

**Nutrient and Water Budget Modeling  
of the Petenwell Flowage  
Adams, Juneau, and Wood Counties  
Wisconsin**

**Final Report to the  
Department of Natural Resources**

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I would like to dedicate this paper to my parents who both passed away during the duration of this project. Through their years they shared with me their passion for the natural world, fostered scientific curiosity, and encouraged me to pursue my dreams. Indeed I was fortunate for the time we spent together.

## ABSTRACT

The Petenwell flowage is a highly eutrophic impoundment located on the Wisconsin River in south-central Wisconsin. High nutrient discharge by municipalities and industries up-river results in blue green algae blooms throughout much of the summer, which creates a nuisance and hampers recreational uses of the flowage. The flowage acts as a nutrient sink, with more nutrients entering than are exiting the flowage. This helps control algae problems in down-river impoundments.

The Wisconsin DNR determined that a model to predict the responses of algae blooms and water clarity in the flowage to changes in inflowing total phosphorus could be a useful management tool. The model selected to be used was BATHTUB which was assembled using water quality data collected at five sites in the flowage and three tributary sites along with daily flow measurements. Data were collected monthly between May and October for two years.

The water quality data indicate that internal loading of phosphorus is occurring during summer months in the upper end of the flowage. Detailed information on the internal loading is currently not available, however, during the calibration of the model a loading estimate of 20 mg/m<sup>2</sup>/day within this segment best fit the water quality water quality in the reservoir down stream.

The model estimates indicate that the overall reservoir chlorophyll *a* bloom frequency will decrease and Secchi disk depth will increase with a reduction in total phosphorus inputs. A 50% reduction of total phosphorus inputs would reduce algal bloom frequency from 114 to 74 days between May and October. The reduction that would occur in the upper part of the reservoir would be from 171 to 134 days; in the lower part of the reservoir bloom frequency would decrease from 37 to 22 days.

Though this model provides a good general reservoir response tool, it could be further refined by collecting additional water quality data during high flow periods, as well as collecting data with greater frequency. Additional sampling should occur up-river to separate out specific sources of phosphorus entering the impoundment.

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## INTRODUCTION

Petenwell Flowage is located on the Wisconsin River in Adams, Juneau and Wood counties. At 23,040 acres, it is the second largest body of water in Wisconsin (Harza, 1993). Throughout the years many studies have been conducted on the Petenwell Flowage; results of many of these studies were addressed in the 10 year management plan which was completed by the Wisconsin Department of Natural Resources (WDNR) in 1996. This plan was comprehensive, and therefore addressed issues pertaining to recreation, aesthetics, environmental quality, habitat, and biota within the reservoir.

Among other problems, Petenwell flowage is a very eutrophic impoundment which experiences excessive blue green algae blooms. These blooms are aesthetically undesirable, a recreational nuisance causing beach closings, and an environmental problem resulting in the reduction of dissolved oxygen, water clarity and occasional fish kills. Nutrient enrichment is the primary cause of the algae blooms (WDNR, 1996, Wisc R Power Co, 1993). Nutrients enter the flowage via the Wisconsin River, its tributaries, and through surface runoff from the Wisconsin River Basin, which extends to the Michigan border. The flowage receives drainage from 15,462 km<sup>2</sup> and 39 sub-watersheds WDNR, 1996 (Figure 1). Nutrient concentrations in the Wisconsin River begin to increase at Tomahawk and continue to increase as you move down stream to the Petenwell Flowage. The flowage is a nutrient sink retaining approximately 48% of the inflow phosphorus (P); an average of 947 kg P enter yet only 490 kg P exit the reservoir daily (WDNR, 1996). Primary point sources of P entering the Wisconsin River are municipal sewage treatment plants, paper industry, and agricultural processing plant effluent discharge (Kreitlow, 1991). These amount to 29 permitted discharge sources on the Wisconsin River above the flowage. Non-point sources of nutrients can be tied to agricultural and residential land use in the Petenwell watershed (Figure 2).

Nutrient sources from land uses include agricultural fertilizer, wind eroded air borne particulates, and lawn fertilizer and septic effluent from intensive housing development around the impounded Fourteen Mile Creek tributary (WDNR, 1992, Burkholder and Cuker, 1991; Daniel, et al, 1990; Sonzogni, et al., 1982, IES Report 105, 1979). Data suggest that adjacent non-point and direct tributary inputs of nutrients are significantly less than nutrients coming into the flowage from the main river.

**Figure 1. Map of Wisconsin showing counties, surface hydrology, and the Upper Wisconsin River Basin which is approximately 15,462 km<sup>2</sup> and contains 39 sub-watersheds.**

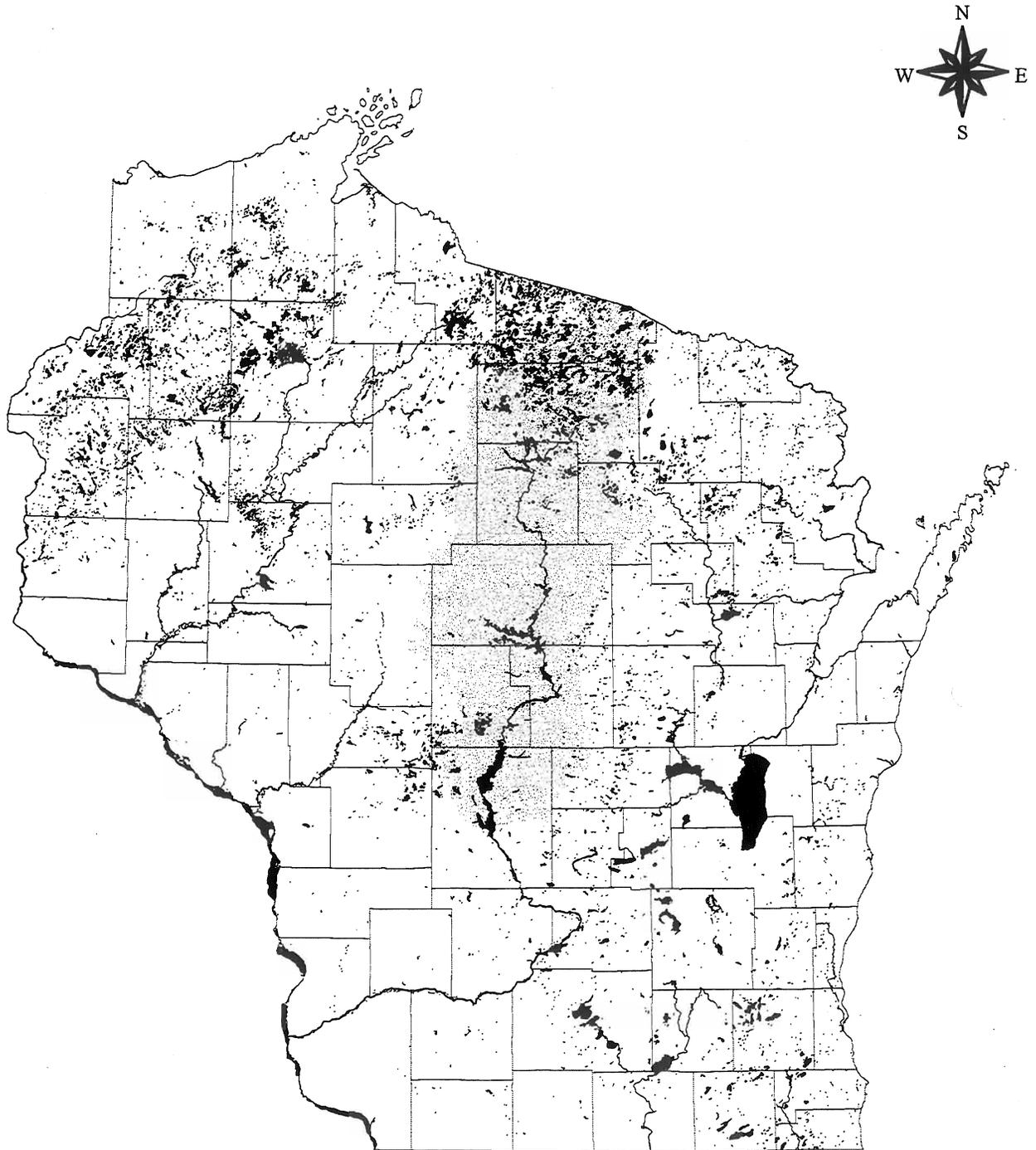


Figure 2. Map of the Petenwell Flowage in Wisconsin showing adjacent land use. From Wisconsin River Power Company, 1995.



FIGURE: EG-1, p. 12

Many upriver point source discharge sites are in the process of adding P removal systems to their effluent processing as a result of Chapter NR 217, Wisc. Admin. Code. It is desirable to determine if these reductions are sufficient to reduce algal blooms in the Petenwell. In 1997 DNR estimated Total P loading to the Wisconsin River above the flowage to be 712,271 lbs/yr (DNR 1996 Table 40). Based on full compliance to the new permits, Total P loading from point source discharges are estimated to be 289,029 lbs/yr (DNR, 1996 Table 41). The majority of facilities are required to reduce Total P discharge to 1.00 mg/l (Table 1). To assist in the determination of the amount of nutrient reduction required to improve the trophic state of the flowage, the Wisconsin DNR recommended that a model of the Petenwell flowage be assembled (WDNR, 1996). This model will be used as a tool to predict changes that may occur in the flowage as a result of changing phosphorus inputs.

### OBJECTIVES

The primary objective of this study was to establish a water quality model for the Petenwell Flowage which would serve as a tool for future management decisions by WDNR watershed and fishery managers. Models will summarize morphometric, historic flow and water quality data for the flowage and its tributaries which will assist in the determination of the physical and chemical attributes that are primarily responsible for eutrophication of the impoundment. The use of two models (FLUX and PROFILE) will summarize the data in a format required for the third model (BATHTUB). Development of the Petenwell models will include the following objectives:

1. Identify point and non-point sources of nutrients from the Wisconsin River, tributaries, and surface runoff within the watershed.
2. Quantify inputs and outputs to the Petenwell Flowage by developing a nutrient budget and water budget.
3. Use the model to predict the effects of nutrient reduction in the flowage on ecological variables such as transparency, dissolved oxygen concentrations, and chlorophyll *a*.
4. Use the model to predict amount of reduction of nutrient inputs required to decrease nutrients in the flowage to achieve various reductions in phytoplankton and improvement in water clarity.

Funding for this project is through a cooperative agreement between the Wisconsin Department of Natural Resources, Golden Sands Resource Conservation & Development, and the University of Wisconsin-Stevens Point Environmental Task Force Program.

## LITERATURE REVIEW

### *Models*

Modeling of a system is a tool that is popular with many natural resource managers. Frequently the resource manager must make management decisions that may not show measurable results for years, so predictive tools such as numeric models can enhance long term decision making capabilities. This tool can be particularly useful when attempting to predict the response of a water body to hydrological environmental or chemical changes. Generally, changes in the trophic state of large bodies of water occur over long periods of time. Use of a model can assist with land use planning within a basin, estimating permissible effluent discharge levels, or necessary reduction of inputs to an aquatic ecosystem to achieve a targeted water quality condition.

Models designed for use on water bodies can be fairly simple or very complex depending upon the complexity of the system and the required results. Simple models are available to assess one component of a system such as nitrogen or oxygen; more complex models interface many physical and chemical characteristics within the water body and/or the basin. Cost is frequently a consideration as data acquisition is frequently an expensive endeavor and model building can be quite time consuming.

Many lake models are not applicable when modeling a reservoir because of the flow through characteristics and short retention times typical of reservoirs. The Army Corps. of Engineers designed the three component FLUX, PROFILE, and BATHTUB model to be used on these unique bodies of water. This reservoir eutrophication modeling system was applied to the Petenwell flowage. It is an empirical model which utilizes average conditions. The model consists of three components; FLUX, PROFILE, and BATHTUB ultimately resulting in two models, a loading model and an eutrophication response model. The primary purpose of FLUX and PROFILE is for data reduction, which is required for input into BATHTUB.

FLUX is used to estimate nutrient loading from tributaries and the main stem of the

**Table 1. Phosphorus loading reductions based on recommendations in Chapter NR 217, Wis. Admin. Code. Table 41 from WDNR, 1996.**

<b>Table 41: Phosphorus Loading Reductions as a Result of Chapter NR 217, Wis. Admin. Code</b>				
Facility	Effluent mgpd	Total-P mgpl	Total-P kg/day	Total-P lb/yr
Eagle River STP	0.33	1.00	1.25	1,006
Rhineland STP	1.30	1.00	4.92	3,958
Rhineland Paper 1	6.12	0.19	4.40	3,540
Rhineland Paper 2	0.43	1.00	1.62	1,303
Packaging Corp.	4.68	1.00	17.71	14,247
Tomahawk STP	0.44	1.00	1.66	1,335
Ward Paper	0.90	1.00	3.40	2,735
Merrill STP	1.41	1.00	5.34	4,296
Brokaw STP	0.02	2.88	0.23	185
Wausau Paper	8.98	1.00	33.99	27,344
Wausau STP	6.10	1.00	22.75	18,301
Foremost (Rothschild)	0.29	1.00	1.09	877
Weyerhaeuser	6.41	1.00	24.26	19,516
Rib Mountain STP	1.4	1.00	5.3	4,264
Mosinee STP	0.33	1.00	1.25	1,006
Mosinee Paper	11.51	0.68	29.63	23,836
Stevens Point STP	3.83	1.00	14.5	11,665
Plover STP	823	1.00	3.11	2,507
Whiting STP	242	1.00	.91	737
Cons. Paper Water Renewal Center	5.2	.44	8.7	6,968
Neenah Paper	1.98	.47	3.5	2,834
Foremost	247	1.00	.935	752
ORE-IDA	1.2	1.00	4.5	3,654
Nekoosa Paper	29.43	1.00	111.9	89,635
Wis. Rapids STP	3.23	1.00	12.22	9,747
Port Edwards STP	456	1.00	1.705	1,372
Vulcan Materials	4.56	--	--	--
Nekoosa STP	377	1.00	1.43	1,148
Cons. Paper Water Quality Center	27.6	.36	37.6	30,262
<b>TOTAL:</b>	<b>129.7</b>		<b>359.2</b>	<b>289,029</b>
Total Point Source Reduction: ~60% (715,571 lbs/yr -> 289,029 lbs/yr) mgpd = million gallons per day				
Point Source Reduction Immediate Source Area: ~41% (393,660 lbs/yr - 161,280 lbs/yr)				

river. Input data required includes sample concentrations of total P, reactive P, total N, inorganic N, and a conservative substance (Cl was used in the Petenwell model). Daily flow is also necessary. Reduced data from FLUX include loading means and coefficients of variation for each input component in each segment. These data are used in the production of a nutrient balance. Based on the loading characteristics of the reservoir and amount of available data, data can be stratified by season, concentration, or flow. This stratification process can provide additional information on relationships that exist within the reservoir and can identify when adjustment of future sampling schemes may be desirable.

PROFILE is used to determine the thermal stratification in a reservoir and for reduction of pool water quality measurements. Reservoir morphometry, location and elevations of monitoring stations, and temperature and oxygen profile data are required to run PROFILE.

The BATHTUB component of the model system is used to produce a nutrient budget and the eutrophication response model. The BATHTUB model assumes steady-state conditions. BATHTUB uses reduced data from the FLUX and PROFILE models. These data include total P, reactive P, total P minus reactive P, total N, organic N, Cl, Secchi disk measurements, chlorophyll *a*, and daily flow values. In the case of the Petenwell flowage, seasonal values (May through October) were used for all components. The nutrient budget and eutrophication model are tools that will be used to predict the levels of reduction of nutrient inputs needed to achieve WDNR target reductions in algal blooms and increased water clarity in the reservoir. Total P, concentration and frequency of chlorophyll *a*, and Secchi disk measurements will be the primary outputs in this study. Preliminary N:P ratios indicated that the system was dominated by P. Therefore, to more accurately model the reservoir nitrogen was held constant.

### ***Eutrophication***

Excessive algal growth in reservoirs can be associated with several conditions. Typically the extent of growth is a function of limiting nutrients. In most freshwater systems P rather than N is the limiting nutrient, however, limitation can change during periods of stratification (Schindler, 1971, Welch, 1992). N:P ratios can be used to determine the limiting nutrient, as well as the trophic status of a lake. Eutrophic lakes tend to have lower N:P ratios

(10:1) than oligotrophic lakes (70:1). These rates also influence type of algal species present. Nutrients in reservoirs are introduced from the main channel flow, tributaries, direct runoff, and groundwater inflow. In addition, the water body can retain and release nutrients from the sediment bed (Singh, 1983). This process is referred to as internal loading. In the Wisconsin River sources of P and N include municipal waste and industrial processing including manufacture of paper and cheese. Non-point sources within the watershed include fertilizers, animal waste, and urban runoff.

Several studies have indicated that a combination of sedimentation and phosphorus enrichment result synergistically, increasing periphyton growth in reservoirs (Kimmel et al, 1981; Burkholder and Coker, 1991). In fact, Burkholder and Coker found periphyton to be a large proportion of the total productivity in reservoirs under these synergistic conditions. A study by Schindler (1971) focused on the roles of P, nitrogen (N) and carbon (C) in relation to periphyton growth. P was found to be the primary limiting nutrient. Low concentrations of N and C also limited phytoplankton growth, however, excess concentrations of N and C did not increase phytoplankton growth without the addition of dissolved reactive P.

Phosphorus release from sediment is seasonal, corresponding with temperature variation and oxic versus anoxic conditions. Jensen and Anderson observed that a rise in temperature from 7° to 14° to 21°C were more significant in the release of soluble reactive P than were pH and nitrate-N. Stauffer and Armstrong observed greater release of P occurring in anoxic conditions when pH was less than 8. James, et al (1995) conducted a study on internal phosphorus loading in Lake Pepin and determined that increased P release occurred in anoxic conditions, yet a significant amount of P release also occurred in oxic conditions.

Retention time is another factor related to algal growth. As retention time increases nutrients are more likely to change to dissolved forms which are more readily taken up by plants. In addition, the time available for phytoplankton growth increases, allowing algal populations to become established and bloom before being flushed from the impoundment. The combination of these factors can result in increased phytoplankton productivity (Taylor, 1971).

Other factors that control P release include reservoir draw down, carp activity, and wind. These factors can all create sediment resuspension and P release. Draw down in winter

months can also cause roots of aquatic macrophytes to become exposed and freeze. This situation may reduce the amount of rooted plant uptake of available P in summer months leaving additional nutrients for algal uptake.

### ***Phosphorus Loading***

Traditionally, P has been the primary nutrient related to increased phytoplankton growth and is becoming the primary focus when addressing eutrophication in fresh water lakes and reservoirs. Phosphorus is found in a variety of forms and availability of P to plants varies with form. Dissolved reactive phosphorus (DRP),  $\text{H}_2\text{PO}_4^-$ , and  $\text{HPO}_4^{2-}$  are directly available to plants for use and P adsorbed on Fe, Al and Ca is partially available to plants when DRP is low. Because of this variation, eutrophication is more closely associated with elevated concentrations of DRP than with total phosphorus (TP), (Sonzogni, et al, 1982; Walker, 1996)

A more thorough characterization of the eutrophication of a water body includes concentrations of chlorophyll *a*, phosphorus (dissolved reactive and total), nitrogen (organic, nitrate, and ammonium), temperature and oxygen gradients, and Secchi disk measurements. Lillie and Mason (1983) developed a water quality index for lakes in Wisconsin which considers chlorophyll *a*, total phosphorus, and Secchi disk measurements (Table 2). Based on this index and using water quality data published by the WDNR in 1993, the Petenwell Flowage ranges from poor to very poor based on P, good to very poor based on chlorophyll *a*, and Secchi disk measurements range from poor to very poor. Later we will see how misleading reservoir averages can be when looking at the response of a flowage as large as Petenwell. The variation in the chlorophyll *a* and Secchi disk measurements is due to seasonality, with the poorest water quality in July and August, corresponding with peak algal blooms, low flow, and poor transparency. The Kruskal Wallis test for seasonality was used to test N:P ratios and at the Nekoosa Bridge (Consolidated data) and Petenwell Dam (Storet data) these data were found to be significant at the 95% CI, indicating that seasonal variation is probably occurring in the flowage (Kreitlow, 1993). This seasonality is likely due to changes in the availability of P throughout the year from variations in flow, temperature, transparency, and color.

Historic water quality, morphometric, and flow data from the Petenwell Flowage are

available dating back to the early 1960s. These data were primarily collected at the Nekoosa Bridge and the Petenwell Dam. The water quality data were collected from 2 to 12 times per year and could be useful in examining changes in water quality due to changes in point source loading as well as variation in water quality that may occur in low flow or high flow years. These data were graphed in FLUX to determine if relationships exist between concentration, time concentration and flow. Using basic statistics, no strong relationships exist between either. Many factors within the upper Wisconsin River Basin have changed over time, including land use, land practices, discharge concentrations and discharge volume. A sub-study to document these changes over time would be necessary to further statistically evaluate these relationships. There are not enough historic data sites within the flowage to use in BATHTUB for comparisons of loading over time.

**Table 2. Water quality index for Wisconsin lakes and ranges of concentrations of total phosphorus, chlorophyll *a*, and Secchi disk measurements for the Petenwell Flowage (WDNR, 1996). Table base on Lilly and Mason, 1983.**

Water Quality Index	Secchi Disk Depth (m)	Chlorophyll <i>a</i> ( $\mu\text{g/L}$ )	T. Phosphorus ( $\mu\text{g/L}$ )
Excellent	>6.0	<1	<1
Very Good	3.0-6.0	1-5	1-10
Good	2.0-3.0	5-10	10-30
Fair	1.5-2.0	10-15	30-50
Poor	1.0-1.5	15-30	50-150
Very Poor	<1.0	>30	>150
<b>Petenwell Flowage</b>	<b>0.6-1.5</b>	<b>8.4-66.6</b>	<b>85-171</b>

### STUDY SITE DESCRIPTION

The Petenwell Flowage is located on the Wisconsin River in the counties of Adams, Juneau and Wood; the dam creating it is operated by Wisconsin River Power Company (WRPCO). The main body of the flowage is approximately 15 miles long, covering

approximately 30,000 acres. Estimated volume for the flowage is 553,200 acre-ft; depth averages 18 ft, as shown in Table 3, with a maximum depth of 45 ft. Between 1980 and 1997 discharge ranged between 604 and 53,019 cfs, with an average of 5,123 cfs. The water's elevation ranged from 912.5 to 924.9 feet above sea level. The flowage's average retention time is estimated at 47 days (WDNR, 1996).

**Table 3. Morphometric data describing the Petenwell Flowage. Information was derived from WRPCO's bathymetric flowage map and planimeter.**

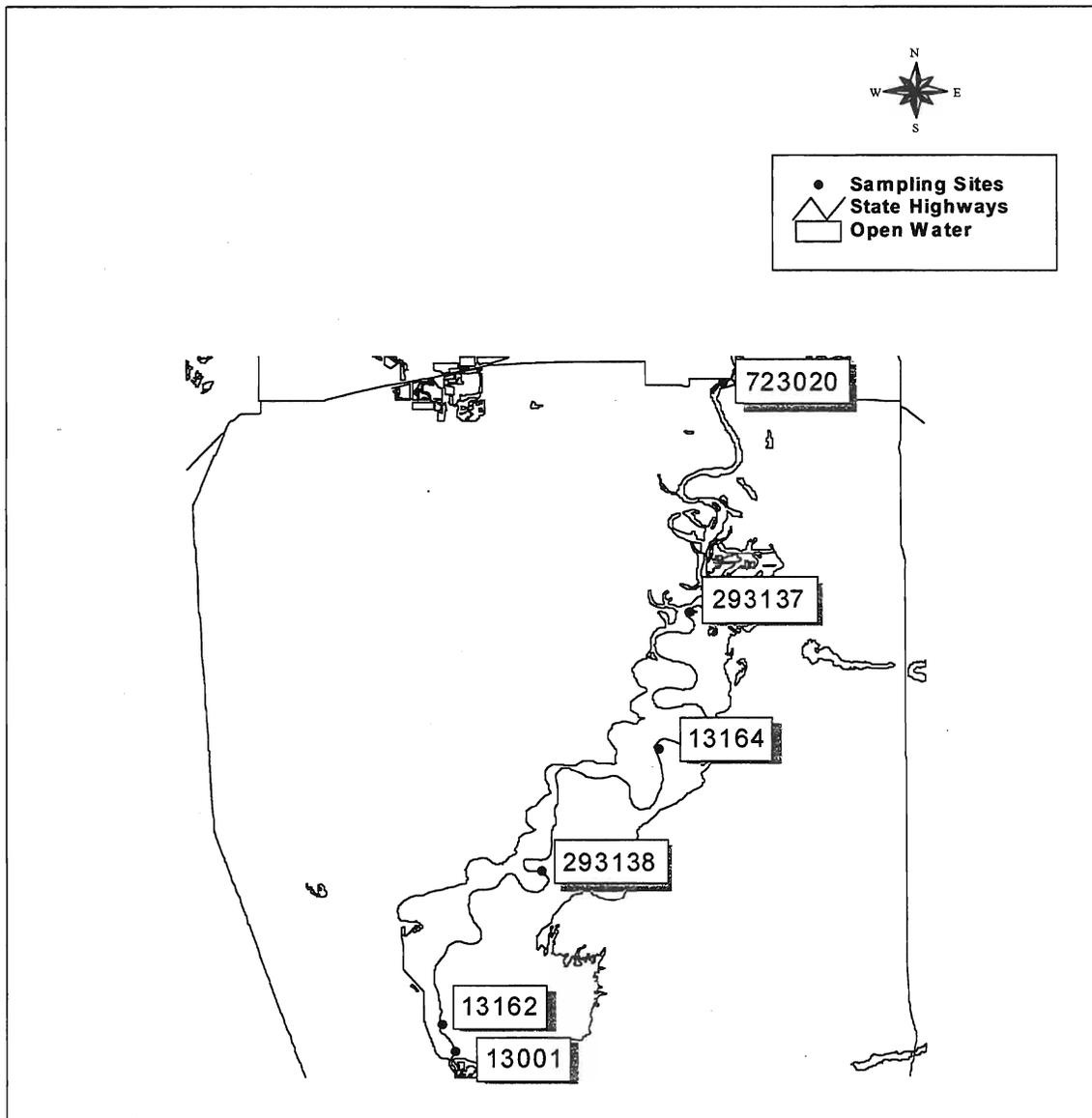
	BATHTUB Model Segment Number						Total Reservoir
	1	2	3	4	5	6	
<b>Area (acre)</b>	2,383	4,408	8,062	5,906	5,682	4,448	30,888
<b>Volume (acre-ft)</b>	17,124	49,296	119,092	132,788	113,180	124,708	553,188
<b>Mean Depth (ft)</b>	7.2	10.5	14.8	22.5	19.9	28	17.9
<b>DNR Sample ID</b>	293137		13164	293138		13162	

## METHODS

### *Experimental Design*

Historic surface water quality data for the Petenwell flowage is available, however, the calibration of the model system requires more annual water quality data than was available. Therefore, additional water quality samples/year were collected for this project over two years (1996/7). The PROFILE model is capable of segmenting a reservoir and determining the optimum number and location of water quality samples sites, however, historic data from five sample sites within the Petenwell flowage could be used with the BATHTUB model after calibration, so the same sample sites were used in this study for surface water collection. Walker (1996) reviewed data available for the Petenwell flowage and confirmed that it would be desirable to continue using these same historic sample sites. Surface water sampling by the WDNR occurred at five sites in the Petenwell Flowage; at the headwaters near Nekoosa, in the primary river channel near New Rome, below Barnum Bay, near the Bighorn Access, and just above the Petenwell Dam (Figure 3). In addition to these sites, samples were taken

**Figure 3. Map of the Petenwell Flowage showing historic water sampling sites.**



from Fourteen Mile, Ten Mile, and Chester Creeks. For this study, six water quality samples sets were collected from the five flowage and three tributary sites between May and October in both 1996 and 1997.

Preliminary calibration of the model indicated seasonal internal loading in the upper part of the reservoir. To determine the boundaries of the internal loading, samples were taken every mile along the river channel (Figure 4). This sampling occurred twice in June and once in September 1998. For uniformity, surface water samples for all sample sites were collected on the same day. These data indicated the need for re-segmentation of the reservoir. To insure the appropriate representation of sample data six segments were used instead of the four originally proposed (Walker, 1999).

#### ***Field Sampling Methods***

The five surface water sample sites on the flowage were located using a global positioning system (GPS) mobile receiver. At each location pH and Secchi disc readings were obtained and temperature/oxygen profiles were measured with an YSI electrode and digital meter. Following these measurements, surface water samples were acquired for water chemistry analysis. Water samples were retrieved using a VanDorn bottle at the surface, mid-depth and 3 ft. above the sediment; then combined to create a composite sample. Composite samples were transferred into three bottles, two un-acidified and one acidified with  $H_2SO_4$  for nutrient analysis; all were kept on ice until delivery to the labs. The State Lab of Hygiene, located in Madison, Wisconsin analyzed the samples from within the flowage for Chlorophyll  $\alpha$ , reactive phosphorus, total phosphorus (TP),  $NO_2+NO_3-N$ ,  $NH_4$ , TKN, chloride, and turbidity. UWSP's Environmental Task Force (ETF) Lab analyzed the tributary samples for reactive phosphorus, TP,  $NO_2+NO_3-N$ ,  $NH_4$ , TKN, and Cl. Both labs used state certified techniques and methods of analysis.

#### ***Data Acquisition/Manipulation***

Water quality and flow data were obtained from a variety of sources. Daily flow and water elevation data for the Wisconsin Rapids and Petenwell dams were supplied by the Wisconsin Valley Improvement Company (WVIC, 1996). Flow information was needed for the Nekoosa Dam (located just above the Petenwell Flowage) however flow measurements were not available, therefore, Wisconsin Rapids flow data were adjusted to reflect the 3.5%

increase in flow at Nekoosa (Morgan, S., 1997).

Gaging stations currently do not exist on Fourteen or Ten Mile Creeks, so estimates were used. Flow data were available for both the Wisconsin River (at Petenwell) and Ten Mile Creek. These data were regressed, with an  $R^2 = 0.92$ . The ratio of flow in the Wisconsin River versus the Ten Mile Creek was 1:0.0132. Missing flow data for the years used in this model (1996/7) were estimated using this relationship. Flow was also needed for Fourteen Mile Creek. By use of regressions, Oberhoffer (1993) developed equations to predict the flows at Fourteen Mile Creek from the Ten Miles flows. These equations were used to predict missing flows for this model (Eq.1 and 2). Flows and inputs from the Chester Creek are insignificant when compared with the Wisconsin River, so the Chester Creek watershed was combined with Fourteen Mile's watershed in the BATHTUB model.

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**Equation 1. Ten Mile Creek Flow > 50 cfs:**

$$14 \text{ Mile Creek (cfs)} = (x-4.41)/0.10$$

**Equation 2. Ten Mile Creek Flow < 50 cfs:**

$$\text{Fourteen Mile Creek (cfs)} = (x-29.1)/0.83$$

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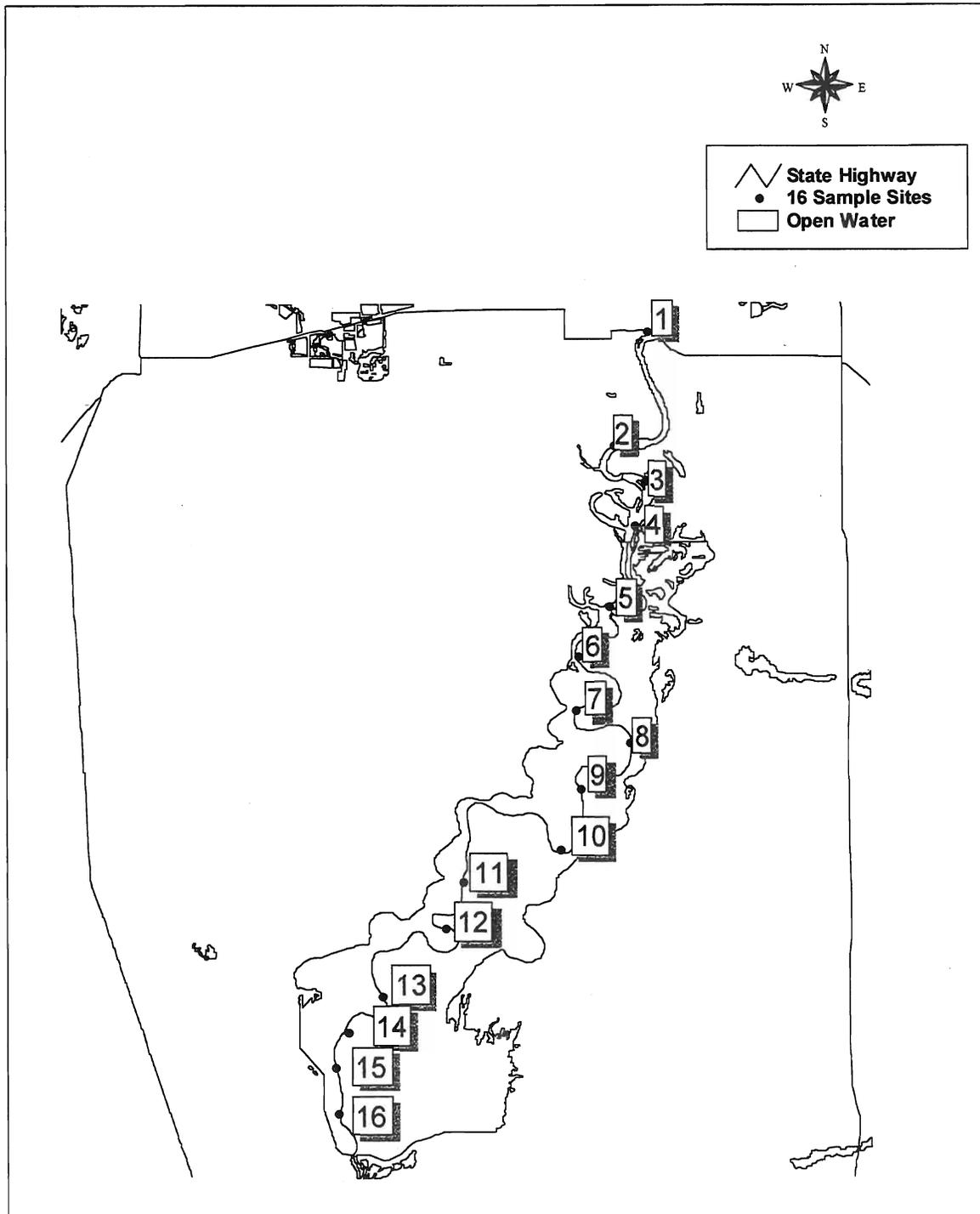
Water quality data for five sites within the Petenwell Flowage were obtained from the STORET system at the Wisconsin DNR. Tributary sample chemistries were obtained from the ETF lab. Chemistry and physical measurements required for the models included: temperature, dissolved oxygen, Secchi disk, Chlorophyll *a*, reactive P, TP,  $\text{NO}_2+\text{NO}_3\text{-N}$ ,  $\text{NH}_4$ , TKN, chloride, color. Units of measure are shown in Table 4. The BATHTUB model requires other data which were derived from the measured chemistry/physical data; total N, organic N, TP minus reactive P, and non-algal turbidity.

The reservoir was segmented based on the location of sample sites taking into account the distribution of chemical concentration within the reservoir which resulted in the use of six segments (Figure 5). Morphometry for each segment was determined using WRPCO's bathymetric flowage map (1993) and a planimeter; area, volume, and mean depth were then calculated for each segment (Table 3).

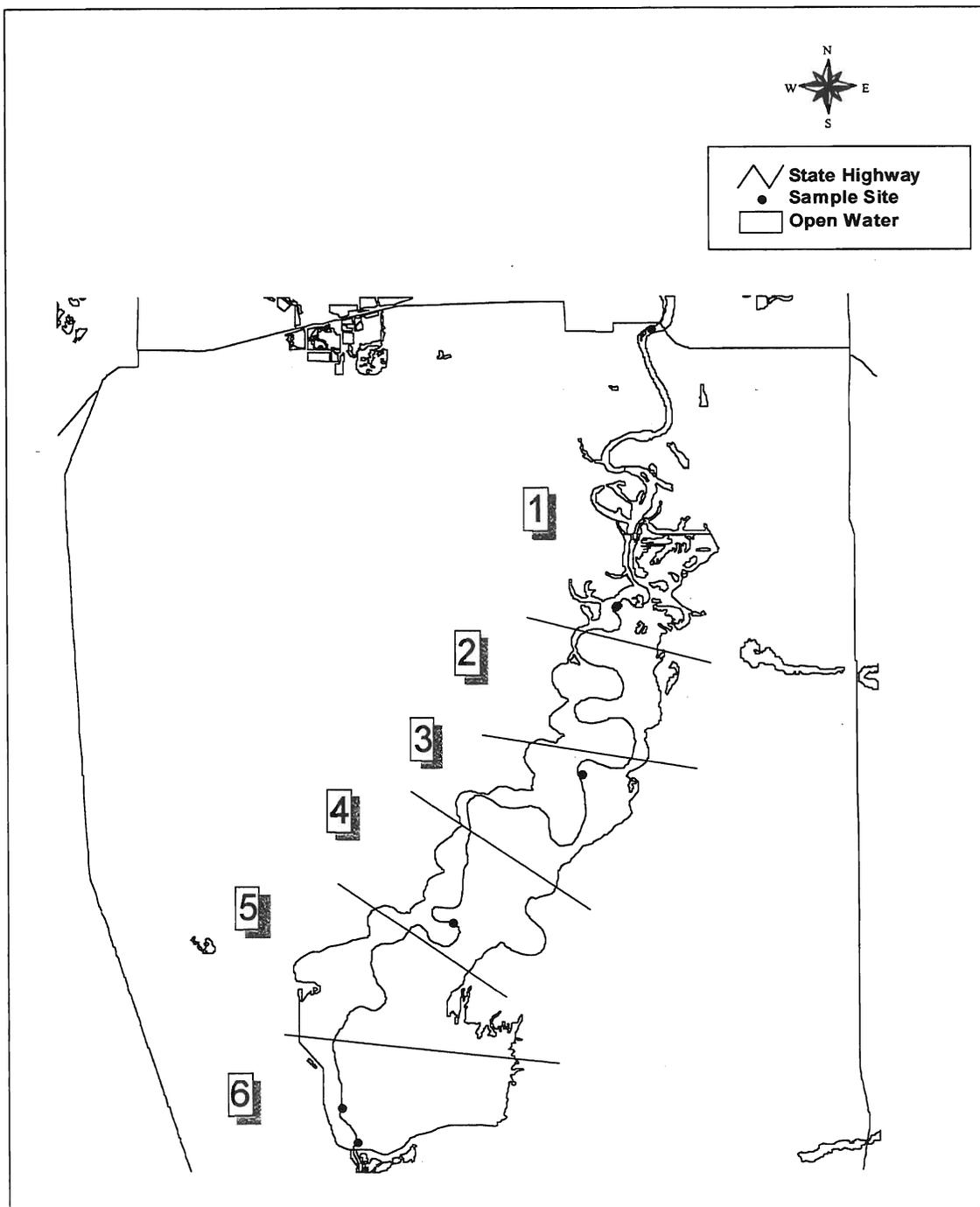
**Table 4. Reported units and levels of detection for laboratory water quality analyses.**

<b>Analysis</b>	<b>Reported Units</b>	<b>Level of Detection</b>
Reactive P	mg/l	0.002
Total P	mg/l	0.002
NO <sub>2</sub> +NO <sub>3</sub> -N	mg/l	0.2
NH <sub>4</sub> -N	mg/l	0.006
TKN	mg/l	0.08
Chlorophyll <i>a</i>	µg/l	1
Chloride	mg/l	1
Turbidity	NTU	1

**Figure 4. Map of Petenwell Flowage showing approximate location of 16 water sampling sites. Samples were obtained in June and September 1998.**



**Figure 5. Map of the Petenwell Flowage showing sample sites and approximate location of segment boundaries used in the BATHTUB model.**



### ***BATHUB Model***

A non-networked model was used for the Petenwell Flowage. The flowage was divided into six segments (Figure 3). Four of these segments correspond with sample sites that have historically been used by the Wisconsin DNR or Consolidated Papers. The other two segments were added to provide a more representative model of the flowage. This model was designed to predict changes in Chlorophyll *a* with the reduction of input P loading. In addition, three tributaries were sampled, including Fourteen Mile, Ten Mile, and Chester Creeks. Increase in P occurred consistently in flowage within Segment 2, presumably due to internal loading. This was accounted for using an internal loading term of 20 mg TP/m<sup>2</sup>/day. The Wisconsin River and Ten Mile Creek were input tributaries to Segment 1. Fourteen Mile Creek and internal loading were an added inputs to Segment 2.

The reservoir eutrophication modeling system which was applied to the Petenwell flowage is an empirical model which utilizes average conditions. The model contains three components; FLUX, PROFILE, and BATHTUB which ultimately result in two models, a nutrient balance and a eutrophication response model.

FLUX is used to estimate nutrient loading in tributaries and the main stem of the river. Input data required includes, total P, reactive P, total N, inorganic N, and a conservative substance (Cl was used in the Petenwell model). Daily flow is also necessary. Loading means and coefficients of variation result for each input component in each segment and are used in the production of a nutrient balance. Based on the loading characteristics of the reservoir and amount of available data, data can be stratified by season, concentration, or flow. This stratification process can provide additional information on relationships that exist within the reservoir and can identify when adjustment of future sampling schemes may be desirable.

PROFILE is used to determine the thermal stratification in a reservoir. Morphometric, temperature and oxygen profile data are required to run PROFILE. Temperature and oxygen data obtained from the Petenwell indicate the flowage is mixed year round.

The BATHTUB component of the model system is used to produce a nutrient budget and the eutrophication response model. The BATHTUB model assumes steady-state conditions. BATHTUB uses reduced data from the FLUX and PROFILE models. These data include Total P, reactive P, Total P - reactive P, Total N, organic N, Cl, Secchi disk

measurements, chlorophyll *a*, and daily flow values. In the case of the Petenwell flowage seasonal values (May through October) were used for all components except flow. The eutrophication model was calibrated for each year of thorough flow and water quality data and validated by Dr. William Walker. Once calibrated, scenarios with varying nutrient inputs were run to predict the level of water quality and algal reduction that is feasible for this reservoir. The nutrient budget and eutrophication model are tools that will be used to predict the levels of reduction of nutrient inputs needed to achieve WDNR target reduction in algal blooms in the reservoir.

### ***Model Calibration/Validation***

The BATHTUB model was assembled using 1996 water quality and flow data and was sent to Dr. Walker for review and calibration. The water chemistry in the upper end of the reservoir indicated the presence of internal loading, but with the minimal number of sample sites it was difficult to discern the spatial extent of the internal loading. Dr. Walker recommended supplemental sampling with additional sample sites within the reservoir. Water quality samples were collected every mile within the reservoir three times in 1998. These data helped to indicate the boundaries of the internal loading in the upper end of the reservoir. The reservoir was re-segmented and morphometry of each segment was re-calculated. The model was sent to Dr. Walker who tested it with 1997 data and re-calibrated the model based on these results.

Default model calibration factors were used with the exception of the following changes that were made by Dr. Walker to the BATHTUB model during the calibration process to better fit the model to the observed Petenwell flowage data and response.

- ▶ The P calibration factor for TP includes a decay rate calibration factor which was changed from 1 to 0.4. Also, an internal loading rate of 20 mg/m<sup>2</sup>-day was specified in the second segment. These adjustments were necessary to simulate the increase in P concentration between the inflow and upper pool to represent the observed P gradient in the middle and lower portion of the reservoir. Internal loading with these factors/rates is about 17% of the total loading.
- ▶ Dispersion rate is the estimation of exchange flows between adjacent segments. This was changed to Model 0 (not calculated). This was necessary to match the

longitudinal gradients in P and other water quality parameters. With the default value (1), longitudinal mixing rates were substantially over-predicted, resulting in a flat profile. This adjustment most likely reflects the tortuous shape of the main river channel within the reservoir (thalweg). Sharp curves in the flow path impede longitudinal mixing. If spatial resolution within the reservoir is important for evaluating management scenarios, a more detailed segmentation scheme (using shorter segment lengths) should be developed.

- ▶ Chlorophyll a/Secchi Slope = 0.015 m<sup>2</sup>/mg (default = 0.025 m<sup>2</sup>/mg). This adjustment is typically required in reservoirs with blue-green algae having relatively large cell sizes and low light attenuation per unit of chlorophyll a. This adjustment influences predicted chlorophyll a and transparency values.
- ▶ Chlorophyll a Coefficient = 1.3 (default = 1.0). This was necessary to match the area-weighted mean chlorophyll a concentration in the reservoir. It reflects differences in algal types, analytical procedures, and growth response relative to the population of reservoirs used in developing the model.

## RESULTS

### *Scenarios*

The DNR proposed several scenarios to be run with the BATHTUB model. The model should provide reservoir response to changes of TP inputs and/or flow regimes. The scenarios included the mean TP for 109 impoundments in Wisconsin, average TP at Lake DuBay, average TP at Nekoosa (prior to NR 217), loading if point source facilities between Lake DuBay and Petenwell were all in compliance with NR 217, loading if discharge from point source facilities between Lake DuBay and Petenwell was 0.5 mg/l, 1.5 times the model concentration of 128 ug/l, and 2 times the model concentration (Table 5). Inflow concentrations were calculated for each scenario. The percent difference between these inflow values and the calibrated model inflow concentration (128 ug/l) were calculated; this same percent difference was used to calculate internal loading concentrations from the model's 20 mg/m<sup>2</sup>/day internal TP loading rate. This determination was based on the assumption that inflow TP and internal loading TP are directly correlated to one another and therefore, if inflow TP is reduced, internal loading should also be reduced. Without a more thorough understanding of the internal loading processes these types of assumptions must be applied.

The above scenarios and calculated TP inflow concentrations are shown in Table 5. The resulting inflow concentrations ranged between 64 and 256 ug/l (50 to 200% of the model standard of 128 ug/l). Because many of the scenarios resulted in similar concentrations, only five of them were selected for discussion in this paper. These concentrations included 64, 112, 128, 155, and 256 ug/l (shown shaded on Table 4). Internal loading TP concentrations were 10, 17, 20, 24, and 40 ug/l, respectively. The percent of the model standard were 50, 87, 100, 120 and 200, respectively.

Results indicate that TP concentrations are not static as they move from the upper to the lower end of the flowage. Regardless of input TP concentrations, concentrations in Segment 2 always increase due to internal loading, then TP decreases in each subsequent segment. As the TP moves through the system, reduced concentrations in the water results from plant (predominantly algae) uptake and/or adsorption/settling out.

**Table 5. Inflow/internal loading TP concentrations calculated for various scenarios used to determine loading with the BATHTUB model of the Petenwell Flowage. Shaded loading pairs are discussed in this paper.**

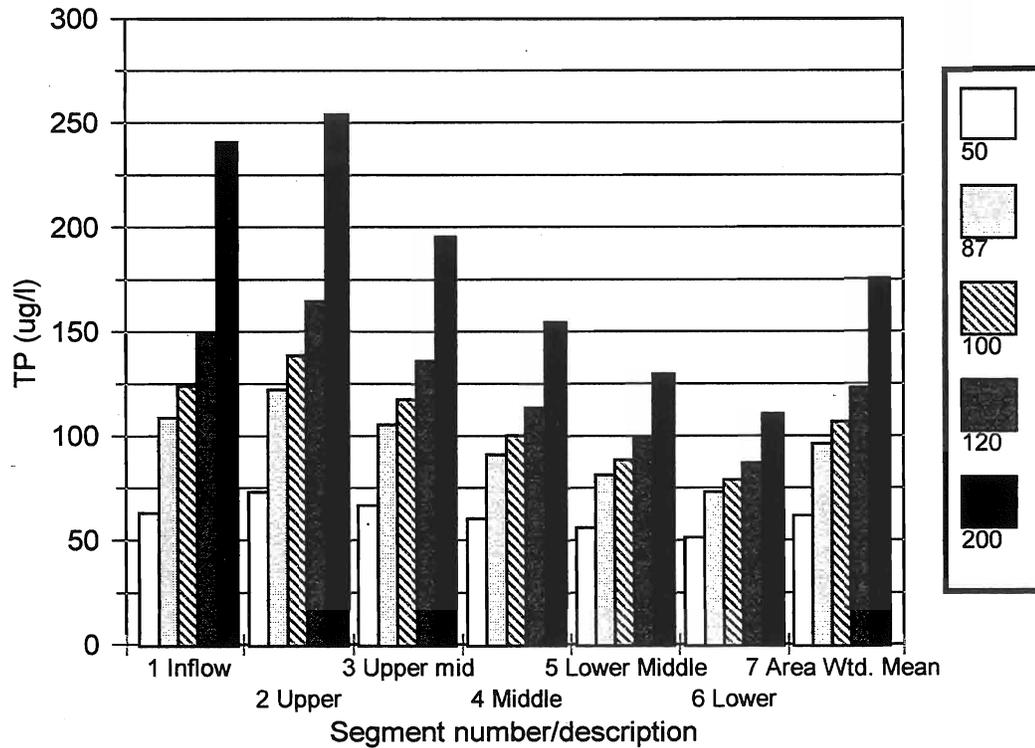
TP Inflow/TP Internal Load (mg/l)	Percent of 128 mg/l	SCENARIO
64 /10	50	Mean TP for 109 Wisc. Impoundments
85/13	66	Upper range of Wisc. 109 Impoundments
100/16	78	Background Ave. TP at DuBay
101/15	79	Loading based on 0.5 ug/l TP <sup>1</sup>
112/17	87	Loading based on 1 ug/l TP <sup>1</sup>
128/20	100	1996 Average loading at Nekoosa (Model Loading)
155/24	120	Average TP LOADING at Nekoosa
192/30	150	1.5 x Model Loading
256/40	200	2 x Model Loading

<sup>1</sup> Calculated for point sources between Lake DuBay and Nekoosa.

DNR's target for TP in the reservoir was 64 ug/l (the mean TP for 109 impoundments in Wisconsin). The 50% reduction (64/10 scenario) was the lowest concentration run through the model and therefore, was the only scenario able to achieve this goal throughout the reservoir. If discharge from up-river point sources between Lake DuBay and Nekoosa were in compliance with recommendations in NR217 (Scenario 112/17), 87% of the model's standard inputs would exist and input in the lower half of the reservoir would come close to meeting the DNR goal with the area weighted mean TP for the total reservoir at 96 ug/l, however, the upper reservoir (Segments 1 to 4) would all exceed the target. Responses for all other scenarios would exceed the TP target value (Figure 6).

TP concentrations were plotted against chlorophyll *a* data for the four primary sample sites. Sample site 293137 (located on the upper end of the flowage) showed a poor relationship between TP and chlorophyll *a* concentrations ( $R^2$  -0.27). This site is located above the flowage and is predominantly riverine with some adjacent wetlands. All other sample sites indicated a reduction in TP which correlated with a reduction in chlorophyll *a*.

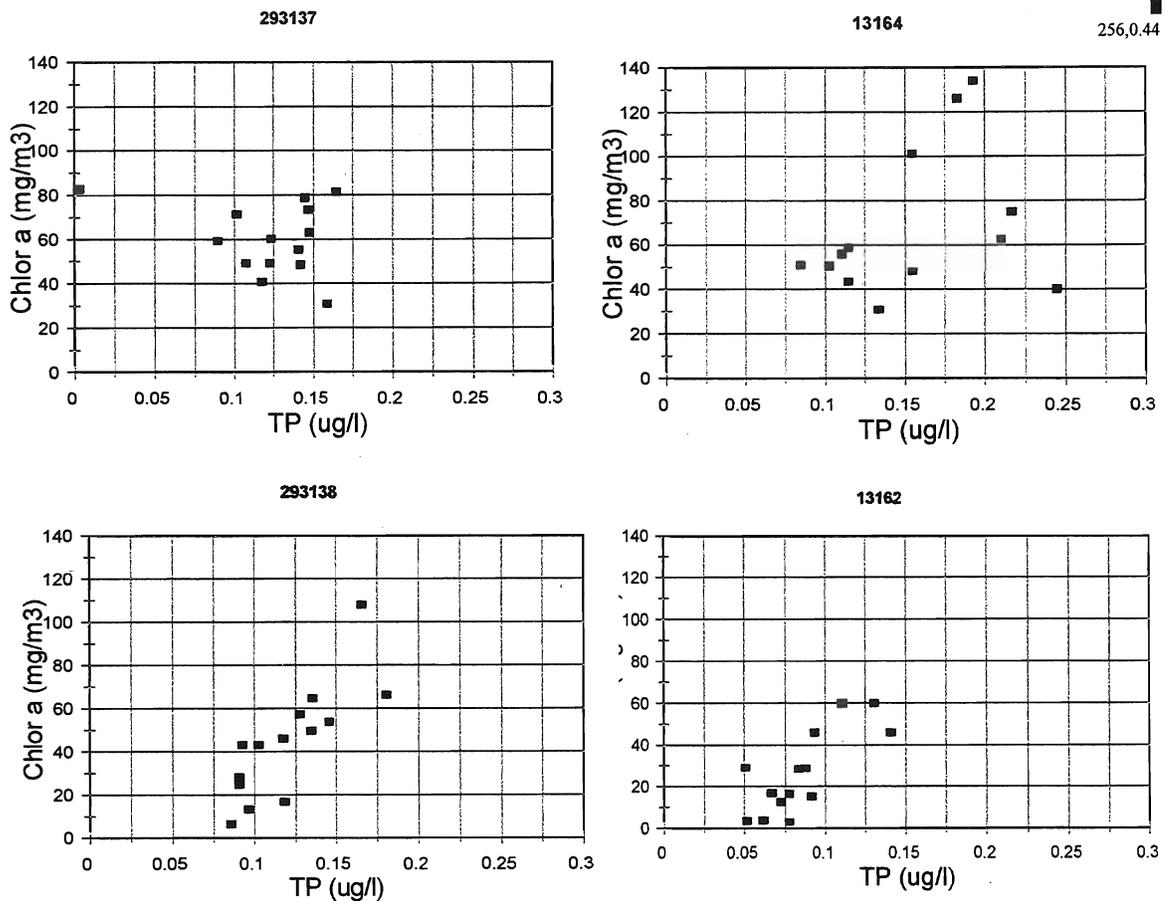
**Figure 6. BATHTUB estimates of TP concentrations for each segment using five scenarios of inflow concentrations and internal TP loading. Values shown in the legend are the percent of inflow and internal TP loading based on the model standard of 128ug/l and 20 mg/m<sup>2</sup>/day, respectively.**



The R<sup>2</sup> values for this relationship at sites 13164, 293138, and 13162 ranged from 0.77 to 0.81 (Figure 7).

Target concentrations for chlorophyll *a* was 22 mg/m<sup>3</sup> (average for 109 impoundments in Wisconsin). BATHTUB estimates this can only be achieved in Segment 6 of the reservoir, however, within this segment targets could be achieved with most of the TP input concentrations (Figure 8). Since it appears to be difficult to universally achieve this goal within the reservoir, we chose to look at reduction in frequency of chlorophyll *a* blooms >30 mg/m<sup>3</sup> between May and October. The upper end of the reservoir clearly has the most significant problem with blooms. The model standard scenario (128/20) showed algae blooms

**Figure 7. TP concentrations (ug/l) versus Chlorophyll *a* (mg/m<sup>3</sup>) at four sample sites within the Petenwell flowage. May through October 1996 and 1997.**

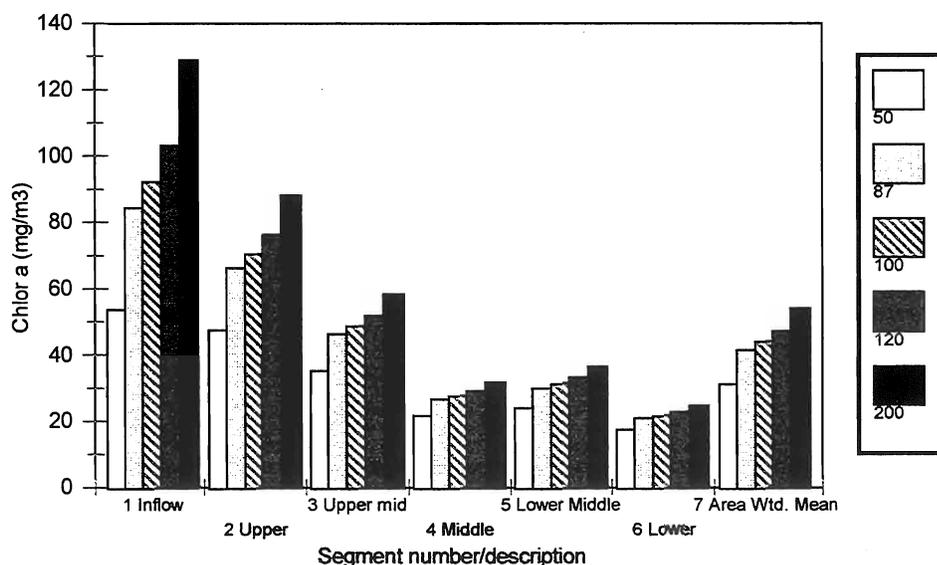


occurring in the first segment 93% of the May to October time period. The frequency can be reduced to 73% of this period if inflow and internal loading TP is reduced by 50% to 64/10, or increased to 97% if TP is increased to 200% of the model standard (256/40). In contrast, Segment 6 had algae blooms 20% of the same time period in 1996. This segment's bloom frequency can be reduced to 12% with the 50% scenario, or increased to 26% with the 200% scenario. Overall, the reservoir experienced blooms 62% of the May through October time period in 1996. Overall reservoir bloom frequency could be reduced to 40% in the same time period with the 50% scenario, or increased to 74% with the 200% scenario. These data are shown in Table 6.

**Table 6. Frequency (days) of algae blooms > 30 ug/l occurring between May and October for five TP inflow/internal loading scenarios. Response of the Petenwell Flowage is shown by segment and reservoir mean.**

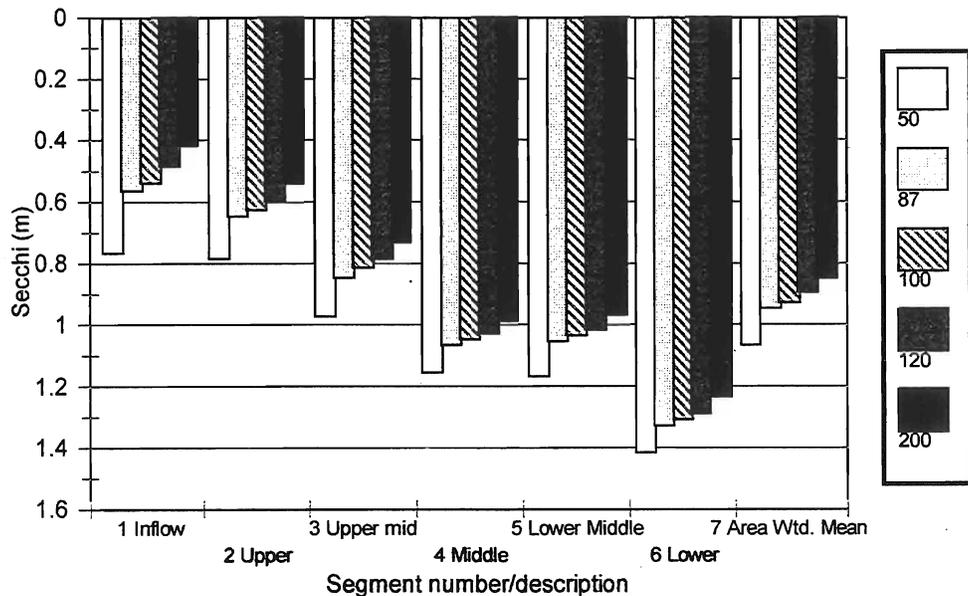
Percent Change	Segment Number						Area wtd. mean
	1	2	3	4	5	6	
50	134	122	88	37	46	22	74
87	167	152	119	57	69	34	107
100	171	157	122	61	74	37	114
120	175	162	131	66	80	40	121
200	179	169	142	76	91	48	135

**Figure 8. BATHTUB estimates of chlorophyll *a* values for each segment using five scenarios of inflow concentrations and internal TP loading. Values shown in the legend are the percent of inflow and internal TP loading TP based on the model standard of 128 ug/l and 20 mg/m<sup>2</sup>/day, respectively.**



Secchi disk measurements were estimated by the model in an attempt to determine the potential clarity of the reservoir. The goal for this measurement was 1.3 m which is the average for 109 impoundments in Wisconsin. Regardless of scenario, the upper five segments will not be able to achieve this goal (Figure 7). It is possible to achieve this goal in Segment 6 if all up-river point sources between Lake DuBay and Nekoosa were compliant with NR217.

**Figure 9. BATHTUB estimates of Secchi disk measurements for each segment using five scenarios of inflow concentrations and internal TP loading. Values shown in the legend are the percent of inflow and internal TP loading based on the model standard of 128 ug/l and 20 mg/m<sup>2</sup>/day, respectively.**



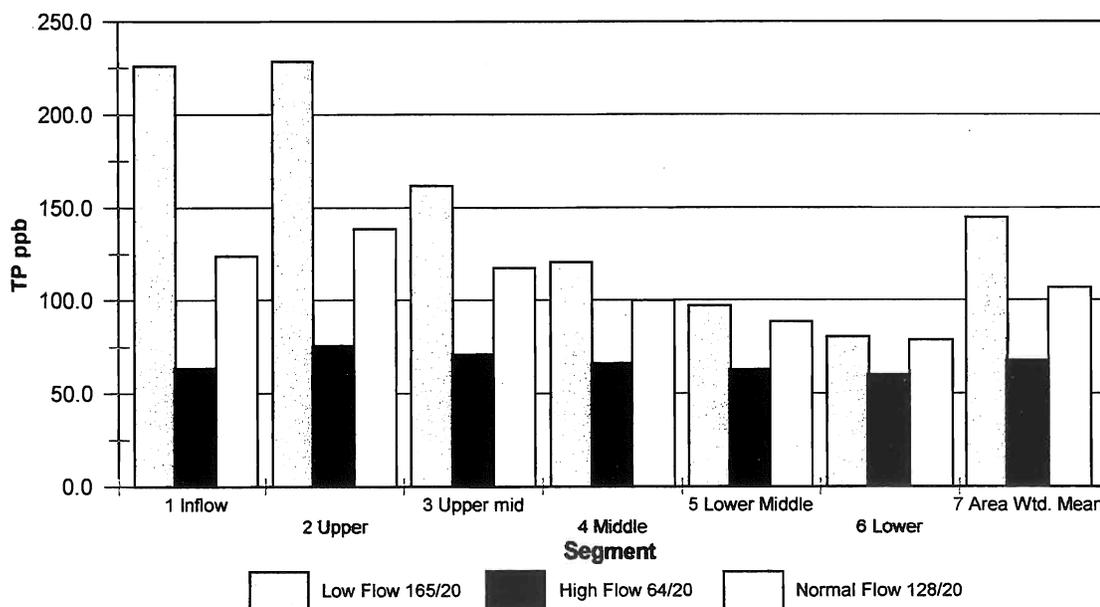
### ***High and Low Flow Scenarios***

High and low flow scenarios were also run in BATHTUB. It should be noted that few high flow events were captured with the data collected to calibrate the model, so the accuracy of the output for high flow events is questionable. Historic USGS flow data were used to determine annual mean high and low flow rates. These data were for the Wisconsin River at Wisconsin Rapids, so flows were adjusted by multiplying the flow rate times 1.035 to estimate flows at Nekoosa. This resulted in an annual mean high flow of 8,754 cfs and an annual mean low flow of 2,107 cfs. To adjust TP concentrations relative to flow conditions, we assumed that point sources are responsible for the majority of TP inputs. This assumption was based

on historic data for a variety of flow conditions which generally shows an inverse relationship between TP concentrations and flow. Therefore, in the low flow scenario TP was increased to 165 ug/l and in the high flow scenario TP was decreased to 64 ug/l. Internal loading was held at 20 mg/m<sup>3</sup>/day for both scenarios. Results of these scenarios are shown in Figures 10, 11, and 12.

During the low flow scenario TP and chlorophyll *a* in the upper half of the flowage remained high and Secchi disk measurements low. In the middle Segment (4) TP, chlorophyll *a*, and Secchi disk measurements all drop nearer to the 1996 scenario results and in the lower part of the reservoir (Segments 5 and 6) TP, chlorophyll *a*, and Secchi measurements are very similar to the 1996 scenario results. This suggests that increased concentrations have the greatest effect in the upper part of the reservoir.

**Figure 10. Estimates of TP concentrations from BATHTUB using annual mean high flow rates, annual mean low flow rates, and 1996 model estimates. Values are shown in legend are Inflow TP (ug/l)/Internal Loading TP (mg/m<sup>2</sup>/day).**

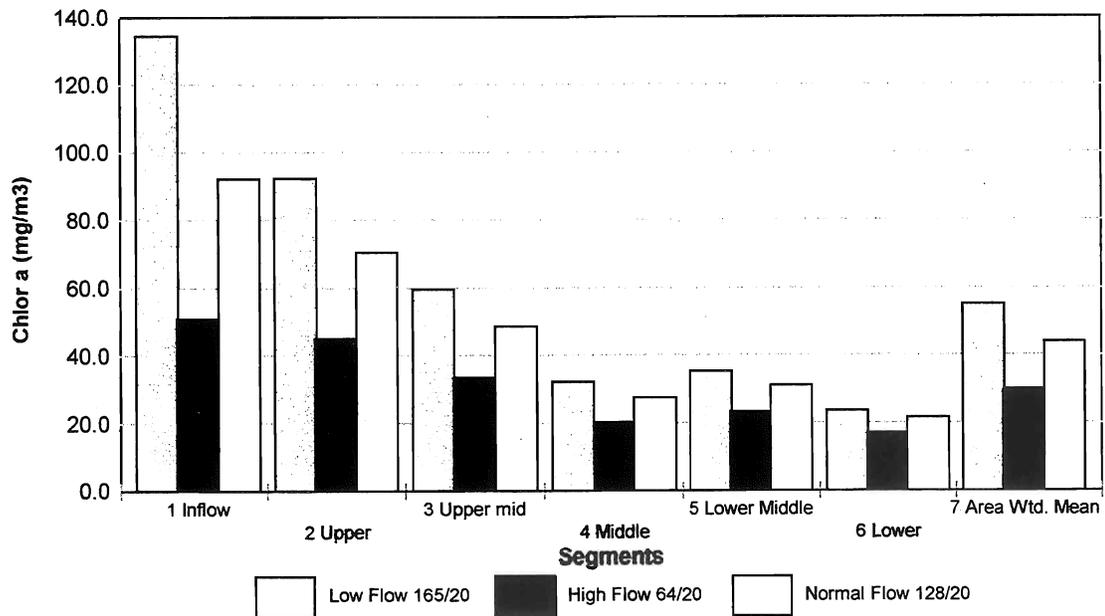


The high flow scenario results in little variation in TP concentrations as it moves through the reservoir with ranges from 59 to 76 ug/l, however, chlorophyll *a* changes from 51

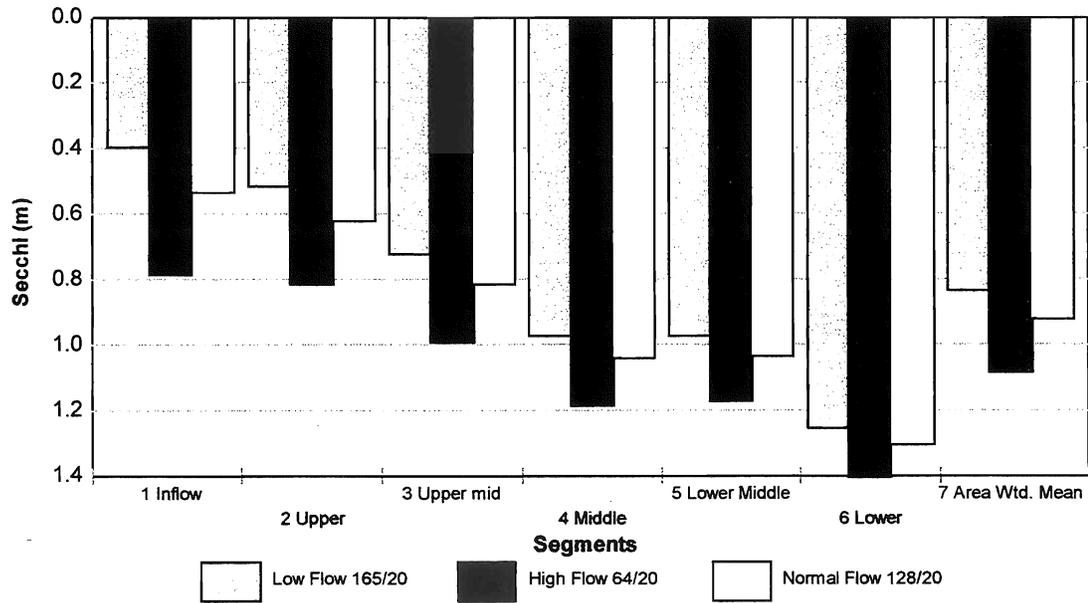
to 17 mg/m<sup>3</sup> and Secchi disk measurements increase from 0.8 to 1.4 m moving from the upper to the lower reservoir, respectively. The faster flow through and dilution of point sources suggests more improvement will occur during wet years compared to dry years.

In the high flow scenario the TP loading entering the reservoir was estimated to be 1,245,890 lbs/year compared to the 1996 loading of 1,352,275 lbs/year (Table 7). Outflow from the reservoir was estimated at 1,164,992 lbs/year during high flow and 848,357 lbs/year for the 1996 model. In an average year (1996) 423,020 more lbs/year TP were retained in the flowage than in a high flow year. In the low flow scenario inflow TP loading was estimated at 622,464 lbs/year and outflow estimates were 338,155 lbs/year. This low flow scenario resulted in retention of 219,608 fewer pounds of TP per year than in the average year.

**Figure 11. Estimates of chlorophyll *a* concentrations from BATHUB using annual mean high flow rates, annual mean low flow rates, and 1996 model estimates. Values are shown in legend are Inflow TP (ug/l)/Internal Loading TP (mg/m<sup>2</sup>/day).**



**Figure 12. Estimates of Secchi disk measurements from BATHTUB using annual mean high flow rates, annual mean low flow rates, and 1996 model estimates. Values are shown in legend are Inflow TP (ug/l)/Internal Loading TP (mg/m<sup>2</sup>/day).**



**Table 7. Total phosphorus loading and retention and water budget estimates for seven scenarios using the BATHTUB model of the Petenwell Flowage.**

Scenario	TP Load (lbs/year)		Retention (lbs/year)	Water Budget (mgd)	
	Inflow	Outflow		Inflow	Outflow
Inflow/Internal Loading					
64/10	681,512	556,100	125,412	3,490	3,529
112/17	1,184,584	784,900	399,685	3,490	3,529
128/20	1,352,275	848,357	503,918	3,490	3,529
155/24	1,635,253	938,155	697,098	3,490	3,529
256/40	2,693,801	1,187,609	1,506,192	3,490	3,529
High Flow 64/20	1,245,890	1,164,992	80,898	6,385	6,423
Low Flow 165/20	622,464	338,155	284,310	1,621	1,659

### *Water Budget*

The reservoir water budget is shown in Table 7. In 1996 the Wisconsin River was the primary source of water to the Petenwell Flowage at 97.3% of the water budget. The 10 Mile Creek supplied approximately 1.3%, and the Chester Creek and 14 Mile Creek supplied approximately 0.7% of the inflow. Precipitation in the reservoir accounted for the remaining inflow. Approximately 99.8% of the water left the flowage as outflow. The remaining 2% was lost through evaporation.

## CONCLUSIONS

1. The Wisconsin River is the major contributor of phosphorus inputs to the Petenwell Flowage. Loading from this source is significantly greater than from tributaries.
2. Phosphorus inputs to the Petenwell Flowage would need to be reduced by 50% to achieve DNR chlorophyll *a* goals of 22 mg/m<sup>3</sup> in at least half of the flowage.
3. Based on BATHTUB model estimates, if all point source discharge between Lake Dubay and Nekoosa were in compliance with NR217 algae bloom frequency (chlorophyll *a* >30 mg/m<sup>3</sup>) in the flowage would be reduced from 114 to 107 days in the flowage between May and October. This frequency could be further reduced with greater reduction in phosphorus inputs to the flowage.
4. Internal loading in the Petenwell flowage should be studied to determine a realistic time period for reduction or exhaustion of loading from this source if inflow phosphorus concentrations were decreased.
5. Current inflow data is not adequate to accurately separate impacts from point and non-point sources. More frequent sampling of more sites from Wausau to Nekoosa are needed to better define the movement of phosphorus through this stretch of river.
6. The Petenwell flowage should be sampled throughout the year (including high flows) and with greater frequency to better define flowage characteristics and responses and to further refine the BATHTUB model.
7. A more dynamic model using data obtained above (#5) may be desirable before requiring more restrictive point source discharge levels.

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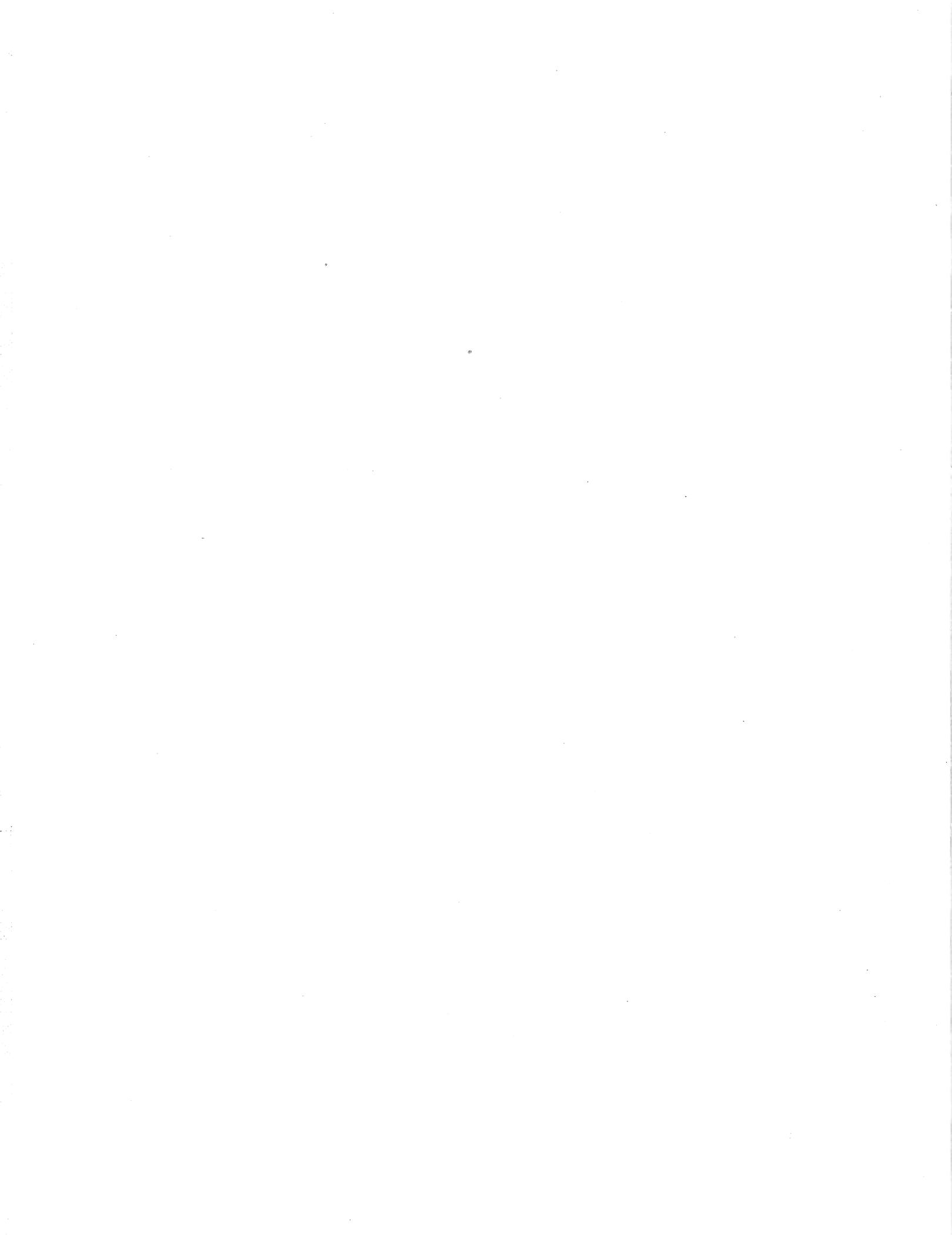


# **APPENDIX**

Water Quality Data

BATHTUB Output Data

Walker Calibration Report



WATER QUALITY DATA COLLECTED AT SAMPLE SITES IN THE PETENWELL FLOWAGE 1994-1997

STATION	DATE	ORGN	NH34N	TKN	NO23N	TOTAL N	TP	ORTHOP	CL	CHLA	SECCHI
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/m3	feet
13001	02/16/94		0.184	0.8	1.000	1.80	0.088	0.065	20		
13001	07/20/94	0.5	0.480	1.2	0.200	1.40	0.110	0.061	15		
13001	10/27/94	0.5	0.303	1.2	0.400	1.60	0.111	0.055	12		
13001	01/25/95		0.129		0.900	0.90	0.090	0.055	16		
13001	04/20/95	0.5	0.263	1.7	0.900	2.60	0.167	0.055	15		
13001	07/20/95	2.6	0.013	2.6	0.005	2.61	0.196	0.012	15		
13001	10/16/95	1.0		1.4	0.400	1.80	0.121	0.041	12		
13001	04/16/96		0.231		0.800	0.80	0.094	0.053	14		
13001	07/15/96			0.200	0.200	0.20	0.040	0.006	10		
13001	07/15/96			0.200	0.200	0.40	0.040	0.006	10		
13001	10/14/96	0.667	0.133	0.8	0.300	1.10	0.054	0.025	15		
13001	01/15/97	0.613	0.187	0.8	0.800	1.60	0.086	0.055	17		
13001	04/24/97	0.700	0.100	0.8	0.500	1.30	0.071	0.022	6		
13001	06/30/97	1.981	0.219	2.2		0.108	0.108	0.480	44		
13001	07/16/97	0.690	0.210	0.9	0.070	0.97	0.076	0.048	13		
13001	10/13/97			1.1	0.300	1.40	0.089	0.027	15		
13001	01/21/98			0.4	0.7	1.10	0.076	0.036			
13001	04/13/98			0.82	0.7	1.52	0.106	0.026			
13001	10/27/98			1.12	0.2	1.32	0.055	0.01			
13162	10/04/94	1.065	0.335	1.4	0.200	1.60	0.108	0.037		19.20	3.70
13162	10/25/94	0.987	0.313	1.3	0.400	1.70	0.104	0.056		4.85	3.00
13162	04/19/95	0.900	0.200	1.1	0.800	1.90	0.100	0.054	15	21.00	3.00
13162	05/17/95		0.014		0.600		0.063	0.005	15	31.20	3.00
13162	05/31/95		0.135		0.200		0.051	0.025	14	0.33	8.20
13162	08/02/95						0.044	0.016	15	0.01	5.80
13162	08/23/95		0.129		0.200		0.073	0.034	15	5.78	4.00
13162	09/13/95		0.014		0.500		0.093	0.041	10	5.20	2.60
13162	10/04/95		0.014		0.600		0.099	0.049	10	8.90	3.00
13162	10/18/95	0.901	0.099	1.0	0.400	1.40	0.090	0.047	12	17.40	3.60
13162	06/19/96	0.605	0.175	0.8	0.100	0.88	0.052	0.020	12	3.31	1.83
13162	07/16/96				0.200		0.051	0.009	10	29.10	1.18
13162	08/06/96		0.202		0.100		0.062	0.030	13	3.80	1.67
13162	08/21/96	1.384	0.116	1.5	0.080	1.58	0.131	0.021	13	59.90	0.58
13162	09/17/96	1.104	0.096	1.2	0.005	1.21	0.141	0.031	14	46.00	1.22
13162	10/01/96	0.594	0.236	0.8	0.090	0.92	0.073	0.030	15	12.50	0.91
13162	10/15/96	0.842	0.158	1.0	0.300	1.30	0.067	0.028	16	16.80	1.24

WATER QUALITY DATA COLLECTED AT SAMPLE SITES IN THE PETENWELL FLOWAGE 1994-1997

STATION	DATE	ORGN	NH34N	TKN	NO23N	TOTAL N	TP	ORTHOP	CL	GHLA	SECCHI
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/m3	feet
13162	05/21/97	0.800		0.8	0.286	1.09	0.111	0.005	9	59.60	0.82
13162	07/01/97	0.315	0.135	0.5	0.070	0.52	0.078	0.037	13	2.97	2.29
13162	07/29/97	1.057	0.143	1.2	0.080	1.28	0.084	0.050	13	28.50	1.22
13162	08/12/97	0.346	0.104	0.5	0.010	0.46	0.092	0.038	12	15.30	1.22
13162	09/09/97	0.987	0.033	1.0	0.400	1.42	0.078	0.031	13	16.40	1.04
13162	09/23/97	0.321	0.129	0.5	0.300	0.75	0.088	0.021	13	28.80	0.82
13162	10/14/97	1.141	0.059	1.2	0.300	1.50	0.094	0.031	14	46.10	0.73
13164	10/04/94	1.094	0.106	1.2	0.400	1.60	0.146	0.036		27.50	1.50
13164	10/25/94	1.187	0.014	1.2	0.600	1.80	0.139	0.042		40.10	3.00
13164	04/19/95	1.100		1.1	0.800	1.90	0.130	0.012	17	60.70	
13164	05/17/95	1.187	0.014	1.2	0.100	1.30	0.145	0.006	14	80.40	2.00
13164	05/31/95				0.060		0.106	0.019	13	14.50	4.20
13164	08/02/95	1.293	0.307	1.6	0.040	1.64	0.215	0.056	19	0.31	1.50
13164	08/23/95	1.187	0.014	1.2	0.300	1.50	0.141	0.031	9	28.20	1.80
13164	09/13/95	1.600		1.6	0.400	2.00	0.161	0.038	11	62.50	2.00
13164	10/04/95	1.087	0.014	1.1	0.400	1.50	0.118	0.028	16	47.20	2.00
13164	10/18/95	1.000		1.0	0.400	1.40	0.127	0.036	10	25.80	1.80
13164	06/19/96	0.917	0.103	1.0	0.200	1.22	0.115	0.015	9	43.60	0.67
13164	07/16/96	2.400		2.4	0.100	2.50	0.183	0.017	14	126.00	0.43
13164	08/06/96	0.955	0.245	1.2	0.060	1.26	0.155	0.034	13	48.50	0.61
13164	08/21/96	1.628	0.172	1.8			0.193	0.042	15	134.00	0.39
13164	09/17/96	0.804	0.296	1.1	0.200	1.30	0.134	0.051	17	31.10	0.70
13164	10/01/96	0.833	0.097	0.9	0.200	1.13	0.111	0.017	17	56.10	0.73
13164	10/15/96	0.965	0.035	1.0	0.040	1.04	0.085	0.007	17	51.30	0.79
13164	05/21/97	1.200		1.2	0.074		0.155	0.006	15	101.00	0.61
13164	07/01/97	5.619	0.161	5.8	0.040	5.84	0.444	0.053	13	256.00	0.03
13164	07/29/97	1.013	0.387	1.4	0.100	1.50	0.245	0.073	13	40.30	0.61
13164	08/12/97	1.258	0.142	1.4	0.010	1.41	0.210	0.038	15	62.40	0.49
13164	09/09/97	0.886	0.054	0.9	0.070	1.01	0.103	0.018	15	50.90	0.79
13164	09/23/97	0.429	0.021	0.5	0.100	0.55	0.115	0.017	13	58.80	0.67
13164	10/14/97	1.485	0.015	1.5	0.200	1.70	0.217	0.022	13	75.10	
293137	10/04/94	1.060		1.1	0.400	1.46	0.141	0.041		27.40	2.00
293137	10/25/94	1.000		1.0	0.600	1.60	0.145	0.056		28.30	2.00
293137	04/18/95	0.987	0.014	1.0	0.600	1.60	0.130	0.017	16	35.40	
293137	05/17/95	1.087	0.014	1.1	0.200	1.30	0.141	0.014	13	59.90	1.80
293137	05/31/95		0.014		0.100		0.113	0.009	12	47.10	2.80

WATER QUALITY DATA COLLECTED AT SAMPLE SITES IN THE PETENWELL FLOWAGE 1994-1997

STATION	DATE	ORGN mg/l	NH34N mg/l	TKN mg/l	NO23N mg/l	TOTAL N mg/l	TP mg/l	ORTHOP mg/l	CL mg/l	CHLA mg/m3	SECCHI feet
293137	08/02/95	0.972	0.328	1.3	0.300	1.60	0.164	0.058	20	0.40	2.80
293137	08/23/95	1.200		1.2	0.500	1.70	0.155	0.051	11	24.00	1.80
293137	09/13/95	0.993	0.107	1.1	0.600	1.70	0.140	0.036	13	30.00	2.20
293137	10/04/95		0.014		0.400		0.137	0.043	15	44.80	2.60
293137	10/18/95		0.089		0.400		0.116	0.050	11	14.20	2.20
293137	06/19/96	1.002	0.108	1.1	0.200	1.31	0.159	0.021	9	30.90	0.46
293137	07/16/96	1.087	0.014	1.1	0.200	1.30	0.090	0.006	16	59.40	0.79
293137	08/06/96				0.100		0.141	0.040	15	55.40	0.76
293137	08/21/96				0.100		0.123	0.024	15	49.20	0.79
293137	09/17/96		0.117		0.300		0.108	0.029	18	49.30	0.73
293137	10/01/96	0.717	0.014	0.7	0.200	0.93	0.102	0.020	17	71.30	0.85
293137	10/15/96	1.087	0.013	1.1	0.200	1.30	0.004	0.005	16	82.80	0.70
293137	05/21/97	1.100		1.1	0.309		0.147	0.006	15	73.50	0.79
293137	07/01/97	1.047	0.053	1.1	0.200	1.30	0.118	0.042	15	41.00	0.79
293137	07/29/97	0.450		0.5	0.300	0.75	0.142	0.035	13	48.60	0.67
293137	08/12/97	1.187	0.013	1.2	0.070	1.27	0.145	0.032	16	78.80	0.55
293137	09/09/97	1.076	0.024	1.1	0.200	1.30	0.124	0.018	15	60.20	0.67
293137	09/23/97	1.039	0.061	1.1	0.300	1.40	0.148	0.038	15	63.00	0.73
293137	10/14/97	1.500		1.5	0.200	1.70	0.165	0.017	13	81.60	0.55
293138	10/04/94	0.991	0.249	1.2	0.300	1.54	0.136	0.042		16.80	2.20
293138	10/25/94	0.861	0.339	1.2	0.400	1.60	0.117	0.035			2.80
293138	04/19/95	1.200		1.2	0.900	2.10	0.090	0.017	17	44.80	
293138	05/17/95		0.014		0.300		0.104	0.006	14	58.80	2.50
293138	05/31/95	1.036	0.164	1.2	0.100	1.30	0.144	0.039	14	1.70	5.00
293138	08/02/95	1.078	0.122	1.2			0.116	0.038	16	0.21	3.50
293138	08/23/95				0.200		0.102	0.026	11	37.20	2.10
293138	09/13/95	1.173	0.127	1.3	0.300	1.60	0.142	0.044	10	35.20	2.00
293138	10/04/95	0.878	0.122	1.0	0.500	1.50	0.104	0.048	13	20.00	2.20
293138	10/18/95		0.106		0.400		0.106	0.039	10	22.00	2.50
293138	06/19/96	0.885	0.085	1.0	0.100	1.07	0.103	0.013	13	43.10	0.85
293138	07/16/96		0.194		0.200		0.086	0.040	11	6.40	1.28
293138	08/06/96	1.211	0.089	1.3	0.040	1.34	0.093	0.021	14	43.40	0.91
293138	08/21/96	1.200	0.100	1.3			0.118	0.036	15	46.20	0.67
293138	09/17/96	0.289	0.289		0.060		0.097	0.042	15	13.10	0.91
293138	10/01/96	0.837	0.293	1.1	0.100	1.23	0.091	0.034	16	28.30	0.94
293138	10/15/96	1.348	0.252	1.6	0.200	1.80	0.128	0.033	16	57.50	1.10



WATER QUALITY DATA COLLECTED AT SAMPLE SITES IN THE PETENWELL FLOWAGE 1994-1997

STATION	DATE	ORGN mg/l	NH34N mg/l	TKN mg/l	NO23N mg/l	TOTAL N mg/l	TP mg/l	ORTHOP mg/l	CL mg/l	CHLA mg/m3	SECCHI feet
723020	07/29/97			1.0	0.300	1.30	0.131	0.042	14	37.0	
723020	08/12/97			1.2	0.090	1.29	0.155	0.041	16	63.9	
723020	09/09/97			1.5	0.200	1.70	0.112	0.032	17	48.2	
723020	09/23/97			1.4	0.300	1.70	0.180	0.081	15	62.1	
723020	10/13/97			1.2	0.200	1.40	0.146	0.014	12		
723020	10/14/97			1.2	0.300	1.50	0.172	0.021	12	77.0	
723020	01/21/98			0.4	0.700	1.10	0.100	0.053	19		
723020	04/13/98			0.84	0.7	1.54	0.138	0.044		69.5	
723020	06/03/98			1.19	0.1	1.29	0.159	0.033		39.9	
723020	06/17/98			1.31	0.2	1.51	0.118	0.022			
723020	07/21/98			1.41	0.2	1.61	0.127	0.024			
723020	10/27/98			1.11	0.3	1.41	0.096	0.005			

**BATHTUB output data for each segment and Petenwell reservoir area weighted mean for nine scenarios.**

SCENARIO	% OF MODEL CONC.	SEGMENT	TOTAL P ug/l	CHL-A mg/m3	SECCHI m
64/10	50	1 Inflow	63.27	53.60	0.76
64/10		2 Upper	73.25	47.43	0.78
64/10		3 Upper mid	66.58	35.26	0.97
64/10		4 Middle	60.39	21.67	1.15
64/10		5 Lower Middle	55.91	24.04	1.16
64/10		6 Lower	51.72	17.47	1.41
64/10		7 Area Wtd. Mean	61.99	31.17	1.06
85/13	66	1 Inflow	83.34	68.61	0.65
85/13		2 Upper	95.00	57.05	0.70
85/13		3 Upper mid	84.22	41.03	0.90
85/13		4 Middle	74.70	24.36	1.10
85/13		5 Lower Middle	68.01	27.21	1.10
85/13		6 Lower	61.96	19.33	1.36
85/13		7 Area Wtd. Mean	77.68	36.57	0.99
100/16	78	1 Inflow	97.57	77.84	0.59
100/16		2 Upper	111.15	62.82	0.66
100/16		3 Upper mid	96.85	44.36	0.86
100/16		4 Middle	84.60	25.85	1.07
100/16		5 Lower Middle	76.19	29.00	1.07
100/16		6 Lower	68.73	20.35	1.33
100/16		7 Area Wtd. Mean	88.74	39.73	0.96
112/17	88	1 Inflow	108.89	84.43	0.56
112/17		2 Upper	122.18	66.21	0.64
112/17		3 Upper mid	105.27	46.28	0.84
112/17		4 Middle	91.06	26.70	1.06
112/17		5 Lower Middle	81.44	30.02	1.05
112/17		6 Lower	73.00	20.92	1.32
112/17		7 Area Wtd. Mean	96.20	41.66	0.94
128/20	100	1 Inflow	123.90	92.22	0.53
128/20		2 Upper	138.55	70.56	0.62
128/20		3 Upper mid	117.46	48.71	0.81
128/20		4 Middle	100.23	27.75	1.04
128/20		5 Lower Middle	88.77	31.31	1.03
128/20		6 Lower	78.91	21.64	1.30
128/20		7 Area Wtd. Mean	106.82	44.05	0.92
152/20	119	1 Inflow	145.43	104.17	0.48
152/20		2 Upper	160.26	79.71	0.59
152/20		3 Upper mid	129.77	52.33	0.78
152/20		4 Middle	106.68	29.69	1.03
152/20		5 Lower Middle	92.09	32.82	1.01
152/20		6 Lower	80.08	22.65	1.28
152/20		7 Area Wtd. Mean	116.80	48.01	0.89

**BATHTUB output data for each segment and Petenwell reservoir area weighted mean for nine scenarios.**

SCENARIO	% OF MODEL CONC.	SEGMENT	TOTAL P ug/l	CHL-A mg/m3	SECCHI m
155/24	120	1 Inflow	149.02	103.22	0.48
155/24		2 Upper	164.20	76.08	0.59
155/24		3 Upper mid	135.92	51.75	0.78
155/24		4 Middle	113.71	29.04	1.02
155/24		5 Lower Middle	99.34	32.92	1.01
155/24		6 Lower	87.26	22.52	1.28
155/24		7 Area Wtd. Mean	122.96	47.15	0.89
256/40	200	1 Inflow	240.73	128.98	0.41
256/40		2 Upper	254.19	87.92	0.53
256/40		3 Upper mid	195.55	58.19	0.73
256/40		4 Middle	154.50	31.72	0.98
256/40		5 Lower Middle	129.86	36.36	0.96
256/40		6 Lower	110.46	24.38	1.23
256/40		7 Area Wtd. Mean	175.16	53.91	0.84
<b>LOW FLOW 250/20</b>					
250/20		1 Inflow	225.99	134.72	0.39
250/20		2 Upper	228.39	92.40	0.51
250/20		3 Upper mid	161.77	59.68	0.72
250/20		4 Middle	120.45	32.38	0.97
250/20		5 Lower Middle	97.52	35.39	0.97
250/20		6 Lower	80.54	23.77	1.25
250/20		7 Area Wtd. Mean	144.75	55.24	0.83
<b>HIGH FLOW 64/20</b>					
64/20		1 Inflow	63.54	50.89	0.78
64/20		2 Upper	75.97	45.00	0.81
64/20		3 Upper mid	71.22	33.68	0.99
64/20		4 Middle	66.54	20.45	1.18
64/20		5 Lower Middle	62.99	23.43	1.17
64/20		6 Lower	59.53	16.86	1.43
64/20		7 Area Wtd. Mean	67.21	29.77	1.08

**BATHTUB ESTIMATE OF CHLOROPHYLL A BLOOM FREQUENCY FOR EACH SEGMENT  
AND PETENWELL RESERVOIR AREA WEIGHTED MEAN FOR NINE SCENARIOS**

SCENARIO	SEGMENT	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency
		CHL-a>10 %	CHL-a>20 %	CHL-a>30 %	CHL-a>40 %	CHL-a>50 %	CHL-a>60 %
64/10	1 Inflow	99.17	89.97	73.44	56.44	42.15	31.13
64/10	2 Upper	98.61	86.06	66.6	48.58	34.63	24.53
64/10	3 Upper mid	95.75	72.73	48.02	30.38	19.12	12.15
64/10	4 Middle	82.57	42.82	20.19	9.70	4.86	2.54
64/10	5 Lower Middle	86.55	49.48	25.24	12.90	6.80	3.71
64/10	6 Lower	72.24	29.87	11.86	4.99	2.24	1.07
64/10	7 Area wtd mean	93.62	65.76	40.2	23.82	14.18	8.59
85/13	1 Inflow	99.74	95.34	84.72	71.24	57.94	46.26
85/13	2 Upper	99.38	91.63	76.63	60.37	46.12	34.77
85/13	3 Upper mid	97.54	80.21	57.74	39.39	26.47	17.80
85/13	4 Middle	87.00	50.34	25.92	13.35	7.08	3.89
85/13	5 Lower Middle	90.40	57.41	32.01	17.58	9.83	5.64
85/13	6 Lower	77.43	35.75	15.41	6.90	3.27	1.63
85/13	7 Area wtd mean	96.26	74.65	50.39	32.47	20.77	13.38
100/16	1 Inflow	99.86	97.01	89.03	77.76	65.69	54.39
100/16	2 Upper	99.60	93.77	81.11	66.20	52.32	40.66
100/16	3 Upper mid	98.18	83.52	62.59	44.30	30.74	21.26
100/16	4 Middle	88.92	54.15	29.12	15.53	8.47	4.77
100/16	5 Lower Middle	92.03	61.39	35.76	20.36	11.73	6.91
100/16	6 Lower	79.84	38.89	17.46	8.07	3.92	2.00
100/16	7 Area wtd mean	97.23	78.74	55.7	37.41	24.8	16.48
112/17	1 Inflow	99.91	97.79	91.29	81.46	70.37	59.53
112/17	2 Upper	99.69	94.75	83.32	69.25	55.69	43.98
112/17	3 Upper mid	98.46	85.16	65.15	47.01	33.18	23.30
112/17	4 Middle	89.87	56.20	30.91	16.79	9.3	5.30
112/17	5 Lower Middle	92.83	63.51	37.87	21.98	12.86	7.68
112/17	6 Lower	81.08	40.62	18.64	8.77	4.32	2.23
112/17	7 Area wtd mean	97.68	80.88	58.69	40.33	27.27	18.44
128/20	1 Inflow	99.95	98.44	93.34	85.02	75.10	64.93
128/20	2 Upper	99.77	95.76	85.76	72.76	59.70	48.06
128/20	3 Upper mid	98.76	86.99	68.15	50.32	36.23	25.90
128/20	4 Middle	90.92	58.63	33.14	18.40	10.38	6.01
128/20	5 Lower Middle	93.71	66.02	40.47	24.03	14.34	8.70
128/20	6 Lower	82.52	42.74	20.13	9.66	4.84	2.53
128/20	7 Area wtd mean	98.13	83.24	62.16	43.86	30.35	20.94
155/24	1 Inflow	99.97	99.03	95.38	88.86	80.49	71.40
155/24	2 Upper	99.85	96.75	88.32	76.64	64.33	52.92
155/24	3 Upper mid	99.04	88.94	71.55	54.20	39.95	29.16
155/24	4 Middle	92.06	61.47	35.84	20.42	11.77	6.93
155/24	5 Lower Middle	94.65	68.92	43.62	26.61	16.24	10.05
155/24	6 Lower	84.13	45.28	21.99	10.82	5.52	2.94
155/24	7 Area wtd mean	98.58	85.84	66.25	48.20	34.28	24.23
256/40	1 Inflow	99.99	99.65	97.94	94.28	88.85	82.24
256/40	2 Upper	99.93	98.12	92.28	83.16	72.59	62.04
256/40	3 Upper mid	99.43	92.11	77.60	61.59	47.39	35.96
256/40	4 Middle	93.96	66.78	41.28	24.69	14.82	9.04
256/40	5 Lower Middle	96.18	74.35	49.99	32.13	20.50	13.18
256/40	6 Lower	87.03	50.39	25.96	13.38	7.10	3.90
256/40	7 Area wtd mean	99.20	90.14	73.74	56.81	42.51	31.46

**BATHTUB ESTIMATE OF CHLOROPHYLL A BLOOM FREQUENCY FOR EACH SEGMENT  
AND PETENWELL RESERVOIR AREA WEIGHTED MEAN FOR NINE SCENARIOS**

SCENARIO	SEGMENT	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency
		CHL-a>10 %	CHL-a>20 %	CHL-a>30 %	CHL-a>40 %	CHL-a>50 %	CHL-a>60 %
<b>LOW FLOW 250/20</b>							
250/20	1 Inflow	99.99	99.72	96.45	95.05	90.15	84.04
250/20	2 Upper	99.95	98.47	91.33	85.18	75.31	65.18
250/20	3 Upper mid	99.50	92.72	75.15	63.20	49.08	37.56
250/20	4 Middle	94.36	68.01	38.96	25.78	15.62	9.61
250/20	5 Lower Middle	95.79	72.85	44.14	30.51	19.22	12.22
250/20	6 Lower	86.08	48.63	22.08	12.46	6.53	3.55
250/20	7 Area wtd mean	99.28	90.82	69.95	58.40	44.11	32.92
<b>HIGH FLOW 64/20</b>							
64/20	1 Inflow	98.97	88.43	70.63	53.14	38.91	28.25
64/20	2 Upper	98.28	84.09	63.47	45.22	31.56	21.95
64/20	3 Upper mid	95.04	70.21	45.07	27.84	17.17	10.72
64/20	4 Middle	80.08	39.21	17.67	8.20	3.99	2.04
64/20	5 Lower Middle	85.63	47.82	23.93	12.05	6.27	3.39
64/20	6 Lower	70.30	27.92	10.76	4.43	1.96	0.92
64/20	7 Area wtd mean	92.65	63.00	37.36	21.59	12.59	7.49

**BATHTUB estimated water balance, TP loading, and TP concentration for each segment using five scenarios.**

CASE: Calibration to 1996 112/17

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 1 Inflow

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
1	1 Wisconsin River	4754.00	98.6	532448.0	99.1	112.0
2	1 10 Mile	62.00	1.3	4588.0	.9	74.0
PRECIPITATION		7.68	.2	288.0	.1	37.5
TRIBUTARY INFLOW		4816.00	99.8	537036.0	99.9	111.5
***TOTAL INFLOW		4823.68	100.0	537324.0	100.0	111.4
ADVECTIVE OUTFLOW		4817.92	99.9	524622.1	97.6	108.9
***TOTAL OUTFLOW		4817.92	99.9	524622.1	97.6	108.9
***EVAPORATION		5.76	.1	.0	.0	.0
***RETENTION		.00	.0	12701.9	2.4	.0

RESID. TIME = .004 YRS, OVERFLOW RATE = 501.9 M/YR, DEPTH = 2.2 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 2 Upper

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
3	1 14 Mile	35.80	.7	930.8	.1	26.0
PRECIPITATION		14.24	.3	534.0	.1	37.5
INTERNAL LOAD		.00	.0	110524.6	17.4	.0
TRIBUTARY INFLOW		35.80	.7	930.8	.1	26.0
ADVECTIVE INFLOW		4817.92	99.0	524622.1	82.4	108.9
***TOTAL INFLOW		4867.96	100.0	636611.6	100.0	130.8
ADVECTIVE OUTFLOW		4857.28	99.8	593479.9	93.2	122.2
***TOTAL OUTFLOW		4857.28	99.8	593479.9	93.2	122.2
***EVAPORATION		10.68	.2	.0	.0	.0
***RETENTION		.00	.0	43131.7	6.8	.0

RESID. TIME = .012 YRS, OVERFLOW RATE = 272.9 M/YR, DEPTH = 3.2 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 3 Upper mid

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
PRECIPITATION		26.08	.5	978.0	.2	37.5
ADVECTIVE INFLOW		4857.28	99.5	593479.9	99.8	122.2
***TOTAL INFLOW		4883.36	100.0	594457.9	100.0	121.7
ADVECTIVE OUTFLOW		4863.80	99.6	512001.9	86.1	105.3
***TOTAL OUTFLOW		4863.80	99.6	512001.9	86.1	105.3
***EVAPORATION		19.56	.4	.0	.0	.0
***RETENTION		.00	.0	82456.0	13.9	.0

RESID. TIME = .030 YRS, OVERFLOW RATE = 149.2 M/YR, DEPTH = 4.5 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 4 Middle

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
PRECIPITATION		19.12	.4	717.0	.1	37.5
ADVECTIVE INFLOW		4863.80	99.6	512001.9	99.9	105.3
***TOTAL INFLOW		4882.92	100.0	512718.9	100.0	105.0
ADVECTIVE OUTFLOW		4868.58	99.7	443353.4	86.5	91.1
***TOTAL OUTFLOW		4868.58	99.7	443353.4	86.5	91.1
***EVAPORATION		14.34	.3	.0	.0	.0
***RETENTION		.00	.0	69365.4	13.5	.0

RESID. TIME = .034 YRS, OVERFLOW RATE = 203.7 M/YR, DEPTH = 6.9 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 5 Lower Middle

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
PRECIPITATION		18.40	.4	690.0	.2	37.5
ADVECTIVE INFLOW		4868.58	99.6	443353.4	99.8	91.1
***TOTAL INFLOW		4886.98	100.0	444043.4	100.0	90.9
ADVECTIVE OUTFLOW		4873.18	99.7	396849.6	89.4	81.4
***TOTAL OUTFLOW		4873.18	99.7	396849.6	89.4	81.4
***EVAPORATION		13.80	.3	.0	.0	.0
***RETENTION		.00	.0	47193.8	10.6	.0

RESID. TIME = .029 YRS, OVERFLOW RATE = 211.9 M/YR, DEPTH = 6.1 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 6 Lower

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
PRECIPITATION		14.40	.3	540.0	.1	37.5
ADVECTIVE INFLOW		4873.18	99.7	396849.6	99.9	81.4
***TOTAL INFLOW		4887.58	100.0	397389.6	100.0	81.3
ADVECTIVE OUTFLOW		4876.78	99.8	356028.3	89.6	73.0
***TOTAL OUTFLOW		4876.78	99.8	356028.3	89.6	73.0
***EVAPORATION		10.80	.2	.0	.0	.0
***RETENTION		.00	.0	41361.3	10.4	.0

RESID. TIME = .031 YRS, OVERFLOW RATE = 270.9 M/YR, DEPTH = 8.5 M

**CASE: Calibration to 1996 256/40**

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 1 Inflow

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
1	1 Wisconsin River	4754.00	98.6	1217024.0	99.6	256.0
2	1 10 Mile	62.00	1.3	4588.0	.4	74.0
-----						
	PRECIPITATION	7.68	.2	288.0	.0	37.5
	TRIBUTARY INFLOW	4816.00	99.8	1221612.0	100.0	253.7
	***TOTAL INFLOW	4823.68	100.0	1221900.0	100.0	253.3
	ADVECTIVE OUTFLOW	4817.92	99.9	1159819.0	94.9	240.7
	***TOTAL OUTFLOW	4817.92	99.9	1159819.0	94.9	240.7
	***EVAPORATION	5.76	.1	.0	.0	.0
	***RETENTION	.00	.0	62080.6	5.1	.0

RESID. TIME = .004 YRS, OVERFLOW RATE = 501.9 M/YR, DEPTH = 2.2 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 2 Upper

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
3	1 14 Mile	35.80	.7	930.8	.1	26.0
-----						
	PRECIPITATION	14.24	.3	534.0	.0	37.5
	INTERNAL LOAD	.00	.0	260058.0	18.3	.0
	TRIBUTARY INFLOW	35.80	.7	930.8	.1	26.0
	ADVECTIVE INFLOW	4817.92	99.0	1159819.0	81.6	240.7
	***TOTAL INFLOW	4867.96	100.0	1421342.0	100.0	292.0
	ADVECTIVE OUTFLOW	4857.28	99.8	1234668.0	86.9	254.2
	***TOTAL OUTFLOW	4857.28	99.8	1234668.0	86.9	254.2
	***EVAPORATION	10.68	.2	.0	.0	.0
	***RETENTION	.00	.0	186674.3	13.1	.0

RESID. TIME = .012 YRS, OVERFLOW RATE = 272.9 M/YR, DEPTH = 3.2 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 3 Upper mid

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
	PRECIPITATION	26.08	.5	978.0	.1	37.5
	ADVECTIVE INFLOW	4857.28	99.5	1234668.0	99.9	254.2
	***TOTAL INFLOW	4883.36	100.0	1235646.0	100.0	253.0
	ADVECTIVE OUTFLOW	4863.80	99.6	951108.5	77.0	195.5
	***TOTAL OUTFLOW	4863.80	99.6	951108.5	77.0	195.5
	***EVAPORATION	19.56	.4	.0	.0	.0
	***RETENTION	.00	.0	284537.4	23.0	.0

RESID. TIME = .030 YRS, OVERFLOW RATE = 149.2 M/YR, DEPTH = 4.5 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 4 Middle

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
PRECIPITATION		19.12	.4	717.0	.1	37.5
ADVECTIVE INFLOW		4863.80	99.6	951108.5	99.9	195.5
***TOTAL INFLOW		4882.92	100.0	951825.5	100.0	194.9
ADVECTIVE OUTFLOW		4868.58	99.7	752171.9	79.0	154.5
***TOTAL OUTFLOW		4868.58	99.7	752171.9	79.0	154.5
***EVAPORATION		14.34	.3	.0	.0	.0
***RETENTION		.00	.0	199653.6	21.0	.0

RESID. TIME = .034 YRS, OVERFLOW RATE = 203.7 M/YR, DEPTH = 6.9 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 5 Lower Middle

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
PRECIPITATION		18.40	.4	690.0	.1	37.5
ADVECTIVE INFLOW		4868.58	99.6	752171.9	99.9	154.5
***TOTAL INFLOW		4886.98	100.0	752861.9	100.0	154.1
ADVECTIVE OUTFLOW		4873.18	99.7	632847.9	84.1	129.9
***TOTAL OUTFLOW		4873.18	99.7	632847.9	84.1	129.9
***EVAPORATION		13.80	.3	.0	.0	.0
***RETENTION		.00	.0	120014.0	15.9	.0

RESID. TIME = .029 YRS, OVERFLOW RATE = 211.9 M/YR, DEPTH = 6.1 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 6 Lower

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
PRECIPITATION		14.40	.3	540.0	.1	37.5
ADVECTIVE INFLOW		4873.18	99.7	632847.9	99.9	129.9
***TOTAL INFLOW		4887.58	100.0	633387.9	100.0	129.6
ADVECTIVE OUTFLOW		4876.78	99.8	538696.0	85.0	110.5
***TOTAL OUTFLOW		4876.78	99.8	538696.0	85.0	110.5
***EVAPORATION		10.80	.2	.0	.0	.0
***RETENTION		.00	.0	94691.9	15.0	.0

RESID. TIME = .031 YRS, OVERFLOW RATE = 270.9 M/YR, DEPTH = 8.5 M

CASE: Calibration to 1996 155/24

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 1 Inflow

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
1	1 Wisconsin River	4754.00	98.6	736870.0	99.3	155.0
2	1 10 Mile	62.00	1.3	4588.0	.6	74.0
-----						
	PRECIPITATION	7.68	.2	288.0	.0	37.5
	TRIBUTARY INFLOW	4816.00	99.8	741458.0	100.0	154.0
	***TOTAL INFLOW	4823.68	100.0	741746.0	100.0	153.8
	ADVECTIVE OUTFLOW	4817.92	99.9	717957.2	96.8	149.0
	***TOTAL OUTFLOW	4817.92	99.9	717957.2	96.8	149.0
	***EVAPORATION	5.76	.1	.0	.0	.0
	***RETENTION	.00	.0	23788.8	3.2	.0

RESID. TIME = .004 YRS, OVERFLOW RATE = 501.9 M/YR, DEPTH = 2.2 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 2 Upper

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
3	1 14 Mile	35.80	.7	930.8	.1	26.0
-----						
	PRECIPITATION	14.24	.3	534.0	.1	37.5
	INTERNAL LOAD	.00	.0	156034.8	17.8	.0
	TRIBUTARY INFLOW	35.80	.7	930.8	.1	26.0
	ADVECTIVE INFLOW	4817.92	99.0	717957.2	82.0	149.0
	***TOTAL INFLOW	4867.96	100.0	875456.8	100.0	179.8
	ADVECTIVE OUTFLOW	4857.28	99.8	797561.3	91.1	164.2
	***TOTAL OUTFLOW	4857.28	99.8	797561.3	91.1	164.2
	***EVAPORATION	10.68	.2	.0	.0	.0
	***RETENTION	.00	.0	77895.6	8.9	.0

RESID. TIME = .012 YRS, OVERFLOW RATE = 272.9 M/YR, DEPTH = 3.2 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 3 Upper mid

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
	PRECIPITATION	26.08	.5	978.0	.1	37.5
	ADVECTIVE INFLOW	4857.28	99.5	797561.3	99.9	164.2
	***TOTAL INFLOW	4883.36	100.0	798539.3	100.0	163.5
	ADVECTIVE OUTFLOW	4863.80	99.6	661077.1	82.8	135.9
	***TOTAL OUTFLOW	4863.80	99.6	661077.1	82.8	135.9
	***EVAPORATION	19.56	.4	.0	.0	.0
	***RETENTION	.00	.0	137462.2	17.2	.0

RESID. TIME = .030 YRS, OVERFLOW RATE = 149.2 M/YR, DEPTH = 4.5 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 4 Middle

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
PRECIPITATION		19.12	.4	717.0	.1	37.5
ADVECTIVE INFLOW		4863.80	99.6	661077.1	99.9	135.9
***TOTAL INFLOW		4882.92	100.0	661794.1	100.0	135.5
ADVECTIVE OUTFLOW		4868.58	99.7	553630.1	83.7	113.7
***TOTAL OUTFLOW		4868.58	99.7	553630.1	83.7	113.7
***EVAPORATION		14.34	.3	.0	.0	.0
***RETENTION		.00	.0	108163.9	16.3	.0

RESID. TIME = .034 YRS, OVERFLOW RATE = 203.7 M/YR, DEPTH = 6.9 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 5 Lower Middle

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
PRECIPITATION		18.40	.4	690.0	.1	37.5
ADVECTIVE INFLOW		4868.58	99.6	553630.1	99.9	113.7
***TOTAL INFLOW		4886.98	100.0	554320.1	100.0	113.4
ADVECTIVE OUTFLOW		4873.18	99.7	484094.8	87.3	99.3
***TOTAL OUTFLOW		4873.18	99.7	484094.8	87.3	99.3
***EVAPORATION		13.80	.3	.0	.0	.0
***RETENTION		.00	.0	70225.4	12.7	.0

RESID. TIME = .029 YRS, OVERFLOW RATE = 211.9 M/YR, DEPTH = 6.1 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 6 Lower

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
PRECIPITATION		14.40	.3	540.0	.1	37.5
ADVECTIVE INFLOW		4873.18	99.7	484094.8	99.9	99.3
***TOTAL INFLOW		4887.58	100.0	484634.8	100.0	99.2
ADVECTIVE OUTFLOW		4876.78	99.8	425544.5	87.8	87.3
***TOTAL OUTFLOW		4876.78	99.8	425544.5	87.8	87.3
***EVAPORATION		10.80	.2	.0	.0	.0
***RETENTION		.00	.0	59090.3	12.2	.0

RESID. TIME = .031 YRS, OVERFLOW RATE = 270.9 M/YR, DEPTH = 8.5 M

CASE: Calibration to 1996 64/10

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 1 Inflow

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
1	1 Wisconsin River	4754.00	98.6	304256.0	98.4	64.0
2	1 10 Mile	62.00	1.3	4588.0	1.5	74.0
-----						
	PRECIPITATION	7.68	.2	288.0	.1	37.5
	TRIBUTARY INFLOW	4816.00	99.8	308844.0	99.9	64.1
	***TOTAL INFLOW	4823.68	100.0	309132.0	100.0	64.1
	ADVECTIVE OUTFLOW	4817.92	99.9	304843.3	98.6	63.3
	***TOTAL OUTFLOW	4817.92	99.9	304843.3	98.6	63.3
	***EVAPORATION	5.76	.1	.0	.0	.0
	***RETENTION	.00	.0	4288.7	1.4	.0

RESID. TIME = .004 YRS, OVERFLOW RATE = 501.9 M/YR, DEPTH = 2.2 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 2 Upper

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
3	1 14 Mile	35.80	.7	930.8	.3	26.0
-----						
	PRECIPITATION	14.24	.3	534.0	.1	37.5
	INTERNAL LOAD	.00	.0	65014.5	17.5	.0
	TRIBUTARY INFLOW	35.80	.7	930.8	.3	26.0
	ADVECTIVE INFLOW	4817.92	99.0	304843.3	82.1	63.3
	***TOTAL INFLOW	4867.96	100.0	371322.6	100.0	76.3
	ADVECTIVE OUTFLOW	4857.28	99.8	355818.7	95.8	73.3
	***TOTAL OUTFLOW	4857.28	99.8	355818.7	95.8	73.3
	***EVAPORATION	10.68	.2	.0	.0	.0
	***RETENTION	.00	.0	15503.9	4.2	.0

RESID. TIME = .012 YRS, OVERFLOW RATE = 272.9 M/YR, DEPTH = 3.2 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 3 Upper mid

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
	PRECIPITATION	26.08	.5	978.0	.3	37.5
	ADVECTIVE INFLOW	4857.28	99.5	355818.7	99.7	73.3
	***TOTAL INFLOW	4883.36	100.0	356796.7	100.0	73.1
	ADVECTIVE OUTFLOW	4863.80	99.6	323814.9	90.8	66.6
	***TOTAL OUTFLOW	4863.80	99.6	323814.9	90.8	66.6
	***EVAPORATION	19.56	.4	.0	.0	.0
	***RETENTION	.00	.0	32981.7	9.2	.0

RESID. TIME = .030 YRS, OVERFLOW RATE = 149.2 M/YR, DEPTH = 4.5 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 4 Middle

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
PRECIPITATION		19.12	.4	717.0	.2	37.5
ADVECTIVE INFLOW		4863.80	99.6	323814.9	99.8	66.6
***TOTAL INFLOW		4882.92	100.0	324531.9	100.0	66.5
ADVECTIVE OUTFLOW		4868.58	99.7	294024.3	90.6	60.4
***TOTAL OUTFLOW		4868.58	99.7	294024.3	90.6	60.4
***EVAPORATION		14.34	.3	.0	.0	.0
***RETENTION		.00	.0	30507.7	9.4	.0

RESID. TIME = .034 YRS, OVERFLOW RATE = 203.7 M/YR, DEPTH = 6.9 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 5 Lower Middle

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
PRECIPITATION		18.40	.4	690.0	.2	37.5
ADVECTIVE INFLOW		4868.58	99.6	294024.3	99.8	60.4
***TOTAL INFLOW		4886.98	100.0	294714.3	100.0	60.3
ADVECTIVE OUTFLOW		4873.18	99.7	272467.7	92.5	55.9
***TOTAL OUTFLOW		4873.18	99.7	272467.7	92.5	55.9
***EVAPORATION		13.80	.3	.0	.0	.0
***RETENTION		.00	.0	22246.6	7.5	.0

RESID. TIME = .029 YRS, OVERFLOW RATE = 211.9 M/YR, DEPTH = 6.1 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 6 Lower

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
PRECIPITATION		14.40	.3	540.0	.2	37.5
ADVECTIVE INFLOW		4873.18	99.7	272467.7	99.8	55.9
***TOTAL INFLOW		4887.58	100.0	273007.7	100.0	55.9
ADVECTIVE OUTFLOW		4876.78	99.8	252245.5	92.4	51.7
***TOTAL OUTFLOW		4876.78	99.8	252245.5	92.4	51.7
***EVAPORATION		10.80	.2	.0	.0	.0
***RETENTION		.00	.0	20762.2	7.6	.0

RESID. TIME = .031 YRS, OVERFLOW RATE = 270.9 M/YR, DEPTH = 8.5 M

CASE: Calibration to 1996 128/20

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 1 Inflow

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
1	1 Wisconsin River	4754.00	98.6	608512.0	99.2	128.0
2	1 10 Mile	62.00	1.3	4588.0	.7	74.0
-----						
	PRECIPITATION	7.68	.2	288.0	.0	37.5
	TRIBUTARY INFLOW	4816.00	99.8	613100.0	100.0	127.3
	***TOTAL INFLOW	4823.68	100.0	613388.0	100.0	127.2
	ADVECTIVE OUTFLOW	4817.92	99.9	596942.8	97.3	123.9
	***TOTAL OUTFLOW	4817.92	99.9	596942.8	97.3	123.9
	***EVAPORATION	5.76	.1	.0	.0	.0
	***RETENTION	.00	.0	16445.3	2.7	.0

RESID. TIME = .004 YRS, OVERFLOW RATE = 501.9 M/YR, DEPTH = 2.2 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 2 Upper

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
3	1 14 Mile	35.80	.7	930.8	.1	26.0
-----						
	PRECIPITATION	14.24	.3	534.0	.1	37.5
	INTERNAL LOAD	.00	.0	130029.0	17.9	.0
	TRIBUTARY INFLOW	35.80	.7	930.8	.1	26.0
	ADVECTIVE INFLOW	4817.92	99.0	596942.8	81.9	123.9
	***TOTAL INFLOW	4867.96	100.0	728436.6	100.0	149.6
	ADVECTIVE OUTFLOW	4857.28	99.8	672976.1	92.4	138.5
	***TOTAL OUTFLOW	4857.28	99.8	672976.1	92.4	138.5
	***EVAPORATION	10.68	.2	.0	.0	.0
	***RETENTION	.00	.0	55460.5	7.6	.0

RESID. TIME = .012 YRS, OVERFLOW RATE = 272.9 M/YR, DEPTH = 3.2 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 3 Upper mid

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
	PRECIPITATION	26.08	.5	978.0	.1	37.5
	ADVECTIVE INFLOW	4857.28	99.5	672976.1	99.9	138.5
	***TOTAL INFLOW	4883.36	100.0	673954.1	100.0	138.0
	ADVECTIVE OUTFLOW	4863.80	99.6	571294.5	84.8	117.5
	***TOTAL OUTFLOW	4863.80	99.6	571294.5	84.8	117.5
	***EVAPORATION	19.56	.4	.0	.0	.0
	***RETENTION	.00	.0	102659.6	15.2	.0

RESID. TIME = .030 YRS, OVERFLOW RATE = 149.2 M/YR, DEPTH = 4.5 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 4 Middle

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
PRECIPITATION		19.12	.4	717.0	.1	37.5
ADVECTIVE INFLOW		4863.80	99.6	571294.5	99.9	117.5
***TOTAL INFLOW		4882.92	100.0	572011.5	100.0	117.1
ADVECTIVE OUTFLOW		4868.58	99.7	487979.3	85.3	100.2
***TOTAL OUTFLOW		4868.58	99.7	487979.3	85.3	100.2
***EVAPORATION		14.34	.3	.0	.0	.0
***RETENTION		.00	.0	84032.2	14.7	.0

RESID. TIME = .034 YRS, OVERFLOW RATE = 203.7 M/YR, DEPTH = 6.9 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 5 Lower Middle

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
PRECIPITATION		18.40	.4	690.0	.1	37.5
ADVECTIVE INFLOW		4868.58	99.6	487979.3	99.9	100.2
***TOTAL INFLOW		4886.98	100.0	488669.3	100.0	100.0
ADVECTIVE OUTFLOW		4873.18	99.7	432591.7	88.5	88.8
***TOTAL OUTFLOW		4873.18	99.7	432591.7	88.5	88.8
***EVAPORATION		13.80	.3	.0	.0	.0
***RETENTION		.00	.0	56077.7	11.5	.0

RESID. TIME = .029 YRS, OVERFLOW RATE = 211.9 M/YR, DEPTH = 6.1 M

SEGMENT BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

SEGMENT: 6 Lower

ID	T LOCATION	--- FLOW ---		--- LOAD ---		CONC MG/M3
		HM3/YR	%	KG/YR	%	
PRECIPITATION		14.40	.3	540.0	.1	37.5
ADVECTIVE INFLOW		4873.18	99.7	432591.7	99.9	88.8
***TOTAL INFLOW		4887.58	100.0	433131.7	100.0	88.6
ADVECTIVE OUTFLOW		4876.78	99.8	384812.1	88.8	78.9
***TOTAL OUTFLOW		4876.78	99.8	384812.1	88.8	78.9
***EVAPORATION		10.80	.2	.0	.0	.0
***RETENTION		.00	.0	48319.6	11.2	.0

RESID. TIME = .031 YRS, OVERFLOW RATE = 270.9 M/YR, DEPTH = 8.5 M

## **Calibration of BATHTUB to Petenwell Reservoir, Wisconsin**

**Prepared for  
University of Wisconsin, Stevens Point**

**By**

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**September 9, 1999**

A previous report (April 30, 1998) described preliminary calibration results and made specific recommendations for additional monitoring and revising model segmentation. This report describes calibration of the revised model to 1996 data, testing against 1997 data, and demonstrates model application to evaluate alternative loading scenarios.

Results are summarized in the following:

Table 1	Model Input File for 1996
Table 2	Model Output Files for 1996
Table 3	Model Input File for 1997
Table 4	Model Output File for 1997
Table 5	Predicted Responses to Hypothetical Reductions in Wisconsin River P Concentration & Internal P Load
Figure 1	Observed & Predicted Conditions, 1996
Figure 2	Observed & Predicted Conditions, 1997
Figure 3	Sampled Flows & Concentrations, Wisconsin River at Nekoosa

Two BATHTUB input files 'PET\_96.BIN' and 'PET\_97.BIN' are provided separately. Contents of these files are listed in Tables 1 and 3, respectively.

The revised model contains 6 segments sorted in downstream order. Reservoir morphometry has been re-computed by LW with segment boundaries specified by the author. Results are listed in the model input files (Tables 1 & 3).

Results of model calibration against 1996 data are given in Tables 1 & 2 and Figure 1. The 1996 phosphorus profile is fit by setting the decay rate calibration factor to 0.4 and specifying an internal loading rate of 20 mg/m<sup>2</sup>-day in the second segment. With these coefficients, internal loading accounts for 17% of the total load. Calibration strategies for other parameters are described in my April 1998 report

Results of model testing against 1997 data (using the 1996 calibrated coefficients) are given in Tables 3 & 4 and Figure 2. Phosphorus concentrations are under-predicted by an average of 20%. The phosphorus profile suggests that the apparent internal loading in segment 2 was greater in 1997 than in 1996. Error analysis results indicate, however, that observed and predicted values are not significantly different, however, given the expected model error and uncertainty in the measurements.

Results suggest that the net sedimentation rate of phosphorus within the reservoir is considerably below typical values observed in the Corps of Engineer reservoirs used for model development. The low sedimentation rate in the reservoir as a whole and/or the apparent internal load in segment 2 could reflect under-estimation of one or more of the tributary phosphorus inputs, in particular the Wisconsin River. Figure 3 shows the daily hydrograph between May and October in 1994-1998 in relation to the dates of sample collection. It is apparent that high-flow regimes were infrequently sampled during these years. Only one major event was captured (June 1996). While the load computation procedure (FLUX program) attempts to account for correlations between flow and concentration, the accuracy and precision of the estimates is limited when high-flow concentration measurements are not available.

Table 5 shows predicted sensitivity to hypothetical reductions in external and internal P loads. The 1996 calibration has been re-run with 0%, 25%, 50%, and 75% reductions in Wisconsin River P concentration (starting with 128 µg/l) and with 0% and 100% reductions in internal loading. Chlorophyll-a sensitivity to reductions in external load is limited by the internal load and high initial P concentration. Given the high calibration coefficient for chlorophyll-a (1.6), it is unlikely that nitrogen limitation is important. Despite the relatively low N/P ratio, potential effects of nitrogen limitation may be offset by algal fixation of atmospheric N.

Since the precise nature of the apparent internal load is unknown, there is considerable uncertainty in forecasting its response to reductions in external load. To the extent that it reflects recycling of recently deposited P or an artifact of sampling limitations, the internal load would be expected to decrease with reductions in external load, but over a longer time scale. Otherwise, an alum treatment or other sediment treatment would provide more immediate control. More detailed field studies would be needed to evaluate the nature and spatial extent of the internal load before proceeding with an alum treatment. Alternative load scenarios can be evaluated by LW using the calibrated input files provided.



Table 1 (ct)

SEGMENT MORPHOMETRY: MEAN/CV

ID LABEL	LENGTH	AREA	ZMEAN	ZMAX	ZEYP
	KM	KM2	M	M	M
1 Inflow	11.20	9.4000	2.20	2.20/ .00	.00/ .00
2 Upper	7.40	17.8000	3.20	3.20/ .00	.00/ .00
3 Upper mid	8.10	32.6000	4.50	4.50/ .00	.00/ .00
4 middle	5.60	23.9000	6.90	6.90/ .00	.00/ .00
5 Lower Middle	5.50	23.0000	6.10	6.10/ .00	.00/ .00
6 Lower	4.20	19.0000	8.50	8.50/ .00	.00/ .00

SEGMENT OBSERVED WATER QUALITY:

SEG	TURBID	CONSER	TOTALP	TOTALN	CHL-A	SECCHI	ORG-N	TP-OP	ECOV	MODV
	L/M	---	MG/M3	MG/M3	MG/M3	M	MG/M3	MG/M3	MG/M3-D	MG/M3-D
1 MN:	.80	15.1	104.0	1210.0	56.9	.7	973.0	83.0	.0	.0
CV:	.00	.07	.18	.18	.11	.09	.09	.12	.00	.00
2 MN:	.80	14.6	139.0	1408.0	70.0	.6	1215.0	113.0	.0	.0
CV:	.00	.07	.18	.08	.11	.07	.09	.12	.00	.00
3 MN:	.50	.0	.0	.0	.0	.0	.0	.0	.0	.0
CV:	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
4 MN:	.00	14.3	102.3	1360.0	34.0	.9	1096.0	71.0	.0	.0
CV:	.00	.05	.06	.12	.21	.08	.09	.10	.00	.00
5 MN:	.50	.0	.0	.0	.0	.0	.0	.0	.0	.0
CV:	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
6 MN:	.00	13.3	82.0	1177.0	24.5	1.2	905.0	56.0	.0	.0
CV:	.00	.06	.17	.11	.33	.13	.17	.25	.00	.00

MODEL COEFFICIENTS:

COEFFICIENT	MEAN	CV
DISPERSION FACTOR	.000	.70
P DECAY RATE	.400	.45
N DECAY RATE	1.000	.55
CHL-A MODEL	1.700	.26
SECCHI MODEL	1.000	.10
ORGANIC N MODEL	1.000	.12
TP-OP MODEL	1.000	.15
ECOV MODEL	1.000	.15
MODV MODEL	1.000	.22
BETA M2/MG	.015	.00
MINIMUM QS	4.000	.00
FLUSHING EFFECT	1.000	.00
CHLOROPHYLL-A CV	.620	.00

Table 2 - Model Output Files for 1996

CASE: Calibration to 1996

GROSS WATER BALANCE:

ID	LOCATION	DRAINAGE AREA KM2	FLOW (MM3/YR)		CV	RUNOFF M/YR
			MEAN	VARIANCE		
1	1 Wisconsin River	15462.000	4754.000	.565E+05	.050	.307
2	1 10 Mile	190.000	62.000	.154E+03	.200	.326
3	1 14 Mile	241.000	35.800	.513E+02	.200	.149
PRECIPITATION		124.900	99.920	.399E+03	.200	.800
TRIBUTARY INFLOW		15893.000	4851.800	.567E+05	.049	.305
***TOTAL INFLOW		16017.900	4951.720	.571E+05	.048	.309
ADVECTIVE OUTFLOW		16017.900	4876.780	.576E+05	.049	.304
***TOTAL OUTFLOW		16017.900	4876.780	.576E+05	.049	.304
***EVAPORATION		.000	74.940	.505E+03	.500	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

ID	LOCATION	LOADING		VARIANCE		CV	CONC MG/M3	EXPORT KG/KM2
		KG/YR	% (I)	KG/YR**2	% (I)			
1	1 Wisconsin River	608512.0	81.4	.336E+10	15.5	.055	128.0	35.4
2	1 10 Mile	4588.0	.6	.133E+08	.1	.756	74.0	24.1
3	1 14 Mile	930.8	.1	.693E+05	.0	.283	26.0	3.9
PRECIPITATION		3747.0	.5	.351E+07	.0	.500	37.5	36.0
INTERNAL LOAD		130029.0	17.4	.169E+11	83.4	1.000	.0	.0
TRIBUTARY INFLOW		614030.8	82.1	.337E+10	15.6	.055	126.6	35.6
***TOTAL INFLOW		747806.8	100.0	.703E+11	100.0	.190	151.0	46.7
ADVECTIVE OUTFLOW		384812.1	51.5	.796E+10	39.2	.232	79.9	24.0
***TOTAL OUTFLOW		384812.1	51.5	.796E+10	39.2	.232	79.9	24.0
***RETENTION		362994.7	48.5	.154E+11	73.5	.342	.0	.0

HYDRAULIC		TOTAL P			
OVERFLOW RESIDENCE	POOL RESIDENCE	TURNOVER	RETENTION		
RATE	TIME	CONC	TIME	RATIO	COEF
M/YR	YRS	MG/M3	YRS	-	-
39.05	.1400	106.7	.0974	5.1313	.4654

CASE: Calibration to 1996

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS USING THE FOLLOWING ERROR TERMS:

- 1 = OBSERVED WATER QUALITY ERROR ONLY
- 2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
- 3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 7 AREA-BED MEAN

VARIABLE	OBSERVED		ESTIMATED		RATIO	T STATISTICS		
	MEAN	CV	MEAN	CV		1	2	3
CONSERVATIVE SUB	14.1	.06	.0	.00	.00	.00	.00	.00
TOTAL P MG/M3	106.7	.14	106.8	.17	1.00	-.01	.00	-.01
TOTAL N MG/M3	1304.0	.10	1304.0	.06	1.00	.00	.00	.00
C-NUTRIENT MG/M3	71.0	.12	71.0	.08	1.00	-.01	.00	.00
CHL A MG/M3	44.0	.17	44.1	.27	1.00	.01	.01	.01
SECCHI M	.9	.09	.9	.17	.99	-.11	-.04	-.05
ORGANIC N MG/M3	1060.2	.11	1199.8	.26	.88	1.13	.49	.44
TP-ORTHOC-P MG/M3	80.1	.17	86.4	.29	.93	-.45	-.21	-.23

CASE: Calibration to 1996

Table 2 (ct)

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES  
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 7 AREA-WTD MEAN

VARIABLE	VALUES		RANKS (%)	
	OBSERVED	ESTIMATED	OBSERVED	ESTIMATED
CONSERVATIVE SUB	14.14	.00	.0	.0
TOTAL P MG/M3	106.69	106.82	81.3	81.4
TOTAL N MG/M3	1304.02	1304.02	66.0	66.0
C.NUTRIENT MG/M3	70.97	71.02	80.5	80.5
CHL A MG/M3	43.95	44.05	97.7	97.8
SECCHI M	.91	.92	40.9	41.5
ORGANIC N MG/M3	1060.18	1199.80	94.3	98.6
TP-ORPIC-P MG/M3	80.07	86.41	84.9	86.7
ANTILOG PC-1	1245.89	1298.16	89.3	89.9
ANTILOG PC-2	16.37	16.85	96.2	96.6
(M - 150) / P	10.62	10.60	25.3	25.2
INORGANIC N / P	9.16	5.11	11.8	3.8
TURBIDITY 1/M	.51	.51	42.1	42.1
SMIX * TURBIDITY	2.79	2.79	43.8	43.8
SMIX / SECCHI	6.03	5.96	66.6	64.9
CHL-A * SECCHI	39.89	40.40	97.3	97.4
CHL-A / TOTAL P	.41	.41	87.9	87.9
FREQ(CHL-a>10) %	98.11	98.13	.0	.0
FREQ(CHL-a>20) %	83.15	83.24	.0	.0
FREQ(CHL-a>30) %	62.02	62.16	.0	.0
FREQ(CHL-a>40) %	43.71	43.86	.0	.0
FREQ(CHL-a>50) %	30.22	30.95	.0	.0
FREQ(CHL-a>60) %	20.64	20.94	.0	.0
CARLSON TSI-P	71.49	71.51	.0	.0
CARLSON TSI-CHLA	67.71	67.73	.0	.0
CARLSON TSI-SEC	61.40	61.25	.0	.0



Table 3 (ct)

SEGMENT MORPHOMETRY: MEAN/CV

ID LABEL	LENGTH		AREA		ZMEAN		ZMIX		ZEYP	
	RM	RM	KM2	KM2	M	M	M	M	M	M
1 InFlow	11.80		9.6000		2.20	2.20/	.12	.00/	.00	.00
2 Upper	4.30		17.8000		3.20	3.20/	.12	.00/	.00	.00
3 Upper mid	5.30		32.6000		4.50	4.50/	.12	.00/	.00	.00
4 Middle	4.70		23.9000		6.80	6.90/	.12	.00/	.00	.00
5 Lower Middle	4.50		23.0000		6.10	6.10/	.12	.00/	.00	.00
6 Lower	3.90		18.0000		6.50	6.50/	.12	.00/	.00	.00

SEGMENT OBSERVED WATER QUALITY:

SEG	TURBID	CONSER	TOTALP	TOTALN	CHL-A	SECCHI	ORG-N	TP-OP	HODV	MODV
	1/M	---	MG/MB	MG/MB	MG/MB	M	MG/MB	MG/MB	MG/MB-D	MG/MB-D
1 MN:	.00	14.6	141.0	1287.0	63.8	.7	1057.0	114.0	.0	.0
CV:	.00	.05	.04	.10	.09	.06	.11	.08	.00	.00
2 MN:	.00	13.9	213.0	2002.0	92.1	.5	1699.0	180.0	.0	.0
CV:	.00	.05	.20	.39	.31	.20	.39	.21	.00	.00
3 MN:	.50	.0	.0	.0	.0	.0	.0	.0	.0	.0
CV:	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
4 MN:	.00	13.4	139.0	1577.0	54.8	.7	1288.0	100.0	.0	.0
CV:	.00	.05	.08	.07	.21	.08	.09	.09	.00	.00
5 MN:	.50	.0	.0	.0	.0	.0	.0	.0	.0	.0
CV:	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
6 MN:	.00	12.4	89.0	1002.0	28.2	1.2	710.0	59.0	.0	.0
CV:	.00	.05	.05	.16	.26	.17	.20	.15	.00	.00

MODEL COEFFICIENTS:

COEFFICIENT	MEAN	CV
DISPERSION FACTOR	.000	.70
P DECAY RATE	.400	.45
N DECAY RATE	1.000	.55
CHL-A MODEL	1.600	.26
SECCHI MODEL	1.000	.10
ORGANIC N MODEL	1.000	.12
TP-OP MODEL	1.000	.15
HODV MODEL	1.000	.15
MODV MODEL	1.000	.22
BETA M2/MG	.015	.00
MINIMUM QS	4.000	.00
FLUSHING EFFECT	1.000	.00
CHLOROPHYLL-A CV	.620	.00

Table 4 - Model Output Files for 1997

CASE: May Oct 1997

GRCSS WATER BALANCE:

ID	LOCATION	DRAINAGE AREA KM2	FLOW (MM3/YR)		CV	RUNOFF M/YR
			MEAN	VARIANCE		
1	1 Wisconsin River	15462.000	3769.000	.355E+C5	.C50	.244
2	1 10 Mile	190.000	49.200	.869E+C2	.200	.239
3	1 14 Mile	241.000	27.700	.307E+C2	.200	.115
PRECIPITATION		124.900	99.920	.399E+C3	.200	.800
TRIBUTARY INFLOW		15893.000	3845.900	.356E+C5	.C49	.242
***TOTAL INFLOW		16017.900	3945.820	.360E+C5	.C48	.246
ADVECTIVE OUTFLOW		16017.900	3870.880	.365E+C5	.C49	.242
***TOTAL OUTFLOW		16017.900	3870.880	.365E+C5	.C49	.242
***EVAPORATION		.000	74.940	.505E+C3	.300	.000

GRCSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

ID	LOCATION	LOADING KG/YR	VARIANCE		CV	CONC MG/M3	EXPORT KG/KM2
			t(1)	KG/YR**2			
1	1 Wisconsin River	572888.0	80.6	.243E+10	77.5	.066	152.0
2	1 10 Mile	3640.8	.5	.839E+07	.3	.756	74.0
3	1 14 Mile	720.2	.1	.415E+05	.C	.263	3.0
PRECIPITATION		3747.0	.5	.351E+07	.1	.500	37.5
INTERNAL LOAD		130079.0	18.3	.676E+09	71.7	.700	.0
TRIBUTARY INFLOW		577249.0	81.2	.244E+10	78.2	.066	150.1
***TOTAL INFLOW		711025.0	100.0	.312E+10	100.0	.079	160.7
ADVECTIVE OUTFLOW		309998.5	43.6	.536E+10	171.9	.236	80.1
***TOTAL OUTFLOW		309998.5	43.6	.536E+10	171.9	.236	80.1
***RETENTION		401026.5	56.4	.640E+10	203.2	.159	.0

HYDRAULIC		TOTAL P			
OVERFLOW RATE	RESIDENCE TIME	POOL CONC	RESIDENCE TIME	TURNOVER RATIO	RETENTION COEF
M/YR	YRS	MG/M3	YRS	-	-
30.99	.1764	145.3	.1396	3.5825	.5640

CASE: May-Oct 1997

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS USING THE FOLLOWING ERROR TERMS:

- 1 = OBSERVED WATER QUALITY ERROR ONLY
- 2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
- 3 = OBSERVED AND PREDICTED ERROR

SEGMENT:	7 AREA-BED MEAN	OBSERVED		ESTIMATED		T STATISTICS			
		MEAN	CV	MEAN	CV	RATIO	1	2	3
	CONSERVATIVE SUB	13.4	.03	13.4	.02	1.00	.00	.00	.00
	TOTAL P MG/M3	145.3	.12	116.8	.13	1.24	1.86	.81	1.23
	TOTAL N MG/M3	1496.6	.20	1496.6	.14	1.00	.00	.00	.00
	C-NUTRIENT MG/M3	88.6	.17	80.7	.10	1.10	.55	.46	.47
	CHL A MG/M3	58.7	.24	48.0	.28	1.22	.85	.58	.55
	SECCHI M	.8	.13	.9	.18	.88	-.94	-.44	-.55
	ORGANIC N MG/M3	1211.4	.22	1289.3	.26	.94	.28	.25	.18
	TP-ORTHOC-P MG/M3	111.8	.15	93.2	.29	1.20	1.23	.50	.56

Table 4 (ct)

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES  
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 7 AREA-WTD MEAN

VARIABLE	----- VALUES -----		--- RANKS (%) ---	
	OBSERVED	ESTIMATED	OBSERVED	ESTIMATED
CONSERVATIVE SUB	13.43	13.43	.0	.0
TOTAL P MG/M3	145.30	116.80	89.1	83.9
TOTAL N MG/M3	1496.64	1496.64	73.5	73.5
C.NUTRIENT MG/M3	88.57	80.74	87.2	84.6
CHL-A MG/M3	58.72	48.01	99.1	98.3
SECCHI M	.79	.89	33.8	40.0
ORGANIC N MG/M3	1211.44	1289.26	96.7	97.5
TP-ORTHO-P MG/M3	111.84	93.18	91.7	88.4
ANTILOG PC-1	1868.26	1526.51	94.0	91.9
ANTILOG DT-2	17.73	17.28	97.3	97.0
(N - 150) / P	9.27	11.53	18.6	28.4
INORGANIC N / P	8.52	8.78	10.5	11.0
TURBIDITY 1/M	.50	.50	41.0	41.0
ENIX * TURBIDITY	2.73	2.73	42.6	42.6
ENIX / SECCHI	6.95	6.14	74.1	66.8
CHL-A * SECCHI	46.20	42.77	98.4	97.9
CHL-A / TOTAL P	.40	.41	87.2	87.6
FREQ(CHL-A>10) %	99.45	98.68	.0	.0
FREQ(CHL-A>20) %	92.32	85.49	.0	.0
FREQ(CHL-A>30) %	78.03	67.37	.0	.0
FREQ(CHL-A>40) %	62.15	49.37	.0	.0
FREQ(CHL-A>50) %	47.97	35.36	.0	.0
FREQ(CHL-A>60) %	36.51	25.16	.0	.0
CARLSON TSI-P	75.94	72.80	.0	.0
CARLSON TSI-CHLA	70.55	68.58	.0	.0
CARLSON TSI-SEC	63.45	61.67	.0	.0

**Table 5**  
**Predicted Responses to Hypothetical Reductions in**  
**Wisconsin River P Concentration & Internal P Load**

**Internal Load Reduction = 0%**

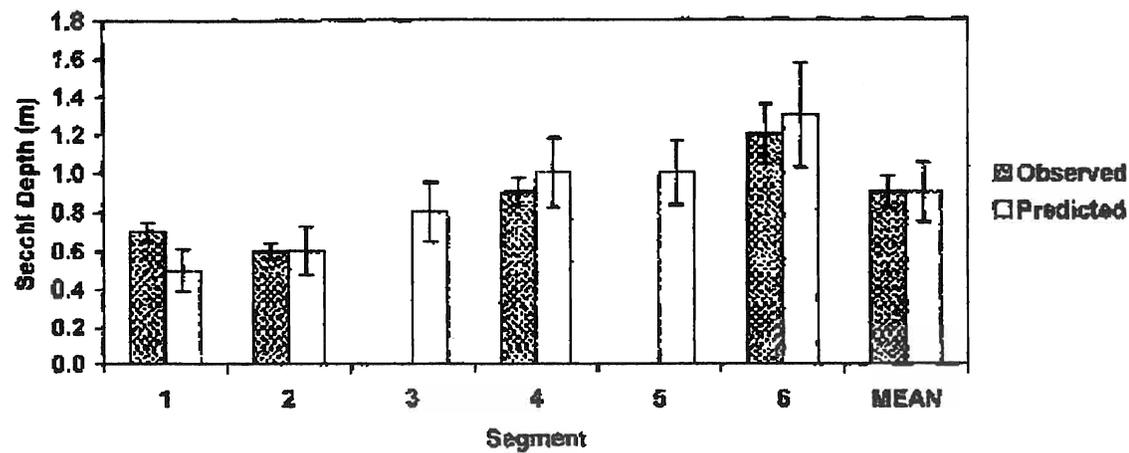
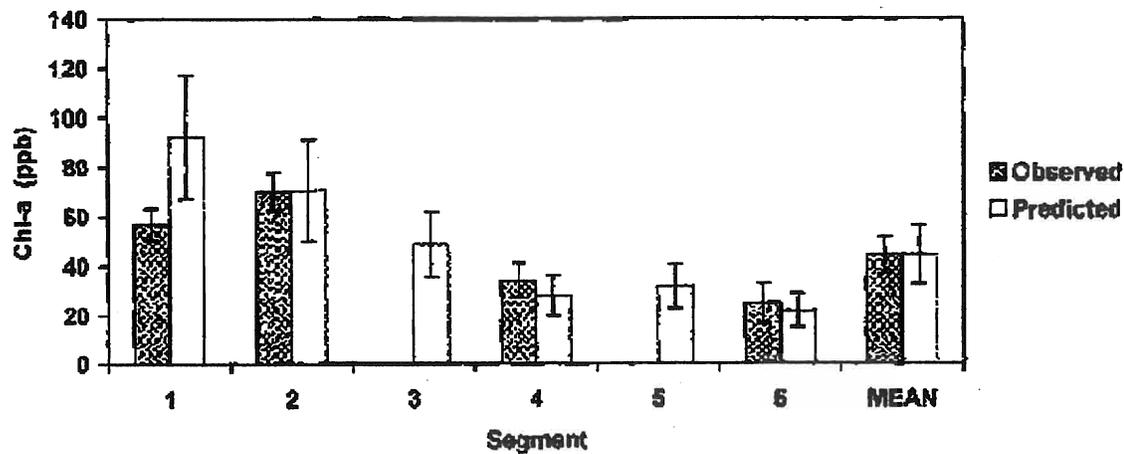
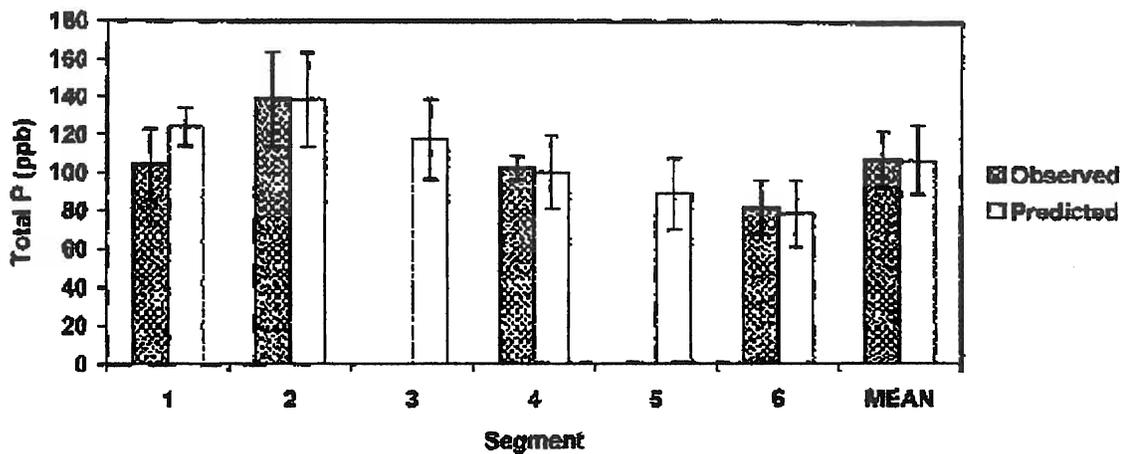
Wisc R. P Reduction	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>Weighted Mean</u>
<b>Total P (ppb)</b>							
0%	123.9	138.6	117.5	100.2	88.8	78.9	106.8
25%	93.8	112.6	97.9	85.4	76.9	69.3	89.3
50%	63.3	85.5	76.6	68.6	62.9	57.7	70.1
75%	32.4	57.2	53.0	49.0	46.0	43.1	48.6
<b>Chlorophyll-a (ppb)</b>							
0%	92.2	70.6	48.7	27.8	31.3	21.6	44.1
25%	75.5	63.3	44.6	26.0	29.1	20.4	39.7
50%	53.6	53.1	38.7	23.3	26.0	18.6	33.7
75%	26.2	38.7	29.7	18.9	20.9	15.5	25.0
<b>Secchi (meters)</b>							
0%	0.53	0.62	0.81	1.04	1.03	1.30	0.92
25%	0.61	0.66	0.86	1.07	1.07	1.33	0.96
50%	0.76	0.74	0.93	1.12	1.12	1.38	1.03
75%	1.10	0.88	1.06	1.21	1.23	1.47	1.16

**Internal Load Reduction = 100%**

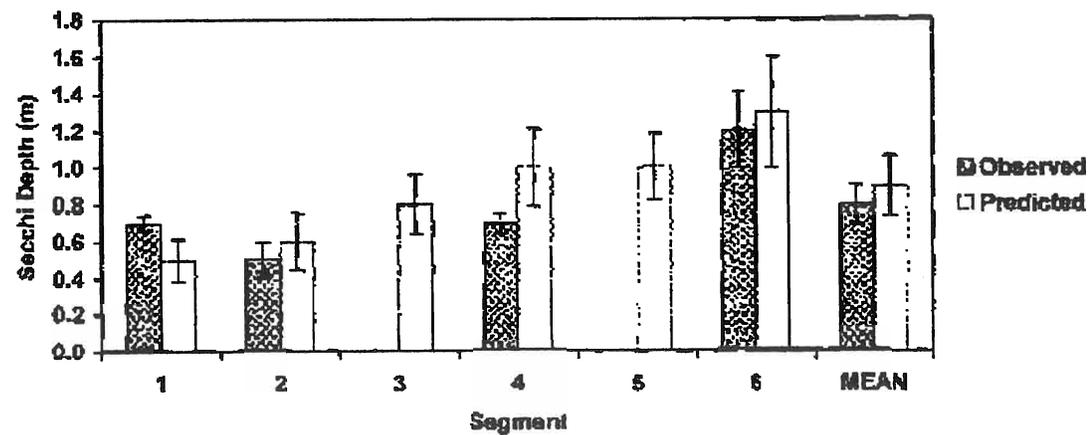
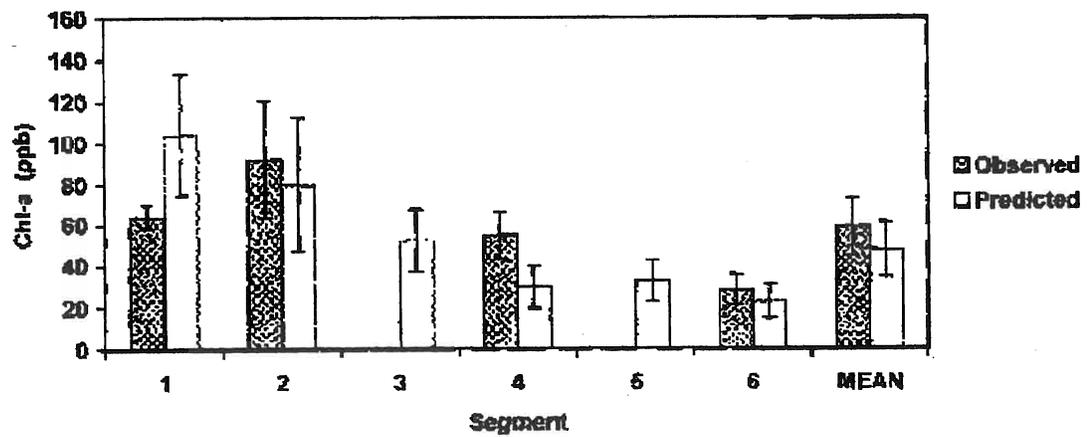
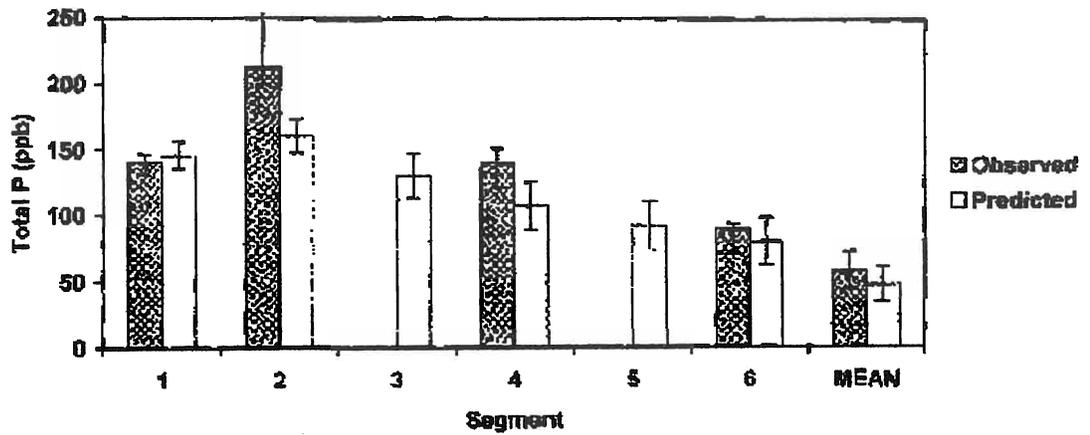
Wisc R. P Reduction	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>Weighted Mean</u>
<b>Total P (ppb)</b>							
0%	123.9	115.3	100.0	87.1	78.2	70.4	93.3
25%	93.8	88.7	79.2	70.6	64.6	59.1	74.4
50%	63.3	60.9	56.2	51.7	48.3	45.2	53.5
75%	32.4	31.8	30.5	29.2	28.1	27.1	29.7
<b>Chlorophyll-a (ppb)</b>							
0%	92.2	64.1	45.1	26.2	29.4	20.6	41.4
25%	75.5	54.5	39.5	23.7	26.4	18.9	36.0
50%	53.6	40.8	31.1	19.6	21.7	16.0	28.1
75%	26.2	21.5	17.8	12.4	13.6	10.7	16.2
<b>Secchi (meters)</b>							
0%	0.53	0.66	0.85	1.07	1.06	1.33	0.95
25%	0.61	0.72	0.92	1.11	1.12	1.37	1.01
50%	0.76	0.85	1.03	1.19	1.21	1.46	1.11
75%	1.10	1.13	1.30	1.37	1.42	1.65	1.35

May-September 1996 Conditions  
Wisconsin River Inflow Conc = 128 ppb for 0% Reduction

**Figure 1**  
**Observed & Predicted Conditions - 1996**



**Figure 2**  
**Observed & Predicted Conditions - 1997**



**Figure 3**  
**Sampled Flows & Concentrations, Wisconsin River at Nekoosa**  
**May-October, 1994-1998**

