# Review of BATHTUB Calibration for Tainter Lake, Wisconsin

prepared for

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by

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## Introduction

This report reviews and revises BATHTUB calibrations for Tainter Lake developed by the USGS (1991a,b,c). Two versions of the model calibration to 1990 data were apparently developed. For purposes of discussion, calibrations are referenced as follows:

| | | |
|---|---|---|
| USGS1 | - | First USGS Calibration (USGS, 1991a) |
| USGS2 | - | Revised USGS Calibration (USGS, 1991c) |
| UNCALIB | - | Version 5.3, Uncalibrated |
| WWW | - | Version 5.3, Calibrated by WWW |

Table 1 summarizes model options and calibration factors used in each USGS calibration and in the author's version. A diskette containing the current version of BATHTUB and the WWW calibration (TLWWW.BIN) is attached to this report. Tables 2, 3, and 4 lists input files for USGS2, UNCALIB, and WWW, respectively. Figures 1 and 2 show observed and predicted concentrations for UNCALIB and WWW, respectively. Observed and predicted diagnostic variables for WWW are listed in Table 5.

The USGS1 & USGS2 calibrations were developed using the early (batch) version of BATHTUB. An input file and calibrated coefficients were supplied only for USGS2. The latest (interactive) version (5.3) uses a different file format but includes a utility for translating input files generated for the batch version. In both versions, tributary TYPE=2 codes are used to identify ungauged tributaries. Unlike the batch version, however, the interactive version automatically estimates flows and concentrations based upon user-supplied land use data and non-point-source export coefficients. Directly specified flow and concentration values for TYPE=2 tributaries are lost in translating files for use with the interactive version. To account for this, flow and concentration values specified for TYPE=2 tributaries in USGS1 & USGS2 have been manually entered in the UNCALIB and WWW files and the TYPE codes have been reset to 1. Even though these are estimated values, they are treated the same as measured values in constructing reservoir flow and nutrient balances.

The UNCALIB version generates a-priori predictions using default coefficients. The only adjusted calibration coefficient in the case is the longitudinal dispersion coefficient for Segment 2, which has has been set to 0.0 to reflect impedence of longitudinal dispersion by the long and narrow river channel between Segments 2 and 3. The WWW version starts with UNCALIB and adjusts certain coefficients to match observed and predicted values for phosphorus, chlorophyll-a, and secchi depth within reasonable error bounds.

Specific comments on the calibrations are listed below:

1. USGS2 calibrates phosphorus, chlorophyll-a, and transparency separately for each segment. This involves adjusting 9 coefficients. While this approach is not neccessarily "wrong", the author prefers a more parsimonious approach to calibration (adjusting fewer coeffients). In WWW, only global calibration factors are adjusted using a least-squares criterion (3 coefficients). Given the uncertainty (CV) in the measured concentrations, exact calibration to each segment does not seem appropriate. If management decisions to be made using the model depend heavily upon water quality in a particular segment (vs. reservoir as a whole), the local calibration approach could be used.

2. All calibrations employ phosphorus model 1 (default). In USGS2, three calibration coefficients are adjusted to match observed concentations in each segment. In WWW, the overall phosphorus sedimentation rate is adjusted slightly (from 1 to 1.13) to provide a least-squares fit of the observed concentrations.

3. USGS2 uses BATHTUB Chlorophyll-a Model 2, which was designed to account for algal growth limitation by phosphorus, light, and or flushing rate. Based upon the extremely high chlorophyll-a concentrations, shallow depth, bluegreen algal types found here, it is unlikely that light or flushing rate are controlling algal densities. Regional experience (primarily in Minnesota) suggests that chlorophyll-a Model 5 (Jones & Bachman regression) is appropriate. WWW uses

Model 5 with a global calibration factor of 0.83, well within the expected 0.5 to 2.0 range for calibration coefficients, based upon error magnitudes estimated from the CE reservoir data set.

4. Based on the memo on the Secchi/Phosphorus relationship (USGS,1991b), the USGS concluded that Secchi Model 3 (apparently used in USGS1) consisted of the following equation:

$$1/S = 0.082 + .022\ P$$

As clearly stated in the program documentation (Walker,1987, p. IV-10), the equation is:

$$S = 17.8\ P^{-0.76}$$

It is puzzling that the USGS chose to guess the equation, instead of looking it up in the documentation. Since this equation was developed from reservoirs with a wide range of non-algal turbidities, the author suggests using Secchi Model 1, as adopted in the USGS1, UNCALIB, and WWW calibrations. Instead of adjusting Secchi calibration factors for each segment, the BETA coefficient (slope of inverse Secchi vs. Chl-a relationship) is adjusted downward from the default value (0.025 $m^2$/mg) to 0.01 $m^2$/mg. Based upon recent model applications in Minnesota and Oregon, this rather drastic adjustment is often necessary in reservoirs dominated by bluegreen algal types. Because of morphological features or mat-forming properties, light extinction per unit chlorophyll-a is lower in these situations.

5. The USGS2 calibration specifies no longitudinal dispersion (lateral mixing between segments). This differs from the default option, which computes longitudinal dispersion using Fischer's equation. The specification of no dispersion between Segments 2 and 3 is justified based upon morphometric considerations (narrow river channel). Based upon the maps provided, however, considerable mixing would be expected between Segments 1 and 2. Accordingly the default dispersion option is specified in the UNCALIB version. As expected, this predicts high mixing rate and little difference in water quality between Segment 1 and 2 (Figure 1), which is contrary to the observed phosphorus, chlorophyll-a, and secchi data. The reason for this is unclear and is perhaps the most puzzling aspect of the calibration. Resetting the calibration factor for Segment 2 to 0.0 improves the predictions (Figure 2). This has the same effect has selecting dispersion Model 0, as in USGS2.

As discussed above, the most puzzling aspect of the calibration is the apparent presence of stronger longitudinal gradients than initially predicted. Data from other years should be examined to determine whether this pattern persists.

Maps suggest that another reservoir segment could be specified at the mouth of the Hay River. This has not been done, apparently because of the absence of observed water quality data for this area. Depending upon its area and volume relative to loads and flows from the Hay River, significant phosphorus retention may be occuring in this region. Exclusion of this segment would not have much effect on prediction of reservoir-average concentrations. If significant retention does occur in this segment, however, sensitivity of average main-lake concentrations to loads from the Hay River would be lower than predicted by the current model. Addition of this segment is suggested if sufficient data are available and if the relative sensitivity to loads from Hay vs. Red Cedar Rivers is important.

USGS (1991a) discusses the potential role of nitrogen limitation in Tainter Lake and reaches the conclusion that the system is primarily phosphorus limited, based upon Total N / Total P ratios. N/P ratios tend to be self-regulating in these highly eutrophic impoundments because of nitrogen fixation. Thus, modeling external nitrogen budgets would not be particuarly useful for predicting trophic response. The focus on phopshorus is appropriate.

Regarding the potential benefits of point-source P limits, the USGS (1991a) concludes that "if such limits are not adpoted, the water quality will continue to deteriorate". This conclusion implies a non-steady-state condition, which cannot be detected by calibrating the model to a single year. "Worsening" conditions would be expected only if point-source loads continue to increase over time.

**References**

Walker, W.W., "Empirical Methods for Predicting Eutrophication in Impoundments, Report 4,, Applications Manual", USAE Waterways Experiment Station, Tech. Report E-81-9, July 1987.

Walker, W.W., "Flux, Profile, & Bathtub Documentation", prepared for USAE Waterways Experiment Station", Draft May 1995.

US Geological Survey, "Summary of the Evaluation and Simulation of Water Quality in Tainter Lake, Dunn County, Wisconsin, June 1991a.

USGS, Memo, Secchi / Phosphorus Relationship, 1991b.

USGS, "Tainter Lake Model Revisions and Re-Calibration", July 9, 1991c.

## List of Figures



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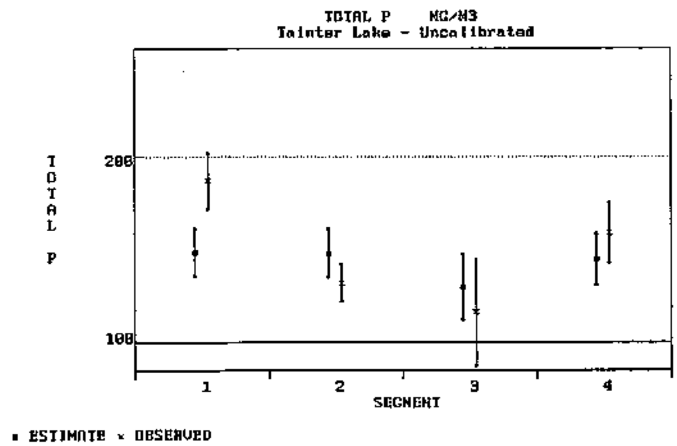
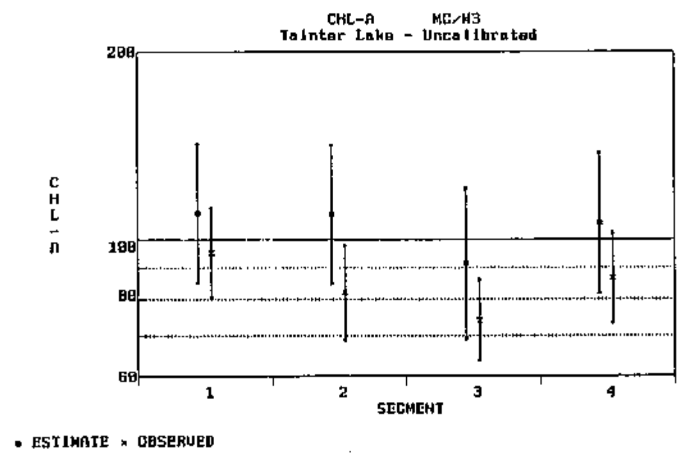
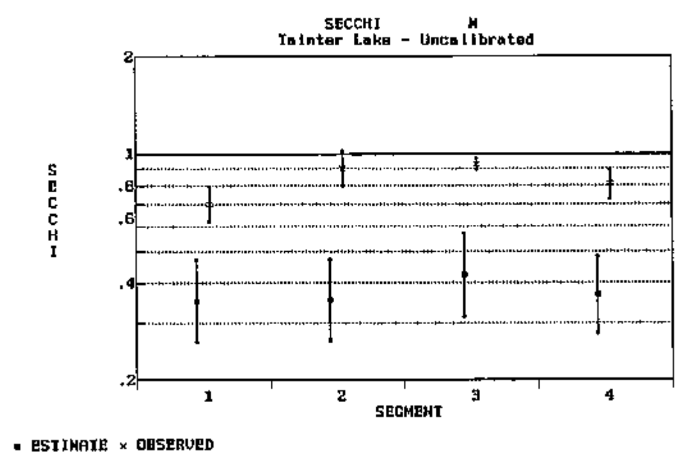
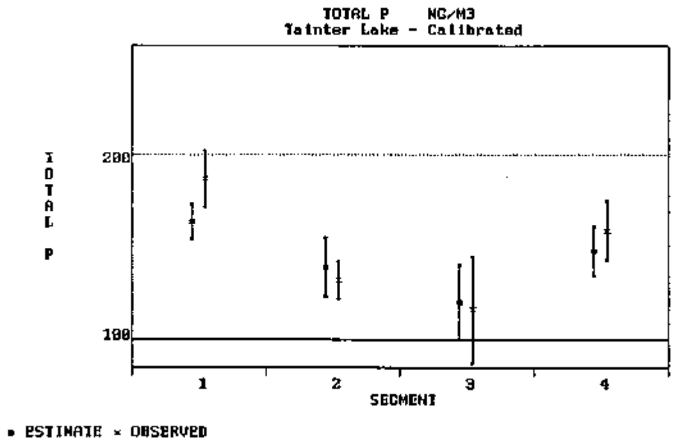
# Figure 1
# Observed & Predicted Values - Uncalibrated

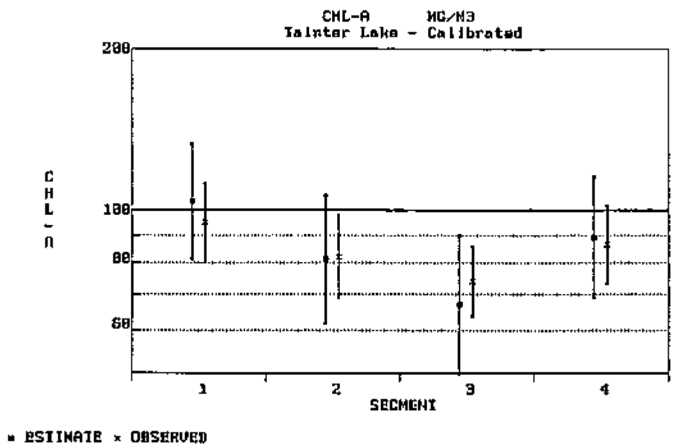


## Figure 2
## Observed & Predicted Values - Calibrated



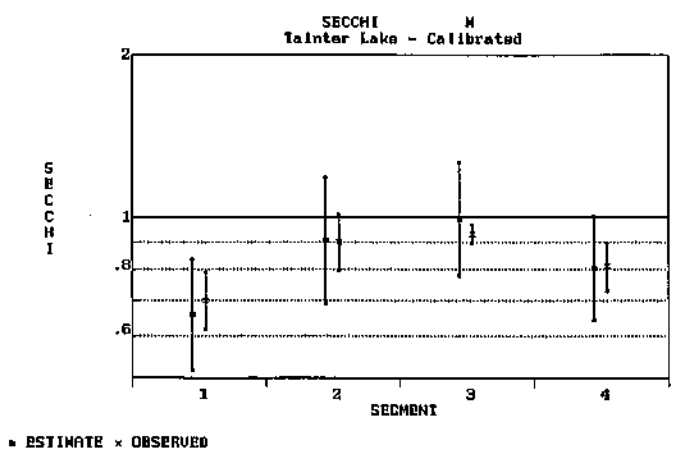



Table 1

**Summary of Tainter Lake Calibrations**

| Version | USGS1 | USGS2 | UNCALIB | WWW |
|---|---|---|---|---|
| Phosphorus Sedimentation | Model 1 (?)<br>Cal = ? | Model 1<br>Cal(1) = 1.16<br>Cal(2) = 0.92<br>Cal(3) = 0.93<br>Cal Option 2 | Model 1<br>Cal Option 1 * | Model 1<br>Cal Option 1<br>Cal = 1.13 |
| Chlorophyll-a | Model 5 (?)<br>Cal = ? | Model 2<br>Cal(1) = 4.08<br>Cal(2) = 6.34<br>Cal(3) = 11.9 | Model 5 | Model 5<br>Cal = 0.81 |
| Secchi Depth | Model 3<br>Cal = ? | Model 1<br>Cal(1) = 1.7<br>Cal(2) = 2.0<br>Cal(3) = 1.8 | Model 1<br>Beta = 0.025 | Model 1<br>Beta = 0.01 |
| Longitudinal Dispersion | Model 0<br>None | Model 0<br>None | Model 1<br>Cal(2) = 0. | Model 2<br>Cal(1) = 0.<br>Cal(2) = 0. |

Cal(n) - Calibration factor for Segment n

Cal - Calibration factor for entire system (Proc = 'Case Edit Mcoefs')

Default Cal(n) and Cal values = 1.0

Beta = Chl-a/Secchi Slope, Default = .025 m2/mg (Proc = "Case Edit Mcoefs')

* Calibration Options for Phosphorus
  1 = Calibrate Decay Rates (default)
  2 = Calibrate Concentrations

## Table 2
## Input File - Original (USGS2)

TAINTER LAKE BATHTUB MODEL, LOAD SCENARIO-1 SIMULATION

MODEL OPTIONS:

| | | |
|---|---|---|
| 1 | CONSERVATIVE SUBSTANCE | 0 NOT COMPUTED |
| 2 | PHOSPHORUS BALANCE | 1 2ND ORDER, AVAIL P |
| 3 | NITROGEN BALANCE | 0 NOT COMPUTED |
| 4 | CHLOROPHYLL-A | 2 P, LIGHT, T |
| 5 | SECCHI DEPTH | 1 VS. CHLA & TURBIDITY |
| 6 | DISPERSION | 0 NONE |
| 7 | PHOSPHORUS CALIBRATION | 2 CONCENTRATIONS |
| 8 | NITROGEN CALIBRATION | 0 NONE |
| 9 | ERROR ANALYSIS | 0 NOT COMPUTED |
| 10 | AVAILABILITY FACTORS | 1 USE FOR MODEL 1 ONLY |
| 11 | MASS-BALANCE TABLES | 1 USE ESTIMATED CONCS |

ATMOSPHERIC LOADS & AVAILABILITY FACTORS:

| VARIABLE | ATMOSPHERIC-LOADS KG/KM2-YR | CV | AVAILABILITY FACTOR |
|---|---|---|---|
| 1 CONSERV | .00 | .00 | .00 |
| 2 TOTAL P | 19.30 | .10 | 1.00 |
| 3 TOTAL N | .00 | .00 | .00 |
| 4 ORTHO P | .00 | .00 | .00 |
| 5 INORG N | .00 | .00 | .00 |

GLOBAL INPUT VALUES:

| PARAMETER | | MEAN | CV |
|---|---|---|---|
| PERIOD LENGTH | YRS | .420 | .000 |
| PRECIPITATION | M | .570 | .000 |
| EVAPORATION | M | .560 | .000 |
| INCREASE IN STORAGE | M | .000 | .000 |

TRIBUTARY DRAINAGE AREAS AND FLOWS:

| ID | TYPE | SEG | NAME | DRAINAGE AREA KM2 | MEAN FLOW HM3/YR | CV OF MEAN FLOW |
|---|---|---|---|---|---|---|
| 1 | 1 | 1 | HAY RIVER GAGE | 1083.000 | 341.000 | .100 |
| 2 | 3 | 1 | HAY RIVER STPS | .000 | 2.400 | .000 |
| 3 | 1 | 1 | RED CEDAR GAGE | 2852.000 | 816.000 | .100 |
| 4 | 3 | 1 | RED CEDAR STPS | .000 | 2.400 | .000 |
| 5 | 3 | 1 | COLFAX STP INFLO | .000 | 2.400 | .250 |
| 6 | 2 | 1 | OTTER CREEK | 91.900 | .000 | .000 |
| 7 | 2 | 1 | SINKING/8-MI CRK | 108.000 | .000 | .000 |
| 8 | 2 | 3 | LAMBS CREEK | 46.900 | .000 | .000 |
| 9 | 2 | 1 | DIRECT RUNOFF | 155.000 | .000 | .000 |
| 10 | 2 | 3 | DIRECT RUNOFF | 15.500 | .000 | .000 |
| 11 | 4 | 3 | CEDAR FALLS DAM | 4353.000 | 1265.000 | .100 |

TRIBUTARY CONCENTRATIONS (PPB): MEAN/CV

| ID | CONSERV | TOTAL P | TOTAL N | ORTHO P | INORG N |
|---|---|---|---|---|---|
| 1 | .0/ .00 | 150.0/ .03 | .0/ .00 | .0/ .00 | .0/ .00 |
| 2 | .0/ .00 | 5240.0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 |
| 3 | .0/ .00 | 179.0/ .04 | .0/ .00 | .0/ .00 | .0/ .00 |
| 4 | .0/ .00 | 3200.0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 |
| 5 | .0/ .00 | 174.0/ .10 | .0/ .00 | .0/ .00 | .0/ .00 |
| 6 | .0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 |
| 7 | .0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 |
| 8 | .0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 |
| 9 | .0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 |
| 10 | .0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 |
| 11 | .0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 |

MODEL SEGMENTS & CALIBRATION FACTORS:

| SEG | OUTFLOW | GROUP | SEGMENT NAME | | P SED | N SED | CHL-A | SECCHI | HOD | DISP |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | CALIBRATION FACTORS | | | | | |
| 1 | 2 | 1 | INFLOW POOL | | 1.16 | .00 | 4.08 | 1.70 | .00 | .000 |
| | | | | CV: | .000 | .000 | .000 | .000 | .000 | .000 |
| 2 | 3 | 1 | MIDDLE POOL | | .92 | .00 | 6.34 | 2.00 | .00 | .000 |
| | | | | CV: | .000 | .000 | .000 | .000 | .000 | .000 |
| 3 | 0 | 2 | LOWER DAM POOL | | .93 | .00 | 11.90 | 1.80 | .00 | .000 |
| | | | | CV: | .000 | .000 | .000 | .000 | .000 | .000 |

SEGMENT MORPHOMETRY: MEAN/CV

| ID | LABEL | LENGTH KM | AREA KM2 | ZMEAN M | ZMIX M | ZHYP M |
|---|---|---|---|---|---|---|
| 1 | INFLOW POOL | 1.80 | 2.9000 | 2.83 | 2.83/ .12 | .00/ .00 |
| 2 | MIDDLE POOL | 3.70 | 1.7600 | 5.41 | 4.84/ .12 | .00/ .00 |
| 3 | LOWER DAM POOL | 2.50 | 1.2800 | 6.43 | 5.40/ .12 | .00/ .00 |

SEGMENT OBSERVED WATER QUALITY:

| SEG | | TURBID 1/M | CONSER --- | TOTALP MG/M3 | TOTALN MG/M3 | CHL-A MG/M3 | SECCHI M | ORG-N MG/M3 | TP-OP MG/M3 | HODV MG/M3-D | MODV MG/M3-D |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MN: | .00 | .0 | 183.0 | .0 | 95.0 | .7 | .0 | .0 | .0 | .0 |
| | CV: | .13 | .00 | .11 | .00 | .18 | .13 | .00 | .00 | .00 | .00 |
| 2 | MN: | .00 | .0 | 125.0 | .0 | 82.0 | .9 | .0 | .0 | .0 | .0 |
| | CV: | .13 | .00 | .07 | .00 | .19 | .13 | .00 | .00 | .00 | .00 |
| 3 | MN: | .00 | .0 | 112.0 | .0 | 74.0 | .9 | .0 | .0 | .0 | .0 |
| | CV: | .04 | .00 | .22 | .00 | .16 | .04 | .00 | .00 | .00 | .00 |

NON-POINT-SOURCE WATERSHED AREAS (KM2):

| ID | COD | NAME | landuse1 | landuse2 | landuse3 | landuse4 |
|---|---|---|---|---|---|---|

MODEL COEFFICIENTS:

| COEFFICIENT | MEAN | CV |
|---|---|---|
| DISPERSION FACTO | 1.000 | .00 |
| P DECAY RATE | 1.000 | .45 |
| N DECAY RATE | 1.000 | .55 |
| CHL-A MODEL | 1.000 | .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 | .025 | .00 |
| MINIMUM QS | 4.000 | .00 |
| FLUSHING EFFECT | 1.000 | .00 |
| CHLOROPHYLL-A CV | .620 | .00 |

CASE NOTES:

**Table 3**
**Input File - Uncalibrated**

Tainter Lake - Uncalibrated

MODEL OPTIONS:

| | | |
|---|---|---|
| 1 | CONSERVATIVE SUBSTANCE | 0 NOT COMPUTED |
| 2 | PHOSPHORUS BALANCE | 1 2ND ORDER, AVAIL P |
| 3 | NITROGEN BALANCE | 0 NOT COMPUTED |
| 4 | CHLOROPHYLL-A | 5 P, JONES & BACHMAN |
| 5 | SECCHI DEPTH | 1 VS. CHLA & TURBIDITY |
| 6 | DISPERSION | 1 FISCHER-NUMERIC |
| 7 | PHOSPHORUS CALIBRATION | 1 DECAY RATES |
| 8 | NITROGEN CALIBRATION | 0 NONE |
| 9 | ERROR ANALYSIS | 1 MODEL & DATA |
| 10 | AVAILABILITY FACTORS | 1 USE FOR MODEL 1 ONLY |
| 11 | MASS-BALANCE TABLES | 1 USE ESTIMATED CONCS |

ATMOSPHERIC LOADS & AVAILABILITY FACTORS:

| VARIABLE | ATMOSPHERIC-LOADS KG/KM2-YR | CV | AVAILABILITY FACTOR |
|---|---|---|---|
| 1 CONSERV | .00 | .00 | .00 |
| 2 TOTAL P | 19.30 | .10 | 1.00 |
| 3 TOTAL N | .00 | .00 | .00 |
| 4 ORTHO P | .00 | .00 | .00 |
| 5 INORG N | .00 | .00 | .00 |

GLOBAL INPUT VALUES:

| PARAMETER | MEAN | CV |
|---|---|---|
| PERIOD LENGTH YRS | .420 | .000 |
| PRECIPITATION M | .570 | .000 |
| EVAPORATION M | .560 | .000 |
| INCREASE IN STORAGE M | .000 | .000 |

TRIBUTARY DRAINAGE AREAS AND FLOWS:

| ID | TYPE | SEG | NAME | DRAINAGE AREA KM2 | MEAN FLOW HM3/YR | CV OF MEAN FLOW |
|---|---|---|---|---|---|---|
| 1 | 1 | 1 | HAY RIVER GAGE | 1083.000 | 341.000 | .100 |
| 2 | 3 | 1 | HAY RIVER STPS | .000 | 2.400 | .000 |
| 3 | 1 | 1 | RED CEDAR GAGE | 2852.000 | 816.000 | .100 |
| 4 | 3 | 1 | RED CEDAR STPS | .000 | 2.400 | .000 |
| 5 | 3 | 1 | COLFAX STP INFLO | .000 | 2.400 | .250 |
| 6 | 1 | 1 | OTTER CREEK | 91.900 | 27.600 | .200 |
| 7 | 1 | 1 | SINKING/8-MI CRK | 108.000 | 32.400 | .200 |
| 8 | 1 | 3 | LAMBS CREEK | 46.900 | 14.100 | .200 |
| 9 | 1 | 1 | DIRECT RUNOFF | 155.000 | 15.500 | .200 |
| 10 | 1 | 3 | DIRECT RUNOFF | 15.500 | 1.500 | .200 |
| 11 | 4 | 3 | CEDAR FALLS DAM | 4353.000 | 1265.000 | .100 |

TRIBUTARY CONCENTRATIONS (PPB): MEAN/CV

| ID | CONSERV | TOTAL P | TOTAL N | ORTHO P | INORG N |
|---|---|---|---|---|---|
| 1 | .0/ .00 | 150.0/ .03 | .0/ .00 | .0/ .00 | .0/ .00 |
| 2 | .0/ .00 | 5240.0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 |
| 3 | .0/ .00 | 179.0/ .04 | .0/ .00 | .0/ .00 | .0/ .00 |
| 4 | .0/ .00 | 3200.0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 |
| 5 | .0/ .00 | 174.0/ .10 | .0/ .00 | .0/ .00 | .0/ .00 |
| 6 | .0/ .00 | 150.0/ .20 | .0/ .00 | .0/ .00 | .0/ .00 |
| 7 | .0/ .00 | 150.0/ .20 | .0/ .00 | .0/ .00 | .0/ .00 |
| 8 | .0/ .00 | 150.0/ .20 | .0/ .00 | .0/ .00 | .0/ .00 |
| 9 | .0/ .00 | 150.0/ .20 | .0/ .00 | .0/ .00 | .0/ .00 |
| 10 | .0/ .00 | 150.0/ .20 | .0/ .00 | .0/ .00 | .0/ .00 |
| 11 | .0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 |

MODEL SEGMENTS & CALIBRATION FACTORS:

| SEG | OUTFLOW | GROUP | SEGMENT NAME | | ----------- CALIBRATION FACTORS ----------- | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | P SED | N SED | CHL-A | SECCHI | HOD | DISP |
| 1 | 2 | 1 | INFLOW POOL | | 1.00 | .00 | 1.00 | 1.00 | .00 | 1.000 |
| | | | | CV: | .000 | .000 | .000 | .000 | .000 | .000 |
| 2 | 3 | 1 | MIDDLE POOL | | 1.00 | .00 | 1.00 | 1.00 | .00 | .000 |
| | | | | CV: | .000 | .000 | .000 | .000 | .000 | .000 |
| 3 | 0 | 2 | LOWER DAM POOL | | 1.00 | .00 | 1.00 | 1.00 | .00 | 1.000 |
| | | | | CV: | .000 | .000 | .000 | .000 | .000 | .000 |

SEGMENT MORPHOMETRY: MEAN/CV

| ID | LABEL | LENGTH KM | AREA KM2 | ZMEAN M | ZMIX M | ZHYP M |
|---|---|---|---|---|---|---|
| 1 | INFLOW POOL | 1.80 | 2.9000 | 2.83 | 2.83/ .12 | .00/ .00 |
| 2 | MIDDLE POOL | 3.70 | 1.7600 | 5.41 | 4.84/ .12 | .00/ .00 |
| 3 | LOWER DAM POOL | 2.50 | 1.2800 | 6.43 | 5.40/ .12 | .00/ .00 |

SEGMENT OBSERVED WATER QUALITY:

| SEG | | TURBID 1/M | CONSER --- | TOTALP MG/M3 | TOTALN MG/M3 | CHL-A MG/M3 | SECCHI M | ORG-N MG/M3 | TP-OP MG/M3 | HODV MG/M3-D | MODV MG/M3-D |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MN: | .00 | .0 | 183.0 | .0 | 95.0 | .7 | .0 | .0 | .0 | .0 |
| | CV: | .13 | .00 | .11 | .00 | .18 | .13 | .00 | .00 | .00 | .00 |
| 2 | MN: | .00 | .0 | 125.0 | .0 | 82.0 | .9 | .0 | .0 | .0 | .0 |
| | CV: | .13 | .00 | .07 | .00 | .19 | .13 | .00 | .00 | .00 | .00 |
| 3 | MN: | .00 | .0 | 112.0 | .0 | 74.0 | .9 | .0 | .0 | .0 | .0 |
| | CV: | .04 | .00 | .22 | .00 | .16 | .04 | .00 | .00 | .00 | .00 |

MODEL COEFFICIENTS:

| COEFFICIENT | MEAN | CV |
|---|---|---|
| DISPERSION FACTO | 1.000 | .00 |
| P DECAY RATE | 1.000 | .45 |
| N DECAY RATE | 1.000 | .55 |
| CHL-A MODEL | 1.000 | .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 | .025 | .00 |
| MINIMUM QS | 4.000 | .00 |
| FLUSHING EFFECT | 1.000 | .00 |
| CHLOROPHYLL-A CV | .620 | .00 |

## Table 4
## Input File - Calibrated (WWW)

MODEL OPTIONS:

| | | |
|---|---|---|
| 1 | CONSERVATIVE SUBSTANCE | 0 NOT COMPUTED |
| 2 | PHOSPHORUS BALANCE | 1 2ND ORDER, AVAIL P |
| 3 | NITROGEN BALANCE | 0 NOT COMPUTED |
| 4 | CHLOROPHYLL-A | 5 P, JONES & BACHMAN |
| 5 | SECCHI DEPTH | 1 VS. CHLA & TURBIDITY |
| 6 | DISPERSION | 1 FISCHER-NUMERIC |
| 7 | PHOSPHORUS CALIBRATION | 1 DECAY RATES |
| 8 | NITROGEN CALIBRATION | 0 NONE |
| 9 | ERROR ANALYSIS | 1 MODEL & DATA |
| 10 | AVAILABILITY FACTORS | 1 USE FOR MODEL 1 ONLY |
| 11 | MASS-BALANCE TABLES | 1 USE ESTIMATED CONCS |

ATMOSPHERIC LOADS & AVAILABILITY FACTORS:

| VARIABLE | ATMOSPHERIC-LOADS KG/KM2-YR | CV | AVAILABILITY FACTOR |
|---|---|---|---|
| 1 CONSERV | .00 | .00 | .00 |
| 2 TOTAL P | 19.30 | .10 | 1.00 |
| 3 TOTAL N | .00 | .00 | .00 |
| 4 ORTHO P | .00 | .00 | .00 |
| 5 INORG N | .00 | .00 | .00 |

GLOBAL INPUT VALUES:

| PARAMETER | | MEAN | CV |
|---|---|---|---|
| PERIOD LENGTH | YRS | .420 | .000 |
| PRECIPITATION | M | .570 | .000 |
| EVAPORATION | M | .560 | .000 |
| INCREASE IN STORAGE | M | .000 | .000 |

TRIBUTARY DRAINAGE AREAS AND FLOWS:

| ID | TYPE | SEG | NAME | DRAINAGE AREA KM2 | MEAN FLOW HM3/YR | CV OF MEAN FLOW |
|---|---|---|---|---|---|---|
| 1 | 1 | 1 | HAY RIVER GAGE | 1083.000 | 341.000 | .100 |
| 2 | 3 | 1 | HAY RIVER STPS | .000 | 2.400 | .000 |
| 3 | 1 | 1 | RED CEDAR GAGE | 2852.000 | 816.000 | .100 |
| 4 | 3 | 1 | RED CEDAR STPS | .000 | 2.400 | .000 |
| 5 | 3 | 1 | COLFAX STP INFLO | .000 | 2.400 | .250 |
| 6 | 1 | 1 | OTTER CREEK | 91.900 | 27.600 | .200 |
| 7 | 1 | 1 | SINKING/8-MI CRK | 108.000 | 32.400 | .200 |
| 8 | 1 | 3 | LAMBS CREEK | 46.900 | 14.100 | .200 |
| 9 | 1 | 1 | DIRECT RUNOFF | 155.000 | 15.500 | .200 |
| 10 | 1 | 3 | DIRECT RUNOFF | 15.500 | 1.500 | .200 |
| 11 | 4 | 3 | CEDAR FALLS DAM | 4353.000 | 1265.000 | .100 |

TRIBUTARY CONCENTRATIONS (PPB): MEAN/CV

| ID | CONSERV | TOTAL P | TOTAL N | ORTHO P | INORG N |
|---|---|---|---|---|---|
| 1 | .0/ .00 | 150.0/ .03 | .0/ .00 | .0/ .00 | .0/ .00 |
| 2 | .0/ .00 | 5240.0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 |
| 3 | .0/ .00 | 179.0/ .04 | .0/ .00 | .0/ .00 | .0/ .00 |
| 4 | .0/ .00 | 3200.0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 |
| 5 | .0/ .00 | 174.0/ .10 | .0/ .00 | .0/ .00 | .0/ .00 |
| 6 | .0/ .00 | 150.0/ .20 | .0/ .00 | .0/ .00 | .0/ .00 |
| 7 | .0/ .00 | 150.0/ .20 | .0/ .00 | .0/ .00 | .0/ .00 |
| 8 | .0/ .00 | 150.0/ .20 | .0/ .00 | .0/ .00 | .0/ .00 |
| 9 | .0/ .00 | 150.0/ .20 | .0/ .00 | .0/ .00 | .0/ .00 |
| 10 | .0/ .00 | 150.0/ .20 | .0/ .00 | .0/ .00 | .0/ .00 |
| 11 | .0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 | .0/ .00 |

MODEL SEGMENTS & CALIBRATION FACTORS:

----------- CALIBRATION FACTORS

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| SEG | OUTFLOW | GROUP | SEGMENT NAME | P SED | N SED | CHL-A | SECCHI | HOD | DISP |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 1 | INFLOW POOL | 1.00 | .00 | 1.00 | 1.00 | .00 | .000 |
| | | | CV: | .000 | .000 | .000 | .000 | .000 | .000 |
| 2 | 3 | 1 | MIDDLE POOL | 1.00 | .00 | 1.00 | 1.00 | .00 | .000 |
| | | | CV: | .000 | .000 | .000 | .000 | .000 | .000 |
| 3 | 0 | 2 | LOWER DAM POOL | 1.00 | .00 | 1.00 | 1.00 | .00 | 1.000 |
| | | | CV: | .000 | .000 | .000 | .000 | .000 | .000 |

SEGMENT MORPHOMETRY: MEAN/CV

| ID | LABEL | LENGTH KM | AREA KM2 | ZMEAN M | ZMIX M | ZHYP M |
|---|---|---|---|---|---|---|
| 1 | INFLOW POOL | 1.80 | 2.9000 | 2.83 | 2.83/ .12 | .00/ .00 |
| 2 | MIDDLE POOL | 3.70 | 1.7600 | 5.41 | 4.84/ .12 | .00/ .00 |
| 3 | LOWER DAM POOL | 2.50 | 1.2800 | 6.43 | 5.40/ .12 | .00/ .00 |

SEGMENT OBSERVED WATER QUALITY:

| SEG | | TURBID 1/M | CONSER --- | TOTALP MG/M3 | TOTALN MG/M3 | CHL-A MG/M3 | SECCHI M | ORG-N MG/M3 | TP-OP MG/M3 | HODV MG/M3-D | MODV MG/M3-D |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MN: | .00 | .0 | 183.0 | .0 | 95.0 | .7 | .0 | .0 | .0 | .0 |
| | CV: | .13 | .00 | .11 | .00 | .18 | .13 | .00 | .00 | .00 | .00 |
| 2 | MN: | .00 | .0 | 125.0 | .0 | 82.0 | .9 | .0 | .0 | .0 | .0 |
| | CV: | .13 | .00 | .07 | .00 | .19 | .13 | .00 | .00 | .00 | .00 |
| 3 | MN: | .00 | .0 | 112.0 | .0 | 74.0 | .9 | .0 | .0 | .0 | .0 |
| | CV: | .04 | .00 | .22 | .00 | .16 | .04 | .00 | .00 | .00 | .00 |

MODEL COEFFICIENTS:

| COEFFICIENT | MEAN | CV |
|---|---|---|
| DISPERSION FACTO | 1.000 | .00 |
| P DECAY RATE | 1.130 | .45 |
| N DECAY RATE | 1.000 | .55 |
| CHL-A MODEL | .810 | .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 | .010 | .00 |
| MINIMUM QS | 4.000 | .00 |
| FLUSHING EFFECT | 1.000 | .00 |
| CHLOROPHYLL-A CV | .620 | .00 |

## Table 5
## Listing of Observed & Predicted Values (WWW)

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: 1 INFLOW POOL

| VARIABLE | | OBSERVED MEAN | OBSERVED CV | ESTIMATED MEAN | ESTIMATED CV | RATIO | T STATISTICS 1 | T STATISTICS 2 | T STATISTICS 3 |
|---|---|---|---|---|---|---|---|---|---|
| TOTAL P | MG/M3 | 183.0 | .11 | 155.6 | .07 | 1.18 | 1.47 | .60 | 1.26 |
| CHL-A | MG/M3 | 95.0 | .18 | 104.1 | .28 | .91 | -.51 | -.26 | -.28 |
| SECCHI | M | .7 | .13 | .7 | .27 | 1.06 | .47 | .22 | .21 |
| ORGANIC N | MG/M3 | .0 | .00 | 2565.8 | .28 | .00 | .00 | .00 | .00 |
| TP-ORTHO-P | MG/M3 | .0 | .00 | 192.5 | .31 | .00 | .00 | .00 | .00 |

SEGMENT: 2 MIDDLE POOL

| VARIABLE | | OBSERVED MEAN | OBSERVED CV | ESTIMATED MEAN | ESTIMATED CV | RATIO | T STATISTICS 1 | T STATISTICS 2 | T STATISTICS 3 |
|---|---|---|---|---|---|---|---|---|---|
| TOTAL P | MG/M3 | 125.0 | .07 | 131.4 | .12 | .95 | -.72 | -.18 | -.37 |
| CHL-A | MG/M3 | 82.0 | .19 | 81.3 | .31 | 1.01 | .05 | .03 | .02 |
| SECCHI | M | .9 | .13 | .9 | .31 | .99 | -.05 | -.02 | -.02 |
| ORGANIC N | MG/M3 | .0 | .00 | 2032.2 | .31 | .00 | .00 | .00 | .00 |
| TP-ORTHO-P | MG/M3 | .0 | .00 | 147.5 | .34 | .00 | .00 | .00 | .00 |

SEGMENT: 3 LOWER DAM POOL

| VARIABLE | | OBSERVED MEAN | OBSERVED CV | ESTIMATED MEAN | ESTIMATED CV | RATIO | T STATISTICS 1 | T STATISTICS 2 | T STATISTICS 3 |
|---|---|---|---|---|---|---|---|---|---|
| TOTAL P | MG/M3 | 112.0 | .22 | 115.1 | .15 | .97 | -.13 | -.10 | -.10 |
| CHL-A | MG/M3 | 74.0 | .16 | 67.1 | .34 | 1.10 | .62 | .28 | .26 |
| SECCHI | M | .9 | .04 | 1.0 | .28 | .94 | -1.67 | -.24 | -.24 |
| ORGANIC N | MG/M3 | .0 | .00 | 1711.0 | .33 | .00 | .00 | .00 | .00 |
| TP-ORTHO-P | MG/M3 | .0 | .00 | 123.2 | .36 | .00 | .00 | .00 | .00 |

SEGMENT: 4 AREA-WTD MEAN

| VARIABLE | | OBSERVED MEAN | OBSERVED CV | ESTIMATED MEAN | ESTIMATED CV | RATIO | T STATISTICS 1 | T STATISTICS 2 | T STATISTICS 3 |
|---|---|---|---|---|---|---|---|---|---|
| TOTAL P | MG/M3 | 150.5 | .12 | 139.7 | .09 | 1.08 | .63 | .28 | .49 |
| CHL-A | MG/M3 | 86.6 | .18 | 89.3 | .29 | .97 | -.17 | -.09 | -.09 |
| SECCHI | M | .8 | .11 | .8 | .25 | 1.01 | .06 | .02 | .02 |
| ORGANIC N | MG/M3 | .0 | .00 | 2223.5 | .29 | .00 | .00 | .00 | .00 |
| TP-ORTHO-P | MG/M3 | .0 | .00 | 164.2 | .32 | .00 | .00 | .00 | .00 |