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FOX RIVER AND GREEN BAY PCB FATE AND TRANSPORT MODEL EVALUATION

TECHNICAL MEMORANDUM 2c -

Computation of Internal Solids Loads in Green Bay and the Lower Fox River

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1.0 SUMMARY

Nutrient dynamics and transformations among various solids sorbent compartments may have a significant impact on PCB fate and transport in the Lower Fox River and Green Bay. Estimation of suspended solids from all sources is an important component of the overall solids balance for the system. This technical memorandum describes the existing methods used to compute internal, or biotic suspended solids (BSS) loads, discusses the applicability of these approaches to the hindcast period, and presents the alternative approaches, that were the recommendations of the Model Evaluation Workgroup ("Workgroup") for model evaluation.

The existing approaches used to estimate BSS loads for the Upper Fox River Model (UFRM), Lower Fox River Model (LFRM), and Green Bay Toxics Model (GBTOX) were first reviewed and discussed. The applicability of applying these approaches to the hindcast period was then assessed. BSS loads were then estimated for each year from available chlorophyll-a data from 1954-1995 for the Lower Fox River from Lake Winnebago to DePere, applying a modified version of the approach used for the Upper Fox River Model (Steuer, et al, 1995). The estimation for the Lower Fox above DePere was conducted to facilitate a hindcast with the UFRM as currently configured.

Alternative approaches (involving independent methodologies) for estimating gross BSS loadings in the upper and lower reaches of the Lower Fox River and Green Bay are described and applied. These approaches, which were recommended by the Model Evaluation Workgroup, involve a Simplified Primary Productivity (SPP) Model for the Lower Fox River, and application of an empirical approach for Green Bay based on primary productivity and related data. The results of applying the empirical approach were compared to results from applying the SPP Model to Green Bay for 1982. Estimated annual total phosphorous loads for each year of the hindcast period (1954-1995) were computed and used to scale the calculated production rates for the Lower Fox River and Green Bay. Light-related data were evaluated to determine if two light domains could be defined: "pre-1972" and "post-1972". It was determined that inadequate data exist for the Lower Fox River to make this comparison, and that Green Bay data indicate no significant differences (and data are also very limited for the "pre-1972" period). An estimate of the monthly internal solids load in each model segment for each year of the hindcast period was developed by scaling using phosphorus loads, and assuming constant light conditions throughout the hindcast period.

2.0 INTRODUCTION

LTI is currently participating as a member of the Model Evaluation Workgroup in an evaluation of the suite of models used to assess the fate and transport of PCBs in the Fox River and Green Bay, in partial fulfillment of the Agreement between the State of Wisconsin and seven paper companies, dated January 31, 1997. One component of the evaluation is the development of historical and current solids and PCB loads to the Fox River (Task 2), as discussed in the "Workplan to Evaluate the Fate and Transport Models for the Fox River and Green Bay", dated September 19, 1997. The computation of internal production of solids is a subtask (Subtask 2c) of this effort. This task involves the generation of a time series of internal solids loads, based on available nutrient, chlorophyll-a, primary productivity, and streamflow data.

Internal or biotic solids contribute to the total suspended solids loads in the Lower Fox River and Green Bay. This assessment of historical loads is important because inaccurate estimates of solids loads can result in an inaccurate hindcast and/or improper model calibration. For example, if solids loads are underestimated, larger than actual resuspension rates and/or smaller than actual settling rates might be erroneously specified. In addition to affecting the hindcast, such errors would in turn affect the utility of the modeling tools for decision making.

Biotic solids loading rates can be computed using empirical, data-driven methods, or using mathematical models. The applications of the UFRM and LFRM to date involved use of empirical approaches, based on data related to algal growth, to estimate loadings. Internal loadings to Green Bay, which served as inputs to GBTOX, were computed within the eutrophication model, GBEUTRO. The first step in this evaluation was to review and understand these existing approaches.

The applicability of these approaches to the hindcast period was then reviewed and evaluated. The availability of water quality and streamflow data for the hindcast period was also assessed. A slightly modified version of the existing approach used for the UFRM was then applied to the hindcast period in order to facilitate a hindcast with the model as currently configured. An alternative, consistent, independent methodology for estimating internal loads for the LFRM and UFRM was then described, proposed for model evaluation (based on Model Evaluation Workgroup recommendations), and applied. An empirical approach based on productivity measurements collected in Green Bay in 1982 was then proposed for model evaluation and applied. The results of this approach were compared to results using the SPP.

3.0 EXISTING METHOD TO ESTIMATE LOADS FOR THE UFRM

3.1 DESCRIPTION OF METHOD

The Upper Fox River Model (UFRM) is described in Steuer, et al. (1995). Total suspended solids were represented in the UFRM by two fractions: 1) a low-organic carbon suspended solid, essentially an abiotic solid, and a 2) high-organic carbon suspended solid, representing chlorophyll-a and point source discharger solids. Chlorophyll-a data were converted to dry weight biotic suspended solids using the stoichiometric relationship (Raghunathan, 1990; DiToro and Connolly, 1980):

BSS = X [ug Chl-a/L] * 23 [mg C/mg Chl-a] * 1.0/0.14 [mg BSS/mg C] = 0.167 X

Where:

X = Chlorophyll a concentration; (ug/l)

C = Biotic organic carbon, (mg/l)

BSS = Biotic suspended solids

As indicated in the above equation, the biotic organic carbon/chlorophyll-a ratio was assumed to be 23, and the particulate organic carbon to biotic solids ratio (fraction organic carbon) was 0.14, based on carbon and chlorophyll data collected during the summer and fall of 1989.

The UFRM employs a net biotic solids loading approach, which is computed as the difference between downstream and upstream water column fluxes. Using this approach, and river discharge data, internal solids loads were computed by Steuer at five locations in the river between Lake Winnebago and DePere, and the BSS load was interpolated between data points to estimate net internal loadings in each of the four reaches between these locations.

3.2 APPLICABILITY TO THE HINDCAST PERIOD

The existing approach could be applied to the hindcast period as follows: using the empirical approach described in Section 3.1, historical chlorophyll-a data could be used to compute BSS concentrations at an upstream location (Lake Winnebago outlet) and a downstream location (above DePere Dam). However, chlorophyll-a data are not available for the full hindcast period. A time series of annual BSS loads could be developed for the entire hindcast period as follows: using available chlorophyll-a concentration and flow data and Beale's Ratio Estimator method (Preston et al., 1989), a time-series of annual BSS loads could be estimated for each location. The internal loading produced between these two stations for each year in the series could then be estimated by difference. This would, however, be a modified version of the existing approach because it incorporates a ratio estimator method to develop a time series of BSS loads for the hindcast period.

Because the immediate objective is to provide inputs to a hindcast with the existing version of the UFRM, this approach was applied to the Lower Fox River from Lake Winnebago to DePere for 1954-1995. All available chlorophyll-a data for the upper and lower end of the reach were obtained from the STORET database. A continuous record of chlorophyll-a data is available for the years 1976-1994 at the Lake Winnebago outlet (Station 713002), and for the years 1975-1994 above DePere Dam (Station 053210). These data represent the upper and lower ends of the reach, respectively. A complete time series was generated from these data using Beale's Ratio Estimator. Streamflows at Wrightstown were used to compute loads. The flow over DePere Dam was estimated by multiplying the historical Wrightstown flow data by 1.017, the basin area ratio for DePere/Wrightstown (6110/6010 sq. mi.). Streamflows at Neenah were estimated by multiplying the historical Wrightstown flow data by 0.98, based on the basin area ratio for Neenah/Wrightstown.

Results of annual net internal loading estimates for the Lower Fox River from Lake Winnebago to DePere are presented in Table 3-1. The estimates for the years 1989-1995 are compared to the loads estimated by Steuer, et al. (1995) for the UFRM runs for those years. The values are also plotted against each other in Figure 3-1 for visual comparison. The estimated net annual loads compare well to each other. Minor differences are likely due to different data sets used in the analyses, and the introduction of an empirical load estimation method, which is necessary to compute estimates for the early years of the hindcast period.

These total annual loads estimated for the Lower Fox from Lake Winnebago to DePere were then allocated to the four reaches by proportioning based on the 1989 estimations by Steuer, et al. For example, in 1989, 35% of the total internal solids load was estimated for, and allocated to reach 1 (between Neenah and Appleton). This ratio was applied to the total internal load for each year of the hindcast period to estimate internal loading in reach 1 for each year. Table 3-2 presents the results of this computation. The estimated annual total internal solids loads to each reach of the Lower Fox River from Lake Winnebago to DePere for the hindcast period can be further distributed to each segment of the UFRM model based on the surficial area of each segment as a percentage of the total surficial area of each of the four reaches of the Lower Fox River from Lake Winnebago to DePere.

3.3 DISCUSSION OF APPROACH

The existing approach for the UFRM provides an independent, empirical approach for estimating loads in the Lower Fox above DePere during years when data are available. It can not be applied to the hindcast period because of data limitations. However, the general existing approach for the UFRM could be applied, with modifications. This would require the use of a ratio estimator method to deal with data gaps in the record.

Table 3-1.
Comparison of Internal Loading Estimates to Values Used in UFRM

Year	Estimated BSS Load (kg/yr)	Internal Loads (kg/yr) Input to UFRM (Steuer, et al., 1995)				
		Between Neenah and Appleton	Between Appleton and Kaukauna	Between Kaukauna and Little Rapids	Between Little Rapids and De Pere	Total
1954	8,443,631					
1955	7,957,164					
1956	8,147,698					
1957	6,343,227					
1958	4,509,636					
1959	8,773,359					
1960	15,692,137					
1961	11,108,644					
1962	11,027,976					
1963	6,470,716					
1964	5,329,093					
1965	10,786,102					
1966	9,449,906					
1967	9,448,740					
1968	9,483,183					
1969	11,356,862					
1970	7,653,463					
1971	9,438,252					
1972	11,545,971					
1973	16,465,990					
1974	10,102,660					
1975	9,450,067					
1976	8,855,513					
1977	5,686,261					
1978	9,895,696					
1979	13,643,257					
1980	10,794,668					
1981	9,249,990					
1982	12,197,281					
1983	13,459,472					
1984	13,938,848					
1985	15,718,090					
1986	15,853,342					
1987	8,433,372					
1988	7,261,854					
1989	8,072,705	4,771,686	2,715,855	5,137,624	845,252	13,470,417
1990	10,495,205	4,646,640	2,075,979	4,701,916	488,248	11,912,783
1991	10,334,713	3,351,894	1,251,366	3,443,789	680,016	8,727,065
1992	11,543,063	3,576,584	1,846,030	5,571,079	878,404	11,872,096
1993	19,304,269	3,950,763	1,577,258	4,507,434	879,450	10,914,904
1994	11,292,069	3,095,912	1,990,742	4,507,434	339,727	9,933,814
1995	6,846,706	3,393,414	1,273,908	4,507,434	922,693	10,097,449

Figure 3-1.

Comparison of Lower Fox River (above DePere) Internal Loading Estimates to Values Used IN UFRM

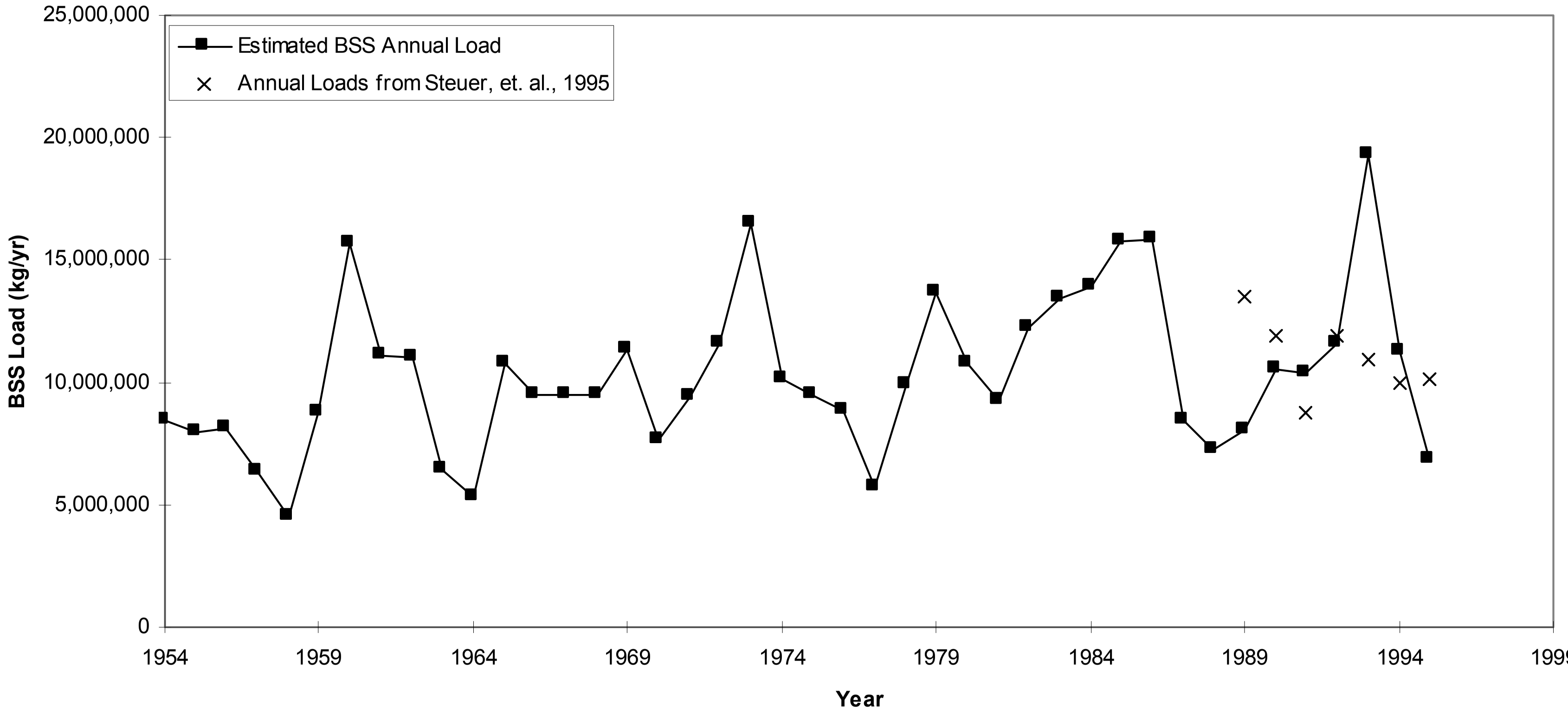


Table 3-2.
Upper Fox River Model Internal Loads Estimated for Hindcast Period (kg/yr)

Year	Estimated Total BSS Load (kg/yr)	Between Neenah and Appleton	Between Appleton and Kaukauna	Between Kaukauna and Little Rapids	Between Little Rapids and De Pere
1954	8,443,631	2,955,271	1,688,726	3,208,580	506,618
1955	7,957,164	2,785,008	1,591,433	3,023,722	477,430
1956	8,147,698	2,851,694	1,629,540	3,096,125	488,862
1957	6,343,227	2,220,130	1,268,645	2,410,426	380,594
1958	4,509,636	1,578,373	901,927	1,713,662	270,578
1959	8,773,359	3,070,675	1,754,672	3,333,876	526,402
1960	15,692,137	5,492,248	3,138,427	5,963,012	941,528
1961	11,108,644	3,888,025	2,221,729	4,221,285	666,519
1962	11,027,976	3,859,792	2,205,595	4,190,631	661,679
1963	6,470,716	2,264,751	1,294,143	2,458,872	388,243
1964	5,329,093	1,865,183	1,065,819	2,025,055	319,746
1965	10,786,102	3,775,136	2,157,220	4,098,719	647,166
1966	9,449,906	3,307,467	1,889,981	3,590,964	566,994
1967	9,448,740	3,307,059	1,889,748	3,590,521	566,924
1968	9,483,183	3,319,114	1,896,637	3,603,609	568,991
1969	11,356,862	3,974,902	2,271,372	4,315,608	681,412
1970	7,653,463	2,678,712	1,530,693	2,908,316	459,208
1971	9,438,252	3,303,388	1,887,650	3,586,536	566,295
1972	11,545,971	4,041,090	2,309,194	4,387,469	692,758
1973	16,465,990	5,763,096	3,293,198	6,257,076	987,959
1974	10,102,660	3,535,931	2,020,532	3,839,011	606,160
1975	9,450,067	3,307,524	1,890,013	3,591,026	567,004
1976	8,855,513	3,099,430	1,771,103	3,365,095	531,331
1977	5,686,261	1,990,191	1,137,252	2,160,779	341,176
1978	9,895,696	3,463,493	1,979,139	3,760,364	593,742
1979	13,643,257	4,775,140	2,728,651	5,184,438	818,595
1980	10,794,668	3,778,134	2,158,934	4,101,974	647,680
1981	9,249,990	3,237,496	1,849,998	3,514,996	554,999
1982	12,197,281	4,269,048	2,439,456	4,634,967	731,837
1983	13,459,472	4,710,815	2,691,894	5,114,599	807,568
1984	13,938,848	4,878,597	2,787,770	5,296,762	836,331
1985	15,718,090	5,501,331	3,143,618	5,972,874	943,085
1986	15,853,342	5,548,670	3,170,668	6,024,270	951,201
1987	8,433,372	2,951,680	1,686,674	3,204,681	506,002
1988	7,261,854	2,541,649	1,452,371	2,759,504	435,711
1989	8,072,705	2,825,447	1,614,541	3,067,628	484,362
1990	10,495,205	3,673,322	2,099,041	3,988,178	629,712
1991	10,334,713	3,617,149	2,066,943	3,927,191	620,083
1992	11,543,063	4,040,072	2,308,613	4,386,364	692,584
1993	19,304,269	6,756,494	3,860,854	7,335,622	1,158,256
1994	11,292,069	3,952,224	2,258,414	4,290,986	677,524
1995	6,846,706	2,396,347	1,369,341	2,601,748	410,802

This approach for the upper portion of the Lower Fox employs data that are either available, or can be estimated using available data (such as chlorophyll-a data). It also is consistent with the existing approach, which employs estimates of net rather than gross internal solids loads.

Biotic solids loading comprises a fairly large proportion of the total solids loading to the Lower Fox River from Lake Winnebago to DePere. Based on information presented in Steuer, et al. (Figure 5-60), biotic solids loading comprised approximately 23% of the total solids loading to the Lower Fox from Lake Winnebago to DePere during the calibration year (April, 1989-April, 1990).

3.4 RECOMMENDATION

A recommended approach is to estimate gross internal solids loads. This approach is recommended because data exist to implement it for the full hindcast period 1954-95. If this recommended approach is implemented, it is important to note that gross rather than net internal solids load estimates will be produced, which would be a departure from the existing approach. A Simplified Primary Productivity (SPP) model, which was recommended for this purpose by the Model Evaluation Workgroup, is described in Appendix B.

4.0 EXISTING METHOD TO ESTIMATE LOADS FOR THE LFRM

4.1 DESCRIPTION OF METHOD

The Lower Fox River Model (LFRM) is described in Velleux and Endicott (1994). Internal solids production was estimated for the LFRM using historical productivity data from the inner bay in the early 1980s, light extinction data from the inner bay in 1980, and the relationship between biotic solids and chlorophyll-a as described by Raghunathan (1990). This approach results in an estimate of gross internal solids loads, and total suspended solids are settled out in the model. Using this approach, Velleux and Endicott estimated that biotic solids production in the Lower Fox account for approximately 5% of the cumulative solids load to the river and inner bay.

Calculations were made using Auer and Conley's data to independently confirm this estimated loading percentage. Productivity estimates in Auer, et al. (1986) were used along with light extinction data (Conley, 1983) to estimate loadings, based on the same approach used by Velleux and Endicott. The load to the river only was estimated at 5,091,020 kg/yr, which is slightly higher than Velleux and Endicott's estimate of 4,630,000 kg/yr (annual load estimated by integration of daily model input values), and represents 3.9% of the total solids load to the river that served as input during the 1989-1990 calibration period. The differences between the two estimates are likely due to interpretation of Auer and Conley's data, and/or the model input set or period of time selected for comparisons. The total solids loads differences, however, are insignificant considering the small contribution of BSS loads to the Lower Fox River below DePere.

Taking into account all these considerations, internal solids production appears to be a very small (5% or less) source of solids in the Lower Fox River below DePere.

4.2 APPLICABILITY TO THE HINDCAST PERIOD

The existing approach requires measurements of productivity throughout the hindcast period. There are some available productivity measurements in the Lower Fox River below DePere, primarily at the mouth, but they do not provide a historical record of productivities at a range of temporal and spatial locations.

One way to use the existing approach for the hindcast period would be to assume that BSS loads were constant over the entire hindcast period, and equal to the loads estimated by Velleux and Endicott (1994). This would provide a complete series of historical loadings using a simple, straightforward approach, recognizing that it is an approximation based on current conditions. As discussed in Section 4.1, internal solids loads provide a relatively small contribution to the overall solids balance, and the error introduced with this approach would not have a large effect on the solids balance.

Following this approach, annual internal loading for the Lower Fox River below DePere is estimated to be 4,630,000 kg/yr for each year of the hindcast period.

4.3 DISCUSSION OF APPROACH

This use of productivity measurements to estimate biotic solids loadings is a conceptually valid approach. However, the computed rate applies to the time period during which productivity measurements were made, and a lower or higher rate may apply during other years. For this reason, an empirical approach for estimating loads for the entire hindcast period is limited by the lack of useful data. Assuming a constant rate of production over the entire 42-year hindcast period does not account for the significant changes in the river that affect productivity. While total internal production is estimated to account for a small percentage of total solids production in the Lower Fox River below DePere, alternative approaches utilizing additional available data were investigated.

4.4 RECOMMENDATION

A simplified primary productivity model (described in Appendix B) was recommended by the Model Evaluation Workgroup for the LFRM during the model evaluation phase of this study. This provides an approach that does not require productivity data, and uses available long term field data for the hindcast period. It is also consistent with the proposed approach for estimating BSS loads in the Lower Fox River from Lake Winnebago to DePere.

5.0 EXISTING METHOD TO ESTIMATE LOADS FOR GBTOX

5.1 DESCRIPTION OF METHOD

The Green Bay Eutrophication Model (GBEUTRO) was run off-line in the Green Bay Mass Balance Study (GBMBS) to generate internal solids inputs to the GBTOX model. GBEUTRO is a conventional chlorophyll-based eutrophication model including phosphorous and nitrogen as the limiting nutrients. The model was used in the GBMBS to quantify internal organic carbon loading in Green Bay due to autochthonous (phytoplankton) production. This model is a deterministic mass balance model driven by advective-dispersive transport, external nutrient loadings, sediment nutrient fluxes, incident solar radiation, underwater light attenuation, and water temperature. The model was calibrated as part of the GBMBS to an extensive set of historical data collected during 1982 and 1989-1990 (Bierman, et al., 1992), years in which total phosphorous loadings to Green Bay differed substantially from each other. Loadings of total phosphorous from the Lower Fox River, for example, were approximately 866 and 456 metric tons in calendar years 1982 and 1989, respectively (Roznowski & Auer, 1983 and Bierman, et al., 1982).

5.2 APPLICABILITY TO THE HINDCAST PERIOD

The existing modeling approach for estimation of internal solids loads in Green Bay would be to use GBEUTRO. Estimated annual total phosphorus loads for each year of the hindcast period (1954-1995) could be separated into soluble reactive phosphorous (SRP) and non-living organic phosphorous (NLOP), based on ratios observed in the calibration model input sets for 1982 and 1989 from the GBMBS. The resulting annual SRP and NLOP loads for each year of the hindcast could then be entered into the respective calibration input set. The result would be two GBEUTRO input sets for each year of the hindcast period, in which the sum of the SRP and NLOP loading equals the total phosphorous estimate for that year of the hindcast. GBEUTRO could then be run for each year of the hindcast period, with each of the two input sets. Model results of gross primary production for the two GBEUTRO runs could then be averaged to develop an estimate of the monthly internal solids load in each model segment for each year of the hindcast period. Figure 5-1 presents this approach for estimating internal solids loads in Green Bay.

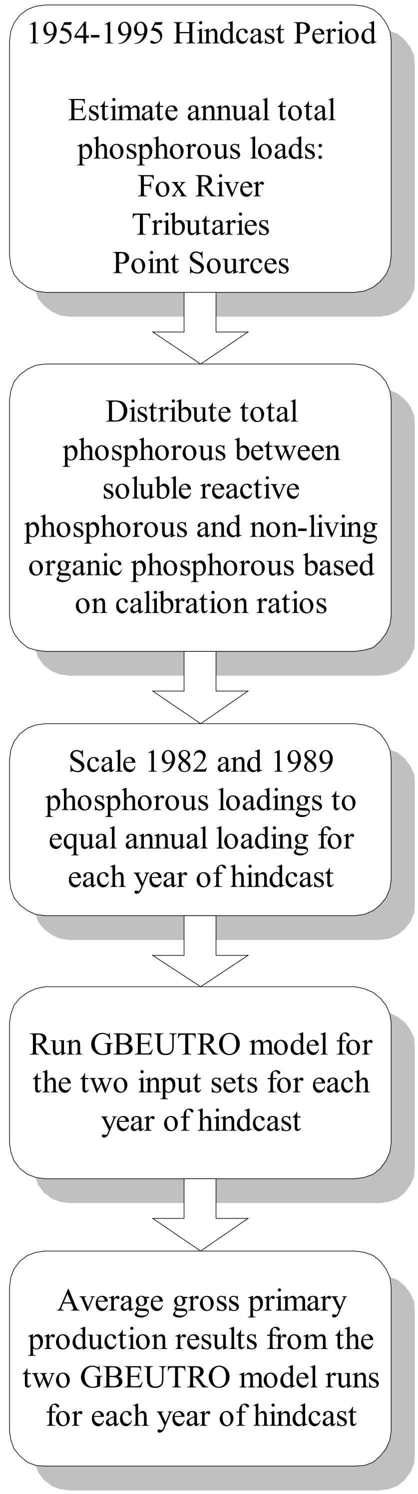


Figure 5-1. One Internal Solids Approach for Green Bay

5.3 DISCUSSION OF APPROACH

The possibility of using GBEUTRO to develop loading estimates for a hindcast using GBTOX has generated considerable discussion of the advantages and disadvantages within the Model Evaluation Workgroup. This section attempts to summarize key points of that discussion.

In order to accurately predict PCB fate and transport in Green Bay for the hindcast period, it is necessary to generate estimates of primary production. Primary production can be directly measured, but is also subject to much spatial and temporal variability. For this reason, an empirical approach would require data to be collected at many locations and times, potentially at great cost, and to be supplemented by interpolation and extrapolation.

The determinants of primary production are well understood (Auer and Canale, 1986 and Thomann and Mueller, 1987), so that a modeling approach is also possible. A model can take into account spatial and temporal variations in temperature, light, nutrients, and other known determinants, so that it is potentially more cost-effective than empirical measurement of primary productivity. The predictive power of such a model is greatly enhanced if it explicitly represents the controlling physical, chemical, and biological processes. To include these explicit process representations, however, introduces a potential area of overlap between models of internal solids loading and models of PCB fate and transport. If these models are to be used in combination with the internal solids loading model providing inputs to the PCB model, then it is important that processes be represented consistently in the two models.

One consequence of achieving this consistency is that the representation of common processes affects the performance of the PCB model twice: once through internal solids loadings forcing functions, and then again through the PCB model itself. The potential exists for error in common components to be reflected in a compound manner in PCB model predictions. The alternative, however, is to generate internal solids loadings using a model with inconsistent process representations, or with simple representations of controlling phenomena. This would not eliminate error in internal solids loadings; it would simply substitute different errors, arising from the alternative representations.

The approach taken in development and calibration of GBTOX and GBEUTRO (Bierman et al., 1992) was as follows:

- GBCL, a hydraulic transport model, was calibrated using chloride data.
- GBEUTRO uses GBCL as a hydraulic chassis, as do all subsequent models in the series.
  - ⇒ GBEUTRO was calibrated to chlorophyll and nutrient data, including phosphorus.
  - ⇒ GBEUTRO uses net settling velocity for biotic carbon.

- GBOCS, an organic carbon sorbents model, uses the output from GBEUTRO as input.

  ⇒ GBOCS introduces greater complexity of particulate dynamics, including settling and resuspension rates for particulate detrital carbon, and decay rates for each of three carbon forms.

  ⇒ GBOCS was calibrated to biotic carbon, particulate detrital carbon, and dissolved organic carbon.

  ⇒ The calibration of GBOCS was subject to several constraints on biotic carbon (which is a state variable in both GBOCS and GBEUTRO): the net settling rate of biotic carbon is required to be the same as in GBEUTRO, and biotic carbon transformation rates are required to be consistent with algal flux losses computed in GBEUTRO.

- Output from GBOCS then serves as input to GBTOX.

  ⇒ GBTOX was calibrated to total PCBs and selected congeners.

It could therefore be argued that GBEUTRO was calibrated before providing inputs and constraints to GBOCS, so that the relationship between GBEUTRO and its successors, including GBTOX, is sequential rather than recursive.

Nevertheless, because GBEUTRO has features in common with GBTOX, the procedure for evaluating GBTOX and alternative Green Bay PCB models could be modified in the following way in order to strive for consistency of process representation:

GBEUTRO could be used to generate internal solids loadings for GBTOX. The evaluation might reveal the need to modify and/or recalibrate GBTOX. If this were to occur, and any GBTOX features or parameters that are common to GBEUTRO were to be modified, then the first step would be to modify these features in GBEUTRO and recalibrate. The recalibrated version of GBEUTRO could then be used to generate new loadings for the reevaluation and recalibration of GBTOX.

It could be asserted, however, that this approach is potentially circular. Autochthonous production within GBEUTRO depends on net settling fluxes of biotic solids (phytoplankton); net settling fluxes of biotic solids depend on the concentration of biotic solids in the water column; and the concentration of biotic solids in the water column depends on autochthonous production.

To further elaborate on this viewpoint, autochthonous production in Green Bay depends on phosphorus and particle cycling between water column and sediments. As represented in GBEUTRO, sediment-water exchanges of phosphorus and particles are represented in terms of net settling velocities. If the net settling of particles is fixed in GBEUTRO through calibration, and if net particle exchange is again treated as a free parameter and calibrated in subsequent models, then this could result in each submodel potentially having different calibrated net exchange values for the same particle types. The representation of net (and ultimately gross) particle exchange should be consistent for each particle type across all submodels. If it were necessary to use new net exchange values in subsequent submodels, this would indicate that the net exchange values initially selected might not be appropriate.

With respect to circularity, a possible response is that potential circularity has been minimized in GBEUTRO because the model was calibrated to both biotic solids (as chlorophyll concentration) and to independent measurements of autochthonous production in 1982. With respect to inconsistencies in calibrated net exchange values, a possible response is as follows. In the subsequent GBTOX model, only sediment-water exchanges of biotic solids are represented in terms of net settling velocities. Sediment-water exchanges of particulate detrital carbon is represented in terms of separate gross settling and resuspension velocities. The only state variable common to both GBEUTRO and GBTOX is biotic solids. Consequently, direct comparisons between GBEUTRO and GBTOX are possible only for biotic solids.

To ensure consistency, autochthonous production and biotic solids net settling rates are the same in GBEUTRO and GBTOX. It could be argued that is not possible to directly compare particulate detrital carbon dynamics between these two models for two reasons: first, particulate detrital carbon is a state variable only in GBTOX and not in GBEUTRO; and second, sediment-water exchanges of particulate detrital carbon in GBTOX are represented in terms of separate gross settling and resuspension velocities, and sediment-water exchanges in GBEUTRO are represented only in terms of net settling velocities.

It is possible that apparent net settling fluxes could be different between GBEUTRO and GBTOX. For biotic solids, differences could occur because loss processes in the water column are represented differently in the two models. Even though both models contain the same autochthonous production rates and biotic solids net settling rates, differences in water column loss processes could result in differences in biotic solids concentrations and hence, differences in net settling fluxes. For non-biotic solids, differences could occur because water column loss processes for particulate detrital carbon in GBTOX do not match the sum of water column loss processes for all of the non-biotic solids state variables in GBEUTRO. This could result in differences between the apparent net settling flux for particulate detrital carbon in GBTOX and the sum of the net settling fluxes for the non-biotic solids types in GBEUTRO.

On a different issue, the methodology described in Section 5.2 is based on calibration in two years: 1982 and 1989. While these two years may appear significantly different compared to each other (i.e. 1982 versus 1989), both of these years occurred after implementation of point source phosphorus controls, the phosphorus ban, and other factors that have significantly changed eutrophic conditions in Green Bay. As a result, the range of conditions examined as part of this calibration may be very narrow relative to the range of conditions that occurred during the hindcast period (1954-1995).

Further, single-year calibrations of eutrophication models are often driven by initial conditions. In a single year simulation, model performance will often depend more on initial conditions than on longer-term processes such as sediment release of phosphorus. As a result, it is very difficult to assess the appropriateness of phosphorus release rates from the sediments in a single year simulation. Model performance in a multi-year simulation may be highly sensitive to the value of this parameter.

Other concerns related to this approach include the effect of assuming that a hydraulic circulation pattern representative of 1989 can be applied to each year of the hindcast period, and the selection of parameter values for the hindcast period to represent changing conditions.

Perhaps most importantly, some Workgroup members were of the opinion that using GBEUTRO would not incorporate an independent load estimation method that does not depend on existing GBTOX model parameters or state variable values. If there were a dependence on model parameters or state variable values, the load estimates would always be subject to later revision as parameter or state variable values change during subsequent Task 3 evaluation and calibration. New loads might in turn lead to new estimates of parameter values which might necessitate yet further re-estimation of loads and so on. An alternative that would avoid this potential problem would be fully independent load estimation, driven by field observations.

5.4 RECOMMENDATION

The Model Evaluation Workgroup was unable to reach complete agreement on the issues discussed in the previous section. In order to make progress with model evaluation, the Model Evaluation Workgroup agreed to recommend an empirical approach for Green Bay that uses available productivity data. Estimates can be scaled for other years using phosphorus loads, and for two different light domains if data are available. This approach is independent of GBTOX parameters, and is driven by field observations. The SPP model can also be applied, for years for which data are available, to compare estimates using a different approach.

6.0 PROPOSED ALTERNATIVES TO EXISTING METHODS

The Model Evaluation Workgroup recommended a set of alternatives for estimating internal solids loads for model evaluation. The alternatives are described below, and the applications of these alternatives are discussed.

6.1 PROPOSED ALTERNATIVE FOR LOWER FOX RIVER ABOVE DEPERE

6.1.1 Description of Approach

The SPP Model is proposed to be applied during subsequent model evaluation phases for estimating a time series of internal solids loads for the 42-year hindcast period. This approach is based on the understanding that primary productivity in aquatic systems is a function of temperature, light, and nutrients. The model is described in detail in Appendix B. Because this approach estimates gross loading rates, the loads estimated this way could be used with a model that accepts gross loads as inputs. In order to accept these loads, the UFRM would need to be modified to incorporate settling and resuspension of biotic solids, and then recalibrated.

The model could be run for two representative time periods in the hindcast period (1954-1971 and 1972-1995) to account for the reduction in solids loads to the river in the early 1970s, and its potential impact on light penetration. However, this approach would be contingent on the availability of sufficient data to determine whether significant differences exist. If sufficient data do not exist to define two light periods, the SPP model could be run for a data-rich period (1989), and the results scaled for other years of the hindcast period using a time series of phosphorus loads.

Potential sources of uncertainty can be identified and described for future use. Internal solids loads for the Lower Fox River from Lake Winnebago to DePere, estimated as described above, may serve as inputs to a modified UFRM. The estimated annual total internal solids loads (as BSS) to each reach of the Lower Fox River from Lake Winnebago to DePere for the hindcast period may be distributed to each segment of that reach, based on the surficial area of each segment as a percentage of the total surficial area of the reach. Internal solids loads may be distributed by month in each segment based on a typical monthly distribution, derived from the 1989 estimates.

The general approach recommended by the Workgroup for model evaluation follows:

1. Evaluate Secchi disk depth data to determine if sufficient data exist for the hindcast period to define two periods: 1954-1971 and 1972-1995. If sufficient data exist, and indicate a difference in light penetration in these two periods, conduct the analysis for two periods; otherwise, handle the entire hindcast period as a single period.

2. Apply SPP model for 1989 using GBMBS data. Include nutrient limitation factors in the model, based on SRP levels reported in GBMBS.

3. Develop a time series of phosphorus loads for the hindcast period using available phosphorus concentration data, streamflows, and Beale's Ratio Estimator.

4. Develop a time series of internal BSS loadings. Calculate a BSS loading for each year in the hindcast period by scaling the calculated BSS loading for 1989 by the ratio of the phosphorus load for 1989 to the phosphorus load for each year.

5. Apply the SPP model a second time, using 1989 forcing functions and data but assuming no nutrient limitation. This represents the highest internal BSS loading possible based upon nutrient effects.

6. If the scaled annual BSS loading for any year is greater than the calculated load from the model run assuming no nutrient limitation, then "cap" the load for that year at the level of the calculated non-nutrient limited loading.

7. Generate a table of monthly BSS loads for the hindcast period. Proportion each annual loading by month according to the proportion of the 1989 loading in each month.

6.1.2 Application of Approach

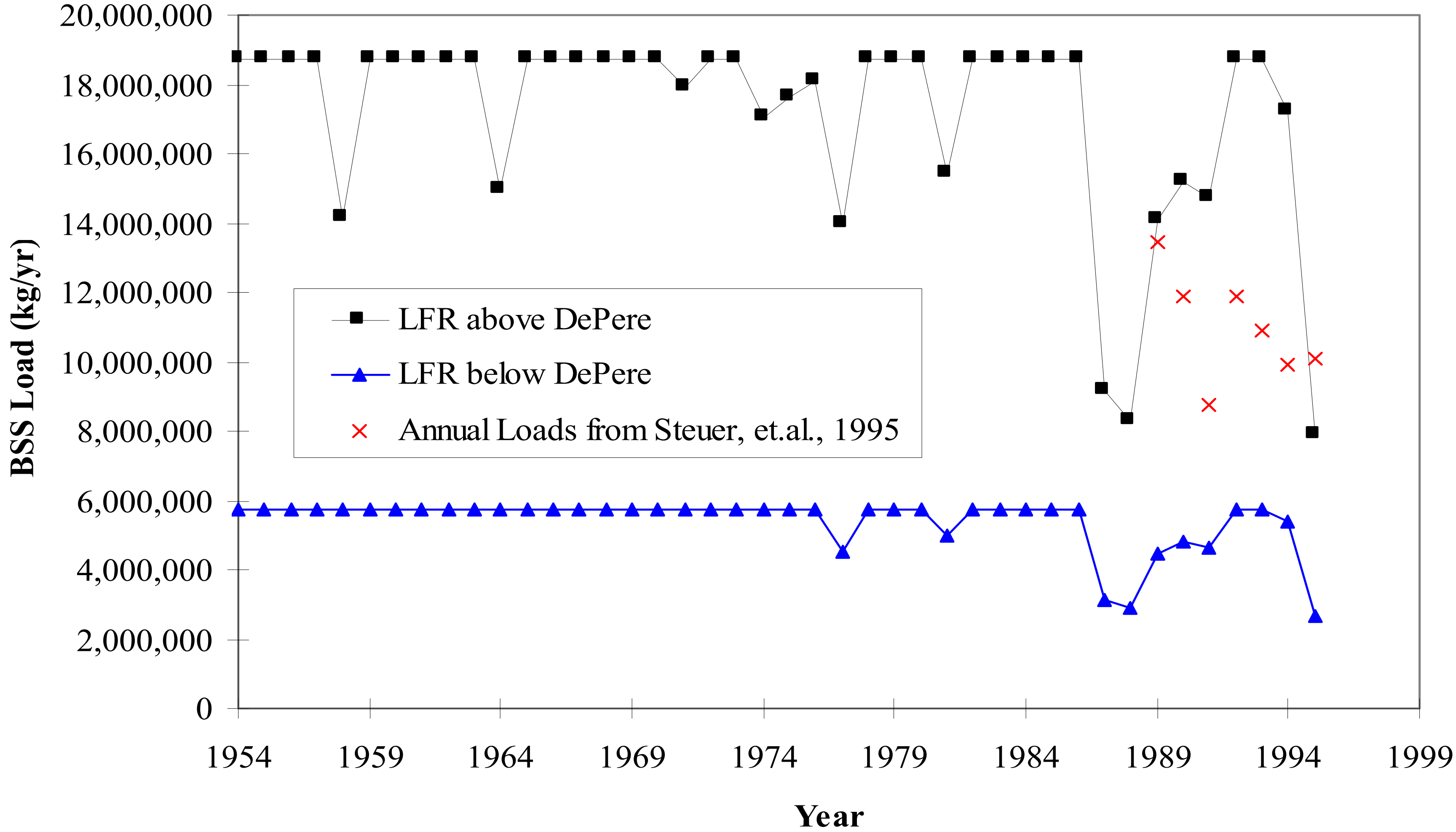
Available Secchi disk depth data were first evaluated to determine if sufficient data exist to define two light periods. No data for the "pre-1972" period were located in the reach above DePere. Therefore, a comparison of light penetration was not possible. Based on this finding, the entire hindcast period was handled as a single period.

The SPP model was applied to estimate internal loadings for 1989. The model requires data related to light, temperature nutrients and chlorophyll-a. The details of the application, along with results, are presented in Tables LF1 through LF3 of Appendix C . Figure 6-1 presents the calculated loads for the hindcast period, and compares results from Steuer, et al. for 1989-1995.

Appendix D (diskette) contains the generated time series of monthly load estimates using estimated historical phosphorus loads for scaling. A time series of phosphorus loads was generated by the following method. The estimated loads for 1989 were scaled to other years of the hindcast period using phosphorus data. The major tributaries contributing phosphorus to southern Green Bay are the Lower Fox (approximately 70% to 78% of the phosphorus load to the bay), Menominee (approximately 13%), Peshtigo (approximately 4%), and Oconto (approximately 5%) (Roznowski & Auer, undated and Klump, et al., 1997). Other smaller tributaries, including the Escanaba River, Pensaukee River, and Duck Creek, contribute approximately 5% of the phosphorus load to Green Bay.

Figure 6-1

Internal BSS Load of the Lower Fox River



Because the Lower Fox River contributes the greatest loading of total phosphorus to the bay, and due to the wealth of data and studies on the Lower Fox, loading estimates were made by first estimating annual loadings from the Lower Fox, and then scaling the smaller tributaries to that load for each year. Scaling factors were based on historical data for the Lower Fox and the smaller tributaries, during years for which tributary loading data were available. A time series of phosphorus loads from the major tributaries to Green Bay was generated using Beale's Unstratified Ratio Estimator for the years 1954-1995, which were compared to available historical loading estimates found in the literature. The details of this evaluation, along with the phosphorus loading estimates, are presented in Appendix A.

6.2 PROPOSED ALTERNATIVE FOR LOWER FOX RIVER BELOW DEPERE

6.2.1 Description of Approach

The SPP Model is proposed to be applied during subsequent model evaluation phases for estimating a time series of internal solids loads for the 42-year hindcast period. This approach is based on the understanding that primary productivity in aquatic systems is a function of temperature, light, and nutrients. The model is described in detail in Appendix B.

The model could be run using two representative time periods in the hindcast period (1954-1971 and 1972-1995) to account for the reduction in solids loads to the river in the early 1970s, and its impact on light penetration. However, this approach would be contingent on the availability of sufficient data to determine whether significant differences exist. If sufficient data do not exist to define two light periods, the SPP model could be run for a data-rich period (1989), and the results scaled for other years of the hindcast period using a time series of phosphorus loads.

Potential sources of uncertainty can be identified and described for future use. The calculated internal solids loads, estimated as described above, may serve as inputs to the LFRM. The estimated annual total internal solids loads (as BSS) to the Lower Fox River below DePere for the hindcast period may be distributed to each segment of the LFRM model based on the surficial area of each segment as a percentage of the total surficial area of the Lower Fox River below DePere. Internal solids loads may be distributed by month in each segment based on a typical monthly distribution, derived from the 1989 estimates.

The general approach recommended by the Workgroup for model evaluation follows:

1. Evaluate Secchi disk depth data to determine if sufficient data exist for the hindcast period to define two periods: 1954-1971 and 1972-1995. If sufficient data exist, and indicate a difference in light penetration in these two periods, conduct the analysis for two periods, otherwise handle the entire hindcast period as a single period.

2. Apply SPP model for 1989 using GBMBS data. Include nutrient limitation factors in the model, based on SRP levels reported in GBMBS.

3. Develop a time series of phosphorus loads for the hindcast period using available phosphorus concentration data, streamflows, and Beale's Ratio Estimator.

4. Develop a time series of internal BSS loadings. Calculate a BSS loading for a each year in the hindcast period by scaling the calculated BSS loading for 1989 by the ratio of the phosphorus load for 1989 to the phosphorus load for each year.

5. Apply SPP model a second time, using 1989 forcing functions and data but assuming no nutrient limitation. This represents the highest estimated internal BSS loading possible based upon nutrient effects.

6. If the scaled annual BSS loading for any year is greater than the calculated load from the model run assuming no nutrient limitation, then "cap" the load for that year at the level of the calculated non-nutrient limited loading.

7. Generate a table of monthly BSS loads for the hindcast period. Proportion each annual loading by month according to the proportion of the 1989 loading in each month.

6.2.2 Application of Approach

Available Secchi disk depth data were first evaluated to determine if sufficient data exist to define two light periods. Only 22 data points were located in this reach for the "pre-1972" period. Ten of these data were collected near the mouth, and show evidence of influences from Green Bay. Most of the readings were collected in the summer months, and insufficient data exist to make year-round estimates. The data that were available suggest that, if anything, depth of light penetration may have been the same as, or slightly higher in the "pre-1972" period compared to present conditions. Due to the limited data available, and the apparent insignificant differences between the two periods, the entire hindcast period was handled as a single period.

The SPP model was applied to estimate internal loadings for 1989. The model requires data related to light, temperature, nutrients, and chlorophyll-a. The details of the application, along with results, are presented in Tables LF1 through LF3 of Appendix C. Figure 6-1 presents the calculated loads for the hindcast period, and also compares results from Steuer, et al., 1995.

Appendix D (diskette) contains the generated time series of monthly loads estimates using estimated historical phosphorus loads to scale. A time-series of phosphorus loads was estimated using the method described in Section 6.1.2 and Appendix A.

6.3 PROPOSED ALTERNATIVE FOR GREEN BAY

6.3.1 Description of Approach

The approach recommended by the Workgroup for model evaluation involves the estimation of loads using an empirical approach based on productivity data. Extensive primary productivity data are available for 1982 (Auer, et al., 1982). Internal solids production can be calculated from these data, and scaled for other years using a time series of phosphorus loads, assuming a linear relationship between phosphorus loads and production.

The model could be run using two representative time periods in the hindcast period (1954-1971 and 1972-1995) to account for the reduction in solids loads to the river in the early 1970s, and its impact on light penetration. However, this approach would be contingent on the availability of sufficient data to determine whether significant differences exist. If sufficient data do not exist to define two light periods, the empirical model could be run for the 1982 period, and the results scaled for other years of the hindcast period using a time series of phosphorus loads.

The results of applying this approach can be compared to an estimate for 1982 using the SPP model.

Potential sources of uncertainty can be identified and described for future use. The Green Bay internal solids loads, estimated as described above, may serve as inputs to the PCB transport model, GBTOX. It is recommended to the Model Evaluation Workgroup that the estimated annual total internal solids loads (as carbon) to Green Bay for the hindcast period be input to the GBTOX model as a monthly load to each segment, just as they are calculated by the GBEUTRO model. The gross primary production values calculated may be separated into biotic carbon (BIC) and dissolved organic carbon (DOC) loads according to the ratios used in the GBMBS (80% BIC, 20% DOC).

The general approach recommended by the Workgroup for model evaluation follows:

1. Evaluate Secchi disk depth data to determine if sufficient data exist for the hindcast period to define two periods: 1954-1971 and 1972-1995. If sufficient data exist, and they indicate a difference in light penetration in these two periods, conduct analysis for two periods, otherwise handle whole hindcast period as a single period.

2. Calculate Green Bay model segment-specific monthly average water column conditions based on the Auer/MTU 1982 data. These data were previously processed for the GBMBS, using the Volume Weighted Average (VWA) method, to represent conditions within each Green Bay model segment. Water column conditions for months outside of the 1982 MTU sampling period are estimated by a range of methods including: averaging, temperature and light condition adjustment (e.g. for Chl-a), and application of 1982 data-based regression equations (e.g. for K_e), as necessary.

3. Calculate 1982 internal solids production (empirical approach) using the processed 1982 Auer/MTU data.

4. Apply SPP model for 1982 for each segment using the processed 1982 Auer/MTU data.

5. Compare results from empirical approach to results from SPP model for 1982.

6. Generate table of monthly BIC loads for the hindcast period by scaling to historical P loads.

6.3.2 Application of Approach

Secchi disk depth data were evaluated to determine if sufficient data exist to define two light periods. Table 6-1 presents summary statistics for the data available for Green Bay. The statistics suggest that no systematic differences exist for these two periods in most segments, but the small data set in the "pre-1972" period introduces uncertainty in this analysis, particularly for the middle and outer bay. It is recommended, based on this analysis, to handle the entire hindcast period as one time period.

Appendix C presents the details and results of the application of the empirical approach to Green Bay for 1982. The estimated loads for 1982 were scaled to other years of the hindcast period using phosphorus data, by the approach described in Section 6.1.2 and Appendix A.

Figure 6-2 presents the estimates of biotic solids production in terms of BIC for the hindcast period, using this approach. These estimates were computed by assuming that 80% of the total carbon mass produced through primary production is biotic carbon (BIC), and 20% is dissolved organic carbon (DOC), consistent with Bierman et al. (1992). The loads may serve as input to the PCB transport model GBTOX. Appendix D (diskette) contains the generated time series of monthly BIC load estimates using estimated historical phosphorus loads to scale. The DOC loads required by GBTOX can be obtained by scaling according to the above percentages.

The loads generated from the empirical approach were higher than the loads generated from the SPP model. Empirical 1982 loads were 5.8%, 7.5%, and 18.8% higher than 1982 loads generated from the SPP model for the inner bay, inner and middle bay, and whole bay, respectively (see Table GB2 of Appendix C).

Table 6-1.
Summary of Secchi Disk Depth by Green Bay Regions for Pre- and Post- 1972 Conditions

Near Fox River Mouth / Inner Green Bay (Segment 1)				
1972-Present			Prior to 1972	
Statistical Summary	Sechhi Disk Depth (m)		Statistical Summary	Sechhi Disk Depth (m)
Median	0.5		Median	0.6
Average	0.704		Average	0.621
Standard Deviation	1.498		Standard Deviation	0.245
Variance	2.243		Variance	0.060
Count	469		Count	89

Inner Green Bay (Segments 2 through 6)				
1972-Present			Prior to 1972	
Statistical Summary	Sechhi Disk Depth (m)		Statistical Summary	Sechhi Disk Depth (m)
Median	1.1		Median	1.3
Average	1.218		Average	1.400
Standard Deviation	0.880		Standard Deviation	0.556
Variance	0.775		Variance	0.309
Count	404		Count	131

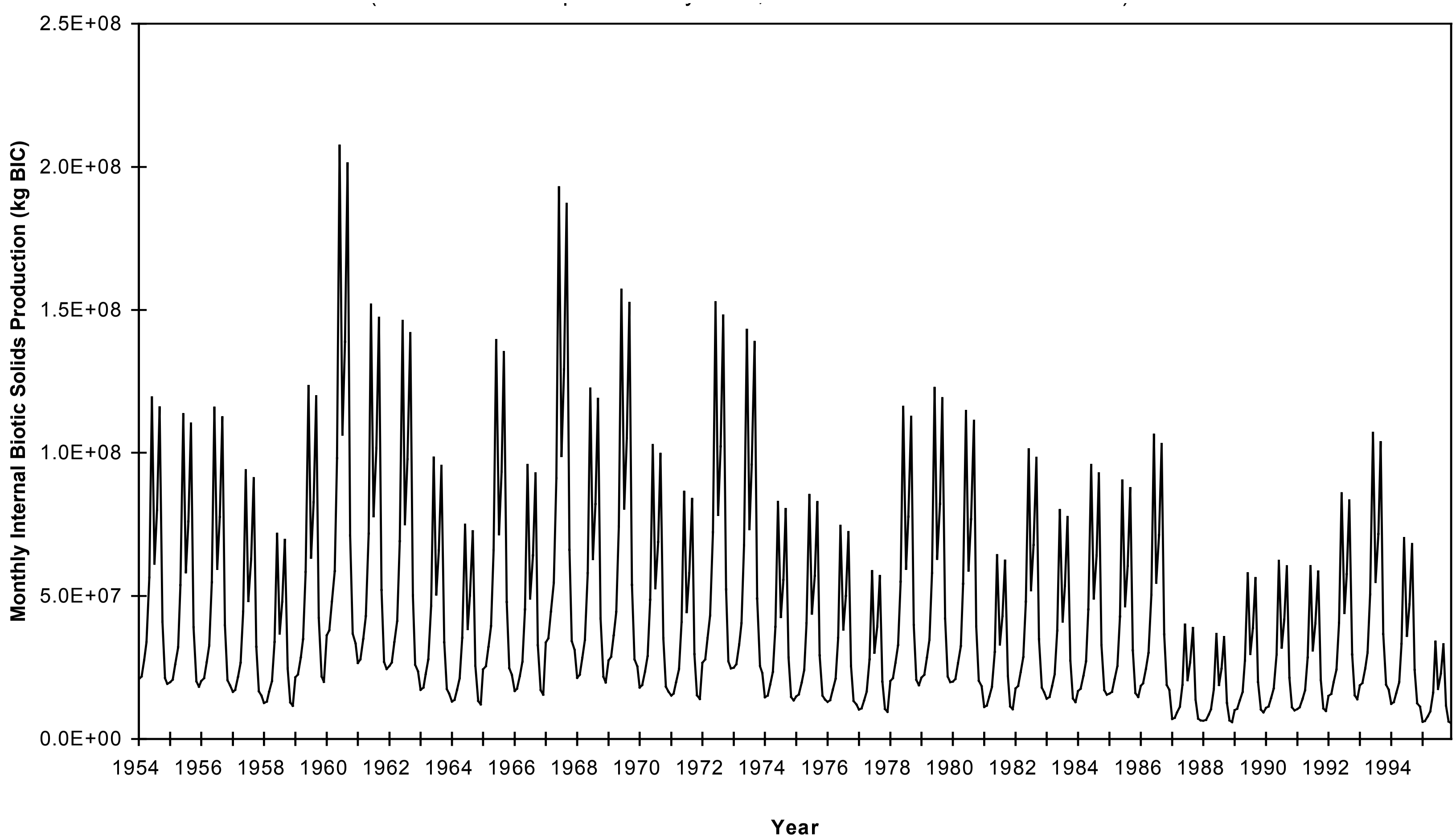
Middle Green Bay (Segments 7 and 8)				
1972-Present			Prior to 1972	
Statistical Summary	Sechhi Disk Depth (m)		Statistical Summary	Sechhi Disk Depth (m)
Median	2.1		*Median	3.657
Average	2.473		Average	3.907
Standard Deviation	1.108		Standard Deviation	0.448
Variance	1.227		Variance	0.201
Count	205		Count	11

Outer Green Bay (Segment 9)				
1972-Present			Prior to 1972	
Statistical Summary	Sechhi Disk Depth (m)		Statistical Summary	Sechhi Disk Depth (m)
Median	4.9		*Median	4.572
Average	4.850		Average	4.907
Standard Deviation	1.504		Standard Deviation	0.914
Variance	2.261		Variance	0.835
Count	57		Count	10

***Median is converted from original pre-1972 values reported in feet.**

Figure 6-2
Empirically Derived Monthly Biotic Solids Production in Green Bay for 1954-1994

(based on 1985 productivity data, and annual external TP loads)



6.4 DISCUSSION OF UNCERTAINTY

Potential sources of uncertainty in these approaches are listed in Tables 6-2 and 6-3. The tables summarize the uncertainty in numerous factors that are used in the estimation of biotic solids. These factors are addressed qualitatively, and ranges are provided, where possible.

The methods used to calculate internal, or biotic suspended solids loads for Green Bay and the Lower Fox River were also evaluated statistically to assess the uncertainty associated with the loadings estimations. The Crystal Ball Version 4.0 software package was used to set up spreadsheet models and Monte Carlo simulations for Green Bay model (GBTOX) segments 1, 6 and 8, and for the reaches of the Lower Fox River above and below DePere Dam. These spreadsheet models replicate the formulas used to calculate internal solids loads in this report. A probability distribution is applied to each parameter in each spreadsheet to describe the uncertainty of that parameter. In addition, sample variation in field data is explicitly incorporated, where available. The Monte Carlo simulation applied to each spreadsheet model uses random numbers to measure the combined effects of parameter uncertainty and sample variability on predicted internal solids loadings. Crystal Ball displays results in a forecast chart that shows the entire range of possible outcomes and the likelihood of achieving each of them. The forecast charts represent a statistical picture of the range of possibilities inherent in the spreadsheet assumptions.

In summary, the Monte Carlo simulations show that parameter uncertainty and sample variability together imply a normalized standard error of about 25% in predicted BIC for Green Bay, and a normalized standard error of about 62% and 64% for predicted BSS in the Lower Fox River, above and below DePere Dam, respectively.

6.4.1 Uncertainty Estimate for Green Bay

6.4.1.1 Approach

As described in Section 6.3, loads to Green Bay were estimated using an empirical approach based on productivity data. Extensive primary production data are available for 1982, and internal solids production was calculated from these data and scaled for other years using a time series of phosphorous loads and assuming a linear relationship between phosphorous loads and production. The September 1982 surveys provide the most robust data set; therefore, these data were used in the Monte Carlo analyses to assess the uncertainty for each of three representative Green Bay model segments (1, 6 and 8). This analysis assumes that the 1982 loading uncertainty results for each segment are also applicable to other segments and time periods.

Table 6-2: Characterization of Uncertainty in SPP modeling of the Lower Fox River and Green Bay

Factor	Range	Comments
Scarcity of data		Lower Fox River: Extrapolation of 1 year of data to 42 years introduces uncertainty. Assumed light and temperature data from 1989 are representative of entire 42 year period. Green Bay: Extrapolated 1982 data to 42 years.
Representativeness of data	Indeterminate. However, VWA-generated S.D.s re available for each Green Bay segment.	Lower Fox River: Segment-wide averaging of field samples. Green Bay: Data from individual stations were processed as volume weighted averages and applied as segment-specific values. These values were averaged on a monthly basis over the 1982 MTU sampling period.
Scaling of 1989 BSS loadings		Lower Fox River: Assumed that BSS loadings could be scaled linearly according to total phosphorus load, up to the point where nutrient limitation was not a factor.
Uncertainty in conversions:		
• Carbon to Chlorophyll-a ratio set to 30 g C/g Chl-a	10 - 112	A site-specific ratio was developed for Green Bay based on data. However, the ratio varies significantly depending on the algal type. The range at left is typical of what might be applied if no data were available.
• Carbon to biotic suspended solids conversion set to 0.40 g C/g BSS	0.22 - 0.70	This varies depending on algal type.
Uncertainty in constants:		
• Maximum algal growth rate set to 2.5/day	1 - 3	This value was adjusted to fit empirical Green Bay productivity results.
• Temperature correction for algal growth set to 1.070	1.01 - 1.18	Reported ranges vary.
• Saturation light intensity based on GBEUTRO calibration and set to 100 Ly/day	100 - 400	Mixed phytoplankton light saturation range (Thomann and Mueller, 1987)
• Michaelis constant for phosphorus limitation set to 1.0 ug P/L	1 - 5	Typical values vary depending on the species.
• Michaelis constant for nitrogen limitation set to 25 ug/L	5 - 25	There were no 1982 data available for determining this. Typical values vary depending on the species.
• Primary production efficiency factor set to 0.8		

Table 6-3. Characterization of Uncertainty in the Empirical Approach used for Green Bay

Factor	Range	Comments
Uncertainty in sampling of data related to productivity calculations	Indeterminate. However, VWA-generated standard deviations are available for each Green Bay segment.	Data from individual stations were processed as volume weighted averages and applied as segment-specific values. These values were averaged on a monthly basis over the 1982 MTU sampling period. The average of the monthly productivity measurements was then applied to months outside of the sampling period.
Uncertainty in conversion factors		Auer measured oxygen production in laboratory studies. There is uncertainty in converting the lab measurements to units of carbon production in the field.
• Saturation light intensity based on GBEUTRO calibration and set to 100 Ly/day	100 - 400	Mixed phytoplankton light saturation range (Thomann and Mueller, 1987)
• Conversion of laboratory incident light to saturation intensity. Conversion calculated as 0.994.	0.994 - 0.487 (based on saturation intensity)	This conversion is based on the assumption of a 550 nm wavelength for the laboratory incident light, and is also a function of the saturation light intensity.
• Nitrogen to carbon ratio set to 0.250 mg N/mg C	0.10 - 0.48 0.25 (mean)	This range is based on Potomac Estuary data presented in the WASP5 user's manual (Ambrose et al, 1993)
• Ammonia uptake preference factor based on bay-wide estimate from 1989 GBMBS data because nitrogen data were not collected in 1982. Value set to 0.500.	approximate range is 0.25 - 0.75	The ammonia uptake preference varies seasonally and spatially through the bay based on 1989 ammonia and nitrate+nitrate data. This factor is also based on an assumed nitrogen Michaelis constant of 25 ug N/L.
• Oxygen to carbon ratio adjusted for ammonia preference factor. O_2:C ratio set to 3.095 mg O_2/mg C	dependent on ammonia uptake preference	A ammonia uptake preference factor of 1.0 reduces the oxygen to carbon mass ratio to the stoichiometric value of 32/12, or 2.67.
• Carbon to Chlorophyll-a ratio set to 30 g C/g Chl-a	5 - 500	A site-specific ratio was developed for Green Bay based on data. However, the ratio varies significantly depending on the algal type. The range at left is typical of what might be used in absence of any data.
• Carbon to biotic suspended solids conversion set to 0.40 g C/g BSS	0.22 - 0.70	This varies depending on algal type.

Table 6.3: Characterization of Uncertainty in the Empirical Approach used for Green Bay (Continued)

Factor	Range	Comments
Representativeness of data		Temperature data collected from different depths
Scarcity of data	May - Sept. sampling, (18 cruises)	Only had data for 1982. Gross primary productivity data was available for 14 of the 18 sampling cruises.
Uncertainty in extrapolating data		Extrapolated 1982 data to 42 years by assuming that productivity is linearly related to phosphorus loads. There is no way to quantify the uncertainty with this assumption unless there are productivity data for a different year.
Uncertainty in phosphorus loads	Ratio of phosphorus load to flow may have changed after the phosphorus ban.	Daily concentrations were not available. Used Beale's Unstratified Ratio Estimator to estimate loads. Assumed constant ratio of phosphorus load to flow over entire 42 year period.

Thirteen input parameters were used to calculate biotic carbon loadings (BIC) for Segments 1, 6 and 8: GPP, volume, temperature, K_e, depth, number of days, θ_T, photo, I_o, I_{sat}, f_{POC}, NCRB and PNH3. Eight of these parameters (number of days, θ_T, Photo, I_o, I_{sat}, f_{POC}, NCRB and PNH3) were assigned identical values in all segments (including number of days, which was held constant at a value of 30). The other five parameters (GPP, volume, temperature, K_e and depth) had segment-specific values. Of these, both the volume and depth parameters were held as constants for each of the segment-specific Crystal Ball analyses.

Table 6-4 summarizes specific information regarding the input parameters, including how the data values were obtained and how they were described for each segment-specific Crystal Ball analysis. Specific numerical values assumed (such as mean, minimum, and maximum) are given in Appendix E. Note that eight input parameters were described with triangular distributions. Of these, only one parameter (K_e) varied between segments. Two input parameters (GPP and temperature) were described with segment-specific normal distributions.

Some daily data from September 1982 cruises are available for GPP, temperature and K_e, and these data were used to calculate a data range, average, standard deviation and standard error of the mean for each segment when possible. September 1982 K_e data were available only for Segment 1. More specific information follows:

- For the GPP parameter, a segment-specific average value was used as the mean in the normal distribution. For segments 6 and 8, the standard deviation for each segment was based on data from the surrounding zone (segments 2-6 and segments 7-11, respectively).

- For the temperature parameter, a segment-specific average value was used as the mean in the normal distribution. A segment-specific standard deviation value was used in the normal distribution.

- The K_e parameter was the most problematic to describe because of the lack of September 1982 data for most of the segments. Where September 1982 data were available (i.e. for Segment 1), a segment-specific average value was used as the most-likely value in the triangular distribution for that segment. The average K_e value for Segment 3 was used for Middle Bay Segment 6, which did not have segment specific K_e data from September 1982. An average of all of the available post-1971 K_e data was calculated for combined Segments 7 and 8 and used for Segment 8. Minimum and maximum values were estimated from all of the available K_e data using best professional judgement.

Table 6-4. Summary of Crystal Ball Input Parameters for Green Bay BIC Forecasts

PARAMETER NAME	CRYSTAL BALL DATA DISTRIBUTION	SOURCE OF PARAMETER VALUES
GPP (a/k/a GROSSP)	Normal	Segment – specific data available for September 1982.
Volume	N/A (constant)	Estimated average values. Values varied between segments.
Temperature	Normal	Segment – specific data available for September 1982 .
K_e	Triangular	Segment – specific data available for September 1982 for Segment 1. Used Segment 3 average for Middle Bay Segment 6. Used average of all post-1971 data from Segments 7 and 8 for Segment 8.
Depth (d)	N/A (constant)	Estimated average values. Values varied from segment to segment.
Number of Days	N/A (constant)	30 days in the month of September.
□□	Triangular	Literature value (Thoman and Mueller, 1982). Same values used for all 3 segments.
Photo	Triangular	Derived from known meteorological data. Same values used for all 3 segments.
I_o	Triangular	Derived from known meteorological data. Same values used for all 3 segments.
I_{sat}	Triangular	Literature value (Bierman, et al, 1992). Same values used for all 3 segments.
f_{POC}	Triangular	Literature value (Bierman, et al, 1992). Same values used for all 3 segments.
PNH3	Triangular	Bay-wide estimate from 1989 GBMBS data. Same values used for all 3 segments.
NCRB	Triangular	Literature value (Bierman, et al, 1992). Same values used for all 3 segments.

6.4.1.2 Uncertainty Estimate Results for Green Bay

Table 6-5 summarizes the statistics associated with each of the three Green Bay segment uncertainty estimate results. The associated spreadsheet models and forecast charts for each segment are presented in Appendix E.

As shown in Table 6-5, approximately 10,000 Monte Carlo trials were performed for each segment simulation. The mean BIC value from each of the three simulations is compared to the associated Monte Carlo standard deviation value and mean standard error value. For Segments 1, 6 and 8, the Monte Carlo standard deviation values are 20%, 26% and 28% of the Monte Carlo mean BIC values, respectively. This normalized standard deviation represents the uncertainty in predicted BIC values, given the assumed parameter uncertainty and actual data variability. For Segments 1, 6 and 8, the Monte Carlo normalized standard errors of means are 0.20%, 0.27% and 0.28% respectively. This normalized standard error of the mean represents the uncertainty in the estimate of mean BIC, attributable to the finite Monte Carlo sample size. The skewness and kurtosis of the predicted BIC distributions for Segments 1, 6 and 8 vary from 0.50 to 0.57 and from 2.81 to 3.19, respectively. These latter two statistical terms describe the degree of asymmetry and peakedness of the forecast distribution curves, respectively. In general, the predicted BIC distributions for the three segments are slightly skewed to the right and single-peaked.

In addition, the Monte Carlo mean BIC values were compared to the September 1982 empirical results (refer to Table 6-5). The Monte Carlo mean BIC values for Segments 1, 6 and 8 vary by -17%, -7% and 18% of the empirical values, respectively. These variations are due to differences between point and distributional parameter estimates and to multiplicative interactions between parameter distributions.

Table 6-5. Summary of Green Bay Monte Carlo Results Uncertainty Estimates for Biotic Carbon Calculations

Green Bay Segment Number	1	6	8
Number of Monte Carlo Trials	9974	9813	9935
Mean BIC	1.14E+06	1.11E+06	8.57E+06
Median BIC	1.11E+06	1.07E+06	8.31E+06
Standard Deviation	2.32E+05	2.93E+05	2.37E+06
Variance	5.41E+10	8.61E+10	5.60E+12
Skewness	0.57	0.57	0.50
Kurtosis	3.19	2.89	2.81
Coefficient of Variability	0.20	0.26	0.28
Range Minimum	5.00E+05	2.50E+05	2.00E+06
Range Maximum	2.00E+06	2.00E+06	1.60E+07
Range Width	1.50E+06	1.75E+06	1.40E+07
Mean Standard Error	2.33E+03	2.96E+03	2.38E+04
BIC Empirical Result	9.73E+05	1.04E+06	1.04E+07
% Difference (Standard Deviation)	20%	26%	28%
% Difference (Mean Standard Error)	0.20%	0.27%	0.28%
% Difference (from Empirical result)	-17%	-7%	18%

6.4.2 Uncertainty Estimate for Lower Fox River

6.4.2.1 Approach

As described in Sections 6.1 and 6.2, internal solids production for the Lower Fox River was estimated using the Simplified Primary Productivity Model. This approach estimates gross loading rates as a function of temperature, light and nutrients. The available light, temperature, secchi depth, chlorophyll-a, soluble reactive phosphorous (SRP) and dissolved inorganic nitrogen (DIN) data from the months of July, August and September were used in the Monte Carlo analyses to assess the uncertainty for the Lower Fox River reaches. This analysis assumes that the mean loading uncertainty results for both sections are also applicable to other seasons of the year.

Eighteen input parameters were used to calculate biotic suspended solids (BSS); Umax, volume, temperature, K_e, depth, number of days, θ_T, photo, I_o, I_{sat}, f_{POC}, Chl-a, CBSS, SRP, K_{mp}, DIN, K_{mn} and CCHL. Eleven of these parameters (Umax, number of days, Θt, photo, I_o, I_{sat}, f_{POC}, Kmp, Kmn, CCHL and CBBS) were assigned identical values for the reaches of the Lower Fox River above and below DePere Dam (including the number of days, which was held constant). The other seven parameters (volume, temperature, Chl-a, SRP, DIN, K_e and depth) had values specific to each reach. Of these, both the volume and depth parameters were treated as reach-specific constants for both of the Crystal Ball analyses.

Table 6-6 summarizes specific information regarding the input parameters, including how the data values were obtained and how they were described for both Crystal Ball analyses. For the Lower Fox above DePere Dam, ten input parameters were described with triangular distributions, four parameters were described with lognormal distributions, and one parameter (temperature) was described with normal distribution in the analyses. For the Lower Fox below DePere Dam, ten input parameters were described with triangular distributions, three parameters were described with lognormal distributions, and two parameters (temperature and Chlorophyll-a) were described with normal distributions in the analyses. The Crystal Ball program was used to assist the selection of either a normal, lognormal, or triangular distribution as a “best fit” to the I_o, temperature, K_e, chlorophyll-a, SRP and DIN data for the Lower Fox above and below DePere Dam, respectively.

Table 6-6. Summary of Crystal Ball Input Parameters for Lower Fox River BSS Forecasts

PARAMETER NAME	CRYSTAL BALL DATA DISTRIBUTION	SOURCE OF PARAMETER VALUES
Umax	Triangular	Task 2c Bay model calibration
Volume	N/A (constant)	Estimated average values. Values varied between segments.
Temperature	Normal	From July, August and September data.
K_e	Lognormal	From July, August and September data.
Depth (d, d^)	N/A (constant)	Estimated average values.
Number of Days	N/A (constant)	
□□	Triangular	Literature value (Thoman and Mueller, 1982). Same value used for both sections.
Photo	Triangular	Derived from known meteorological data.
I_o	Triangular	Derived from known meteorological data.
I_{sat}	Triangular	Literature value (Bierman, et al, 1992).
f_{POC}	Triangular	Literature value (Bierman, et al, 1992).
Chl-a	Lognormal above DePere, normal below DePere	From July, August and September data.
CBSS	Triangular	Literature value (Bierman, et al, 1992).
SRP	Lognormal	From July, August and September data.
K_{mp}	Triangular	Literature value (U.S. EPA, 1993)
DIN	Lognormal	From July, August and September data
K_{mn}	Triangular	Literature value (U.S. EPA, 1993)
CCHL	Triangular	Literature value (Bierman, et al, 1992).

6.4.2.2 Uncertainty Estimate Results for Lower Fox River

Table 6-7 summarizes the statistics associated with the Lower Fox River uncertainty estimate results. The associated spreadsheet models and forecast charts for both sections are presented in Appendix E.

As shown in Table 6-7, approximately 10,000 Monte Carlo trials were performed for each reach. Each Monte Carlo simulation represented the months of July-September, and incorporated estimates of variability using data from all available years. The mean BSS values are compared to the associated Monte Carlo standard deviation values and mean standard error values. For the Lower Fox above and below DePere Dam, the Monte Carlo standard deviation values are 62% and 64% of the Monte Carlo mean BSS values, respectively. This normalized standard deviation represents the uncertainty in predicted BSS values, given the issued parameter uncertainty and actual data variability. For the Lower Fox above and below DePere Dam, the Monte Carlo normalized standard errors of means are 0.62% and 0.64% of the Monte Carlo mean BSS values, respectively. This normalized standard error represents the uncertainty in the estimate of mean BSS, attributable to the finite Monte Carlo sample size. The skewness and kurtosis of the Monte Carlo probability forecasts for the Lower Fox above and below DePere Dam are 1.13 and 1.03, and 4.08 and 4.02, respectively. In general, the predicted BSS distributions for the Lower Fox reaches are skewed to the right and single-peaked.

In addition, the Monte Carlo mean BSS values were compared to the July, August and September 1989 simplified primary productivity results (refer to Table 6-7). The Monte Carlo mean BSS value for the Lower Fox above DePere differs from the July through September 1989 SPP results by –71.4% to 30.4%. The Monte Carlo mean BSS value for the Lower Fox below DePere differs from the July through September 1989 SPP results by 85.2% to 8%. The mean BSS values differ because several years of data were used for the Monte Carlo analysis, in order to take advantage of richer data for some variables from other years, whereas the SPP results were based only on 1989 data.

Table 6-7. Summary of Lower Fox River Monte Carlo Results Uncertainty Estimates for BSS Calculations

Fox River Section	Above DePere Dam	Below DePere Dam
Number of Monte Carlo Trials	9806	9906
Mean BSS	3.33E+06	8.76E+05
Median BSS	2.86E+06	7.57E+05
Standard Deviation	2.06E+06	5.62E+05
Variance	4.24E+12	3.16E+11
Skewness	1.13	1.03
Kurtosis	4.08	4.02
Coefficient of Variability	0.62	0.64
Range Minimum	0.00E+00	-1.00E+06
Range Maximum	1.10E+07	3.00E+06
Range Width	1.10E+07	4.00E+06
Mean Standard Error	2.08E+04	5.65E+03
BSS Calculated Result for July-89	4.78E+06	9.53E+05
BSS Calculated Result for Aug-89	2.57E+06	8.11E+05
BSS Calculated Result for Sept-89	1.94E+06	4.73E+05
% Difference (Standard Deviation)	62%	64%
% Difference (Mean Standard Error)	0.62%	0.64%
% Difference (from July-89 Simplified Primary Productivity result)	30.39%	8.0%
% Difference (from Aug-89 Simplified Primary Productivity result)	-29.51%	-8.0%
% Difference (from Sept-89 Simplified Primary Productivity result)	-71.4%	-85.2%

7.0 REFERENCES

Auer, Martin T. and R.P. Canale. 1986. Mathematical Modeling of Primary Production in Green Bay (Lake Michigan, USA), a Phosphorus and Light-Limited System. Hydrobiological Bulletin 20 (1/2):195-211.

Auer, Martin T., R.P. Canale, and J.H. Wiersma. 1983. A Steady-State Model for Chloride, Total Phosphorus and Total Organic Carbon in Green Bay (Lake Michigan). In: Proceedings of the 2nd Symposium on Environmental Biology. U.S. Environmental Protection Agency, Washington, D.C.

Auer, Martin T., M.S. Kieser and R.P. Canale. 1986. Identification of Critical Nutrient Levels Through Field Verification of Models for Phosphorus and Phytoplankton Growth. Can. J. Fish. Sci., Vol. 43.

Conley, D.J. 1983. Limnological Characteristics of Green Bay, Lake Michigan, May-October, 1980. M.S. Thesis. University of Wisconsin-Green Bay, Green Bay, Wisconsin.

Bierman, V.J. et al. 1992. Development and Validation of an Integrated Exposure Model for Toxic Chemicals in Green Bay, Lake Michigan. Cooperative Agreement CR-814885, U.S. Environmental Protection Agency.

DiToro, D.M. and Connolly, J.P. 1980. Mathematical Models of Water Quality in Large Lakes: Part 2-Lake Erie. Environmental Research Lab, USEPA, Duluth, MN. EPA-600/3-80-065.

Hughes, P.E. 1993. Hydrologic and Water Quality Data for the East River Basin of Northeastern Wisconsin. Open File Rep. U.S. Geol. Surv. No. 89-245.

Millard, E.S. and P.E. Sager. 1994. Comparison of Phosphorus, Light Climate, and Photosynthesis between Two Culturally Eutrophied Bays: Green Bay, Lake Michigan, and the Bay of Quinte, Lake Ontario. Can. J. Fish. Aquat. Sci., Vol.51, No. 51.

Klump, J. Val, David N. Edgington, Paul E. Sager, and Dale M. Robertson. 1997. Sedimentary phosphorus cycling and a phosphorus mass balance for the Green Bay (Lake Michigan) ecosystem. Can. J. Fish. Aquat. Sci. Vol. 54.

Patterson, Dale. September 28, 1992. Letter to Vic Bierman in regards to Phosphorus Loads for Mass Balance Management Runs. State of Wisconsin, Department of Natural Resources.

Persson, Lynn, Victoria Harris, Cynthia Lukas, Jeanne Christie, H.J. Harris, Lee Meyers, John Sullivan, Paula Allen, and Ron Baba. 1988. Lower Green Bay Remedial Action Plan for the Lower Fox River and Lower Green Bay Area of Concern. Wisconsin Department of Natural Resources, PUBL WR 175-87 Rev. 88.

Preston, Stephen D., Victor J. Bierman, Jr., and Stephen E. Sillman. 1989. An Evaluation of Methods for the Estimation of Tributary Mass Loads. Water Resources Research, 25(6):1379-1389.

Raghunathan, Ramesh K. 1990. Development of a Dynamic Mass Balance Model for PCBs in Green Bay. M.S. Thesis. Department of Civil and Environmental, Clarkson University, Potsdam, New York.

Roznowski, Denis M. and Martin T. Auer. Undated. Draft: Tributary Loadings to Green Bay: A Mass Balance Approach. Department of Civil Engineering, Michigan Technological University, Houghton, Michigan.

Sager, Paul E. And James H. Wiersma. 1975. Phosphorus sources for lower Green Bay, Lake Michigan. Journal WPCF, 504-514.

Sonzogni, William C., T.J. Monteith, W.N. Bach and G.H. Hughes. 1978. United States Great Lakes Tributary Loadings. Technical Report of the International Reference Group on Great Lakes Pollution from Land Use Activities of the International Joint Commission. U.S. EPA Contract No. 68-01-1598.

Sridharan, N. and G.F. Lee. 1974. Phosphorus Studies in Lower Green Bay, Lake Michigan. Journal Water Pollution Control Federation Vol. 46, No. 4.

Steuer, Jeffrey, Steve Jaeger, and Dale Patterson. 1995. A Deterministic PCB Transport Model for the Lower Fox River between Lake Winnebago and DePere, Wisconsin. Wisconsin Department of Natural Resources, PUBL WR 389-95.

Velleux, Mark and Douglas Endicott. 1994. Development of a Mass Balance Model for Estimating PCB Export from the Lower Fox River to Green Bay. J. Great Lakes Res. 20(2):416-434.

APPENDIX A

Estimation Of Phosphorus Loads To Green Bay

1.0 APPROACH FOR ESTIMATING PHOSPHORUS LOADS TO GREEN BAY

This section describes the approach used to estimate phosphorus loads to Green Bay from the Lower Fox River and other tributaries. The Lower Fox River carries the largest external load of phosphorus to the bay, so loads for the Lower Fox were first estimated, and then loads from other tributaries were scaled to the Fox River load.

2.0 HISTORICAL PHOSPHORUS LOADING ESTIMATES

2.1 Background

Several sources of phosphorus loading data are available in the literature, with an emphasis on loads from the Lower Fox River. Klump, Edgington, Sager and Robertson (1997) recently developed a phosphorus budget for Green Bay, and provide a useful compilation of historical phosphorus loading estimates from numerous sources. Other loading estimates are available in the literature, and they are based on different approaches, using various data sets, assumptions and methods of calculation. They were used in the current study as a reference to compare to computed estimates.

Initial estimates of phosphorus loading to Green Bay were made in the early 1970s, and at that time it was recognized that the Lower Fox River was the major contributor to the bay. Phosphorus loading from the Lower Fox River in the 1960s was estimated to be 1,206,000 kg/year (Sager & Wiersma, 1975), and 1,680,000 kg/year by Sridharan and Lee (1974). Sager and Wiersma (1975) estimated the load to be 2,200,000 kg/year, based on sampling from July, 1970 through October, 1971.

Approximately 50-75 % of this substantial nutrient loading was attributed to nonpoint sources, and the remaining originated from point sources in the basin, primarily municipal treatment plants (Sager and Wiersma, 1975 and IJC, 1978). Phosphorus control measures in the 1970s resulted in a reduction in P loads from municipal treatment plants by approximately 84% (Klump, et al., 1997). Roznowski and Auer estimated that for 1978-1982, the Lower Fox River contributed 793,242 kg/year. The 1993 estimate of P loading from the Lower Fox River is approximately 700,000-800,000 kg/year (Klump, et al., 1997 and WDNR, 1993), and only approximately 6% of this load is attributed to point sources (Roznowski and Auer, undated and Millard and Sager, 1994).

The dominance of nonpoint sources accounts for the strong relationship between river flow and mass loadings of phosphorus, and results in a high variability in mass loadings. This variability is reflected in the estimates of historical annualized mass loadings.

Table A.1 includes various estimates of historical phosphorus loadings from the Lower Fox River to Green Bay.

Table A.1 Estimation of Phosphorus Loads From Major Tributaries of Green Bay

	Fox River Load at Depere Computed with Ratio Estimator Method, kg/yr		Fox River Phosphorus Load Estimates from the Literature			Estimated P Loads for Other Tributaries		Tributary Load Estimates from the Literature	
Year	Estimated Load at Green Bay/Depere	Estimated Load at Mouth *	Value	Reference	Comments	(Menominee, Oconto, Peshtigo, Pensaukee, Duck, Ungaged)	Escanaba River	Value	Reference
1954	767,774	987,163				268,721	15,355		
1955	723,542	940,719				253,240	14,471		
1956	740,867	958,910				259,303	14,817		
1957	576,795	786,635				201,878	11,536		
1958	410,075	611,579				143,526	8,202		
1959	797,755	1,018,643				279,214	15,955		
1960	1,426,847	1,679,189	1,680,000	Sridharan & Lee, 1974	Estimate is for "Prior to 1972" Based on 1960s data	499,396	28,537		
1961	1,010,091	1,241,596				353,532	20,202		
1962	968,308	1,197,723				338,908	19,366		
1963	609,962	821,460				213,487	12,199		
1964	433,700	636,385				151,795	8,674		
1965	917,999	1,144,899				321,300	18,360		
1966	589,956	800,454				206,485	11,799		
1967	1,317,689	1,564,573				461,191	26,354		
1968	790,778	1,011,317				276,772	15,816		
1969	1,049,767	1,283,255				367,418	20,995		
1970	642,444	855,566	1,206,000	Sager & Wiersma, 1975	Estimate by Zar (1972)	224,855	12,849		
1971	520,298	727,313	2,200,000	Sager & Wiersma, 1975	Based on data collected July, 1970 - Oct, 1971	182,104	10,406		
1972	1,016,522	1,248,348	1,109,070	Sridharan & Lee, 1974	"Early 1970s" estimate	355,783	20,330		
1973	944,579	1,172,808	1,088,000	Auer, et al., 1983	Based on 1972 data	330,603	18,892	248,200	Auer, et al., 1983 **(1972 data)
1974	494,161	699,869				172,956	9,883		
1975	512,020	718,621	500,000	Sonzogni, et al., 1978	Based on 1975-76 data	179,207	10,240		
1976	524,839	599,061	520,000	Sonzogni, et al., 1978	Based on 1975-76 data	183,694	10,497		
1977	405,932	474,209				142,076	8,119		
1978	836,236	926,028	991,045	Roznowski & Auer, 1983		292,683	16,725	219,703	Roznowski & Auer, 1983 **
1979	885,857	978,130	971,844 529,000	Roznowski & Auer, 1983 Klump, 1997	1979-1980 data	310,050	17,717	427,817 187,000 (1979-1989)	Roznowski & Auer, 1983 ** Klump, et al., 1997
1980	825,302	914,547	684,810 793,242	Roznowski & Auer, 1983 Roznowski & Auer, 1983	1978-1982 mean	288,856	16,506	258,942 250,000 (1980)	Roznowski & Auer, 1983 ** Klump, et al., 1997
1981	447,867	518,240	452,567	Roznowski & Auer, 1983		156,753	8,957	271,525	Roznowski & Auer, 1983 **
1982	725,605	809,865	866,399	Roznowski & Auer, 1983		253,962	14,512	154,636	Roznowski & Auer, 1983 **
1983	566,120	642,406				198,142	11,322		
1984	683,862	766,035				239,352	13,677		
1985	643,529	723,685				225,235	12,871	250,000 (1975-1990)	Klump, et al., 1997
1986	763,116	849,252				267,091	15,262		
1987	266,328	327,624				93,215	5,327		
1988	240,783	300,802	432,000 395,000	Klump, et al., 1997 U.S EPA Mass Balance Study	U.S. EPA (MBS 1988-89 data)	84,274	4,816	165,000 (1988-1989) 171,000 (1989-1990)	EPA Mass Balance Study Klump, et al., 1997
1989	408,811	465,752	567,000 545,000	Klump, et al., 1997 U.S EPA Mass Balance Study	U.S. EPA (MBS 1988-89 data)	143,084	8,176	172,000 (1988-1989) 232,000 (1989-1990)	EPA Mass Balance Study Klump, et al., 1997
1990	440,776	499,315				154,272	8,816		
1991	426,945	484,792	545,000	Klump, et al., 1997	1982-1991 data	149,431	8,539		
1992	618,094	685,499				216,333	12,362		
1993	776,309	851,624	719,000	Klump, et al., 1997	WDNR, 1993	271,708	15,526		
1994	500,309	561,824				175,108	10,006		
1995	229,551	277,529				80,343	4,591		

1955 - 1976: loads estimated using Mason Street data (Green Bay)
1977 - 1995: loads estimated using Depere Dam data

* Computed as Depere Load + load from 7 point sources below Depere + East River load
** Computed loads from Menominee, Oconto and Peshtigo only

3.0 ESTIMATION OF LOWER FOX RIVER PHOSPHORUS LOADINGS

3.1 Approach Used to Compute Lower Fox River Phosphorus Loadings

Input loading rates from tributaries are generally quantified by measuring flow and concentration close to the river mouth, and then computing load as the product of flow and concentration over time. However, available water quality data are generally limited, and available only for discrete points in time. A variety of estimation approaches are available to address this problem, as summarized in Preston, et al. (1989).

Beale's Unstratified Ratio Estimator was used to calculate annual phosphorus loads. Beale's Unstratified Ratio Estimator calculates annual loads as the product of the total annual flow volume and the ratio of mean daily load and mean daily discharge (Preston, et al, 1992). The relationship of mean daily load to mean daily discharge can be applied to periods when only flow data are available to estimate annual loads.

3.2 Data Used to Compute Lower Fox River Phosphorus Loads

No long-term record of flow or phosphorus concentration exists near the mouth of the Lower Fox River. This is primarily due to a recognition of potential seiching effects at the mouth. WDNR maintained a monitoring station at Green Bay (Mason Street) from 1961-1976, before it was moved upstream to DePere to eliminate potential impacts due to seiching. The DePere monitoring station has operated from 1977 to the present. Because the Mason Street data provide the only long-term record of phosphorus in the Lower Fox in the 1960s and early 1970s, the data collected at Mason Street were used in the load estimations for the first half of the hindcast period, recognizing that the data were possibly impacted by the sampling location. Data were not adjusted for this station due to uncertainty about the extent to which seiching effects impacted the data. All available WDNR data for phosphorus from DePere Dam (station 053210) and Mason Street Bridge in Green Bay (station 053001) were retrieved from the STORET database.

A continuous record of streamflow measurements at Rapid Croche Dam at Wrightstown (USGS Station 04084500) exists for the hindcast period. To compute phosphorus loads, the flow over DePere Dam was estimated by multiplying the historical Wrightstown flow data by 1.017, the basin area ratio for DePere/Wrightstown (6110/6010 sq. mi.). The flow at the mouth of the Lower Fox was estimated by multiplying the historical Wrightstown flow data by 1.057, the basin area ratio for Green Bay (Mason Street)/Wrightstown (6350/6010 sq. mi.).

3.3 Estimation of Phosphorus Loads at the Mouth of the Lower Fox River

The loading estimates computed from DePere and Mason Street data do not include downstream point and nonpoint source loads. There are 7 point sources in the reach from DePere to the mouth, including the Green Bay Metropolitan Sewerage District's (GBMSD) plant at the mouth. Four of these point sources discharge below Mason Street. During the Green Bay Mass Balance Study (Bierman, et al., 1992), these 7 point sources contributed approximately 100 kg/day, or 36,500 kg/year to the Lower Fox. Approximately 65% of this load originated from the GBMSD plant. This is consistent with Roznowski and Auer's estimates of total annual loads from these 7 point source dischargers for each of the years from 1978-1982, ranging from 20,010-38,279 kg/year (Roznowski and Auer, undated).

This estimate is also consistent with WDNR's estimate (104 kg/day, or 37,960 kg/yr) of average increase in annualized loading between DePere and the mouth (Patterson, 1992). WDNR's estimate is based on a correlation using DePere data and summer loads measured by Sager. It is unclear whether Sager's data included impacts from the GBMSD plant at the mouth. However, the total additional loading between DePere and the mouth is small compared to current estimates of total phosphorus loadings from the Lower Fox to Green Bay (100 kg/day compared to approximately 2,200 kg/day, or less than 5%). Therefore, for the years 1989-1995, during which the GBMSD plant was discharging at approximately 0.3 mg/l total phosphorus, an assumption was made that an additional 100 kg/day phosphorus, or 36,500 kg/year, was added in the reach below DePere. For the years 1976-1988, it was estimated that point sources below DePere contributed 47,980 kg/yr to the Lower Fox, based on data collected by Roznowski and Auer (undated), and verbal information obtained from John Kennedy at GBMSD (approximately 30 mgd at 1 mg/l).

For the years 1954-1975, before point source phosphorus controls were in place, loadings in this lower reach were likely substantially higher. Phosphorus loads for the pulp and paper mills below DePere Dam were estimated using literature values for "typical" phosphorus concentrations along with flow data. Sager and Wiersma (1975) provide typical values of 2.4 mg/l for total phosphate and 0.38 mg/l for orthophosphate in pulp mill effluent. According to Sager and Wiersma, with flows ranging from 0.32 to 26.16 cfs, total phosphorus loads per plant ranged from 3 to 238 kg/day. Historical flow data were not available for the plants located below DePere, but current estimates of flow for each plant are reported by Bierman, et al. (1992). These flows were used to estimate historical loads, recognizing that historical flows may have been higher or lower than current flows. Resulting estimated loads ranged from 21 to 125 kg/day per plant. The phosphorus load from the Green Bay Metropolitan Sewer District Plant was estimated to be 69,000 kg/year, based on verbal information obtained from John Kennedy at GBMSD for operating conditions from 1954-1975 (approximately 10 mgd at 4-6 mg/l). The resulting total annual phosphorus load from the 7 dischargers for 1954-1975 is estimated to be 181,000 kg/year.

The only tributary discharging into the reach below DePere is the East River. Hughes (1993) estimated that phosphorus loading from this watershed is approximately 75 tonnes/year (75,000 kg/yr), based on 1986 monitoring data. However, 1986 was an unusually wet year, and average long-term values are likely lower (Klump, et al., 1997). Hughes' estimate is approximately 10% of the estimated phosphorus load at DePere in 1986 (which does not include the major point source dischargers below DePere). Other sources indicate that the East River is a less significant source of phosphorus. Roznowski and Auer (undated) determined that the East River contribution is insignificant when compared to the Lower Fox River total load to Green Bay. For the current study, phosphorus loadings from the East River were estimated at 5 % of the estimated load at DePere for any given year.

4.0 PHOSPHORUS LOADINGS FROM OTHER TRIBUTARIES

Estimates of P loads in the 1980s and 1990s from other tributaries contributing to southern Green Bay (Duck, Oconto, Peshtigo, Pensaukee, Menominee and ungaged flow) are available in the literature. Klump, et al. presents estimates of loadings from these tributaries for several time periods from 1975-1990. Estimates of the total phosphorus loading contribution from these tributaries ranged from 165,000 to 250,000 kg/year.

It was assumed for this study that loads from these tributaries vary proportionally to Lower Fox River loads. Historical loading estimates for the 1980s and 1990s indicate that these tributaries contribute in proportion to approximately 30-40% of the Lower Fox River load (Klump, et al., 1997). For purposes of this study, it was assumed that these tributaries contribute 35% of the Lower Fox River load for any given year. Several of these tributaries are largely undeveloped and have historically been dominated by nonpoint sources, as compared to the Lower Fox, which was dominated by point sources until controls reduced these loads. In order to lessen the impact of point sources on scaling, the load from the other tributaries was estimated as 35% of the load at DePere. This differs very little from 35% of the total Lower Fox River load for recent years, because of the relative insignificance of loadings between DePere and the mouth for those years, and it avoids confounding the estimates with higher point-source loadings for this reach in earlier years.

Loadings from the Escanaba River to northern Green Bay were also input to the Eutrophication model by similarly scaling to Lower Fox River loads. Current estimates of loadings are 15,700 kg/year, or approximately 2 % of the Lower Fox River load (Klump, et al., 1997).

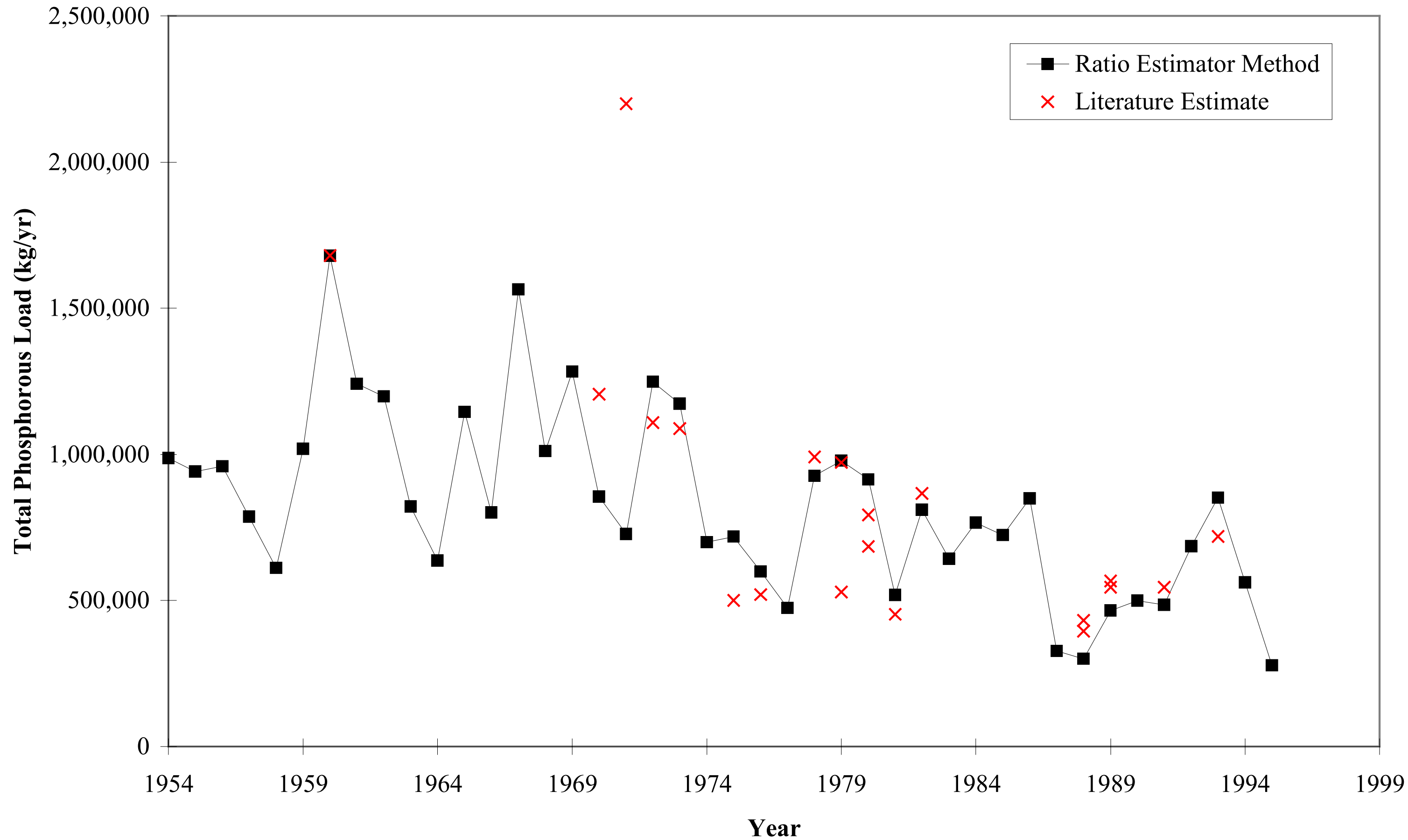
5.0 RESULTS OF PHOSPHORUS LOADING ESTIMATES

Computed annual loadings for the years 1954-1995 are presented in Table A.1. The results indicate that the Lower Fox River contributes approximately 78% of the phosphorus load to Green Bay in any given year. This is consistent with the findings of Roznowski and Auer (undated) and Klump, et al. (1997).

Computed loads were compared to available estimates of loadings from various sources (Table A.1 and Figure A.1). In general, the calculated loads compared favorably with the loads estimated by other parties. The one exception is the large load estimated by Sager and Wiersma, based on 1970-1971 data (2,200,000 kg/yr). This estimated load is approximately double other estimates of loadings reported in the literature for that time period, and approximately four times the loads estimated for 1970 and 1971 in the current study. The reason for the difference is unknown, but it may be accounted for by different estimation methods, assumptions and data sets.

Figure A-1

Estimation and Comparison of Phosphorous Loads from the Lower Fox River to Green Bay



APPENDIX B

A Simplified Primary Productivity Model For Estimating Internal Solids Production

Primary productivity in aquatic systems is a function of temperature, light, and nutrients. Models for primary productivity are widely used and appear often in the scientific literature in textbooks (Thomann & Mueller, 1987), journal articles (Auer & Canale, 1986) and the Water Quality Analysis Simulation Program (WASP5) Model Documentation (Ambrose, et al., 1993). These types of models are commonly incorporated into contemporary water quality models as primary productivity submodels (e.g. WASP5). This appendix describes a simplified model for primary productivity, which may be used as an approach to estimate internal solids loads in the Lower Fox River for the hindcast period.

The rate of primary productivity is limited by temperature (T), light (L), and nutrients (N):

$$\left(\frac{dC}{dt}\right)_{ppr} = \mu_{max} \cdot f(T) \cdot f(L) \cdot f(N) \cdot (0.80) \cdot C$$

$$f(T) = 1.07^{(T-20)} \qquad f(L) = \left(\frac{2.718 \cdot PHOTO}{K_e \cdot H}\right) \cdot \left[e^{-\alpha_1} - e^{-\alpha_0}\right] \qquad f(N) = \text{minimum}\left(\frac{P}{P+K_P}, \frac{N}{N+K_N}\right)$$

$$\alpha_0 = \frac{I_0}{I_{sat}} \qquad \alpha_1 = (\alpha_0) \cdot e^{-(K_e \cdot H)}$$

$I_o = I_T / PHOTO$

where:

C = ug chl *a*/liter

μ_{max} = maximum growth rate of phytoplankton

T = temperature (degrees Celsius)

0.80 = fraction of primary productivity to particulate organic carbon (POC); remainder to dissolved organic carbon (DOC) exudation (Bierman, et al., 1992)

PHOTO = photoperiod (dimensionless)

K_e = light extinction coefficient

H = water column depth, meters

I_o/I_{sat} = Incident solar radiation/saturation light intensity

P = soluble reactive phosphorous (SRP) concentration

K_P = Michaelis half-saturation constant for phosphorous

N = dissolved inorganic nitrogen (DIN) concentration

K_N = Michaelis half-saturation constant for nitrogen

Conversion: 0.075 mg BSS/ug chl *a* (Bierman, et al., 1992)

Field Data Needs:

Chlorophyll-a

Water column depth, volume, and temperature

Secchi depth

SRP and DIN

References:

Auer, Martin T. and R.P. Canale. 1986. Mathematical Modeling of Primary Production in Green Bay (Lake Michigan, USA), a Phosphorus and Light-Limited System. Hydrobiological Bulletin 20 (1/2):195-211.

Thomann, R.V. and J.A. Mueller, 1987. *Principles of Surface Water Quality Modeling and Control*. Harper & Row Publishers, New York, New York.

U.S. Environmental Protection Agency (EPA), 1993. *The Water Quality Analysis Simulation Program, WASP5 - Part A: Model Documentation*. Environmental Research Laboratory, Office of Research and Development, Athens, Georgia.

APPENDIX C

APPLICATION OF ALTERNATIVE RECOMMENDED APPROACHES

Table LF1. Application of Simplified Primary Productivity Model to the Lower Fox River for 1989.

Lower Fox River Productivity Model

Constants:

u max	=	2.5	per day	Task 2c Bay model calibration
Isat	=	100	langleys/day	GBEUTRO model input set
Kp	=	2.0	ug P/l	U.S. EPA, 1993
Kn	=	20.0	ug N/l	U.S. EPA, 1993
theta T	=	1.07		
fraction POC	=	0.8		Bierman, et al., 1992
carbon to chlorophyl ratio	=	30	g carbon/g Chl-a	Bierman, et al., 1992
biotic solids conversion	=	0.4	g carbon/g BSS	Bierman, et al., 1992

Variables:

Io	langleys/day	GBEUTRO model input set - 1989
PHOTO	fraction of day	GBEUTRO model input set

Data:

All data from project database from 1989.
Secchi and chlorophyll-a data missing values replace from 1988 or 1990.
SRP, DIN, and temperature values for missing months were interpolated.

Lower Fox River, Lake Winnebago to DePere

segment volume = 33,240,214 cubic meters WDNR (1995)
depth = 2.01 meters WDNR (1995)

Month	temp. (deg. C)	f(T)	Secchi	Ke	Io	PHOTO	f(L)	f(N)	alpha0	alpha1	Chl-a (ug/L)	SRP (ug P/L)	DIN (ug N/L)	P ratio	N ratio	dC/dt (ug Chl-a/L/day)	V*dC/dt (kg BSS/day)	mass BSS (kg)
1	**1.0**	**0.28**	**2.55**	**0.75**	**148**	**0.38**	**0.275**	**0.79**	**3.89**	**0.8657**	**9**	**7.5**	**205**	**0.79**	**0.91**	**1.08**	**2,690**	**83,401**
2	**3.5**	**0.33**	**2.85**	**0.69**	**266**	**0.42**	**0.172**	**0.95**	**6.28**	**1.5607**	**5**	**36.9**	**569**	**0.95**	**0.97**	**0.53**	**1,328**	**37,510**
3	**5.9**	**0.39**	**0.92**	**1.67**	**306**	**0.47**	**0.305**	**0.97**	**6.47**	**0.2260**	**10**	**66.3**	**933**	**0.97**	**0.98**	**2.28**	**5,696**	**176,582**
4	**6.1**	**0.39**	**0.77**	**1.95**	**369**	**0.54**	**0.330**	**0.63**	**6.78**	**0.1347**	**28**	**3.3**	**372**	**0.63**	**0.95**	**4.50**	**11,218**	**336,550**
5	**15.5**	**0.74**	**0.60**	**2.44**	**532**	**0.62**	**0.321**	**0.69**	**8.62**	**0.0642**	**36**	**4.4**	**275**	**0.69**	**0.93**	**11.73**	**29,244**	**906,563**
6	**20.9**	**1.06**	**0.61**	**2.40**	**660**	**0.65**	**0.337**	**0.83**	**10.17**	**0.0815**	**35**	**9.5**	**282**	**0.83**	**0.93**	**20.69**	**51,571**	**1,547,120**
7	**26.5**	**1.55**	**0.43**	**3.31**	**631**	**0.63**	**0.255**	**0.70**	**9.97**	**0.0128**	**112**	**4.6**	**115**	**0.70**	**0.85**	**61.90**	**154,322**	**4,783,968**
8	**18.0**	**0.87**	**0.42**	**3.38**	**553**	**0.58**	**0.231**	**0.77**	**9.47**	**0.0105**	**107**	**6.8**	**80**	**0.77**	**0.80**	**33.27**	**82,945**	**2,571,297**
9	**19.3**	**0.95**	**0.53**	**2.73**	**490**	**0.52**	**0.245**	**0.83**	**9.51**	**0.0394**	**67**	**55.7**	**97**	**0.97**	**0.83**	**25.98**	**64,773**	**1,943,188**
10	**12.2**	**0.59**	**0.56**	**2.60**	**318**	**0.44**	**0.223**	**0.76**	**7.15**	**0.0388**	**68**	**6.3**	**151**	**0.76**	**0.88**	**13.54**	**33,760**	**1,046,565**
11	**6.4**	**0.40**	**0.54**	**2.68**	**147**	**0.39**	**0.189**	**0.83**	**3.76**	**0.0171**	**55**	**9.6**	**192**	**0.83**	**0.91**	**6.84**	**17,050**	**511,513**
12	**0.6**	**0.27**	**0.75**	**2.00**	**112**	**0.37**	**0.224**	**0.87**	**3.04**	**0.0550**	**18**	**13.4**	**278**	**0.87**	**0.93**	**1.89**	**4,701**	**145,719**
																annual	**38,275**	**14,089,976**
																summer	**88,403**	**10,845,572**

Lower Fox River, DePere to mouth

segment volume = 18,981,500 cubic meters Lower Fox River Model input sets
depth = 4.51 meters Lower Fox River Model input sets

Month	temp. (deg. C)	f(T)	Secchi	Ke	Io	PHOTO	f(L)	f(N)	alpha0	alpha1	Chl-a (ug/L)	SRP (ug P/L)	DIN (ug N/L)	P ratio	N ratio	dC/dt (ug Chl-a/L/day)	V*dC/dt (kg BSS/day)	mass BSS (kg)
1	**0.4**	**0.27**	**1.45**	**1.14**	**148**	**0.38**	**0.192**	**0.85**	**3.89**	**0.0225**	**7**	**11.5**	**270**	**0.85**	**0.93**	**0.61**	**864**	**26,772**
2	**3.4**	**0.33**	**1.78**	**0.97**	**266**	**0.42**	**0.242**	**0.81**	**6.28**	**0.0782**	**4**	**8.7**	**341**	**0.81**	**0.94**	**0.51**	**729**	**20,587**
3	**6.4**	**0.40**	**0.86**	**1.77**	**306**	**0.47**	**0.160**	**0.75**	**6.47**	**0.0022**	**11**	**6.0**	**412**	**0.75**	**0.95**	**1.05**	**1,497**	**46,395**
4	**9.4**	**0.49**	**0.57**	**2.55**	**369**	**0.54**	**0.128**	**0.62**	**6.78**	**0.0001**	**49**	**3.2**	**484**	**0.62**	**0.96**	**3.77**	**5,368**	**161,041**
5	**16.0**	**0.76**	**1.41**	**1.17**	**532**	**0.62**	**0.305**	**0.78**	**8.62**	**0.0444**	**48**	**7.0**	**546**	**0.78**	**0.96**	**17.32**	**24,655**	**764,320**
6	**21.1**	**1.08**	**1.18**	**1.35**	**660**	**0.65**	**0.283**	**0.80**	**10.17**	**0.0229**	**38**	**7.9**	**361**	**0.80**	**0.95**	**18.47**	**26,288**	**788,649**
7	**25.1**	**1.41**	**0.33**	**4.25**	**631**	**0.63**	**0.090**	**0.75**	**9.97**	**0.0000**	**113**	**6.2**	**263**	**0.75**	**0.93**	**21.59**	**30,731**	**952,646**
8	**23.6**	**1.27**	**0.30**	**4.65**	**553**	**0.58**	**0.076**	**0.81**	**9.47**	**0.0000**	**118**	**8.4**	**105**	**0.81**	**0.84**	**18.37**	**26,156**	**810,844**
9	**19.4**	**0.96**	**0.36**	**3.91**	**490**	**0.52**	**0.079**	**0.78**	**9.51**	**0.0000**	**93**	**7.3**	**160**	**0.78**	**0.89**	**11.08**	**15,769**	**473,061**
10	**12.0**	**0.58**	**0.33**	**4.25**	**318**	**0.44**	**0.063**	**0.76**	**7.15**	**0.0000**	**95**	**6.2**	**343**	**0.76**	**0.94**	**5.26**	**7,492**	**232,263**
11	**7.5**	**0.43**	**0.37**	**3.81**	**147**	**0.39**	**0.060**	**0.75**	**3.76**	**0.0000**	**62**	**5.9**	**335**	**0.75**	**0.94**	**2.40**	**3,413**	**102,403**
12	**0.7**	**0.27**	**0.70**	**2.12**	**112**	**0.37**	**0.099**	**0.88**	**3.04**	**0.0002**	**42**	**14.5**	**305**	**0.88**	**0.94**	**1.99**	**2,833**	**87,823**
																annual	**12,150**	**4,466,804**
																summer	**24,736**	**3,025,200**

Table LF2. Application of Simplified Primary Productivity Model to the Lower Fox River for 1989 Assuming No Nutrient Limitation.

Lower Fox River Productivity Model

Constants:

u max	=	2.5	per day	Task 2c Bay model calibration
Isat	=	100	langleys/day	GBEUTRO model input set
Kp	=	1.0	ug P/l	U.S. EPA, 1993
Kn	=	25.0	ug N/l	U.S. EPA, 1993
theta T	=	1.07		
fraction POC	=	0.8		Bierman, et al., 1992
carbon to chlorophyl ratio	=	30	g carbon/g Chl-a	Bierman, et al., 1992
biotic solids conversion	=	0.4	g carbon/g BSS	Bierman, et al., 1992

Variables:

Io	langleys/day	GBEUTRO model input set - 1989
PHOTO	fraction of day	GBEUTRO model input set

Data:

All data from project database from 1989.
Secchi and chlorophyll-a data missing values replace from 1988 or 1990.
Temperature values for missing months were interpolated.

Lower Fox River, Lake Winnebago to DePere

segment volume	=	33,240,214	cubic meters	WDNR (1995)
depth	=	2.01	meters	WDNR (1995)

Month	temp. (deg. C)	f(T)	Secchi	Ke	Io	PHOTO	f(L)	f(N)	alpha0	alpha1	Chl-a (ug/L)	SRP (ug P/L)	DIN (ug N/L)	P ratio	N ratio	dC/dt (ug Chl-a/L/day)	V*dC/dt (kg BSS/day)	mass BSS (kg)
1	1.0	0.28	2.55	0.75	148	0.38	0.275	1	3.89	0.8657	9			0.00	0.00	1.37	3,408	105,641
2	3.5	0.33	2.85	0.69	266	0.42	0.172	1	6.28	1.5607	5			0.00	0.00	0.56	1,400	39,543
3	5.9	0.39	0.92	1.67	306	0.47	0.305	1	6.47	0.2260	10			0.00	0.00	2.35	5,868	181,906
4	6.1	0.39	0.77	1.95	369	0.54	0.330	1	6.78	0.1347	28			0.00	0.00	7.20	17,949	538,480
5	15.5	0.74	0.60	2.44	532	0.62	0.321	1	8.62	0.0642	36			0.00	0.00	17.05	42,501	1,317,538
6	20.9	1.06	0.61	2.40	660	0.65	0.337	1	10.17	0.0815	35			0.00	0.00	25.05	62,455	1,873,648
7	26.5	1.55	0.43	3.31	631	0.63	0.255	1	9.97	0.0128	112			0.00	0.00	88.67	221,055	6,852,711
8	18.0	0.87	0.42	3.38	553	0.58	0.231	1	9.47	0.0105	107			0.00	0.00	43.06	107,341	3,327,560
9	19.3	0.95	0.53	2.73	490	0.52	0.245	1	9.51	0.0394	67			0.00	0.00	31.35	78,145	2,344,362
10	12.2	0.59	0.56	2.60	318	0.44	0.223	1	7.15	0.0388	68			0.00	0.00	17.83	44,456	1,378,150
11	6.4	0.40	0.54	2.68	147	0.39	0.189	1	3.76	0.0171	55			0.00	0.00	8.26	20,597	617,908
12	0.6	0.27	0.75	2.00	112	0.37	0.224	1	3.04	0.0550	18			0.00	0.00	2.17	5,400	167,396
																annual	**50,881**	**18,744,843**
																summer	**117,249**	**14,398,281**

Lower Fox River, DePere to mouth

segment volume	=	18,981,500	cubic meters	Lower Fox River Model input sets
depth	=	4.51	meters	Lower Fox River Model input sets

Month	temp. (deg. C)	f(T)	Secchi	Ke	Io	PHOTO	f(L)	f(N)	alpha0	alpha1	Chl-a (ug/L)	SRP (ug P/L)	DIN (ug N/L)	P ratio	N ratio	dC/dt (ug Chl-a/L/day)	V*dC/dt (kg BSS/day)	mass BSS (kg)
1	0.4	0.27	1.45	1.14	148	0.38	0.192	1	3.89	0.0225	7			0.00	0.00	0.71	1,014	31,428
2	3.4	0.33	1.78	0.97	266	0.42	0.242	1	6.28	0.0782	4			0.00	0.00	0.63	896	25,301
3	6.4	0.40	0.86	1.77	306	0.47	0.160	1	6.47	0.0022	11			0.00	0.00	1.40	1,998	61,947
4	9.4	0.49	0.57	2.55	369	0.54	0.128	1	6.78	0.0001	49			0.00	0.00	6.13	8,723	261,691
5	16.0	0.76	1.41	1.17	532	0.62	0.305	1	8.62	0.0444	48			0.00	0.00	22.27	31,700	982,697
6	21.1	1.08	1.18	1.35	660	0.65	0.283	1	10.17	0.0229	38			0.00	0.00	23.14	32,936	988,078
7	25.1	1.41	0.33	4.25	631	0.63	0.090	1	9.97	0.0000	113			0.00	0.00	28.60	40,720	1,262,322
8	23.6	1.27	0.30	4.65	553	0.58	0.076	1	9.47	0.0000	118			0.00	0.00	22.76	32,403	1,004,479
9	19.4	0.96	0.36	3.91	490	0.52	0.079	1	9.51	0.0000	93			0.00	0.00	14.13	20,109	603,261
10	12.0	0.58	0.33	4.25	318	0.44	0.063	1	7.15	0.0000	95			0.00	0.00	6.97	9,919	307,503
11	7.5	0.43	0.37	3.81	147	0.39	0.060	1	3.76	0.0000	62			0.00	0.00	3.20	4,561	136,832
12	0.7	0.27	0.70	2.12	112	0.37	0.099	1	3.04	0.0002	42			0.00	0.00	2.26	3,224	99,936
																annual	**15,684**	**5,765,475**
																summer	**31,542**	**3,858,139**

Table LF3
Estimation of Internal Biotic Suspendend Solids Loads from the Lower Fox River

	TP Load Scaling Factor (load for year/1989 load)		Scaled BSS Loads (kg/yr)	
Year	At DePere	At Fox River mouth	LFR above DePere	LFR below DePere
1954	1.88	2.12	18,744,843	5,765,475
1955	1.77	2.02	18,744,843	5,765,475
1956	1.81	2.06	18,744,843	5,765,475
1957	1.41	1.69	18,744,843	5,765,475
1958	1.00	1.31	14,133,540	5,765,475
1959	1.95	2.19	18,744,843	5,765,475
1960	3.49	3.61	18,744,843	5,765,475
1961	2.47	2.67	18,744,843	5,765,475
1962	2.37	2.57	18,744,843	5,765,475
1963	1.49	1.76	18,744,843	5,765,475
1964	1.06	1.37	14,947,794	5,765,475
1965	2.25	2.46	18,744,843	5,765,475
1966	1.44	1.72	18,744,843	5,765,475
1967	3.22	3.36	18,744,843	5,765,475
1968	1.93	2.17	18,744,843	5,765,475
1969	2.57	2.76	18,744,843	5,765,475
1970	1.57	1.84	18,744,843	5,765,475
1971	1.27	1.56	17,932,458	5,765,475
1972	2.49	2.68	18,744,843	5,765,475
1973	2.31	2.52	18,744,843	5,765,475
1974	1.21	1.50	17,031,627	5,765,475
1975	1.25	1.54	17,647,151	5,765,475
1976	1.28	1.29	18,088,967	5,745,312
1977	0.99	1.02	13,990,749	4,547,912
1978	2.05	1.99	18,744,843	5,765,475
1979	2.17	2.10	18,744,843	5,765,475
1980	2.02	1.96	18,744,843	5,765,475
1981	1.10	1.11	15,436,070	4,970,199
1982	1.77	1.74	18,744,843	5,765,475
1983	1.38	1.38	18,744,843	5,765,475
1984	1.67	1.64	18,744,843	5,765,475
1985	1.57	1.55	18,744,843	5,765,475
1986	1.87	1.82	18,744,843	5,765,475
1987	0.65	0.70	9,179,193	3,142,092
1988	0.59	0.65	8,298,765	2,884,851
1989	1.00	1.00	14,089,976	4,466,804
1990	1.08	1.07	15,191,673	4,788,693
1991	1.04	1.04	14,714,977	4,649,414
1992	1.51	1.47	18,744,843	5,765,475
1993	1.90	1.83	18,744,843	5,765,475
1994	1.22	1.21	17,243,522	5,388,194
1995	0.56	0.60	7,911,646	2,661,646

		1989 load assuming no nutrient limitation:	18,744,843	5,765,475

BSS loads were scaled by total phosphorus loads using 1989 TP loads and 1989 modeled BSS loads as a baseline. Scaled BSS loads were not allowed to exceed loads modeled with no nutrient limitation.

Table GB1.
Monthly averaged VWA output and environmental forcing conditions for 1982 Green Bay data for use in SPP model and empirical calculations to estimate internal solids loads.

Notes:

1. VWA processed 1982 data for each Green Bay model segment were averaged by month for May through September for most parameters. Gross primary production data were available only for June through September
2. Estimates of VWA processed parameters for months with no data during 1982 were developed as follows:
   a. Gross Primary Production (GROSP) estimated as the average of the June through September monthly values for each segment since these are based on measurements taken under controlled incident light (200 uE/m^2/sec) and water temperature (20 ^oC) conditions.
   b. Abiotic suspended solids (ASS) and soluble reactive phosphorus (SRP) concentrations were estimated as the average of the May through September monthly values for each segment.
   c. Chlorophyll *a* (Chl-a) concentrations were estimated based the average of the May through September levels and then adjusted for temperature and light conditions, as follows:

$$\text{Chl-a} = \text{Chla}_{ave} * (q_T^{(T-20)} / q_T^{(Tave-20)}) * (\text{Ia} / \text{Ia}_{ave})$$

where

Chla_{ave} = May through September average Chl-a concentration for each segment (ug Chl-a/L)

q_T = Temperature correction factor for algal growth, Theta_T (dimensionless)

T_{ave} = May through September average water temperature for each segment (^oC)

Ia_{ave} = May through September average photoperiod incident solar radiation for each segment (Ly/day)

Note: $\text{Ia} = I_T / \text{PHOTO}$

   d. Light extinction (K_e) values for 1982 (used to represent the 1972-1995 light "domain") were estimated for months with no data by applying the following multiple linear regression which was developed based measured Ke, Chl-a, and ASS (18 matched records, R^2=0.94)

$$K_e = 0.363524 + 0.104754 * \text{ASS} + 0.101974 * \text{Chl-a}_{d.w.}$$

$$\text{Chl-a}_{d.w.} = \text{Chl-a} / 1000 * \text{CCHL} * 2.0 = \text{algal dry weight concentration}$$

3. Pre-1972 light "domain" Ke estimates are based on assessment of Secchi Disk depth data collected in four regions of Green Bay: Fox River mouth/Inner Bay (Segment 1), Inner Bay (Segments 2-6), Middle Bay (Segments 7 and 8), and Outer Bay (Segment 9). The following relationship between Secchi depth and light extinction, developed from 1982 data, is used to develop the correction to pre-1972 conditions.

$$K_e = 1.326 / SD + 0.2275 \qquad [\, R^2 = 0.88 \text{ and } N = 18 \,]$$

where SD = Secchi Depth (meters)

Analysis of existing data indicates differences in Secchi depths between these periods are either insignificant, or a result of limited available pre-1972 data.

Table GB1.
Monthly averaged VWA output and environmental forcing conditions for 1982 Green Bay Data for use in SPP model and empirical calculations to estimate internal solids loads.

Green Bay Segment	Month	1982 Processed VWA Output								1982 Environmental Forcing Conditions				Geometry for 1982		Conversion of 1982 K_e to pre-1972 Conditions	
		GROSP @ 20°C	RESP @ 20°C	Chl-a (ug/L)	ASS (mg/L)	BSS (mg/L)	TSS (mg/L)	SRP (ug/L)	K_e (m^{-1})	Temp (deg. C)	I_0 (Ly/day)	Photo (--)	I_a (Ly/day)	Volume (m^3)	Depth (m)	Secchi ratio <1972 vs. 1972-1995	$Ke_{pre-1972}$ (m^{-1})
1																	
	1	**9.88**	**2.72**	**6.12**	**15.58**			**11.19**	**2.03**	2.03	118.8	0.38	313.25	1.195E+08	2.72	1.00	2.03
	2	**9.88**	**2.72**	**8.57**	**15.58**			**11.19**	**2.05**	2.20	183.6	0.42	434.04	1.195E+08	2.72	1.00	2.05
	3	**9.88**	**2.72**	**8.79**	**15.58**			**11.19**	**2.05**	3.25	196.0	0.47	414.81	1.195E+08	2.72	1.00	2.05
	4	**9.88**	**2.72**	**17.58**	**15.58**			**11.19**	**2.10**	7.50	338.8	0.54	622.13	1.195E+08	2.72	1.00	2.10
	5	**9.88**	**2.72**	11.63	6.06	1.74	7.81	4.88	2.44	15.30	353.0	0.62	571.56	1.195E+08	2.72	1.00	2.44
	6	6.51	2.42	36.29	14.63	5.44	20.00	6.69	1.73	19.58	545.5	0.65	839.80	1.195E+08	2.72	1.00	1.73
	7	10.14	2.48	70.66	14.76	10.60	26.85	11.35	3.82	25.20	600.8	0.63	949.84	1.195E+08	2.72	1.00	3.82
	8	12.13	2.81	81.72	24.18	12.26	36.44	19.58	5.04	23.30	553.4	0.58	948.35	1.195E+08	2.72	1.00	5.04
	9	10.75	3.19	77.06	18.28	11.56	29.84	13.42	4.45	17.43	441.5	0.52	857.28	1.195E+08	2.72	1.00	4.45
	10	**9.88**	**2.72**	**18.97**	**15.58**			**11.19**	**2.11**	9.70	257.2	0.44	578.52	1.195E+08	2.72	1.00	2.11
	11	**9.88**	**2.72**	**5.96**	**15.58**			**11.19**	**2.03**	2.40	116.4	0.39	297.57	1.195E+08	2.72	1.00	2.03
	12	**9.88**	**2.72**	**4.62**	**15.58**			**11.19**	**2.02**	2.07	86.8	0.37	235.87	1.195E+08	2.72	1.00	2.02

Green Bay Segment	Month	1982 Processed VWA Output								1982 Environmental Forcing Conditions				Geometry for 1982		Conversion of 1982 K_e to pre-1972 Conditions	
		GROSP @ 20°C	RESP @ 20°C	Chl-a (ug/L)	ASS (mg/L)	BSS (mg/L)	TSS (mg/L)	SRP (ug/L)	K_e (1/meter)	Temp (deg. C)	I_T (Ly/day)	Photo (--)	I_a (Ly/day)	Volume (m^3)	Depth (m)	Secchi ratio <1972 vs. 1972-1995	$Ke_{pre-1972}$ (m^{-1})
2																	
	1	**6.52**	**2.01**	**4.81**	**11.25**			**8.86**	**1.57**	2.03	118.8	0.38	313.25	1.732E+08	4.33	1.00	1.57
	2	**6.52**	**2.01**	**6.74**	**11.25**			**8.86**	**1.58**	2.20	183.6	0.42	434.04	1.732E+08	4.33	1.00	1.58
	3	**6.52**	**2.01**	**6.69**	**11.25**			**8.86**	**1.58**	2.75	196.0	0.47	414.81	1.732E+08	4.33	1.00	1.58
	4	**6.52**	**2.01**	**12.29**	**11.25**			**8.86**	**1.62**	5.75	338.8	0.54	622.13	1.732E+08	4.33	1.00	1.62
	5	**6.52**	**2.01**	8.49	4.68	1.27	5.95	3.19	**0.91**	13.93	353.0	0.62	571.56	1.732E+08	4.33	1.00	0.91
	6	3.32	1.45	26.65	11.50	4.00	15.40	5.28	**1.73**	19.03	545.5	0.65	839.80	1.732E+08	4.33	1.00	1.73
	7	7.08	2.28	44.26	8.87	6.64	15.73	7.12	**1.56**	23.38	600.8	0.63	949.84	1.732E+08	4.33	1.00	1.56
	8	7.74	2.01	63.67	15.04	9.55	24.59	15.56	**2.33**	22.60	553.4	0.58	948.35	1.732E+08	4.33	1.00	2.33
	9	7.93	2.30	62.28	16.14	9.34	25.48	13.17	**2.44**	17.37	441.5	0.52	857.28	1.732E+08	4.33	1.00	2.44
	10	**6.52**	**2.01**	**14.78**	**11.25**			**8.86**	**1.63**	9.55	257.2	0.44	578.52	1.732E+08	4.33	1.00	1.63
	11	**6.52**	**2.01**	**4.69**	**11.25**			**8.86**	**1.57**	2.40	116.4	0.39	297.57	1.732E+08	4.33	1.00	1.57
	12	**6.52**	**2.01**	**3.63**	**11.25**			**8.86**	**1.56**	2.07	86.8	0.37	235.87	1.732E+08	4.33	1.00	1.56

Table GB1.
Monthly averaged VWA output and environmental forcing conditions for 1982 Green Bay Data for use in SPP model and empirical calculations to estimate internal solids loads.

Green Bay Segment	Month	1982 Processed VWA Output								1982 Environmental Forcing Conditions				Geometry for 1982		Conversion of 1982 K_e to pre-1972 Conditions	
		GROSP @ 20°C	RESP @ 20°C	Chl-a (ug/L)	ASS (mg/L)	BSS (mg/L)	TSS (mg/L)	SRP (ug/L)	K_e (1/meter)	Temp (deg. C)	I_T (Ly/day)	Photo (--)	I_a (Ly/day)	Volume (m^3)	Depth (m)	Secchi ratio <1972 vs. 1972-1995	$Ke_{pre-1972}$ (m^{-1})
3																	
	1	**7.27**	**2.35**	**5.58**	**12.25**			**9.05**	**1.68**	2.03	118.8	0.38	313.25	9.931E+07	4.14	1.00	1.68
	2	**7.27**	**2.35**	**7.83**	**12.25**			**9.05**	**1.69**	2.20	183.6	0.42	434.04	9.931E+07	4.14	1.00	1.69
	3	**7.27**	**2.35**	**7.76**	**12.25**			**9.05**	**1.69**	2.75	196.0	0.47	414.81	9.931E+07	4.14	1.00	1.69
	4	**7.27**	**2.35**	**14.26**	**12.25**			**9.05**	**1.73**	5.75	338.8	0.54	622.13	9.931E+07	4.14	1.00	1.73
	5	**7.27**	**2.35**	12.42	6.51	1.86	8.37	4.46	1.98	13.93	353.0	0.62	571.56	9.931E+07	4.14	1.00	1.98
	6	3.00	1.34	27.15	12.30	4.07	16.16	5.38	1.85	19.03	545.5	0.65	839.80	9.931E+07	4.14	1.00	1.85
	7	10.56	3.82	60.73	10.83	9.11	19.95	6.73	2.41	23.38	600.8	0.63	949.84	9.931E+07	4.14	1.00	2.41
	8	8.23	2.16	70.94	15.16	10.64	25.81	15.41	3.65	22.60	553.4	0.58	948.35	9.931E+07	4.14	1.00	3.65
	9	7.28	2.09	67.04	16.46	10.06	26.51	13.26	4.48	17.37	441.5	0.52	857.28	9.931E+07	4.14	1.00	4.48
	10	**7.27**	**2.35**	**17.15**	**12.25**			**9.05**	**1.75**	9.55	257.2	0.44	578.52	9.931E+07	4.14	1.00	1.75
	11	**7.27**	**2.35**	**5.44**	**12.25**			**9.05**	**1.68**	2.40	116.4	0.39	297.57	9.931E+07	4.14	1.00	1.68
	12	**7.27**	**2.35**	**4.21**	**12.25**			**9.05**	**1.67**	2.07	86.8	0.37	235.87	9.931E+07	4.14	1.00	1.67

Green Bay Segment	Month	1982 Processed VWA Output								1982 Environmental Forcing Conditions				Geometry for 1982		Conversion of 1982 K_e to pre-1972 Conditions	
		GROSP @ 20°C	RESP @ 20°C	Chl-a (ug/L)	ASS (mg/L)	BSS (mg/L)	TSS (mg/L)	SRP (ug/L)	K_e (1/meter)	Temp (deg. C)	I_T (Ly/day)	Photo (--)	I_a (Ly/day)	Volume (m^3)	Depth (m)	Secchi ratio <1972 vs. 1972-1995	$Ke_{pre-1972}$ (m^{-1})
4																	
	1	**2.81**	**1.02**	**2.33**	**6.43**			**4.95**	**1.05**	2.03	118.8	0.38	313.25	1.011E+09	6.32	1.00	1.05
	2	**2.81**	**1.02**	**3.26**	**6.43**			**4.95**	**1.06**	2.20	183.6	0.42	434.04	1.011E+09	6.32	1.00	1.06
	3	**2.81**	**1.02**	**3.20**	**6.43**			**4.95**	**1.06**	2.60	196.0	0.47	414.81	1.011E+09	6.32	1.00	1.06
	4	**2.81**	**1.02**	**5.69**	**6.43**			**4.95**	**1.07**	5.10	338.8	0.54	622.13	1.011E+09	6.32	1.00	1.07
	5	**2.81**	**1.02**	7.38	2.18	1.11	3.29	1.87	**0.64**	12.50	353.0	0.62	571.56	1.011E+09	6.32	1.00	0.64
	6	2.15	1.10	14.21	7.42	2.13	9.54	4.95	**1.23**	18.05	545.5	0.65	839.80	1.011E+09	6.32	1.00	1.23
	7	1.52	0.70	11.10	3.50	1.66	5.18	4.02	**0.80**	21.18	600.8	0.63	949.84	1.011E+09	6.32	1.00	0.80
	8	3.37	1.07	27.14	7.12	4.07	11.19	8.10	**1.28**	21.44	553.4	0.58	948.35	1.011E+09	6.32	1.00	1.28
	9	4.20	1.20	32.06	11.93	4.81	16.74	5.81	**1.81**	17.40	441.5	0.52	857.28	1.011E+09	6.32	1.00	1.81
	10	**2.81**	**1.02**	**7.17**	**6.43**			**4.95**	**1.08**	9.60	257.2	0.44	578.52	1.011E+09	6.32	1.00	1.08
	11	**2.81**	**1.02**	**2.27**	**6.43**			**4.95**	**1.05**	2.40	116.4	0.39	297.57	1.011E+09	6.32	1.00	1.05
	12	**2.81**	**1.02**	**1.76**	**6.43**			**4.95**	**1.05**	2.07	86.8	0.37	235.87	1.011E+09	6.32	1.00	1.05

Table GB1.
Monthly averaged VWA output and environmental forcing conditions for 1982 Green Bay Data for use in SPP model and empirical calculations to estimate internal solids loads.

Green Bay Segment	Month	1982 Processed VWA Output								1982 Environmental Forcing Conditions				Geometry for 1982		Conversion of 1982 K_e to pre-1972 Conditions	
		GROSP @ 20^{o}C	RESP @ 20^{o}C	Chl-a (ug/L)	ASS (mg/L)	BSS (mg/L)	TSS (mg/L)	SRP (ug/L)	K_e (1/meter)	Temp (deg. C)	I_T (Ly/day)	Photo (--)	I_a (Ly/day)	Volume (m^3)	Depth (m)	Secchi ratio <1972 vs. 1972-1995	$Ke_{pre\text{-}1972}$ (m^{-1})
5																	
	1	**4.19**	**1.31**	**3.38**	**7.98**			**6.94**	**1.22**	2.03	118.8	0.38	313.25	1.881E+08	5.88	1.00	1.22
	2	**4.19**	**1.31**	**4.74**	**7.98**			**6.94**	**1.23**	2.20	183.6	0.42	434.04	1.881E+08	5.88	1.00	1.23
	3	**4.19**	**1.31**	**4.65**	**7.98**			**6.94**	**1.23**	2.60	196.0	0.47	414.81	1.881E+08	5.88	1.00	1.23
	4	**4.19**	**1.31**	**8.27**	**7.98**			**6.94**	**1.25**	5.10	338.8	0.54	622.13	1.881E+08	5.88	1.00	1.25
	5	**4.19**	**1.31**	12.72	5.45	1.91	7.36	2.59	1.96	13.03	353.0	0.62	571.56	1.881E+08	5.88	1.00	1.96
	6	2.44	1.33	14.69	8.17	2.20	10.36	4.66	1.36	18.30	545.5	0.65	839.80	1.881E+08	5.88	1.00	1.36
	7	5.89	1.58	36.65	5.80	5.50	11.30	5.54	1.99	22.54	600.8	0.63	949.84	1.881E+08	5.88	1.00	1.99
	8	4.70	1.28	35.19	9.56	5.28	14.84	12.24	2.64	22.48	553.4	0.58	948.35	1.881E+08	5.88	1.00	2.64
	9	3.72	1.04	40.27	10.90	6.04	16.94	9.67	4.00	17.43	441.5	0.52	857.28	1.881E+08	5.88	1.00	4.00
	10	**4.19**	**1.31**	**10.35**	**7.98**			**6.94**	**1.26**	9.50	257.2	0.44	578.52	1.881E+08	5.88	1.00	1.26
	11	**4.19**	**1.31**	**3.29**	**7.98**			**6.94**	**1.22**	2.40	116.4	0.39	297.57	1.881E+08	5.88	1.00	1.22
	12	**4.19**	**1.31**	**2.55**	**7.98**			**6.94**	**1.21**	2.07	86.8	0.37	235.87	1.881E+08	5.88	1.00	1.21

Green Bay Segment	Month	1982 Processed VWA Output								1982 Environmental Forcing Conditions				Geometry for 1982		Conversion of 1982 K_e to pre-1972 Conditions	
		GROSP @ 20^{o}C	RESP @ 20^{o}C	Chl-a (ug/L)	ASS (mg/L)	BSS (mg/L)	TSS (mg/L)	SRP (ug/L)	K_e (1/meter)	Temp (deg. C)	I_T (Ly/day)	Photo (--)	I_a (Ly/day)	Volume (m^3)	Depth (m)	Secchi ratio <1972 vs. 1972-1995	$Ke_{pre\text{-}1972}$ (m^{-1})
6																	
	1	**2.59**	**0.89**	**2.35**	**6.54**			**4.65**	**1.06**	2.03	118.8	0.38	313.25	6.379E+08	7.97	1.00	1.06
	2	**2.59**	**0.89**	**3.29**	**6.54**			**4.65**	**1.07**	2.20	183.6	0.42	434.04	6.379E+08	7.97	1.00	1.07
	3	**2.59**	**0.89**	**3.23**	**6.54**			**4.65**	**1.07**	2.60	196.0	0.47	414.81	6.379E+08	7.97	1.00	1.07
	4	**2.59**	**0.89**	**5.73**	**6.54**			**4.65**	**1.08**	5.10	338.8	0.54	622.13	6.379E+08	7.97	1.00	1.08
	5	**2.59**	**0.89**	9.40	4.63	1.41	6.04	2.10	1.44	12.50	353.0	0.62	571.56	6.379E+08	7.97	1.00	1.44
	6	2.20	1.00	12.96	7.42	1.94	9.36	4.89	1.12	18.05	545.5	0.65	839.80	6.379E+08	7.97	1.00	1.12
	7	2.43	0.86	18.74	4.75	2.81	7.56	4.36	1.01	21.18	600.8	0.63	949.84	6.379E+08	7.97	1.00	1.01
	8	2.94	0.91	23.23	6.59	3.48	10.08	7.22	1.55	21.44	553.4	0.58	948.35	6.379E+08	7.97	1.00	1.55
	9	2.81	0.78	28.28	9.30	4.24	13.54	4.67	1.99	17.40	441.5	0.52	857.28	6.379E+08	7.97	1.00	1.99
	10	**2.59**	**0.89**	**7.23**	**6.54**			**4.65**	**1.09**	9.60	257.2	0.44	578.52	6.379E+08	7.97	1.00	1.09
	11	**2.59**	**0.89**	**2.28**	**6.54**			**4.65**	**1.06**	2.40	116.4	0.39	297.57	6.379E+08	7.97	1.00	1.06
	12	**2.59**	**0.89**	**1.77**	**6.54**			**4.65**	**1.06**	2.07	86.8	0.37	235.87	6.379E+08	7.97	1.00	1.06

Table GB1.
Monthly averaged VWA output and environmental forcing conditions for 1982 Green Bay Data for use in SPP model and empirical calculations to estimate internal solids loads.

Green Bay Segment	**Month**	**1982 Processed VWA Output**								**1982 Environmental Forcing Conditions**				**Geometry for 1982**		**Conversion of 1982 K_e to pre-1972 Conditions**	
		GROSP @ 20°C	RESP @ 20°C	Chl-a (ug/L)	ASS (mg/L)	BSS (mg/L)	TSS (mg/L)	SRP (ug/L)	K_e (1/meter)	Temp (deg. C)	I_T (Ly/day)	Photo (--)	I_a (Ly/day)	Volume (m^3)	Depth (m)	Secchi ratio <1972 vs. 1972-1995	$Ke_{pre-1972}$ (m^{-1})
7																	
	1	**1.17**	**0.66**	**1.21**	**2.96**			**2.01**	**0.68**	2.03	118.8	0.38	313.25	6.724E+09	9.95	1.00	0.68
	2	**1.17**	**0.66**	**1.69**	**2.96**			**2.01**	**0.68**	2.20	183.6	0.42	434.04	6.724E+09	9.95	1.00	0.68
	3	**1.17**	**0.66**	**1.65**	**2.96**			**2.01**	**0.68**	2.50	196.0	0.47	414.81	6.724E+09	9.95	1.00	0.68
	4	**1.17**	**0.66**	**2.65**	**2.96**			**2.01**	**0.69**	3.50	338.8	0.54	622.13	6.724E+09	9.95	1.00	0.69
	5	**1.17**	**0.66**	4.68	2.22	0.70	2.92	1.80	**0.62**	8.50	353.0	0.62	571.56	6.724E+09	9.95	1.00	0.62
	6	1.45	0.88	5.04	4.11	0.76	5.14	2.32	**0.82**	15.45	545.5	0.65	839.80	6.724E+09	9.95	1.00	0.82
	7	0.44	0.45	5.52	1.98	0.83	2.65	1.76	**0.60**	18.72	600.8	0.63	949.84	6.724E+09	9.95	1.00	0.60
	8	1.09	0.59	9.92	2.42	1.49	3.86	2.36	**0.68**	18.70	553.4	0.58	948.35	6.724E+09	9.95	1.00	0.68
	9	1.71	0.73	14.75	4.06	2.21	6.27	1.79	**0.88**	16.10	441.5	0.52	857.28	6.724E+09	9.95	1.00	0.88
	10	**1.17**	**0.66**	**3.69**	**2.96**			**2.01**	**0.70**	9.50	257.2	0.44	578.52	6.724E+09	9.95	1.00	0.70
	11	**1.17**	**0.66**	**1.18**	**2.96**			**2.01**	**0.68**	2.40	116.4	0.39	297.57	6.724E+09	9.95	1.00	0.68
	12	**1.17**	**0.66**	**0.91**	**2.96**			**2.01**	**0.68**	2.07	86.8	0.37	235.87	6.724E+09	9.95	1.00	0.68

Green Bay Segment	**Month**	**1982 Processed VWA Output**								**1982 Environmental Forcing Conditions**				**Geometry for 1982**		**Conversion of 1982 K_e to pre-1972 Conditions**	
		GROSP @ 20°C	RESP @ 20°C	Chl-a (ug/L)	ASS (mg/L)	BSS (mg/L)	TSS (mg/L)	SRP (ug/L)	K_e (1/meter)	Temp (deg. C)	I_T (Ly/day)	Photo (--)	I_a (Ly/day)	Volume (m^3)	Depth (m)	Secchi ratio <1972 vs. 1972-1995	$Ke_{pre-1972}$ (m^{-1})
8																	
	1	**0.94**	**0.54**	**1.14**	**2.65**			**1.97**	**0.65**	2.03	118.8	0.38	313.25	7.248E+09	12.50	1.00	0.65
	2	**0.94**	**0.54**	**1.60**	**2.65**			**1.97**	**0.65**	2.20	183.6	0.42	434.04	7.248E+09	12.50	1.00	0.65
	3	**0.94**	**0.54**	**1.56**	**2.65**			**1.97**	**0.65**	2.50	196.0	0.47	414.81	7.248E+09	12.50	1.00	0.65
	4	**0.94**	**0.54**	**2.50**	**2.65**			**1.97**	**0.66**	3.50	338.8	0.54	622.13	7.248E+09	12.50	1.00	0.66
	5	**0.94**	**0.54**	4.04	2.71	0.61	3.32	2.02	0.88	8.50	353.0	0.62	571.56	7.248E+09	12.50	1.00	0.88
	6	0.73	0.53	4.05	3.45	0.61	4.22	1.83	0.60	15.45	545.5	0.65	839.80	7.248E+09	12.50	1.00	0.60
	7	0.39	0.40	6.96	1.49	1.04	2.46	1.98	0.56	18.72	600.8	0.63	949.84	7.248E+09	12.50	1.00	0.56
	8	1.04	0.56	8.76	2.09	1.31	3.29	2.23	0.70	18.70	553.4	0.58	948.35	7.248E+09	12.50	1.00	0.70
	9	1.59	0.67	13.84	3.52	2.08	5.59	1.77	0.75	16.10	441.5	0.52	857.28	7.248E+09	12.50	1.00	0.75
	10	**0.94**	**0.54**	**3.48**	**2.65**			**1.97**	**0.66**	9.50	257.2	0.44	578.52	7.248E+09	12.50	1.00	0.66
	11	**0.94**	**0.54**	**1.11**	**2.65**			**1.97**	**0.65**	2.40	116.4	0.39	297.57	7.248E+09	12.50	1.00	0.65
	12	**0.94**	**0.54**	**0.86**	**2.65**			**1.97**	**0.65**	2.07	86.8	0.37	235.87	7.248E+09	12.50	1.00	0.65

Table GB1.
Monthly averaged VWA output and environmental forcing conditions for 1982 Green Bay Data for use in SPP model and empirical calculations to estimate internal solids loads.

Green Bay Segment	**Month**	**1982 Processed VWA Output**								**1982 Environmental Forcing Conditions**				**Geometry for 1982**		**Conversion of 1982 K_e to pre-1972 Conditions**	
		GROSP @ 20°C	RESP @ 20°C	Chl-a (ug/L)	ASS (mg/L)	BSS (mg/L)	TSS (mg/L)	SRP (ug/L)	K_e (1/meter)	Temp (deg. C)	I_T (Ly/day)	Photo (--)	I_a (Ly/day)	Volume (m^3)	Depth (m)	Secchi ratio <1972 vs. 1972-1995	$Ke_{pre-1972}$ (m^{-1})
9																	
	1	**1.02**	**0.67**	**0.86**	**2.22**			**1.72**	**0.60**	2.03	118.8	0.38	313.25	2.986E+10	11.70	1.00	0.60
	2	**1.02**	**0.67**	**1.21**	**2.22**			**1.72**	**0.60**	2.20	183.6	0.42	434.04	2.986E+10	11.70	1.00	0.60
	3	**1.02**	**0.67**	**1.18**	**2.22**			**1.72**	**0.60**	2.50	196.0	0.47	414.81	2.986E+10	11.70	1.00	0.60
	4	**1.02**	**0.67**	**1.89**	**2.22**			**1.72**	**0.61**	3.50	338.8	0.54	622.13	2.986E+10	11.70	1.00	0.61
	5	**1.02**	**0.67**	2.73	3.55	0.41	3.97	1.52	0.60	7.20	353.0	0.62	571.56	2.986E+10	11.70	1.00	0.60
	6	1.77	1.21	2.73	2.32	0.41	2.72	1.61	0.54	13.35	545.5	0.65	839.80	2.986E+10	11.70	1.00	0.54
	7	0.30	0.41	2.31	0.94	0.35	1.37	1.15	0.29	18.34	600.8	0.63	949.84	2.986E+10	11.70	1.00	0.29
	8	0.49	0.42	3.84	0.78	0.58	1.36	1.41	**0.47**	19.38	553.4	0.58	948.35	2.986E+10	11.70	1.00	0.47
	9	1.51	0.63	15.41	3.53	2.31	5.84	2.93	0.42	15.10	441.5	0.52	857.28	2.986E+10	11.70	1.00	0.42
	10	**1.02**	**0.67**	**2.60**	**2.22**			**1.72**	**0.61**	9.25	257.2	0.44	578.52	2.986E+10	11.70	1.00	0.61
	11	**1.02**	**0.67**	**0.84**	**2.22**			**1.72**	**0.60**	2.40	116.4	0.39	297.57	2.986E+10	11.70	1.00	0.60
	12	**1.02**	**0.67**	**0.65**	**2.22**			**1.72**	**0.60**	2.07	86.8	0.37	235.87	2.986E+10	11.70	1.00	0.60

Green Bay Segment	**Month**	**1982 Processed VWA Output**								**1982 Environmental Forcing Conditions**				**Geometry for 1982**		**Conversion of 1982 K_e to pre-1972 Conditions**	
		GROSP @ 20°C	RESP @ 20°C	Chl-a (ug/L)	ASS (mg/L)	BSS (mg/L)	TSS (mg/L)	SRP (ug/L)	K_e (1/meter)	Temp (deg. C)	I_T (Ly/day)	Photo (--)	I_a (Ly/day)	Volume (m^3)	Depth (m)	Secchi ratio <1972 vs. 1972-1995	$Ke_{pre-1972}$ (m^{-1})
10																	
	1	**0.91**	**0.48**	**1.47**	**3.45**			**2.04**	**0.68**	4.07	118.8	0.38	313.25	2.085E+09	7.55	1.00	0.68
	2	**0.91**	**0.48**	**2.08**	**3.45**			**2.04**	**0.68**	4.40	183.6	0.42	434.04	2.085E+09	7.55	1.00	0.68
	3	**0.91**	**0.48**	**2.03**	**3.45**			**2.04**	**0.68**	4.70	196.0	0.47	414.81	2.085E+09	7.55	1.00	0.68
	4	**0.91**	**0.48**	**3.16**	**3.45**			**2.04**	**0.69**	5.25	338.8	0.54	622.13	2.085E+09	7.55	1.00	0.69
	5	**0.91**	**0.48**	6.55	2.82	0.98	3.80	3.75	**0.62**	6.90	353.0	0.62	571.56	2.085E+09	7.55	1.00	0.62
	6	1.99	0.98	3.96	3.99	0.59	4.81	1.78	**0.82**	9.78	545.5	0.65	839.80	2.085E+09	7.55	1.00	0.82
	7	0.11	0.27	2.77	2.61	0.42	2.85	1.38	**0.60**	9.86	600.8	0.63	949.84	2.085E+09	7.55	1.00	0.60
	8	0.29	0.27	2.88	2.69	0.43	3.18	1.82	**0.68**	9.10	553.4	0.58	948.35	2.085E+09	7.55	1.00	0.68
	9	1.26	0.42	12.49	5.16	1.87	7.03	1.48	**0.88**	13.07	441.5	0.52	857.28	2.085E+09	7.55	1.00	0.88
	10	**0.91**	**0.48**	**4.16**	**3.45**			**2.04**	**0.70**	10.40	257.2	0.44	578.52	2.085E+09	7.55	1.00	0.70
	11	**0.91**	**0.48**	**1.47**	**3.45**			**2.04**	**0.68**	4.90	116.4	0.39	297.57	2.085E+09	7.55	1.00	0.68
	12	**0.91**	**0.48**	**0.99**	**3.45**			**2.04**	**0.68**	2.40	86.8	0.37	235.87	2.085E+09	7.55	1.00	0.68

Table GB1.
Monthly averaged VWA output and environmental forcing conditions for 1982 Green Bay Data for use in SPP model and empirical calculations to estimate internal solids loads.

Green Bay Segment	Month	1982 Processed VWA Output								1982 Environmental Forcing Conditions				Geometry for 1982		Conversion of 1982 K_e to pre-1972 Conditions	
		GROSP @ 20°C	RESP @ 20°C	Chl-a (ug/L)	ASS (mg/L)	BSS (mg/L)	TSS (mg/L)	SRP (ug/L)	K_e (1/meter)	Temp (deg. C)	I_T (Ly/day)	Photo (--)	I_a (Ly/day)	Volume (m^3)	Depth (m)	Secchi ratio <1972 vs. 1972-1995	$Ke_{pre-1972}$ (m^{-1})
11																	
	1	**0.73**	**0.42**	**1.50**	**3.07**			**2.19**	**0.65**	4.07	118.8	0.38	313.25	4.348E+09	11.00	1.00	0.65
	2	**0.73**	**0.42**	**2.12**	**3.07**			**2.19**	**0.65**	4.40	183.6	0.42	434.04	4.348E+09	11.00	1.00	0.65
	3	**0.73**	**0.42**	**2.07**	**3.07**			**2.19**	**0.65**	4.70	196.0	0.47	414.81	4.348E+09	11.00	1.00	0.65
	4	**0.73**	**0.42**	**3.22**	**3.07**			**2.19**	**0.66**	5.25	338.8	0.54	622.13	4.348E+09	11.00	1.00	0.66
	5	**0.73**	**0.42**	6.29	2.57	0.94	3.51	4.28	0.88	6.90	353.0	0.62	571.56	4.348E+09	11.00	1.00	0.88
	6	1.27	0.63	4.68	2.94	0.70	3.85	1.56	0.60	9.78	545.5	0.65	839.80	4.348E+09	11.00	1.00	0.60
	7	0.08	0.31	3.07	2.50	0.46	3.12	1.75	0.56	9.86	600.8	0.63	949.84	4.348E+09	11.00	1.00	0.56
	8	0.29	0.27	3.16	2.48	0.47	2.90	2.14	0.70	9.10	553.4	0.58	948.35	4.348E+09	11.00	1.00	0.70
	9	1.29	0.49	12.05	4.87	1.81	6.68	1.24	0.75	13.07	441.5	0.52	857.28	4.348E+09	11.00	1.00	0.75
	10	**0.73**	**0.42**	**4.25**	**3.07**			**2.19**	**0.66**	10.40	257.2	0.44	578.52	4.348E+09	11.00	1.00	0.66
	11	**0.73**	**0.42**	**1.51**	**3.07**			**2.19**	**0.65**	4.90	116.4	0.39	297.57	4.348E+09	11.00	1.00	0.65
	12	**0.73**	**0.42**	**1.01**	**3.07**			**2.19**	**0.65**	2.40	86.8	0.37	235.87	4.348E+09	11.00	1.00	0.65

Green Bay Segment	Month	1982 Processed VWA Output								1982 Environmental Forcing Conditions				Geometry for 1982		Conversion of 1982 K_e to pre-1972 Conditions	
		GROSP @ 20°C	RESP @ 20°C	Chl-a (ug/L)	ASS (mg/L)	BSS (mg/L)	TSS (mg/L)	SRP (ug/L)	K_e (1/meter)	Temp (deg. C)	I_T (Ly/day)	Photo (--)	I_a (Ly/day)	Volume (m^3)	Depth (m)	Secchi ratio <1972 vs. 1972-1995	$Ke_{pre-1972}$ (m^{-1})
12																	
	1	**0.76**	**0.65**	**1.44**	**3.20**			**1.91**	**0.60**	4.07	118.8	0.38	313.25	1.918E+10	11.80	1.00	0.60
	2	**0.76**	**0.65**	**2.04**	**3.20**			**1.91**	**0.60**	4.40	183.6	0.42	434.04	1.918E+10	11.80	1.00	0.60
	3	**0.76**	**0.65**	**1.99**	**3.20**			**1.91**	**0.60**	4.70	196.0	0.47	414.81	1.918E+10	11.80	1.00	0.60
	4	**0.76**	**0.65**	**3.10**	**3.20**			**1.91**	**0.61**	5.25	338.8	0.54	622.13	1.918E+10	11.80	1.00	0.61
	5	**0.76**	**0.65**	4.79	3.61	0.72	4.33	3.08	0.60	6.90	353.0	0.62	571.56	1.918E+10	11.80	1.00	0.60
	6	1.48	1.24	3.10	2.40	0.47	2.84	1.48	0.54	9.78	545.5	0.65	839.80	1.918E+10	11.80	1.00	0.54
	7	-0.02	0.38	2.79	1.95	0.42	2.31	1.03	0.29	9.86	600.8	0.63	949.84	1.918E+10	11.80	1.00	0.29
	8	0.07	0.38	2.03	2.61	0.30	2.91	1.01	**0.47**	9.10	553.4	0.58	948.35	1.918E+10	11.80	1.00	0.47
	9	1.52	0.61	15.46	5.42	2.32	7.74	2.92	0.42	13.07	441.5	0.52	857.28	1.918E+10	11.80	1.00	0.42
	10	**0.76**	**0.65**	**4.09**	**3.20**			**1.91**	**0.61**	10.40	257.2	0.44	578.52	1.918E+10	11.80	1.00	0.61
	11	**0.76**	**0.65**	**1.45**	**3.20**			**1.91**	**0.60**	4.90	116.4	0.39	297.57	1.918E+10	11.80	1.00	0.60
	12	**0.76**	**0.65**	**0.97**	**3.20**			**1.91**	**0.60**	2.40	86.8	0.37	235.87	1.918E+10	11.80	1.00	0.60

Table GB2.
Application of Emprical Primary Productivity Calculation to Green Bay for 1982.

Conversion Factor		Value	Units	Description
I_{sat}	=	100	Ly/day	saturation light intensity, GBEUTRO calibration (Bierman, et al., 1992)
TLX	=	0.994	---	[1]conversion of laboratory incident light to saturation intensity
NCRB	=	0.250	mg N / mg C	nitrogen to carbon ratio (Bierman, et al., 1992)
PNH3	=	0.500	---	[2]ammonia uptake preference factor
O2CRB	=	3.095	mg O_2 / mg C	[3]oxygen to carbon ratio adjusted for ammonia preference factor
f_{POC}	=	0.80	--	primary production efficiency factor (Bierman, et al., 1992)
CCHL	=	30.00	g C/g Chl-a	carbon to Chlorophyll-a ratio (Bierman, et al., 1992)
CBSS	=	0.40	g C/g BSS	carbon to biotic suspended solids conversion (Bierman, et al., 1992)

[1] TLX = $(89.77/I_{sat}) * \exp(-89.77/I_{sat}+1)$
where 89.77 Ly/day = 200 uE/m^2/sec for a 550 nm wavelength

[2] Bay-wide estimate from 1989 GBMBS data. Nitrogen data was not collected in 1982.

[3] O2CRB = PNH3*32/12+(1-PNH3)*32*(1/12+1.5*NCRB/14)

Green Bay Primary Productivity
Estimation Comparison for 1982
(kg biotic carbon soilds per year)

Segment	Empirical	SPP Model
1	1.338E+07	1.125E+07
2	1.315E+07	1.261E+07
3	6.501E+06	6.134E+06
4	3.126E+07	2.965E+07
5	6.296E+06	5.668E+06
6	1.327E+07	1.368E+07
7	7.371E+07	6.191E+07
8	5.412E+07	5.485E+07
9	3.088E+08	2.187E+08
10	9.690E+04	9.876E+04
11	5.040E+04	4.908E+04
12	4.177E+06	8.146E+06
Inner Bay Total (1- 6)	8.385E+07	7.899E+07
Inner & Middle Bay Total (1-8,10,11)	2.118E+08	1.959E+08
Bay-wide Total (1-12)	5.248E+08	4.227E+08
Bay-wide Total (kg BSS)	1.312E+09	1.057E+09

Inner Bay includes Segments 1 through 6
Middle Bay includes Segments 7, 8, 10 and 11

Outer Bay includes Segments 9 and 12

Table GB2.
Application of Emprical Primary Productivity Calculation to Green Bay for 1982.

Green Bay Segment	Month	Segment Specific Conversion Factors						Gross Primary Production Conversion to Internal Biotic Carbon Load					
		f (T) *temperature*	a_0 *light*	a_1 *light*	f (L) *light*	$a_{1\ pre\text{-}1972}$ *light*	f $(L)_{pre\text{-}1972}$ *light*	GPP @ 20°C (mg O_2/L/day) *from VWA*	GPPC (mg C/L/day)	GPPChla (ug Chl-a/L/day) *see SPP dC/dt*	Vol*GPPC (kg C/day)	Mass BIC (kg C)	Mass BIC $_{pre\text{-}1972}$ (kg C)
1													
	1	0.297	3.132	1.242E-02	0.176	1.242E-02	0.176	9.88	0.1340	4.468	16,016	496,500	496,500
	2	0.300	4.340	1.651E-02	0.200	1.651E-02	0.200	9.88	0.1543	5.143	18,438	516,264	516,264
	3	0.322	4.148	1.572E-02	0.223	1.572E-02	0.223	9.88	0.1845	6.151	22,052	683,614	683,614
	4	0.429	6.221	2.037E-02	0.253	2.037E-02	0.253	9.88	0.2789	9.296	33,328	999,826	999,826
	5	0.728	5.716	7.494E-03	0.250	7.494E-03	0.250	9.88	0.4677	15.590	55,890	1,732,582	1,732,582
	6	0.972	8.398	7.561E-02	0.347	7.561E-02	0.347	6.51	0.5708	19.026	68,209	2,046,283	2,046,283
	7	1.422	9.498	2.938E-04	0.166	2.938E-04	0.166	10.14	0.6200	20.667	74,092	2,296,859	2,296,859
	8	1.250	9.483	1.055E-05	0.116	1.055E-05	0.116	12.13	0.4561	15.204	54,505	1,689,667	1,689,667
	9	0.841	8.573	4.715E-05	0.116	4.715E-05	0.116	10.75	0.2715	9.050	32,443	973,281	973,281
	10	0.498	5.785	1.851E-02	0.206	1.851E-02	0.206	9.88	0.2633	8.778	31,470	975,568	975,568
	11	0.304	2.976	1.183E-02	0.180	1.183E-02	0.180	9.88	0.1407	4.690	16,813	504,388	504,388
	12	0.297	2.359	9.585E-03	0.163	9.585E-03	0.163	9.88	0.1243	4.142	14,849	460,318	460,318

Green Bay Segment	Month	Segment Specific Conversion Factors						Gross Primary Production Conversion to Internal Biotic Carbon Load					
		f (T) *temperature*	a_0 *light*	a_1 *light*	f (L) *light*	$a_{1\ pre\text{-}1972}$ *light*	f $(L)_{pre\text{-}1972}$ *light*	GPP @ 20°C (mg O_2/L/day) *from VWA*	GPPC (mg C/L/day)	GPPChla (ug Chl-a/L/day) *see SPP dC/dt*	Vol*GPPC (kg C/day)	Mass BIC (kg C)	Mass BIC $_{pre\text{-}1972}$ (kg C)
2													
	1	0.297	3.132	3.480E-03	0.144	3.480E-03	0.144	6.52	0.0725	2.418	12,566	389,531	389,531
	2	0.300	4.340	4.581E-03	0.165	4.581E-03	0.165	6.52	0.0837	2.791	14,503	406,096	406,096
	3	0.311	4.148	4.385E-03	0.184	4.385E-03	0.184	6.52	0.0969	3.228	16,774	520,008	520,008
	4	0.381	6.221	5.669E-03	0.210	5.669E-03	0.210	6.52	0.1355	4.518	23,475	704,256	704,256
	5	0.663	5.716	1.133E-01	0.381	1.133E-01	0.381	6.52	0.4281	14.271	74,150	2,298,661	2,298,661
	6	0.936	8.398	4.655E-03	0.234	4.655E-03	0.234	3.32	0.1894	6.314	32,806	984,171	984,171
	7	1.257	9.498	1.088E-02	0.251	1.088E-02	0.251	7.08	0.5811	19.369	100,643	3,119,940	3,119,940
	8	1.192	9.483	3.970E-04	0.157	3.970E-04	0.157	7.74	0.3771	12.570	65,315	2,024,761	2,024,761
	9	0.837	8.573	2.258E-04	0.133	2.258E-04	0.133	7.93	0.2289	7.630	39,646	1,189,390	1,189,390
	10	0.493	5.785	4.935E-03	0.170	4.935E-03	0.170	6.52	0.1417	4.723	24,542	760,809	760,809
	11	0.304	2.976	3.317E-03	0.148	3.317E-03	0.148	6.52	0.0761	2.538	13,186	395,574	395,574
	12	0.297	2.359	2.704E-03	0.133	2.704E-03	0.133	6.52	0.0672	2.238	11,631	360,546	360,546

Table GB2.
Application of Emprical Primary Productivity Calculation to Green Bay for 1982.

Green Bay Segment	Month	Segment Specific Conversion Factors						Gross Primary Production Conversion to Internal Biotic Carbon Load					
		f (T) *temperature*	a_0 *light*	a_1 *light*	f (L) *light*	$a_{1\ pre\text{-}1972}$ *light*	f $(L)_{pre\text{-}1972}$ *light*	GPP @ 20°C ($mg\ O_2/L/day$) *from VWA*	GPPC (mg C/L/day)	GPPChla (ug Chl-a/L/day) *see SPP dC/dt*	Vol*GPPC (kg C/day)	Mass BIC (kg C)	Mass BIC $_{pre\text{-}1972}$ (kg C)
3													
	1	0.297	3.132	2.974E-03	0.141	2.974E-03	0.141	7.27	0.0791	2.636	7,854	243,486	243,486
	2	0.300	4.340	3.893E-03	0.161	3.893E-03	0.161	7.27	0.0912	3.041	9,062	253,723	253,723
	3	0.311	4.148	3.727E-03	0.180	3.727E-03	0.180	7.27	0.1055	3.518	10,480	324,890	324,890
	4	0.381	6.221	4.741E-03	0.205	4.741E-03	0.205	7.27	0.1475	4.915	14,645	439,340	439,340
	5	0.663	5.716	1.574E-03	0.204	1.574E-03	0.204	7.27	0.2553	8.512	25,359	786,122	786,122
	6	0.936	8.398	3.989E-03	0.230	3.989E-03	0.230	3.00	0.1678	5.593	16,664	499,909	499,909
	7	1.257	9.498	4.365E-04	0.172	4.365E-04	0.172	10.56	0.5934	19.780	58,930	1,826,828	1,826,828
	8	1.192	9.483	2.596E-06	0.105	2.596E-06	0.105	8.23	0.2677	8.924	26,588	824,223	824,223
	9	0.837	8.573	7.554E-08	0.075	7.554E-08	0.075	7.28	0.1194	3.980	11,859	355,759	355,759
	10	0.493	5.785	4.098E-03	0.165	4.098E-03	0.165	7.27	0.1540	5.135	15,297	474,215	474,215
	11	0.304	2.976	2.836E-03	0.145	2.836E-03	0.145	7.27	0.0830	2.767	8,242	247,268	247,268
	12	0.297	2.359	2.318E-03	0.130	2.318E-03	0.130	7.27	0.0732	2.441	7,272	225,433	225,433

Green Bay Segment	Month	Segment Specific Conversion Factors						Gross Primary Production Conversion to Internal Biotic Carbon Load					
		f (T) *temperature*	a_0 *light*	a_1 *light*	f (L) *light*	$a_{1\ pre\text{-}1972}$ *light*	f $(L)_{pre\text{-}1972}$ *light*	GPP @ 20°C ($mg\ O_2/L/day$) *from VWA*	GPPC (mg C/L/day)	GPPChla (ug Chl-a/L/day) *see SPP dC/dt*	Vol*GPPC (kg C/day)	Mass BIC (kg C)	Mass BIC $_{pre\text{-}1972}$ (kg C)
4													
	1	0.297	3.132	4.079E-03	0.148	4.079E-03	0.148	2.81	0.0320	1.067	32,375	1,003,619	1,003,619
	2	0.300	4.340	5.451E-03	0.169	5.451E-03	0.169	2.81	0.0370	1.234	37,436	1,048,200	1,048,200
	3	0.308	4.148	5.222E-03	0.188	5.222E-03	0.188	2.81	0.0424	1.413	42,867	1,328,888	1,328,888
	4	0.365	6.221	7.114E-03	0.217	7.114E-03	0.217	2.81	0.0577	1.925	58,376	1,751,284	1,751,284
	5	0.602	5.716	1.021E-01	0.375	1.021E-01	0.375	2.81	0.1651	5.504	166,927	5,174,745	5,174,745
	6	0.876	8.398	3.583E-03	0.227	3.583E-03	0.227	2.15	0.1108	3.694	112,033	3,360,987	3,360,987
	7	1.083	9.498	6.114E-02	0.320	6.114E-02	0.320	1.52	0.1375	4.582	138,977	4,308,280	4,308,280
	8	1.102	9.483	3.001E-03	0.196	3.001E-03	0.196	3.37	0.1897	6.323	191,779	5,945,151	5,945,151
	9	0.839	8.573	9.285E-05	0.122	9.285E-05	0.122	4.20	0.1121	3.738	113,380	3,401,411	3,401,411
	10	0.495	5.785	6.246E-03	0.175	6.246E-03	0.175	2.81	0.0634	2.112	64,058	1,985,808	1,985,808
	11	0.304	2.976	3.884E-03	0.151	3.884E-03	0.151	2.81	0.0336	1.120	33,969	1,019,079	1,019,079
	12	0.297	2.359	3.140E-03	0.136	3.140E-03	0.136	2.81	0.0296	0.987	29,932	927,884	927,884

Table GB2.
Application of Emprical Primary Productivity Calculation to Green Bay for 1982.

Green Bay Segment	Month	Segment Specific Conversion Factors						Gross Primary Production Conversion to Internal Biotic Carbon Load					
		f (T) *temperature*	a_0 *light*	a_1 *light*	f (L) *light*	$a_{1\ pre\text{-}1972}$ *light*	f $(L)_{pre\text{-}1972}$ *light*	GPP @ 20°C (mg O_2/L/day) *from VWA*	GPPC (mg C/L/day)	GPPChla (ug Chl-a/L/day) *see SPP dC/dt*	Vol*GPPC (kg C/day)	Mass BIC (kg C)	Mass BIC $_{pre\text{-}1972}$ (kg C)
5													
	1	0.297	3.132	2.405E-03	0.137	2.405E-03	0.137	4.19	0.0443	1.475	8,325	258,088	258,088
	2	0.300	4.340	3.174E-03	0.157	3.174E-03	0.157	4.19	0.0511	1.705	9,619	269,334	269,334
	3	0.308	4.148	3.043E-03	0.175	3.043E-03	0.175	4.19	0.0586	1.952	11,015	341,454	341,454
	4	0.365	6.221	4.007E-03	0.200	4.007E-03	0.200	4.19	0.0795	2.651	14,960	448,792	448,792
	5	0.624	5.716	5.648E-05	0.145	5.648E-05	0.145	4.19	0.0986	3.288	18,555	575,197	575,197
	6	0.891	8.398	2.882E-03	0.221	2.882E-03	0.221	2.44	0.1249	4.164	23,496	704,893	704,893
	7	1.188	9.498	7.985E-05	0.147	7.985E-05	0.147	5.89	0.2674	8.914	50,302	1,559,362	1,559,362
	8	1.183	9.483	1.719E-06	0.102	1.719E-06	0.102	4.70	0.1476	4.918	27,754	860,382	860,382
	9	0.841	8.573	5.386E-10	0.060	5.386E-10	0.060	3.72	0.0484	1.614	9,107	273,208	273,208
	10	0.491	5.785	3.457E-03	0.162	3.457E-03	0.162	4.19	0.0865	2.884	16,272	504,428	504,428
	11	0.304	2.976	2.292E-03	0.140	2.292E-03	0.140	4.19	0.0464	1.548	8,736	262,068	262,068
	12	0.297	2.359	1.866E-03	0.127	1.866E-03	0.127	4.19	0.0409	1.365	7,701	238,732	238,732

Green Bay Segment	Month	Segment Specific Conversion Factors						Gross Primary Production Conversion to Internal Biotic Carbon Load					
		f (T) *temperature*	a_0 *light*	a_1 *light*	f (L) *light*	$a_{1\ pre\text{-}1972}$ *light*	f $(L)_{pre\text{-}1972}$ *light*	GPP @ 20°C (mg O_2/L/day) *from VWA*	GPPC (mg C/L/day)	GPPChla (ug Chl-a/L/day) *see SPP dC/dt*	Vol*GPPC (kg C/day)	Mass BIC (kg C)	Mass BIC $_{pre\text{-}1972}$ (kg C)
6													
	1	0.297	3.132	6.555E-04	0.116	6.555E-04	0.116	2.59	0.0232	0.775	14,828	459,682	459,682
	2	0.300	4.340	8.675E-04	0.133	8.675E-04	0.133	2.59	0.0269	0.897	17,165	480,622	480,622
	3	0.308	4.148	8.315E-04	0.148	8.315E-04	0.148	2.59	0.0308	1.027	19,652	609,210	609,210
	4	0.365	6.221	1.104E-03	0.171	1.104E-03	0.171	2.59	0.0420	1.401	26,805	804,142	804,142
	5	0.602	5.716	5.926E-05	0.146	5.926E-05	0.146	2.59	0.0592	1.972	37,744	1,170,050	1,170,050
	6	0.876	8.398	1.086E-03	0.197	1.086E-03	0.197	2.20	0.0986	3.286	62,886	1,886,567	1,886,567
	7	1.083	9.498	3.093E-03	0.213	3.093E-03	0.213	2.43	0.1460	4.868	93,154	2,887,765	2,887,765
	8	1.102	9.483	4.092E-05	0.128	4.092E-05	0.128	2.94	0.1080	3.601	68,918	2,136,454	2,136,454
	9	0.839	8.573	1.154E-06	0.088	1.154E-06	0.088	2.81	0.0542	1.805	34,551	1,036,521	1,036,521
	10	0.495	5.785	9.541E-04	0.138	9.541E-04	0.138	2.59	0.0461	1.536	29,394	911,203	911,203
	11	0.304	2.976	6.245E-04	0.119	6.245E-04	0.119	2.59	0.0244	0.813	15,557	466,695	466,695
	12	0.297	2.359	5.076E-04	0.107	5.076E-04	0.107	2.59	0.0215	0.716	13,700	424,704	424,704

Table GB2.
Application of Emprical Primary Productivity Calculation to Green Bay for 1982.

Green Bay Segment	Month	Segment Specific Conversion Factors						Gross Primary Production Conversion to Internal Biotic Carbon Load					
		f (T) *temperature*	a_0 *light*	a_1 *light*	f (L) *light*	$a_{1\ pre\text{-}1972}$ *light*	f $(L)_{pre\text{-}1972}$ *light*	GPP @ 20°C ($mg\ O_2/L/day$) *from VWA*	GPPC (mg C/L/day)	GPPChla (ug Chl-a/L/day) *see SPP dC/dt*	Vol*GPPC (kg C/day)	Mass BIC (kg C)	Mass BIC $_{pre\text{-}1972}$ (kg C)
7													
	1	0.297	3.132	3.585E-03	0.145	3.585E-03	0.145	1.17	0.0131	0.437	88,206	2,734,390	2,734,390
	2	0.300	4.340	4.823E-03	0.166	4.823E-03	0.166	1.17	0.0152	0.506	102,117	2,859,274	2,859,274
	3	0.306	4.148	4.621E-03	0.185	4.621E-03	0.185	1.17	0.0173	0.576	116,146	3,600,511	3,600,511
	4	0.327	6.221	6.522E-03	0.214	6.522E-03	0.214	1.17	0.0214	0.712	143,672	4,310,156	4,310,156
	5	0.459	5.716	1.142E-02	0.266	1.142E-02	0.266	1.17	0.0373	1.243	250,744	7,773,050	7,773,050
	6	0.735	8.398	2.295E-03	0.215	2.295E-03	0.215	1.45	0.0594	1.978	399,097	11,972,901	11,972,901
	7	0.917	9.498	2.325E-02	0.279	2.325E-02	0.279	0.44	0.0295	0.984	198,530	6,154,415	6,154,415
	8	0.916	9.483	1.116E-02	0.233	1.116E-02	0.233	1.09	0.0604	2.012	405,870	12,581,972	12,581,972
	9	0.768	8.573	1.360E-03	0.160	1.360E-03	0.160	1.71	0.0546	1.821	367,332	11,019,954	11,019,954
	10	0.491	5.785	5.691E-03	0.173	5.691E-03	0.173	1.17	0.0259	0.864	174,349	5,404,805	5,404,805
	11	0.304	2.976	3.412E-03	0.148	3.412E-03	0.148	1.17	0.0138	0.459	92,542	2,776,262	2,776,262
	12	0.297	2.359	2.749E-03	0.134	2.749E-03	0.134	1.17	0.0121	0.404	81,489	2,526,162	2,526,162

Green Bay Segment	Month	Segment Specific Conversion Factors						Gross Primary Production Conversion to Internal Biotic Carbon Load					
		f (T) *temperature*	a_0 *light*	a_1 *light*	f (L) *light*	$a_{1\ pre\text{-}1972}$ *light*	f $(L)_{pre\text{-}1972}$ *light*	GPP @ 20°C ($mg\ O_2/L/day$) *from VWA*	GPPC (mg C/L/day)	GPPChla (ug Chl-a/L/day) *see SPP dC/dt*	Vol*GPPC (kg C/day)	Mass BIC (kg C)	Mass BIC $_{pre\text{-}1972}$ (kg C)
8													
	1	0.297	3.132	9.509E-04	0.122	9.509E-04	0.122	0.94	0.0088	0.294	63,867	1,979,884	1,979,884
	2	0.300	4.340	1.272E-03	0.139	1.272E-03	0.139	0.94	0.0102	0.340	74,005	2,072,138	2,072,138
	3	0.306	4.148	1.220E-03	0.155	1.220E-03	0.155	0.94	0.0116	0.387	84,159	2,608,940	2,608,940
	4	0.327	6.221	1.702E-03	0.180	1.702E-03	0.180	0.94	0.0144	0.479	104,257	3,127,698	3,127,698
	5	0.459	5.716	1.016E-04	0.153	1.016E-04	0.153	0.94	0.0172	0.572	124,452	3,858,006	3,858,006
	6	0.735	8.398	4.924E-03	0.236	4.924E-03	0.236	0.73	0.0330	1.100	239,206	7,176,168	7,176,168
	7	0.917	9.498	8.825E-03	0.244	8.825E-03	0.244	0.39	0.0228	0.760	165,203	5,121,304	5,121,304
	8	0.916	9.483	1.447E-03	0.180	1.447E-03	0.180	1.04	0.0448	1.494	324,808	10,069,057	10,069,057
	9	0.768	8.573	7.549E-04	0.150	7.549E-04	0.150	1.59	0.0476	1.587	345,121	10,353,631	10,353,631
	10	0.491	5.785	1.468E-03	0.145	1.468E-03	0.145	0.94	0.0174	0.582	126,453	3,920,039	3,920,039
	11	0.304	2.976	9.054E-04	0.124	9.054E-04	0.124	0.94	0.0092	0.308	66,999	2,009,970	2,009,970
	12	0.297	2.359	7.315E-04	0.112	7.315E-04	0.112	0.94	0.0081	0.271	58,971	1,828,105	1,828,105

Table GB2.
Application of Emprical Primary Productivity Calculation to Green Bay for 1982.

Green Bay Segment	Month	Segment Specific Conversion Factors						Gross Primary Production Conversion to Internal Biotic Carbon Load					
		f (T)	a_0	a_1	f (L)	$a_{1\ pre\text{-}1972}$	f $(L)_{pre\text{-}1972}$	GPP @ 20°C	GPPC	GPPChla	Vol*GPPC	Mass BIC	Mass BIC $_{pre\text{-}1972}$
		temperature	*light*	*light*	*light*	*light*	*light*	(mg O_2/L/day)	(mg C/L/day)	(ug Chl-a/L/day)	(kg C/day)	(kg C)	(kg C)
								from VWA		*see SPP dC/dt*			
9													
	1	0.297	3.132	2.741E-03	0.140	2.741E-03	0.140	1.02	0.0109	0.364	326,428	10,119,260	10,119,260
	2	0.300	4.340	3.705E-03	0.160	3.705E-03	0.160	1.02	0.0127	0.422	378,315	10,592,814	10,592,814
	3	0.306	4.148	3.549E-03	0.178	3.549E-03	0.178	1.02	0.0144	0.480	430,238	13,337,374	13,337,374
	4	0.327	6.221	5.057E-03	0.207	5.057E-03	0.207	1.02	0.0179	0.595	533,301	15,999,039	15,999,039
	5	0.421	5.716	5.291E-03	0.238	5.291E-03	0.238	1.02	0.0265	0.882	790,283	24,498,762	24,498,762
	6	0.638	8.398	1.526E-02	0.275	1.526E-02	0.275	1.77	0.0806	2.687	2,406,847	72,205,409	72,205,409
	7	0.894	9.498	3.230E-01	0.368	3.230E-01	0.368	0.30	0.0256	0.854	764,731	23,706,651	23,706,651
	8	0.959	9.483	3.948E-02	0.278	3.948E-02	0.278	0.49	0.0342	1.140	1,021,459	31,665,234	31,665,234
	9	0.718	8.573	6.295E-02	0.267	6.295E-02	0.267	1.51	0.0751	2.503	2,242,462	67,273,869	67,273,869
	10	0.483	5.785	4.471E-03	0.167	4.471E-03	0.167	1.02	0.0214	0.712	637,549	19,764,006	19,764,006
	11	0.304	2.976	2.608E-03	0.143	2.608E-03	0.143	1.02	0.0115	0.382	342,443	10,273,299	10,273,299
	12	0.297	2.359	2.096E-03	0.129	2.096E-03	0.129	1.02	0.0101	0.336	301,368	9,342,408	9,342,408

Green Bay Segment	Month	Segment Specific Conversion Factors						Gross Primary Production Conversion to Internal Biotic Carbon Load					
		f (T)	a_0	a_1	f (L)	$a_{1\ pre\text{-}1972}$	f $(L)_{pre\text{-}1972}$	GPP @ 20°C	GPPC	GPPChla	Vol*GPPC	Mass BIC	Mass BIC $_{pre\text{-}1972}$
		temperature	*light*	*light*	*light*	*light*	*light*	(mg O_2/L/day)	(mg C/L/day)	(ug Chl-a/L/day)	(kg C/day)	(kg)	(kg)
								from VWA		*see SPP dC/dt*			
10													
	1	0.340	3.59E-03	2.102E-05	7.136E-04	2.102E-05	7.136E-04	0.91	0.0001	0.002	120	3,719	3,719
	2	0.348	4.82E-03	2.765E-05	1.066E-03	2.765E-05	1.066E-03	0.91	0.0001	0.003	183	5,130	5,130
	3	0.355	4.62E-03	2.654E-05	1.141E-03	2.654E-05	1.141E-03	0.91	0.0001	0.003	200	6,206	6,206
	4	0.369	6.52E-03	3.578E-05	1.838E-03	3.578E-05	1.838E-03	0.91	0.0002	0.005	335	10,042	10,042
	5	0.412	1.14E-02	1.022E-04	4.007E-03	1.022E-04	4.007E-03	0.91	0.0004	0.013	816	25,292	25,292
	6	0.501	2.30E-03	4.540E-06	6.488E-04	4.540E-06	6.488E-04	1.99	0.0002	0.006	351	10,521	10,521
	7	0.504	2.32E-02	2.426E-04	8.567E-03	2.426E-04	8.567E-03	0.11	0.0001	0.004	253	7,842	7,842
	8	0.478	1.12E-02	6.683E-05	3.418E-03	6.683E-05	3.418E-03	0.29	0.0001	0.004	254	7,878	7,878
	9	0.626	1.36E-03	1.780E-06	2.862E-04	1.780E-06	2.862E-04	1.26	0.0001	0.002	122	3,666	3,666
	10	0.522	5.69E-03	2.974E-05	1.298E-03	2.974E-05	1.298E-03	0.91	0.0002	0.005	335	10,383	10,383
	11	0.360	3.41E-03	2.003E-05	7.005E-04	2.003E-05	7.005E-04	0.91	0.0001	0.002	125	3,737	3,737
	12	0.304	2.75E-03	1.634E-05	5.324E-04	1.634E-05	5.324E-04	0.91	0.0000	0.001	80	2,479	2,479

Table GB2.
Application of Emprical Primary Productivity Calculation to Green Bay for 1982.

Green Bay Segment	Month	Segment Specific Conversion Factors						Gross Primary Production Conversion to Internal Biotic Carbon Load					
		f (T)	a_0	a_1	f (L)	$a_{1\ pre-1972}$	f $(L)_{pre-1972}$	GPP @ 20°C	GPPC	GPPChla	Vol*GPPC	Mass BIC	Mass BIC $_{pre-1972}$
		temperature	*light*	*light*	*light*	*light*	*light*	(mg O_2/L/day)	(mg C/L/day)	(ug Chl-a/L/day)	(kg C/day)	(kg C)	(kg C)
								from VWA		*see SPP dC/dt*			
11													
	1	0.340	9.51E-04	7.630E-07	1.373E-04	7.630E-07	1.373E-04	0.73	0.0000	0.000	39	1,199	1,199
	2	0.348	1.27E-03	9.901E-07	2.041E-04	9.901E-07	2.041E-04	0.73	0.0000	0.000	59	1,646	1,646
	3	0.355	1.22E-03	9.516E-07	2.186E-04	9.516E-07	2.186E-04	0.73	0.0000	0.000	64	1,992	1,992
	4	0.369	1.70E-03	1.247E-06	3.484E-04	1.247E-06	3.484E-04	0.73	0.0000	0.001	106	3,189	3,189
	5	0.412	1.02E-04	6.712E-09	1.772E-05	6.712E-09	1.772E-05	0.73	0.0000	0.000	6	187	187
	6	0.501	4.92E-03	7.051E-06	1.322E-03	7.051E-06	1.322E-03	1.27	0.0002	0.007	952	28,556	28,556
	7	0.504	8.83E-03	1.895E-05	2.453E-03	1.895E-05	2.453E-03	0.08	0.0000	0.001	110	3,414	3,414
	8	0.478	1.45E-03	6.342E-07	2.965E-04	6.342E-07	2.965E-04	0.29	0.0000	0.000	46	1,427	1,427
	9	0.626	7.55E-04	2.038E-07	1.285E-04	2.038E-07	1.285E-04	1.29	0.0000	0.001	117	3,520	3,520
	10	0.522	1.47E-03	1.006E-06	2.430E-04	1.006E-06	2.430E-04	0.73	0.0000	0.001	105	3,257	3,257
	11	0.360	9.05E-04	7.280E-07	1.349E-04	7.280E-07	1.349E-04	0.73	0.0000	0.000	40	1,206	1,206
	12	0.304	7.31E-04	5.981E-07	1.028E-04	5.981E-07	1.028E-04	0.73	0.0000	0.000	26	802	802

Green Bay Segment	Month	Segment Specific Conversion Factors						Gross Primary Production Conversion to Internal Biotic Carbon Load					
		f (T)	a_0	a_1	f (L)	$a_{1\ pre-1972}$	f $(L)_{pre-1972}$	GPP @ 20°C	GPPC	GPPChla	Vol*GPPC	Mass BIC	Mass BIC $_{pre-1972}$
		temperature	*light*	*light*	*light*	*light*	*light*	(mg O_2/L/day)	(mg C/L/day)	(ug Chl-a/L/day)	(kg C/day)	(kg C)	(kg C)
								from VWA		*see SPP dC/dt*			
12													
	1	0.340	2.74E-03	2.259E-06	3.971E-04	2.259E-06	3.971E-04	0.76	0.0000	0.001	515	15,954	15,954
	2	0.348	3.71E-03	2.978E-06	5.962E-04	2.978E-06	5.962E-04	0.76	0.0000	0.001	790	22,131	22,131
	3	0.355	3.55E-03	2.858E-06	6.381E-04	2.858E-06	6.381E-04	0.76	0.0000	0.002	863	26,761	26,761
	4	0.369	5.06E-03	3.869E-06	1.040E-03	3.869E-06	1.040E-03	0.76	0.0001	0.003	1,460	43,793	43,793
	5	0.412	5.29E-03	4.615E-06	1.257E-03	4.615E-06	1.257E-03	0.76	0.0001	0.003	1,973	61,155	61,155
	6	0.501	1.53E-02	2.629E-05	4.195E-03	2.629E-05	4.195E-03	1.48	0.0008	0.027	15,542	466,255	466,255
	7	0.504	3.23E-01	1.067E-02	1.338E-01	1.067E-02	1.338E-01	**0.09**	0.0016	0.055	31,414	973,839	973,839
	8	0.478	3.95E-02	1.568E-04	1.106E-02	1.568E-04	1.106E-02	0.07	0.0001	0.003	1,878	58,226	58,226
	9	0.626	6.30E-02	4.432E-04	1.711E-02	4.432E-04	1.711E-02	1.52	0.0042	0.141	81,205	2,436,144	2,436,144
	10	0.522	4.47E-03	3.251E-06	7.453E-04	3.251E-06	7.453E-04	0.76	0.0001	0.003	1,483	45,966	45,966
	11	0.360	2.61E-03	2.153E-06	3.896E-04	2.153E-06	3.896E-04	0.76	0.0000	0.001	534	16,029	16,029
	12	0.304	2.10E-03	1.754E-06	2.953E-04	1.754E-06	2.953E-04	0.76	0.0000	0.001	342	10,599	10,599

Table GB3.
Application of Simplified Primary Productivity Model to Green Bay for 1982.

Constant		Value	Units	Description
Umax	=	2.500	1/day	maximum algal growth rate (adjusted to "fit" empirical productivity results)
q_T	=	1.070	--	temperature correction for algal growth (Thomann and Mueller, 1982)
I_{sat}	=	100	Ly/day	saturation light intensity, GBEUTRO calibration (Bierman, et al., 1992)
K_{mp}	=	1.00	ug P/L	Michaelis constant for phosphorus limitation (Ambrose, et al., 1993)
K_{mn}	=	no 82 data	ug N/L	Michaelis constant for nitrogen limitation (Ambrose, et al., 1993)
f_{POC}	=	0.80	--	primary production efficiency factor (Bierman, et al., 1992)
CCHL	=	30.00	g C/g Chl-a	carbon to Chlorophyll-a ratio (Bierman, et al., 1992)
CBSS	=	0.40	g C/g BSS	carbon to biotic suspended solids conversion (Bierman, et al., 1992)

Green Bay Simplified Primary Productivity Model
Prediction Summary for 1982

Segment	Annual BIC Production (kg)
1	**1.125E+07**
2	**1.261E+07**
3	**6.134E+06**
4	**2.965E+07**
5	**5.668E+06**
6	**1.368E+07**
7	**6.191E+07**
8	**5.485E+07**
9	**2.187E+08**
10	**9.876E+04**
11	**4.908E+04**
12	**8.146E+06**
Total	**4.227E+08 kg BIC, or**
	1.057E+09 kg BSS

Table GB3.
Application of Simplified Primary Productivity Model to Green Bay for 1982.

Green Bay Segment	Month	Number of Days	SPP Model Factors					SPP Model Calculations				
			f (T) *temperature*	**a_0** *light*	**a_1** *light*	**f (L)** *light*	**f (N)** *nutrients*	**Chl-a (ug Chl-a/L)** *from VWA*	**dC/dt (ug Chl-a/L/day)**	**dC/dt (mg C/L/day)**	**Vol*dC/dt (kg C/day)**	**Mass BIC (kg)**
1												
	1	31	0.297	3.132	1.242E-02	0.176	0.918	6.12	0.59	0.0176	2,100	65,104
	2	28	0.300	4.340	1.651E-02	0.200	0.918	8.57	0.95	0.0284	3,388	94,864
	3	31	0.322	4.148	1.572E-02	0.223	0.918	8.79	1.16	0.0348	4,158	128,889
	4	30	0.429	6.221	2.037E-02	0.253	0.918	17.58	3.50	0.1051	12,564	376,909
	5	31	0.728	5.716	7.494E-03	0.250	0.830	11.63	3.51	0.1054	12,596	390,477
	6	30	0.972	8.398	7.561E-02	0.347	0.870	36.29	21.32	0.6396	76,430	2,292,910
	7	31	1.422	9.498	2.938E-04	0.166	0.919	70.66	30.56	0.9167	109,547	3,395,960
	8	31	1.250	9.483	1.055E-05	0.116	0.951	81.72	22.49	0.6746	80,618	2,499,159
	9	30	0.841	8.573	4.715E-05	0.116	0.931	77.06	13.93	0.4180	49,947	1,498,419
	10	31	0.498	5.785	1.851E-02	0.206	0.918	18.97	3.57	0.1071	12,802	396,869
	11	30	0.304	2.976	1.183E-02	0.180	0.918	5.96	0.60	0.0180	2,147	64,406
	12	31	0.297	2.359	9.585E-03	0.163	0.918	4.62	0.41	0.0123	1,469	45,552

Green Bay Segment	Month	Number of Days	SPP Model Factors					SPP Model Calculations				
			f (T) *temperature*	**a_0** *light*	**a_1** *light*	**f (L)** *light*	**f (N)** *nutrients*	**Chl-a (ug Chl-a/L)** *from VWA*	**dC/dt (ug Chl-a/L/day)**	**dC/dt (mg C/L/day)**	**Vol*dC/dt (kc C/day)**	**Mass BIC (kg)**
2												
	1	31	0.297	3.132	3.480E-03	0.144	0.899	4.81	0.37	0.0111	1,924	59,651
	2	28	0.300	4.340	4.581E-03	0.165	0.899	6.74	0.60	0.0180	3,112	87,146
	3	31	0.311	4.148	4.385E-03	0.184	0.899	6.69	0.69	0.0206	3,571	110,690
	4	30	0.381	6.221	5.669E-03	0.210	0.899	12.29	1.77	0.0530	9,181	275,429
	5	31	0.663	5.716	1.133E-01	0.381	0.761	8.49	3.27	0.0980	16,972	526,118
	6	30	0.936	8.398	4.655E-03	0.234	0.841	26.65	9.83	0.2949	51,077	1,532,301
	7	31	1.257	9.498	1.088E-02	0.251	0.877	44.26	24.49	0.7348	127,276	3,945,554
	8	31	1.192	9.483	3.970E-04	0.157	0.940	63.67	22.43	0.6729	116,554	3,613,169
	9	30	0.837	8.573	2.258E-04	0.133	0.929	62.28	12.86	0.3857	66,797	2,003,919
	10	31	0.493	5.785	4.935E-03	0.170	0.899	14.78	2.22	0.0666	11,542	357,805
	11	30	0.304	2.976	3.317E-03	0.148	0.899	4.69	0.38	0.0114	1,966	58,990
	12	31	0.297	2.359	2.704E-03	0.133	0.899	3.63	0.26	0.0078	1,344	41,668

Table GB3.
Application of Simplified Primary Productivity Model to Green Bay for 1982.

Green Bay Segment	Month	Number of Days	SPP Model Factors					SPP Model Calculations				
			f (T) *temperature*	a_0 *light*	a_1 *light*	f (L) *light*	f (N) *nutrients*	Chl-a (ug Chl-a/L) *from VWA*	dC/dt (ug Chl-a/L/day)	dC/dt (mg C/L/day)	Vol*dC/dt (kc C/day)	Mass BIC (kg)
3												
	1	31	0.297	3.132	2.974E-03	0.141	0.900	5.58	0.42	0.0126	1,255	38,894
	2	28	0.300	4.340	3.893E-03	0.161	0.900	7.83	0.68	0.0204	2,028	56,795
	3	31	0.311	4.148	3.727E-03	0.180	0.900	7.76	0.78	0.0234	2,327	72,139
	4	30	0.381	6.221	4.741E-03	0.205	0.900	14.26	2.01	0.0602	5,974	179,231
	5	31	0.663	5.716	1.574E-03	0.204	0.817	12.42	2.74	0.0823	8,170	253,256
	6	30	0.936	8.398	3.989E-03	0.230	0.843	27.15	9.85	0.2955	29,344	880,324
	7	31	1.257	9.498	4.365E-04	0.172	0.871	60.73	22.87	0.6860	68,131	2,112,069
	8	31	1.192	9.483	2.596E-06	0.105	0.939	70.94	16.67	0.5001	49,670	1,539,759
	9	30	0.837	8.573	7.554E-08	0.075	0.930	67.04	7.87	0.2362	23,454	703,627
	10	31	0.493	5.785	4.098E-03	0.165	0.900	17.15	2.52	0.0756	7,504	232,637
	11	30	0.304	2.976	2.836E-03	0.145	0.900	5.44	0.43	0.0129	1,282	38,464
	12	31	0.297	2.359	2.318E-03	0.130	0.900	4.21	0.29	0.0088	877	27,176

Green Bay Segment	Month	Number of Days	SPP Model Factors					SPP Model Calculations				
			f (T) *temperature*	a_0 *light*	a_1 *light*	f (L) *light*	f (N) *nutrients*	Chl-a (ug Chl-a/L) *from VWA*	dC/dt (ug Chl-a/L/day)	dC/dt (mg C/L/day)	Vol*dC/dt (kc C/day)	Mass BIC (kg)
4												
	1	31	0.297	3.132	4.079E-03	0.148	0.832	2.33	0.17	0.0051	5,145	159,485
	2	28	0.300	4.340	5.451E-03	0.169	0.832	3.26	0.27	0.0082	8,336	233,418
	3	31	0.308	4.148	5.222E-03	0.188	0.832	3.20	0.31	0.0093	9,373	290,572
	4	30	0.365	6.221	7.114E-03	0.217	0.832	5.69	0.75	0.0224	22,672	680,157
	5	31	0.602	5.716	1.021E-01	0.375	0.651	7.38	2.17	0.0651	65,840	2,041,049
	6	30	0.876	8.398	3.583E-03	0.227	0.832	14.21	4.69	0.1408	142,381	4,271,440
	7	31	1.083	9.498	6.114E-02	0.320	0.801	11.10	6.17	0.1850	187,071	5,799,198
	8	31	1.102	9.483	3.001E-03	0.196	0.890	27.14	10.45	0.3135	316,899	9,823,875
	9	30	0.839	8.573	9.285E-05	0.122	0.853	32.06	5.62	0.1685	170,331	5,109,926
	10	31	0.495	5.785	6.246E-03	0.175	0.832	7.17	1.03	0.0310	31,368	972,412
	11	30	0.304	2.976	3.884E-03	0.151	0.832	2.27	0.17	0.0052	5,257	157,700
	12	31	0.297	2.359	3.140E-03	0.136	0.832	1.76	0.12	0.0036	3,590	111,277

Table GB3.
Application of Simplified Primary Productivity Model to Green Bay for 1982.

Green Bay Segment	Month	Number of Days	SPP Model Factors					SPP Model Calculations				
			f (T) *temperature*	**a_0** *light*	**a_1** *light*	**f (L)** *light*	**f (N)** *nutrients*	**Chl-a (ug Chl-a/L)** *from VWA*	**dC/dt (ug Chl-a/L/day)**	**dC/dt (mg C/L/day)**	**Vol*dC/dt (kc C/day)**	**Mass BIC (kg)**
5												
	1	31	0.297	3.132	2.405E-03	0.137	0.874	3.38	0.24	0.0072	1,357	42,060
	2	28	0.300	4.340	3.174E-03	0.157	0.874	4.74	0.39	0.0117	2,197	61,508
	3	31	0.308	4.148	3.043E-03	0.175	0.874	4.65	0.44	0.0131	2,470	76,568
	4	30	0.365	6.221	4.007E-03	0.200	0.874	8.27	1.06	0.0317	5,958	178,749
	5	31	0.624	5.716	5.648E-05	0.145	0.722	12.72	1.66	0.0499	9,390	291,080
	6	30	0.891	8.398	2.882E-03	0.221	0.823	14.69	4.76	0.1427	26,833	804,998
	7	31	1.188	9.498	7.985E-05	0.147	0.847	36.65	10.84	0.3253	61,198	1,897,147
	8	31	1.183	9.483	1.719E-06	0.102	0.924	35.19	7.86	0.2358	44,354	1,374,983
	9	30	0.841	8.573	5.386E-10	0.060	0.906	40.27	3.65	0.1096	20,624	618,732
	10	31	0.491	5.785	3.457E-03	0.162	0.874	10.35	1.44	0.0431	8,116	251,606
	11	30	0.304	2.976	2.292E-03	0.140	0.874	3.29	0.25	0.0074	1,386	41,590
	12	31	0.297	2.359	1.866E-03	0.127	0.874	2.55	0.17	0.0050	947	29,361

Green Bay Segment	Month	Number of Days	SPP Model Factors					SPP Model Calculations				
			f (T) *temperature*	**a_0** *light*	**a_1** *light*	**f (L)** *light*	**f (N)** *nutrients*	**Chl-a (ug Chl-a/L)** *from VWA*	**dC/dt (ug Chl-a/L/day)**	**dC/dt (mg C/L/day)**	**Vol*dC/dt (kc C/day)**	**Mass BIC (kg)**
6												
	1	31	0.297	3.132	6.555E-04	0.116	0.823	2.35	0.13	0.0040	2,548	78,973
	2	28	0.300	4.340	8.675E-04	0.133	0.823	3.29	0.22	0.0065	4,132	115,709
	3	31	0.308	4.148	8.315E-04	0.148	0.823	3.23	0.24	0.0073	4,646	144,014
	4	30	0.365	6.221	1.104E-03	0.171	0.823	5.73	0.59	0.0176	11,255	337,643
	5	31	0.602	5.716	5.926E-05	0.146	0.677	9.40	1.12	0.0335	21,381	662,803
	6	30	0.876	8.398	1.086E-03	0.197	0.830	12.96	3.71	0.1114	71,084	2,132,514
	7	31	1.083	9.498	3.093E-03	0.213	0.813	18.74	7.05	0.2114	134,866	4,180,838
	8	31	1.102	9.483	4.092E-05	0.128	0.878	23.23	5.77	0.1732	110,511	3,425,829
	9	30	0.839	8.573	1.154E-06	0.088	0.824	28.28	3.46	0.1037	66,152	1,984,552
	10	31	0.495	5.785	9.541E-04	0.138	0.823	7.23	0.81	0.0244	15,561	482,392
	11	30	0.304	2.976	6.245E-04	0.119	0.823	2.28	0.14	0.0041	2,603	78,078
	12	31	0.297	2.359	5.076E-04	0.107	0.823	1.77	0.09	0.0028	1,776	55,064

Table GB3.
Application of Simplified Primary Productivity Model to Green Bay for 1982.

Green Bay Segment	Month	Number of Days	SPP Model Factors					SPP Model Calculations				
			f (T) *temperature*	a_0 *light*	a_1 *light*	f (L) *light*	f (N) *nutrients*	Chl-a (ug Chl-a/L) *from VWA*	dC/dt (ug Chl-a/L/day)	dC/dt (mg C/L/day)	Vol*dC/dt (kc C/day)	Mass BIC (kg)
7												
	1	31	0.297	3.132	3.585E-03	0.145	0.667	1.21	0.07	0.0021	13,973	433,167
	2	28	0.300	4.340	4.823E-03	0.166	0.667	1.69	0.11	0.0034	22,669	634,730
	3	31	0.306	4.148	4.621E-03	0.185	0.667	1.65	0.12	0.0037	25,146	779,533
	4	30	0.327	6.221	6.522E-03	0.214	0.667	2.65	0.25	0.0074	49,918	1,497,526
	5	31	0.459	5.716	1.142E-02	0.266	0.643	4.68	0.74	0.0221	148,461	4,602,287
	6	30	0.735	8.398	2.295E-03	0.215	0.699	5.04	1.11	0.0333	224,137	6,724,096
	7	31	0.917	9.498	2.325E-02	0.279	0.638	5.52	1.80	0.0541	363,795	11,277,654
	8	31	0.916	9.483	1.116E-02	0.233	0.702	9.92	2.97	0.0890	598,474	18,552,692
	9	30	0.768	8.573	1.360E-03	0.160	0.642	14.75	2.32	0.0697	468,561	14,056,818
	10	31	0.491	5.785	5.691E-03	0.173	0.667	3.69	0.42	0.0126	84,535	2,620,580
	11	30	0.304	2.976	3.412E-03	0.148	0.667	1.18	0.07	0.0021	14,276	428,280
	12	31	0.297	2.359	2.749E-03	0.134	0.667	0.91	0.05	0.0014	9,742	302,007

Green Bay Segment	Month	Number of Days	SPP Model Factors					SPP Model Calculations				
			f (T) *temperature*	a_0 *light*	a_1 *light*	f (L) *light*	f (N) *nutrients*	Chl-a (ug Chl-a/L) *from VWA*	dC/dt (ug Chl-a/L/day)	dC/dt (mg C/L/day)	Vol*dC/dt (kc C/day)	Mass BIC (kg)
8												
	1	31	0.297	3.132	9.509E-04	0.122	0.663	1.14	0.05	0.0016	11,832	366,803
	2	28	0.300	4.340	1.272E-03	0.139	0.663	1.60	0.09	0.0027	19,213	537,960
	3	31	0.306	4.148	1.220E-03	0.155	0.663	1.56	0.10	0.0029	21,309	660,591
	4	30	0.327	6.221	1.702E-03	0.180	0.663	2.50	0.19	0.0058	42,363	1,270,880
	5	31	0.459	5.716	1.016E-04	0.153	0.669	4.04	0.38	0.0114	82,593	2,560,372
	6	30	0.735	8.398	4.924E-03	0.236	0.646	4.05	0.91	0.0272	197,322	5,919,661
	7	31	0.917	9.498	8.825E-03	0.244	0.664	6.96	2.07	0.0621	450,076	13,952,371
	8	31	0.916	9.483	1.447E-03	0.180	0.690	8.76	2.00	0.0599	434,153	13,458,733
	9	30	0.768	8.573	7.549E-04	0.150	0.639	13.84	2.04	0.0611	442,588	13,277,650
	10	31	0.491	5.785	1.468E-03	0.145	0.663	3.48	0.33	0.0099	71,704	2,222,829
	11	30	0.304	2.976	9.054E-04	0.124	0.663	1.11	0.06	0.0017	12,087	362,623
	12	31	0.297	2.359	7.315E-04	0.112	0.663	0.86	0.04	0.0011	8,245	255,596

Table GB3.
Application of Simplified Primary Productivity Model to Green Bay for 1982.

Green Bay Segment	Month	Number of Days	SPP Model Factors					SPP Model Calculations				
			f (T) *temperature*	a_0 *light*	a_1 *light*	f (L) *light*	f (N) *nutrients*	Chl-a (ug Chl-a/L) *from VWA*	dC/dt (ug Chl-a/L/day)	dC/dt (mg C/L/day)	Vol*dC/dt (kc C/day)	Mass BIC (kg)
9												
	1	31	0.297	3.132	2.741E-03	0.140	0.633	0.86	0.05	0.0014	40,543	1,256,832
	2	28	0.300	4.340	3.705E-03	0.160	0.633	1.21	0.07	0.0022	65,845	1,843,651
	3	31	0.306	4.148	3.549E-03	0.178	0.633	1.18	0.08	0.0024	73,032	2,263,991
	4	30	0.327	6.221	5.057E-03	0.207	0.633	1.89	0.16	0.0049	145,274	4,358,220
	5	31	0.421	5.716	5.291E-03	0.238	0.603	2.73	0.33	0.0099	295,598	9,163,549
	6	30	0.638	8.398	1.526E-02	0.275	0.617	2.73	0.59	0.0178	531,284	15,938,529
	7	31	0.894	9.498	3.230E-01	0.368	0.534	2.31	0.81	0.0244	727,112	22,540,476
	8	31	0.959	9.483	3.948E-02	0.278	0.585	3.84	1.20	0.0360	1,073,821	33,288,464
	9	30	0.718	8.573	6.295E-02	0.267	0.745	15.41	4.41	0.1323	3,949,894	118,496,814
	10	31	0.483	5.785	4.471E-03	0.167	0.633	2.60	0.27	0.0080	238,297	7,387,208
	11	30	0.304	2.976	2.608E-03	0.143	0.633	0.84	0.05	0.0014	41,418	1,242,542
	12	31	0.297	2.359	2.096E-03	0.129	0.633	0.65	0.03	0.0009	28,248	875,685

Green Bay Segment	Month	Number of Days	SPP Model Factors					SPP Model Calculations				
			f (T) *temperature*	a_0 *light*	a_1 *light*	f (L) *light*	f (N) *nutrients*	Chl-a (ug Chl-a/L) *from VWA*	dC/dt (ug Chl-a/L/day)	dC/dt (mg C/L/day)	Vol*dC/dt (kc C/day)	Mass BIC (kg)
10												
	1	31	0.340	3.585E-03	2.102E-05	7.136E-04	0.671	1.47	0.00	1.434E-05	30	927
	2	28	0.348	4.823E-03	2.765E-05	1.066E-03	0.671	2.08	0.00	3.104E-05	65	1,812
	3	31	0.355	4.621E-03	2.654E-05	1.141E-03	0.671	2.03	0.00	3.308E-05	69	2,138
	4	30	0.369	6.522E-03	3.578E-05	1.838E-03	0.671	3.16	0.00	8.611E-05	180	5,386
	5	31	0.412	1.142E-02	1.022E-04	4.007E-03	0.789	6.55	0.02	5.118E-04	1,067	33,083
	6	30	0.501	2.295E-03	4.540E-06	6.488E-04	0.640	3.96	0.00	4.939E-05	103	3,089
	7	31	0.504	2.325E-02	2.426E-04	8.567E-03	0.579	2.77	0.01	4.151E-04	866	26,831
	8	31	0.478	1.116E-02	6.683E-05	3.418E-03	0.645	2.88	0.01	1.825E-04	380	11,795
	9	30	0.626	1.360E-03	1.780E-06	2.862E-04	0.596	12.49	0.00	8.004E-05	167	5,006
	10	31	0.522	5.691E-03	2.974E-05	1.298E-03	0.671	4.16	0.00	1.135E-04	237	7,337
	11	30	0.360	3.412E-03	2.003E-05	7.005E-04	0.671	1.47	0.00	1.497E-05	31	936
	12	31	0.304	2.749E-03	1.634E-05	5.324E-04	0.671	0.99	0.00	6.431E-06	13	416

Table GB3.
Application of Simplified Primary Productivity Model to Green Bay for 1982.

Green Bay Segment	Month	Number of Days	SPP Model Factors					SPP Model Calculations				
			f (T) *temperature*	**a_0** *light*	**a_1** *light*	**f (L)** *light*	**f (N)** *nutrients*	**Chl-a (ug Chl-a/L)** *from VWA*	**dC/dt (ug Chl-a/L/day)**	**dC/dt (mg C/L/day)**	**Vol*dC/dt (kc C/day)**	**Mass BIC (kg)**
11												
	1	31	0.340	9.509E-04	7.630E-07	1.373E-04	0.687	1.50	0.00	2.885E-06	13	389
	2	28	0.348	1.272E-03	9.901E-07	2.041E-04	0.687	2.12	0.00	6.214E-06	27	756
	3	31	0.355	1.220E-03	9.516E-07	2.186E-04	0.687	2.07	0.00	6.625E-06	29	893
	4	30	0.369	1.702E-03	1.247E-06	3.484E-04	0.687	3.22	0.00	1.706E-05	74	2,225
	5	31	0.412	1.016E-04	6.712E-09	1.772E-05	0.811	6.29	0.00	2.235E-06	10	301
	6	30	0.501	4.924E-03	7.051E-06	1.322E-03	0.610	4.68	0.00	1.132E-04	492	14,768
	7	31	0.504	8.825E-03	1.895E-05	2.453E-03	0.636	3.07	0.00	1.448E-04	629	19,511
	8	31	0.478	1.447E-03	6.342E-07	2.965E-04	0.681	3.16	0.00	1.835E-05	80	2,473
	9	30	0.626	7.549E-04	2.038E-07	1.285E-04	0.554	12.05	0.00	3.220E-05	140	4,200
	10	31	0.522	1.468E-03	1.006E-06	2.430E-04	0.687	4.25	0.00	2.222E-05	97	2,994
	11	30	0.360	9.054E-04	7.280E-07	1.349E-04	0.687	1.51	0.00	3.012E-06	13	393
	12	31	0.304	7.315E-04	5.981E-07	1.028E-04	0.687	1.01	0.00	1.298E-06	6	175

Green Bay Segment	Month	Number of Days	SPP Model Factors					SPP Model Calculations				
			f (T) *temperature*	**a_0** *light*	**a_1** *light*	**f (L)** *light*	**f (N)** *nutrients*	**Chl-a (ug Chl-a/L)** *from VWA*	**dC/dt (ug Chl-a/L/day)**	**dC/dt (mg C/L/day)**	**Vol*dC/dt (kc C/day)**	**Mass BIC (kg)**
12												
	1	31	0.340	2.741E-03	2.259E-06	3.971E-04	0.656	1.44	0.00	7.670E-06	147	4,560
	2	28	0.348	3.705E-03	2.978E-06	5.962E-04	0.656	2.04	0.00	1.669E-05	320	8,965
	3	31	0.355	3.549E-03	2.858E-06	6.381E-04	0.656	1.99	0.00	1.778E-05	341	10,573
	4	30	0.369	5.057E-03	3.869E-06	1.040E-03	0.656	3.10	0.00	4.681E-05	898	26,934
	5	31	0.412	5.291E-03	4.615E-06	1.257E-03	0.755	4.79	0.00	1.125E-04	2,157	66,866
	6	30	0.501	1.526E-02	2.629E-05	4.195E-03	0.597	3.10	0.01	2.332E-04	4,473	134,198
	7	31	0.504	3.230E-01	1.067E-02	1.338E-01	0.508	2.79	0.19	5.726E-03	109,822	3,404,493
	8	31	0.478	3.948E-02	1.568E-04	1.106E-02	0.503	2.03	0.01	3.246E-04	6,227	193,024
	9	30	0.626	6.295E-02	4.432E-04	1.711E-02	0.745	15.46	0.25	7.391E-03	141,752	4,252,556
	10	31	0.522	4.471E-03	3.251E-06	7.453E-04	0.656	4.09	0.00	6.264E-05	1,201	37,246
	11	30	0.360	2.608E-03	2.153E-06	3.896E-04	0.656	1.45	0.00	8.003E-06	153	4,605
	12	31	0.304	2.096E-03	1.754E-06	2.953E-04	0.656	0.97	0.00	3.428E-06	66	2,038

APPENDIX D

TABLES OF MONTHLY VALUES SCALED TO PHOSPHORUS LOADS

These data can be found in MS Excel files gb_bic.xls and lf_bss2.xls

that are included in the file: TM2c Internal Solids.zip

APPENDIX E

Uncertainty Estimates Using Crystal Ball

GREEN BAY MONTE CARLO ANALYSIS - Biotic Carbon (BIC)

SEGMENT 1: **Sep-82**

Empirical BIC Mass (Green Bay - Seg 1) **1.07E+06 kilograms**

Input Parameters:	Value	Units	Expected Min Value:	Expected Max Value:	Standard Deviation	Standard Error	MC Distribution
GPP	11.12	$mg\text{-}O_2/L/d$	5.739	14.27	2.023	0.369	normal
Volume	1.195E+08	m^3	1.195E+08	1.195E+08		0	
TEMP	18.39	^oC	15.80	22.40	1.35		normal
K_e	4.46	m^{-1}	*3*	*5.5*			triangle
d	2.72	m	2.72	2.72		0	
# Days	30	days	30	30		0	
THETA_T	1.07	- - -	1.06	1.08			triangular
PHOTO	0.52	- - -	0.48	0.55			triangular
I_o	441.50	Ly/day	300	500			triangular
I_{sat}	100	Ly/day	50	200			triangular
fPOC	0.8	- - -	0.6	0.9			triangular
PNH3	0.5		0.25	0.75			triangular
NCRB	0.25		0.2	0.3			triangular
O2CRB	3.10	$mg\text{-}O_2/mg\text{-}C$	2.67	3.52			
TLX	0.99	- - -	0.99	0.99			

$MASS_{bic}$ = #Days * VOL * GPPC / 1000

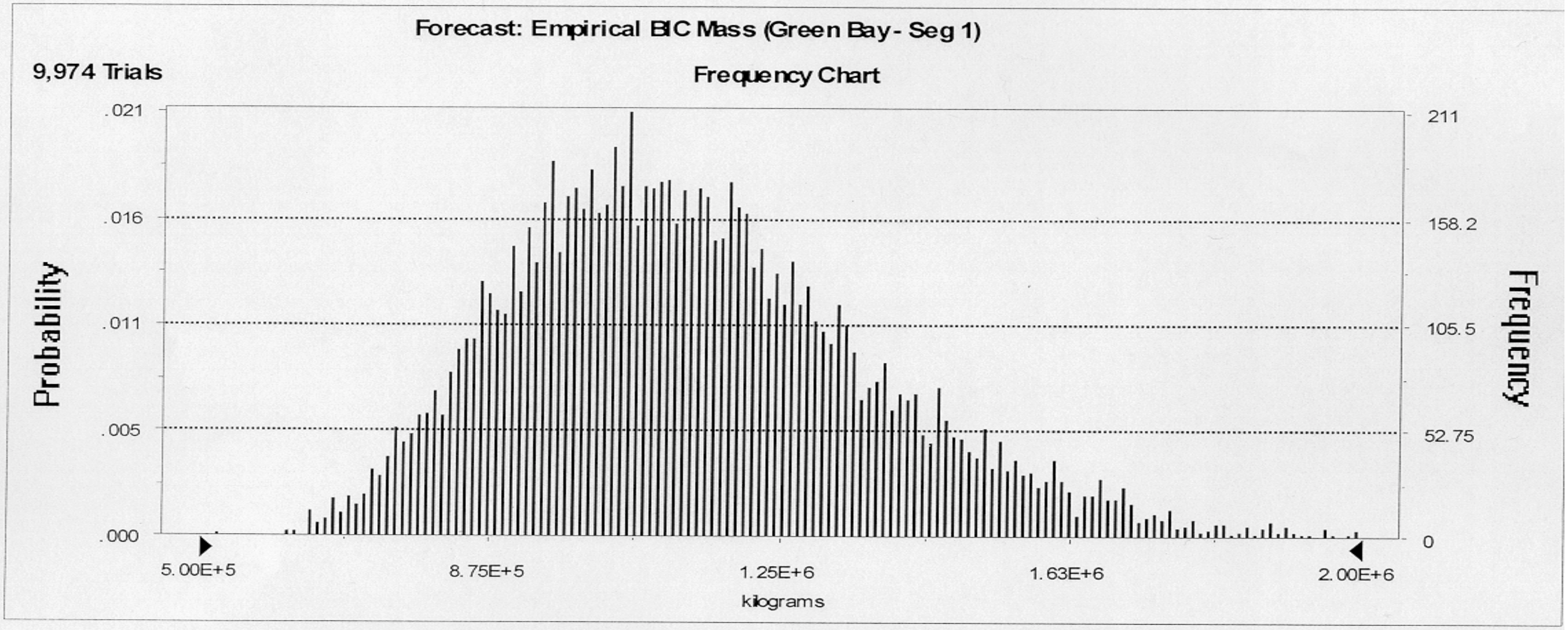
$= \#Days * VOL * GPP * fPOC * THETA\_T^{(TEMP-20)} * 2.718 * PHOTO * [e^{[-Io/(Isat * PHOTO)]exp(-Ke * d)} - e^{-Io/(Isat * PHOTO)}] / d / K_e / O2CRB / TLX / 1000$

O2CRB = PHN3 * 32/12 + (1 - PHN3) * 32 * (1/12 + 1.5 * NCRB/14)

TLX = $(89.77 / I_{sat}) * EXP(-89.77 / I_{sat} + 1)$

Crystal Ball Report
Simulation started on 12/28/98 at 14:09:28
Simulation stopped on 12/28/98 at 14:12:24

Forecast: Empirical BIC Mass (Green Bay - Seg 1) **Cell: C4**



GREEN BAY MONTE CARLO ANALYSIS - Biotic Carbon (BIC)

SEGMENT 6: Sep-82

Empirical BIC Mass (Green Bay - Seg 6) **1.09E+06 kilograms**

Input Parameters:	Value	Units	Expected Min Value:	Expected Max Value:	Standard Deviation	Standard Error	MC Distribution
GPP	2.79	$mg\text{-}O_2/L/d$	1	4.535		0.342	normal
Volume	6.379E+08	m^3	6.379E+08	6.379E+08		0	
TEMP	17.90	°C	16.22	19.17	1.25		normal
K_e	1.94	m^{-1}	1	3			triangle
d	7.97	m	7.97	7.97		0	
# Days	30	days	30	30		0	
THETA_T	1.07	- - -	1.06	1.08			triangular
PHOTO	0.52	- - -	0.48	0.55			triangular
I_o	441.50	Ly/day	300	500			triangular
I_{sat}	100	Ly/day	50	200			triangular
fPOC	0.8	- - -	0.6	0.9			triangular
PNH3	0.5		0.25	0.75			triangular
NCRB	0.25		0.2	0.3			triangular
O2CRB	3.10	$mg\text{-}O_2/mg\text{-}C$	2.67	3.52			
TLX	0.99	- - -	0.99	0.99			

$MASS_{bic}$ = #Days * VOL * GPPC / 1000

$= \#Days * VOL * GPP * fPOC * THETA\_T^{(TEMP-20)} * 2.718 * PHOTO * [e^{[-Io/(Isat * PHOTO)]exp(-Ke * d)} - e^{-Io/(Isat * PHOTO)}] / d / K_e / O2CRB / TLX / 1000$

O2CRB = PHN3 * 32/12 + (1 - PHN3) * 32 * (1/12 + 1.5 * NCRB/14)

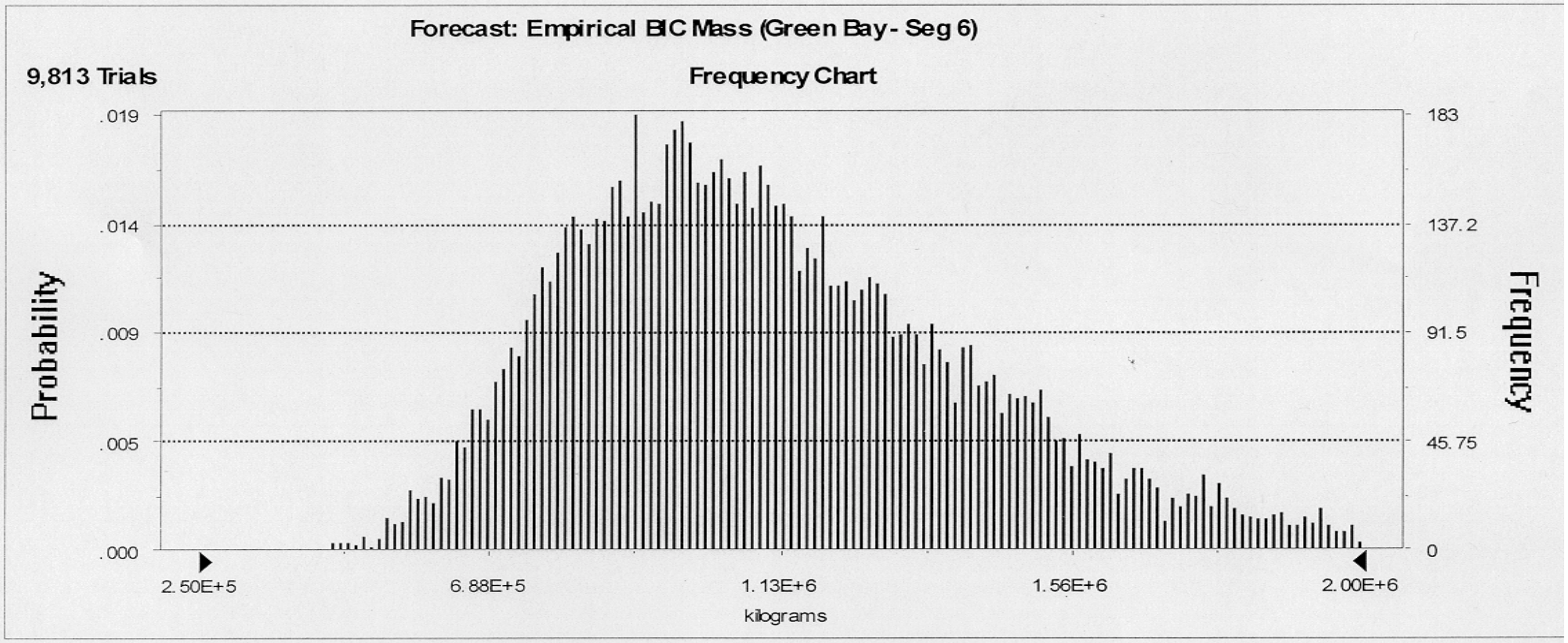
TLX = $(89.77 / I_{sat}) * EXP(-89.77 / I_{sat} + 1)$

Crystal Ball Report

Simulation started on 12/28/98 at 15:07:06

Simulation stopped on 12/28/98 at 15:10:23

Forecast: Empirical BIC Mass (Green Bay - Seg 6) **Cell: C4**



GREEN BAY MONTE CARLO ANALYSIS - Biotic Carbon (BIC)
SEGMENT 8: Sep-82

Empirical BIC Mass (Green Bay - Seg 8) **9.81E+06 kilograms**

Input Parameters:	Value	Units	Expected Min Value:	Expected Max Value:	Standard Deviation	Standard Error	MC Distribution
GPP	1.49	mg-O_2/L/d	0.274	2.975		0.154	normal
Volume	7.248E+09	m^3	7.248E+09	7.248E+09		0	
TEMP	16.50	^oC	14.47	18.10	1.15		normal
K_e	0.76	m^{-1}	0.5	1.5			triangle
d	12.50	m	12.50	12.50		0	
# Days	30	days	30	30		0	
THETA_T	1.07	- - -	1.06	1.08			triangular
PHOTO	0.52	- - -	0.48	0.55			triangular
I_o	441.50	Ly/day	300	500			triangular
I_{sat}	100	Ly/day	50	200			triangular
fPOC	0.8	- - -	0.6	0.9			triangular
PNH3	0.5		0.25	0.75			triangular
NCRB	0.25		0.2	0.3			triangular
O2CRB	3.10	mg-O_2/mg-C	2.67	3.52			
TLX	0.99	- - -	0.99	0.99			

$MASS_{bic}$ = #Days * VOL * GPPC / 1000

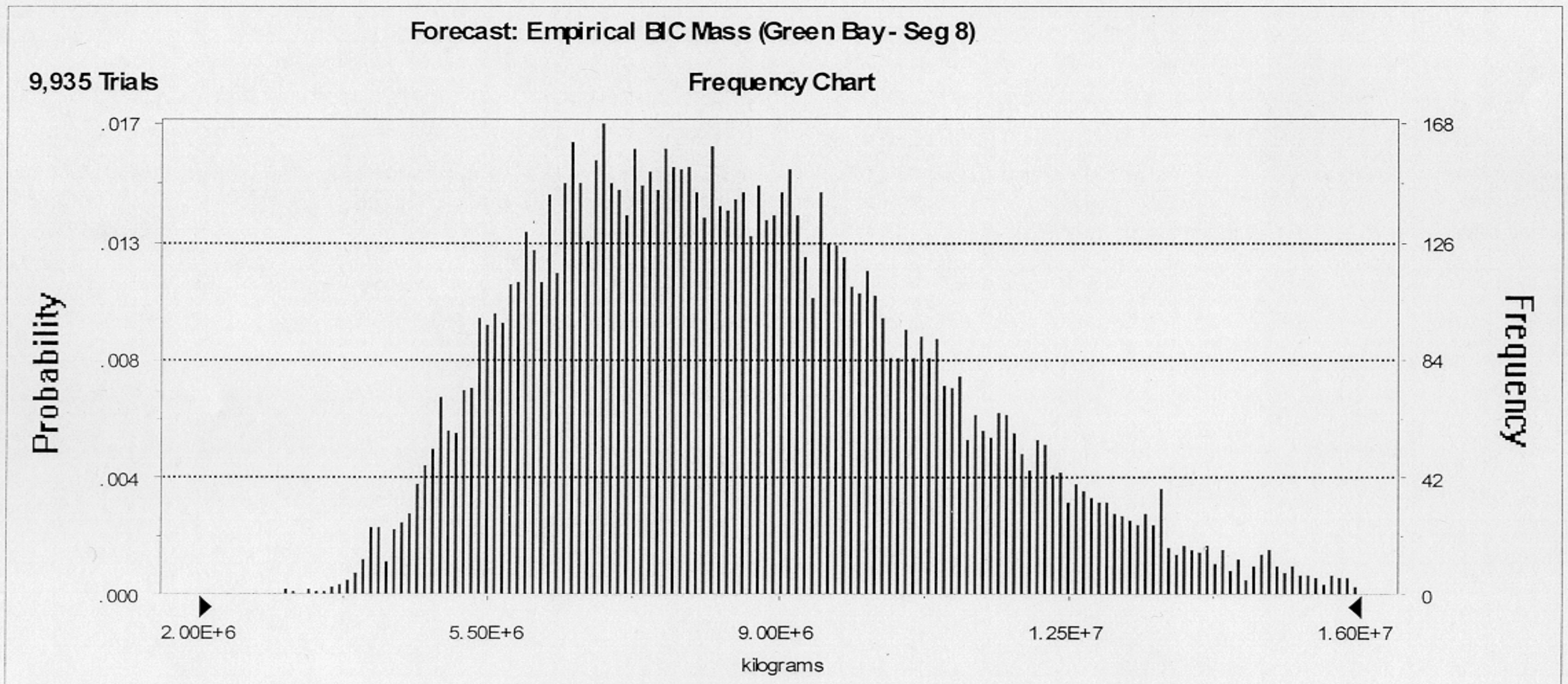
$= \#Days * VOL * GPP * fPOC * THETA\_T^{(TEMP-20)} * 2.718 * PHOTO * [e^{[-Io/(Isat * PHOTO)]exp(-Ke * d)} - e^{-Io/(Isat * PHOTO)}] / d / K_e / O2CRB / TLX / 1000$

O2CRB = PHN3 * 32/12 + (1 - PHN3) * 32 * (1/12 + 1.5 * NCRB/14)

TLX = $(89.77 / I_{sat}) * EXP(-89.77 / I_{sat} + 1)$

Crystal Ball Report
Simulation started on 12/28/98 at 15:24:39
Simulation stopped on 12/28/98 at 15:27:57

Forecast: Empirical BIC Mass (Green Bay - Seg 8) **Cell: C4**



UPPER FOX MONTE CARLO ANALYSIS - Biotic Suspended Solids (BSS)

July 1989

BSS Mass (Upper Fox) 4.78E+06 kilograms

Input Parameters:		Units	Expected Min Value:	Expected Max Value:	Mean	Standard Deviation	Standard Error	MC Distribution
Umax	2.50	1/day	2	3				triangle
Volume	3.324E+07	m^3						
TEMP	26.50	°C	7.00	29.00	21.37	4.19		normal
K_e	3.31	m^{-1}	2	6.5	3.33	0.68		lognormal
d	2.01	m					0	
# Days	31	days					0	
THETA_T	1.07	- - -	1.06	1.08				triangular
PHOTO	0.63	- - -	0.6	0.65				triangular
I_o	631	Ly/day	100	875				triangular
I_{sat}	100	Ly/day	50	200				triangular
fPOC	0.8	- - -	0.6	0.9				triangular
Chl-a	112	ug/l	21.5	225	102.2	43.06		lognormal
CBSS	0.4	g-carbon/g-bss	0.3	0.5				triangular
SRP	4.625	ug-P/L	3	710	24.05	32.79		lognormal
Kmp	2	ug-P/L	1	3				triangular
DIN	115	ug-N/L	19	2333	101.11	149.53		lognormal
Kmn	20	ug-N/L	10	30				triangular
CCHL	30	g-carbon/g-chl-a	20	50				triangular

$MASS_{bss}$ = Umax * #Days * VOL * fPOC * THETA_T$^{(TEMP-20)}$ * 2.718 * PHOTO * [$e^{[-Io/(Isat * PHOTO)]exp(-Ke * d)}$ - $e^{-Io/(Isat * PHOTO)}$] * Chl-a * CCHL * [min{SRP/(SRP + Kmp) , DIN/(DIN + Kmn)}] / d / K_e / CBSS / 1000000

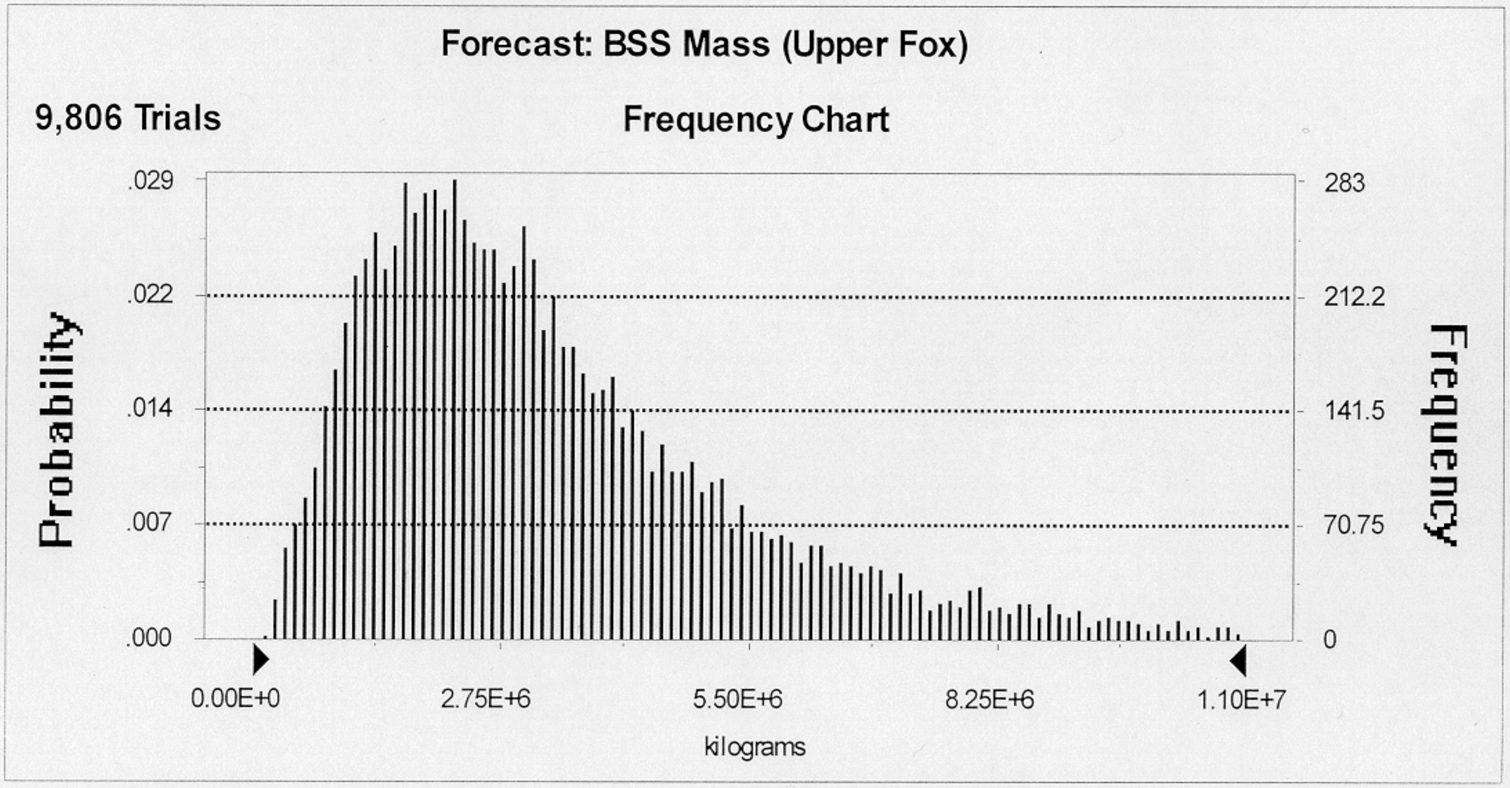
	constant
	triangular distribution
	normal distribution
	lognormal

Crystal Ball Report

Simulation started on 1/4/99 at 16:30:14

Simulation stopped on 1/4/99 at 16:34:38

Forecast: BSS Mass (Upper Fox) **Cell: C4**



LOWER FOX MONTE CARLO ANALYSIS - Biotic Suspended Solids (BSS)

July 1989

BSS Mass (Lower Fox) **9.53E+05 kilograms**

Input Parameters:		Units	Expected Min Value:	Expected Max Value:	Standard Deviation	Standard Error	MC Distribution
Umax	2.50	1/day	2	3			triangular
Volume	1.898E+07	m^3					
TEMP	25.08	^oC	13.50	28.20	1.35		normal
K_e	4.25	m^{-1}	1.1	6.9			lognormal
d	4.51	m				0	
# Days	31	days				0	
THETA_T	1.07	- - -	1.06	1.08			triangular
PHOTO	0.63	- - -	0.6	0.65			triangular
I_o	631	Ly/day	100	875			triangular
I_{sat}	100	Ly/day	50	200			triangular
fPOC	0.8	- - -	0.6	0.9			triangular
Chl-a	113	ug/l	23	337			normal
CBSS	0.4	g-carbon/g-bss	0.3	0.5			triangular
SRP	6.15	ug-P/L	2	230			lognormal
Kmp	2	ug-P/L	1	3			triangular
DIN	262.97	ug-N/L	19.75	2333			lognormal
Kmn	20	ug-N/L	10	30			triangular
CCHL	30	g-carbon/g-chl-a	20	50			triangular

$MASS_{bss}$ = Umax * #Days * VOL * fPOC * THETA_T$^{(TEMP-20)}$ * 2.718 * PHOTO * [$e^{[-Io/(Isat * PHOTO)]exp(-Ke * d)}$ - $e^{-Io/(Isat * PHOTO)}$] * Chl-a * CCHL * [min{SRP/(SRP + Kmp) , DIN/(DIN + Kmn)}] / d / K_e / CBSS / 1000000

(yellow)	constant
(grey)	triangular distribution
(cyan)	normal distribution
(magenta)	lognormal

Crystal Ball Report
Simulation started on 1/5/99 at 11:43:01
Simulation stopped on 1/5/99 at 11:50:22

Forecast: BSS Mass (Lower Fox)