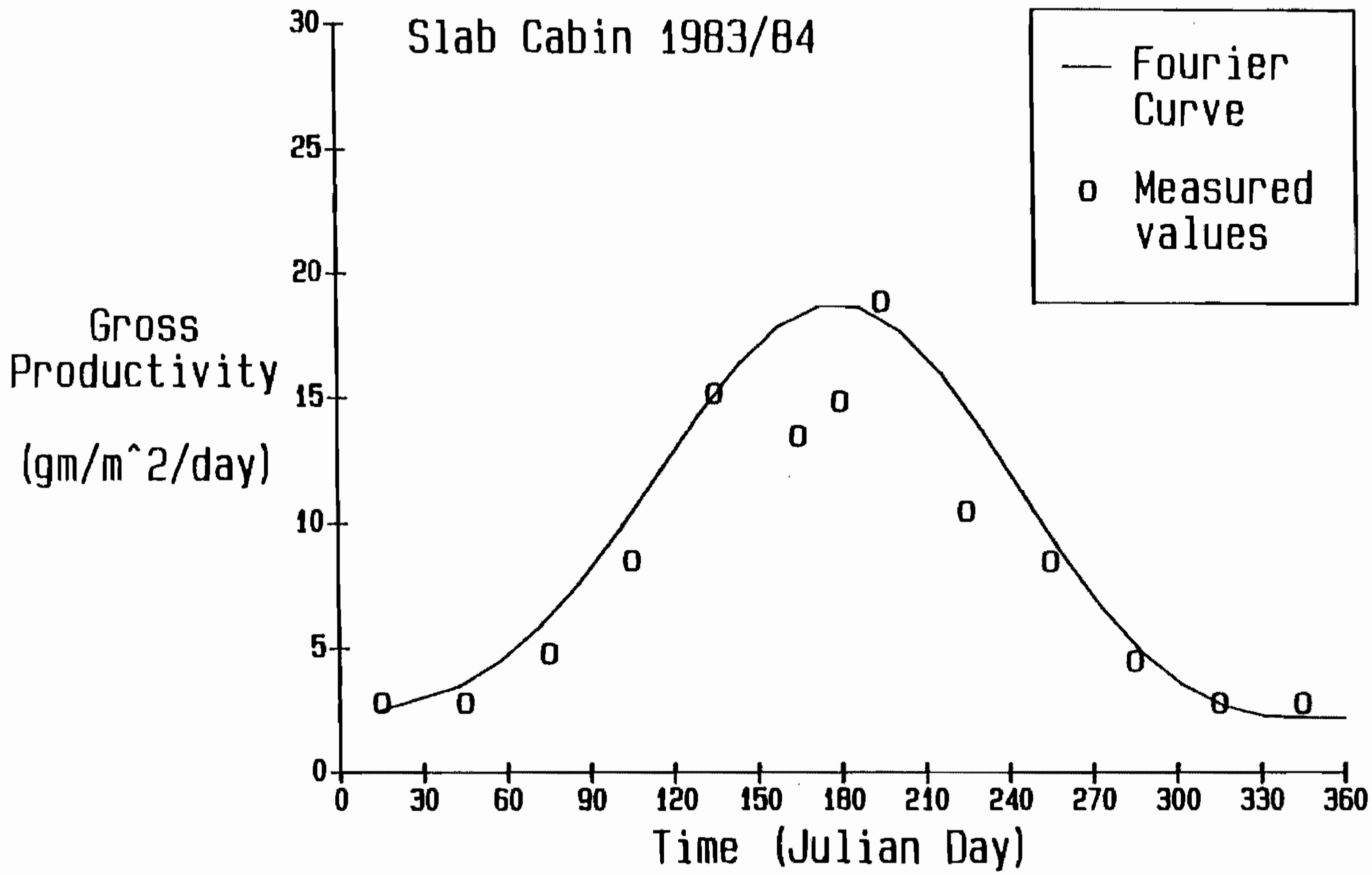


Figure 6.6 Annual Producitivity Curve for Slab Cabin Run in 1983/84

Pg versus Solar Radiation and TSP

Productivity is affected by a number of environmental factors including solar radiation and nutrient concentration. For wasteload allocation purposes, it would be desirable to relate productivity to these environmental factors. A relationship between Pg, SR, and TSP was developed with data from seven separate surveys conducted on Spring Creek and Slab Cabin Run. Only data collected during June and July were used. Michaelis-Menton kinetics for phosphorus limitation were assumed in the development of the empirical relationship. Analysis of the primary productivity and solar radiation data indicated that during the period of June and July, photosynthesis is a linear function of solar radiation. Consequently, a relationship of the form:

$$Pg = alpha \times SR \frac{(TSP)}{K_c + TSP} \quad \text{.................................} \quad (8)$$

where Pg = gross productivity in $gm/m_2/day$, alpha = regression coefficient, SR = total daily solar radiation in $kcal/m^2/day$, TSP = in-stream total soluble phosphorus concentration in mg/L, and K_c = half saturation constant for phosphorus uptake.

A Statistical Analysis Systems (SAS) nonlinear regression procedure, which fits nonlinear regression models by least squares, was used to estimate the two parameters alpha and K_c. The data that was used to develop the empirical equation are presented in Table C.1 of Appendix C. The final equation is:

$$Pg = 0.0038 \ SR \frac{(TSP)}{0.0123 + TSP} \quad \text{..............................} \quad (8a)$$

Statistics for the nonlinear equation can be found in Table 6.4. The eta squared value, which is analogous to the r^2 value (Glass and Hakstian, 1969), is 0.88, which is statistically significant. The F test, a more important statistical test which incorporates the mean square error (MSE), yields a high value, 270.92, which is highly significant. A plot of the relationship is given in Figure 6.7.

With a statistically significant relationship between Pg, SR and TSP established, Pg values were calculated for each individual segment based on measured in-stream phosphorus concentrations and solar radiation values obtained from the meteorology department at The Pennsylvania State University.

Photosynthesis-Plant Respiration Ratio versus Solar Radiation

Using past survey data sets which included assessments of oxygen sinks associated with community respiration, plant respiration was estimated as the difference between total community respiration and uptake derived from sediment oxygen demand as well as carbonaceous and nitrogenous biochemical oxygen demand. Subsequently, a linear relationship was found to exist between the Photosynthesis-Plant Respiration ratio (Pg/Rp) and solar radiation. The relationship is given as:

$$Pg/Rp = 0.685 + 9.41 \times 10^{-5}(SR) \quad \text{.........................} \quad (9)$$

$R^2 = 0.521$

df (corrected) = 29

which is significant at the 0.05 level. The data sets are presented in Table 6.5 and a plot of the data is given in Figure 6.8.

Table 6.4: Summary Statistics for Nonlinear Regression between Pg, SR, and TSP

Degrees of Freedom (corrected)	=	69
Mean Square Error	=	34.38
F	=	270.92
r squared (eta squared)	=	0.88

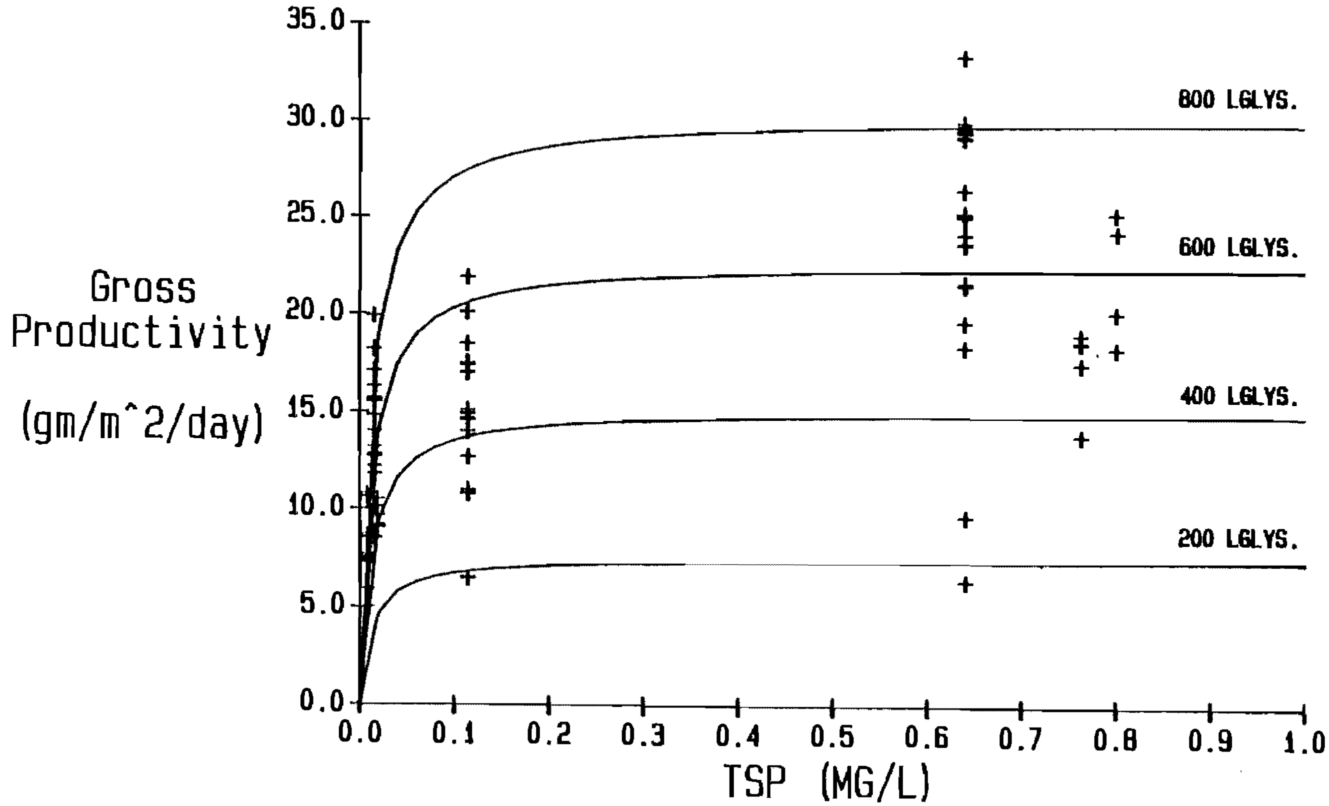


Figure 6.7: Plot of Nonlinear Relationship between Pg and TSP at different Solar Radiation. Solar Radiation is plotted as Langlies (1 Langley = 10 kcal/m^2/day).

Table 6.5: Data Used in the Development of Pg/Rp and SR Relationship

Data Set	System	Pg/Rp	SR kcal/m^2/day
1	Upper Spring Creek 1966	0.60	402
		0.99	1812
		1.22	3546
		1.33	3880
		1.09	5660
		1.00	4029
		1.13	6467
		1.28	7496
		0.84	3559
		1.10	1753
2	Lower Spring Creek (7-9) 1966	0.63	402
		0.80	4421
		1.03	5660
		0.77	1648
		1.24	6686
		0.86	4029
		1.04	6467
		1.68	7496
		1.13	5850
		0.96	3559
		0.60	1751
3	Lower Spring Creek (9-10) 1966	0.88	424
		0.93	402
		0.93	4421
		0.75	1648
		1.13	6686
		1.06	4029
		1.70	6467
		1.72	7496
		1.49	5850
		1.34	3559

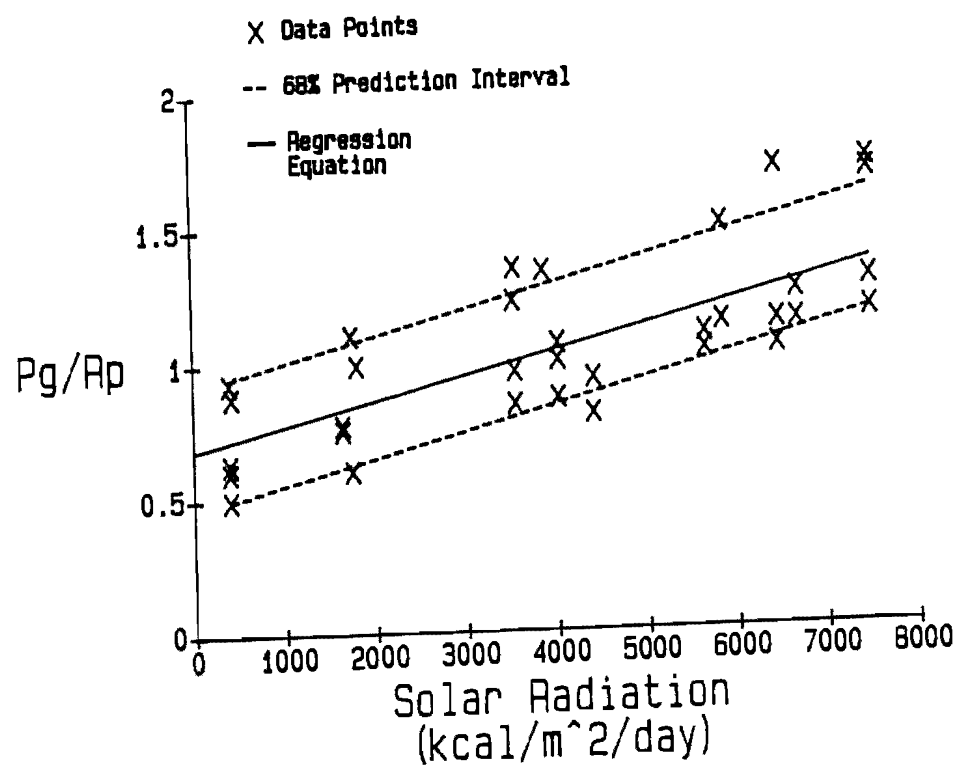


Figure 6.8: Plot of Linear Regression for P/Rp versus Solar Radiation

Chapter 7. SYNOPTIC STREAM SURVEYS

Two synoptic stream surveys were conducted in 1985 on the Bellefonte segment and the UAJA segment. Also, in 1984 a synoptic stream survey was performed on the Bellefonte segment. During the stream surveys, stream flow, time of travel and water quality data were collected. The ultimate goal of each survey was to characterize the assimilative capacity of the stream.

Bellefonte Survey, 1985

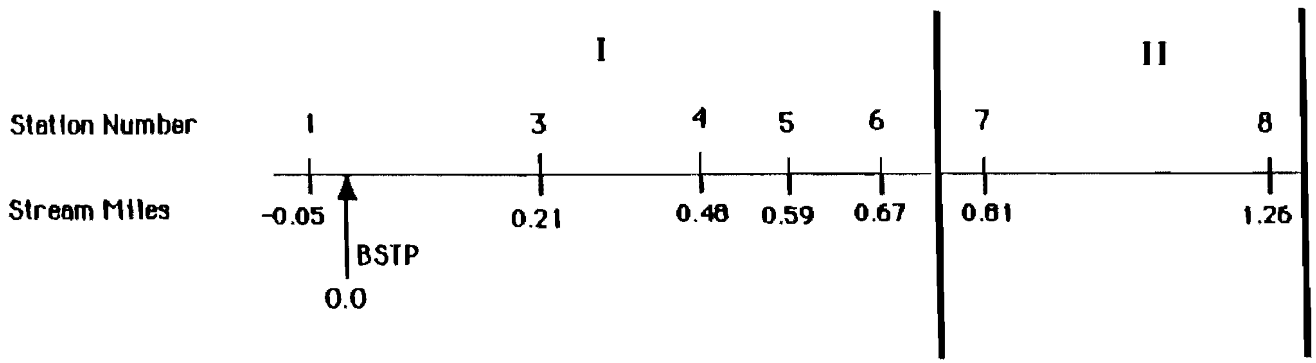
The Bellefonte survey was conducted on July 25, 1985. The weather for the day could be described as mostly cloudy in the morning and partly sunny in the afternoon. As a result, the total solar radiation for the day was 2110 kcal/m^2/day, which is relatively low. The survey began at 4:00 a.m. and continued until 12:00 midnight. Grab sample DO and temperature values were collected at each station approximately every two hours. Continuous recording DO and temperature meters were located at stations 4, 6, and 8 for the survey and allowed to run for the survey period.

The schematic in Figure 7.1 shows the segments, the sampling stations and mile points, the slopes, and the average depths, velocities and flows for the survey day.

At 4:00 a.m. and 2:00 p.m., water samples were collected at each sampling station. In addition, water samples were collected from the effluent of the BSTP at 4:05 a.m., 1:21 p.m., and 8:18 p.m. All water samples were tested for pH, alkalinity, TKN, NO_3-N, NO_2-N, NH_3-N, filtered and unfiltered total and ortho-phosphorus, Cl^-, BOD_5 (uninhibited and inhibited) and BOD_{20} (uninhibited and inhibited). The results from the water quality tests for the 4:00 a.m., 2:00 p.m. and average profiles can be found in Tables D.1, D.2, and D.3 in Appendix D.

The DIURNAL model was run for each individual segment using Pg and Rp values estimated from the empirical relationships given in equations 8a and 9. Segment I started at the complete mix point (station 4) and ended at station 6, just above the dam. Reach II began at station 7, below the dam, and ended at station 8. The reaction coefficients that were used in the DIURNAL analysis are listed in Table 7.1. The reaeration rate was obtained using the Owens et al. formula. The CBOD oxygen uptake rate was considered to be zero order since the BOD is relatively constant throughout the segment. It was calculated as the product of the deoxygenation rate estimated using equation 5 and the average in-stream CBOD. The sediment oxygen demand term that was used in each segment was derived from previous data collected in the Spring Creek system and corrected for temperature. The productivity and plant respiration terms are obtained from the empirical formulas.

The results from the DIURNAL analysis yielded 4:00 a.m. and 2:00 p.m. DO profile responses as shown in Figure 7.2 The data used for this plot are given in Table F.1 in Appendix F. Diurnal DO curves, which can be computed for any given location in the reach, were obtained from the



Reach	I	II
Slope:	0.0032 ft/ft	0.0012 ft/ft
Avg. Velocity:	0.93 fps	1.58 fps
Avg. Depth:	2.21 ft	1.69 ft
Flow:	171 cfs	171 cfs

Figure 7.1: Schematic of the Bellefonte Reach, 1985

Table 7.1: Summary of Reaction Coefficients for Bellefonte DIURNAL Analysis, 1985

Segment	Q cfs	Ka 1/day	KdL	KrL	Kn	So	Pm	Rp	TSP mg/L
			----mg/L/day----			----mg/L/day----			
1	171	4.80	2.41	2.41	0.00	4.97	24.10	11.67	0.075
2	171	11.20	2.41	2.41	0.00	6.50	31.49	15.26	0.075

Table 7.2: Summary of Reaction Coefficients for UAJA DIURNAL Analysis, 1985

Segment	Q cfs	Ka	Kd	Kr	Kn	So	Pm	Rp	TSP mg/L
		-------------1/day----------------					---mg/L/day-------		
1	46.70	11.98	1.58	1.58	0	8.45	82.64	32.04	0.076
2	46.70	16.34	1.58	1.58	0	8.45	97.73	35.63	0.076
3	57.50	21.70	1.43	1.43	0	9.98	102.55	39.77	0.115
4	57.80	21.70	1.41	1.41	0	0	103.11	39.98	0.112
5	70.70	21.70	1.28	1.28	0	0	102.90	39.90	0.119

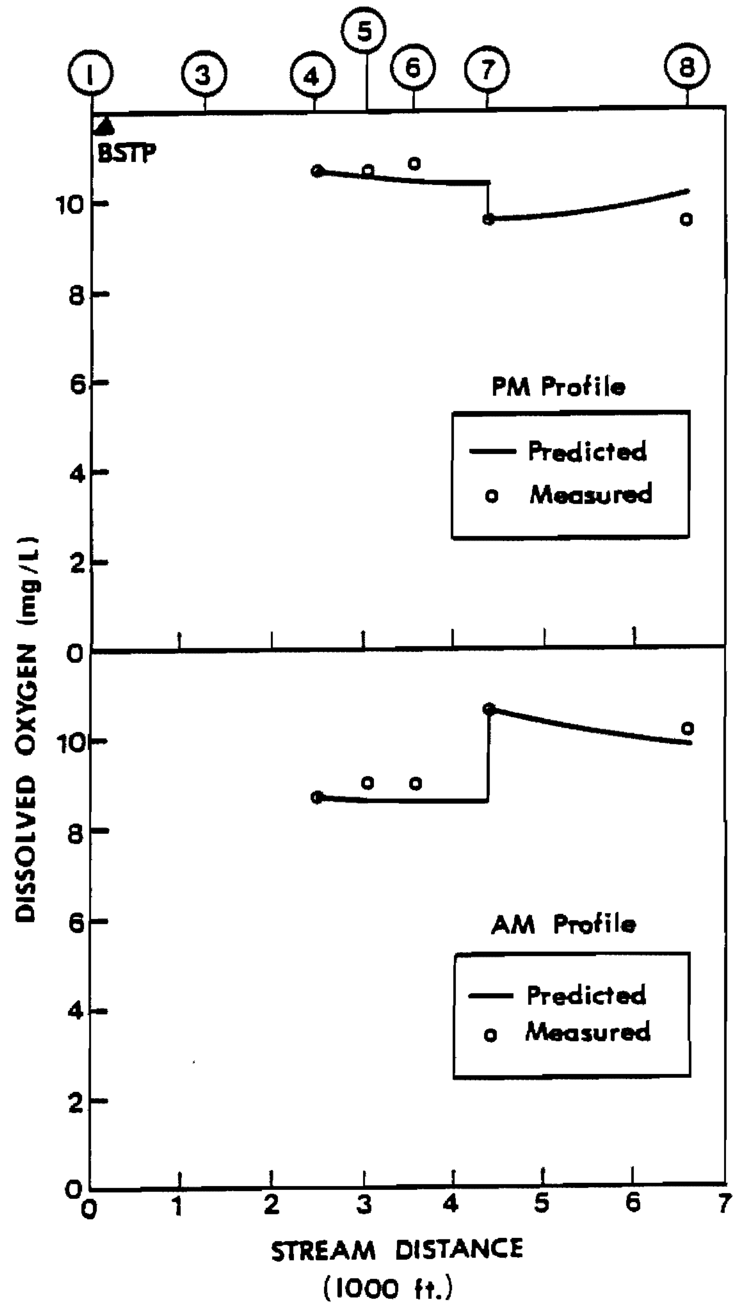


Figure 7.2: AM and PM DO Profile for the Bellefonte Reach, 1985

DIURNAL program for stations 5, 6, and 8. Figures 7.3a, 7.3b, and 7.4 show the predicted and observed DO curves for each station.

To determine how well the DO model, using Pg and Rp values derived from the empirical relationships, predicts the DO in the stream, a linear regression was performed on the observed and predicted DO data for the diurnal curves at stations 5, 6, and 8. Theoretically, if the observed and predicted DO values were the same, the slope of the regression line would be 1.0 and the intercept would be 0.0.

The protocol for the linear regression analysis was taken from the Model Verification Program (MVP) theory (DiToro, Fitzpatrick, and Thomann, 1982). The MVP theory uses the following linear regression equation:

$$\text{observed} = \text{alpha} + \text{beta (predicted)} \quad \text{......................} \quad (10)$$

where: alpha = intercept; beta = slope.

Tests of significance on the slope and intercept were performed using the following test statistics (T.S.):

slope:

$$\text{T.S.} = \frac{\text{beta} - 1}{\text{s(beta)}} \quad \text{......................................} \quad (11)$$

where: s(beta) = standard deviation of beta.

intercept:

$$\text{T.S.} = \frac{\text{alpha}}{\text{s(alpha)}} \quad \text{......................................} \quad (12)$$

where: s(alpha) = standard deviation of alpha.

A linear regression was performed on the observed versus predicted DO data from the diurnal curves at stations 5, 6, and 8. The resulting regression equation is:

$$\text{observed} = -0.4099 + 1.033 \text{ (predicted)} \quad \text{................} \quad (13)$$

A plot of the observed versus predicted DO values is shown in Figure 7.5.

A two tailed student "t" test was conducted on both the slope and the intercept, with a 2.5 percent probability in each tail. The calculations for the two "t" tests are shown in Appendix E. The conclusion for both tests was that there is insufficient evidence to say that the slope does not equal 1.0 or that the intercept does not equal 0.0.

UAJA Survey, 1985

The UAJA survey was performed on July 17, 1985. The weather was sunny, and the solar radiation was 4274 kcal/m^2/day. The survey period

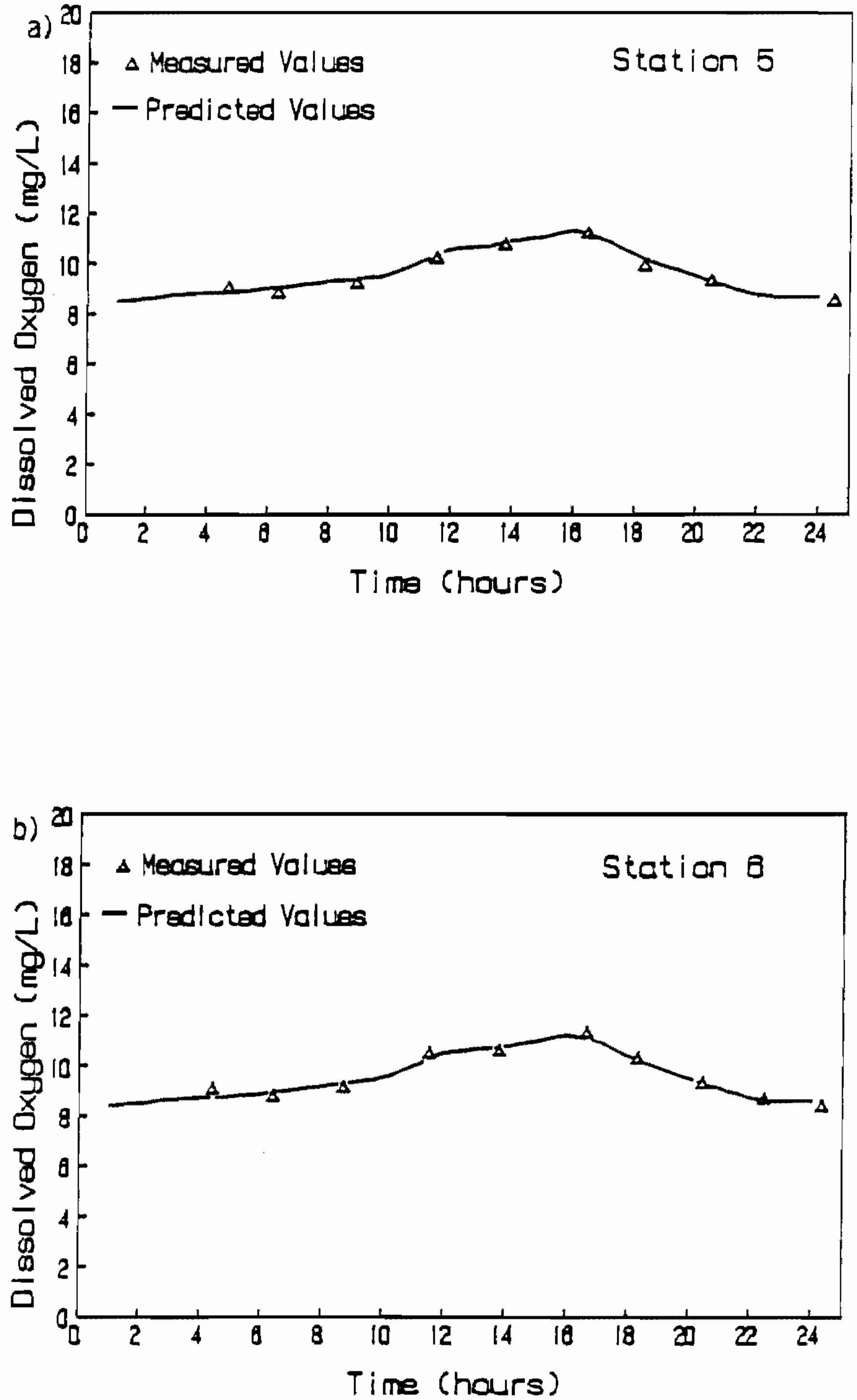


Figure 7.3: a) Predicted Diurnal Curve at Station 5, Bellefonte Reach
b) Predicted Diurnal Curve at Station 6, Bellefonte Reach

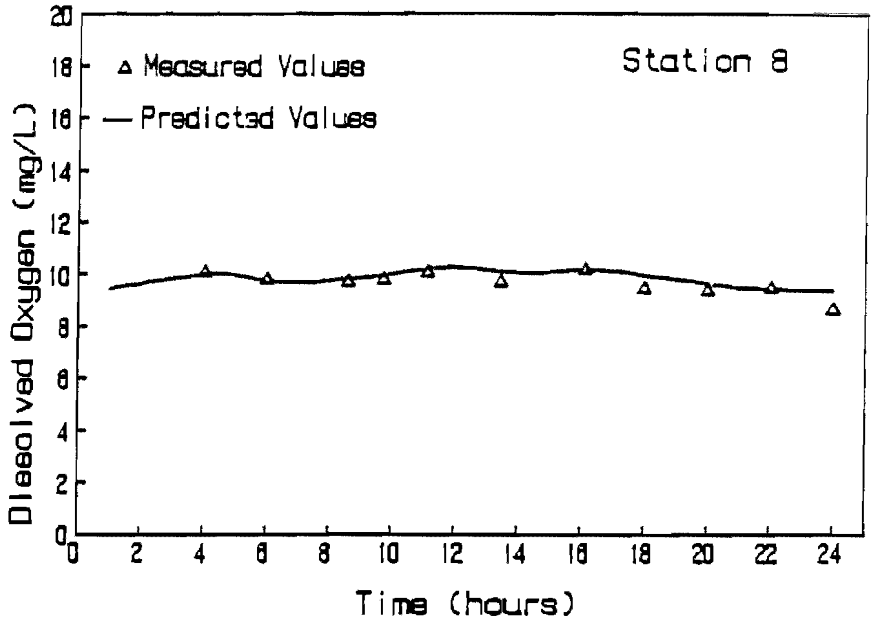


Figure 7.4: Predicted Diurnal Curve at Station 8, Bellefonte Reach

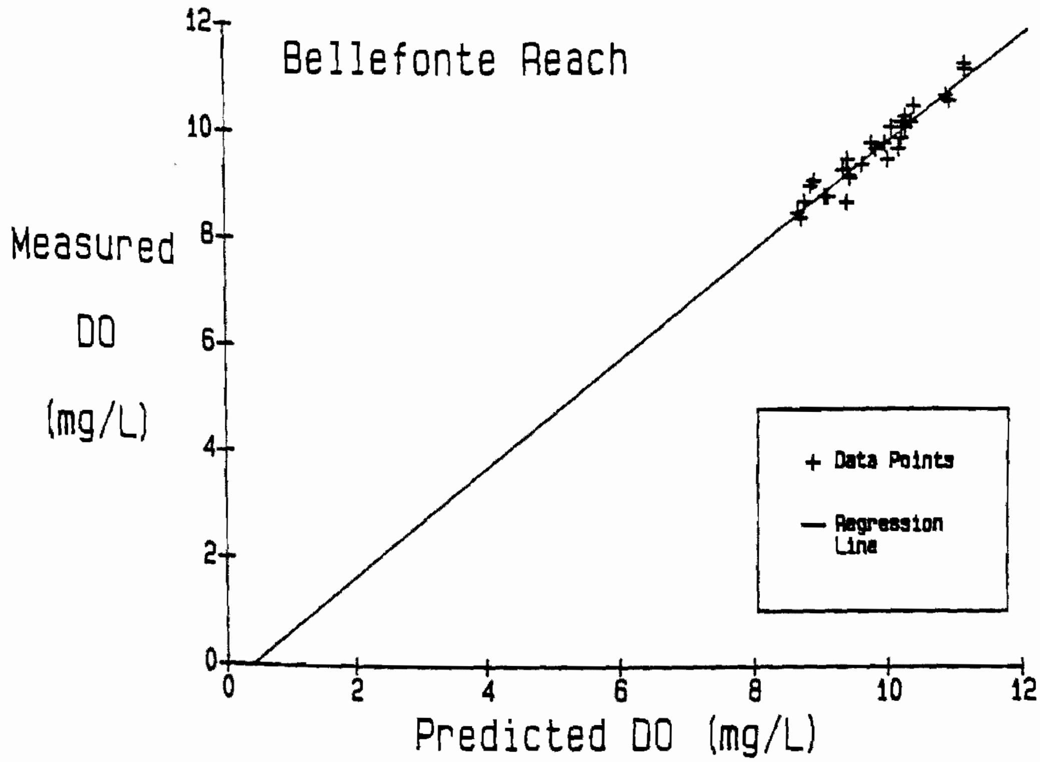


Figure 7.5: Linear Regression Plot of Predicted DO Values from Empirical Relationships and Measured DO Values for the Bellefonte Reach, 1985

again ran from 4:00 a.m. to 12:00 midnight. Grab sample DO and temperature values were collected six times during the survey period at 18 different locations in the segment. The continuous recording DO meters were located at stations 2, 3 and between stations 3 and 4 and allowed to run for the survey period.

The reach was broken up into five different segments. Figure 7.6 is a schematic of the UAJA reach showing the different segments, slopes, velocities, depths, and water quality sampling stations and locations. The schematic also shows the two dams that are located in the system. The location of the dams and the discharges dictated the partitioning of the segments.

Sampling and data analysis protocols were similar to those used in the Bellefonte reach survey. Tables D.4, D.5, and D.6 in Appendix D are summary tables of water quality data that were collected at 4:00 a.m., 2:00 p.m., and average values for each water quality station. The same tests that were performed on the Bellefonte samples also were performed on the UAJA samples. The four point sources in the UAJA segment were sampled four times during the survey period.

Again, using values of Pg and Rp estimated from equations 8a and 9 the DIURNAL model was run for each reach in the UAJA segment. The reaction coefficients that were used for each reach are listed in Table 7.2.

As with the Bellefonte survey, initial DO curves for each reach were developed with Fourier series equation of the following type:

$$Pg = A_0 + A_1\cos(\pi/12*t) + B_1\sin(\pi/12*t) + A_2\cos(\pi/6*t) + B_2\sin(\pi/6*t) \quad \text{..(14)}$$

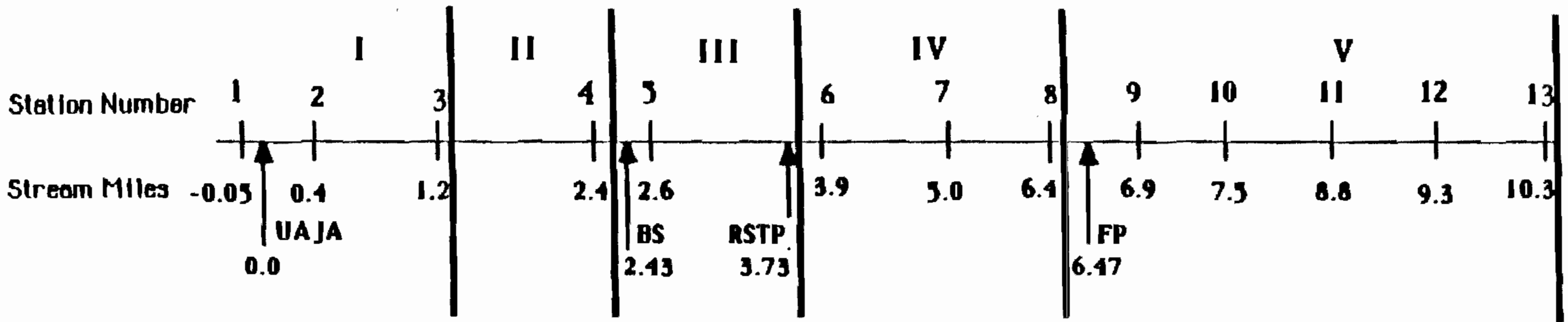
and stream DO data.

The 4:00 a.m. and 2:00 p.m. DO profile responses that were predicted by the DO model are shown in Figure 7.7. The data for this plot is given in Table F.2 of Appendix F. Diurnal response curves were called for at stations 3, 4, 6, 8, 11, and 13, and Figures 7.8a, 7.8b, 7.9a, 7.9b, 7.10a, and 7.10b show the resultant predicted diurnal curves and the measured values.

The predicted versus observed DO values from the six diurnal curves were evaluated by the MVP procedure to determine how well the model predicts the measured data. A plot of the predicted versus measured data is shown in Figure 7.11. The regression equation is:

$$\text{observed} = -0.694 + 1.053 \quad \text{.................................} \quad (15)$$

Significance tests were run on alpha and beta to determine if the intercept, alpha, was zero, and the slope, beta, was one. Calculations for the significance tests can be found in Appendix E. The results from the two tailed "t" tests at and alpha of 0.05 indicate that the intercept and the slope are not significantly different than zero and one, respectively.



Reach:	I	II	III	IV	V
Slope (ft/ft):	0.0015	0.0027	0.0027	0.0034	0.0042
Avg. Velocity (fps):	0.85	0.85	1.30	1.30	1.30
Avg. Depth (ft):	1.30	1.10	1.10	1.10	1.10
Flow (cfs):	46.7	46.7	57.5	57.8	70.7

Figure 7.6: Schematic of the UAJA Reach

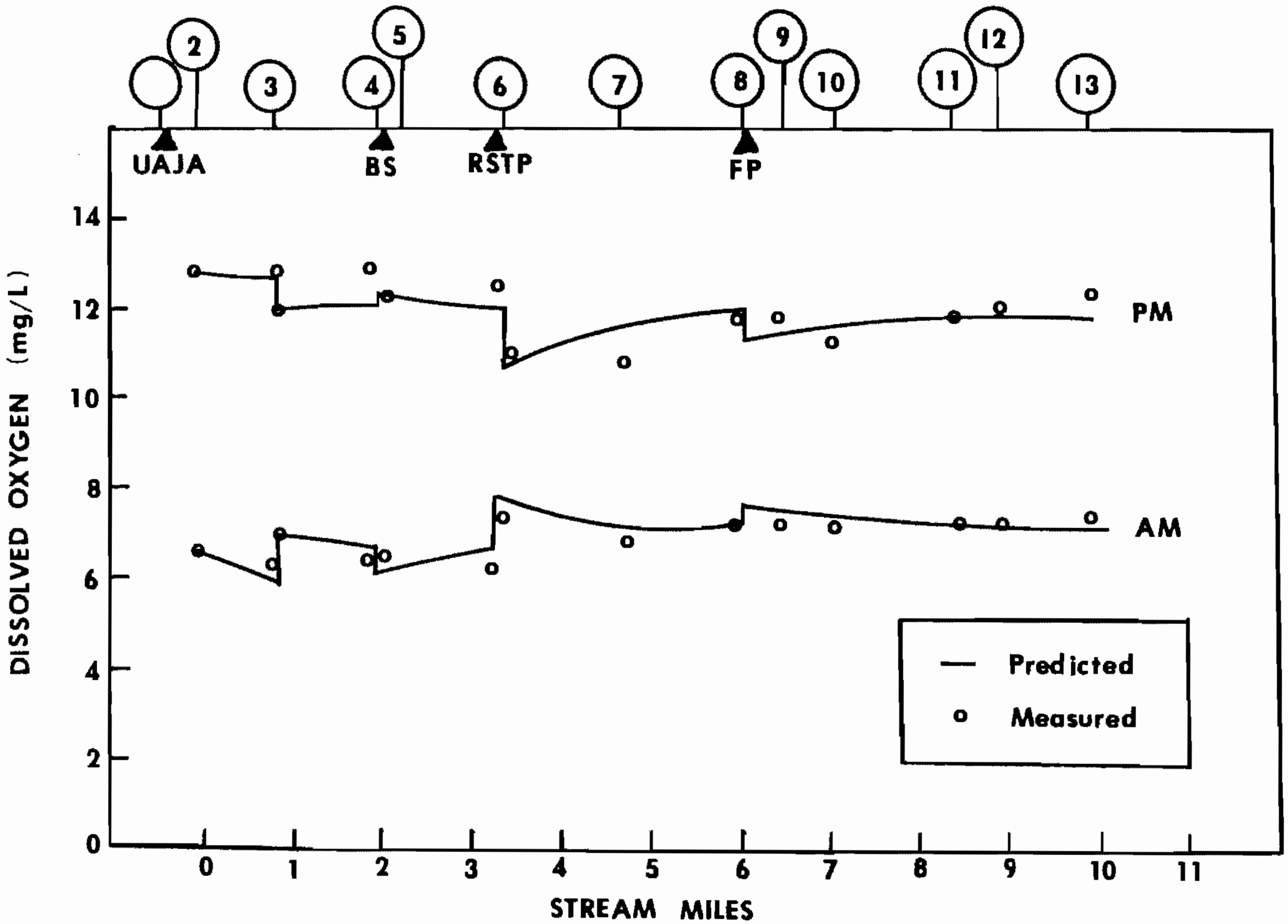
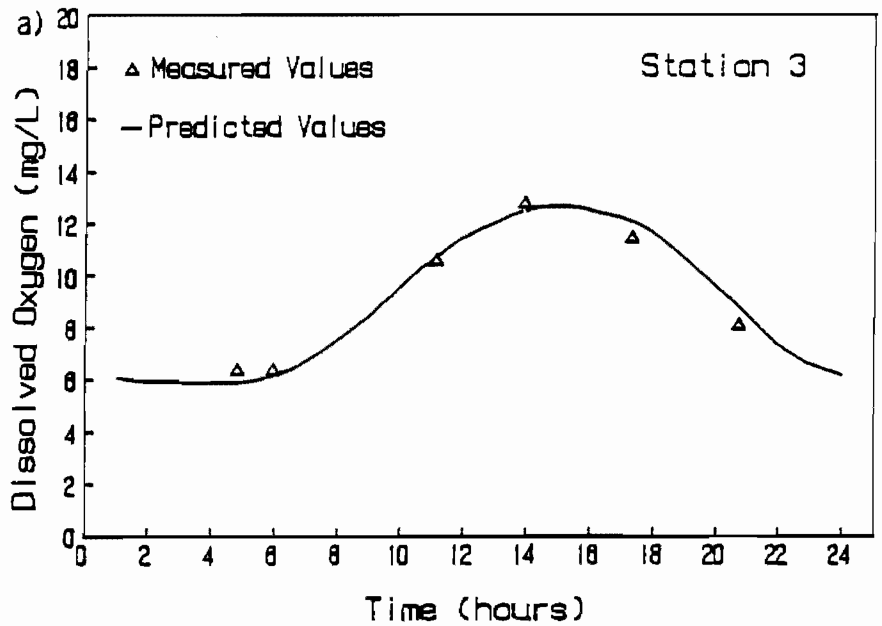


Figure 7.7: AM and PM DO Profiles for the UAJA Reach



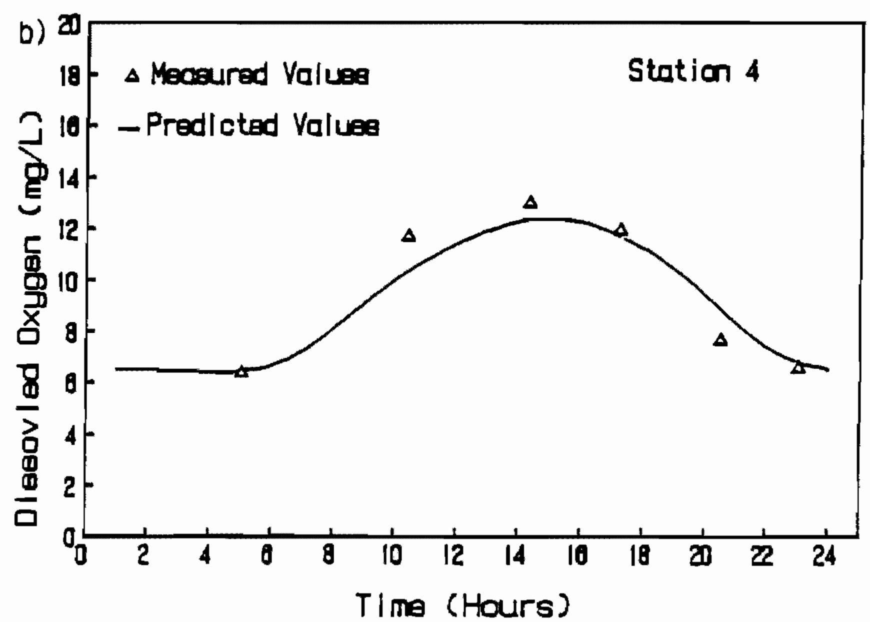
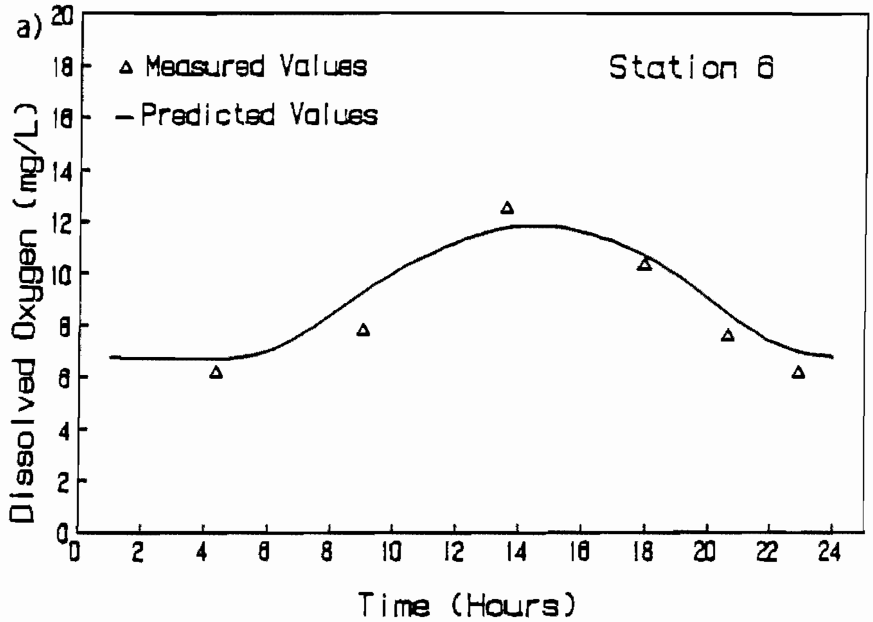


Figure 7.8: a) Predicted Diurnal Curve at Station 3, UAJA Reach
b) Predicted Diurnal Curve at Station 4, UAJA Reach



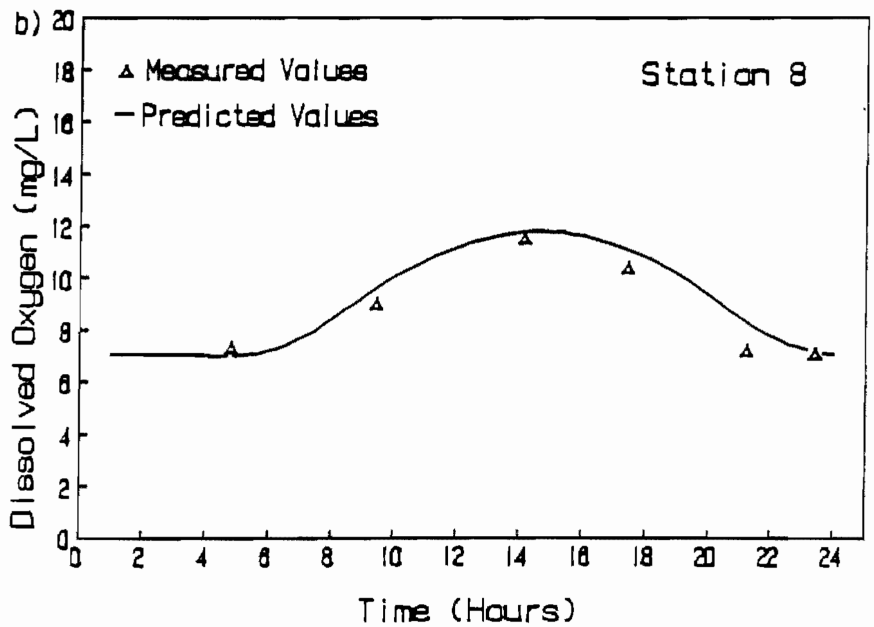
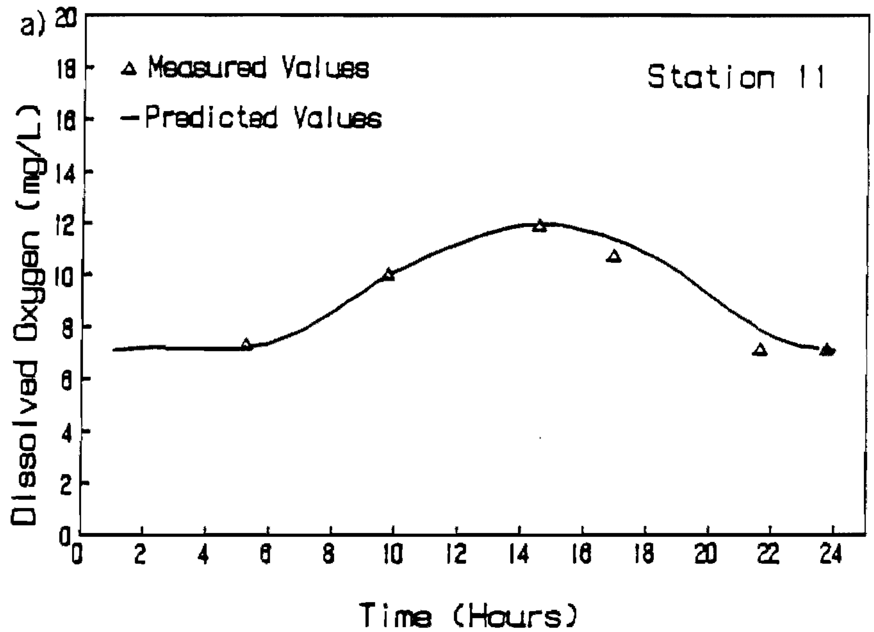


Figure 7.9: a) Predicted Diurnal Curve at Station 6, UAJA Reach
b) Predicted Diurnal Curve at Station 8, UJAJ Reach



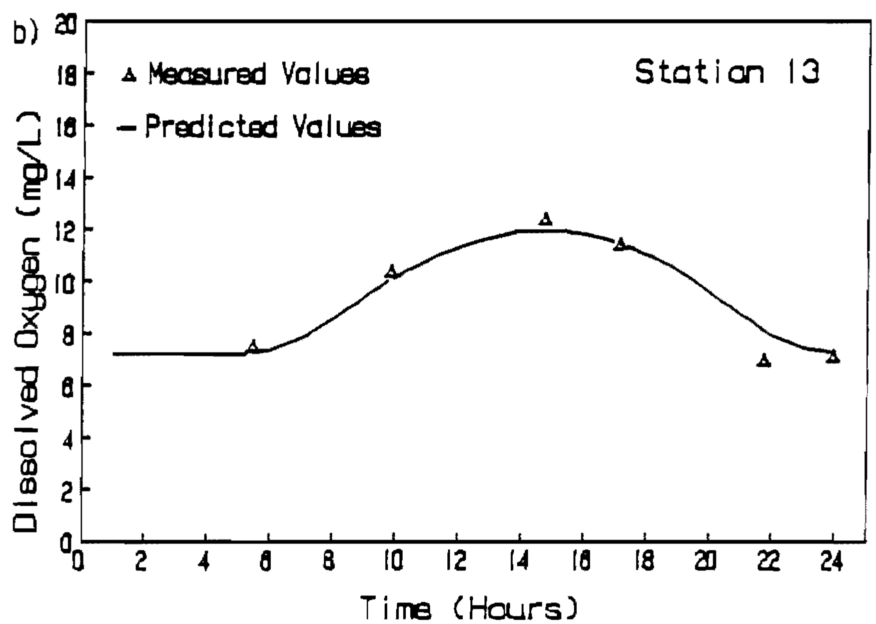


Figure 7.10: a) Predicted Diurnal Curve at Station 11, UAJA Reach
b) Predicted Diurnal Curve at Station 13, UAJA Reach

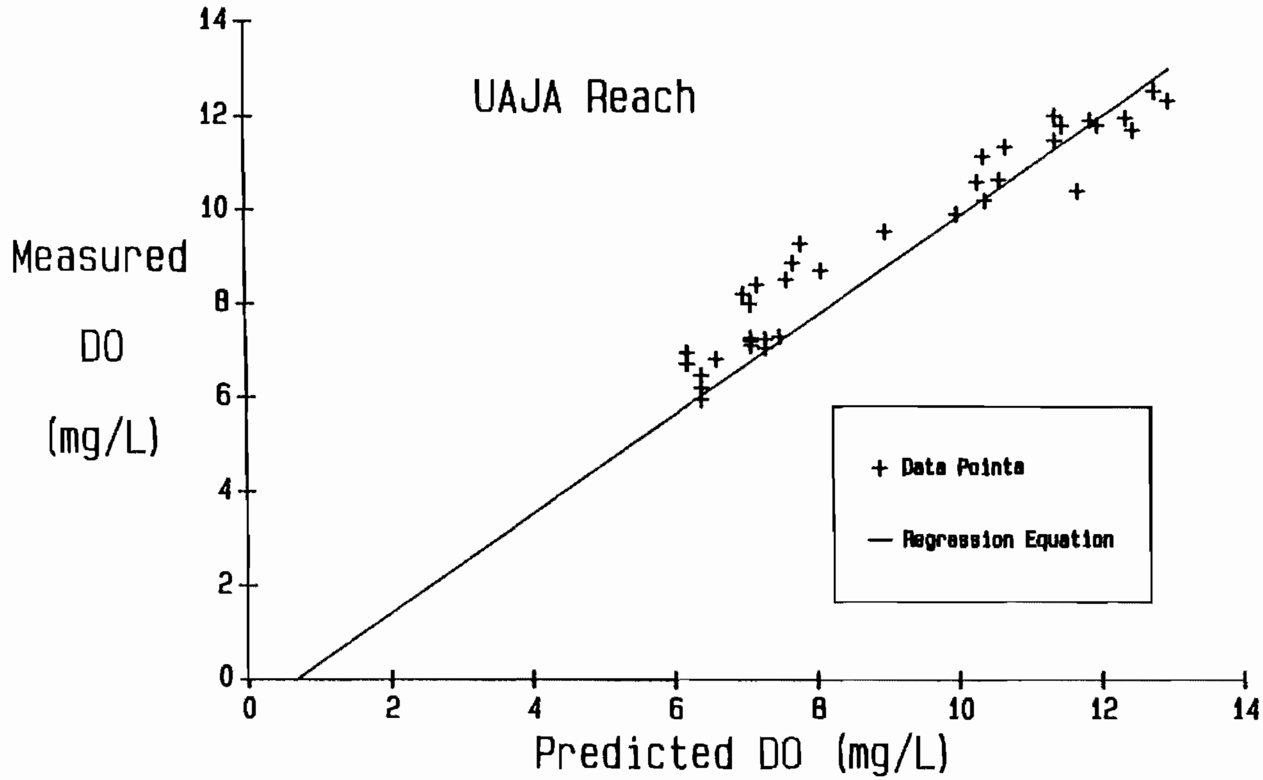


Figure 7.11: Linear Regression Plot of Predicted DO Values from Empirical Relationships and Measured DO Values for the UAJA Reach

Bellefonte, 1984

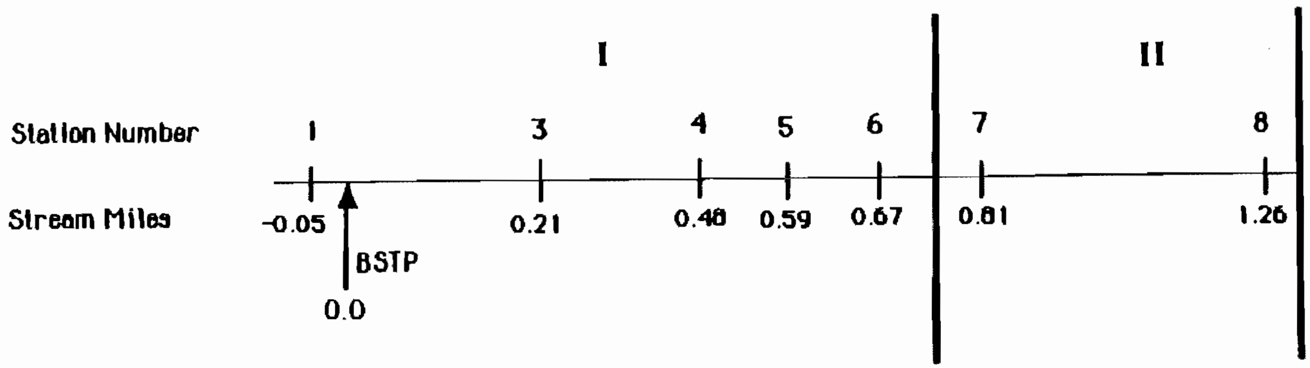
On July 31, 1984, a 24-hour reconnaissance survey was conducted on the Bellefonte reach. The water quality and gaging stations were the same as for the 1985 survey. The survey began at 4:00 a.m. and continued until 6:00 p.m. of the same day. The total solar radiation for the day was 4,172 kcal/m^2/day. Dissolved oxygen, temperature, and water quality data were collected at 4:00 a.m. and 2:00 p.m. Continuous recording DO meters were placed at stations 1, 6, and 8 for the survey day. Stream flow and time of travel data also were collected for the day. Tables D.7, D.8, and D.9 in Appendix D present a summary of the water quality data that were collected during the survey.

An analysis using DIURNAL was performed on the reach in two segments as in 1985. A schematic of the Bellefonte reach is given in Figure 7.11a. The program was initiated at station 4 (the complete mix point) and stopped at station 6 (above the dam), and reinitiated at station 7 (below the dam). An initial DO curve was estimated at station 4 and 7 from the two measured DO values. The reaction rates that were used in the analysis are listed in Table 7.3. For reasons indicated earlier, the BOD was assumed to be zero order. The Owens formula was used to calculate the reaeration rates for the two segments. The productivity and respiration values that were used were derived from the empirical formulas that were developed. Figure 7.2 presents the predicted 4:00 a.m. and 2:00 p.m. DO profiles compared to the measured points.

Comparison of Measured and Predicted DO Values

To obtain some measure of the reliability of model predictions, distributions of the absolute differences between measured and predicted values were examined. Probability distributions were developed from data secured from the respective surveys as given in Tables 7.4 and 7.5. A skewed Gumbel distribution was ultimately used because it best fit the data.

Examination of Figures 7.13 and 7.14 would indicate that, at the fifty percent probability level, the dissolved oxygen can be predicted within 0.50 mg/L, using the methodology employed in this study.



Reach:	I	II
Slope:	0.0032 ft/ft	0.0012 ft/ft
Avg. Velocity:	1.10 fps	1.80 fps
Avg. Depth:	2.78 ft	1.75 ft
Flow:	243 cfs	243 cfs

Figure 7.11a: Schematic of the Bellefonte Reach, 1984

Table 7.3: Summary of Reaction Coefficients for Bellefonte DIURNAL Analysis, 1984

Segment	Q	Ka	KdL	KrL	Kn	So	Pm	Rp	TSP
	cfs	1/day	--mg/L/day--		1/day	-----mg/L/day-----			mg/L
1	243	3.78	4.88	4.88	0.00	6.51	38.14	14.79	0.082
2	243	11.64	4.88	4.88	0.00	6.51	27.29	10.56	0.082

Table 7.4: Measured and Predicted Values at UAJA Stations

Station	Time	Measured	Predicted	|Measured - Predicted|
3	4:47	6.40	5.95	0.45
	5:55	6.40	6.20	0.20
	11:05	10.60	10.65	0.05
	1:55	12.80	12.53	0.27
	5:20	11.40	12.00	0.60
	8:44	8.10	8.70	0.60
4	4:57	6.40	6.46	0.06
	10:25	11.70	10.40	1.30
	2:20	13.00	12.32	0.68
	5:11	12.00	11.80	0.20
	8:31	7.70	8.86	1.16
	11:01	6.60	6.80	0.20
6	4:17	6.20	6.70	0.50
	8:54	7.80	9.28	1.48
	1:25	12.50	11.70	0.80
	5:53	10.30	10.60	0.30
	8:38	7.60	8.50	0.90
	10:52	6.20	6.94	0.74
8	4:47	7.30	7.05	0.25
	9:21	9.00	9.54	0.54
	2:06	11.50	11.80	0.30
	5:22	10.40	11.14	0.74
	9:10	7.20	8.40	1.20
	11:25	7.10	7.20	0.10
11	5:12	7.30	7.24	0.06
	9:39	10.00	9.91	0.09
	2:28	11.90	11.91	0.01
	4:53	10.70	11.34	0.64
	9:33	7.10	8.00	0.90
	11:43	7.10	7.10	0.00

Table 7.4 Concluded

Station	Time	Measured	Predicted	|Measured − Predicted|
13	5:25	7.50	7.30	0.20
	9:49	10.40	10.20	0.20
	2:39	12.40	11.97	0.43
	5:05	11.40	11.48	0.08
	9:41	7.00	8.19	1.19
	11:53	7.10	7.26	0.16

Table 7.5: Measured and Predicted Values at Bellefonte Stations

Station	Time	Measured	Predicted	|Measured − Predicted|
5	4:37	9.00	8.80	0.20
	6:19	8.80	9.01	0.21
	8:55	9.20	9.38	0.18
	11:29	10.20	10.29	0.09
	1:50	10.70	10.80	0.10
	4:23	11.20	11.08	0.12
	6:20	9.90	10.14	0.24
	8:33	9.30	9.28	0.02
	12:33	8.50	8.61	0.11
6	4:25	9.10	8.85	0.25
	6:25	8.80	9.06	0.26
	8:52	9.15	9.39	0.24
	11:30	10.50	10.33	0.17
	1:43	10.60	10.86	0.26
	4:35	11.30	11.08	0.22
	6:20	10.30	10.19	0.11
	8:25	9.30	9.28	0.02
	10:25	8.70	8.71	0.01
	12:20	8.40	8.66	0.26
8	4:00	10.10	10.00	0.10
	6:00	9.80	9.70	0.10
	8:35	9.70	9.77	0.07
	9:40	9.80	9.90	0.10
	11:10	10.10	10.21	0.11
	1:25	9.70	10.11	0.41
	4:10	10.20	10.15	0.05
	6:00	9.50	9.94	0.44
	8:00	9.40	9.57	0.17
	10:00	9.50	9.35	0.15
	12:00	8.70	9.33	0.63

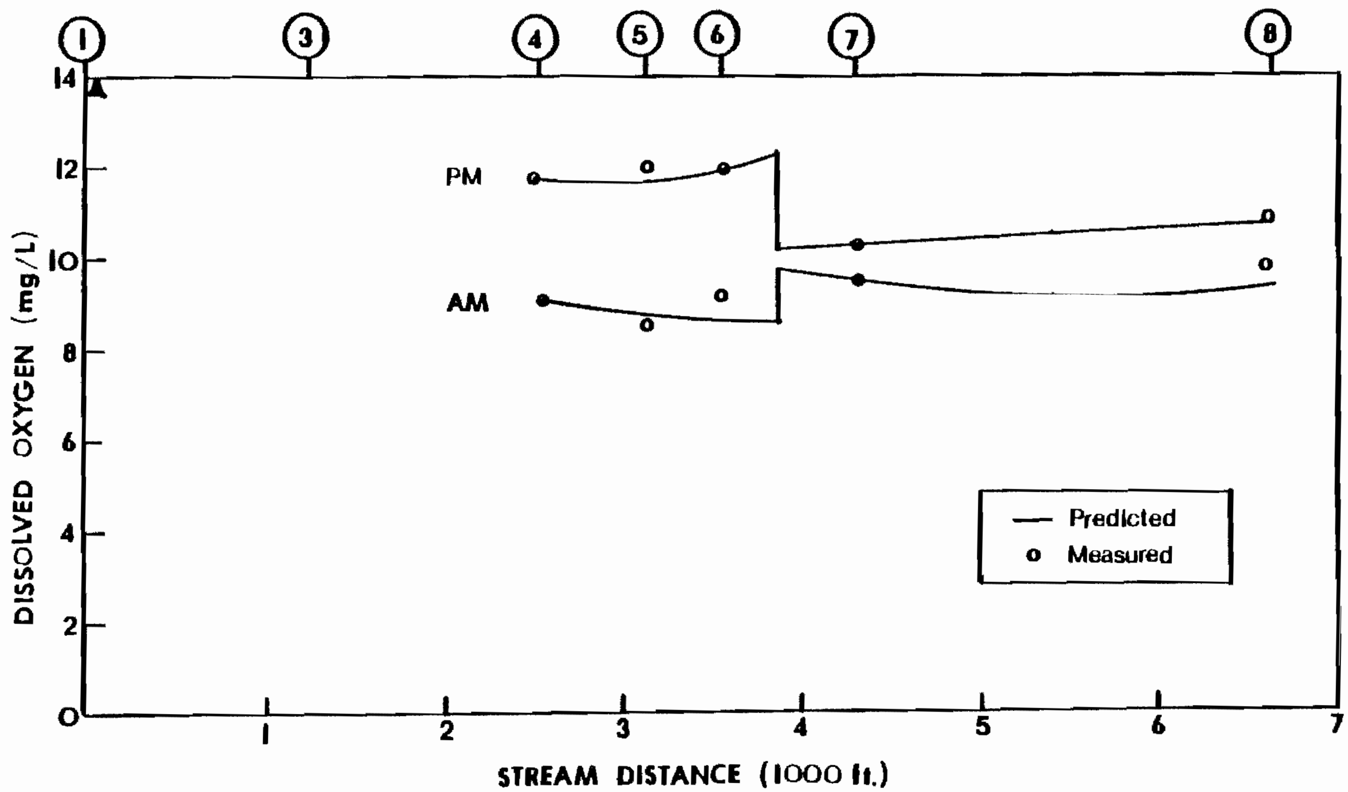


Figure 7.12: AM and PM DO Profile for the Bellefonte Reach, 1984

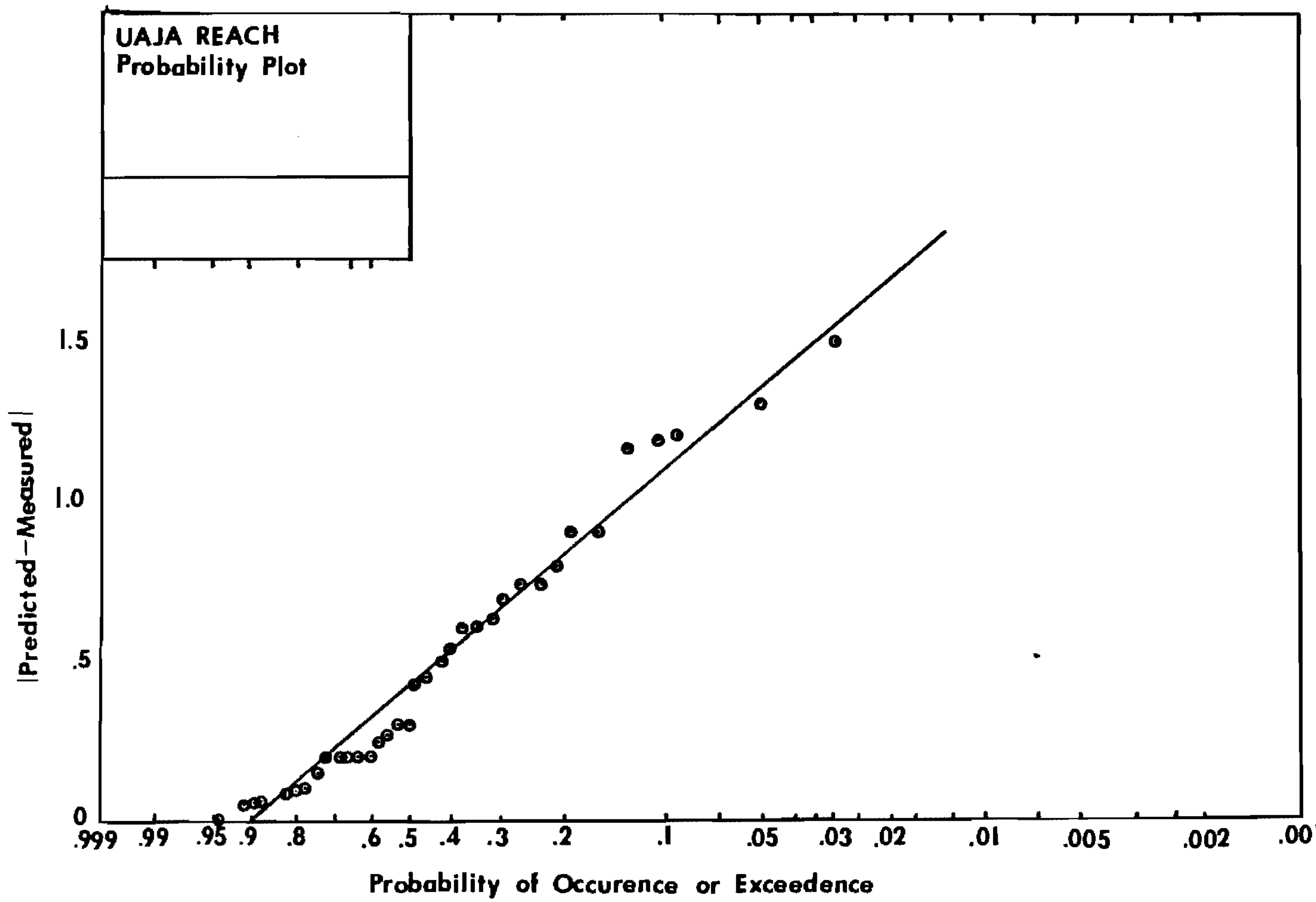


Figure 7.13: Probablility Plot for the UAJA Reach of the |Measured-Predicted| DO values

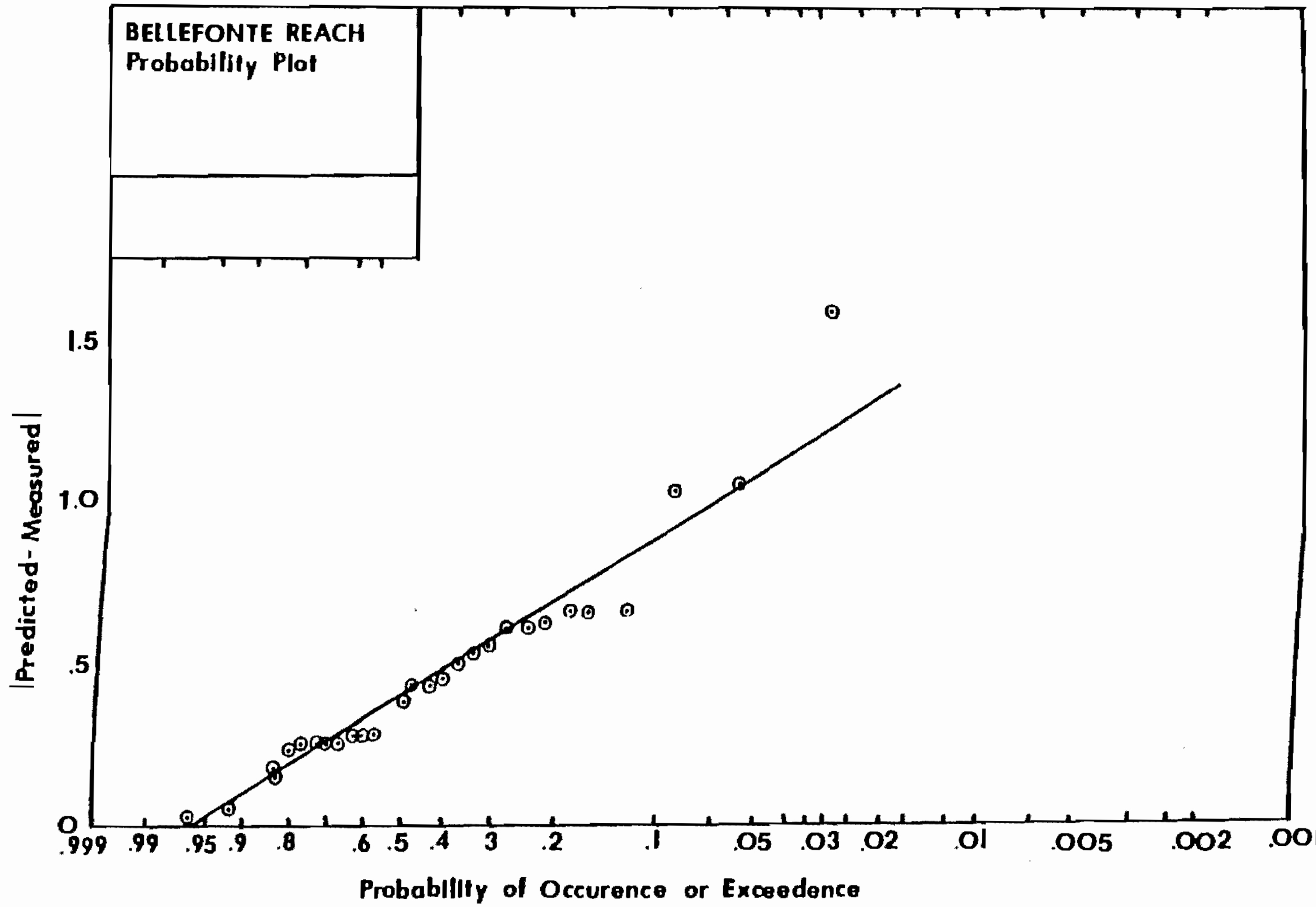


Figure 7.14: Probabillity Plot for the Bellefonte Reach of the |Measured-Predicted| DO values

Chapter 8. TREATMENT SCENARIOS

Effluent Phosphorus Alternatives

In an attempt to characterize the stream dissolved oxygen response under $Q_{(7-10)}$ streamflow conditions, several scenarios employing various effluent qualities were developed for the UAJA and Bellefonte reaches.

Using protocols, previously described, namely the estimation of in-stream levels of photosynthesis (Pg) and aquatic plant respiration (Rp) employing equations 8a and 9 dissolved oxygen profiles were calculated for effluent TSP concentrations ranging from 0.13 mg/L TSP to 2.0 mg/L TSP, for the UAJA and Bellefonte discharges. Effluent 5-day BOD values examined included 3.6 mg/L and 10 mg/L for the UAJA discharge and 4.0 for the Bellefonte discharge. Effluent qualities for other discharges on the stream were assumed to be similar to those characterized during the survey period. For analysis purposes, a solar radiation value, representing an average intensity for June and July, of 5130 kcal/m^2/day was used, together with in-stream temperatures of 15.5°C and 18.0°C for the Bellefonte and UAJA reaches, respectively.

Reaction coefficients, rates, and in-stream TSP concentrations estimated for a TSP effluent concentration of 0.13 mg/L are presented in Tables 8.1 and 8.2, for the $Q_{(7-10)}$ analyses. Summaries for the range of conditions examined are given in Tables 8.3 and 8.4. Resulting mid-afternoon and pre-dawn dissolved oxygen profiles are shown in Figures 8.1 and 8.2.

Examination of Figure 8.1 indicates that the dissolved oxygen water quality standards (5 mg/L DO) will be met for the Bellefonte reach, under all conditions of loading. In-stream DO values are expected to average from 9 mg/L to 10 mg/L, with instantaneous values remaining above a concentration of 8 mg/L.

For the UAJA reach, although estimated average daily DO concentrations will range from 8.5 to 9.0 mg/L, instantaneous minimum concentrations will fall below 5.0 mg/L for the segment immediately below the UAJA discharge, for all loading conditions. These responses are summarized in Table 8.5, for several BOD and TSP effluent qualities. In addition components of the total oxygen deficit at the critical point derived from the several operative oxygen sinks are delineated in Table 8.6. Oxygen uptake associated with aquatic plant respiration accounts for some 60 percent of the total deficits estimated to occur at the critical point, during the pre-dawn period. Given the productive nature of the stream, it can be expected that pre-dawn dissolved oxygen levels would fall below 5.0 mg/L, in this segment, during severe low flow conditions, even under existing background in-stream phosphorus concentrations.

The magnitude and extent of impact estimated to occur below the UAJA discharge, for various phosphorus limits is presented in Table 8.7. This impact is localized both temporally and spatially.

Table 8.1: Reaction Coefficients for UAJA at Q(7-10) Conditions for Diurnal Analysis

Seg.	Q	V	H	Ka	Kd	Kn	So	Pm	Rp	TSP
	cfs	fps	ft	-------1/day-------			------mg/l/day------			mg/L
1	20.5	0.39	1.13	9.22	2.43	0	9.72	114.39	41.70	0.077
2	20.5	0.64	0.92	18.79	2.34	0	10.10	140.50	51.22	0.077
3	25.8	0.75	0.96	19.31	2.09	0	11.44	134.15	48.88	0.075
4	25.8	0.74	1.05	16.22	2.09	0	0.00	122.00	44.96	0.075
5	32.0	0.89	0.88	25.44	1.89	0	0.00	148.11	53.36	0.082

Table 8.2: Reaction Coefficients for Bellefonte at Q(7-10) Conditions for DIURNAL Analysis

Seg.	Q	V	H	Ka	Kn	Kd	So	Pm	Rp	TSP
	cfs	fps	ft	---1/day---		--------mg/l/day--------				mg/L
1	97.7	0.96	1.49	10.10	0	1.74	6.51	82.47	30.06	0.056
2	97.7	1.09	1.30	14.16	0	1.74	6.51	94.53	34.46	0.056

Table 8.3: TSP, Pm, and Rp Values for Different Effluent TSP Concentrations in the UAJA Reach

Seg.	Effluent TSP Concentrations (mg/L)											
	0.13			0.5			1.0			2.0		
	TSP*	Pm**	Rp**	TSP	Pm	Rp	TSP	Pm	Rp	TSP	Pm	Rp
1	0.077	114.4	41.7	0.187	124.5	45.4	0.336	128.0	46.7	0.627	130.1	47.4
2	0.077	140.4	51.2	0.187	152.9	55.7	0.336	157.2	57.3	0.627	159.7	58.2
3	0.075	134.2	48.9	0.162	145.1	52.9	0.304	150.1	54.7	0.512	152.5	55.6
4	0.075	122.0	45.0	0.162	132.7	48.4	0.304	137.3	50.0	0.512	139.4	50.8
5	0.082	148.1	53.4	0.151	157.5	57.5	0.266	162.8	59.4	0.434	165.7	60.4

* In-stream TSP (mg/L)

** mg/L/day

Table 8.4: TSP, Pm, and Rp Values for Different Effluent TSP Concentrations in the Bellefonte Reach

Seg.	Effluent TSP Concentrations (mg/L)											
	0.13			0.5			1.0			2.0		
	TSP*	Pm**	Rp**	TSP	Pm	Rp	TSP	Pm	Rp	TSP	Pm	Rp
1	0.056	82.5	30.1	0.071	85.6	31.2	0.090	88.5	32.3	0.127	91.7	33.4
2	0.056	94.5	34.5	0.071	98.2	35.8	0.090	101.5	37.0	0.127	105.1	38.3

* In-stream TSP mg/L
** mg/L/day

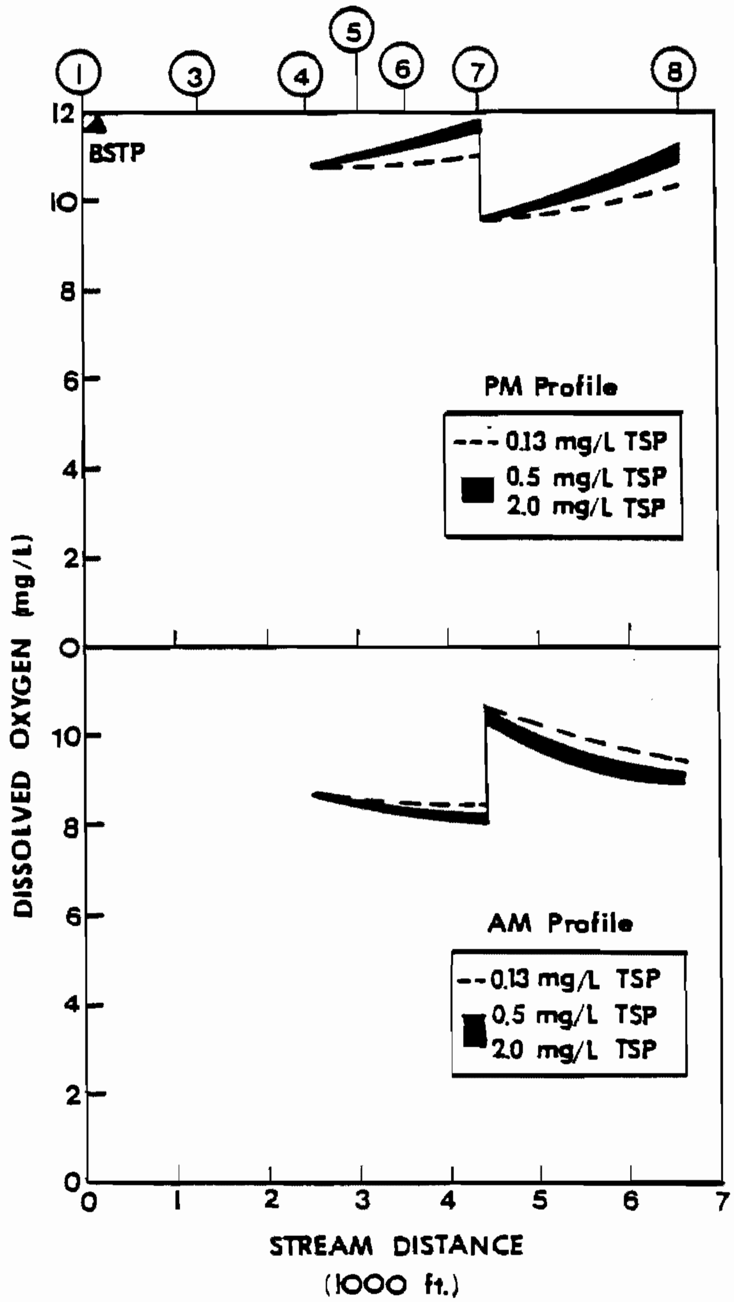


Figure 8.1: Predicted AM and PM DO Profiles at Different Effluent TSP Concentrations under $Q_{(7-10)}$ Conditions for the Bellefonte Reach

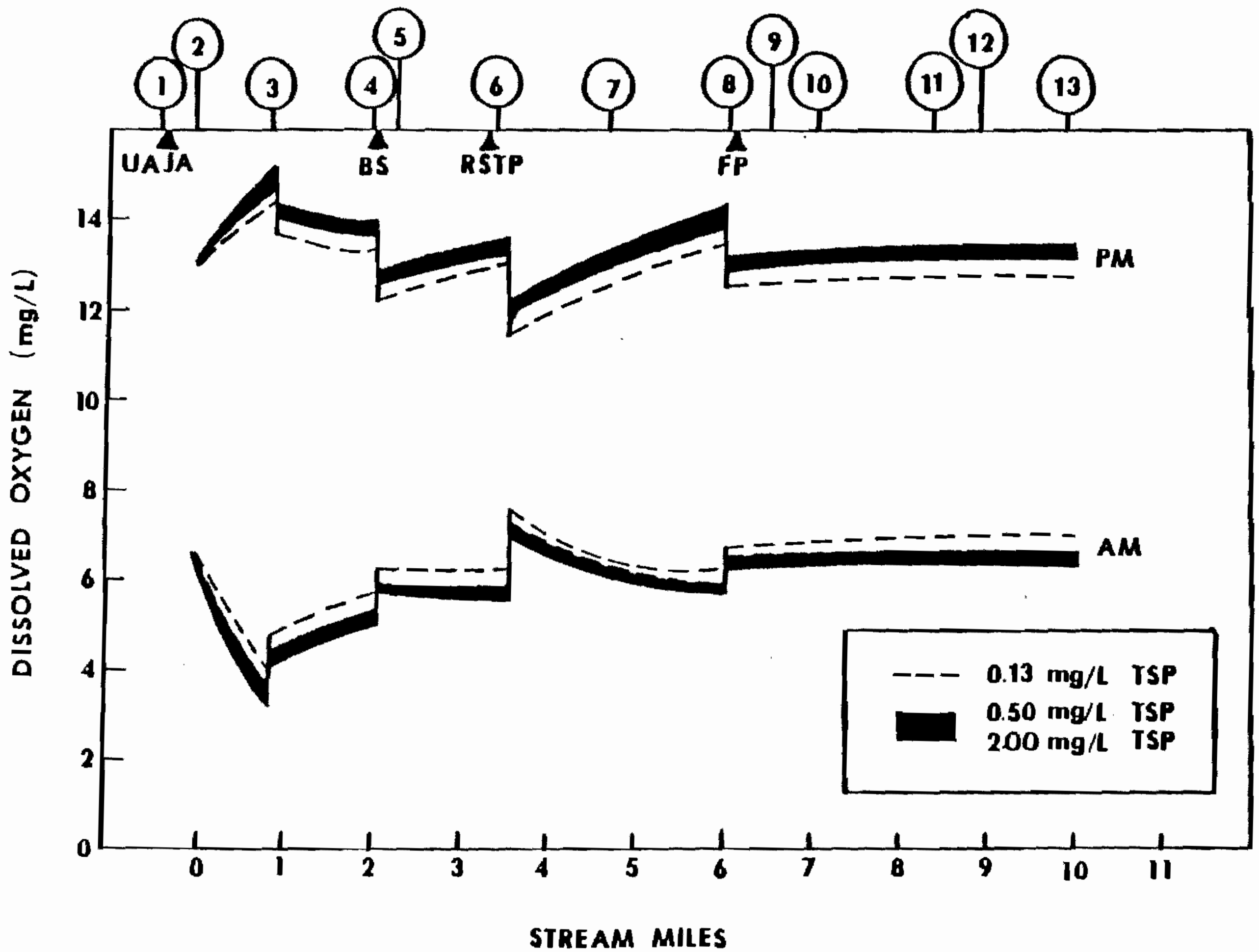


Figure 8.2: Predicted AM and PM DO Profiles at Different Effluent TSP Concentrations under $Q_{(7-10)}$ Conditions for the UAJA Reach

Table 8.5: Minimum DO Values for the UAJA Reach at Q(7-10) and Various Loading Conditions

Condition	DO Saturation (mg/L)	Total Deficit (mg/L)	Minimum DO at x=0.85 mi. (mg/L)
BOD5 = 3.56 TSP = 0.13	9.45	5.42	4.03
BOD5 = 3.56 TSP = 2.0	9.45	5.87	3.58
BOD5 = 10.0 TSP = 0.13	9.45	5.97	3.48
BOD5 = 10.0 TSP = 2.0	9.45	6.56	2.89

Table 8.6: Summary of Individual Deficits Produced at the Critical Point with a BOD Loading of 3.56 mg/L and an Effluent TSP Concentration of 0.13 mg/L for the UAJA Discharge

Effluent TSP concentration (mg/L)	Deficit (mg/L) From					Total	Total - plant Respiration
	Do	CBOD	NBOD	Plant Resp.	SOD		
0.13	0.948	0.502	0	3.276	0.671	5.38	2.12
0.5	0.948	0.502	0	3.564	0.671	5.69	2.12
1.0	0.948	0.502	0	3.666	0.671	5.79	2.12
2.0	0.948	0.502	0	3.723	0.671	5.84	2.12

Table 8.7: Minimum and Average DO Values at Different TSP Levels for UAJA Reach at Critical Point

Effluent TSP (mg/L)	Min. DO (mg/L)	Avg. DO (mg/L)	No. Hours below 5.0	Distance affected (mi.)
0.13	4.03	8.26	8	0.54
0.50	3.70	8.82	8	0.88
1.00	3.60	8.83	8	1.00
2.00	3.58	8.85	8	1.24

Discussion

Spring Creek, by nature of its chemistry, is a productive stream, exhibiting significant growth of aquatic macrophytes, especially in its upper reaches, in segments subject to siltation.

From the perspective of dissolved oxygen, the present analysis would suggest that the segment of Spring Creek below the Bellefonte discharge will be minimally impacted at effluent total soluble phosphorus limits of 2 mg/L, with average and pre-dawn dissolved oxygen levels expected to remain above the quality dissolved oxygen target of 5.0 mg/L.

For the segment below the University Area Joint Authority discharge at the $Q_{(7-10)}$ flow regime, pre-dawn violations of the dissolved oxygen standard can be expected, even for background chemistries. Increasing effluent limits from 0.13 mg/L to 2.0 mg/L total soluble phosphorus could result in a pre-dawn increase of 0.50 mg/L DO deficit generated, with an additional 0.7 mile impacted. Average daily DO concentrations, will however, remain above 5.0 mg/L.

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Appendix A

BOD DATA FOR UAJA AND BELLEFONTE, 1985 SURVEY

Table A.1: AM BOD Data for UAJA Reach

Sample Location	Type	BOD 5 (mg/L)	BOD 7 (mg/L)	BOD 9 (mg/L)	BOD 15 (mg/L)	BOD 20 (mg/L)
1A	U*	0.2				1.3
	I**	0.0				1.1
2A	U	2.8	5.4	5.4	5.2	4.9
	I	2.2	5.1	5.3	5.1	4.9
3A	U	1.2				3.2
	I	1.1				3.1
4A	U	1.2				3.2
	I	1.0				3.2
5A	U	1.6	2.3	2.4	3.1	3.4
	I	1.1	1.6	1.7	2.4	2.8
6A	U	2.0	2.7	3.4	4.0	4.5
	I	1.9	2.8	3.4	4.3	4.6
7A	U	1.2				4.8
	I	1.0				4.2
8A	U	1.2				2.9
	I	1.2				2.9
9A	U	0.1	1.2	1.4	2.0	2.1
	I	0.4	1.3	1.6	2.0	2.2
10A	U	0.8				2.7
	I	0.7				2.5
11A	U	1.1				2.1
	I	1.3				2.4
12A	U	1.0				1.9
	I	1.0				1.8
13A	U	1.1				2.2
	I	1.0				1.7

* U = Uninhibited BOD test

** I = Inhibited BOD test

Table A.2: PM BOD Data for UAJA Reach

Sample Location	Type	BOD 5 (mg/L)	BOD 7 (mg/L)	BOD 9 (mg/L)	BOD 15 (mg/L)	BOD 20 (mg/L)
1P	U	0.5				0.8
	I	0.6				0.9
2P	U	1.2	1.9	4.7	5.0	4.7
	I	1.1	2.1	4.7	5.2	4.7
3P	U	1.1				2.4
	I	1.2				2.2
4P	U	1.4				2.4
	I	1.4				2.4
5P	U	1.4	1.2	1.9	2.1	2.2
	I	1.4	1.0	1.4	1.8	2.2
6P	U	3.5	4.4	5.1	6.2	6.4
	I	3.4	4.1	5.0	6.3	6.4
7P	U	1.3				2.7
	I	1.3				2.5
8P	U	1.0				2.0
	I	1.1				1.8
9P	U	1.3	0.9	1.6	1.7	2.1
	I	1.1	0.7	1.0	1.4	1.9
10P	U	1.1				1.8
	I	1.2				2.1
11P	U	1.1				1.9
	I	1.0				1.5
12P	U	1.0				1.5
	I	0.9				1.4
13P	U	0.9				1.7
	I	1.0				1.7

Table A.3: AM BOD Data for Bellefonte Reach

Sample Location	Type	BOD 5 (mg/L)	BOD 7 (mg/L)	BOD 9 (mg/L)	BOD 15 (mg/L)	BOD 20 (mg/L)
1A	U	0.4				1.7
	I	0.5				1.3
3MA	U	1.0				1.2
	I	0.7				0.9
3PA	U	0.8				2.0
	I	0.4				1.8
4A	U	1.0	1.9	2.2	1.8	1.6
	I	0.6	1.3	2.1	1.6	1.5
5A	U	0.9				1.8
	I	0.9				2.0
6A	U	0.4				2.1
	I	0.3				1.9
7A	U	0.6				1.5
	I	0.3				1.5
8A	U	0.6				2.1
	I	0.5				2.0

Table A.4: PM BOD Data for Bellefonte Reach

Sample Location	Type	BOD 5 (mg/L)	BOD 7 (mg/L)	BOD 9 (mg/L)	BOD 15 (mg/L)	BOD 20 (mg/L)
1P	U	0.4				1.3
	I	0.3				1.0
3MP	U	0.2				0.7
	I	0.1				0.8
3PP	U	1.2				4.6
	I	1.1				4.9
4P	U	0.7	1.5	2.3	1.9	2.9
	I	0.3	0.3	0.6	1.4	2.8
5P	U	0.7				2.6
	I	0.5				2.4
6P	U	0.8				3.0
	I	0.5				2.8
7P	U	0.9				2.5
	I	0.7				2.3
8P	U	0.7				2.5
	I	0.8				2.6

Table A.5: BOD Data for Point Source Discharges

Sample Location	Time	Type	BOD 5 (mg/L)	BOD 20 (mg/L)	TKN (mg/L)	NH3-N (mg/L)
UAJA1	4:19 am	U	3.4	4.7	4.50	3.66
		I	3.6	4.8		
UAJA2	10:32 am	U	3.6	4.4	1.90	0.21
		I	3.7	4.4		
UAJA3	1:25 pm	U	0.0	4.5	1.95	0.59
		I	0.0	4.5		
UAJA4	5:43 pm	U	0.0	3.5	5.05	3.70
		I	0.0	2.7		
UAJA		U	0.3	5.2	3.70	2.60
COMPOSITE		I	0.3	5.3		
BS1	5:01 am	U	1.1	2.8	1.65	0.19
		I	1.1	2.5		
BS2	10:27 am	U	1.3	2.7	0.80	0.20
		I	1.3	2.3		
BS3	2:26 pm	U	1.4	3.4	0.90	0.26
		I	1.3	3.2		
BS4	8:32 pm	U	0.9	3.2	1.20	0.32
		I	0.8	2.8		
RSTP1	6:05 am	U	31.0	90.0	14.40	13.65
		I	30.0	36.0		
RSTP2	8:54 am	U	32.0	92.0	13.60	---
		I	32.0	62.0		
RSTP3	1:25 pm	U	68.0	264.0	15.20	11.50
		I	60.0	102.0		
RSTP4	8:35 pm	U	11.0	65.0	12.80	8.90
		I	10.0	38.0		
RSTP		U	47.0	108.0	18.40	10.20
COMPOSITE		I	50.0	98.0		

Table A.5 Continued

Sample Location	Time	Type	BOD 5 (mg/L)	BOD 20 (mg/L)	TKN (mg/L)	NH3-N (mg/L)
FP1	4:52 am	U	0.9	2.6	0.85	0.04
		I	1.1	2.6		
FP2	9:30 am	U	2.2	5.1	0.95	0.28
		I	2.2	4.9		
FP3	2:09 pm	U	3.1	6.7	1.10	0.41
		I	2.8	6.5		
FP4	9:12 pm	U	1.7	5.9	1.35	0.42
		I	1.7	5.6		
BSTP1	4:15 am	U	0.0	0.0	9.30	7.65
		I	0.0	0.0		
BSTP2	8:55 am	U	0.4	11.4	9.60	7.80
		I	0.0	10.8		
BSTP3	1:21 pm	U	0.0	11.2	12.40	10.50
		I	0.0	11.2		
BSTP4	8:18 pm	U	9.2	11.6	17.60	12.15
		I	8.9	11.8		
BSTP		U	4.1	11.4	12.60	10.30
COMPOSITE		I	3.6	11.6		

Appendix B

DATA FOR ANNUAL PRODUCTIVITY CURVES

Table B.1: Average Pg values used for Annual Productivity Curve

Data Set	System	Month	n	Pg gm/m^2/d	sigma Pg gm/m^2/d
1	Spring Creek 1966	Mar	1	6.5	--
		Apr	5	8.0	--
		May	1	6.1	--
		Jun	2	11.7	1.0
		Jul	2	13.0	--
		Aug	1	6.0	--
		Nov	1	2.7	--
		Dec	1	2.7	--
2	Lower Spring Creek (7-9) 1966	Jan	--	4.0*	--
		Feb	--	5.1*	--
		Mar	1	7.8	--
		Apr	--	14.2*	--
		May	3	17.7	4.3
		Jun	2	24.8	0.5
		Jun/Jul	4	21.2	2.5
		Jul	2	19.4	--
		Aug	1	14.2	--
		Oct	--	7.8*	--
		Nov	1	5.1	--
		Dec	1	4.0	--
3	Lower Spring Creek (9-10) 1966	Jan	--	4.6*	--
		Feb	--	4.8*	--
		Mar	1	11.1	--
		Apr	5	15.7	2.5
		May	2	16.3	1.4
		Jun	2	18.9	0.2
		Jun/Jul	4	16.7	2.0
		Jul	2	15.8	--
		Aug	1	8.2	--
		Nov	1	4.8	--
		Dec	2	4.6	0.0

Table B.1 Continued

Data Set	System	Month	n	Pg gm/m^2/d	sigma Pg gm/m^2/d
4	Spring Creek (3-4) 1980	Jan	--	3*	--
		Feb	--	3*	--
		Mar	--	5.8*	--
		Apr	--	9.5*	--
		May	7	12.0	2.2
		Jun	2	6.6	0.7
		Jun/Jul	10	7.9	2.0
		Jul	8	8.3	1.7
		Aug	10	8.8	1.5
		Sept	7	8.1	1.1
		Nov	3	3.4	0.6
5	Slab Cabin Run 1980	Jan	--	4.2*	--
		Feb	--	4.3*	--
		Mar	--	6.3*	--
		Apr	--	8.8*	--
		May	3	13.8	2.9
		Jun	8	26.1	2.5
		Jun/Jul	17	25.0	4.6
		Jul	9	23.9	5.1
		Aug	9	10.2	2.2
		Sept	6	8.5	1.7
		Oct	23	6.5	1.5
		Nov	--	4.2*	--
		Dec	--	4.2*	--

Table B.1 Continued

Data Set	System	Month	n	Pg gm/m^2/d	sigma Pg gm/m^2/d
6	Spring Creek (3-4) 1983/84	Jan	--	3*	--
		Feb	--	3*	--
		Mar	--	3.2*	--
		Apr	2	5.4	--
		May	3	12.7	0.4
		Jun	12	15.5	3.0
		Jun/Jul	17	14.0	3.0
		Jul	5	11.3	1.9
		Aug	5	11.7	2.5
		Sept	5	5.4	1.2
		Oct	13	3.2	1.0
		Nov	--	3*	--
		Dec	--	3*	--
7	Slab Cabin Run 1983/84	Jan	--	2.8*	--
		Feb	--	2.8*	--
		Mar	--	4.8*	--
		Apr	--	8.3*	--
		May	3	15.1	2.9
		Jun	13	13.5	3.0
		Jun/Jul	17	14.9	4.1
		Jul	4	18.9	1.6
		Aug	5	10.4	0.5
		Sept	4	8.5	0.7
		Oct	6	4.5	0.5
		Nov	4	2.5	--
		Dec	--	2.8*	--

* = assumed point

Appendix C

DATA USED FOR PG, SR AND TSP RELATIONSHIP

Table C.1: Data Used for Pg, TSP and SR Relationship

Data Set	System	Date	Pg gm/m^2/day	Solar Radiation kcal/m^2/day	Avg. TSP mg/L
1	Spring Creek	6/14/66	9.05	4029	0.019
	(3-4)	6/15/66	9.17	6467	
	1966	7/20/66	10.51	7496	
		7/20/67	9.65	3559	
2	Lower	6/14/66	24.36	4029	0.802
	Spring Creek	6/15/66	25.33	6467	
	(7-9)	7/20/66	18.41	7496	
	1966	7/20/67	20.26	3559	
3	Lower	6/14/66	18.69	4029	0.764
	Spring Creek	6/15/66	19.09	6467	
	(9-10)	7/20/66	17.60	7496	
	1966				
4	Spring Creek	6/29/80	5.90	1600	0.008
	(3-4)	6/30/80	7.30	4340	
	1980	7/13/80	10.80	6770	
		7/25/80	8.70	6220	
		7/26/80	8.50	6090	
		7/27/80	10.60	4760	
		7/28/80	5.00	1310	
		7/29/80	7.50	5320	
		7/30/80	7.70	4180	
		7/31/80	7.40	2850	

Table C.1 Continued

Data Set	System	Date	Pg gm/m^2/day	Solar Radiation kcal/m^2/day	Avg. TSP mg/L
5	Slab Cabin	6/19/80	23.70	6530	0.641
	Run	6/20/80	9.70	2400	
	1980	6/21/80	21.70	2400	
		6/22/80	24.20	6250	
		6/23/80	26.50	6110	
		6/24/80	25.10	4610	
		6/25/80	29.20	6470	
		6/26/80	29.60	6450	
		7/23/80	21.60	3890	
		7/24/80	25.30	6350	
		7/25/80	29.50	6220	
		7/26/80	33.40	6090	
		7/27/80	30.00	4760	
		7/28/80	6.40	1310	
		7/29/80	19.70	5320	
		7/31/80	18.40	2850	
6	Spring Creek	6/3/83	15.60	3940	0.016
	(3-4)	6/14/83	15.50	6730	
	1983/84	6/15/83	16.30	6270	
		6/16/83	13.20	6170	
		7/6/83	10.10	5220	
		7/7/83	11.80	6990	
		7/26/83	8.50	6600	
		7/27/83	14.00	6510	
		7/28/83	12.20	5460	
		6/5/84	14.80	6970	
		6/6/84	12.70	4070	
		6/7/84	18.20	6140	
		6/12/84	19.90	7130	
		6/13/84	12.80	5340	
		6/14/84	15.70	5410	
		6/27/84	12.80	4200	
		6/28/84	17.10	5660	

Table C.1 Continued

Data Set	System	Date	Pg gm/m^2/day	Solar Radiation kcal/m^2/day	Avg. TSP mg/L
7	Slab Cabin	6/9/83	10.80	6970	0.115
	Run	6/22/83	14.90	7330	
	1983/84	6/23/83	14.90	7330	
		6/24/83	15.10	6550	
		7/19/83	17.50	3350	
		7/20/83	17.40	3920	
		7/21/83	21.90	3500	
		7/22/83	18.50	3900	
		6/5/84	17.00	6970	
		6/6/84	12.70	4070	
		6/7/84	20.10	6120	
		6/12/84	14.60	7130	
		6/13/84	14.00	5350	
		6/14/84	11.00	5310	
		6/27/84	6.50	4200	
		6/28/84	9.40	5660	

Appendix D

WATER QUALITY DATA

Table D.1: Bellefonte 1985 Survey Water Quality Data 7-25-85 4:00 am Profile

STATION	1	2	3	4	5	6	7	8
MILE POINT	0	0.21	0.21	0.48	0.59	0.67	0.82	1.28
DISSOLVED OXYGEN mg/L	9.10	8.95	9.00	8.90	9.00	9.10	10.50	10.10
TEMPERATURE oC	14.00	14.50	14.00	14.25	14.00	14.00	14.00	14.00
pH	7.78	7.85	7.89	7.89	7.95	7.90	8.00	8.00
ALKALINITY mg CaCO3/L	179.55	176.40	540.75	181.65	177.45	176.40	176.40	172.20
TKN mg TKN-N/L	0.450	0.750	0.700	0.650	0.650	0.700	0.650	0.750
NITRATE NITROGEN mg NO3-N/L	2.800	2.750	2.800	2.800	2.800	2.800	2.800	2.800
NITRITE NITROGEN mg NO2-N/L	0.015	0.025	0.015	0.025	0.025	0.025	0.020	0.025
AMMONIA NITROGEN mg NH3-N/L	0.010	0.235	0.025	0.135	0.110	0.120	0.090	0.090
TOTAL SUSPENDED SOLIDS mg/L	7.120	5.800	7.280	7.880	7.920	9.600	12.480	12.840
TOTAL PHOSPHORUS mg/L	0.059	0.082	0.060	0.077	0.068	0.072	0.072	0.080
FILTERED TOTAL PHOSPHORUS mg/L	0.060	0.078	0.057	0.072	0.071	0.078	0.071	0.077
ORTHO-PHOSPHORUS mg/L	0.045	0.071	0.047	0.068	0.068	0.069	0.055	0.069
FILTERED ORTHO-PHOSPHORUS mg/L	0.056	0.073	0.053	0.069	0.064	0.075	0.067	0.071
Cl (mg/L)	12.40	17.82	12.80	15.97	17.45	17.17	16.02	16.78
CBOD5 UNINHIBITED (mg/L)	0.4	0.8	1.0	1.0	0.9	0.4	0.6	0.6
CBOD5 INHIBITED (mg/L)	0.5	0.4	0.7	0.6	0.9	0.3	0.3	0.5
CBOD20 UNINHIBITED (mg/L)	1.7	2.0	1.2	1.8	1.8	2.1	1.5	2.1
CBOD20 INHIBITED (mg/L)	1.3	1.8	0.9	1.5	2.0	1.9	1.5	2.0

Table D.2: Bellefonte 1985 Survey Water Quality Data 7-25-85 2:00 pm Profile

STATION	1	3	3	4	5	6	7	8
MILE POINT	0	0.21	0.21	0.48	0.59	0.67	0.62	1.26
DISSOLVED OXYGEN mg/L	10.8	10.3	10.8	10.8	10.7	10.6	9.8	9.7
TEMPERATURE oC	15.00	15.00	15.00	15.50	15.25	14.50	14.00	14.50
pH	8.14	8.02	8.19	8.16	8.18	8.15	8.21	8.24
ALKALINITY mg $CaCO_3$/L	171.15	170.10	164.85	172.20	180.65	170.10	188.00	181.70
TKN mg TKN-N/L	0.500	1.500	0.750	0.600	0.800	0.800	0.650	0.700
NITRATE NITROGEN mg NO_3-N/L	3.250	3.100	3.260	3.200	3.250	3.250	3.250	3.250
NITRITE NITROGEN mg NO_2-N/L	0.010	0.045	0.010	0.030	0.025	0.030	0.020	0.030
AMMONIA NITROGEN mg NH_3-N/L	<0.005	0.760	0.010	0.320	0.245	0.230	0.085	0.095
TOTAL SUSPENDED SOLIDS mg/L	1.52	2.12	<1.00	<1.00	<1.00	1.96	2.6	2.32
TOTAL PHOSPHORUS mg/L	0.047	0.167	0.051	0.091	0.096	0.084	0.075	0.084
FILTERED TOTAL PHOSPHORUS mg/L	0.048	0.130	0.047	0.082	0.078	0.073	0.059	0.059
ORTHO-PHOSPHORUS mg/L	0.042	0.149	0.045	0.088	0.080	0.077	0.058	0.063
FILTERED ORTHO-PHOSPHORUS mg/L	0.043	0.120	0.048	0.077	0.071	0.062	0.057	0.056
Cl (mg/L)	14.96	32.38	14.75	20.4	19.56	19.85	17.82	18.74
CBOD5 UNINHIBITED (mg/L)	0.4	1.2	0.2	0.7	0.7	0.8	0.9	0.7
CBOD5 INHIBITED (mg/L)	0.3	1.1	0.1	0.3	0.5	0.6	0.7	0.8
CBOD20 UNINHIBITED (mg/L)	1.3	4.6	0.7	2.9	2.6	3.0	2.5	2.5
CBOD20 INHIBITED (mg/L)	1.0	4.9	0.8	2.8	2.4	2.8	2.3	2.6

Table D.3: Bellefonte 1985 Survey Water Quality Data 7-25-85 Average Values

STATION	1	3M	3P	4	5	6	7	8
MILE POINT	0	0.21	0.21	0.48	0.59	0.67	0.82	1.26
DISSOLVED OXYGEN mg/L	9.95	9.63	9.90	9.85	9.85	9.85	10.15	9.90
TEMPERATURE oC	14.60	14.75	14.50	14.88	14.63	14.25	14.00	14.25
pH	7.96	7.94	8.04	8.03	8.06	8.03	8.11	8.12
ALKALINITY mg $CaCO_3$/L	175.35	173.25	352.80	176.93	169.05	173.25	172.20	166.95
TKN mg TKN-N/L	0.475	1.125	0.725	0.625	0.725	0.750	0.650	0.726
NITRATE NITROGEN mg NO_3-N/L	3.025	2.925	3.025	3.000	3.025	3.026	3.025	3.025
NITRITE NITROGEN mg NO_2-N/L	0.013	0.035	0.013	0.028	0.025	0.028	0.020	0.028
AMMONIA NITROGEN mg NH_3-N/L	0.010	0.493	0.018	0.228	0.178	0.175	0.068	0.093
TOTAL SUSPENDED SOLIDS mg/L	4.32	3.86	3.64	3.94	3.96	5.78	7.54	7.58
TOTAL PHOSPHORUS mg/L	0.053	0.125	0.066	0.084	0.082	0.078	0.074	0.082
FILTERED TOTAL PHOSPHORUS mg/L	0.054	0.103	0.052	0.077	0.075	0.076	0.065	0.068
ORTHO-PHOSPHORUS mg/L	0.044	0.110	0.046	0.077	0.074	0.073	0.057	0.066
FILTERED ORTHO-PHOSPHORUS mg/L	0.050	0.097	0.050	0.073	0.068	0.069	0.062	0.063
Cl (mg/L)	13.68	25.10	13.78	18.19	18.50	18.51	18.92	17.76
CBOD5 UNINHIBITED (mg/L)	0.4	1.0	0.6	0.9	0.8	0.6	0.8	0.7
CBOD5 INHIBITED (mg/L)	0.4	0.8	0.4	0.5	0.7	0.4	0.5	0.7
CBOD20 UNINHIBITED (mg/L)	1.5	3.3	1.0	2.3	2.2	2.6	2.0	2.3
CBOD20 INHIBITED (mg/L)	1.2	3.4	0.9	2.2	2.2	2.4	1.9	2.3

Table D.4: UAJA Survey Water Quality Data 7-17-85 4:00 am Profile

STATION	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13
MILE POINT	-0.005	0.38	1.21	2.43	2.57	3.93	5.04	6.47	8.93	7.53	8.79	9.33	10.29
DISSOLVED OXYGEN mg/L	6.90	8.90	6.40	8.40	6.50	6.20	6.90	7.30	7.10	7.10	7.30	7.35	7.50
TEMPERATURE oC	16.00	16.00	17.00	17.00	17.00	16.00	16.50	17.50	17.00	17.00	18.00	16.50	16.50
pH	7.80	7.71	7.74	7.77	7.80	7.78	7.65	7.91	7.89	7.86	7.85	7.92	7.93
ALKALINITY mg CaCO3/L	218.40	216.30	216.30	203.70	197.40	207.90	185.85	197.40	208.85	193.20	198.35	203.70	195.30
TKN mg TKN-N/L	0.850	0.950	0.850	0.900	0.850	1.100	1.100	0.700	0.800	0.750	0.750	0.800	0.800
NITRATE NITROGEN mg NO3-N/L	3.250	3.850	3.800	3.950	3.950	3.800	2.300	3.900	3.800	3.700	3.600	3.500	3.450
NITRITE NITROGEN mg NO2-N/L	0.030	0.070	0.950	0.125	0.115	0.110	0.050	0.060	0.050	0.045	0.035	0.030	0.030
AMMONIA NITROGEN mg NH3-N/L	0.320	0.165	0.135	0.140	0.235	0.360	0.080	0.045	0.045	0.025	0.020	0.150	0.035
TOTAL SUSPENDED SOLIDS mg/L	1.840	15.520	10.120	7.840	15.680	30.400	6.240	28.980	8.480	21.120	16.320	18.680	4.440
TOTAL PHOSPHORUS mg/L	0.067	0.120	0.158	0.179	0.148	0.183	0.127	0.210	0.205	0.199	0.192	0.223	0.193
FILTERED TOTAL PHOSPHORUS mg/L	0.057	0.072	0.080	0.085	0.093	0.108	0.096	0.131	0.131	0.132	0.139	0.134	0.134
ORTHO-PHOSPHORUS mg/L	0.036	0.072	0.100	0.103	0.095	0.117	0.092	0.134	0.131	0.127	0.119	0.122	0.121
FILTERED ORTHO-PHOSPHORUS mg/L	0.040	0.054	0.061	0.074	0.071	0.098	0.084	0.112	0.114	0.115	0.117	0.113	0.113
Cl (mg/L)	19.78	27.70	23.74	27.31	26.51	22.55	9.48	24.14	22.55	21.37	21.37	20.97	19.79
CBOD5 UNINHIBITED (mg/L)	0.2	2.8	1.2	1.2	1.6	2.0	1.2	1.2	0.1	0.8	1.1	1.0	1.1
CBOD5 INHIBITED (mg/L)	0.0	2.2	1.1	1.0	1.1	1.9	1.0	1.2	0.4	0.7	1.3	1.0	1.0
CBOD20 UNINHIBITED (mg/L)	1.3	4.9	3.2	3.2	3.4	4.5	4.8	2.9	2.1	2.7	2.1	1.9	2.2
CBOD20 INHIBITED (mg/L)	1.1	4.9	3.1	3.2	2.8	4.6	4.2	2.9	2.2	2.5	2.4	1.8	1.7

Table D.6: UAJA Survey Water Quality Data 7-17-86 2:00 pm Profile

STATION	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13
Mile Point	-0.005	0.36	1.21	2.43	2.67	3.93	5.04	6.47	6.93	7.53	8.79	9.33	10.29
DISSOLVED OXYGEN mg/L	14.4	12.9	12.8	13.0	12.1	12.5	10.8	11.5	11.8	11.4	11.9	12.2	12.4
TEMPERATURE oC	19.00	19.25	20.00	21.00	20.25	19.00	18.50	20.00	18.00	20.00	20.00	20.50	21.00
pH	8.36	8.16	8.24	8.43	8.42	8.35	8.21	8.37	8.24	8.43	8.56	8.82	8.66
ALKALINITY mg CaCO3/L	225.75	201.60	197.40	198.45	202.65	200.55	190.05	188.80	183.20	186.90	185.85	192.15	190.05
TKN mg TKN-N/L	0.650	0.800	0.600	0.700	0.650	1.000	0.700	0.600	0.650	0.650	0.600	0.700	0.550
NITRATE NITROGEN mg NO3-N/L	3.400	4.700	4.700	4.000	3.900	3.450	3.700	3.700	3.700	3.800	3.500	3.600	3.450
NITRITE NITROGEN mg NO2-N/L	0.015	0.020	0.025	0.025	0.030	0.050	0.050	0.035	0.030	0.030	0.020	0.020	0.015
AMMONIA NITROGEN mg NH3-N/L	0.015	0.050	0.040	0.025	0.035	0.310	0.080	0.030	0.040	0.035	0.055	0.035	0.045
TOTAL SUSPENDED SOLIDS mg/L	<1.00	<1.00	<1.00	<1.00	<1.00	1.04	2.88	1.44	1.56	<1.00	<1.00	<1.00	1.08
TOTAL PHOSPHORUS mg/L	0.054	0.088	0.111	0.100	0.095	0.141	0.114	0.115	0.121	0.112	0.114	0.123	0.113
FILTERED TOTAL PHOSPHORUS mg/L	0.052	0.069	0.100	0.090	0.101	0.157	0.123	0.119	0.096	0.106	0.107	0.108	0.107
ORTHO-PHOSPHORUS mg/L	0.036	0.082	0.110	0.089	0.092	0.139	0.106	0.100	0.095	0.100	0.098	0.103	0.100
FILTERED ORTHO-PHOSPHORUS mg/L	0.029	9.047	0.072	0.068	0.081	0.131	0.102	0.100	0.082	0.087	0.089	0.088	0.086
Cl (mg/L)	19.39	35.23	34.04	28.89	26.51	20.18	21.76	22.95	21.76	21.76	21.76	20.9	21.37
CBOD5 UNINHIBITED (mg/L)	0.5	1.2	1.1	1.4	1.4	3.5	1.3	1.0	1.3	1.1	1.1	1.0	0.8
CBOD5 INHIBITED (mg/L)	0.6	1.1	1.2	1.4	1.4	3.4	1.3	1.1	1.1	1.2	1.0	0.9	1.0
CBOD20 UNINHIBITED (mg/L)	0.8	4.7	2.4	2.4	2.2	6.4	2.7	2.0	2.1	1.8	1.9	1.5	1.7
CBOD20 INHIBITED (mg/L)	0.9	4.7	2.2	2.4	2.2	6.4	2.5	1.8	1.9	2.1	1.5	1.4	1.7

Table D.6: UAJA Survey Water Quality Data 7-17-85 Average Values

STATION	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13
MILE POINT	-0.005	0.36	1.21	2.43	2.57	3.93	5.04	6.47	6.93	7.53	8.79	9.33	10.29
DISSOLVED OXYGEN mg/L	10.65	10.90	9.60	9.70	9.30	9.35	8.65	9.40	9.45	9.25	9.60	9.78	9.95
TEMPERATURE oC	17.50	17.63	18.50	19.00	18.63	17.50	17.50	18.75	18.00	18.50	18.00	18.50	18.75
pH	8.08	7.94	7.99	8.10	8.11	8.07	7.93	8.14	8.07	8.15	8.21	8.27	8.30
ALKALINITY mg CaCO3/L	222.08	208.95	208.85	201.08	200.03	204.23	187.95	192.15	200.03	190.05	191.10	197.93	192.68
TKN mg TKN-N/L	0.650	0.875	0.725	0.800	0.750	1.050	0.900	0.650	0.725	0.700	0.675	0.750	0.875
NITRATE NITROGEN mg NO3-N/L	3.325	4.275	4.250	3.875	3.925	3.625	3.000	3.800	3.750	3.650	3.550	3.550	3.450
NITRITE NITROGEN mg NO2-N/L	0.023	0.045	0.488	0.075	0.073	0.080	0.050	0.048	0.040	0.038	0.028	0.025	0.023
AMMONIA NITROGEN mg NH3-N/L	0.168	0.108	0.088	0.083	0.135	0.335	0.080	0.038	0.043	0.030	0.038	0.093	0.040
TOTAL SUSPENDED SOLIDS mg/L	0.92	7.76	5.08	3.82	7.64	15.72	4.58	15.20	5.02	10.58	8.16	8.34	2.76
TOTAL PHOSPHORUS mg/L	0.081	0.104	0.135	0.140	0.122	0.162	0.121	0.163	0.183	0.156	0.153	0.173	0.153
FILTERED TOTAL PHOSPHORUS mg/L	0.055	0.071	0.090	0.088	0.097	0.133	0.110	0.125	0.114	0.119	0.123	0.121	0.121
ORTHO-PHOSPHORUS mg/L	0.036	0.077	0.105	0.098	0.094	0.128	0.099	0.117	0.113	0.114	0.109	0.113	0.111
FILTERED ORTHO-PHOSPHORUS mg/L	0.035	4.551	0.067	0.071	0.076	0.114	0.093	0.106	0.098	0.101	0.103	0.101	0.100
Cl (mg/L)	19.59	31.47	28.89	28.10	26.51	21.37	15.62	23.55	22.16	21.57	21.57	20.84	20.58
CBOD5 UNINHIBITED (mg/L)	0.4	2.0	1.2	1.3	1.5	2.8	1.3	1.1	0.7	1.0	1.1	1.0	1.0
CBOD5 INHIBITED (mg/L)	0.3	1.7	1.2	1.2	1.3	2.7	1.2	1.2	0.8	1.0	1.2	1.0	1.0
CBOD20 UNINHIBITED (mg/L)	1.1	4.8	2.8	2.8	2.8	5.5	3.8	2.5	2.1	2.3	2.0	1.7	2.0
CBOD20 INHIBITED (mg/L)	1.0	4.8	2.7	2.8	2.5	5.5	3.4	2.4	2.1	2.3	2.0	1.6	1.7

Table D.7: Bellefonte 1984 Survey Water Quality Data 7-31-84 4:00 am Profile

STATION	1	3M	3P	4	5	6	7	8
MILE POINT	0	0.21	0.21	0.48	0.59	0.67	0.82	1.26
DISSOLVED OXYGEN mg/L	9.50	9.50	9.40	9.50	8.65	9.20	9.60	9.70
TEMPERATURE oC	13.00	13.00	13.00	13.00	13.00	13.00	12.50	12.50
pH	8.01	8.03	7.99	8.02	8.03	8.03	8.10	8.12
ALKALINITY mg $CaCO_3$/L	179.55	176.40	540.75	181.65	177.45	176.40	176.40	172.20
TKN mg TKN-N/L	0.450	0.750	0.700	0.650	0.650	0.700	0.650	0.750
NITRATE NITROGEN mg NO_3-N/L	3.400	3.400	3.350	3.400	3.450	3.450	3.460	3.400
NITRITE NITROGEN mg NO_2-N/L	0.010	0.010	0.020	0.020	0.015	0.020	0.015	0.020
AMMONIA NITROGEN mg NH_3-N/L	<0.005	0.020	0.230	0.105	0.080	0.090	0.070	0.070
TOTAL SUSPENDED SOLIDS mg/L	7.120	5.800	7.280	7.880	7.920	9.600	12.480	12.840
TOTAL PHOSPHORUS mg/L	0.041	0.058	0.165	0.098	0.089	0.102	0.101	0.099
FILTERED TOTAL PHOSPHORUS mg/L	0.036	0.029	0.135	0.073	0.062	0.068	0.052	0.076
ORTHO-PHOSPHORUS mg/L	0.046	0.049	0.155	0.091	0.078	0.085	0.070	0.076
FILTERED ORTHO-PHOSPHORUS mg/L	0.032	0.036	0.133	0.077	0.064	0.074	0.060	0.053
Cl (mg/L)	18.10	18.50	19.40	18.90	18.70	18.50	18.10	17.70
CBOD5 UNINHIBITED (mg/L)	0.4	0.8	1.0	1.0	0.9	0.4	0.6	0.6
CBOD5 INHIBITED (mg/L)	0.5	0.4	0.7	0.6	0.9	0.3	0.3	0.5
CBOD20 UNINHIBITED (mg/L)	5.2	5.4	8.7	6.6	6.3	6.7	6.4	5.9
CBOD20 INHIBITED (mg/L)	4.6	5.4	6.8	6.4	6.4	6.1	6.2	5.8

CBOD20 UNINHIBITED (mg/L)	[illegible]	[illegible]	[illegible]					
CBOD20 INHIBITED (mg/L)	4.6	5.4	6.8	6.4	6.4	6.1	6.2	5.8

Table D.8: Bellefonte 1984 Survey Water Quality Data 7-31-84 2:00 pm Profile

STATION	1	3H	3P	4	5	6	7	8
Mile Point	0	0.21	0.21	0.48	0.59	0.67	0.82	1.26
DISSOLVED OXYGEN mg/L	11.8	12.0	11.8	12.0	12.0	11.9	10.1	10.3
TEMPERATURE oC	15.00	16.00	18.00	16.00	18.00	16.50	15.50	15.50
pH	8.53	8.54	8.46	8.5	8.51	8.47	8.47	8.44
ALKALINITY mg CaCO3/L	171.15	170.10	164.85	172.20	180.65	170.10	168.00	181.70
TKN mg TKN-N/L	0.500	1.500	0.760	0.800	0.800	0.800	0.650	0.700
NITRATE NITROGEN mg NO3-N/L	3.050	3.060	3.000	3.050	3.000	3.000	3.000	3.000
NITRITE NITROGEN mg NO2-N/L	0.020	0.015	0.025	0.020	0.020	0.025	0.020	0.020
AMMONIA NITROGEN mg NH3-N/L	0.010	0.040	0.475	0.220	0.210	0.215	0.140	0.130
TOTAL SUSPENDED SOLIDS mg/L	1.52	2.12	<1.00	<1.00	<1.00	1.96	2.6	2.32
TOTAL PHOSPHORUS mg/L	0.037	0.068	0.263	0.142	0.123	0.122	0.078	0.093
FILTERED TOTAL PHOSPHORUS mg/L	0.032	0.039	0.216	0.118	0.114	0.107	0.071	0.081
ORTHO-PHOSPHORUS mg/L	0.400	0.061	0.218	0.122	0.117	0.117	0.087	0.090
FILTERED ORTHO-PHOSPHORUS mg/L	0.033	0.045	0.188	0.107	0.105	0.104	0.073	0.076
Cl (mg/L)	17.4	18.1	19.3	18.5	18.7	18.1	18.1	17.9
CBOD5 UNINHIBITED (mg/L)	0.4	1.2	0.2	0.7	0.7	0.8	0.9	0.7
CBOD5 INHIBITED (mg/L)	0.3	1.1	0.1	0.3	0.5	0.5	0.7	0.8
CBOD20 UNINHIBITED (mg/L)	1.3	4.6	0.7	2.9	2.8	3.0	2.5	2.5
CBOD20 INHIBITED (mg/L)	1.0	4.9	0.8	2.8	2.4	2.8	2.3	2.6

Table D.9: Bellefonte 1984 Survey Water Quality Data 7-31-84 Average Values

STATION	1	3M	3P	4	5	6	7	8
MILE POINT	0	0.21	0.21	0.48	0.59	0.87	0.82	1.26
DISSOLVED OXYGEN mg/L	10.75	10.65	10.70	10.75	10.25	9.65	10.05	4.85
TEMPERATURE oC	14.00	14.50	14.50	14.60	14.60	14.75	14.00	14.00
pH	8.27	8.29	8.23	8.28	8.27	8.25	8.29	8.28
ALKALINITY mg $CaCO_3$/L	175.35	173.25	362.80	176.93	169.05	173.25	172.20	166.95
TKN mg TKN-N/L	0.475	1.125	0.725	0.625	0.725	0.750	0.650	0.725
NITRATE NITROGEN mg NO_3-N/L	3.225	3.225	3.175	3.225	3.226	3.225	3.225	3.200
NITRITE NITROGEN mg NO_2-N/L	0.015	0.013	0.023	0.020	0.018	0.023	0.018	0.020
AMMONIA NITROGEN mg NH_3-N/L	0.010	0.030	0.353	0.163	0.145	0.153	0.105	0.100
TOTAL SUSPENDED SOLIDS mg/L	4.32	3.96	4.14	4.44	4.48	5.78	7.54	7.58
TOTAL PHOSPHORUS mg/L	0.039	0.062	0.214	0.119	0.108	0.112	0.090	0.096
FILTERED TOTAL PHOSPHORUS mg/L	0.034	0.034	0.176	0.096	0.088	0.088	0.062	0.079
ORTHO-PHOSPHORUS mg/L	0.223	0.050	0.186	0.107	0.098	0.101	0.079	0.083
FILTERED ORTHO-PHOSPHORUS mg/L	0.033	0.041	0.161	0.092	0.085	0.089	0.067	0.065
Cl (mg/L)	17.75	18.30	19.35	18.70	18.70	18.30	18.10	17.80
CBOD5 UNINHIBITED (mg/L)	0.4	1.0	0.6	0.9	0.8	0.6	0.8	0.7
CBOD5 INHIBITED (mg/L)	0.4	0.8	0.4	0.5	0.7	0.4	0.5	0.7
CBOD20 UNINHIBITED (mg/L)	3.3	5.0	4.7	4.8	4.5	4.9	4.5	4.2
CBOD20 INHIBITED (mg/L)	2.8	5.1	3.8	4.6	4.4	4.4	4.2	4.2

Appendix E

STATISTICS

I. Significance tests for slope and Intercept for Bellefonte Segment 1985.

a) Slope

H_0: beta = 1

H_a: beta ≠ 1

T.S.: $\frac{\text{beta} - 1}{s(\text{beta})} = \frac{1.033 - 1}{0.05753} = 0.573$

Critical Region: $-t_{alpha/2} > t > t_{alpha/2}$

$$t_{(0.05,\ 28)} = 1.701$$

Conclusion: Fail to reject H_0: beta = 1 at alpha = 0.1, and conclude that there is insufficient evidence to say that beta does not equal 1.0

b) Intercept

H_0: alpha = 0

H_a: alpha ≠ 0

T.S.: $\frac{\text{alpha}}{s(\text{alpha})} = \frac{-0.4099}{0.5616} = -0.729$

Critical Region: $-t_{alpha/2} > t > t_{alpha/2}$

$$t_{(0.05,\ 28)} = 1.701$$

Conclusion: Fail to reject H_0: alpha = 0 at alpha = 0.1, and conclude that there is insufficient evidence to say that alpha does not equal 0

II. Significance tests for slope and Intercept for UAJA Segment 1985.

a) Slope

H_0: beta = 1

H_a: beta ≠ 1

T.S.: $\frac{\text{beta} - 1}{s(\text{beta})} = \frac{1.053 - 1}{0.04869} = 1.088$

Critical Region: $-t_{alpha/2} > t > t_{alpha/2}$

$$t_{(0.05,\ 28)} = 1.701$$

Conclusion: Fail to reject H_0: beta = 1 at alpha = 0.1, and conclude that there is insufficient evidence to say that beta does not equal 1.0

b) Intercept

H_0: alpha = 0

H_a: alpha ≠ 0

T.S.: $\frac{\text{alpha}}{s(\text{alpha})} = \frac{-0.694}{0.6089} = -1.139$

Critical Region: $-t_{alpha/2} > t > t_{alpha/2}$

$$t_{(0.05,\ 28)} = 1.701$$

Conclusion: Fail to reject H_0: alpha = 0 at alpha = 0.1, and conclude that there is insufficient evidence to say that alpha does not equal 0

Appendix F

DO PROFILE DATA

Table F.1: AM and PM DO Profile Data for the Bellefonte Survey, 1985

Distance (miles)	Predicted Values AM	Predicted Values PM	Measured Values AM	Measured Values PM
0.00	8.90	10.80	8.90	10.80
0.02	8.88	10.80		
0.06	8.85	10.80		
0.10	8.82	10.80		
0.12	8.81	10.80	9.00	10.70
0.13	8.79	10.80		
0.17	8.76	10.80		
0.19	8.75	10.80	9.10	10.60
0.34	10.50	9.85	10.50	9.85
0.43	10.39	9.90		
0.52	10.29	9.94		
0.61	10.19	9.98		
0.70	10.09	10.02		
0.78	9.99	10.06	10.10	9.70

Table F.2: AM and PM DO Profile Data for the UAJA Reach

Distance (miles)	Predicted Values AM	PM	Measured Values AM	PM
0.00	6.60	12.81	6.60	12.80
0.17	6.40	12.77		
0.34	6.24	12.73		
0.51	6.10	12.71		
0.68	5.99	12.63		
0.85	5.89	12.53	6.40	12.80
0.85	6.80	12.00	6.80	12.00
0.97	6.72	11.83		
1.22	6.61	11.53		
1.46	6.54	11.46		
1.70	6.48	11.38		
1.95	6.44	11.33		
2.07	6.44	11.31	6.40	13.00
2.07	6.69	12.20		
2.21	6.50	12.10	6.50	12.10
2.44	6.54	12.04		
2.68	6.59	11.98		
2.91	6.63	11.95		
3.15	6.66	11.89		
3.38	6.69	11.83	6.20	12.50
3.38	7.40	11.20	7.40	11.20
3.93	7.19	11.44		
4.47	7.09	11.65		
4.75	7.06	11.71	6.90	10.80
5.29	7.05	11.78		
5.84	7.05	11.08		
6.11	7.05	11.81	7.30	11.50
6.11	7.20	11.60		
6.57	7.10	11.80	7.10	11.80
7.24	7.14	11.78		
7.91	7.16	11.85		
8.59	7.18	11.92	7.30	11.90
8.92	7.19	11.93	7.35	12.22
9.93	7.21	11.96	7.50	12.40

Table F.3: DO Profile Data for UAJA (10 mg/L BOD Requirement)

Distance	0.13 TSP		0.50 TSP		2.0 TSP	
miles	AM	PM	AM	PM	AM	PM
0.00	6.60	12.81	6.60	12.81	6.60	12.81
0.17	5.49	12.85	5.40	13.33	5.35	13.42
0.34	4.69	12.77	4.51	13.66	4.42	13.82
0.51	4.12	12.63	3.85	13.82	3.75	14.03
0.68	3.75	12.59	3.39	13.98	3.25	14.22
0.85	3.48	12.53	3.05	14.08	2.89	14.35
0.85	4.17	12.18	3.79	13.55	3.64	13.79
0.97	4.54	11.93	4.04	13.42	3.90	13.65
1.22	5.08	11.65	4.42	13.31	4.28	13.54
1.46	5.42	11.50	4.67	13.26	4.54	13.49
1.70	5.66	11.44	4.85	13.26	4.72	13.49
1.95	5.83	11.44	4.97	13.28	4.84	13.51
2.07	5.89	11.45	5.02	13.30	4.88	13.53
2.07	6.43	10.75	5.69	12.27	5.58	12.45
2.37	6.21	11.27	5.65	12.56	5.52	12.76
2.67	6.08	11.62	5.63	12.78	5.49	12.99
2.97	6.02	11.84	5.63	12.92	5.49	13.14
3.27	5.98	11.98	5.63	13.01	5.49	13.24
3.57	5.96	12.06	5.64	13.07	5.50	13.30
3.57	7.35	11.02	7.15	11.63	7.07	11.77
4.08	6.76	11.98	6.48	12.78	6.36	12.97
4.59	6.48	12.43	6.16	13.35	6.02	13.44
5.09	6.36	12.65	6.01	13.62	5.87	13.80
5.60	6.33	12.74	5.95	13.75	5.80	13.99
6.11	6.32	12.79	5.93	13.81	5.77	14.06
6.11	6.67	11.81	6.33	12.69	6.21	12.88
6.87	6.92	12.09	6.62	12.88	6.50	13.08
7.64	7.00	12.19	6.72	12.98	6.60	13.18
8.40	7.03	12.24	6.75	13.02	6.63	13.22
9.17	7.05	12.26	6.77	13.04	6.65	13.25
9.93	7.06	12.28	6.78	13.06	6.66	13.26

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