SIMPLIFIED MODEL FOR POLYCHLORINATED BIPHENYLS (PCBS) IN GREEN BAY, LAKE MICHIGAN

BY

WASIF M. MOHAMMAD

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Scott C. Martin 11/2/92
Advisor Date

Sally M. Hotchkiss November 13, 1992
Dean of the Graduate School Date

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ABSTRACT

SIMPLIFIED MODEL FOR POLYCHLORINATED BIPHENYLS (PCBS) IN GREEN BAY, LAKE MICHIGAN

Wasif M. Mohammad
Master of Science in Civil Engineering
Youngstown State University, 1992

A user - friendly microcomputer model, STOXGB (Simplified Toxic Substance Model for Green Bay) was developed and then applied to simulate the time varying fate of polychlorinated biphenyls (PCBs) in Green Bay, Lake Michigan, over the period 1940-1989. The STOXGB model, based on the Thomann and Mueller (1987) suspended and toxic substance models, includes loadings and partitioning of the contaminants between the phases of air, water, suspended and bottom sediments. Expressions for horizontal and vertical transport rates for diffusion between water and sediments, dry atmospheric deposition, volatilization, sediment deposition, burial and resuspension, and water and suspended matter inflow and outflow are also included in the model. Initial model inputs were developed by averaging calibrated parameter values from the more complex GBTOX model (Bierman <u>et al</u>., 1992). Despite uncertainties in the loadings of POC (particulate organic carbon) and PCBs and the simplified dynamics of the model, the results show appreciable comparability to available field data for 1989.

The model was also used to explore four different managerial scenarios, corresponding to different future loading assumptions for POC and PCBs. The model predicts that, under 50% and 100% PCB loading reductions, dramatic improvements will occur in Green Bay within the next 50 years. The predicted response is most rapid for water column and inner bay segments. Further studies are recommended to identify historical loading trends of POC and PCBs to Green Bay for the period of 1940 to the present.

TO MY FAMILY.....

I do not know where I would be without my family, especially my parents, whose endless support enabled me to finish this work. To my three sisters, Noormah, Nadeema, and Najeeba and two brothers, Wamiq and Majid. I could not have done it without you guys. My uncle in New York, thank you so very much for many things you did for me during my stay in the United States.

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CHAPTER I

INTRODUCTION

Environmental fate models in the form of long term mass balances of contaminants in large water bodies can play an invaluable role in enhancing our understanding of how lakes and their biota become contaminated, how long a system may take to respond to input changes, and how different sources, such as tributaries and atmospheric deposition, contribute to the total burden of contamination (Modeling Task Force, 1987).

These models bring together expressions for different kinds of processes to create a complete description of the chemical in the system over time. They may also uncover the important processes, suggest a monitoring approach, and identify sensitivities. Overall, models provide a mass balance of the contaminant (Bierman et al., 1992).

The U.S. Environmental Protection Agency (1989) has developed a comprehensive plan for modeling toxic substances in Green Bay, Lake Michigan. The ultimate goal of the Green Bay Mass Balance Study is to develop and validate a modeling framework to improve the understanding of sources, transport and fate of toxic chemicals. The major objective is to develop an overall model to quantify the relationship between source inputs of toxic chemicals and their concentrations in water, sediments and biota. This model will be used to predict responses of the bay to different regulatory and remedial action scenarios. The purpose of this thesis project was to perform additional analysis of the data and modeling results from the USEPA (1989) study.

1.1 Historical Background on Green Bay and PCBs

Green Bay is an elongated arm of Lake Michigan partially separated from the lake by the Door County Peninsula (Figure 1-1). The bay is oriented in a northeast-southwest direction and is 119 miles long with a maximum width of 23 miles. The depth of the bay averages 10-15 feet in the inner portion (southwest end) to 120 feet at its deepest point in the outer portion (Bierman et al., 1992).

Water quality conditions in Green Bay from the 1920s through the 1970s were characterized by fish kills, periodic lack of dissolved oxygen, and the increasing dominance of pollution-tolerant organisms. Dramatic improvements in dissolved oxygen occurred over the period 1972 to 1985 following the expenditure of over $300 million in pollution controls to reduce discharges of biological oxygen demand (BOD) from point sources (Bierman et al., 1992).

The Lower Fox River below the Depere Dam (the last of 12 dams on the Lower Fox River, located seven miles upstream from Green Bay) and Lower Green Bay have been designated by the International Joint Commission as an Area of Concern due to water quality problems that limit certain beneficial uses. These problems include (1) biota and habitat; (2) toxic substances; and (3) nutrients and eutrophication. In

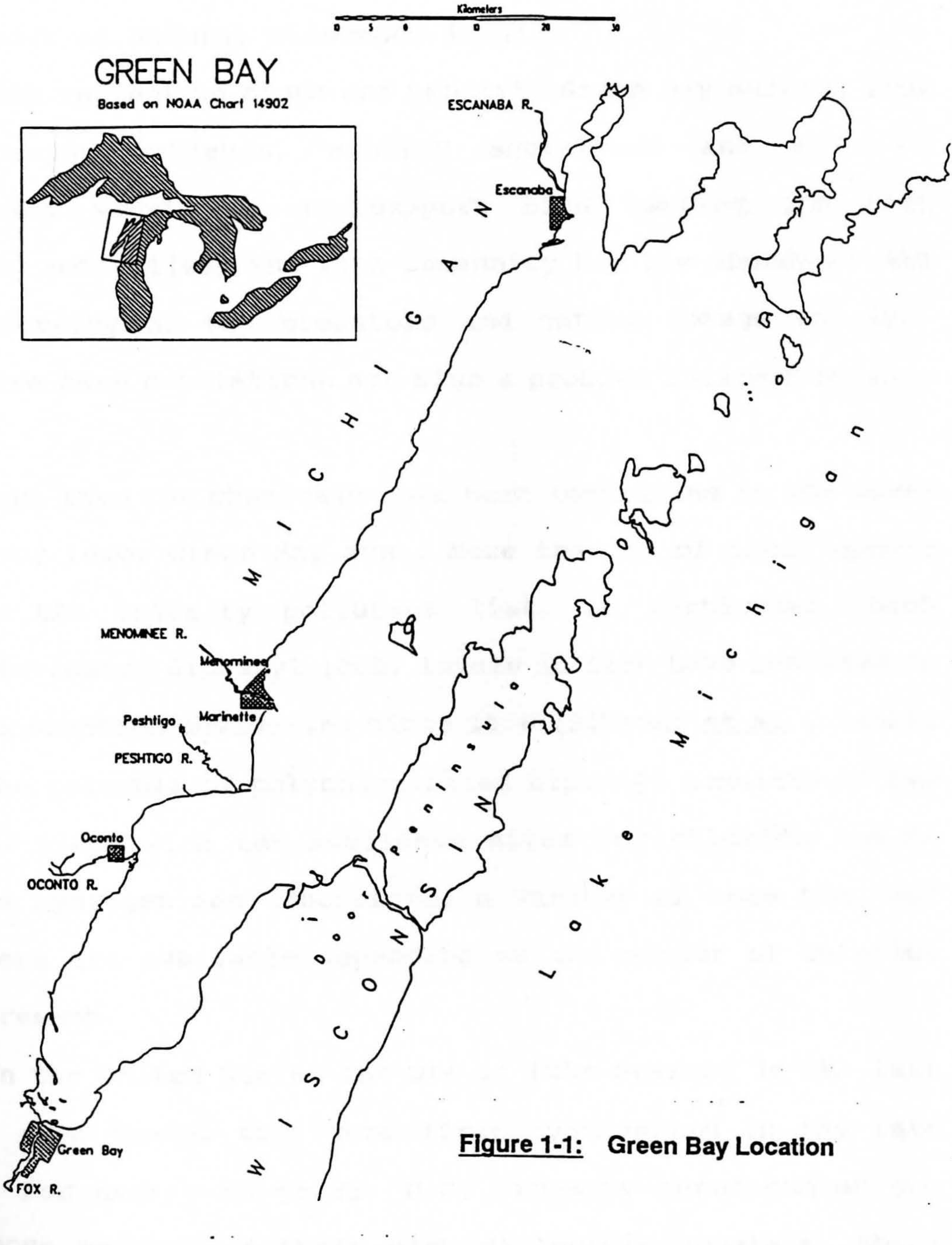


Figure 1-1: Green Bay Location

particular, the potential human health risk associated with toxic substances was one of the primary reasons for development of a Remedial Action Plan for the area (Wisconsin Department of Natural Resources 1988).

With respect to biota and habitat, Green Bay suffers from disappearing wetlands, eroding shorelines and lack of underwater vegetation to support bird nesting and fish spawning activities. The fish community has low abundance and low diversity of top predators and native forage species. Excessive carp populations are also a problem (Bierman et al., 1992).

More than 100 chemicals have been identified in the Lower Fox River Lower Green Bay area. More than 20 of these appear on the EPA priority pollutant list. In particular, high Polychlorinated Biphenyl (PCB) levels in fish have resulted in fish consumption advisories since 1976 (Bierman et al., 1992).

The molecule of polychlorinated biphenyl consists of two Benzene rings with ten available sites for chloride ion to replace hydrogen ion. Therefore, a variety of more than 200 congeners are available depending on the number of chloride ions present.

In the United States the use of PCBs started in the late 1920s, even though they were first synthesized in the late 1800s. For nearly 50 years, U.S. industry manufactured and used PCBs because of their high dielectric constant, their high chemical and thermal stability, their non-flammability, and low production cost. Some of these same characteristics which make PCBs industrially desirable also render them persistent in nature, and enable their environmental accumulation (Rodgers and Swain 1983).

The Great Lakes have been contaminated by PCBs since the mid-1950s (Neidermeyer and Hickey 1976, Eisenreich et al. 1983). Because of the persistent existence of PCBs in the environment, and their adverse effects on human health, in 1971 the United States took a firm step to minimize the production and use of PCBs. Finally, in 1977 all U.S. production of PCBs ceased, but there remained a legacy of more than $6x10^5$ metric tons of PCBs having been produced, and the majority was presumably used in the United States (Zimmerman 1982). Because the Great Lakes have exaggerated hydraulic retention times, their large surface area to drainage basin ratios, extreme depth, generally low suspended sediment load per unit volume, and distinctive biological characteristics, they are particularly susceptible to organohalide compounds such as PCB (Sonzogni and Swain 1980). Atmospheric transport of PCBs has been suggested as a major, if not the primary, source of PCBs to Lake Michigan (Rodgers and Swain 1983).

1.2 Description of 1989-90 PCBs Study of Green Bay

The Green Bay Mass Balance Study (GBMBS) was intended to provide information to aid and support regulatory activities. However, its main goals were to:

(1) carry out a detailed mass balance of Great Lakes toxic substances, notably individual PCB compounds

or congeners in Green Bay, and

(2) based on the mass balance data, apply predictive tools that will allow resource managers to evaluate the impact of management decisions.

The GBMBS will serve as a pilot for future modeling studies of Great Lakes ecosystems. The Green Bay Project has engaged numerous investigators involved in project design, field collection, analysis and processing of data, quality assurance, data management and modeling activities. The project was coordinated by the USEPA Great Lakes National Program Office (GLNPO), Chicago, Illinois. Modeling activities were facilitated by the USEPA Large Lakes Research Station (Bierman et al., 1992).

The water quality data used in the GBMBS fell into two broad categories: **historical field data** and **program-generated field data.** Historical data were restricted primarily to conventional constituents, while program-generated data consisted of both conventional constituents and toxic chemicals. Most of the program-generated data were acquired during field sampling cruises conducted in the Lower Fox River and Green Bay between April 1989 and April 1990. The principal historical data used were acquired in 1982 (Auer 198?).

The overall objective of the GBMBS modeling work was to quantify the relationships between external source inputs of solids, nutrients and toxic chemicals and concentration distributions of these constituents in the water column and sediments for Green Bay. The conceptual approach used to accomplish this objective is shown in Figure 1-2. A series of models was developed and applied to describe, respectively, the hydraulics, particle dynamics and toxic chemical dynamics in Green Bay (Bierman et al. 1992).

1.3 Objective of the Study

The main objective of this study is to develop and calibrate a much simpler model for toxic substances in Green Bay (STOXGB) to quantify the relationship between source inputs of particulate organic carbon (POC) and polychlorinated biphenyl (PCBs) and their concentrations in water column and bottom sediment of Green Bay.

The development of this model is based on the work done by Thomann and Mueller (1987) for the Suspended Substances Model and the Toxic Substances Model.

The study also included the following aspects:

(1) Review and modify the model equations for POC and PCBs developed by Thomann and Mueller (1987);

(2) Develop and write a computer program for the Model STOXGB in Quick Basic, including the preprocessor;

(3) Process the calibrated input data of the Model GBTOX and change it according to the STOXGB requirement;

(4) Obtain the results from the STOXGB model by using all the calibrated parameters from GBTOX and compare the results of both models;

(5) Calibrate the new model in order to give the best possible agreement with the Green Bay field

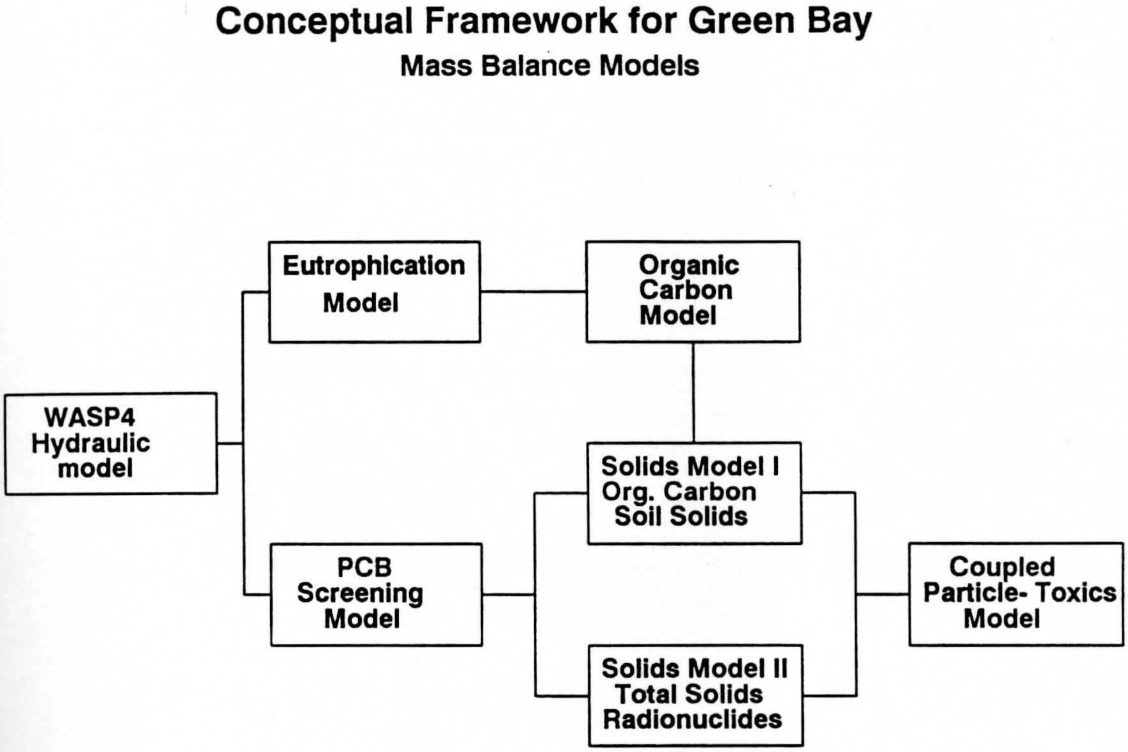


Figure 1-2: **Conceptual Framework for Green Bay Mass Balance Study Modeling Work (from Bierman et al., 1992).**

generated data;

(6) Use the new model (STOXGB) to investigate some future managerial scenarios.

Chapter II

LITERATURE REVIEW

2.1 Toxic Substances in the Environment

The presence of toxic substances, such as organic and inorganic chemicals, heavy metals and radionuclides, has become a major environmental problem in recent years. The toxic substances are present in all phases of the environment - air, water and land.

A toxicant is a substance that, above a certain level of exposure or dose, has detrimental effects on tissues, organs, or biological processes (Manahan, 1990). Polychlorinated biphenyls are consider as toxic substances, whose accumulation in living organism can cause cancer. These compounds are made by substituting from 1 to 10 chloride atoms onto the biphenyl (two benzene rings) aromatic structure as shown in Figure 2-1 (a). With different combinations of chloride atoms, PCBs have about 209 different compounds (congeners). One example of PCB congeners is given in Figure 2-1 (b) (Manahan, 1990).

Polychlorinated biphenyls have very high chemical, thermal and biological stability; low vapor pressure; and high dielectric constants. Because of these properties PCBs were used extensively as coolant-insulation fluids in transformers and capacitors; for impregnation of cotton and asbestos; as plasticizers; and as additives to some epoxy paints (Stanley, 1990). The negative side of PCB use is that its properties,

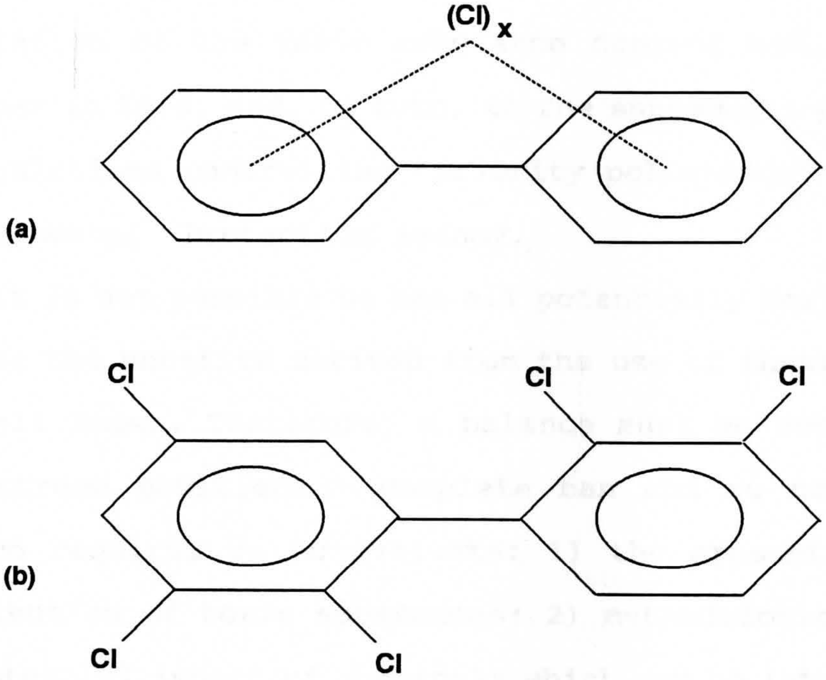


Figure 2-1: General Polychlorinated Structure (where x may range from 1 to 10); (b) 5-Chlorine Congener (from Manahan, 1990)

such as high chemical, thermal and biological stability also make them very persistent in nature.

Only after studying the accumulation of toxic substances in both the terrestrial and aquatic food chains has the problem become increasingly evident. This concern led to the formulation of the Toxic Substance Control Act, enacted by Congress in 1976, and, in turn, to the subsequent promulgation of regulations controlling "priority pollutants" by the U.S. Environmental Protection Agency.

It is not possible to ban all potentially toxic chemicals because the benefits derived from the use of these substances are well known. Therefore, a balance must be sought between the extreme positions - complete ban and no control. This balance requires us to evaluate: 1) the present extent and distribution of toxic substances; 2) methodologies to assess the potential impact of chemicals which may be introduced into the environment; 3) cost-effective approaches to minimize these impacts (O'Connor, 1982).

2.2 Introduction to Water Quality Modeling

Water quality modeling is a very effective way of predicting concentrations of chemicals. Figure 2-2 shows the principal components of a mathematical modeling framework (Thomann and Mueller, 1987). The upper two steps enclosed with the dashed lines, namely, "theoretical construct" and "numerical specification" are considered as a mathematical model. Mathematical modeling consists of writing and solving

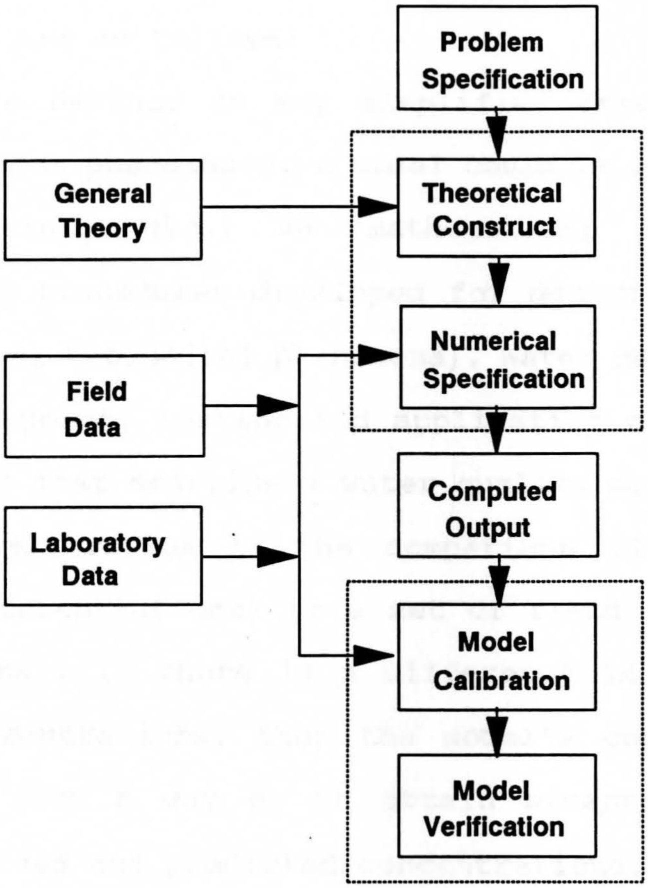


Figure 2-2: Principal Components of Modeling Framework (Thomann and Mueller, 1987).

mass-balance equations for each substance (or state variable) of interest. Following this initial model specification are the steps of model calibration and model verification. More general definitions of model, model calibration and model verification are as follows:

Model is defined as any simplified description of an actual system or phenomenon. A model could be physical (e.g., cars, buildings, etc.) or mathematical (equations or computational procedures developed for describing physical, chemical and/or biological phenomena). Water quality modeling is the development, testing and application of mathematical relationships that describe a water quality problem.

Model Calibration is the comparison of model output (predicted concentrations) to a set of field data (observed concentrations). If there is a difference in predicted and observed concentrations, then the model's coefficients are adjusted in such a way as to obtain acceptable agreement between observed and predicted concentrations.

Model Verification is the testing of a calibrated model on an additional set of field data, preferably under different external conditions, to further examine model validity. The verified model is then often used for forecasts of expected water quality under a variety of potential scenarios (Thomann and Mueller, 1987).

2.3 Theory of Mass Balance

Toxic substances may exist in all phases of the aquatic environment - in solution, in suspension, in the bed and air boundaries, and in the various levels of the food chain. The interrelationships among these phases depend on the transport, reactions and transfer of the substance. The equations describing the spatial and temporal distribution of these substances are developed using the principle of mass conservation. A general expression of this principle for a specified volume, V, is (Thomann and Mueller, 1987):

$$V \frac{dC}{dt} = J_i + \sum R_i + \sum T_i + \sum W \tag{2-1}$$

where

c_i = concentration of the chemical in spatial segment i;

J = transport through the system;

R = reactions within the system;

T = transfer from the one phase to another;

W = inputs.

Thomann and Mueller (1987) presented a simplified model of suspended solids and toxic substances that accounts for most of the important processes controlling the movement of toxics in lakes. This model is described below.

2.4 A Simple Toxic Substance Model for Completely Mixed Lakes

2.4.1 Suspended Solids Model

The first step in development of the overall model is the mass balance of suspended solids because many chemicals, such as PCBs, sorb to suspended particulate matter. In this model, a single class of solids is considered incorporating inorganic solids and organic particulate matter.

For a single completely mixed lake, the mass balance equation for solids in the water column is given by:

$$V_1 \frac{dm_1}{dt} = Wm - Qm_1 - v_s Am_1 + v_u Am_2 \tag{2-2}$$

where

V_1 = volume of the water column (L^3);

m_1, m_2 = the concentrations of solids in the water column and bottom sediment on a mass per bulk volume basis (M/L^3);

Wm = mass input of solids (M/T);

Q = flow out (L^3/T);

A = interfacial area between the water column and sediment (L^2);

v_s = the settling velocity of the particulate (L/T);

v_u = the resuspension velocity of the solids from the sediment to the water column (L/T).

Equation 2-2 represents a balance of solids between:

(1) input of solids externally (Wm) and internally from the flux due to sediment resuspension (v_u A m_2);

(2) losses of solids due to flow transport from the lake (Qm) and settling from the water column (v_s A m_1); and

(3) the time rate of change of the solid's mass in the water column (V dm_1/dt).

Since equation 2-2 depends on an interaction with the sediment, a similar equation is written for the sediment segment underlying the water column. The mass balance equation for solids in the bottom sediment is given by:

$$V_2 \frac{dm_2}{dt} = v_s\, Am_1 - v_u\, Am_2 - v_d\, Am_2 \tag{2-3}$$

where

V_2 = bulk volume the sediment (L^3)

v_d = the net sedimentation velocity of the surface sediment segment (L/T)

Equation 2-3 for the solids in the sediment bed is a flux balance between the incoming solids due to settling from the water column, loss due to resuspension, loss due to net sedimentation (v_d Am_2) and the time rate of change of solids in the sediment (V_2 dm_2/dt). The sediment is assumed to be stationary and interacting only with the overlying water column (Thomann and Mueller, 1987).

2.4.2 Toxic Substance Model

The development of a mathematical model for the physical-chemical fate of a toxic substance in water includes the following features:

(1) the mechanism of sorption-desorption of the chemical with the suspended particulates in the water column and sediment;

(2) loss of the chemical due to mechanisms such as biodegradation, volatilization, chemical and biochemical reactions, and photolysis;

(3) transport of the toxicant due to advective flow transport, dispersion and mixing;

(4) particulate settling and resuspension between sediment and water column; and

(5) direct inclusion of external inputs.

The concentrations of a toxicant in the water column and in the bottom sediments are given by mass balances for each of these segments of the water body. The toxicant is assumed to be composed of two forms:

(1) the dissolved form, c'_d (M_T / L^3_w; M_T = mass of toxicant) where "dissolved" is considered in an operational manner, i.e., all toxicant passing, for example, a 0.45 um filter, and

(2) the particulate form, c_p (M_T / L^3), i.e., the toxicant sorbed onto particulate matter in the water column or sediment. The total toxicant concentration c_T(M_T / L^3) is then:

$$c_T = c_p + \phi c_d' \quad where\ \phi = porosity \tag{2-4}$$

or

$$c_T = c_p + c_d \quad where\ c_d = \phi c_d' \tag{2-5}$$

Since the dissolved toxicant concentration is the mass of toxicant per unit volume of water and the total toxicant concentration is the mass of toxicant per unit volume of water plus solids, the porosity of the volume must be introduced to maintain a consistent mass balance. The quantity c_d therefore represents the porosity corrected dissolved concentration of the toxicant (O' Connor, 1982).

Equations are required for the particulate and dissolved forms and the kinetic interactions of sorption and desroption between the two forms of the chemical. However, for most chemicals these reaction kinetics tend to be "fast" (on the order of minutes-hours) compared to the time scales of the other mechanisms involved. These latter mechanisms include bacterial decay, net loss rates to the sediment and sedimentation rates that have reaction times on the order of days to years (O' Connor, 1982).

The "fast" kinetics of sorption-desorption indicate that for time scales of days to years, there will be virtually continuous equilibration of the dissolved and particulate forms depending on the local solids concentration. This partitioning between the two components permits the specification of the fraction of dissolved and particulate toxicant to the total. The dissolved and particulate toxicants are, therefore, assumed to be always in a "local equilibrium" with each other. A partition coefficient can then be defined as follows:

$$K_p = \frac{r}{C_d'} \tag{2-6}$$

where

K_p = equilibrium partition coefficient (L^3/M);

r = the concentration of the chemical on a per unit solids basis (M_T/M).

The porosity corrected partition coefficient is given by:

$$K_p' = \frac{K_p}{\phi} = \frac{r}{C_d} \tag{2-7}$$

From Equations (2-5) and (2-7), the fraction of the total toxicant that is dissolved is given by:

$$f_d = \frac{1}{(1 + K_p' m)} \tag{2-8}$$

Similarly, the fraction of the total toxicant in particulate form is given by:

$$f_p = \frac{K_p' m}{(1 + K_p')} \tag{2-9}$$

The local equilibrium assumption permits specification, at all times and places, of the fractions of total toxicant in the dissolved and particulate forms. Attention can then be focused solely on the mass balance equation for the total toxicant.

For a single completely mixed lake, the mass balance for the total toxicant is given by (Thomann and Mueller, 1987):

$$\begin{aligned} V_1 \frac{dc_{T1}}{dt} &= W_{T1} - Qc_{T1} - v_s A f_{p1} c_{T1} + v_u A f_{p2} c_{T2} \\ &\quad + k_f A\left(f_{d2} \frac{c_{T2}}{\phi} - f_{d1} c_{T1}\right) - K_1 V_1 c_{T1} \\ &\quad + k_l A\left(\frac{c_g}{He} - f_{d1} c_{T1}\right) \end{aligned} \tag{2-10}$$

where

c_{T1}, c_{T2} = the water column and sediment total toxicant concentration (M_T/L^3);

K_f = the sediment water diffusive transfer coefficient (L/T);

k_l = the volatilization transfer coefficient (L/T);

c_g = the toxicant concentration in the atmosphere overlying the water (M_T/L^3_g);

He = Henry's constant for partitioning between the gaseous and aqueous phase;

K_1 = an overall loss rate (1/T) given by:

$$K_1 = K_{d1}\, f_{d1} + K_{p1}\, f_{p1} \tag{2-11}$$

In equation (2-11), K_{d1} and K_{p1} are the loss rates of the dissolved and particulate forms, respectively, due to mechanisms such as biological degradation and photolysis.

There is a total of seven terms on the right - hand side of Equation (2-10) which represent, respectively:

(1) the external input of toxicant;

(2) the transport out of the lake due to flow;

(3) the loss due to particulate settling;

(4) the gain due to particulate resuspension;

(5) the flux of chemical from (to) the sediment due to interstitial diffusion of the dissolved form;

(6) the overall loss of the chemical due to decay; and

(7) the flux of the dissolved form of the chemical to the atmosphere due to volatilization.

Similarly the equation for the total toxicant in the sediment segment is given by (Thomann and Mueller, 1987):

$$V_2 \frac{dc_{T2}}{dt} = v_s A f_{p1} c_{T1} - v_u A f_{p2} c_{T2} + k_f A \left(f_{d1} c_{T1} - f_{d2} \frac{c_{T2}}{\phi} \right) - v_d A f_{p2} c_{T2} - K_2 V_2 c_{T2} \qquad (2\text{-}12)$$

where

$$K_2 = K_{d2}\, f_{d2} + K_{p2}\, f_{p2} \qquad (2\text{-}13)$$

All the terms of Equation (2-12) represent similar mechanisms as in the water column. Descriptions of the five terms on the right - hand side of Equation 2-12 are as follows:

(1) influx due to settling;

(2) loss due to resuspension;

(3) diffusive exchange of interstitial dissolved chemical;

(4) loss due to net sedimentation; and

(5) loss due to decay processes in the sediment.

It should also be noted that if the water column segment interacts through dispersive mixing with an adjacent segment, then an additional term must be added to account for turbulent mixing and advective transport (Thomann and Mueller, 1987).

2.5 Modeling Approach for Green Bay Mass Balance Modeling Study

The overall conceptual approach used in the Green Bay Mass Balance Study (GBMBS) involved the development of a series of individual models to describe hydraulics, particle/sorbent dynamics and toxic chemical dynamics in Green Bay. These individual models were coupled within an integrated exposure modeling framework (Figure 2-3).

All the models applied in the GBMBS are based on the principle of conservation of mass. For each state variable a partial differential equation is written in which changes in mass are expressed as a function of space and time. These equations are applied in the form of a finite difference approximation in which each partial differential equation is transformed to a coupled system of ordinary differential equations which are a function only of time. The spatial dimension is then represented as a system of coupled segments, or control volumes. For a given state variable each of the ordinary differential equations corresponds to a dynamic mass balance for a particular spatial segment (Bierman et al., 1992).

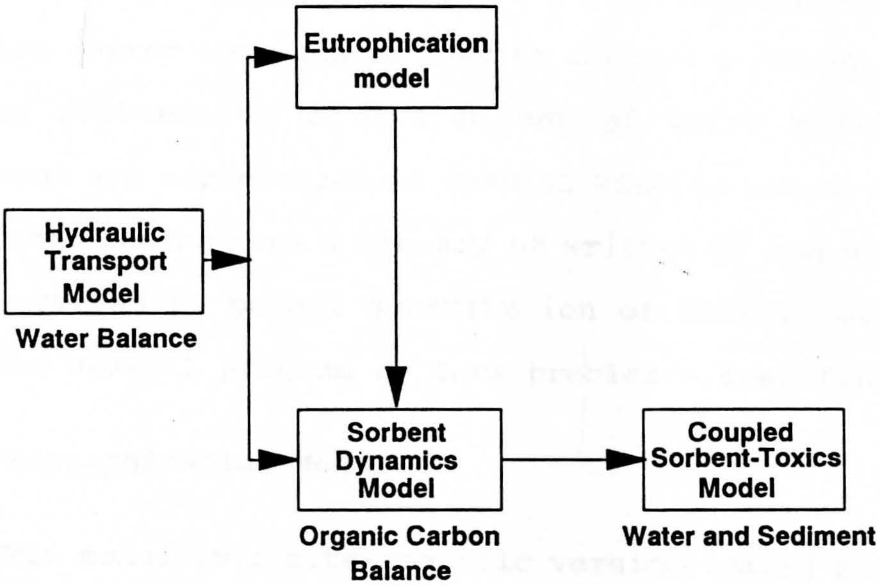


Figure 2-3: Conceptual Framework For Green Bay Mass Balance Models, (Bierman et al, 1992).

2.5.1 WASP4 Modeling Framework

All of the models used in the GBMBS were developed within the WASP4 computer coding framework maintained and distributed by the EPA Center for Exposure Assessment Modeling, Athens, Georgia (Ambrose et al., 1988). WASP4 is a dynamic compartment modeling system that can be used to analyze a variety of water quality problems in a diverse set of water bodies. Model processes are represented in special kinetic subroutines that are either chosen from a library or written by the user. WASP4 is structured to permit substitution of kinetic subroutines into the overall program to form problem - specific models.

2.5.2 Eutrophication Model

This model is a site-specific version (named EUTRO4E) of the WASP3/Lake Erie Eutrophication Model (DiToro and Connolly 1980). The purpose of this model is to quantify the internal loading rates of particulate organic carbon to Green Bay due to primary production. Organic carbon is the most important environmental sorbent for hydrophobic organic chemicals such as PCBs (Karickhoff 1984).

2.5.3 Hydraulic Transport Model

In the GBMBS, mass balances for chloride and heat (temperature) were performed by applying the Hydraulic Model. The Hydraulic Model is used to quantify physical exchanges among the model segments in terms of advection and bulk dispersion. Results from the WASP4 Hydraulic Model are then specified as inputs to all of the other models.

2.5.4 Sorbent Dynamics Model

The Sorbent Dynamics Model was used to determine the dynamics of inorganic and organic particles in Green Bay. The inorganic and organic solids must be coupled to provide a complete particle dynamics framework for the Toxic Chemical Model (Bierman et al., 1992).

Biotic carbon (BIC), particulate detrital carbon (PDC), and dissolved organic carbon (DOC) are the three state variables in this model, named the Green Bay Organic Carbon Sorbent Model (GBOCS). BIC represents particulate organic carbon (POC) contained in live phytoplankton biomass. PDC represents particulate detrital carbon derived from phytoplankton decomposition, zooplankton excretion and allochthonous sources. DOC represents microparticulates (colloids) and macromolecules that can not be separated from whole water samples by conventional filtration or centrifugation. DOC is derived from decomposition of BIC and PDC, and from allochthonous sources (Bierman et al., 1992).

The reasons for separating POC into BIC and PDC is based not only on the fact that they have different origins, but also on differences in their characteristics and principal controlling processes. Relationships between the organic carbon state variables and conventional measurements for suspended solids and organic carbon are shown in Figure 2.4(a).

2.5.5 Coupled Sorbent-Toxics Model

The Toxics Model was used to provide the quantitative relationships between external source inputs of toxic chemicals to the bay and spatial/temporal concentration distributions in the water column and sediments. This toxic chemical model was designed primarily for modeling hydrophobic organic chemicals such as PCBs, DDT and dieldrin.

The Green Bay Toxic Chemical Model (GBTOX) uses total toxic chemical concentration as the state variable. The total toxic chemical concentration is separated into four components (Figure 2.4(b)):

(1) toxic chemical in the truly dissolved aqueous phase,

(2) toxic chemical phase sorbed to BIC,

(3) toxic chemical phase sorbed to PDC, and

(4) toxic chemical phase sorbed to DOC

Figure 2.5 shows the schematic diagram of toxic chemical compartments and process mechanisms in GBTOX. The Hydraulic Model, GBTOX and GBOCS all utilize the same computer code so the toxic substance kinetics are properly coupled to hydrodynamic and organic carbon sorbent behavior. GBTOX has some additional water column and sediment variables representing dissolved phase (unbound) toxic chemical concentration. Additional process mechanisms include equilibrium phase partitioning between the toxic chemical and BIC, PDC and DOC, and air-water and sediment-water exchanges of dissolved phase toxic chemical (Bierman, et al., 1992).

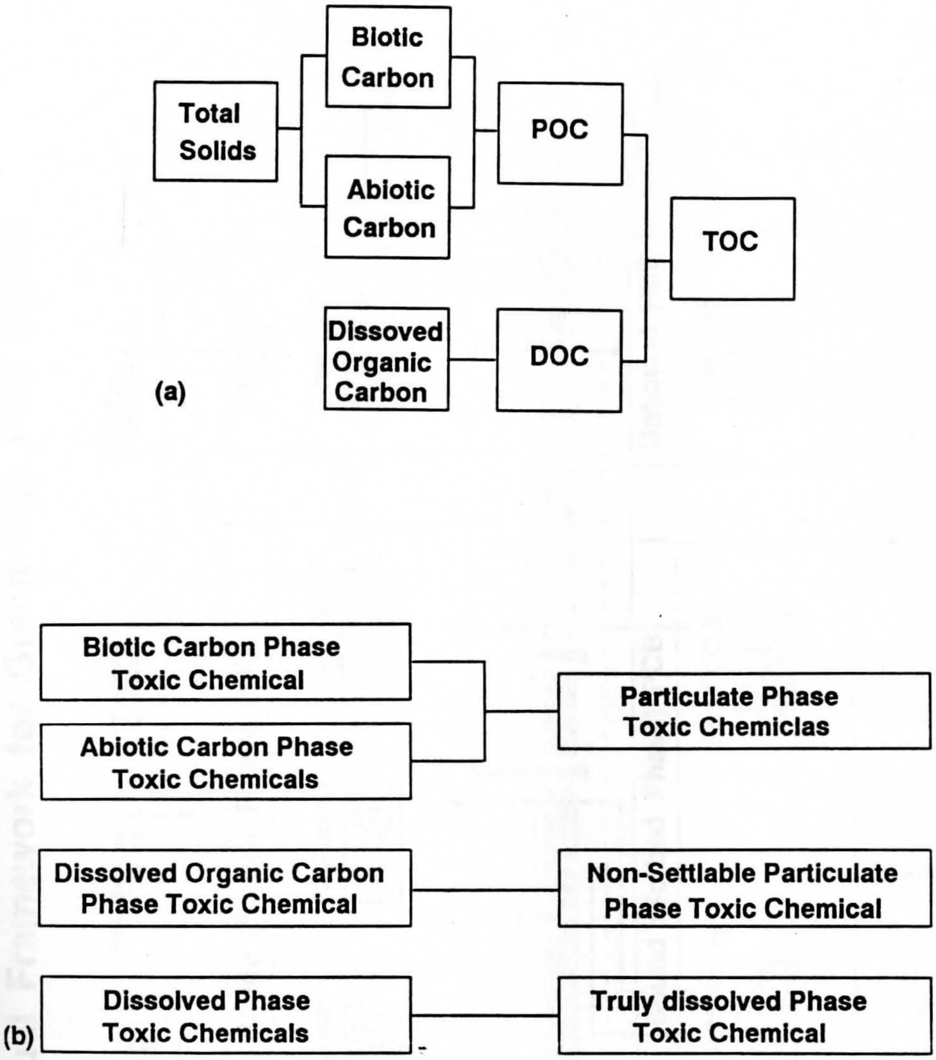


Figure 2-4: State Variables in GBMBS Models (Bierman et al., 1992) (a) Dynamic Sorbent Model; (b) Toxics Sorbent Model.

Conceptual Framework for Green Bay PCB Model

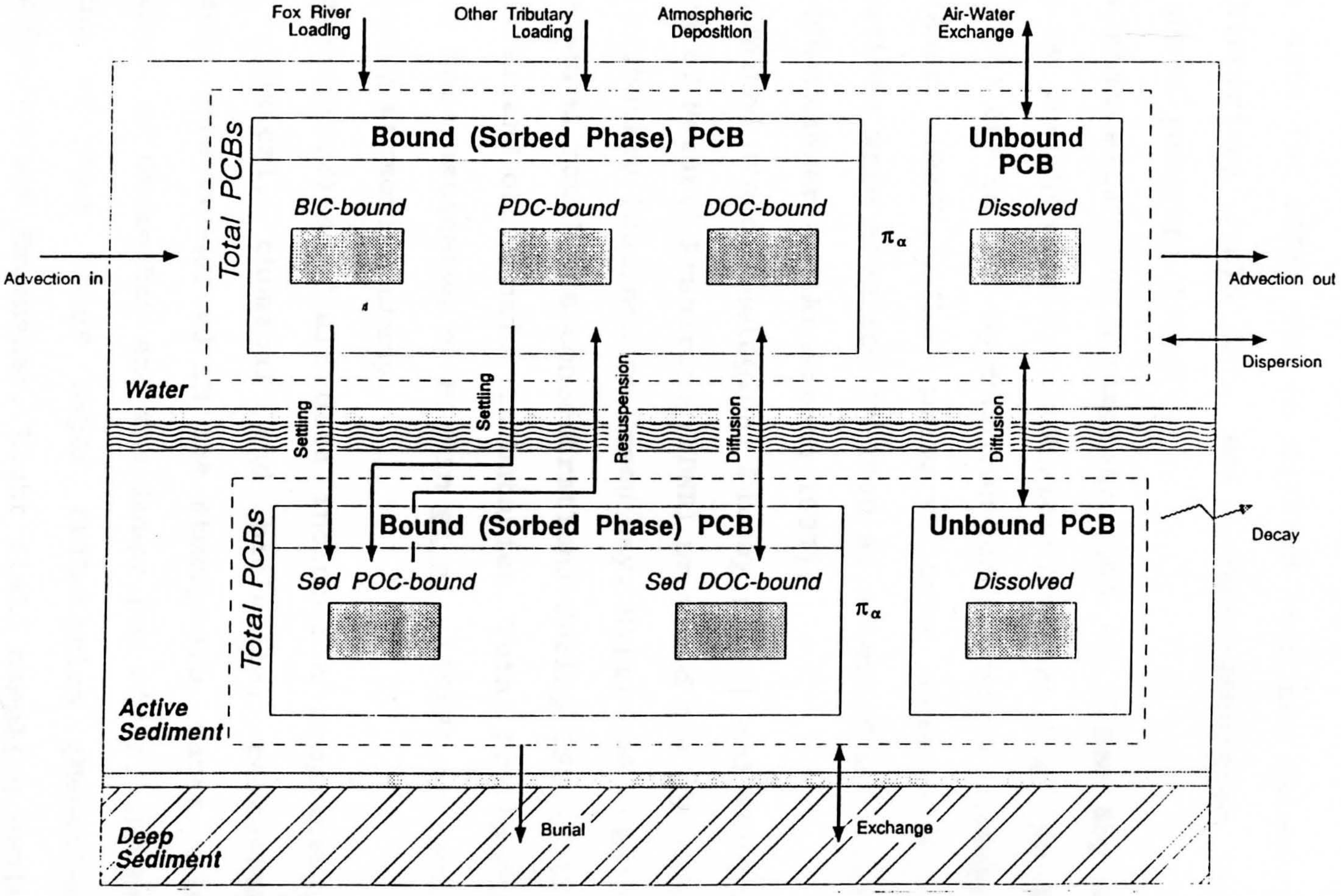


Figure 2-5: **Conceptual Framework for Green Bay PCB Model, GBTOX, (from Bierman et al., 1992).**

2.6 Data Collection and Processing for Green Bay

2.6.1 Historical and Program-Generated Field Data

The data for GBMBS can be divided into two categories, namely historical field data and program-generated (i.e., 1987-90 GBMBS program) field data.

The most extensive **historical data** on Green Bay were acquired by the University of Wisconsin-Green Bay in 1980 (Conley 1983) and in 1982 by Michigan Technological University (MTU) (Auer 198?). The primary data used for PCB concentrations were acquired in 1980 at selected stations in the bay (Swackhamer and Armstrong 1987).

The United States Geological Survey (USGS) and Wisconsin Department of Natural Resources (WDNR) provided the historical data for tributary loadings to Green Bay. Marti and Armstrong (1990) measured total PCB concentrations during 1980-1983 in the Fox River and other major tributaries. Total PCB loadings to the bay were estimated by Martin <u>et al</u>. (1988) as part of a preliminary screening study.

Program-generated field data included a comprehensive list of physical, chemical and biological parameters. Measurements were conducted in the atmosphere, water column and sediments of Green Bay and the Lower Fox river, and near the mouths of four other major tributaries (Menominee, Peshtigo, Oconto and Escanaba). Eight field sampling cruises were conducted between April 1989 and April 1990 at 27 principal water quality stations. Sediment sampling was conducted during the period 1987-1990 at 167 locations in the bay.

2.6.2 Spatial Segmentation

The spatial segmentation for the models applied in the GBMBS was developed from digitized bathymetric and shoreline data from Lake Michigan (Schwab and Sellers 1980).

A total of 12 spatial water column segments were used in Green Bay (Figure 2-6). Nine of the segments (segments 1-9) are the water surface segments and the remaining three segments (10-12) are bottom water segments. An assumed 14-meter deep thermocline separates the surface (epilimnion) and bottom (hypolimnion) water layers. The principal design criteria for this water column segmentation grid were the following (Bierman _et al_., 1992):

(1) bathymetry of Green Bay;
(2) horizontal and vertical gradients in water quality constituents;
(3) available data on characteristic water circulation patterns;
(4) location of external hydraulic and constituent source inputs;
(5) transport exchanges between Green Bay and Lake Michigan;
(6) complexity of organizing and reducing data for model input and for comparisons with model output;

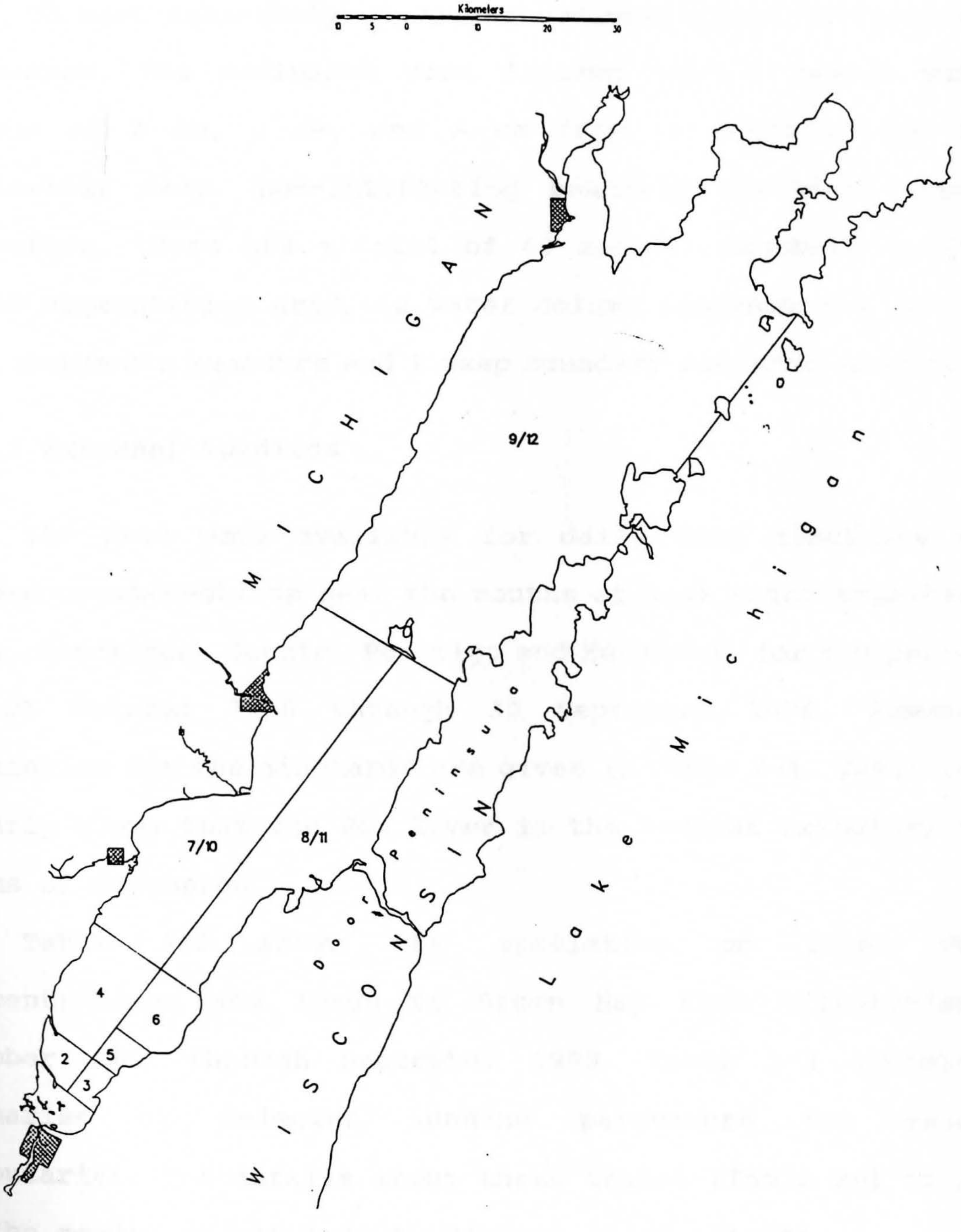


Figure 2-6: Spatial Segmentation of Green Bay GBTOX (adapted from Bierman et al., 1992).

(7) feasibility of interpreting model output in the form of tabular and graphical displays for each spatial segment.

To more accurately represent sediment-water interaction processes, the sediments were divided into 3 layers with depths of 2 cm, 2 cm, and 8 cm (top to bottom), and an infinitely deep, non-interacting boundary sediment layer. Therefore, there are a total of 49 spatial segments in the model segmentation grid, 12 water column segments and 36 (12 x 3) sediments segments and 1 deep boundary sediment segments.

2.6.3 External Loadings

The data were available for daily mean discharge at stream cross-sections near the mouths of each major tributary (Fox, Menominee, Oconto, Peshtigo and Escanaba) for the period of 01 October 1988 through 30 September 1990. Summary statistics for the discharge are given in Table 2-1. Table 2-1 clearly shows that the Fox River is the largest tributary in terms of discharge.

Table 2-2 shows the statistics on total PCB concentrations and loads to Green Bay from tributaries, October 1988 through September 1990. Table 2-3 contains summaries of selected loading parameters for major tributaries. For details about these tables (Table 2-1 to 2-3) the reader is referred to Bierman <u>et al</u>. (1992).

Table 2-1. Summary Statistics for Green Bay Tributary discharge for the Period, October 1988 through September 1990 (m3/day), from Bierman, et al. (1992).

Tributary	Minimum	Maximum	Mean	Std.Dev.
Fox (DePere Dam)	5.427	114.745	44.453	27.454
Fox (Mouth)	4.165	148.522	55.756	31.944
Menominee	1.215	9.161	2.422	1.302
Oconto	0.606	6.739	2.617	1.756
Peshtigo	1.386	19.265	4.457	4.494
Escanaba	1.475	16.114	3.971	3.717

Table 2-3. Mean Daily Load of Selected Parameters for Primary Source Categories, 1989 (Kg/day) from Bierman, et al. (1992).

Tributary	DOC	POC
Fox	6.26E+4	1.53E+4
Menominee	5.83E+4	6.90E+3
Oconto	1.59E+4	1.56E+3
Peshtigo	1.39E+4	1.67E+3
Escanaba	2.79E+4	4.06E+3

Table 2-2 Summary Statistics on Total PCB Concentrations and Loads to Green Bay from Tributaries, October 1988 through September 1990, from Bierman, et al. (1992).

	Concentration, ng/L			Load, kg/d		
Contaminant	Mean	Median	Std Dev	Mean	Median	Std Dev
			Escanaba River			
Total PCB_Max	4.91E+00	4.69E+00	3.43E+00	6.62E-03	5.65E-03	3.82E-03
Total PCB_Min	4.64E+00	4.38E+00	3.57E+00	6.25E-03	5.28E-03	3.99E-03
Total PCB_18	4.63E-02	4.71E-02	9.20E-03	9.00E-05	6.00E-05	8.00E-05
Total PCB_28+31	1.95E-01	2.00E-01	7.12E-02	3.00E-04	2.40E-04	1.70E-04
Total PCB_56+60	7.07E-02	6.99E-02	4.17E-02	9.00E-05	8.00E-05	3.00E-05
Total PCB_101	7.50E-03	7.80E-03	2.90E-03	1.00E-05	1.00E-05	1.00E-05
Total PCB_130+158+163	1.11E-01	6.20E-02	3.41E-01	1.10E-04	8.00E-05	3.30E-04
Total PCB_180	1.74E-02	1.79E-02	5.90E-03	3.00E-05	2.00E-05	3.00E-05
			Oconto River			
Total PCB_Max	2.44E+00	2.37E+00	4.66E-01	3.81E-03	2.24E-03	4.80E-03
Total PCB_Min	2.31E+00	2.24E+00	4.73E-01	3.66E-03	2.11E-03	4.75E-03
Total PCB_18	4.22E-02	4.18E-02	6.70E-03	6.00E-05	4.00E-05	6.00E-05
Total PCB_28+31	1.63E-01	1.53E-01	4.06E-02	2.80E-04	1.40E-04	4.30E-04
Total PCB_56+60	7.86E-02	7.81E-02	3.23E-02	1.00E-04	8.00E-05	7.00E-05
Total PCB_101	6.45E-02	5.50E-02	3.09E-02	1.40E-04	5.00E-05	2.80E-04
Total PCB_130+158+163	4.21E-02	4.09E-02	2.33E-02	5.00E-05	4.00E-05	5.00E-05
Total PCB_180	2.48E-02	2.27E-02	8.70E-03	5.00E-05	2.00E-05	7.00E-05
			Peshtigo River			
Total PCB_Max	6.83E+00	4.26E+00	7.20E+00	2.41E-02	5.17E-03	6.49E-02
Total PCB_Min	6.80E+00	4.10E+00	7.51E+00	2.45E-02	5.00E-03	6.81E-02
Total PCB_18	7.71E-02	6.64E-02	3.37E-02	1.90E-04	8.00E-05	3.20E-04
Total PCB_28+31	2.31E-01	1.97E-01	1.05E-01	5.80E-04	2.30E-04	1.00E-03
Total PCB_56+60	1.38E-01	9.59E-02	1.16E-01	4.40E-04	1.10E-04	1.03E-03
Total PCB_101	8.39E-02	6.95E-02	4.26E-02	2.20E-04	8.00E-05	3.90E-04
Total PCB_130+158+163	9.36E-02	6.73E-02	7.62E-02	2.90E-04	8.00E-05	6.80E-04
Total PCB_180	3.13E-02	2.37E-02	2.21E-02	9.00E-05	3.00E-05	2.00E-04
			Menomine River			
Total PCB_Max	2.12E+00	1.99E+00	4.74E-01	1.60E-02	1.04E-02	1.40E-02
Total PCB_Min	1.99E+00	1.85E+00	5.05E-01	1.53E-02	9.62E-03	1.41E-02
Total PCB_18	4.56E-02	4.17E-02	1.28E-02	3.50E-04	2.20E-04	3.30E-04
Total PCB_28+31	1.35E-01	1.28E-01	3.00E-02	1.01E-03	6.70E-04	8.70E-04
Total PCB_56+60	4.88E-02	4.65E-02	9.20E-03	3.70E-04	2.40E-04	3.10E-04
Total PCB_101	5.19E-02	4.88E-02	1.02E-02	4.00E-04	2.50E-04	3.50E-04
Total PCB_130+158+163	9.39E-02	3.67E-02	1.44E-01	1.24E-03	1.90E-04	3.03E-03
Total PCB_180	3.37E-02	3.24E-02	5.10E-03	2.50E-04	1.70E-04	2.10E-04
			Fox River (Exclusive of Point Sources)			
Total PCB_Max	3.50E+01	3.40E+01	2.63E+01	3.49E-01	2.09E-01	4.54E-01
Total PCB_Min	3.49E+01	3.39E+01	2.64E+01	3.48E-01	2.09E-01	4.54E-01
Total PCB_18	1.44E+00	1.38E+00	1.15E+00	1.43E-02	8.56E-03	1.89E-02
Total PCB_28+31	5.15E+00	4.92E+00	4.09E+00	5.16E-02	3.06E-02	6.97E-02
Total PCB_56+60	9.60E-01	8.91E-01	8.16E-01	9.59E-03	5.58E-03	1.33E-02
Total PCB_101	3.97E-01	3.87E-01	2.97E-01	3.96E-03	2.37E-03	5.18E-03
Total PCB_130+158+163	3.84E-01	3.88E-01	2.53E-01	3.82E-03	2.35E-03	4.70E-03
Total PCB_180	1.70E-01	1.66E-01	1.25E-01	1.69E-03	1.02E-03	2.20E-03

Chapter III

DEVELOPMENT AND APPLICATION OF STOXGB

3.1 Mass Transport Processes

Mass transport refers to the movement of some mass of a substance from one point to another in a system. In developing a mass-balance model, all significant transport processes must be accounted for. Processes important in the movement of pollutants in natural waters are reviewed below.

3.1.1 Mass Transport within the Bulk Liquid

Some of the important mass transport processes responsible for the movement of materials within the bulk liquid phase in natural systems are the following:

Advection is the mass transport by bulk fluid flow.

Molecular diffusion is the movement of mass because of the natural random motion of particles in water (Brownian motion).

Eddy Diffusion is the net movement of mass from a region of high concentration to low concentration.

Dispersion is the sum of molecular and eddy diffusion.

3.1.2 Inter-Phase Mass Transport Processes

In natural systems, phase boundaries also exist where different processes (i.e., besides advection and dispersion) can act as sources (inputs) or sinks (losses) of a pollutant or other dissolved substance of interest in a modeling study.

3.1.2.1 Air-Water Interface

Rain and snow can carry pollutants that are deposited directly on the water surface and are known as **wet deposition.** On the other hand, **dry deposition** is the deposition of dust and aerosols which could carry pollutants.

Absorption is the process by which when atmospheric gases and gaseous pollutants become dissolved in water.
Opposite to absorption is **volatilization**, in which dissolved substances in water are converted to the gaseous phase.

3.1.2.2 Sediment-Water Interface

Dissolved substances can attach themselves to the surface of suspended solids by some physical and chemical forces; this process of attachment is called **adsorption.** The reverse process of adsorption is known as **desorption.**
Some suspended particles, carrying toxic substances, can settle in the water column because of gravity, and this process is called **deposition** (or sedimentation).

Resuspension occurs when the same settled particles are scoured by fluid shear forces during periods of high flow or wind-induced turbulence.

3.2 Model Equations

The model developed for this project was named Simplified Toxics Model for Green Bay (STOXGB). A schematic diagram of STOXGB is represented in Figure 3-1. In developing this mechanistic, dynamic model's equations, two state variables were considered - particulate organic carbon (POC) and total PCBs. Two equations of mass balance were written for each state variable - one for each of the two physical compartments (water column and bottom sediment).

The following assumptions were made in developing the model:

i) each spatial segment of the bay is completely mixed,
ii) decay of pollutants is of first order, and
iii) loading is time variable.

3.2.1 Equations for Particulate Organic Carbon (POC)

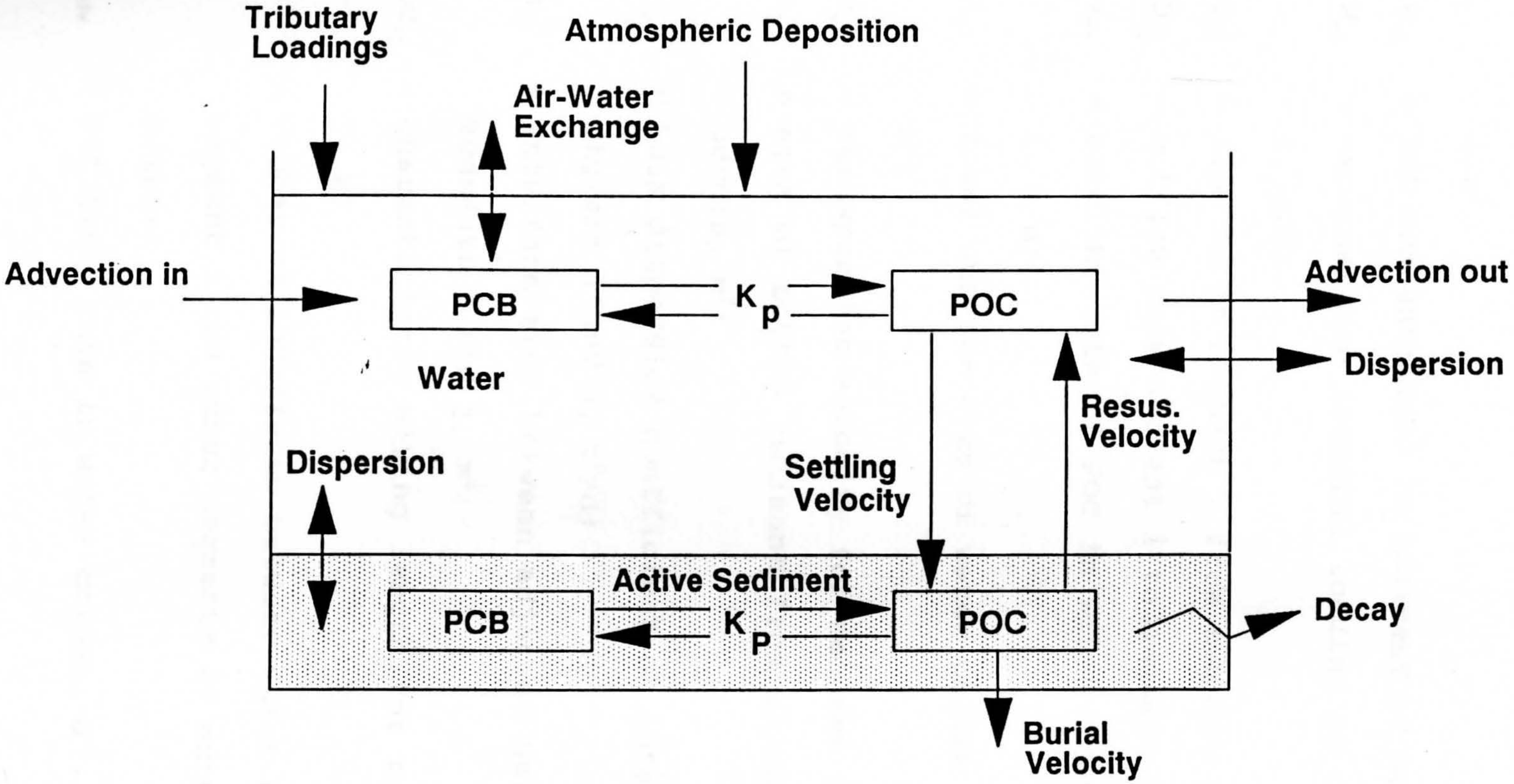
Following are the equations for POC in water column and bottom sediment for each segment:

(A) Mass Balance Equation for POC in Water Column

$$V_i \frac{dm_i}{dt} = W_{mi} + \sum_{j=1}^{n} (Q_{ji} m_j) - (\sum_{j=1}^{n} Q_{ij}) m_i - v_{si} A_i m_i + v_{ui} A_i' m_{si} - \sum_{j=1}^{n} \frac{E_{ij}}{Lc_{ij}} A_{ij} (m_i - m_j) - K_{dw} V_i m_i \tag{3-1}$$

where

V_i = volume of water column in segment i, m^3;



POC = Particulate Organic Carbon
PCB = Polychlorinated Biphenyl
K_p Partition Coefficient

Figure 3-1 Conceptual Framework for STOXGB Model.

m_i = POC concentration in water column of segment i, g/m^3;

m_{si} = POC concentration in sediment of segment i, g/m^3;

W_{mi} = external and internal loading of POC to segment i, g/d;

Q_{ji} = flow in to segment i from segment j, m^3/d;

Q_{ij} = outflow from segment i to segment j, m^3/d;

v_{si} = settling rate of POC in water column of segment i, m/d;

A_i = total surface area of water column of segment i, m^2;

v_{ui} = resuspension velocity for segment i, m/d;

A_i' = area of bottom sediment from which resuspension occurs, m^2;

E_{ij} = bulk dispersion coefficient at interface between segment i and j, m^2/d;

A_{ij} = interface area between adjacent water column of segments i and j, m^2;

Lc_{ij} = characteristic mixing length for segments i and j, m;

n = number of interfaces between water column of segment i and other segments or external water bodies;

K_{dw} = POC decay rate in water column, d^{-1}.

(B) Mass Balance Equation for POC in Bottom Sediment

$$V_{si}\,\frac{dm_{si}}{dt} = v_{si}A_i m_i - v_{ui}A_i' m_{si} - v_{di}A_i' m_{si} - K_{ds}V_{si}m_{si} \tag{3-2}$$

where

V_{si} = volume of bottom sediment of segment i, m^3;

v_{di} = burial velocity to deep sediments, m/d;

K_{ds} = POC decay rate in bottom sediment, d^{-1}.

Equations 3-1 and 3-2 are modified slightly compared to the equations of Thomann and Mueller (1987). The modification is based on the fact that the loss of POC is also significant due to POC decay in the water column and bottom sediments. The last term in Equation 3-1 and 3-2 shows the loss of POC in water column and bottom sediment, respectively. A term accounting for dispersion between adjacent spatial segments has also been added in the water column. All other terms have the same meaning as described in Chapter 2 (section 2.4).

3.2.2 Equations for Polychlorinated Biphenyl (PCB)

Following are the equations for PCBs in water column and bottom sediment for each segment:

(A) Mass Balance Equation for PCB in Water Column

$$
\begin{aligned}
V_i \frac{dC_{Ti}}{dt} &= W_{Ti} + \sum_{j=1}^{n} (Q_{ji}C_{Tj}) - (\sum_{j=1}^{n} Q_{ij})\, C_{Ti} + K_{fi}A_i^{\prime}(\frac{f_{dsi}}{\phi}C_{Tsi} - f_{di}C_{Ti}) \\
&\quad - (K_{di}f_{di})\, V_iC_{Ti} + K_iA_i[(\frac{Cg}{He}) - f_{di}C_{Ti}] - v_{si}A_ifp_iC_{Ti} \\
&\quad + v_{ui}A_i^{\prime}fp_{si}C_{Tsi} - \sum_{j=1}^{n} \frac{E_{ij}}{LC_{ij}}A_{ij}(C_{Ti} - C_{Tj})
\end{aligned}
\tag{3-3}
$$

where

C_{Ti} = PCB concentration in water column of segment i, g/m^3;

C_{Tsi} = PCB concentration in sediment of segment i, g/m^3;

W_{Ti} = external loading of PCB to segment i, g/d;

K_{fi} = diffusion rate between water column and bottom sediment of segment i, m/d;

f_{dsi} = dissolved fraction of PCBs in bottom sediment of segment i;

f_{di} = dissolved fraction of PCBs in water column of segment i;

ϕ = porosity of bottom sediment of segment i;

K_{di} = total decomposition rate of PCBs in water column of segment i, d^{-1};

K_i = volatilization exchange rate , m/d;

Cg = atmospheric concentration of PCB, g/m^3

He = Henry's constant, atm-m^3/mol;

v_{si} = settling rate of PCB in water column of segment i, m/d;

fp_i = particulate fraction of PCBs in water column;

fp_{si} = particulate fraction of PCBs in bottom sediment.

(B) Mass Balance Equation for PCB in Bottom Sediment

$$V_{si}\,\frac{dC_{Tsi}}{dt} = -\,K_{fi}A_i'\left(\frac{f_{dsi}}{\phi}C_{Tsi} - f_{di}C_{Ti}\right) - (K_{dsi}f_{dsi})\,V_{si}C_{Tsi} + v_{si}A_i fp_i C_{Ti} - v_{ui}A_i' fp_{si}C_{Tsi} - v_{di}A_i' fp_{si}C_{Tsi} \qquad (3\text{-}4)$$

where

K_{dsi}= total decomposition rate of PCBs in bottom sediment of segment i, d^{-1};

v_{di} = burial velocity to deep sediments, m/d.

3.3 Numerical Solution

Differential mass balance equations developed in mathematical models are actually initial value problems of the form:

$$y' = \frac{dy}{dt} = f(t,y) \qquad y(a) = \alpha \quad a \le t \le b \qquad (3\text{-}5)$$

where

y = concentration of some material of interest, e.g. POC or PCB;

a,b = limits of time range for which a solution exists;

α = the initial value of y at t = a

Numerical techniques provide a sequence of approximations to the exact solution at uniform increments of time. There are different kinds of numerical techniques available to solve initial value problems, e.g., Euler's Method, Modified Euler's Method and Runge-Kutta Methods. Following is a discussion of the fourth-order Runge-Kutta method, which was chosen for this application.

3.3.1 Runge-Kutta Method

The Runge-Kutta methods utilize the high order local truncation error of the Taylor methods while eliminating the computation and evaluation of the derivatives of f(t,y). The most common Rung-Kutta method in use is of order four. Fourth order Runge-Kutta method is a simple way to calculate fourth order Taylor Method predictions without evaluating derivatives of f(t,y) (Burden et al., 1978).

The fourth order Runge-Kutta difference equation for the initial value problem:

$$\frac{dy}{dt} = f(t,y) \qquad y(o) = \alpha \tag{3-6}$$

is given by:

$W_{i+1} = W_i + 1/6(K_1 + 2K_2 + 2K_3 + K_4)$

where

$K_2 = hf\ (t_i + h/2,\ W_i + 1/2\ K_1);$ h = time increment;

$K_3 = hf\ (t_i + h/2,\ W_i + 1/2\ K_2);$

$K_4 = hf\ (t_i + h,\ W_i + K_3);$

$W_o = \alpha.$

For more detail the reader is referred to Burden et al. (1978), Chapter 6 (Runge-Kutta Methods).

3.4 Development of Model Program STOXGB

The STOXGB program is written in Quickbasic (4.5). The model program consist of three parts, i.e., input, computations and output. The input structure consists of a series of data tables, and is designed to be "user-friendly". A listing of the STOXGB program is presented in Appendix A. Figure 3-2 shows the flow chart for STOXGB.

3.4.1 Input Structure

In order to run STOXGB three sets of data are required:

(1) time period and time increment;

(2) system-specific data which are constant for all segments; and

(3) segment specific data.

3.4.1.1 Data Set #1

Data set #1 consists of time period and time increment. Time period refers to the total duration of time for which the model simulation has to run. The time increment used in this project is 0.00274 year (one day) although it may be varied by the user. Table 3-1 shows the description of each variable, its program code symbol and units.

3.4.1.2 Data Set #2

Data set #2 is the system specific data, i.e, interface areas, characteristic lengths, flows, etc., for each segment. Data set #2 also contains the boundary conditions and atmospheric concentrations of PCBs. The only boundary conditions required for STOXGB are the concentrations of the state variables in the water column at the Lake Michigan

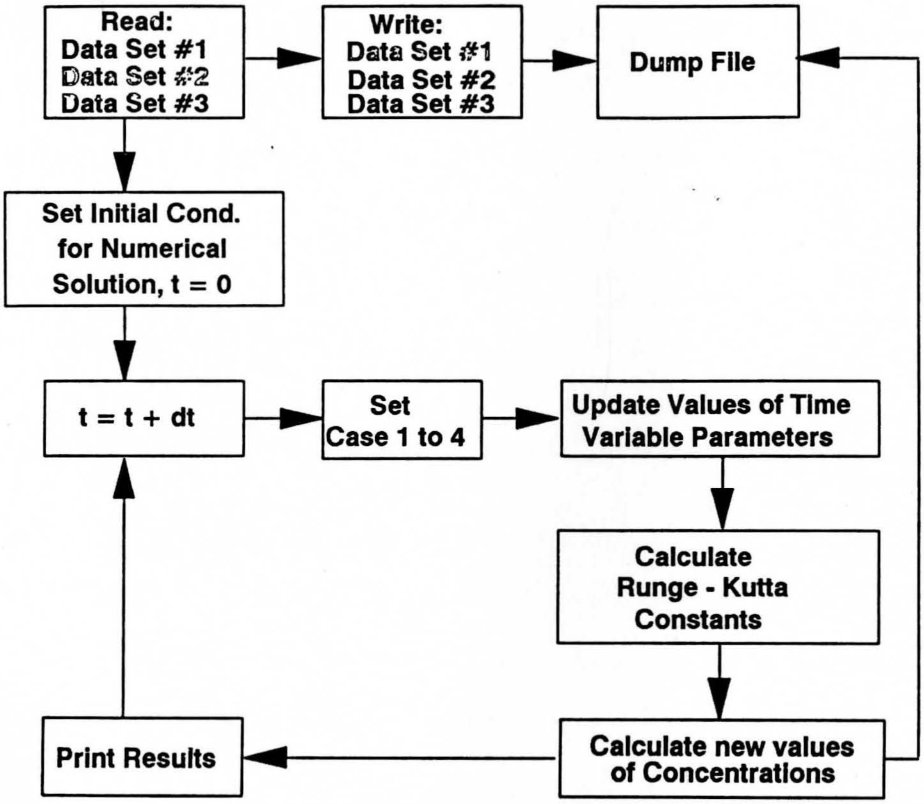


Figure 3-2: Flow Diagram of the STOXGB Model.

Table 3-1. Description of Variables for Data Set #1.

No.	Variable Description	Code	units
1.	Initial Time	t1	yrs
2.	Final Time	t2	yrs
3.	Time Step	INC	yrs

boundary. The atmospheric concentrations of PCBs and the boundary conditions can be specified on an annual basis. Table 3-2 shows the descriptions of all variables in data set #2, their program codes, units and whether they are time variable.

3.4.1.3 Data Set #3

All the segment specific data is contained is data set #3. This data set consists of initial conditions, volumes, areas, model parameters and loadings. Once again the loadings can be specified on an annual basis. Table 3-3 shows the description of all variables in data set #3, their program codes, units and whether they are time variable.

3.4.2 Computations

For computations the model STOXGB uses the fourth-order Runge-Kutta method. First, concentrations in each segment are set at initial conditions. Then time is incremented and the equations are solved for the new concentrations. The procedure is repeated until the solution has been generated for the desired time.

3.4.3 Output Structure

The model predicts the concentrations of each state variable in each segment for each time increment. Although the model computations use a time increment of 0.00274 year (one day), results are printed to the screen only at the end of each year. The model also creates a dump file which contains

Table 3-2. Description of Variables for Data Set #2.

No.	Variable Description	Code	unit	Time Variable
1.	Int. Areas, Segment 1,2	INTA12	m2	No
2.	Int. Areas, Segment 2,3	INTA23	m2	No
3.	Int. Areas, Segment 3,4	INTA34	m2	No
4.	Int. Areas, Segment 4LM[1]	INTA4LM	m2	No
5.	Charac. Length, Segment 1,2	CHL12	m	No
6.	Charac. Length, Segment 2,3	CHL23	m	No
7.	Charac. Length, Segment 3,4	CHL34	m	No
8.	Charac. Length, Segment 4,LM	CHL4LM	m	No
9.	Bulk Disp. Coeff.,Segment 1,2	BDSC12	m^2/d	No
10.	Bulk Disp. Coeff.,Segment 2,3	BDSC23	m^2/d	No
11.	Bulk Disp. Coeff.,Segment 3,4	BDSC34	m^2/d	No
12.	Bulk Disp. Coeff.,Segment 4LM	BDSC4LM	m^2/d	No
13.	Flow from Fox to Segment 1	QF1	m^3/d	No
14.	Flow from Seg.#2 to Segment 1	Q21	m^3/d	No
15.	Flow from Seg #1 to Segment 2	Q12	m^3/d	No
16.	Flow from Seg #3 to Segment 2	Q32	m^3/d	No
17.	Flow from Seg #2 to Segment 3	Q23	m^3/d	No
18.	Flow from Seg #4 to Segment 3	Q43	m^3/d	No
19.	Flow from Menominee to Seg.#3	QM3	m^3/d	No

Table 3-2 Continue

No.	Variable Description	Code	unit	Time Variable
20.	Flow from Peshtigo to Seg. 3	QP3	m^3/d	No
21.	Flow from Oconto to Seg.#3	QO3	m^3/d	No
22.	Flow from Seg.#3 to Seg.#4	Q34	m^3/d	No
23.	Flow from LM to Segment 4	QLM4	m^3/d	No
24.	Flow from Escanaba to Seg.#4	QE4	m^3/d	No
25.	Flow from Segment 4 to LM	Q4LM	m^3/d	No
26.	Henry's Constant	HEN	-	No
27.	Atmospheric Conc. of PCB	ACP	ng/l	Yes
28.	POC Conc. of Lake Mich.	W1LM	mg/l	Yes
29.	PCB Conc. of Lake Mich.	W3LM	ng/l	Yes

[1] Lake Michigan

Table 3-3. Description of Variables for Data Set #3

No.	Variable Description	Code	unit	Time Variable
1.	Initial POC Conc.in WC[1]	W1	mg/l	No
2.	Initial POC Conc.in BS[2]	W2	mg/l	No
3.	Initial PCB Conc.in WC	W3	ng/l	No
4.	Initial PCB Conc.in BS	W4	ng/l	No
5.	Volume of WC	V1	m^3	No
6.	Volume of BS	V2	m^3	No
7.	Surface Area of WC	SA1	m^2	No
8.	Area of Sediment, Deposition	ASD	m^2	No
9.	Area of Sediment, Resusp.	ASR	m^2	No
10.	Sed. Porosity	SEDP	-	No
11.	Deep Burial Velocity	DBV	m/d	No
12.	Resuspension Velocity	RSV	m/d	No
13.	Settling Rate of POC	SRO1	m/d	No
14.	Settling Rate of PCB	SRP1	m/d	No
15.	POC Decay Rate in WC	DECR1	1/d	No
16.	POC Decay Rate in BS	DECR2	1/d	No
17.	Decom. Rate of PCB in WC	DRP1	1/d	No
18.	Decom. Rate of PCB in BS	DRP2	1/d	No
19.	Partition Coefficient	PRTC	m^3/Kg	No
20.	Volatilization Exchange Rate	VEXR	m/d	No
21.	Disp. Coef. b/w Sed. and WC	Esi	m^2/d	No
22.	Charc. Length b/w Sed. and WC	Lsi	m	No
23.	External Loading of PCB	ELP	Kg/d	Yes
24.	External Loading of POC	ELO	Kg/d	Yes
25.	Internal Loading of POC	ILO	Kg/d	Yes

[1] Water Column
[2] Bottom Sediment

the description, program code, units and the value of each input variable from each data set as well as the simulation results at the end of each year. A sample printout of the output and the dump file is included in Appendix B.

3.5 Formation of Input Data

To assemble an input data set for modeling POC and PCBs with the STOXGB structure, the following information is required:

(1) Segmentation geometry - volumes, interface areas, characteristic mixing lengths, and depths;

(2) Flow rates - from tributaries to segments and from segment to segment;

(3) POC and PCBs mass loading rates from all significant sources;

(4) Boundary conditions - POC and PCBs concentrations in waters external to, but bordering on, the system of interest (Lake Michigan);

(5) Initial conditions - POC and PCB concentrations in water column and bottom sediment of each segment at the start of the simulation period;

(6) Bulk dispersion coefficients at each segment interface, and water column - bottom sediment interfaces;

(7) Transport and transformation parameters; e.g settling velocities, resuspension and burial velocities, POC and PCB decay rates.

The option exists to specify loadings and boundary conditions as time-variable inputs (on a yearly basis).

3.5.1 Segmentation Geometry

The STOXGB model uses a total of eight spatial segments in Green Bay. Four segments are the water column segments and the remaining four are the bottom sediment segments. The bottom sediment consists of only one active layer, which simplifies the sediment-water interaction processes. The depth of active sediment layer is assumed to be 4 cm. This corresponds to the top two bottom sediment layers (each 2 cm thick) in GBTOX. The spatial segmentations of the model GBTOX and STOXGB models are compared in Figure 3-3 a) and b) respectively. The correspondence between GBTOX and STOXGB water column segments is shown in Table 3-4. Because of this correspondence, it was possible to obtain morphometric parameters for STOXGB segments by summing those for the appropriate GBTOX segments. Water column morphometry for GBTOX and STOXGB are summarized in Tables 3-5 and 3-6, respectively, while bottom sediment segment morphometry is summarized in Tables 3-7 and 3-8, respectively.

3.5.2 Flow Rates

External flows in the Fox, Oconto, Peshtigo, Menominee, and Escanaba Rivers were measured daily at USGS gaging stations during the period of 01 October 1988 through 30 September 1990. These flows were adjusted to account for contributions from ungaged downstream drainage areas. The

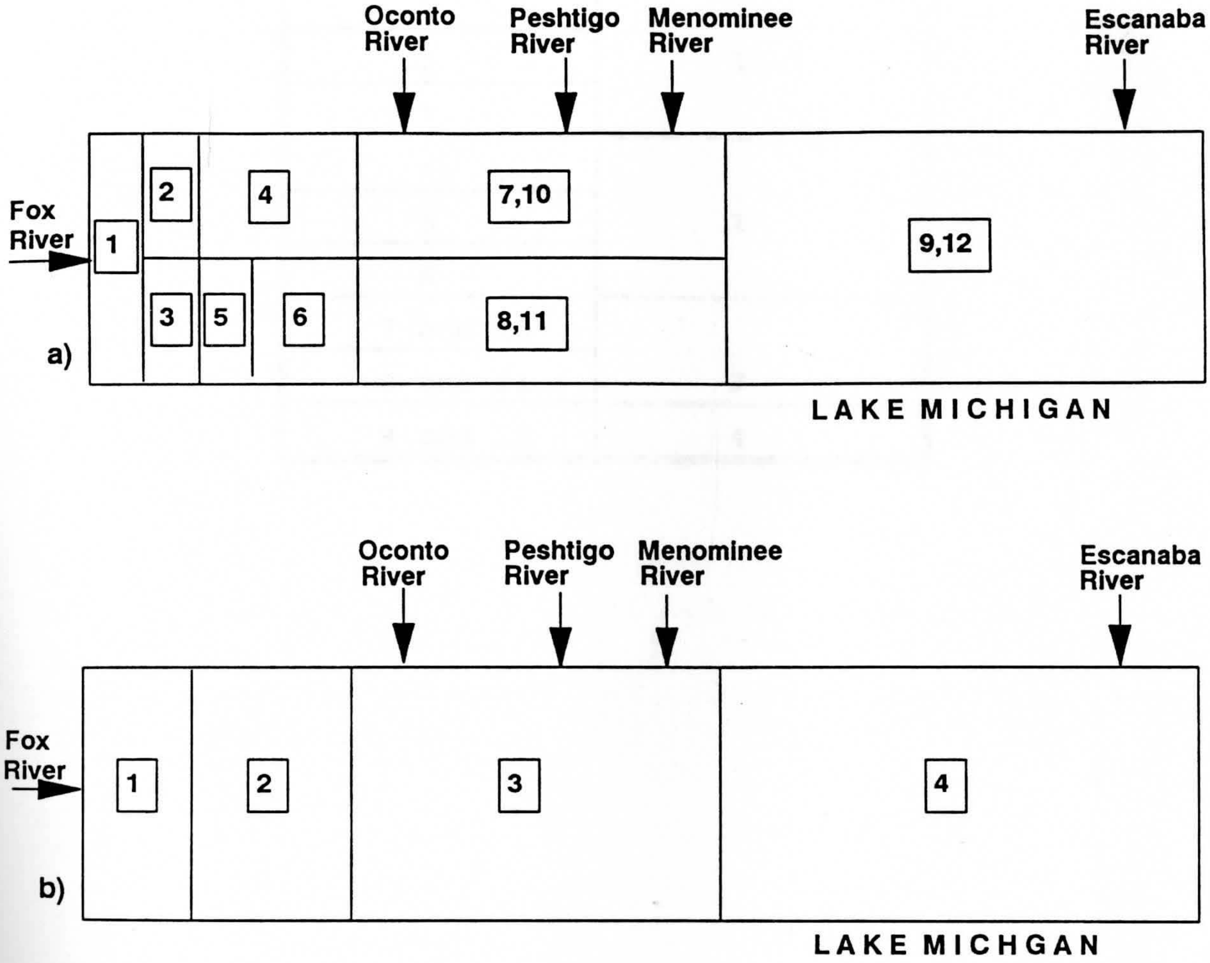


Figure 3-3: Spatial Segmentation of Green Bay (a) GBTOX (adapted from Bierman et al., 1992); (b) STOXGB.

Table 3-4. Correlation of GBTOX and STOXGB Spatial Segmentation.

TOXGB Segments	STOXGB segments
1	1
2	
3	
4	2
5	
6	
7 and 10	3
8 and 11	
9 and 12	4

Table 3-5. Water Column Morphometry of Green Bay (GBTOX), from Bierman et al. (1992).

Segment No.	Volume (m^3)	Mean Depth (m)	Surface Area (m^2)
1	1.112E+8	2.53	4.395E+7
2	1.657E+8	4.14	4.002E+7
3	9.478E+7	3.95	2.399E+7
4	9.809E+8	6.13	1.600E+8
5	1.820E+8	5.69	3.190E+7
6	6.227E+8	7.78	8.004E+7
7	6.649E+9	9.84	6.757E+8
10	2.033E+9	7.37	2.758E+8
8	7.213E+9	12.40	5.817E+8
11	4.273E+9	10.80	3.956E+8
9	2.968E+10	11.60	2.559E+9
12	1.887E+10	12.30	1.534E+9

Table 3-6. Water Column Morphometry of Green Bay (STOXGB).

Segment No.	Volume (m^3)	Mean Depth (m)	Surface Area (m^2)
1	3.717E+8	3.44	1.080E+8
2	1.786E+9	6.57	2.719E+8
3	2.017E+10	16.04	1.257E+9
4	4.855E+10	18.97	2.550E+9

Table 3-7. Bottom Sediment Morphometry of Green Bay (GBTOX) from Bierman, *et al*. (1992).

Sediment Segment	Overlying WC Segment	Total Seg. Volume(m^3)	Deposition Area (m^2)	Resuspension Area (m^2)
13+25	1	1.76E+6	4.395E+7	4.393E+7
14+26	2	1.60E+6	4.002E+7	4.000E+7
15+27	3	9.60E+5	2.399E+7	2.399E+7
16+28	4	4.32E+6	1.600E+8	1.080E+8
17+29	5	1.28E+6	3.190E+7	3.199E+7
18+30	6	3.20E+6	8.004E+7	8.004E+7
19+31	7	1.20E+7	3.999E+8	3.000E+8
20+32	10	1.104E+7	2.758E+8	2.760E+8
21+33	8	6.20E+6	1.861E+8	1.550E+8
22+34	11	1.584E+7	3.956E+8	3.960E+8
23+35	9	3.712E7	1.025E+8	9.280E+8
24+36	12	6.48E+7	1.534E+9	1.620E+9

Table 3-8. Bottom Sediment Morphometry of Green Bay (STOXGB).

Segment No.	Sediment Volume(m^3)	Deposition Area (m^2)	Resuspension Area (m^2)
1	4.32E+6	1.080E+8	1.080E+8
2	8.80E+6	2.719E+8	2.200E+8
3	4.51E+7	1.257E+9	1.127E+9
4	1.02E+8	2.550E+9	2.550E+9

GBTOX model uses the flows on a daily average basis while STOXGB uses the annual averages.

The estimated exchange flow from Lake Michigan alone is twenty times the combined flow of all tributaries to Green Bay. Therefore, it was very important and critical to estimate the routing scheme and the flow rate of Lake Michigan inflows. Based on the studies of Mortimer (1979), Modlin and Beeton (1970), and Miller and Saylor (1985), a range of 5,000 to 10,000 m^3/s was set for mean Lake Michigan exchange flow.

Internal flows were derived through the calibration of the Hydraulic Transport Model (Green Bay Chloride Model (GBCL)) by Bierman et al., (1992). Initially, the fractions of Lake Michigan inflows routed between segments were based on flow estimates from Mortimer (1979). Data from a number of sources (Gottlieb, et al., 1990, NOAA, 1988-90, Navy/NOAA, 1988-90) also proved useful in identifying circulation patterns within the bay and in Lake Michigan (Bierman et al., 1992). Figure 3-4 shows the routing of flows in Green Bay for STOXGB. To develop internal flow inputs for STOXGB, the calibrated results from GBCL were averaged over a one-year period, and a general counterclockwise pattern was assumed.

3.5.3 Loadings

POC and PCBs concentrations were monitored periodically during October 1988 to September 1990 in all significant tributaries.

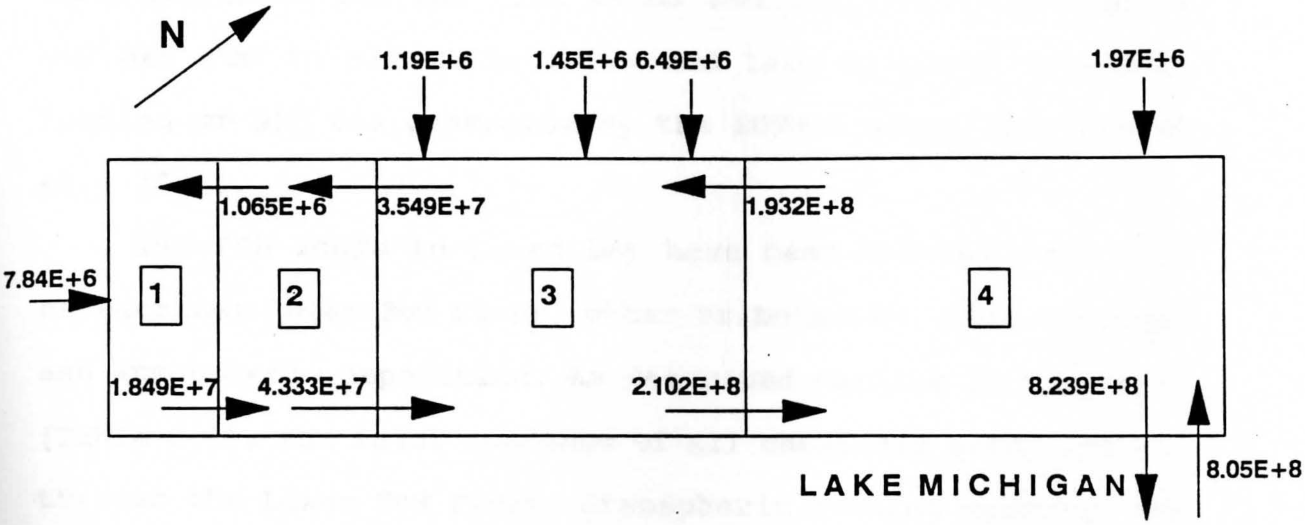


Figure 3-4: Routing of Flows for STOXGB with "Spring Flushing" Included, for Green Bay, Cubic meter/ Day

The Green Bay Organic Carbon Sorbent (GBOCS) Model required both external and internal loadings for three sorbents i.e. dissolved organic carbon (DOC), particulate detrital carbon (PDC) and biotic carbon (BIC) (total organic carbon (TOC) = DOC + POC, where POC = BIC + PDC). The external loadings for DOC and POC were directly calculated with the data available for the flow rates and the concentrations of DOC and PDC in all tributaries and Lake Michigan. Internal loading of BIC was generated by the EUTRO4 model (Bierman _et al_., 1992).

The PCB loads to Green Bay have been divided into four categories: Lower Fox River, other tributaries, Lake Michigan and atmospheric deposition. As described earlier in Chapter 2 (Table 2-2), the major loadings of all chemicals enter the bay through the Lower Fox River. Atmospheric loading accounts for only about 6% of the total PCB loading. External loadings for PCBs were also calculated from the data available for the flow rates and the concentrations of PCBs in all tributaries and Lake Michigan.

Loadings of POC and PCBs were calculated and input on a daily average basis for GBTOX. The STOXGB model uses loadings of POC and PCBs on a yearly average basis. For POC loading, STOXGB uses the calculated value for 1989 used by TOXGB, and assumes it to be constant for the entire simulation period. Similarly, for PCBs the STOXGB uses the loading for 1989 used by GBTOX. The loading pattern for PCBs for each segment in STOXGB is such that the loading was assumed to be zero initially (1940), and increase linearly up to a value three times that of 1989 in 1970, and finally decrease linearly to the 1989 value. Total loading of PCB consists of loadings from the tributaries and atmosphere. Figure 3-5 shows the graphic representation of the PCB external loading for each segment. More discussion of the loadings assumptions for POC and PCBs is presented in Chapters 4 and 5.

3.5.4 Boundary and Initial Conditions

The only boundary conditions required for STOXGB were the concentrations of the state variables, POC and PCB, in the water column at the Lake Michigan boundary. The boundary condition values were obtained from the Lake Michigan Great Lakes International Surveillance Plan data.

The Model STOXGB has the ability to enter the atmospheric concentration of PCB, and the POC and PCB boundary conditions on an annual basis. POC boundary concentration for segment four was held constant at 0.24 mg/l (BIC = 0.04 mg/l, PDC = 0.20 mg/l) throughout the simulation period. The pattern used for PCB boundary condition is such that initially (1940) it increases linearly from 0 to three times the 1989 value (4.8 ng/l) in 1970 and then decreases linearly to the 1989 value (1.6 ng/l). Similarly, for atmospheric concentration the value increases linearly from 0 to 1.5 ng/l (twice the value of 1989) in 1970 and decreases linearly from 1970 to 1989 to the value of 0.77 ng/l) (Figure 3-6). Figure 3-7 shows the graphical presentation of PCB boundary values for segment

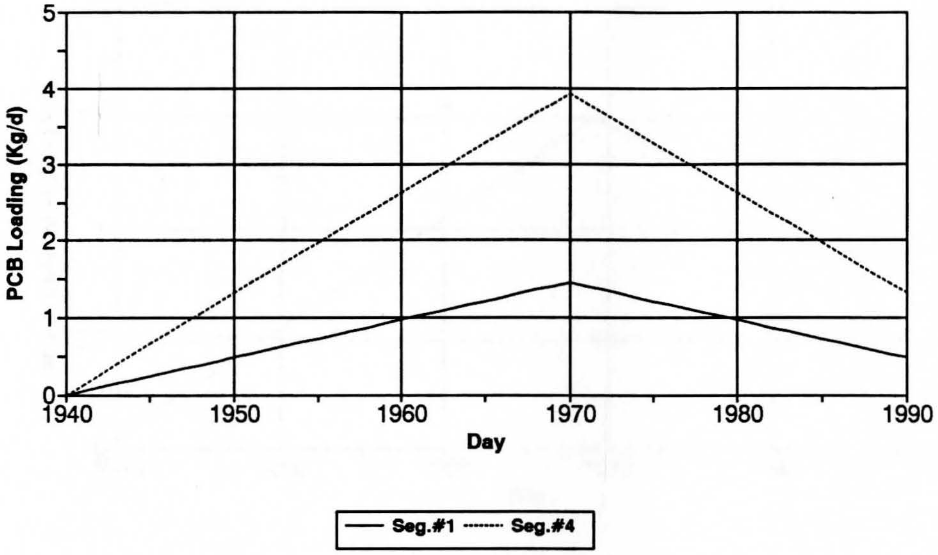


Figure 3-5 a): PCB Loading for Segment 1 and 4 VS Time

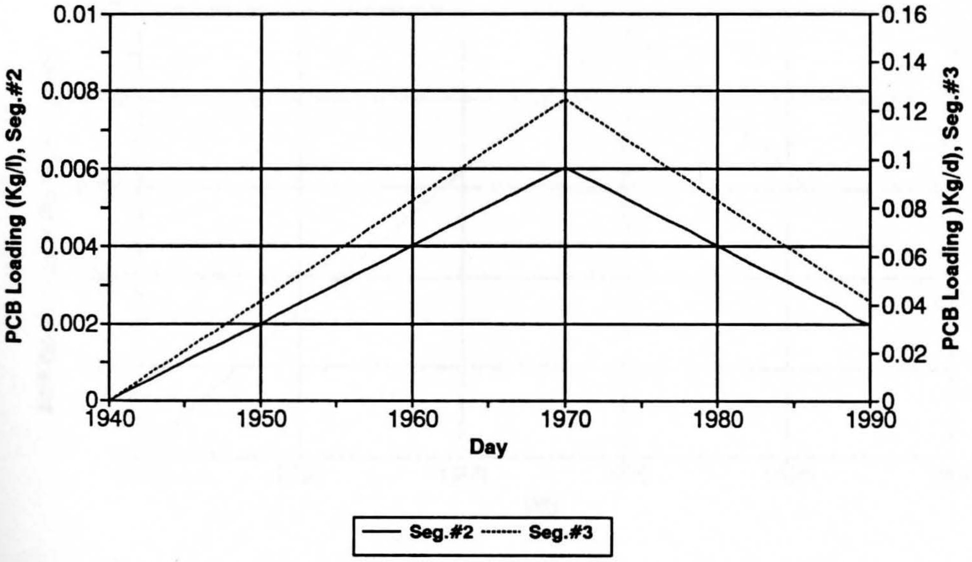


Figure 3-5 b): PCB Loading for Segment 2 and 3 VS Time

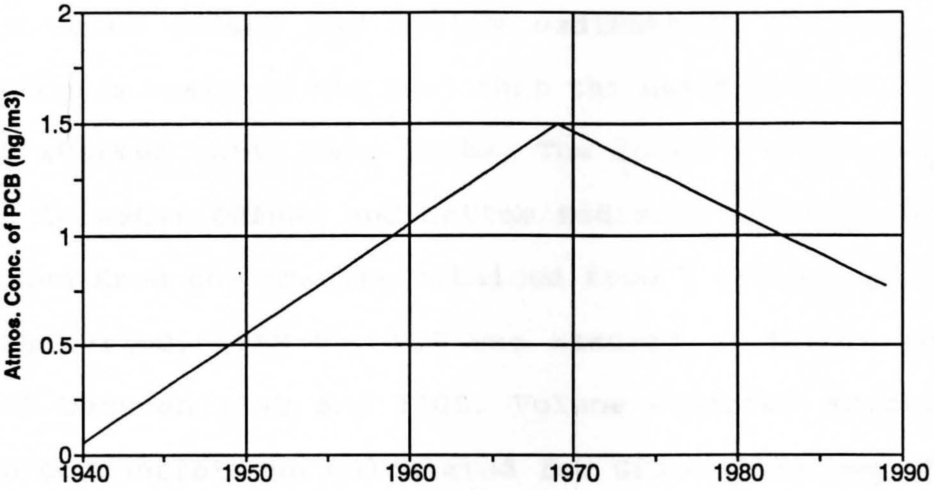


Figure 3-6: Atmospheric Concentration of PCB VS Time

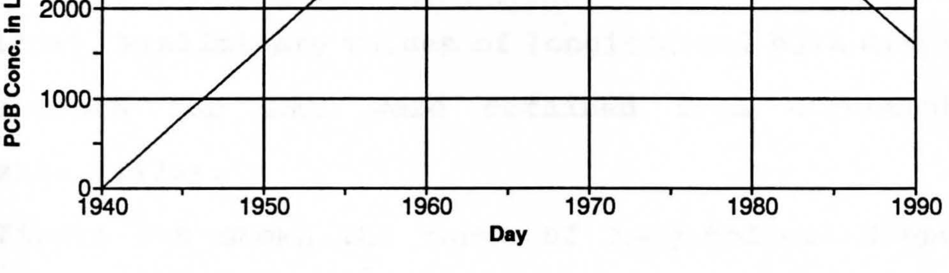


Figure 3-7: PCB Concentration in Lake Michigan VS Time

four. More discussion of boundary value assumptions for POC, PCBs and the atmospheric concentration of PCB is presented in Chapters 4 and 5.

The STOXGB model assumes initial concentrations of PCBs both in water column and bottom sediment to be zero. This assumption is based on the fact that the manufacturing of PCBs was not started until late 1920s. The initial concentrations for POC in water column and bottom sediment for each segment were taken from the results obtained from 7 cruises during an 18-month period, 1988-90. POC was assumed to remain roughly constant between 1940 and 1989. Volume-weighted average POC and PCB concentrations calculated for GBTOX (Bierman et al., 1992) were modified to STOXGB segmentation. These values (Table 3-9) were used in evaluating the accuracy of model predictions.

3.5.5 Dispersion Coefficient

The STOXGB model used longitudinal and vertical dispersion coefficients which were derived from the calibration of GBCL (Green Bay Chloride Model) (Bierman et al., 1992). Preliminary values of longitudinal bulk dispersion coefficients for GBCL were obtained from Ahrnsbrak and Ragotzkie (1970).

Figure 3-8 shows the range of longitudinal dispersion coefficients used by STOXGB.

Table 3-9. Volume Weighted Average Values of POC and PCB in Water Column and Bottom Sediment for STOXGB, 1989.

Segment No.	POC Concentration (mg/l)		PCB Concentration (ng/l)	
	WC	BS	WC	BS
1.	2.346	7000	21.02	80000
2.	1.072	8080	8.45	129828
3.	0.606	10790	4.14	67356
4.	0.398	12860	2.47	13179

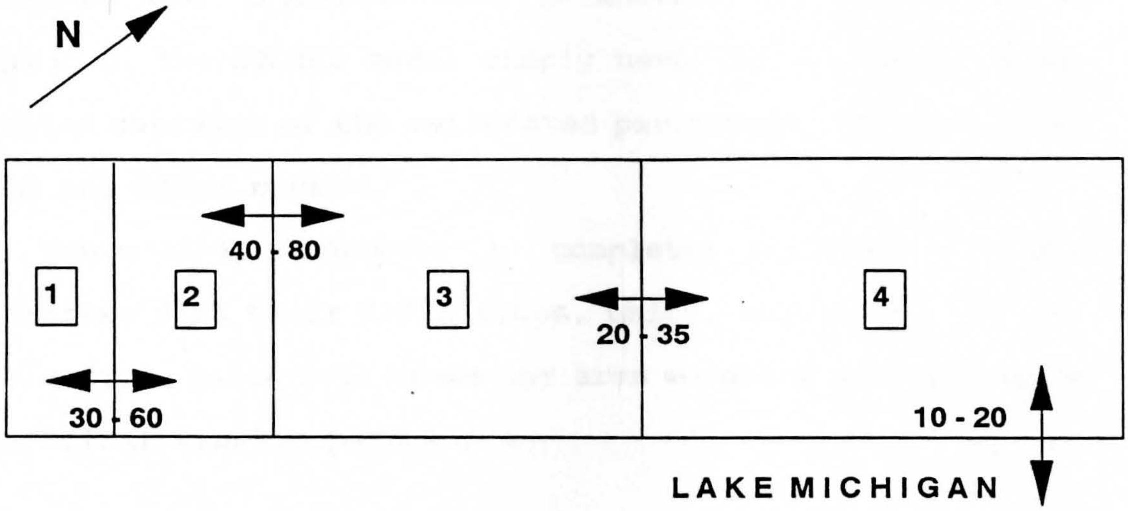


Figure 3-8: Bulk Dispersion Coefficient for STOXGB, meter sq./s

3.5.6 Kinetic Parameters

Based on the conceptualization of STOXGB (Figure 3-1), there are a number of transport and transformation parameters that must be specified to run the model. The discussion about how the GBOCS and GBTOX models were used to derive all the transport and transformation parameters was presented in Chapter 2. The STOXGB model simply uses the volume-/or area-weighted averages of the calibrated parameters derived by the GBOCS and GBTOX models.

Table 3-10 presents a complete listing of these parameters with their definitions, units, and source for this application. Table 3-11 shows the area weighted average values of critical kinetic parameters.

3.6 Differences Between GBTOX and STOXGB Models

One of the main reasons why the model STOXGB was developed is to see whether it can predict the concentrations of POC and PCBs similar to those predicted by GBTOX. The simulation time for GBTOX is eighteen months, while simulation time for STOXGB is fifty years, from 1940 to 1990. There are many differences in GBTOX and STOXGB models. As the name suggests, Simplified Toxics Model for Green Bay (STOXGB) is quite simple as compared to GBTOX. Some of the main differences between GBTOX and STOXGB are listed below.

(1) Different segmentations;

(2) Different bottom sediment geometry;

Table 3-10. Critical Kinetic Parameters for STOXGB.

Code	Definition	Units	Source
SEDP	Sediment Porosity	Dimensionless	Field Data
DBV	Deep Burial Velocity	m/d	Analysis of Field Data
RSV	Resuspension Velocity	m/d	Analysis of Field Data
SRO1	Settling Velocity of POC (PDC, BIC)	m/d	Literature/ EUTRO4
SRP1	Settling Rate of PCB	m/d	Literature/ EUTRO4
DECR 1	POC Decay Rate in WC	1/d	EUTRO4; Calibration
DECR 2	POC Decay Rate in BS	1/d	Literature
DRP1	Decom. Rate of PCB in WC	1/d	Literature
DRP2	Decom. Rate of PCB in BS	1/d	Literature
PRTC	Partition Coefficient	m^3/Kg	Analysis of Field Data
VEXR	Volatilization Exchange Rate	m/d	Literature
Esi	Vertical sediment-water diffusion coefficient.	m^2/d	Literature
Hen	Henry's Law Constant; chemical specific, temperature dependant.	Dimensionless	Literature

Table 3-11. Area Weighted Average Values of Selected Kinetic Parameters for each Segment, STOXGB

Seg.#	Burial Velocity (mm/yr)	Resusp. Velocity (mm/yr)	Settling Rate (m/d)	Decay Rate[1] (1/d)
1	1.77	141.64	1.748	0.0428
2	3.68	73.16	1.328	0.0388
3	3.05	23.65	0.797	0.0379
4	0.97	13.09	0.922	0.0395

[1] All values of Burial velocity, Resuspension velocity and settling rate are same for POC and PCB except that Decay rate for PCB was assumed to be zero.

(3) Flows and concentrations were input on daily average basis in GBTOX, while they are annually averaged in STOXGB;

(4) Settling, resuspension and burial velocities are time variable in GBTOX while STOXGB assumes them to be constant.

(5) The processes considered by the two models are the same, but GBTOX uses more advanced formulas for many kinetic coefficients - e.g., resuspension, volatilization.

(6) GBTOX is designed to simulate short-term (seasonal) dynamics of sorbents and toxics, while STOXGB is designed to simulate long-term (years to decades) trends.

The GBTOX model uses WASP4 format , therefore, the level of complexity is very flexible. GBTOX can also be run for long term predictions, howerer since the STOXGB was developed for this specific purpose, it is much easier to use as compare to GBTOX.

CHAPTER IV

MODEL APPLICATION AND RESULTS

4.1 Model Application

The STOXGB model, as suggested by its name (Simplified Toxics Model for Green Bay), is much simpler then the GBTOX model applied by Bierman et al. (1992). In particular, the complexities of such parameters as the water column geometry, and the time resolution of flows, loadings, etc., have been reduced as compared to the GBTOX model. One of the main reasons for developing STOXGB model was to see if the simpler model could produce logical results for a long term basis using the same (or similar) input data as GBTOX.

Unfortunately a dilemma of modelers is that if the models are simple and easily understood, they will be subject to the criticism that they do not include descriptions of all the complexities of a system. If they are complex, few other than the developer will take the time to understand and check the model; thus, the model may contain unidentified mistakes and there will be a lack of confidence in using it for proposing practical remedial measures. Perhaps the art of modeling (as distinct from the science) is the ability to select only the key processes and express them using robust, easily understood and verified expressions so that the user can remain "in tune" with the results and have confidence that they are intuitively reasonable (Mackay, 1989).

Keeping this idea in mind, the STOXGB model was developed to evaluate results of the "parent model", GBTOX, and to provide the capability for convenient long term analysis of PCBs in Green Bay. The STOXGB model was applied for three different cases with variations in the number of parameters that were calibrated, and for four different managerial scenarios, with variation in the loading patterns assumed for POC and PCBs.

Following is a listing of the different cases and scenarios for which the STOXGB model was applied:

(1) Case #1: No calibration; input data from GBTOX;
(2) Case #2: Partial calibration; resuspension and burial velocities unchanged;
(3) Case #3: Full calibration;
(4) Managerial Scenario #1 - 1989 loading continued;
(5) Managerial Scenario #2 - 50% reduction in POC loads;
(6) Managerial Scenario #3 - 50% reduction in PCB loads;
(7) Managerial Scenario #4 - 100% reduction in PCB loads.

4.2 Case #1, Uncalibrated Results

As described in Chapter 2 (section 2.7) all the critical kinetic and stoichiometric parameters (resuspension, deep burial and settling velocities, partitioning coefficient, etc.) were carefully derived and calibrated for GBTOX. The first test for the new model (STOXGB) was to see if it could generate some reasonable results without changing any input parameters, i.e. using values taken directly from GBTOX with spatial and/or temporal averaging , where necessary. A list of the parameters, their code names, units and values is presented in Table 4-1. The comparison between uncalibrated results for Case #1 and observed (measured) values of POC and PCB concentration in the water column and bottom sediment is given in Table 4-2. Since reliable PCB field data are only available for 1989-90, only the model output for 1989 is included in Table 4-2.

Figures 4-1 to 4-20 show the changes in POC and PCB concentrations in water column and bottom sediment of each segment with respect to time for the 1940-1989 simulation period. Figures 4-21 to 4-24 show spatial concentration profiles of POC and PCB both in water column and bottom sediment in each segment versus distance from the Fox River mouth.

The general pattern in 1989 field generated data is that the POC and PCB concentrations in the water column decrease from segment 1 to segment 4. POC concentrations in the bottom sediments follow the opposite pattern, increasing steadily from segment 1 to segment 4. The field data for PCB concentrations in the bottom sediments did not show a consistent trend, with seg. 2 > seg. 1 > seg. 3 > seg. 4. The historical trends predicted by STOXGB (Figures 4-1 to 4-20) must be considered as speculative at this point, since no data is available for comparison. PCB predictions closely follow the assumed loading trends, reaching peaks between 1970 and

Table 4-1. Values of all Parameters Used in Case #1, STOXGB

Parameter (Code) (Units)	Seg. #1	Seg. #2	Seg. #3	Seg. #4
Bulk Disp. Ceoff. (BDSC) (m2/d)	4.320E+6	5.184E+6	2.38E+6	1.296E+6
Sed. Porosity (SEDP)	0.92	0.93	0.95	0.94
Burial Velocity (DBV) (m/d)	4.850E-6	1.008E-5	8.35E-6	2.658E-6
Resus. Velocity (RSV) (m/d)	3.890E-4	2.000E-4	6.58E-5	3.562E-5
Set. Rate of POC (SRO1), (m/d)	1.75	1.33	0.80	0.92
Set. Rate of PCB (SRP1), (m/d)	1.75	1.33	0.80	0.92
Decay POC in WC (DECR1) (1/d)	0.0428	0.0388	0.0379	0.0395
Decay POC in BS (DECR2) (1/d)	0.0001	0.0001	0.0001	0.0001
Decay PCB in WC (DRP1) (1/d)	0.00	0.00	0.00	0.00
Decay PCB in BS (DRP2) (1/d)	0.00	0.00	0.00	0.00
Partition Coeff. (PRTC) (m3/Kg)	2000	2000	2000	2000
Volatil. Rate (VEXR) (m/d)	0.2345	0.2345	0.2345	0.2345
Disp. Coef. WC/BS (Esi) (m2/d)	3.922E-4	3.922E-4	3.92E-4	3.922E-4

Table 4-2. Comparison of Uncalibrated Results of STOXGB for 1989 and the 1989 Field Data.

Segment No.	1989 Field Data			
	POC, mg/l		PCB, ng/l	
	WC	BS	WC	BS
1	2.346	7000	21.02	80000
2	1.072	8080	8.45	129828
3	0.606	10790	4.14	67356
4	0.398	12860	2.47	13179
	STOXGB Results, Case #1			
1	1.924	8464	14.91	55810
2	0.8246	5141	2.058	9100
3	0.2616	2692	2.156	13770
4	0.2660	5788	3.167	40060

Model Simulation for Green Bay

Case 1: Uncalibrated Results

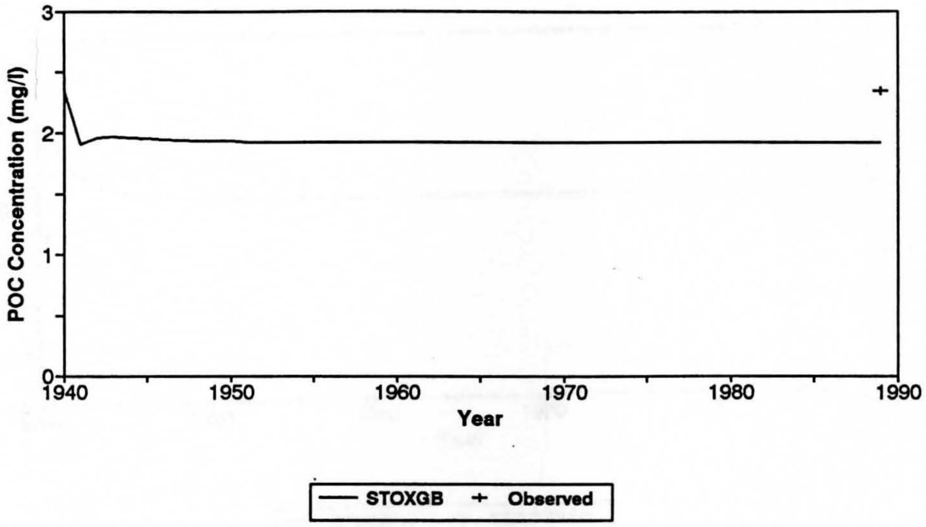


Figure 4-1: STOXGB Results for POC in Water Column of Segment #1 Versus Time - Case 1.

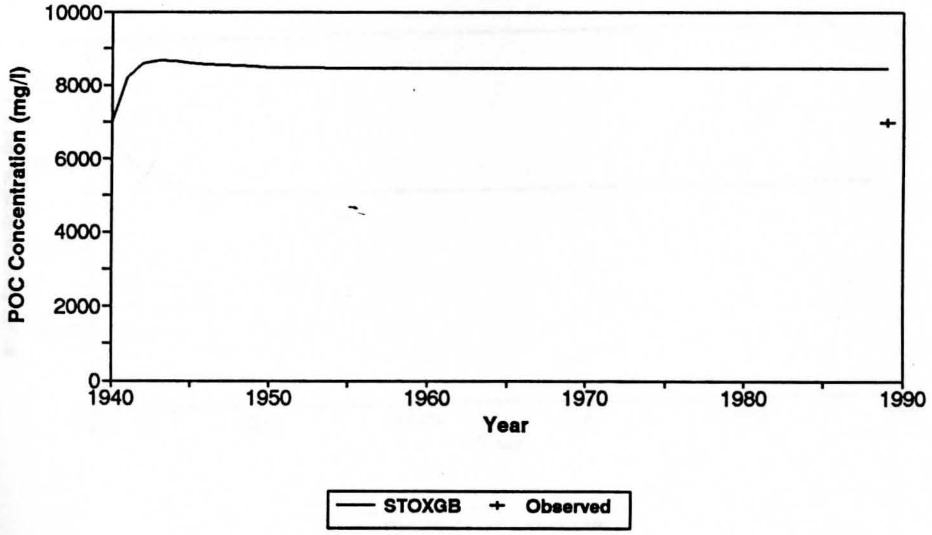


Figure 4-2: STOXGB Results for POC in Bottom Sediment of Segment #1 Versus Time - Case 1.

Model Simulation for Green Bay

Case 1: Uncalibrated Results

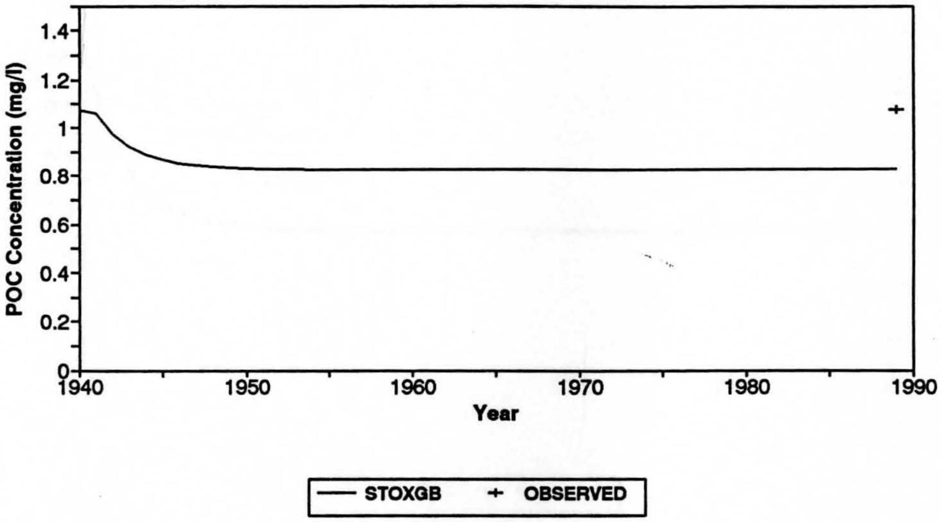


Figure: 4-3 STOXGB Results for POC in Water Column of Segment #2 Versus Time - Case 1.

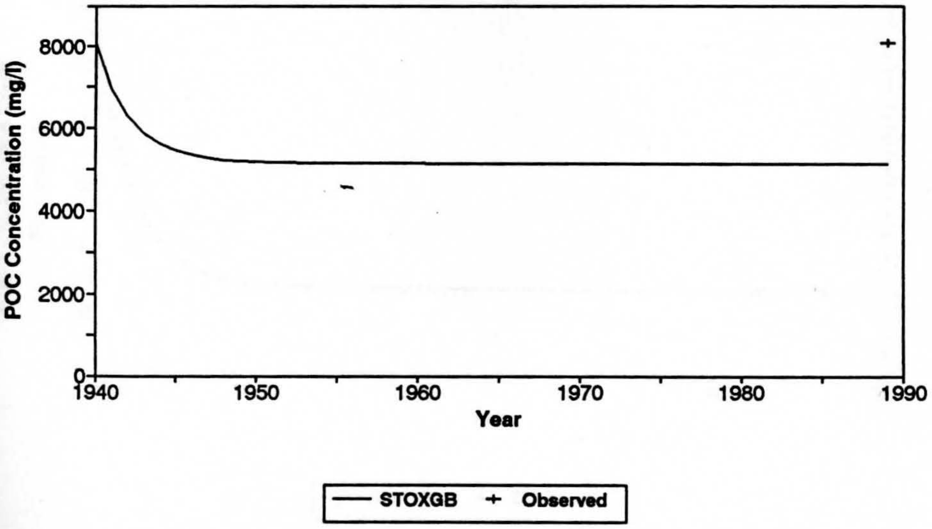


Figure. 4-4 STOXGB Results for POC in Bottom Sediment of Segment #2 Versus Time - Case 1.

Model Simulation for Green Bay

Case 1: Uncalibrated Results

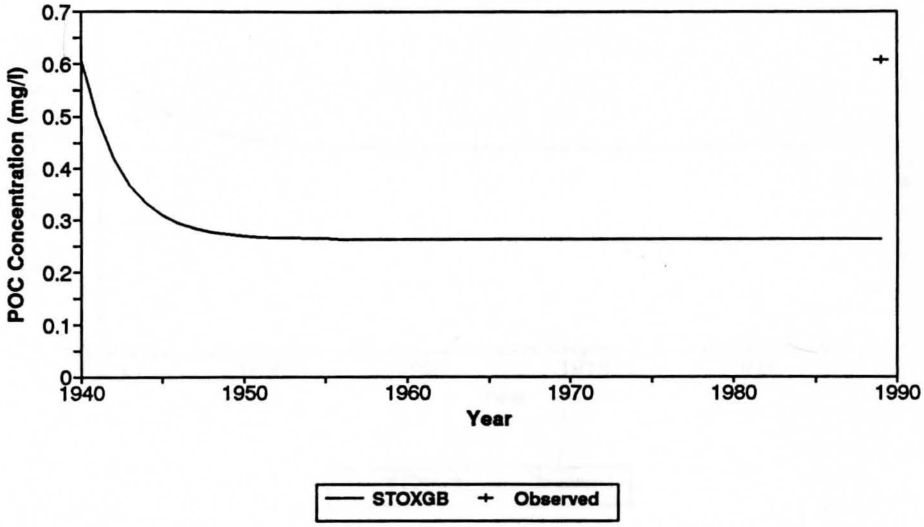


Figure 4-5: STOXGB Results for POC in Water Column of Segment #3 Versus Time - Case 1.

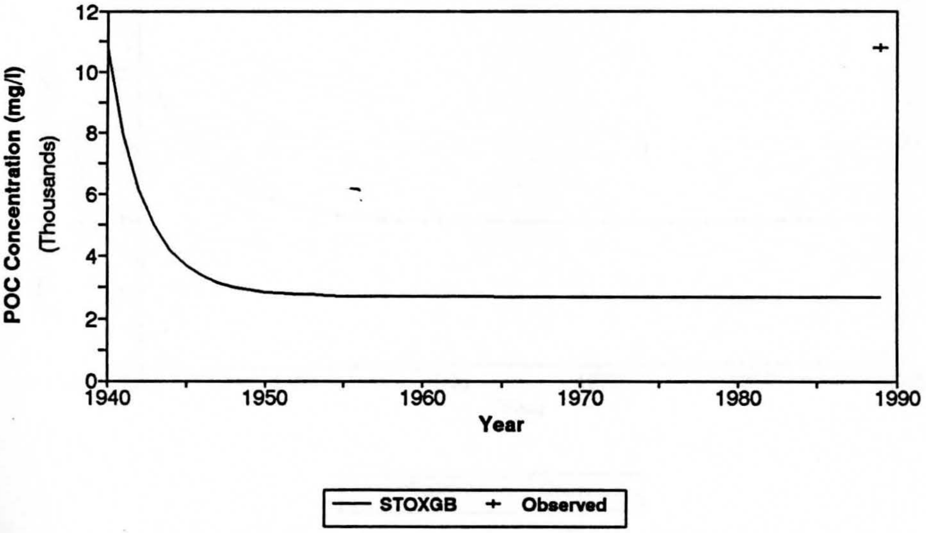
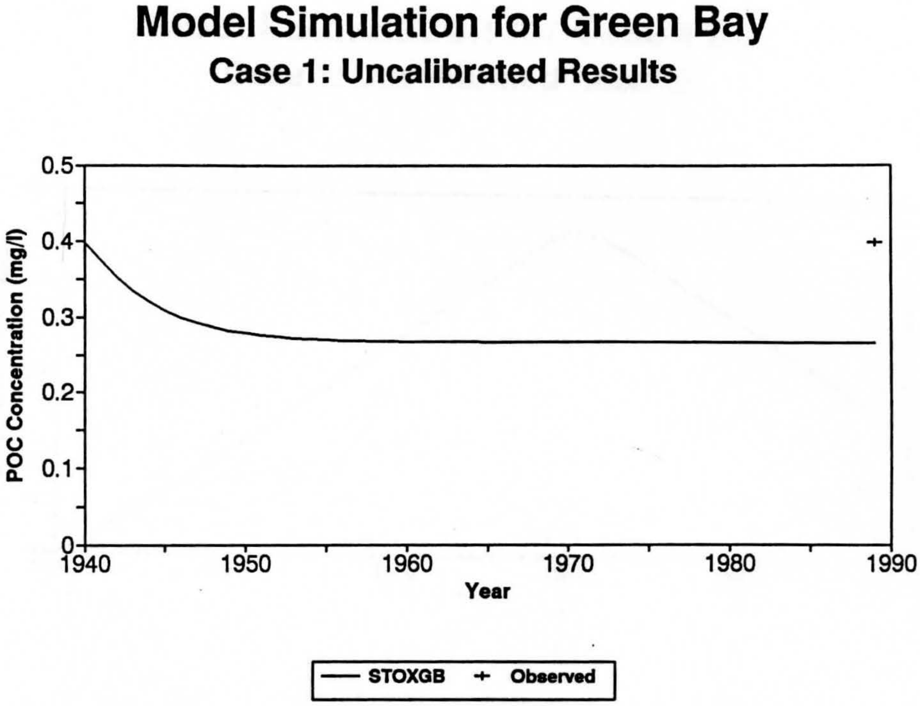


Figure 4-6: STOXGB Results for POC in Bottom Sediment of Segment #3 Versus Time - Case 1.



Model Simulation for Green Bay
Case 1: Uncalibrated Results

Figure 4-7: STOXGB Results for POC in Water Column of Segment #4 Versus Time - Case 1.

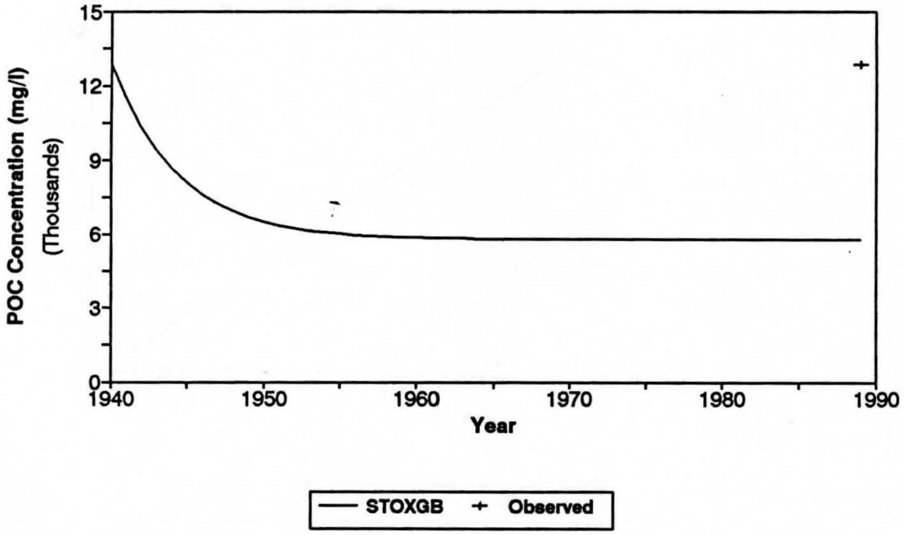
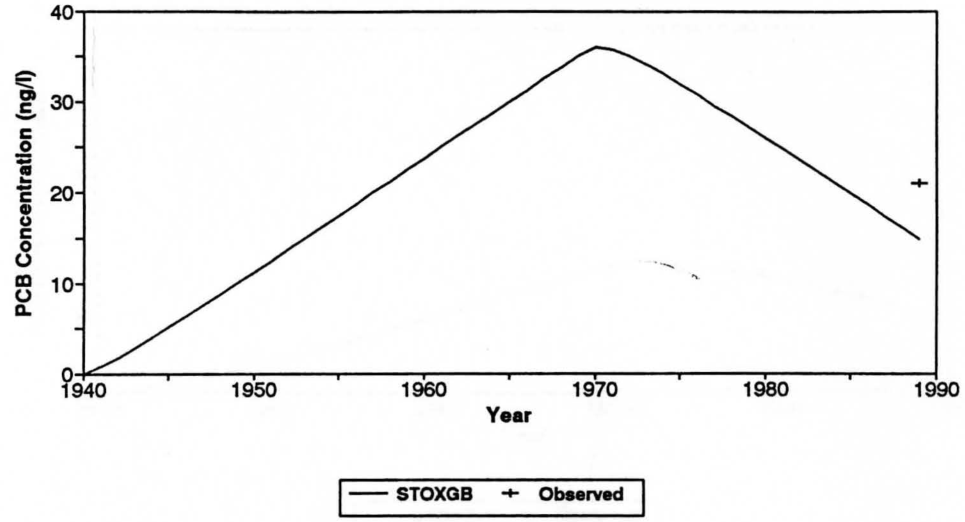


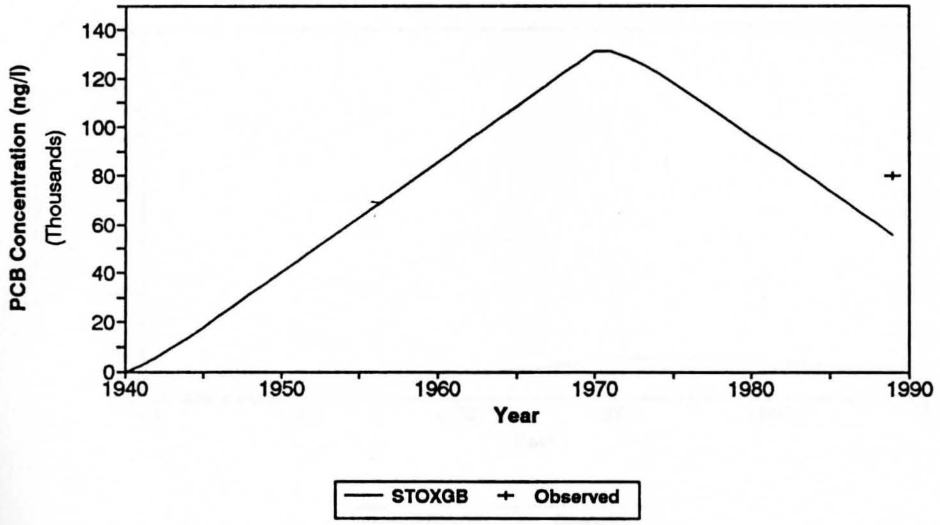
Figure 4-8: STOXGB Results for POC in Bottom Sediment of Segment #4 Versus Time - Case 1.

Model Simulation for Green Bay

Case 1: Uncalibrated Results



<u>Figure 4-9:</u> **STOXGB Results for PCB in Water Column of Segment #1 Versus Time - Case 1.**



<u>Figure 4-10:</u> **STOXGB Results for PCB in Bottom Sediment of Segment #1 Versus Time - Case 1.**

Model Simulation for Green Bay

Case 1: Uncalibrated Results

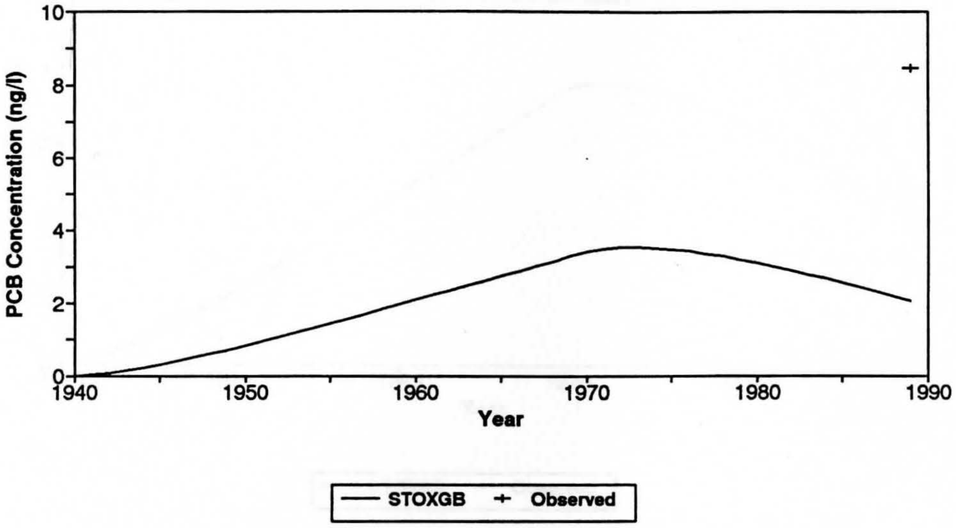


Figure 4-11: STOXGB Results for PCB in Water Column of Segment #2 Versus Time - Case 1.

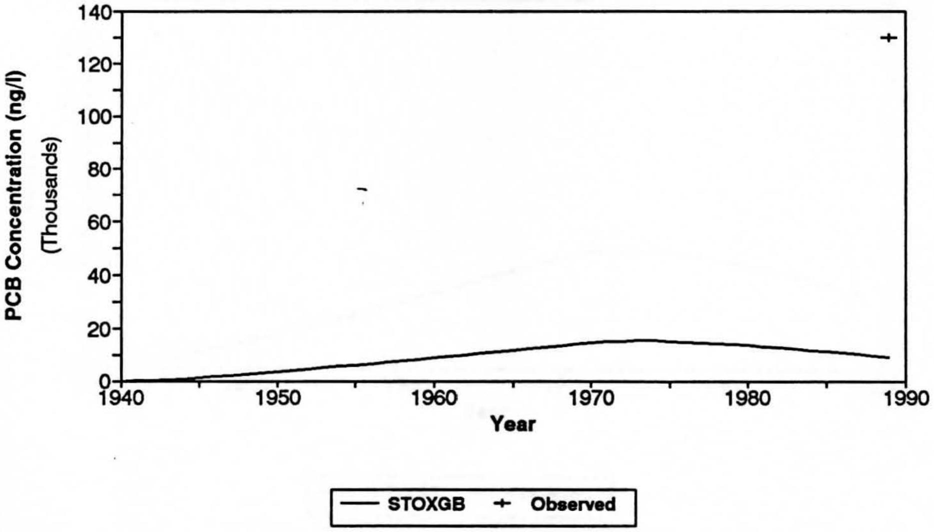


Figure 4-12: STOXGB Results for PCB in Bottom Sediment of Segment #2 Versus Time - Case 1.

Model Simulation for Green Bay

Case 1: Uncalibrated Results

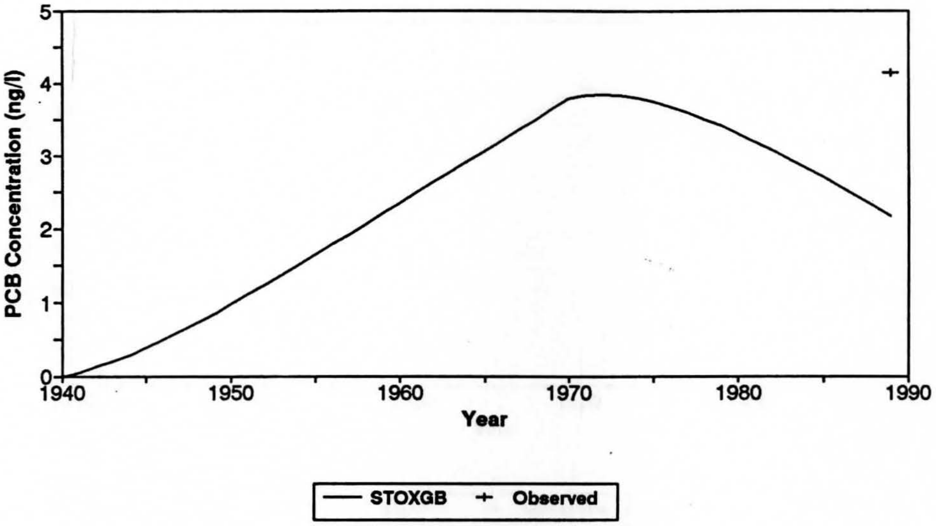


Figure 4-13: STOXGB Results for PCB In Water Column of Segment #3 Versus Time - Case 1.

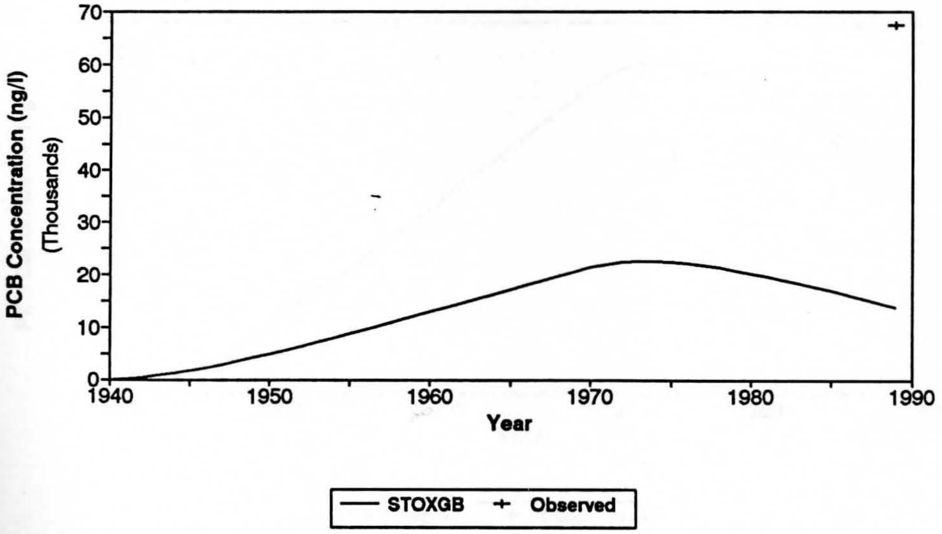


Figure 4-14: STOXGB Results for PCB In Bottom Sediment of Segment #3 Versus Time - Case 1.

Model Simulation for Green Bay
Case 1: Uncalibrated Results

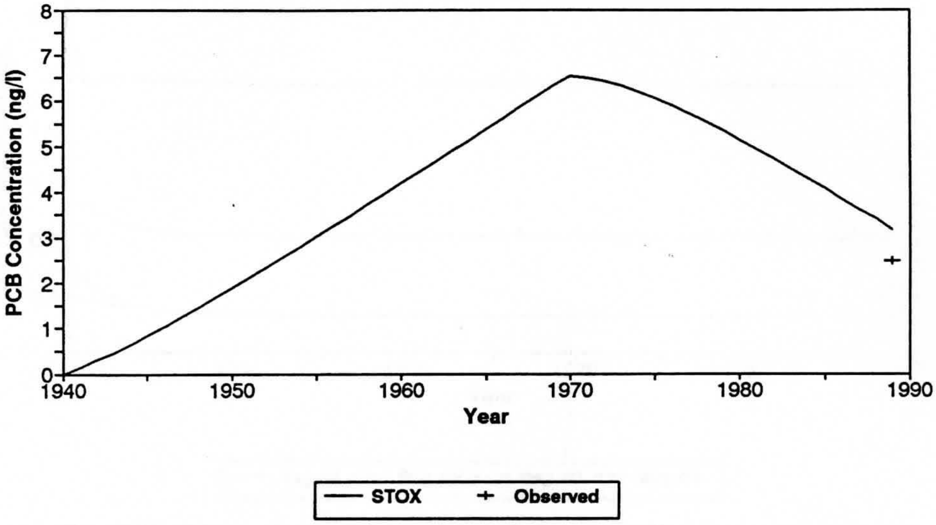


Figure 4-15: STOXGB Results for PCB in Water Column of Segment #4 Versus Time - Case 1.

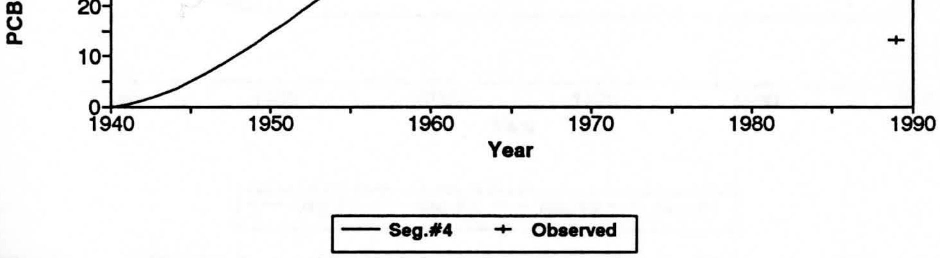


Figure 4-16: STOXGB Results for PCB in Bottom Sediment of Segment #4 Versus Time - Case 1.

Model Simulation for Green Bay

Case 1: Uncalibrated Results

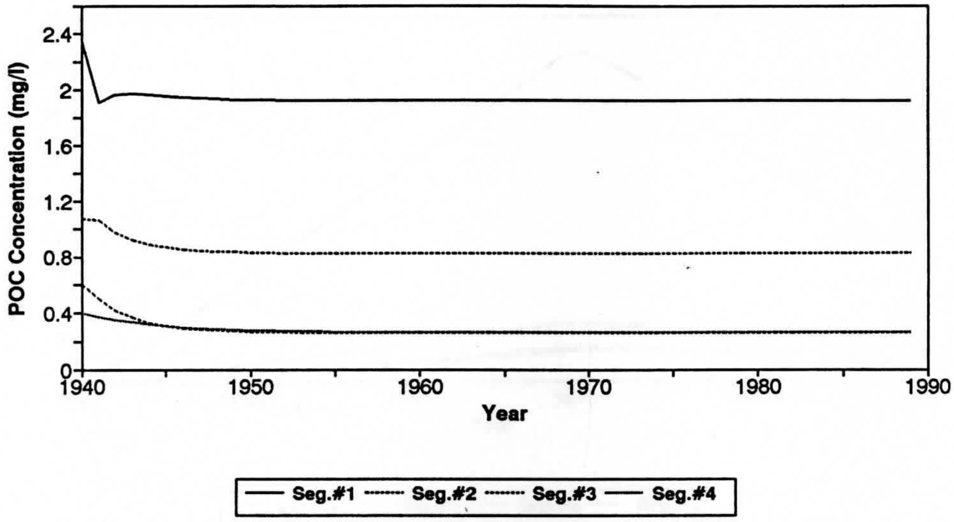


Figure 4-17: STOXGB Results for POC in Water Column of all Segments Versus Time - Case 1.

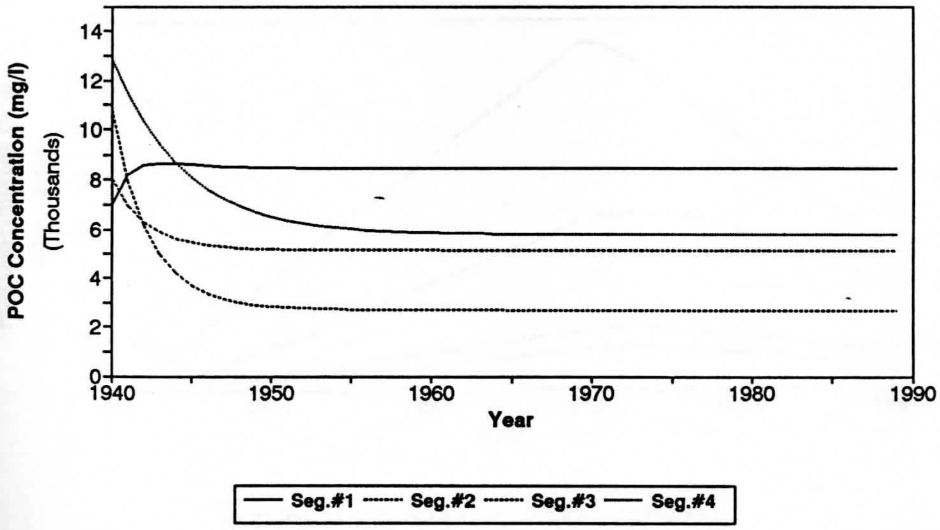


Figure 4-18: STOXGB Results for POC in Bottom Sediment of all Segments Versus Time - Case 1.

Model Simulation for Green Bay

Case 1: Uncalibrated Results

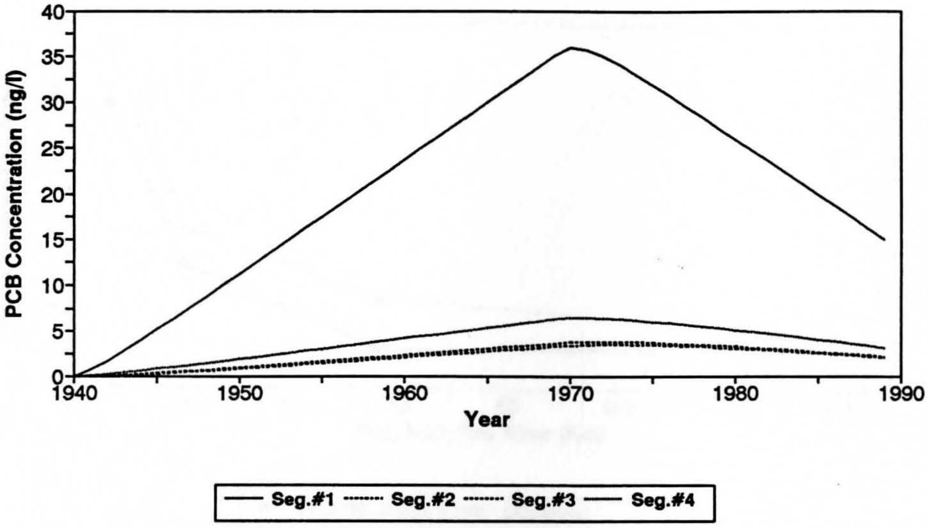


Figure 4-19: STOXGB Results for PCB in Water Column of all Segments Versus Time - Case 1.

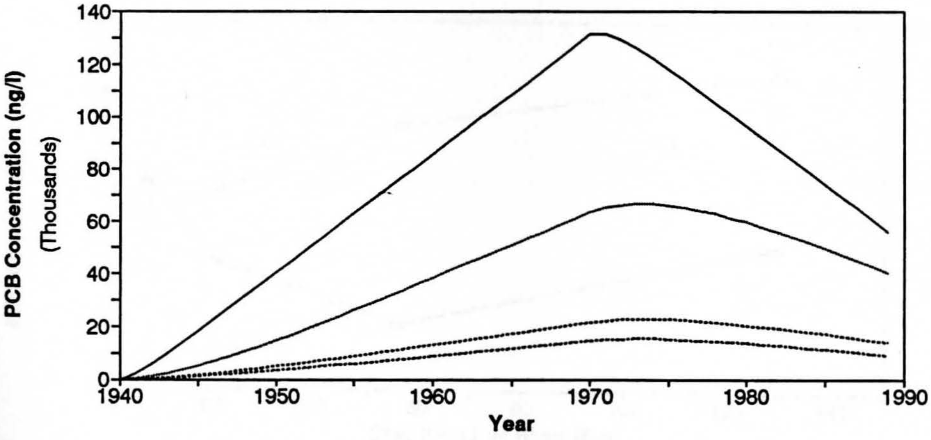


Figure 4-20: STOXGB Results for PCB in Bottom Sediment of all Segments Versus Time - Case 1.

Model Simulation for Green Bay

Spatial Graphs

Case 1: Uncalibrated Results for 1989

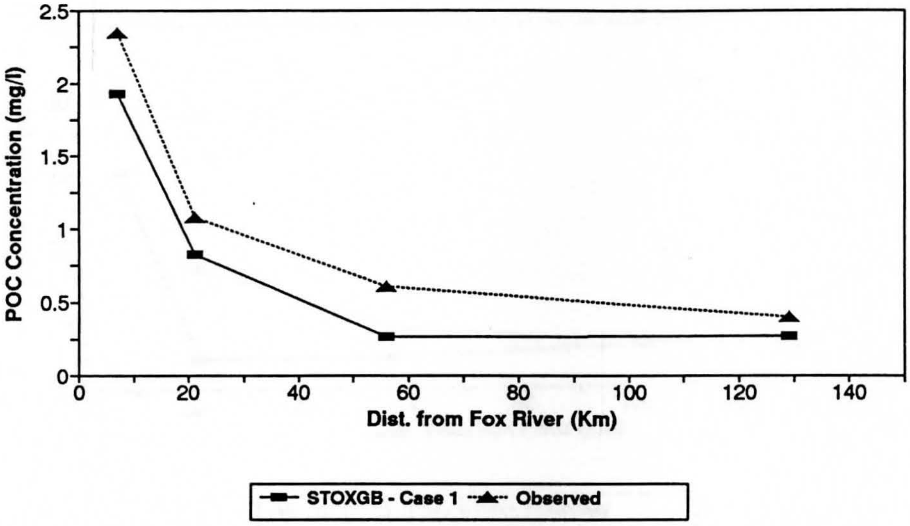


Figure 4-21: STOXGB Results for POC in Water Column Versus Distance from Fox River - Case 1, 1989 Values.

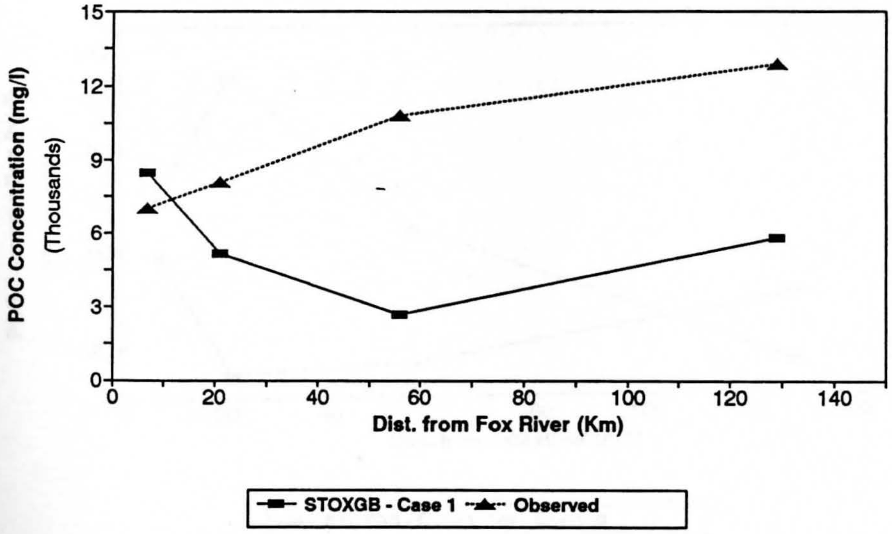


Figure 4-22: STOXGB Results for POC in Bottom Sediment Versus Distance from Fox River - Case 1, 1989 Values.

Model Simulation for Green Bay

Spatial Graphs

Case 1: Uncalibrated Results for 1989

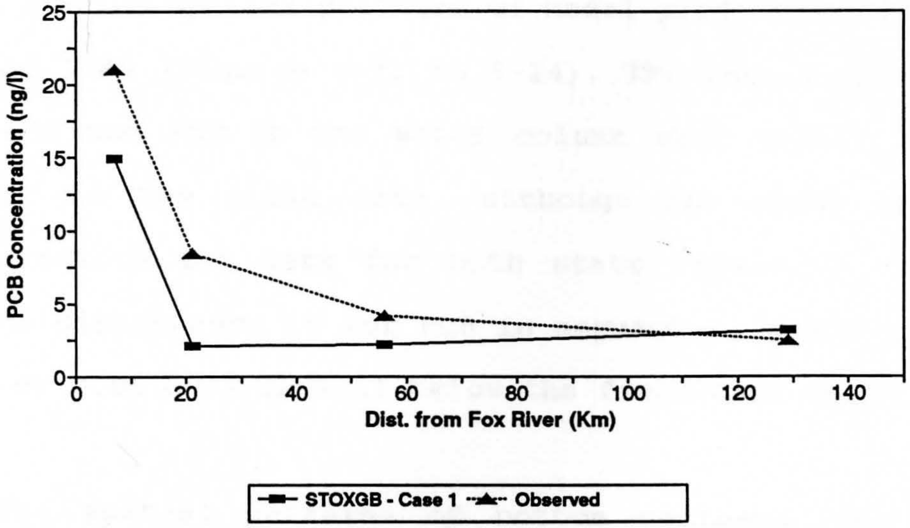


Figure 4-23: STOXGB Results for PCB in Water Column Versus Distance from Fox River - Case 1, 1989 Values.

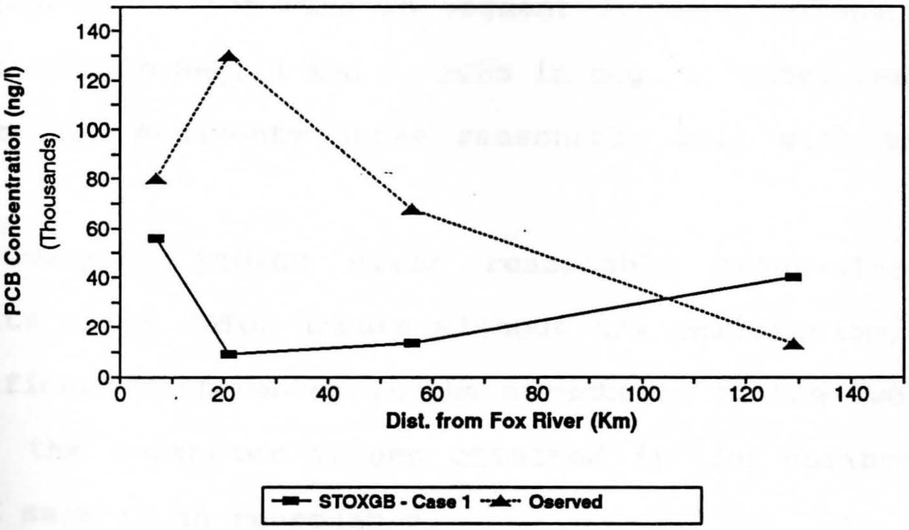


Figure 4-24: STOXGB Results for PCB in Bottom Sediment Versus Distance from Fox River - Case 1, 1989 Values.

1975 in all segments. Predictions for POC, with the assumption of a constant loading, show significant adjustments to a steady-state value within the first ten years of the simulation.

The performance of STOXGB can best be evaluated using the plots showing spatial patterns of model predictions and field data of 1989 (Figures 4-21 to 4-24). The case 1 results for 1989 POC and PCB in the water column show trends that are similar to the field data, although the model generally underpredicts the data for both state variables. The most serious discrepancy is for PCB in segment 2, where the model value of 2.06 ng/l is well below the field data value of 8.45 ng/l.

The spatial patterns of bottom sediment POC and PCB concentrations predicted by STOXGB for 1989 differ considerably from the field data. Again, the largest discrepancy is for PCBs in segment 2. Nevertheless, in some cases (POC in Seg. 1 and 2, PCBs in seg. 1) model results for the bottom sediments agree reasonably well with the field data.

Overall, STOXGB gives reasonable order-of-magnitude results using GBTOX inputs without any calibration, despite significant differences in the structures of the two models. Thus, the parameter values obtained in the calibration of GBTOX seem to be reasonable.

4.3 Case #2, Calibrated Results (RSV, DBV unchanged)

In calibrating any mass balance model, there are two general approaches that can be taken. One approach is to measure (either directly or indirectly) the rate or extent of a given process included in the model formulation. Then, given knowledge of how system variables affect the process and a measure of these system variables, the coefficient(s) for the process can be computed on a site-specific basis (Chapra and Reckhow 1983). The second approach involves comparing the model state variables output with field observations of the state variables at the same points in space and time. Then the unknown process coefficients are adjusted, with constraints dictated by literature and process understanding, until the model provides a "best" representation of the field observations. There are several methods available for quantitatively arriving at a "best fit" to the data (Thomann et al., 198?).

In calibration of the STOXGB model, both of the above approaches were used. The aim in all cases is to minimize the deviation between the model and the data without using coefficient values outside the "acceptable" range.

One of the innovative ideas used in calibrating GBTOX was to calculate the mean resuspension and burial velocities from field data. The GBTOX model considers resuspension and burial velocities to be time variable, and adjusts the value of resuspension as a function of wind.

Considering the fact that the values of resuspension and burial velocities were more accurately determined, in Case #2 STOXGB was "partially" calibrated by changing the values of other kinetic parameters, but not resuspension and burial velocities.

Table 4-3 shows a listing of the critical parameters, their code names, units and the final values used in STOXGB for Case #2. The following parameters were adjusted in the calibration process:

(1) Bulk dispersion coefficient;
(2) Settling rate of POC;
(3) Settling rate of PCB;
(4) Decay rate of POC in water column;
(5) Decay rate of POC in bottom sediment;
(6) Partition coefficient; and
(7) Volatilization rate.

Model predictions showed the greatest sensitivity to settling rates of POC and PCB and decay rate of POC in water column and bottom sediment.

Table 4-4 shows the comparison of calibrated results (without changing RSV and DBV) from STOXGB and the measured concentrations of POC and PCB in water column and bottom sediments.

Figures 4-25 to 4-28 show the predicted and observed concentration profiles of POC and PCBs in water column and bottom sediment of each segment (plotted by distance from the Fox River). The numerical values represented by these graphs are listed in Table 4-4. The results of Case #2 are much

Table 4-3. Values of Parameters Used in Case #2, STOXGB

Parameter (Code) (Units)	Seg. #1	Seg. #2	Seg. #3	Seg. #4
Bulk Disp. Ceoff. (BDSC) (m2/d)	2.592E+6	3.456E+6	1.73E+6	1.728E+6
Sed. Porosity (SEDP)	0.92	0.93	0.95	0.94
Burial Velocity (DBV) (m/d)	4.850E-6	1.008E-5	8.35E-6	2.658E-6
Resus. Velocity (RSV) (m/d)	3.890E-4	2.000E-4	6.58E-5	3.562E-5
Set. Rate of POC (SRO1), (m/d)	1.50	1.75	1.20	1.20
Set. Rate of PCB (SRP1), (m/d)	1.50	1.75	1.20	1.20
Decay POC in WC (DECR1) (1/d)	0.020	0.020	0.0085	0.025
Decay POC in BS (DECR2) (1/d)	0.001	0.0005	0.00	0.00
Decay PCB in WC (DRP1) (1/d)	0.00	0.00	0.00	0.00
Decay PCB in BS (DRP2) (1/d)	0.00	0.00	0.00	0.00
Partition Coeff. (PRTC) (m3/Kg)	2512	2512	2512	1585
Volatil. Rate (VEXR) (m/d)	0.10	0.10	0.10	0.40
Disp. Coef. WC/BS (Esi) (m2/d)	3.922E-4	3.922E-4	3.92E-4	3.922E-4

Table 4-4. Comparison of Calibrated Results of STOXGB (1989 values) for Case #2 (RSV and DBV unchanged) and the 1989 Field Data.

Segment No.	1989 Field Data			
	POC, mg/l		PCB, ng/l	
	WC	BS	WC	BS
1	2.346	7000	21.02	80000
2	1.072	8080	8.45	129828
3	0.606	10790	4.14	67356
4	0.398	12860	2.47	13179
	STOXGB Results, Case #2			
1	2.003	6924	21.20	70460
2	1.040	8046	4.765	29640
3	0.6046	9784	2.388	24910
4	0.3954	12400	2.564	36780

Model Simulation for Green Bay

Spatial Graphs

Case 2: Calibrated Results (RSV, DBV Unchanged) for 1989

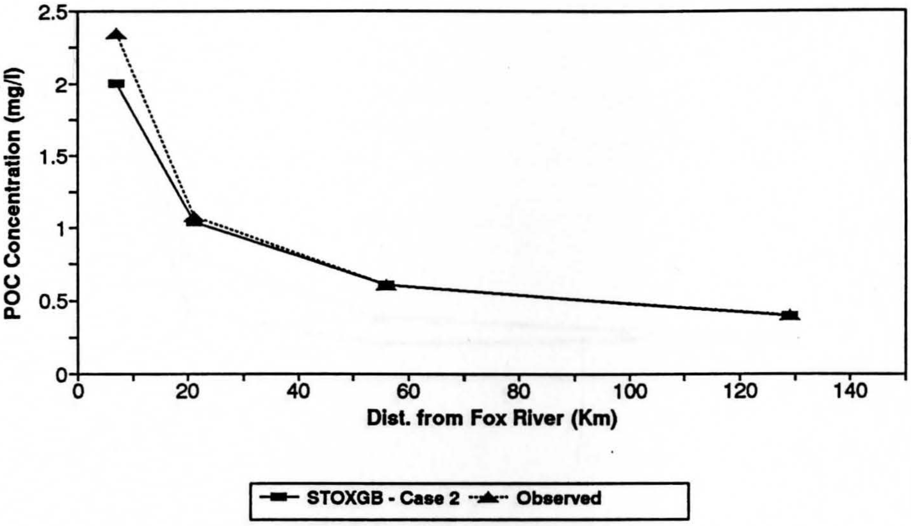


Figure: 4-25 STOXGB Results for POC in Water Column Versus Distance from Fox River - Case 2, 1989 Values.

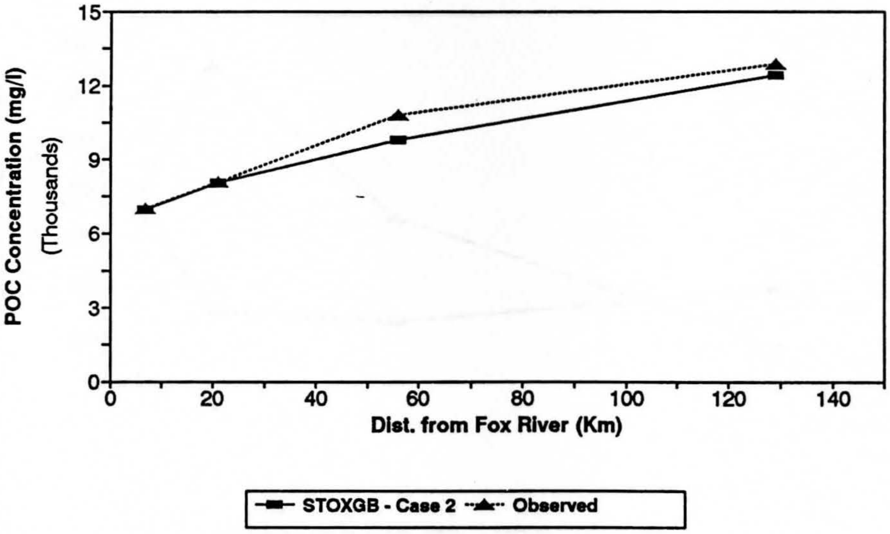


Figure: 4-26 STOXGB Results for POC in Bottom Sediment Versus Distance from Fox River - Case 2, 1989 Values.

Model Simulation for Green Bay

Spatial Graphs

Case 2: Calibrated Results (RSV, DBV Unchanged) for 1989

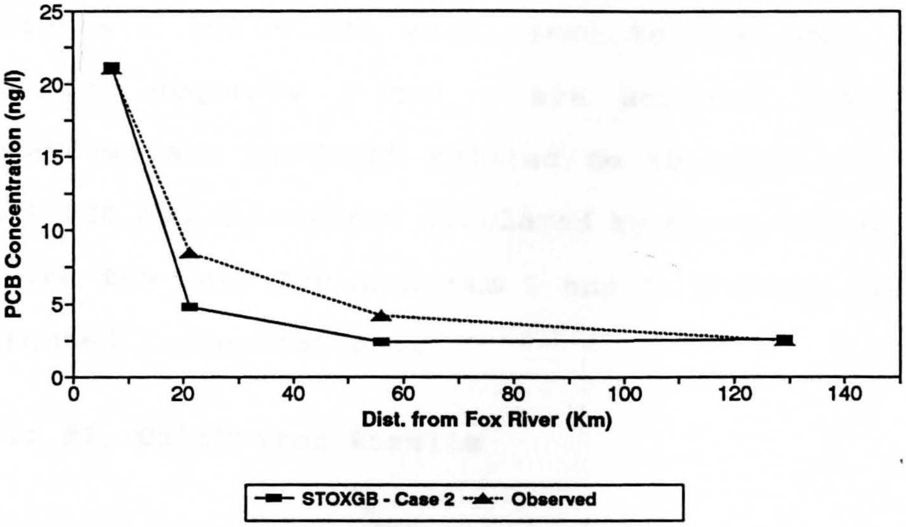


Figure: 4-27 STOXGB Results for PCB in Water Column Versus Distance from Fox River - Case 2, 1989 Values.

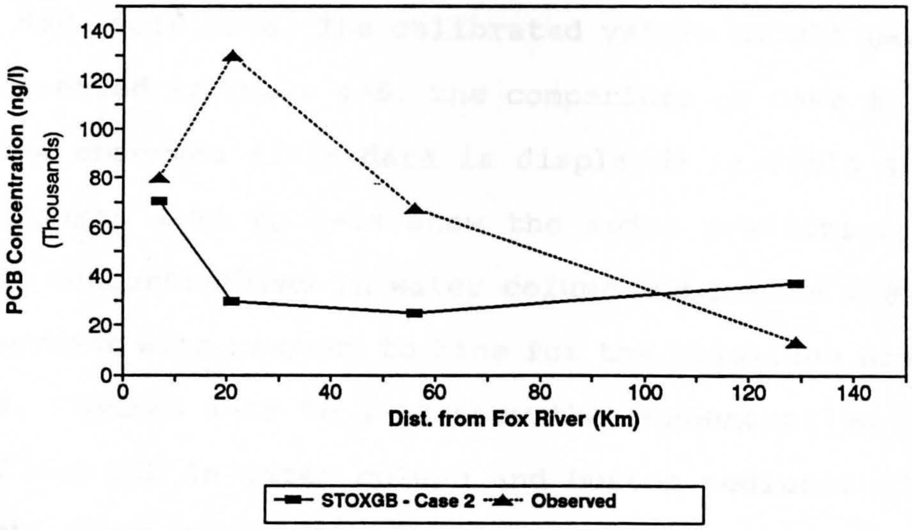


Figure: 4-28 STOXGB Results for PCB in Bottom Sediment Versus Distance from Fox River - Case 2, 1989 Values.

closer to the field data as compared to Case #1. POC concentrations in water column and bottom sediment not only follow the correct spatial pattern, but there is also a close agreement between the concentrations predicted by STOXGB and the measured field data. PCB simulations in the water column of segments 1 and 4 are very close to the data, but the results for segments 2 and 3 are somewhat low. These discrepancies are no doubt related to the fact that bottom sediment PCB concentrations simulated by the model again fall well below the data for segments 2 and 3. Further discussion is presented in Section 4.5.

4.4 Case #3, Calibrated Results

The only difference between Case #2 and Case #3 is that in Case #3 the values of resuspension and burial velocities were also calibrated in order to get closer results to 1989-90 Green Bay field data. The calibrated values of all parameters are presented in Table 4-5. The comparison of Case #3 results with the observed field data is displayed in Table 4-6.

Figures 4-29 to 4-48 show the model predictions of POC and PCB concentrations in water column and bottom sediment of each segment with respect to time for the 1940-1989 simulation period. Figures 4-49 to 4-52 show the concentration profiles of POC and PCB in water column and bottom sediment of each segment, plotted according to distance from the Fox River. The model results for Case #3 are closer to the field data than either Case #1 and Case #2. These results are very much in

Table 4-5. Calibrated Values of Parameters Used in Case #3, STOXGB.

Parameter (Code) (Units)	Seg. #1	Seg. #2	Seg. #3	Seg. #4
Bulk Disp. Ceoff. (BDSC) (m2/d)	2.592E+6	3.456E+6	1.73E+6	1.728E+6
Sed. Porosity (SEDP)	0.92	0.93	0.95	0.94
Burial Velocity (DBV) (m/d)	4.850E-6	4.790E-6	3.84E-6	2.740E-6
Resus. Velocity (RSV) (m/d)	3.890E-4	1.510E-4	5.75E-5	5.480E-5
Set. Rate of POC (SRO1), (m/d)	1.50	1.75	1.20	1.45
Set. Rate of PCB (SRP1), (m/d)	1.50	1.75	1.20	1.45
Decay POC in WC (DECR1) (1/d)	0.0.19	0.020	0.0085	0.018
Decay POC in BS (DECR2) (1/d)	0.001	0.00089	0.00015	0.00
Decay PCB in WC (DRP1) (1/d)	0.00	0.00	0.00	0.00
Decay PCB in BS (DRP2) (1/d)	0.00	0.00	0.00	0.00
Partition Coeff. (PRTC) (m3/Kg)	2512	2512	2512	1585
Volatil. Rate (VEXR) (m/d)	0.10	0.10	0.10	0.40
Disp. Coef. WC/BS (Esi) (m2/d)	3.922E-4	3.922E-4	3.92E-4	3.922E-4

Table 4-6. Comparison of Calibrated Results of STOXGB (1989 values) and the Field Data for 1989.

Segment No.	1989 Field Data			
	POC, mg/l		PCB, ng/l	
	WC	BS	WC	BS
1	2.346	7000	21.02	80000
2	1.072	8080	8.45	129828
3	0.606	10790	4.14	67356
4	0.398	12860	2.47	13179
	STOXGB Results, Case #3			
1	1.936	6695	22.10	73390
2	0.8374	7939	6.117	51440
3	0.5806	10440	3.060	38590
4	0.4703	11850	2.620	28720

Model Simulation for Green Bay

Case 3: Calibrated Results

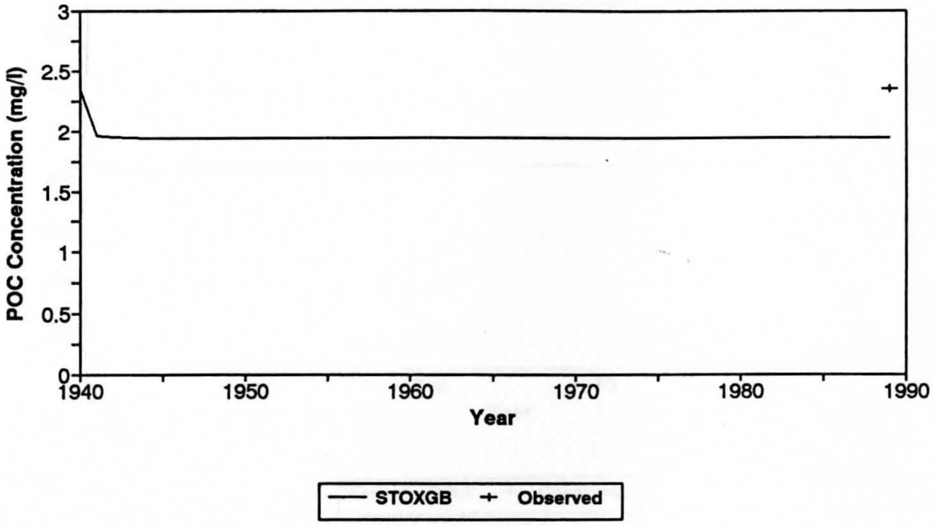


Figure 4-29: STOXGB Results for POC In Water Column of Segment #1 Versus Time - Case 3.

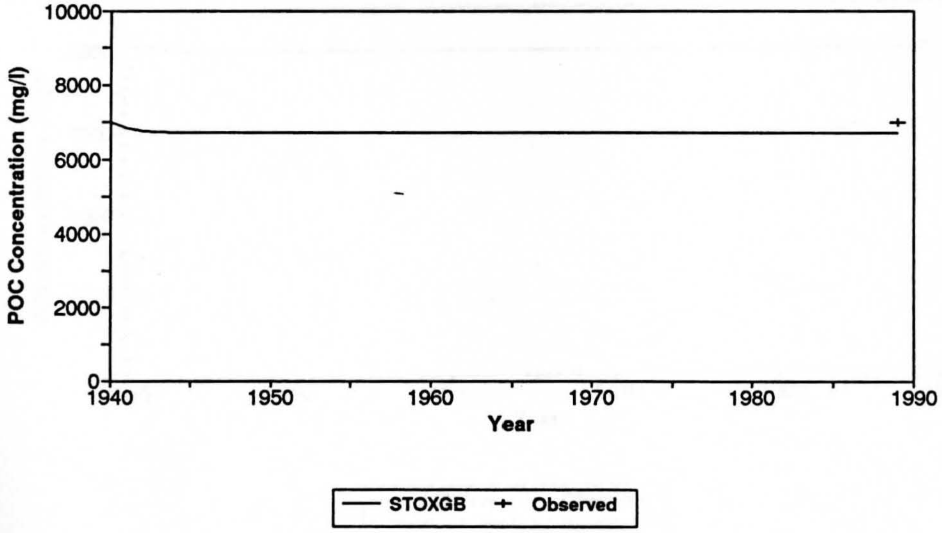


Figure 4-30: STOXGB Results for POC In Bottom Sediment of Segment #1 Versus Time - Case 3.

Model Simulation for Green Bay

Case 3: Calibrated Results

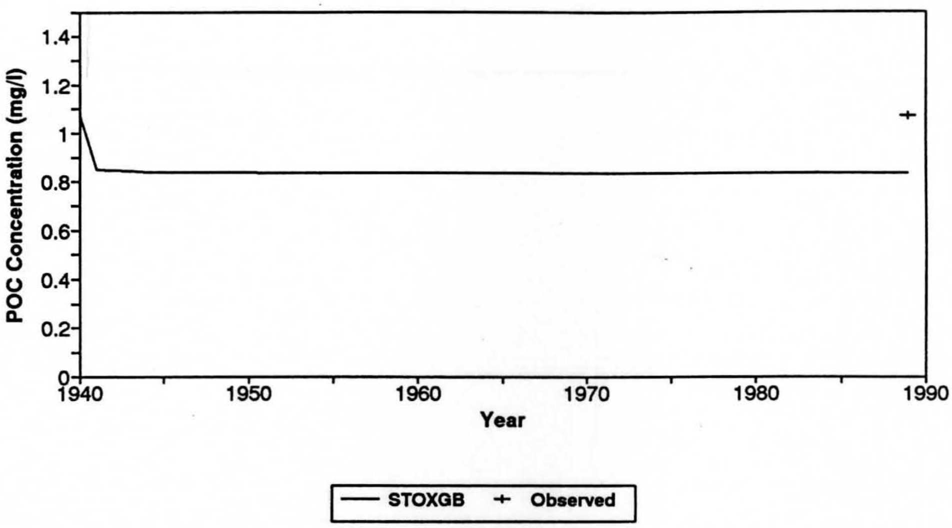


Figure 4-31: STOXGB Results for POC in Water Column of Segment #2 Versus Time - Case 3.

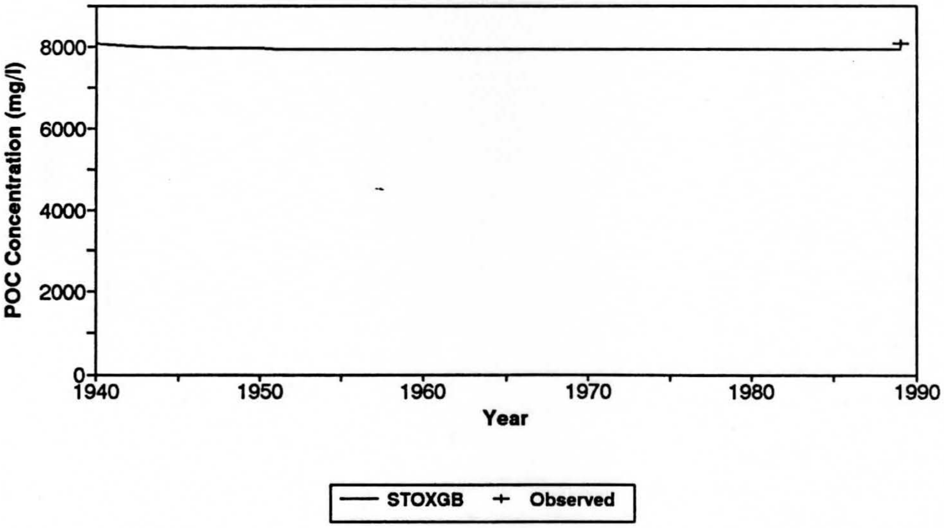


Figure 4-32: STOXGB Results for POC in Bottom Sediment of Segment #2 Versus Time - Case 3.

Model Simulation for Green Bay

Case 3: Calibrated Results

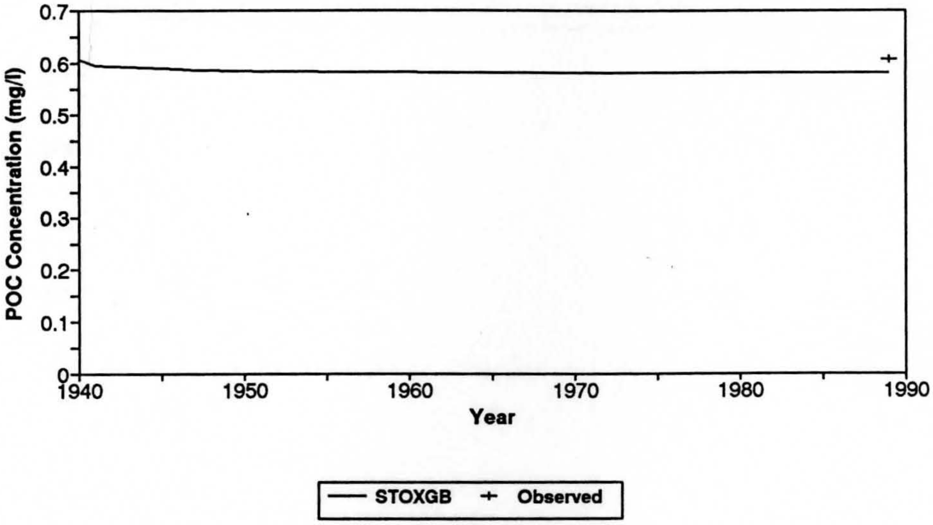


Figure 4-33: STOXGB Results for POC In Water Column of Segment #3 Versus Time - Case 3.

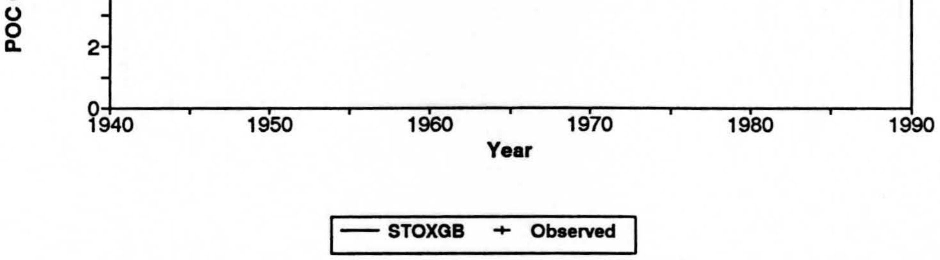


Figure 4-34: STOXGB Results for POC In Bottom Sediment of Segment #3 Versus Time - Case 3.

Model Simulation for Green Bay

Case 3: Calibrated Results

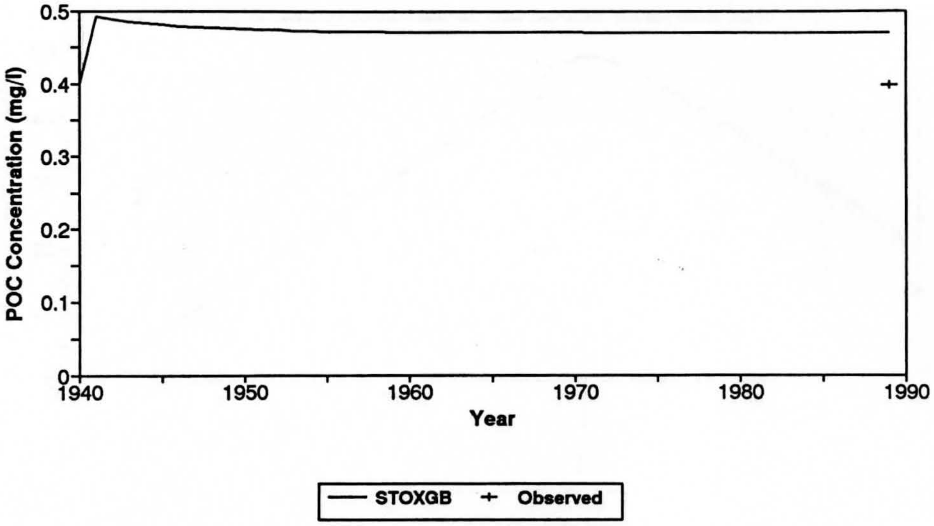


Figure 4-35: STOXGB Results for POC in Water Column of Segment #4 Versus Time - Case 3.

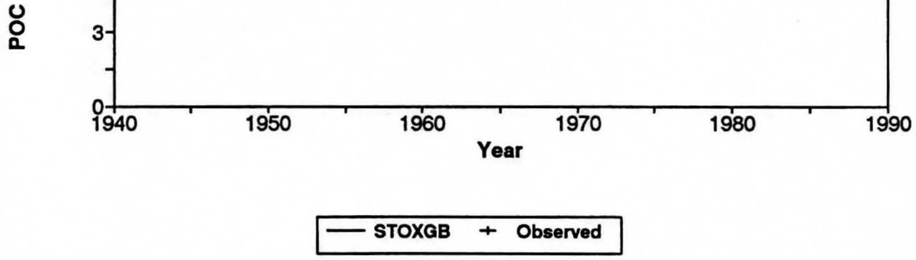


Figure 4-36: STOXGB Results for POC in Bottom Sediment of Segment #4 Versus Time - Case 3.

Model Simulation for Green Bay

Case 3: Calibrated Results

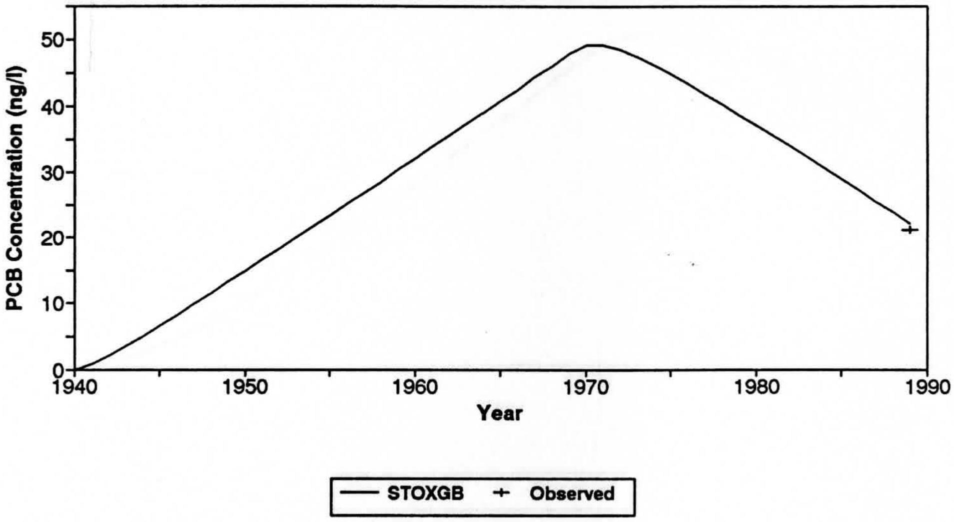


Figure 4-37: STOXGB Results for PCB in Water Column of Segment #1 Versus Time - Case 3.

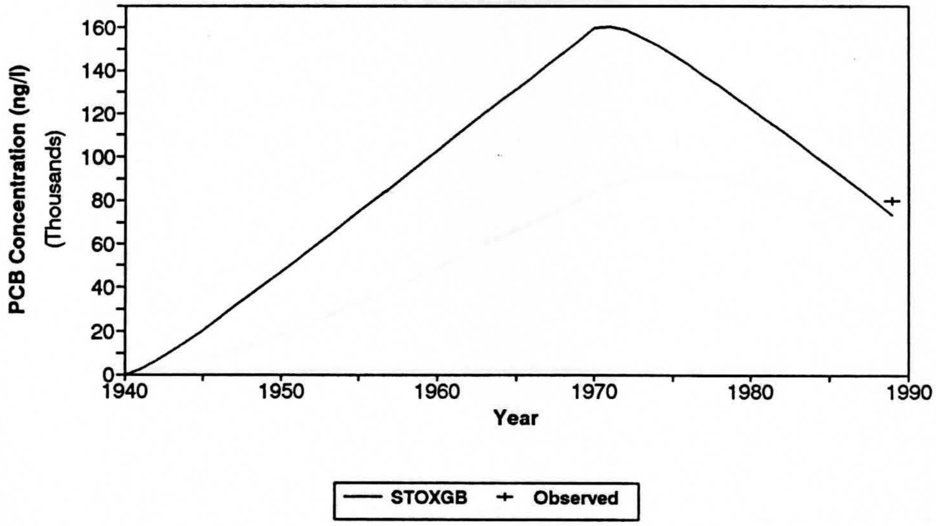


Figure 4-38: STOXGB Results for PCB in Bottom Sediment of Segment #1 Versus Time - Case 3.

Model Simulation for Green Bay

Case 3: Calibrated Results

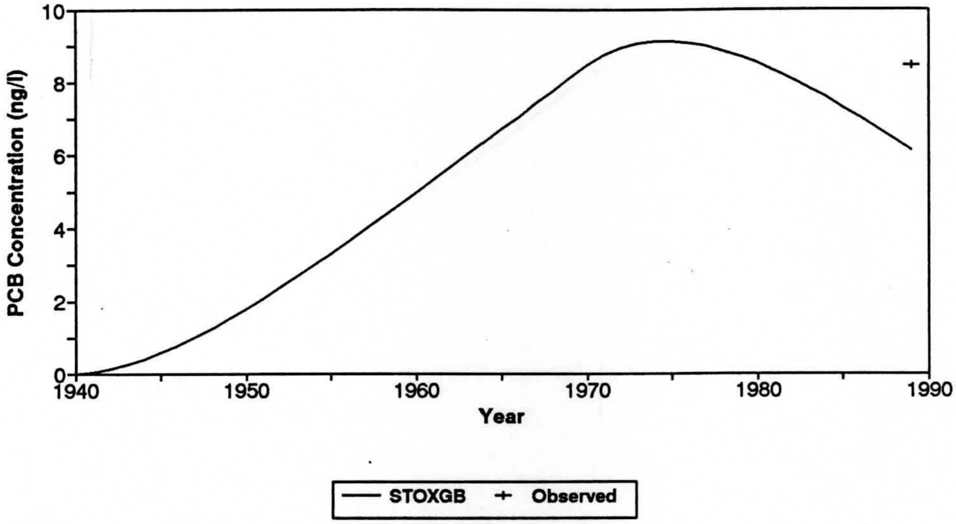


Figure 4-39: STOXGB Results for PCB in Water Column of Segment #2 Versus Time - Case 3.

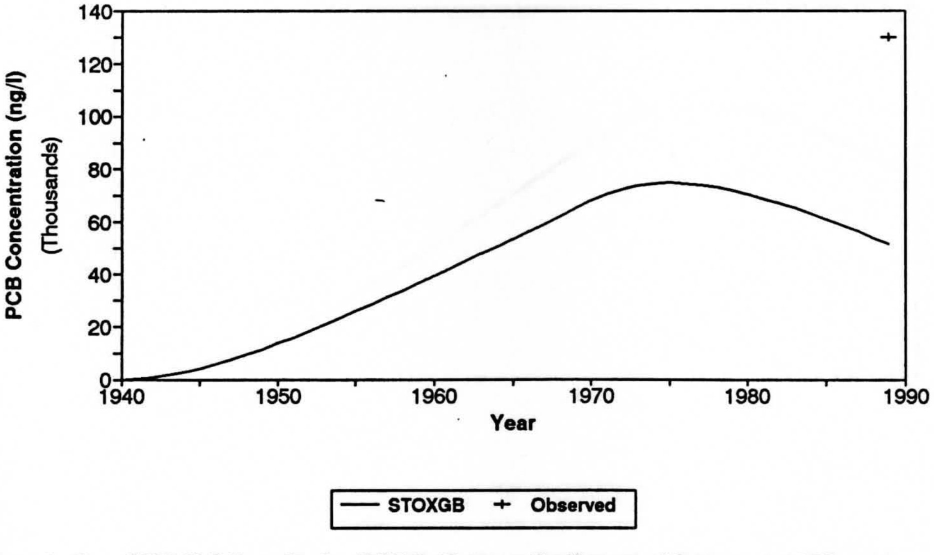


Figure 4-40: STOXGB Results for PCB in Bottom Sediment of Segment #2 Versus Time - Case 3.

Model Simulation for Green Bay

Case 3: Calibrated Results

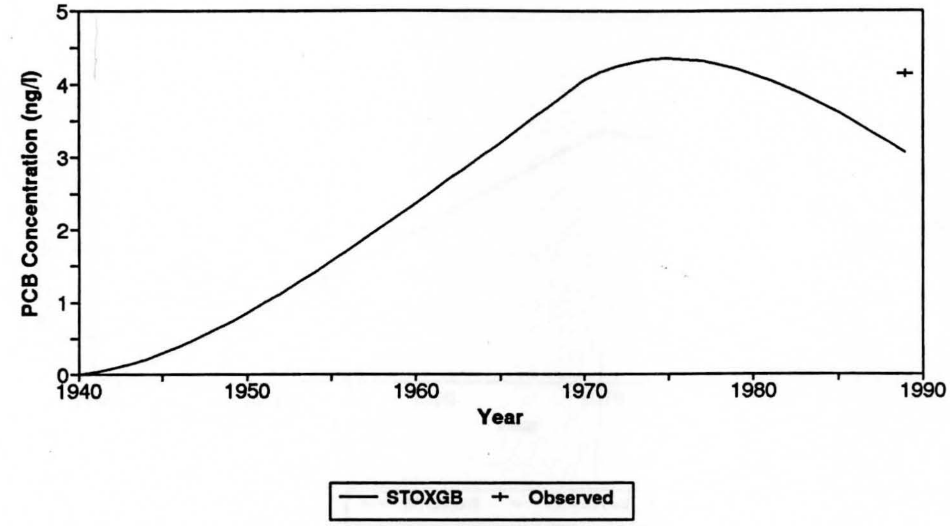


Figure 4-41: STOXGB Results for PCB in Water Column of Segment #3 Versus Time - Case 3.

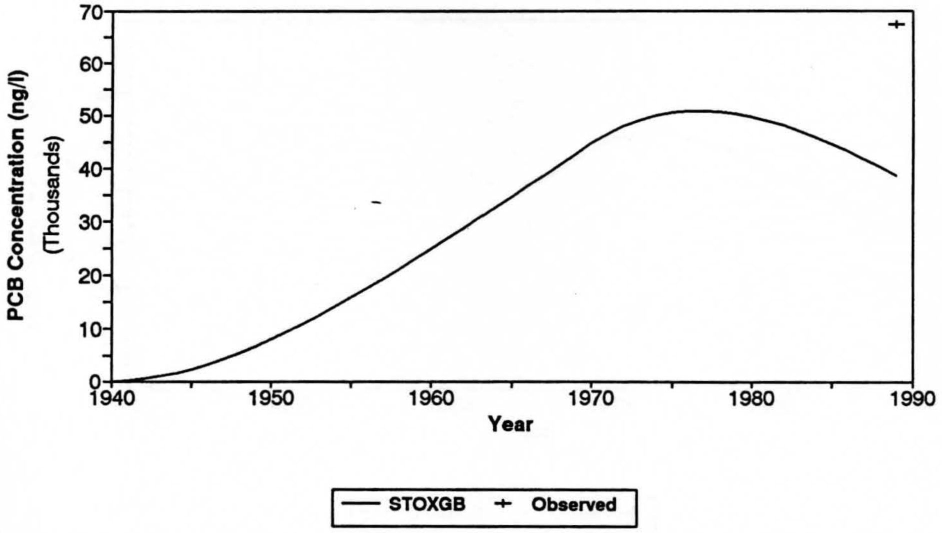


Figure 4-42: STOXGB Results for PCB in Bottom Sediment of Segment #3 Versus Time - Case 3.

Model Simulation for Green Bay

Case 3: Calibrated Results

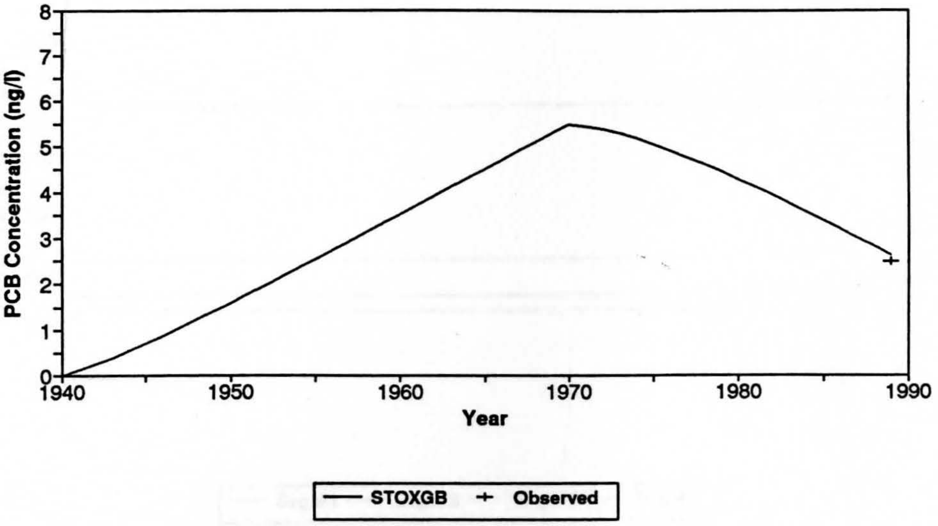


Figure 4-43: STOXGB Results for PCB in Water Column of Segment #4 Versus Time - Case 3.

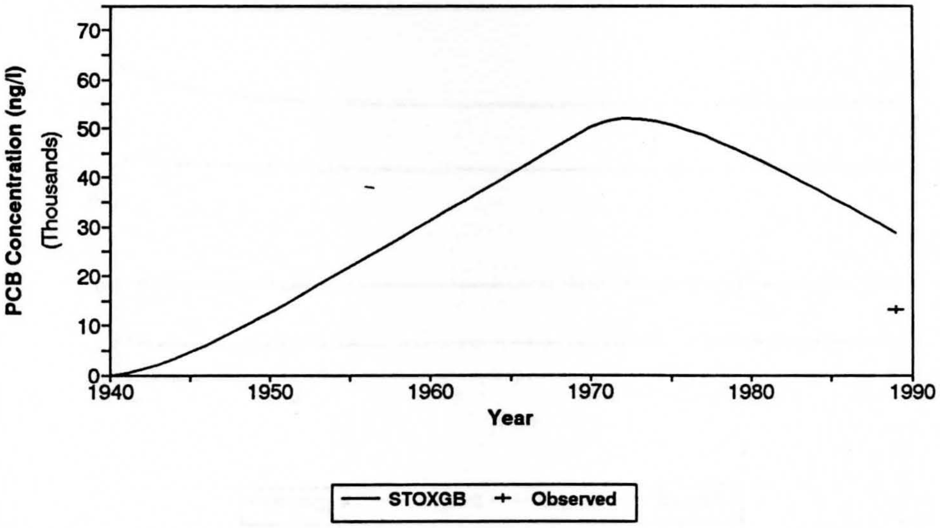


Figure 4-44: STOXGB Results for PCB in Bottom Sediment of Segment #4 Versus Time - Case 3.

Model Simulation for Green Bay

Case 3: Calibrated Results

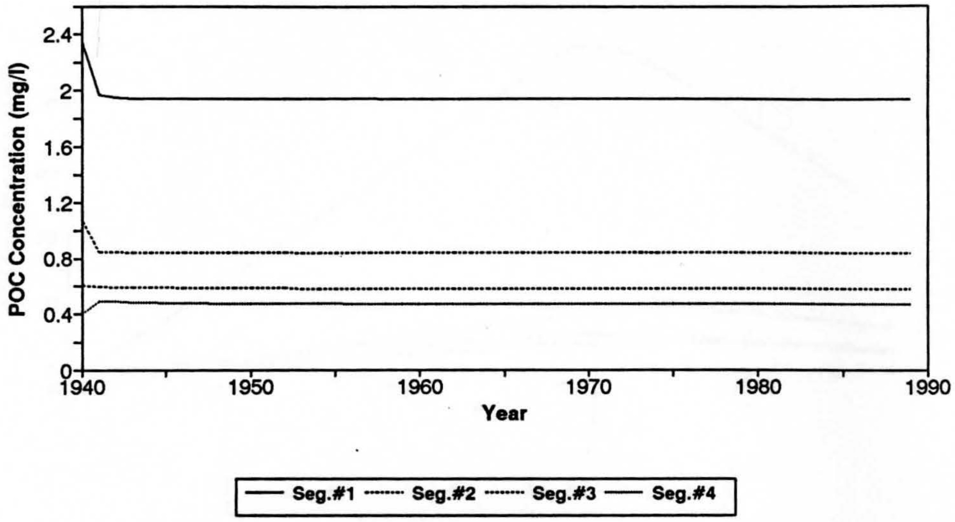


Figure: 4-45 STOXGB Results for POC in Water Column of all Segments Versus Time - Case 3.

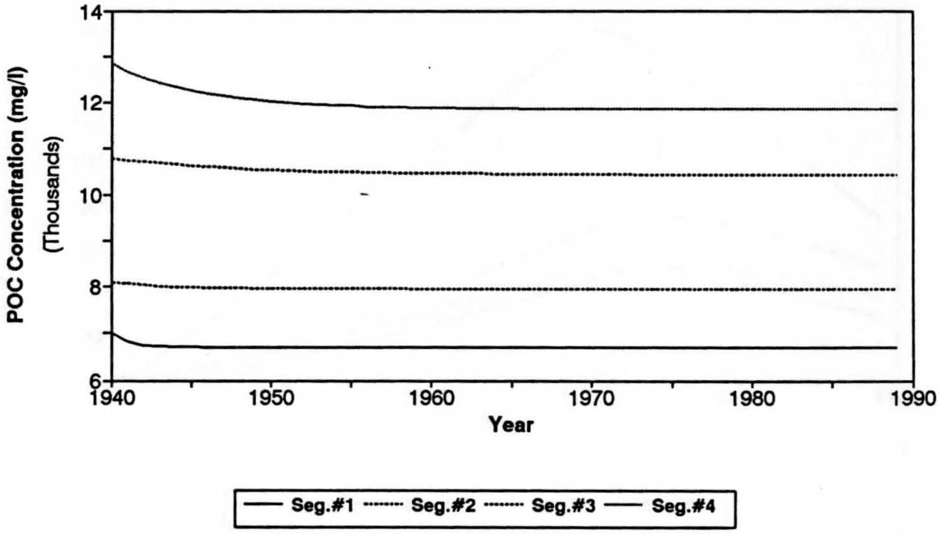


Figure: 4-46 STOXGB Results for POC in Bottom Sediment of all Segments Versus Time - Case 3.

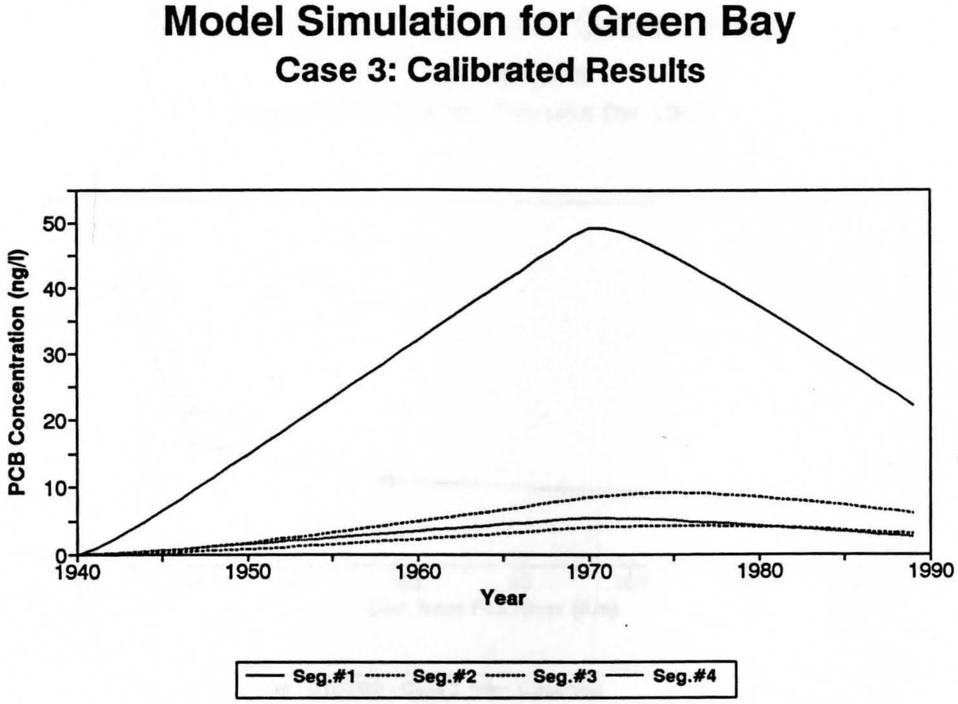


Figure 4-47: STOXGB Results for PCB in Water Column of all Segments Versus Time - Case 3.

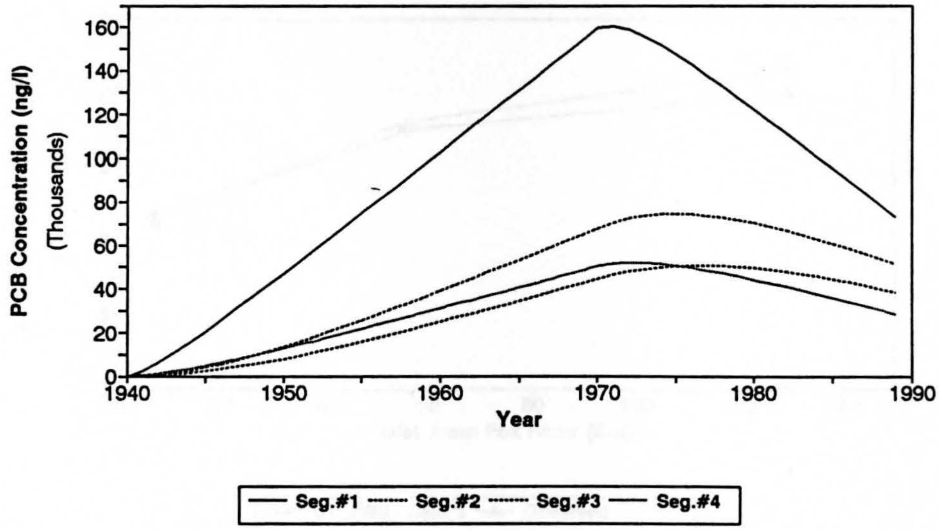


Figure 4-48: STOXGB Results for PCB in Bottom Sediment of all Segments Versus Time - Case 3.

Model Simulation for Green Bay

Spatial Graphs

Case 3: Calibrated Results for 1989

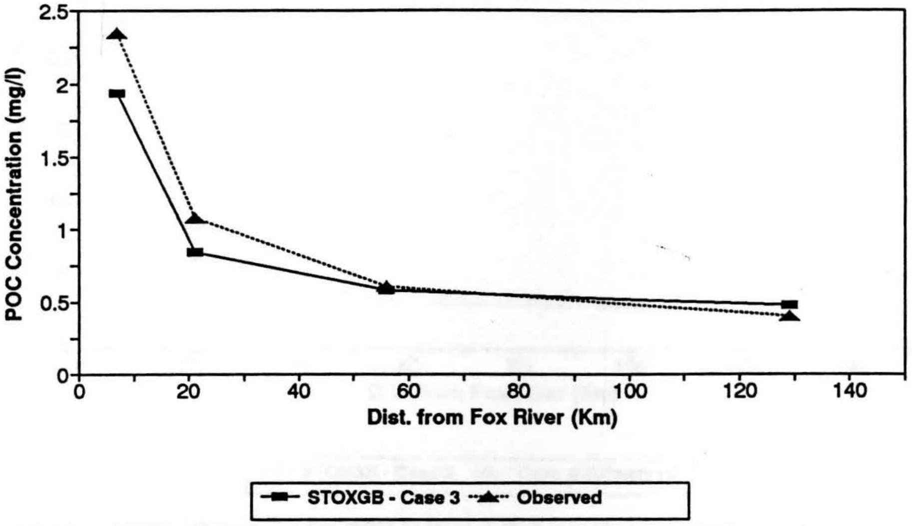


Figure 4-49: STOXGB Results for POC in Water Column Versus Distance from Fox River - Case 3, 1989 Values.

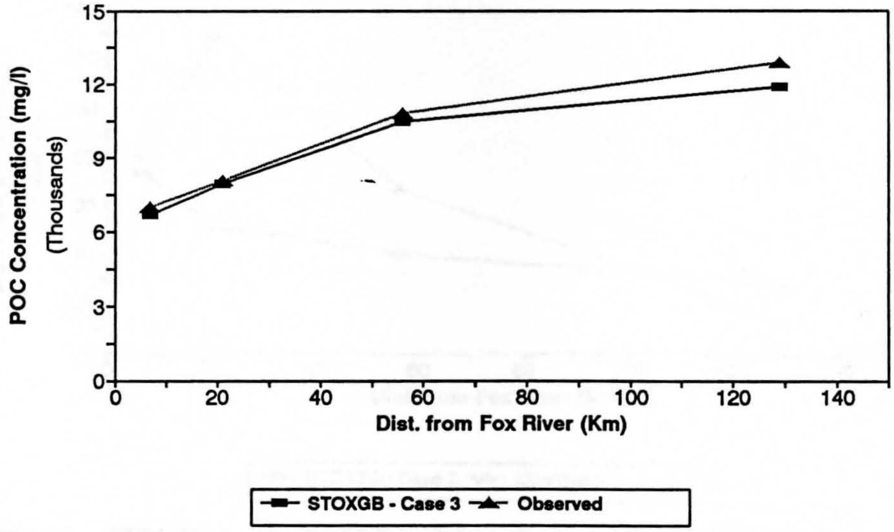


Figure 4-50: STOXGB Results for POC in Bottom Sediment Versus Distance from Fox River - Case 3, 1989 Values.

Model Simulation for Green Bay
Spatial Graphs
Case 3: Calibrated Results for 1989

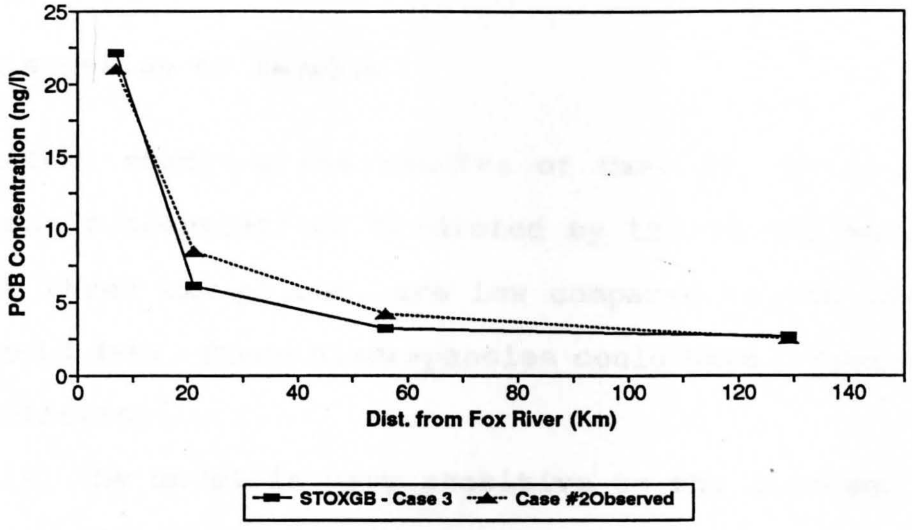


Figure 4-51: **STOXGB Results for PCB in Water Column Versus Distance from Fox River - Case 3, 1989 Values.**

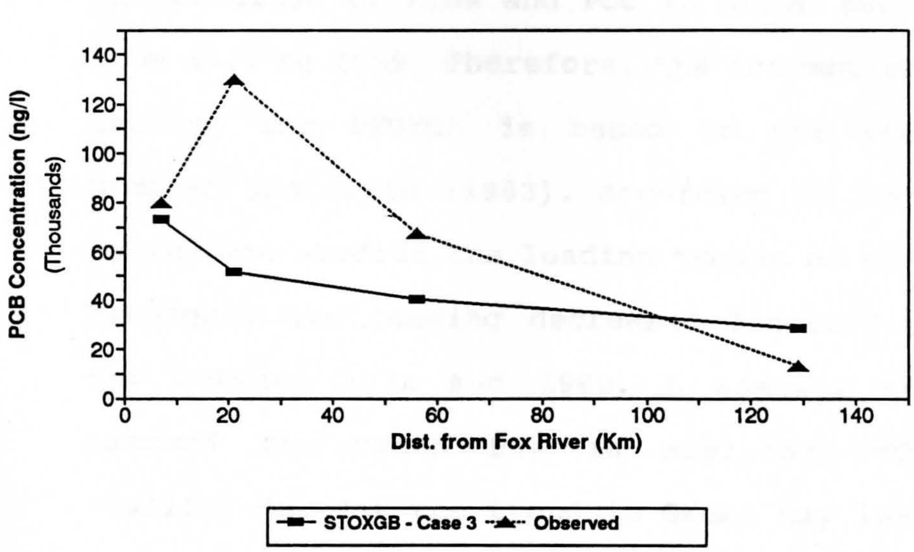


Figure 4-52: **STOXGB Results for PCB in Bottom Sediment Versus Distance from Fox River - Case 3, 1989 Values.**

agreement with the 1989 Green Bay field generated data. The concentrations of POC and PCB follow the same pattern as dictated by the field data with only one exception - PCB in bottom sediment for segment 2. Probable causes for this discrepancy are discussed in Section 4.5.

4.5 Discussion of Results

After studying the results of Case #1, it is apparent that the concentrations predicted by the STOXGB model, with two or three exceptions, are low compared to the 1989 Green Bay field data. These discrepancies could have occurred due to the following:

(1) The model is very sensitive to the loadings of both POC, externally and internally, and PCB. Unfortunately, there is no data available regarding the loadings of PCBs and POC in Green Bay starting from 1940 to 1989. Therefore, the assumption for PCB loading for STOXGB is based on the studies of Rodgers and Swain (1983). According to Rodgers and Swain, who studied the loading trends of PCB in Lake Michigan, the loading decreased linearly by about 55% between 1972 and 1980. A similar trend was assumed for Green Bay in applying STOXGB. In reality, however the trend in Green Bay loading may have been different than for Lake Michigan.

(2) POC loadings, both externally and internally, are kept constant at the values of 1989. In reality, the

loading of POC would probably have been higher before the 1970s when secondary treatment of wastewater was not required by law. Higher POC loadings during the 1960s and 1970s could have resulted in greater deposition of PCBs to the bottom sediments.

(3) Simplified dynamic structure of the model (i.e., the use of annual average kinetic coefficients);

(4) The simplified assumption of bottom sediment geometry (i.e., the use of only one bottom sediment layer, compared to three in GBTOX);

(5) The procedures used in averaging field data and GBTOX input parameters may have produced inaccuracies, particularly for the bottom sediments.

With the adjustments to STOXGB model coefficients made in Cases #2 and #3, the model performance improved considerably. The resulting set of calibrated input parameters are believed to be more consistent with the simplified spatial segmentation and kinetic structure of STOXGB than the Case #1 inputs. The one problem that could not be solved is the low model results for PCBs in bottom sediments of segments #2 and #3. This discrepancy is most likely due to simplified sediment segmentation and inaccuracies in the loading assumptions for POC and/or PCBs.

In the past, many scientists (Hermanson <u>et al</u>., 1991; Rodgers and Swain, 1983) tried to investigate PCB loading trends in Lake Michigan. Rodgers and Swain (1983) estimated

PCB loading trends in Lake Michigan by analyzing PCB in coregonid fishes (bloater chubs) collected from Lake Michigan between 1972 and 1980. Hermanson et al. (1991) analyzed ten sediment cores from Lake Michigan and Green Bay for PCB, ^{210}Pb, and ^{137}Cs. All studies showed a decline in PCBs concentrations after the ban on new uses of PCB in 1977, while they were at a peak in the late 1960s and early 1970s. Radioactive dating information could be combined with sediment PCB profiles to yield an estimate of historical loadings of PCBs in Green Bay.

4.6 Managerial Scenarios

Once the STOXGB model was calibrated, the 1989 model results were used as initial conditions to run four different managerial scenarios. The main reason for applying the STOXGB model to these scenarios was to predict the future concentrations of PCB in Green Bay. The simulation time for each scenario was taken as fifty years (from 1989 to 2039). Due to the significance of the PCB problem in segments #1 and #2 of Green Bay, the results are plotted and discussed only for these two segments.

As described earlier, the model is very sensitive to the loadings of POC and PCB. Unfortunately, no past data are available for PCB loading to Green Bay from 1940 to 1989. But in the future, because of the severity of the problem, efforts may be directed at reducing the PCB loading. The STOXGB model was run to obtain predictions of conditions under different assumptions for PCB (and POC).

4.6.1 Scenario #1 - 1989 Loadings

For Scenario #1, the loadings of POC and PCB were taken as constant at 1989 values throughout the entire 50-year period. With this assumption, the model predicts that within 5 to 10 years the concentrations of PCBs will become constant at slightly lower than the 1989 values (Figures 4-53 and 4-54).

Table 4-7 shows the results of Scenario #1, i.e. concentration of PCBs in water column and bottom sediment of segments 1 and 2. In the case of segment 1, the STOXGB model predicts that the PCB concentration would decrease to 17.42 ng/l as compared to 22.10 ng/l within five years and then become constant until the year 2039. Similarly, for segment 2, within ten years the PCB concentration would decrease by about 21.2% from the 1989 value and then become constant until the year 2039.

4.6.2 Scenario #2 - 50% POC Loading Reduction

In Scenario #2, the external and internal loadings of POC were reduced by one-half while the loadings for PCB were the same as for Scenario #1. This reduction of POC loadings was primarily to see if this would affect the concentrations of PCBs in the water column and bottom sediments. The results presented in Table 4-8, and Figures 4-55 and 4-56, apparently show no change in PCB concentration while the POC concentrations were reduced to one-half of 1989 values in both the water column and bottom sediment of each segment.

Model Simulation for Green Bay

Managerial Scenario #1

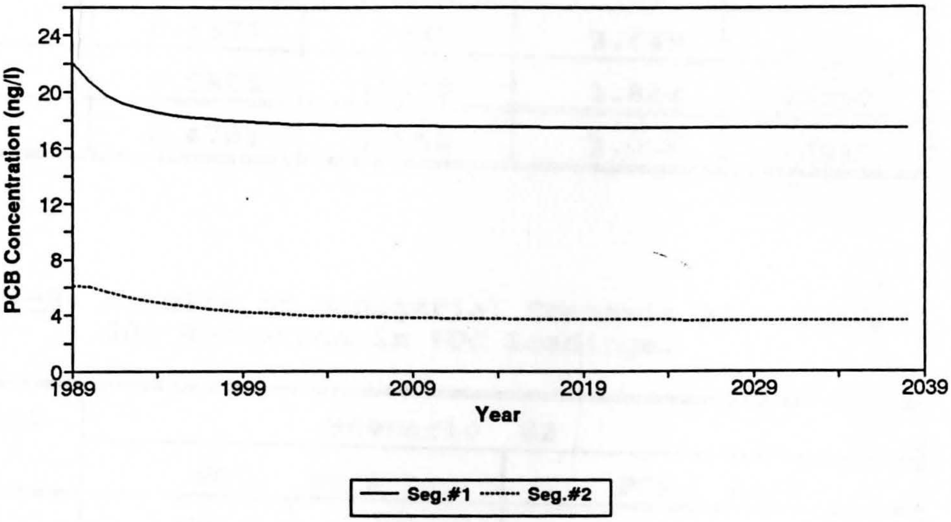


Figure 4-53: STOXGB Results for PCB in Water Column of Segment #1 and #2 Versus Time - Scenario 1.

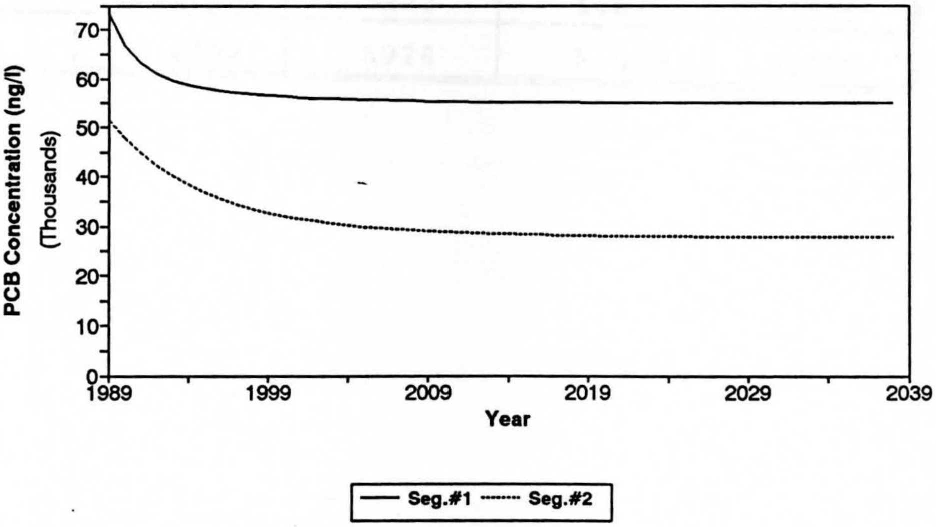


Figure 4-54: STOXGB Results for PCB in Bottom Sediment of Segment #1 and #2 Versus Time - Scenario 1.

Table 4-7. Results of Managerial Scenario #1, STOXGB-1989 Loading Levels.

Segment No.	Scenario #1			
	POC, mg/l		PCB, ng/l	
	WC	BS	WC	BS
1	1.936	6695	17.42	55010
2	0.8373	7939	3.645	27730
3	0.5805	10440	1.842	21360
4	0.4703	11850	2.055	22110

Table 4-8. Results of Managerial Scenario #2, STOXGB-50% Reduction in POC Loadings.

Segment No.	Scenario #2			
	POC, mg/l		PCB, ng/l	
	WC	BS	WC	BS
1	0.9682	3347	17.42	55010
2	0.4187	3970	3.645	27730
3	0.2904	5223	1.842	21360
4	0.2352	5928	2.055	22110

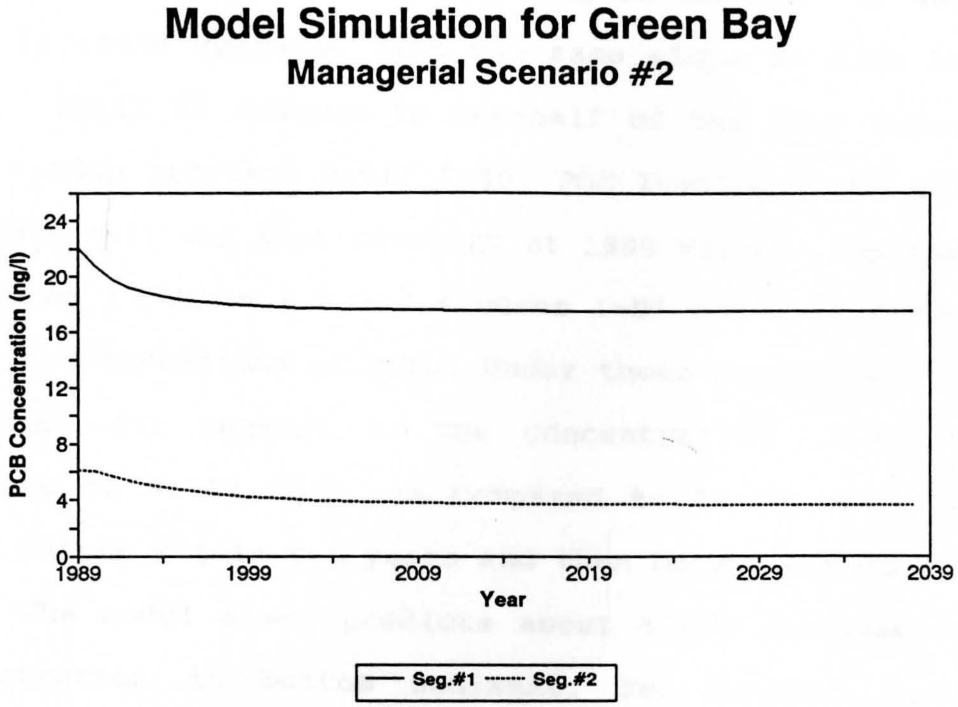


Figure 4-55: **STOXGB Results for PCB in Water Column of Segment #1 and #2 Versus Time - Scenario 2.**

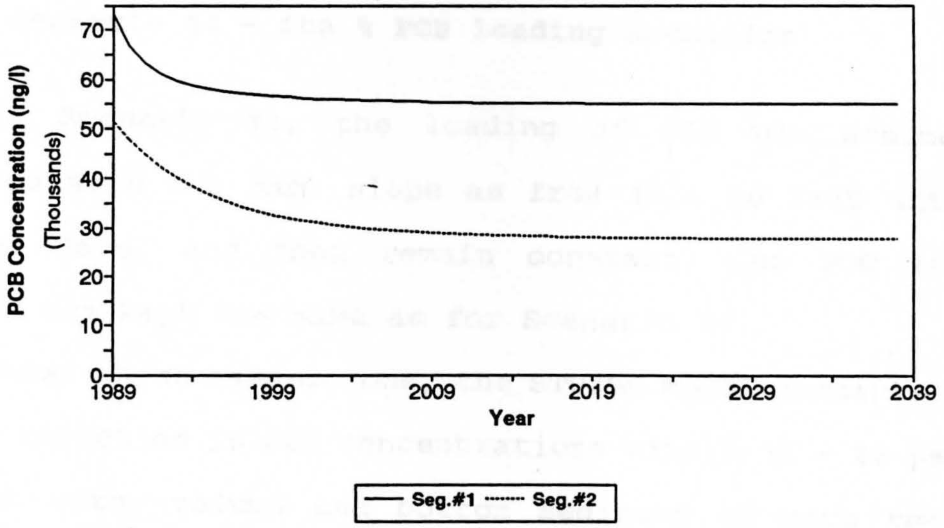


Figure 4-56: **STOXGB Results for PCB in Bottom Sediment of Segment #1 and #2 Versus Time - Scenario 2.**

4.6.3 Scenario #3 - 50% PCB Loading Reduction

The assumption for PCB loading in Scenario #3 was such that it would decrease with the same slope as from 1970 to 1989, until it reduces to one-half of the 1989 value, and then become constant until 2039. POC loading (both external and internal) was kept constant at 1989 values. The results, presented in Table 4-9 and Figures 4-57 and 4-58, show much lower concentrations of PCBs. Under these prescribed loading patterns, for segment 1, the concentration of PCB would decrease to 8.707 ng/l, as compared to 22.10 ng/l, in the water column within ten years and then become constant until 2039. The model also predicts about a 60% decrease in PCB concentration in bottom sediment. For segment 2, model predicts about a 70% decrease in PCB concentration both in water column and bottom sediment.

4.6.4 Scenario #4 - 100 % PCB loading Reduction

In Scenario #4, the loading of PCB was assumed to decrease with the same slope as from 1970 to 1989 until it reached zero, and then remain constant. The POC loading pattern was kept the same as for Scenario #3.

Under these assumptions, the STOXGB model predicts about 99.98% reduction in PCB concentrations within 10 - 15 years, in both water column and bottom sediment of each segment. Results of Scenario #4 are shown in Table 4-10, Figure 4-59 and Figure 4-60.

Model Simulation for Green Bay

Managerial Scenario #3

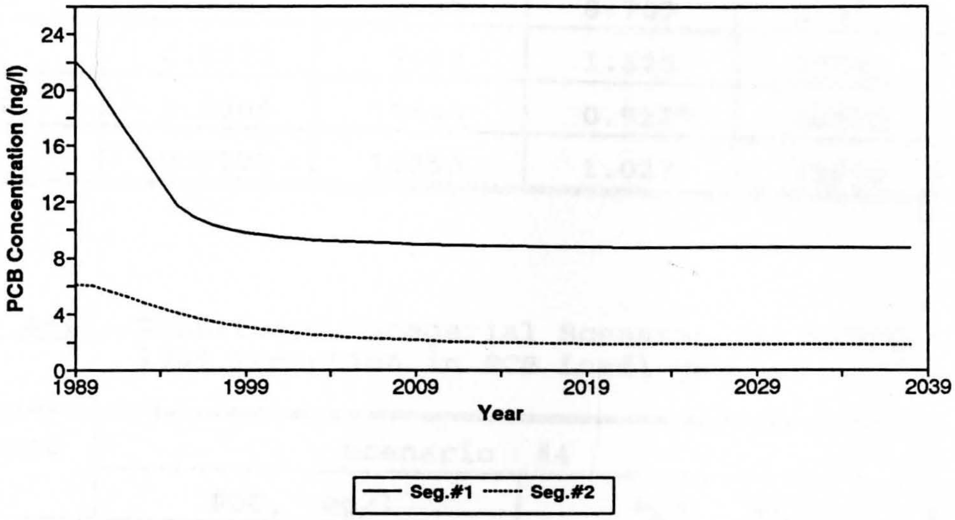


Figure 4-57: **STOXGB Results for PCB in Water Column of Segment #1 and #2 Versus Time - Scenario 3.**

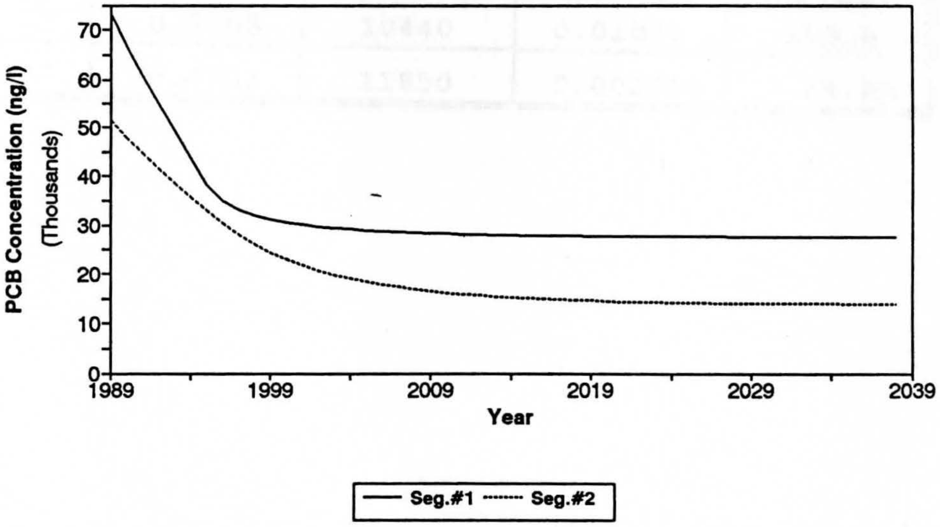


Figure 4-58: **STOXGB Results for PCB in Bottom Sediment of Segment #1 and #2 Versus Time - Scenario 3.**

Table 4-9. Results of Managerial Scenario #3, STOXGB-50% Reduction in PCB Loadings.

Segment No.	Scenario #3			
	POC, mg/l		PCB, ng/l	
	WC	BS	WC	BS
1	1.936	6695	8.707	27500
2	0.8373	7939	1.825	13890
3	0.5805	10440	0.9227	10720
4	0.4703	11850	1.027	11050

Table 4-10. Results of Managerial Scenario #4, STOXGB-100% Reduction in PCB Loadings.

Segment No.	Scenario #4			
	POC, mg/l		PCB, ng/l	
	WC	BS	WC	BS
1	1.936	66950	0.01169	38.30
2	0.8373	7939	0.01516	124.5
3	0.5805	10440	0.01030	150.8
4	0.4703	11850	0.002046	29.29

Model Simulation for Green Bay

Managerial Scenario #4

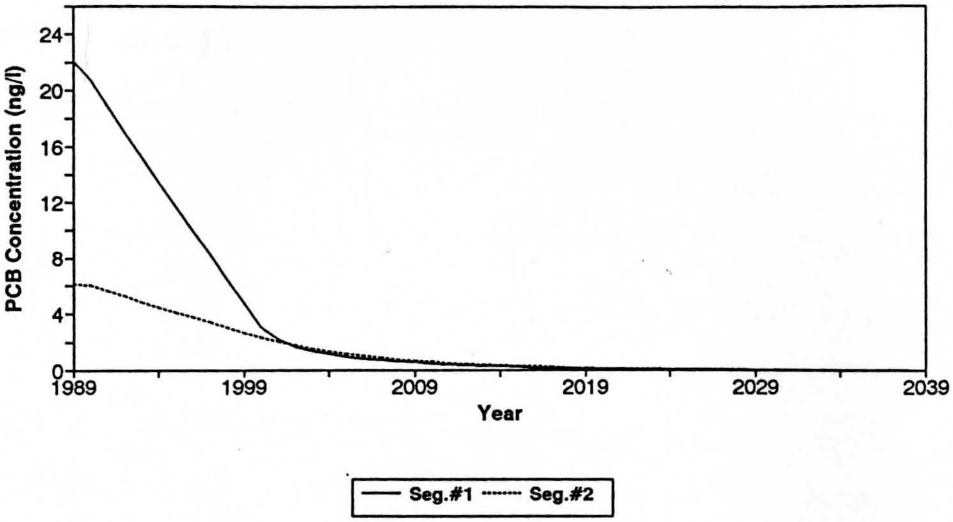


Figure 4-59: STOXGB Results for PCB in Water Column of Segment #1 and #2 Versus Time - Scenario 4.

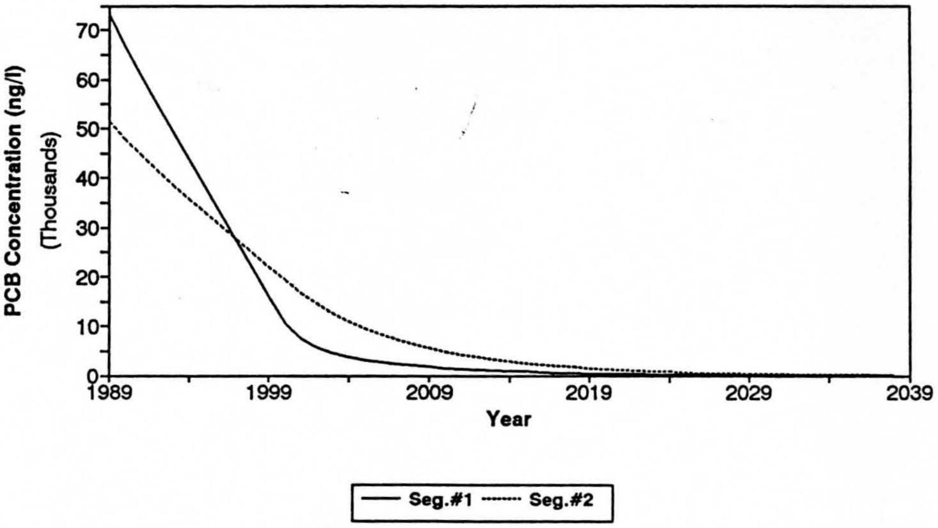


Figure 4-60: STOXGB Results for PCB in Bottom Sediment of Segment #1 and #2 Versus Time - Scenario 4.

As a whole, for all scenarios, it is noticed that it takes less time for segment 1 to reach steady state as compared to segment 2. This difference is because there is a direct loading of PCBs to segment 1 through the Fox River while in segment 2 the loading is indirect (through advection, dispersion, etc.).

Chapter V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Models can play a very significant role in the understanding of toxic fate and response issues. Simplified Toxics Model for Green Bay (STOXGB) is a user-friendly microcomputer model designed to be used interactively to assist in evaluating the more complex Green Bay Toxics Model, GBTOX, as well as regulatory and remedial options to control toxic contamination.

Based on Thomann and Mueller's (1987) suspended solid and toxic substance model with some modification, the STOXGB model was written in Quick Basic and applied to three different levels of calibration (Cases #1 to #3). Input data was mostly obtained by averaging the calibrated values of parameters from GBTOX (Bierman et al., 1992). The model was also applied to four different managerial scenarios. The application of STOXGB to Green Bay for the period 1940-1989 was constrained by a relatively small amount of available information regarding the historical loading and environmental concentrations of PCBs in water and sediment. However, the fully calibrated model simulated known concentrations of PCBs for 1989 reasonably well, and served as a means of identifying needs for future monitoring and research.

The pattern for POC and PCB concentration according to field data is such that the concentration of POC and PCB in the water column decreases from the inner to the outer part of Green Bay (or from model segment 1 to 4). PCB concentrations in the bottom sediments also decrease in a similar manner, with the exception of segment 2 which has the highest concentration. The pattern for POC concentration is just the opposite, i.e., POC concentration increases from segment 1 to segment 4.

Using averaged inputs from GBTOX (Bierman et al., 1992) with no calibration (Case #1), STOXGB shows some disagreement in the pattern of POC and PCB concentrations both in the water column and bottom sediment throughout the bay as compared to the field data. The results are within the same order of magnitude, however, which indicates that the program functions properly and calibrated parameters from GBTOX are reasonable.

The results of Case #2, where the model was calibrated without changing resuspension or burial velocities, further enhanced the credibility of the model. The pattern of 1989 POC and PCB concentrations predicted by STOXGB throughout Green Bay are close to those dictated by the field data.

Finally, the model results where all parameters were adjusted to achieve calibration show good agreement with field concentrations of POC and PCB in the water column and bottom sediment in each segment. One significant problem with the Case #3 calibration is the underestimation of PCBs in segment 2 bottom sediments by the model. The most likely explanations are the lack of information on historical PCB loads, or oversimplified sediment segmentation in the model. The calibrated model was considered to be accurate enough for use in preliminary analysis of long-term response to remedial actions.

Four different managerial scenarios involving future changes in POC and PCB loadings were evaluated using STOXGB. If the loading of PCB remains constant at 1989 values for the next fifty years (Scenario 1, 1989 - 2039), the model predicts a reduction by about 21% in PCB concentration in water column and bottom sediment of segments 1 and 4, and a reduction by about 40% in segment 2 and 3. Under the same conditions as Scenario #1, if POC loading reduces to half (Scenario #2) the model predicts that within 5 to ten years the concentration of POC would also reduce to half throughout Green Bay, but PCBs would not be affected.

Similarly, the model predicts about 65% reduction in PCB concentrations within 5 to 10 years throughout the bay with the loadings of PCBs reduced to one-half of 1989 values (Scenario #3). Finally, the model predicts that if PCB loadings decrease linearly to zero between 1989 and 2005 (Scenario #4) concentrations will decline by 99.9% in all segments by 2039. However, the bottom sediments in the outer bay will respond much more slowly than those in the inner bay.

The lack of the field data and historical loading estimates were two of the major difficulties faced during model calibration. To use the STOXGB model effectively, more data are required so that the loadings of POC and PCB can be estimated correctly. It is, therefore, strongly recommended that:

(1) methods for estimating POC and PCB concentrations in, and loadings to, Green Bay from 1940 to 1988 should be investigated;

(2) in the future, continued monitoring of the POC and PCB concentrations in Green Bay should be conducted; and

(3) the STOXGB model should be recalibrated as new data on POC and PCBs in Green Bay become available.

(4) to further explore the differences between GBTOX and STOXGB the two models should be run with the same input data.

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APPENDIX A

Listing of the STOXGB Program (Preprocessor):

```
D = 72
R = 4

DIM ACP(D), W1LM(D), W3LM(D)
DIM W1(D), W2(D), W3(D), W4(D), V1(D), V2(D), SA1(D), ASD(D), ASR(D)
DIM SEDP(D), DBV(D), RSV(D), SRO1(D), SRP1(D), DECR1(D), DECR2(D)
DIM DRP1(D), DRP2(D), PRTC(D), VEXR(D), Esi(D), Lsi(D)
DIM ELP(R, D), ELO(R, D), ILO(R, D)

F$ = "#####.##"
F1$ = ".###^^^^"
DFILEO$ = "MODEL.DAT"

name$ = "   Developed by Wasif Mohammad   "
name1$ = "Youngstown State University, 1992"

MAIN:

    COLOR 7, 1
    CLS
    FOR I = 1 TO 25
    COLOR 0, 0: LOCATE 17, 30 + I: PRINT " "
    NEXT I

    FOR I = 1 TO 6
    COLOR 0, 0: LOCATE -I + 18, 54: PRINT "  "
    NEXT I

    LOCATE 5, 26: PRINT STRING$(35, 177)
    LOCATE 4, 59: PRINT "  "

    COLOR 15, 4
    LOCATE 3, 24: PRINT "    Simplified Toxic Model For      "
    LOCATE 4, 24: PRINT " Green Bay, Lake Michigan (STOXGB) "
    LOCATE 8, 32: PRINT " M A I N   M E N U "
    LOCATE 11, 29: PRINT "                          "
    LOCATE 12, 29: PRINT "  1 - Create Data File    "
    LOCATE 13, 29: PRINT "  2 - Edit Data File      "
    LOCATE 14, 29: PRINT "  3 - Computation         "
    LOCATE 15, 29: PRINT "  4 - Quit                "
    LOCATE 16, 29: PRINT "                          "
    LOCATE 23, 2: COLOR 15, 4: PRINT "Date: "; DATE$

in:

    COLOR 15, 1
    FOR I = 1 TO 80
    LOCATE 19, I: PRINT " "
    LOCATE 20, I: PRINT " "
    NEXT I

    LOCATE 23, 80
    I$ = INKEY$
    IF LEN(I$) = 0 THEN GOTO film

vali:

    IF VAL(I$) = 1 THEN GOTO create
    IF VAL(I$) = 2 THEN GOTO edit
    IF VAL(I$) = 3 THEN GOTO comp
    IF VAL(I$) = 4 THEN GOTO quit
```

```
    GOTO film

comp:

    OPEN "mstoxgb.bat" FOR OUTPUT AS #1
    PRINT #1, "cstoxgb"
    PRINT #1, "stoxgb"
    CLOSE #1
    SYSTEM

create:

    COLOR 15, 1
    FOR I = 1 TO 80
    LOCATE 19, I: PRINT " "
    LOCATE 20, I: PRINT " "
    NEXT I

    LOCATE 19, 25: PRINT name$
    LOCATE 20, 25: PRINT name1$

    COLOR 0, 1
    FOR I = 6 TO 12
    FOR j = 1 TO 80
    LOCATE I, j: PRINT " "
    LOCATE 24 - I, 81 - j: PRINT " "
    NEXT j
    NEXT I

    FOR I = 1 TO 50
    COLOR 0, 0: LOCATE 14, 17 + I: PRINT " "
    NEXT I

    FOR I = 1 TO 2
    COLOR 0, 0: LOCATE -I + 14, 66: PRINT "  "
    NEXT I

    COLOR 15, 4
    LOCATE 8, 33: PRINT " CREATE OPTION "

    LOCATE 11, 16: PRINT "                                                  "
    LOCATE 12, 16: PRINT " Enter File Name to Create :                      "
    LOCATE 13, 16: PRINT "                                                  "

    LOCATE 12, 45: INPUT "", FILEO$
    GOTO create1

edit:

    COLOR 15, 1
    FOR I = 1 TO 80
    LOCATE 19, I: PRINT " "
    LOCATE 20, I: PRINT " "
    NEXT I

    LOCATE 19, 25: PRINT name$
    LOCATE 20, 25: PRINT name1$

    COLOR 0, 1
    FOR I = 6 TO 12
    FOR j = 1 TO 80
    LOCATE I, j: PRINT " "
    LOCATE 24 - I, 81 - j: PRINT " "
    NEXT j
    NEXT I

    FOR I = 1 TO 50
    COLOR 0, 0: LOCATE 14, 17 + I: PRINT " "
    NEXT I

    FOR I = 1 TO 2
    COLOR 0, 0: LOCATE -I + 14, 66: PRINT "  "
```

```
    NEXT I

    COLOR 15, 4
    LOCATE 8, 35: PRINT " EDIT OPTION "
    LOCATE 11, 16: PRINT " Enter Input File Name    :                       "
    LOCATE 12, 16: PRINT "                                                  "
    LOCATE 13, 16: PRINT " Enter Output File Name   :                       "
    LOCATE 11, 43: INPUT "", FILEI$
    LOCATE 13, 43: INPUT "", FILEO$

    OPEN FILEI$ FOR INPUT AS #1
    INPUT #1, t1, t2, INC
    INPUT #1, INTA12, INTA23, INTA34, INTA4LM, CHL12, CHL23, CHL34, CHL4LM, BDSC12
    INPUT #1, BDSC23, BDSC34, BDSC4LM, QF1, Q21, Q12, Q32, Q23, Q43
    INPUT #1, QM3, QP3, QO3, Q34, QLM4, QE4, Q4LM, HEN
    FOR I = 1 TO 72
    INPUT #1, ACP(I), W1LM(I), W3LM(I)
    NEXT I
    FOR R = 1 TO 4
    INPUT #1, W1(R), W2(R), W3(R), W4(R), V1(R), V2(R), SA1(R), ASD(R), ASR(R)
    INPUT #1, SEDP(R), DBV(R), RSV(R), SRO1(R), SRP1(R), DECR1(R), DECR2(R)
    INPUT #1, DRP1(R), DRP2(R), PRTC(R), VEXR(R), Esi(R), Lsi(R)
    FOR j = 1 TO 72
    INPUT #1, ELP(R, j), ELO(R, j), ILO(R, j)
    NEXT j
    NEXT R
    CLOSE #1

create1:

    COLOR 15, 1
    CLS
    COLOR 12, 1: LOCATE 1, 15: PRINT STRING$(11, 176): COLOR 14, 1: LOCATE 1, 27: PRINT "  STOXGB
    MODEL": COLOR 12, 1: LOCATE 1, 43: PRINT STRING$(11, 176)
    COLOR 14, 1:
    LOCATE 4, 15: PRINT "     Hi, welcome to STOXGB Model."
    LOCATE 5, 15: PRINT "This Model can predict concentration of "
    LOCATE 6, 15: PRINT "POCs and PCBs for a given period of time."
    COLOR 15, 1
    LOCATE 8, 15: PRINT "In order to run this model, the user "
    LOCATE 9, 15: PRINT "has to give three kinds of data:"
    COLOR 10, 1: LOCATE 10, 15: PRINT "Data Set #1 - Time period and step"
    COLOR 13, 1: LOCATE 11, 15: PRINT "Data Set #2 - Constants for all segments"
    COLOR 11, 1: LOCATE 12, 15: PRINT "Data Set #3 - Data  for each segment"
    COLOR 10, 1: LOCATE 14, 10: PRINT "Please Enter Data Set #1"
    COLOR 14, 1: LOCATE 15, 9: PRINT CHR$(218); STRING$(41, 196); STRING$(1, 210); STRING$(9,
    196); STRING$(1, 191)
    FOR I = 17 TO 21 STEP 2: LOCATE I, 9: PRINT CHR$(195); STRING$(41, 196); STRING$(1, 215);
    STRING$(9, 196); STRING$(1, 180)
    NEXT I
    FOR I = 16 TO 22 STEP 2: LOCATE I, 9: PRINT CHR$(179)
    LOCATE I, 51: PRINT CHR$(186)
    LOCATE I, 61: PRINT CHR$(179)
    NEXT I
    COLOR 14, 1: LOCATE 16, 10: PRINT "Discription of Variable (unit) (Variable)": COLOR 12, 1: LOCATE
    16, 53: PRINT "Input"
    COLOR 14, 1: LOCATE 17, 9: PRINT CHR$(198); STRING$(41, 205); STRING$(1, 206); STRING$(9,
    205); STRING$(1, 181)
    COLOR 14, 1: LOCATE 18, 10: PRINT "Enter the initial time (yrs) (t1)": COLOR 12, 1: LOCATE 18, 52:
    PRINT t1
    COLOR 14, 1: LOCATE 20, 10: PRINT "Enter the final time (yrs) (t2)": COLOR 12, 1: LOCATE 20, 52:
    PRINT t2
    COLOR 14, 1: LOCATE 22, 10: PRINT "Time Step (yrs) (INC) ": COLOR 12, 1: LOCATE 22, 52: PRINT INC
    COLOR 14, 1: LOCATE 23, 9: PRINT CHR$(192); STRING$(41, 196); STRING$(1, 208); STRING$(9,
    196); STRIG$(217)

    COLOR 12, 1:
    LOCATE 18, 53: INPUT "", t1$
    IF t1$ = "" THEN t1 = t1 ELSE t1 = VAL(t1$)
    LOCATE 20, 53: INPUT "", t2$
    IF t2$ = "" THEN t2 = t2 ELSE t2 = VAL(t2$)
    LOCATE 22, 53: INPUT "", INC$
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    IF INC$ = "" THEN INC = INC ELSE INC = VAL(INC$)

CHECK:

    COLOR 12, 1: LOCATE 24, 20: INPUT "Is  the Data correct (Y/N) :", YN$
    IF YN$ = "N" OR YN$ = "n" GOTO edit ELSE GOTO EDIT1

EDIT1:

    GOSUB constant
    COLOR 13, 1: LOCATE 1, 10: PRINT "Please Enter Data Set #2"
    COLOR 14, 1
    LOCATE 2, 9: PRINT CHR$(218); STRING$(43, 196); STRING$(1, 210); STRING$(11, 196); STRING$(1, 191)
    FOR I = 4 TO 21 STEP 2: LOCATE I, 9: PRINT CHR$(195); STRING$(43, 196); STRING$(1, 215);
    STRING$(11, 196); STRING$(1, 180)
    NEXT I
    FOR I = 3 TO 22 STEP 2: LOCATE I, 9: PRINT CHR$(179)
    LOCATE I, 53: PRINT CHR$(186)
    LOCATE I, 65: PRINT CHR$(179)
    NEXT I
    LOCATE 3, 10: PRINT "Discription of Constants (unit) (Variable)": COLOR 12, 1: LOCATE 3, 55:
    PRINT"Input"
    COLOR 14, 1: LOCATE 4, 9: PRINT CHR$(198); STRING$(43, 205); STRING$(1, 206); STRING$(11,
    205); STRING$(1, 181)
    LOCATE 5, 10: PRINT "Int. Areas, Seg.1,2 (m2) (INTA12)": COLOR 12, 1: LOCATE 5, 54: PRINT INTA12:
    COLOR 14, 1
    LOCATE 7, 10: PRINT "Int. Areas, Seg.2,3 (m2) (INTA23)": COLOR 12, 1: LOCATE 7, 54: PRINT INTA23:
    COLOR 14, 1
    LOCATE 9, 10: PRINT "Int. Areas, Seg.3,4 (m2) (INTA34)": COLOR 12, 1: LOCATE 9, 54: PRINT INTA34:
    COLOR 14, 1
    LOCATE 11, 10: PRINT "Int. Areas, Seg.4,LM (m2) (INTA4LM)": COLOR 12, 1: LOCATE 11, 54: PRINT
    INTA4LM: COLOR 14, 1
    LOCATE 13, 10: PRINT "Charac. Length, Seg.1,2 (m) (CHL12)": COLOR 12, 1: LOCATE 13, 54: PRINT
    CHL12: COLOR 14, 1
    LOCATE 15, 10: PRINT "Charac. Length, Seg.2,3 (m) (CHL23)": COLOR 12, 1: LOCATE 15, 54: PRINT
    CHL23: COLOR 14, 1
    LOCATE 17, 10: PRINT "Charac. Length, Seg.3,4 (m) (CHL34)": COLOR 12, 1: LOCATE 17, 54: PRINT
    CHL34: COLOR 14, 1
    LOCATE 19, 10: PRINT "Charac. Length, Seg.4LM (m) (CHL4LM)": COLOR 12, 1: LOCATE 19, 54: PRINT
    CHL4LM: COLOR 14, 1
    LOCATE 21, 10: PRINT "Bulk Disp. Coeff.,Seg.1,2 (m2/d) (BDSC12)": COLOR 12, 1: LOCATE 21, 54:
    PRINT BDSC12: COLOR 14, 1
    LOCATE 22, 9: PRINT CHR$(192); STRING$(43, 196); STRING$(1, 208); STRING$(11, 196); STRING$(1,
    217)

    COLOR 12, 1
    LOCATE 5, 55: INPUT "", INTA12$
    IF INTA12$ = "" THEN INTA12 = INTA12 ELSE INTA12 = VAL(INTA12$)
    LOCATE 7, 55: INPUT "", INTA23$
    IF INTA23$ = "" THEN INTA23 = INTA23 ELSE INTA23 = VAL(INTA23$)
    LOCATE 9, 55: INPUT "", INTA34$
    IF INTA34$ = "" THEN INTA34 = INTA34 ELSE INTA34 = VAL(INTA34$)
    LOCATE 11, 55: INPUT "", INTA4LM$
    IF INTA4LM$ = "" THEN INTA4LM = INTA4LM ELSE INTA4LM = VAL(INTA4LM$)
    LOCATE 13, 55: INPUT "", CHL12$
    IF CHL12$ = "" THEN CHL12 = CHL12 ELSE CHL12 = VAL(CHL12$)
    LOCATE 15, 55: INPUT "", CHL23$
    IF CHL23$ = "" THEN CHL23 = CHL23 ELSE CHL23 = VAL(CHL23$)
    LOCATE 17, 55: INPUT "", CHL34$
    IF CHL34$ = "" THEN CHL34 = CHL34 ELSE CHL34 = VAL(CHL34$)
    LOCATE 19, 55: INPUT "", CHL4LM$
    IF CHL4LM$ = "" THEN CHL4LM = CHL4LM ELSE CHL4LM = VAL(CHL4LM$)
    LOCATE 21, 55: INPUT "", BDSC12$
    IF BDSC12$ = "" THEN BDSC12 = BDSC12 ELSE BDSC12 = VAL(BDSC12$)
    GOSUB constant

    COLOR 13, 1: LOCATE 1, 10: PRINT "Continue Entering Data Set #2"
    COLOR 14, 1
    LOCATE 2, 9: PRINT CHR$(218); STRING$(43, 196); STRING$(1, 210); STRING$(11, 196); STRING$(1,
    191)
    FOR I = 4 TO 21 STEP 2: LOCATE I, 9: PRINT CHR$(195); STRING$(43, 196); STRING$(1, 215);
    STRING$(11, 196); STRING$(1, 180)
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NEXT I
FOR I = 3 TO 22 STEP 2: LOCATE I, 9: PRINT CHR$(179)
LOCATE I, 53: PRINT CHR$(186)
LOCATE I, 65: PRINT CHR$(179)
NEXT I
LOCATE 3, 10: PRINT "Discription of Constants (unit) (Variable)": COLOR 12, 1: LOCATE 3, 55:
PRINT "Input"
COLOR 14, 1: LOCATE 4, 9: PRINT CHR$(198); STRING$(43, 205); STRING$(1, 206); STRING$(11,
STRING$(1, 181)
LOCATE 5, 10: PRINT "Bulk Disp. Coeff.,Seg.2,3 (m2/d) (BDSC23)": COLOR 12, 1: LOCATE 5, 54:
PRINT BDSC23: COLOR 14, 1
LOCATE 7, 10: PRINT "Bulk Disp. Coeff.,Seg.3,4 (m2/d) (BDSC34)": COLOR 12, 1: LOCATE 7, 54:
PRINT BDSC34: COLOR 14, 1
LOCATE 9, 10: PRINT "Bulk Disp. Coeff.,Seg.4LM (m2/d) (BDSC4LM)": COLOR 12, 1: LOCATE 9, 54:
PRINT BDSC4LM: COLOR 14, 1
LOCATE 11, 10: PRINT "Flow from Fox to Seg.#1 (m3/d) (QF1)": COLOR 12, 1: LOCATE 11, 54: PRINT
QF1: COLOR 14, 1
LOCATE 13, 10: PRINT "Flow from Seg #2 to Seg.#1 (m3/d) (Q21)": COLOR 12, 1: LOCATE 13, 54:
PRINT Q21:  COLOR 14, 1
Q12 = QF1 + Q21
LOCATE 15, 10: PRINT "Flow from Seg #1 to Seg.#2 (m3/d) (Q12)": COLOR 12, 1: LOCATE 15, 54:
PRINT USING F1$; Q12: COLOR 14, 1
LOCATE 17, 10: PRINT "Flow from Seg #3 to Seg.#2 (m3/d) (Q32) ": COLOR 12, 1: LOCATE 17, 54:
PRINT Q32: COLOR 14, 1
Q23 = Q32 + QF1
LOCATE 19, 10: PRINT "Flow from Seg #2 to Seg.#3 (m3/d) (Q23)": COLOR 12, 1: LOCATE 19, 54:
PRINT USING F1$; Q23: COLOR 14, 1
LOCATE 21, 10: PRINT "Flow from Seg #4 to Seg.#3 (m3/d) (Q43)": COLOR 12, 1: LOCATE 21, 54:
PRINT Q43: COLOR 14, 1
LOCATE 22, 9: PRINT CHR$(192); STRING$(43, 196); STRING$(1, 208); STRING$(11, 196); STRING$(1,
217)

COLOR 12, 1
LOCATE 5, 55: INPUT "", BDSC23$
IF BDSC23$ = "" THEN BDSC23 = BDSC23 ELSE BDSC23 = VAL(BDSC23$)
LOCATE 7, 55: INPUT "", BDSC34$
IF BDSC34$ = "" THEN BDSC34 = BDSC34 ELSE BDSC34 = VAL(BDSC34$)
LOCATE 9, 55: INPUT "", BDSC4LM$
IF BDSC4LM$ = "" THEN BDSC4LM = BDSC4LM ELSE BDSC4LM = VAL(BDSC4LM$)
LOCATE 11, 55: INPUT "", QF1$
IF QF1$ = "" THEN QF1 = QF1 ELSE QF1 = VAL(QF1$)
LOCATE 13, 55: INPUT "", Q21$
IF Q21$ = "" THEN Q21 = Q21 ELSE Q21 = VAL(Q21$)
LOCATE 17, 55: INPUT "", Q32$
IF Q32$ = "" THEN Q32 = Q32 ELSE Q32 = VAL(Q32$)
LOCATE 21, 55: INPUT "", Q43$
IF Q43$ = "" THEN Q43 = Q43 ELSE Q43 = VAL(Q43$)
GOSUB constant

COLOR 13, 1: LOCATE 1, 10: PRINT "Continue Entering Data Set #2"
COLOR 14, 1
LOCATE 2, 9: PRINT CHR$(218); STRING$(43, 196); STRING$(1, 210); STRING$(11, 196); STRING$(1,
191)
FOR I = 4 TO 19 STEP 2: LOCATE I, 9: PRINT CHR$(195); STRING$(43, 196); STRING$(1, 215);
STRING$(11,196); STRING$(1, 180)
NEXT I
FOR I = 3 TO 20 STEP 2: LOCATE I, 9: PRINT CHR$(179)
LOCATE I, 53: PRINT CHR$(186)
LOCATE I, 65: PRINT CHR$(179)
NEXT I
LOCATE 3, 10: PRINT "Discription of Constants (unit) (Variable)": COLOR 12, 1: LOCATE 3, 55:
PRINT "Input"
COLOR 14, 1: LOCATE 4, 9: PRINT CHR$(198); STRING$(43, 205); STRING$(1, 206); STRING$(11,
205); STRING$(1, 181)
LOCATE 5, 10: PRINT "Flow from Menominee to Seg.#3 (m3/d) (QM3)": COLOR 12, 1: LOCATE 5, 54:
PRINT QM3: COLOR 14, 1
LOCATE 7, 10: PRINT "Flow from Peshtigo to Seg.#3 (m3/d) (QP3)": COLOR 12, 1: LOCATE 7, 54:
PRINT QP3: COLOR 14, 1
LOCATE 9, 10: PRINT "Flow from Oconto to Seg.#3 (m3/d) (QO3)": COLOR 12, 1: LOCATE 9, 54:
PRINT QO3: COLOR 14, 1
Q34 = Q43 + QF1 + QM3 + QP3 + QO3
LOCATE 11, 10: PRINT "Flow from Seg.#3 to Seg.#4 (m3/d) (Q34)": COLOR 12, 1: LOCATE 11, 54:
```

```
    PRINT USING F1$; Q34: COLOR 14, 1
    LOCATE 13, 10: PRINT "Flow from LM to Seg.#4 (m3/d) (QLM4)": COLOR 12, 1: LOCATE 13, 54: PRINT
    QLM4: COLOR 14, 1
    LOCATE 15, 10: PRINT "Flow from Escanaba to Seg.#4 (m3/d) (QE4)": COLOR 12, 1: LOCATE 15, 54:
    PRINT QE4: COLOR 14, 1
    Q4LM = QLM4 + QF1 + QM3 + QP3 + QO3 + QE4
    LOCATE 17, 10: PRINT "Flow from Seg.#4 to LM (m3/d) (Q4LM)": COLOR 12, 1: LOCATE 17, 54: PRINT
    USING F1$; Q4LM: COLOR 14, 1
    LOCATE 19, 10: PRINT "Henry's Constant (atm-m3/mol) (HEN)": COLOR 12, 1: LOCATE 19, 54: PRINT
    HEN: COLOR 14, 1
    LOCATE 20, 9: PRINT CHR$(192); STRING$(43, 196); STRING$(1, 208); STRING$(11, 196); STRING$(1,
    217)

    COLOR 12, 1
    LOCATE 5, 55: INPUT "", QM3$
    IF QM3$ = "" THEN QM3 = QM3 ELSE QM3 = VAL(QM3$)
    LOCATE 7, 55: INPUT "", QP3$
    IF QP3$ = "" THEN QP3 = QP3 ELSE QP3 = VAL(QP3$)
    LOCATE 9, 55: INPUT "", QO3$
    IF QO3$ = "" THEN QO3 = QO3 ELSE QO3 = VAL(QO3$)
    LOCATE 13, 55: INPUT "", QLM4$
    IF QLM4$ = "" THEN QLM4 = QLM4 ELSE QLM4 = VAL(QLM4$)
    LOCATE 15, 55: INPUT "", QE4$
    IF QE4$ = "" THEN QE4 = QE4 ELSE QE4 = VAL(QE4$)
    LOCATE 19, 55: INPUT "", HEN$
    IF HEN$ = "" THEN HEN = HEN ELSE HEN = VAL(HEN$)

CHECK1:

    COLOR 12, 1: LOCATE 22, 21: INPUT "Is  the Data correct (Y/N) :", YN$
    IF YN$ = "N" OR YN$ = "n" GOTO EDIT1 ELSE GOTO ACP1

ACP1:

    CLS
    COLOR 13, 1: LOCATE 1, 6: PRINT "Atmospheric Concentration of PCB for Different Yrs. (ACP)
    (ng/m3)"
    COLOR 14, 1: LOCATE 2, 5: PRINT CHR$(218); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196);
    STRING$(1, 194); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194); STRING$(5,
    196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194); STRING$(5, 196); STRING$(1, 194);
    STRING$(10, 196); STRING$(1, 191)
    FOR I = 4 TO 21 STEP 2: LOCATE I, 5: PRINT CHR$(195); STRING$(5, 196); STRING$(1, 197);
    STRING$(10,196); STRING$(1, 197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196); STRING$(1,
    197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 197); STRING$(5, 196);
    STRING$(1, 197); STRING$(10, 196); STRING$(1, 180)
    NEXT I
    II = 0: GOSUB scrn

    COLOR 12, 1
    N = 1
    FOR j = 5 TO 22 STEP 2
    LOCATE j, 12: PRINT ACP(N)
    LOCATE j, 29: PRINT ACP(N + 9)
    LOCATE j, 46: PRINT ACP(N + 18)
    LOCATE j, 63: PRINT ACP(N + 27)
    N = N + 1
    NEXT j

    K = 13
    START = 1
    FINISH = 9

40 :

    j = 5
    FOR N = START TO FINISH
    LOCATE j, K: PRINT ACP$
    LOCATE j, K: INPUT "", ACP$
    IF ACP$ = "" THEN ACP(N) = ACP(N) ELSE ACP(N) = VAL(ACP$)
    j = j + 2
    ACP$ = ""
    NEXT N
```

```
    START = START + 9
    FINISH = FINISH + 9
    K = K + 17
    IF N > 36 GOTO CHECKACP1
    GOTO 40

CHECKACP1:

    COLOR 12, 1: LOCATE 24, 25: INPUT "Is  the Data correct (Y/N) :", YN$
    IF YN$ = "N" OR YN$ = "n" GOTO ACP1 ELSE GOTO ACP2

ACP2:

    CLS
    COLOR 13, 1: LOCATE 1, 6: PRINT "Atmospheric Concentration of PCB for Different Yrs. (ACP)
    (ng/m3)"
    COLOR 14, 1: LOCATE 2, 5: PRINT CHR$(218); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196);
    STRING$(1, 194); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194);  STRING$(5,
    196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194); STRING$(5, 196); STRING$(1, 194);
    STRING$(10, 196); STRING$(1, 191)
    FOR I = 4 TO 21 STEP 2: LOCATE I, 5: PRINT CHR$(195); STRING$(5, 196); STRING$(1, 197);
    STRING$(10,196); STRING$(1, 197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196);  STRING$(1,
    197); STRING$(5,196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 197); STRING$(5, 196);
    STRING$(1, 197); STRING$(10, 196); STRING$(1, 180)
    NEXT I

    II = 36: GOSUB scrn

    COLOR 12, 1
    N = 37
    FOR j = 5 TO 22 STEP 2
    LOCATE j, 12: PRINT ACP(N)
    LOCATE j, 29: PRINT ACP(N + 9)
    LOCATE j, 46: PRINT ACP(N + 18)
    LOCATE j, 63: PRINT ACP(N + 27)
    N = N + 1
    NEXT j

    K = 13
    START = 37
    FINISH = 45

50 :

    j = 5
    FOR N = START TO FINISH
    LOCATE j, K: PRINT ACP$
    LOCATE j, K: INPUT "", ACP$
    IF ACP$ = "" THEN ACP(N) = ACP(N) ELSE ACP(N) = VAL(ACP$)
    j = j + 2
    ACP$ = ""
    NEXT N
    START = START + 9
    FINISH = FINISH + 9
    K = K + 17
    IF N > 72 GOTO CHECKACP2
    GOTO 50

CHECKACP2:

    COLOR 12, 1: LOCATE 24, 25: INPUT "Is  the Data correct (Y/N) :", YN$
    IF YN$ = "N" OR YN$ = "n" GOTO ACP2 ELSE GOTO W1LM1

W1LM1:

    CLS
    COLOR 13, 1: LOCATE 1, 6: PRINT "POC Concentration of Lake Mich. for Different Yrs. (W1LM)
    (mg/m3)"
    COLOR 14, 1: LOCATE 2, 5: PRINT CHR$(218); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196);
    STRING$(1, 194); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194);  STRING$(5,
    196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194); STRING$(5, 196); STRING$(1, 194);
    STRING$(10, 196); STRING$(1, 191)
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```
    FOR I = 4 TO 21 STEP 2: LOCATE I, 5: PRINT CHR$(195); STRING$(5, 196); STRING$(1, 197);
    STRING$(10, 196); STRING$(1, 197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196);
    STRING$(1, 197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 197); STRING$(5,
    196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 180)
    NEXT I

    II = 0: GOSUB scrn

    COLOR 12, 1
    N = 1
    FOR j = 5 TO 22 STEP 2
    LOCATE j, 12: PRINT W1LM(N)
    LOCATE j, 29: PRINT W1LM(N + 9)
    LOCATE j, 46: PRINT W1LM(N + 18)
    LOCATE j, 63: PRINT W1LM(N + 27)
    N = N + 1
    NEXT j

    K = 13
    START = 1
    FINISH = 9

60 :

    j = 5
    FOR N = START TO FINISH
    LOCATE j, K: PRINT W1LM$
    LOCATE j, K: INPUT "", W1LM$
    IF W1LM$ = "" THEN W1LM(N) = W1LM(N) ELSE W1LM(N) = VAL(W1LM$)
    j = j + 2
    W1LM$ = ""
    NEXT N
    START = START + 9
    FINISH = FINISH + 9
    K = K + 17
    IF N > 36 GOTO CHECKW1LM1
    GOTO 60

CHECKW1LM1:

    COLOR 12, 1: LOCATE 24, 25: INPUT "Is  the Data correct (Y/N) :", YN$
    IF YN$ = "N" OR YN$ = "n" GOTO W1LM1 ELSE GOTO W1LM2

W1LM2:

    CLS
    COLOR 13, 1: LOCATE 1, 6: PRINT "POC Concentration of Lake Mich. for Different Yrs. (W1LM)
    (mg/m3)"
    COLOR 14, 1: LOCATE 2, 5: PRINT CHR$(218); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196);
    STRING$(1, 194); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194);  STRING$(5,
    6); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194); STRING$(5, 196); STRING$(1, 194);
    STRING$(10, 196); STRING$(1, 191)
    FOR I = 4 TO 21 STEP 2: LOCATE I, 5: PRINT CHR$(195); STRING$(5, 196); STRING$(1, 197);
    STRING$(10,196); STRING$(1, 197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196);  STRING$(1,
    197); STRING$(5,196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 197); STRING$(5, 196);
    STRING$(1, 197); STRING$(10, 196); STRING$(1, 180)
    NEXT I

    II = 36: GOSUB scrn

    COLOR 12, 1
    N = 37
    FOR j = 5 TO 22 STEP 2
    LOCATE j, 12: PRINT W1LM(N)
    LOCATE j, 29: PRINT W1LM(N + 9)
    LOCATE j, 46: PRINT W1LM(N + 18)
    LOCATE j, 63: PRINT W1LM(N + 27)
    N = N + 1
    NEXT j

    K = 13
    START = 37
```

```
    FINISH = 45

70 :

    j = 5
    FOR N = START TO FINISH
    LOCATE j, K: PRINT W1LM$
    LOCATE j, K: INPUT "", W1LM$
    IF W1LM$ = "" THEN W1LM(N) = W1LM(N) ELSE W1LM(N) = VAL(W1LM$)
    j = j + 2
    W1LM$ = ""
    NEXT N
    START = START + 9
    FINISH = FINISH + 9
    K = K + 17
    IF N > 72 GOTO CHECKW1LM2
    GOTO 70

CHECKW1LM2:

    COLOR 12, 1: LOCATE 24, 25: INPUT "Is  the Data correct (Y/N) :", YN$
    IF YN$ = "N" OR YN$ = "n" GOTO W1LM2 ELSE GOTO W3LM1


    CLS
    COLOR 13, 1: LOCATE 1, 6: PRINT "PCB Concentration of Lake Mich. for Different Yrs. (W3LM)
    (ng/m3)"
    COLOR 14, 1: LOCATE 2, 5: PRINT CHR$(218); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196);
    STRING$(1, 194); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194);  STRING$(5,
    196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194); STRING$(5, 196); STRING$(1, 194);
    STRING$(10, 196); STRING$(1, 191)
    FOR I = 4 TO 21 STEP 2: LOCATE I, 5: PRINT CHR$(195); STRING$(5, 196); STRING$(1, 197);
    STRING$(10,196); STRING$(1, 197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196);  STRING$(1,
    197); STRING$(5,196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 197); STRING$(5, 196);
    STRING$(1, 197); STRING$(10, 196); STRING$(1, 180)
    NEXT I

    II = 0: GOSUB scrn

    COLOR 12, 1
    N = 1
    FOR j = 5 TO 22 STEP 2
    LOCATE j, 12: PRINT W3LM(N)
    LOCATE j, 29: PRINT W3LM(N + 9)
    LOCATE j, 46: PRINT W3LM(N + 18)
    LOCATE j, 63: PRINT W3LM(N + 27)
    N = N + 1
    NEXT j

    K = 13
    START = 1
    FINISH = 9

80 :

    j = 5
    FOR N = START TO FINISH
    LOCATE j, K: PRINT W3LM$
    LOCATE j, K: INPUT "", W3LM$
    IF W3LM$ = "" THEN W3LM(N) = W3LM(N) ELSE W3LM(N) = VAL(W3LM$)
    j = j + 2
    W3LM$ = ""
    NEXT N
    START = START + 9
    FINISH = FINISH + 9
    K = K + 17
    IF N > 36 GOTO CHECKW3LM1
    GOTO 80

CHECKW3LM1:

    COLOR 12, 1: LOCATE 24, 25: INPUT "Is  the Data correct (Y/N) :", YN$
```

```
    IF YN$ = "N" OR YN$ = "n" GOTO W3LM1 ELSE GOTO W3LM2

W3LM2:

    CLS
    COLOR 13, 1: LOCATE 1, 6: PRINT "PCB Concentration of Lake Mich. for Different Yrs. (W3LM)
    (ng/m3)"
    COLOR 14, 1: LOCATE 2, 5: PRINT CHR$(218); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196);
    STRING$(1, 194); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194);  STRING$(5,
    196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194); STRING$(5, 196); STRING$(1, 194);
    STRING$(10, 196); STRING$(1, 191)
    FOR I = 4 TO 21 STEP 2: LOCATE I, 5: PRINT CHR$(195); STRING$(5, 196); STRING$(1, 197);
    STRING$(10,196); STRING$(1, 197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196);  STRING$(1,
    197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 197); STRING$(5, 196);
    STRING$(1, 197); STRING$(10, 196); STRING$(1, 180)
    NEXT I

    II = 36: GOSUB scrn

    COLOR 12, 1
    N = 37
    FOR j = 5 TO 22 STEP 2
    LOCATE j, 12: PRINT W3LM(N)
    LOCATE j, 29: PRINT W3LM(N + 9)
    LOCATE j, 46: PRINT W3LM(N + 18)
    LOCATE j, 63: PRINT W3LM(N + 27)
    N = N + 1
    NEXT j

    K = 13
    START = 37
    FINISH = 45

90 :

    j = 5
    FOR N = START TO FINISH
    LOCATE j, K: PRINT W3LM$
    LOCATE j, K: INPUT "", W3LM$
    IF W3LM$ = "" THEN W3LM(N) = W3LM(N) ELSE W3LM(N) = VAL(W3LM$)
    j = j + 2
    W3LM$ = ""
    NEXT N
    START = START + 9
    FINISH = FINISH + 9
    K = K + 17
    IF N > 72 GOTO CHECKW3LM2
    GOTO 90

CHECKW3LM2:

    COLOR 12, 1: LOCATE 24, 25: INPUT "Is  the Data correct (Y/N) :", YN$
    IF YN$ = "N" OR YN$ = "n" GOTO W3LM2 ELSE GOTO EDIT2
    COLOR 14, 1

EDIT2:

    SEGNO = 1
    FOR R = 1 TO 4

10 :GOSUB segment

    COLOR 11, 1: LOCATE 1, 10: PRINT "Please Enter Data Set #3"
    COLOR 14, 1: LOCATE 2, 9: PRINT CHR$(218); STRING$(43, 196); STRING$(1, 210); STRING$(11, 196);
    STRING$(1, 191)
    FOR I = 4 TO 21 STEP 2: LOCATE I, 9: PRINT CHR$(195); STRING$(43, 196); STRING$(1, 215);
    STRING$(11, 196); STRING$(1, 180)
    NEXT I

    FOR I = 3 TO 22 STEP 2: LOCATE I, 9: PRINT CHR$(179)
    LOCATE I, 53: PRINT CHR$(186)
    LOCATE I, 65: PRINT CHR$(179)
```

```
NEXT I
COLOR 14, 1: LOCATE 3, 10: PRINT "Discription of Variable (unit) (Variable)": COLOR 12, 1:
LOCATE 3,55: PRINT "Input"
COLOR 14, 1: LOCATE 4, 9: PRINT CHR$(198); STRING$(43, 205); STRING$(1, 206); STRING$(11,
205); STRING$(1, 181)
LOCATE 5, 10: PRINT "Initial POC Conc.in WC (mg/m3) (W1)": COLOR 12, 1: LOCATE 5, 54: PRINT
W1(R): COLOR 14, 1
LOCATE 7, 10: PRINT "Initial POC Conc.in BS (mg/m3) (W2)": COLOR 12, 1: LOCATE 7, 54: PRINT
W2(R): COLOR 14, 1
LOCATE 9, 10: PRINT "Initial PCB Conc.in WC (ng/m3) (W3)": COLOR 12, 1: LOCATE 9, 54: PRINT
W3(R): COLOR 14, 1
LOCATE 11, 10: PRINT "Initial PCB Conc.in BS (ng/m3) (W4)": COLOR 12, 1: LOCATE 11, 54: PRINT
W4(R): COLOR 14, 1
LOCATE 13, 10: PRINT "Volume of WC(m3) (V1)": COLOR 12, 1: LOCATE 13, 54: PRINT V1(R): COLOR
14, 1
LOCATE 15, 10: PRINT "Volume of BS(m3) (V2)": COLOR 12, 1: LOCATE 15, 54: PRINT V2(R): COLOR
14, 1
LOCATE 17, 10: PRINT "Surface Area of WC (m2) (SA1)": COLOR 12, 1: LOCATE 17, 54: PRINT
SA1(R): COLOR 14, 1
LOCATE 19, 10: PRINT "Area of Sediment, Dep., (m2) (ASD)": COLOR 12, 1: LOCATE 19, 54: PRINT
ASD(R): COLOR 14, 1
LOCATE 21, 10: PRINT "Area of Sediment, Resus.(m2) (ASR)": COLOR 12, 1: LOCATE 21, 54: PRINT
ASR(R): COLOR 14, 1
LOCATE 22, 9: PRINT CHR$(192); STRING$(43, 196); STRING$(1, 208); STRING$(11, 196); STRING$(1,
217)

COLOR 12, 1
LOCATE 5, 55: INPUT "", W1$(R)
IF W1$(R) = "" THEN W1(R) = W1(R) ELSE W1(R) = VAL(W1$(R))
LOCATE 7, 55: INPUT "", W2$(R)
IF W2$(R) = "" THEN W2(R) = W2(R) ELSE W2(R) = VAL(W2$(R))
LOCATE 9, 55: INPUT "", W3$(R)
IF W3$(R) = "" THEN W3(R) = W3(R) ELSE W3(R) = VAL(W3$(R))
LOCATE 11, 55: INPUT "", W4$(R)
IF W4$(R) = "" THEN W4(R) = W4(R) ELSE W4(R) = VAL(W4$(R))
LOCATE 13, 55: INPUT "", V1$(R)
IF V1$(R) = "" THEN V1(R) = V1(R) ELSE V1(R) = VAL(V1$(R))
LOCATE 15, 55: INPUT "", V2$(R)
IF V2$(R) = "" THEN V2(R) = V2(R) ELSE V2(R) = VAL(V2$(R))
LOCATE 17, 55: INPUT "", SA1$(R)
IF SA1$(R) = "" THEN SA1(R) = SA1(R) ELSE SA1(R) = VAL(SA1$(R))
LOCATE 19, 55: INPUT "", ASD$(R)
IF ASD$(R) = "" THEN ASD(R) = ASD(R) ELSE ASD(R) = VAL(ASD$(R))
LOCATE 21, 55: INPUT "", ASR$(R)
IF ASR$(R) = "" THEN ASR(R) = ASR(R) ELSE ASR(R) = VAL(ASR$(R))

GOSUB segment

COLOR 11, 1: LOCATE 1, 10: PRINT "Continue Entering Data Set #3"
COLOR 14, 1: LOCATE 2, 9: PRINT CHR$(218); STRING$(43, 196); STRING$(1, 210); STRING$(11,
196); STRING$(1, 191)
FOR I = 4 TO 21 STEP 2: LOCATE I, 9: PRINT CHR$(195); STRING$(43, 196); STRING$(1, 215);
STRING$(11, 196); STRING$(1, 180)
NEXT I
FOR I = 3 TO 22 STEP 2: LOCATE I, 9: PRINT CHR$(179)
LOCATE I, 53: PRINT CHR$(186)
LOCATE I, 65: PRINT CHR$(179)
NEXT I
COLOR 14, 1: LOCATE 3, 10: PRINT "Discription of Variable (unit) (Variable)": COLOR 12, 1:
LOCATE 3,55: PRINT "Input"
COLOR 14, 1: LOCATE 4, 9: PRINT CHR$(198); STRING$(43, 205); STRING$(1, 206); STRING$(11,
205); STRING$(1, 181)
LOCATE 5, 10: PRINT "Sed. Porosity (SEDP)": COLOR 12, 1: LOCATE 5, 54: PRINT SEDP(R): COLOR
14, 1
LOCATE 7, 10: PRINT "Deep Burial Velocity (m/d) (DBV)": COLOR 12, 1: LOCATE 7, 54: PRINT
DBV(R): COLOR 14, 1
LOCATE 9, 10: PRINT "Resuspension Velocity (m/d) (RSV)": COLOR 12, 1: LOCATE 9, 54: PRINT
RSV(R): COLOR 14, 1
LOCATE 11, 10: PRINT "Settling Rate of POC (m/d) (SRO1)": COLOR 12, 1: LOCATE 11, 54: PRINT
SRO1(R):COLOR 14, 1
LOCATE 13, 10: PRINT "Settling Rate of PCB (m/d) (SRP1)": COLOR 12, 1: LOCATE 13, 54: PRINT
SRP1(R):COLOR 14, 1
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    LOCATE 15, 10: PRINT "POC Decay Rate in WC (DECR1) (1/d)": COLOR 12, 1: LOCATE 15, 54: PRINT
    DECR1(R):COLOR 14, 1
    LOCATE 17, 10: PRINT "POC Decay Rate in BS (DECR2) (1/d)": COLOR 12, 1: LOCATE 17, 54: PRINT
    DECR2(R):COLOR 14, 1
    LOCATE 19, 10: PRINT "Decom. Rate of PCB in WC (1/d) (DRP1)": COLOR 12, 1: LOCATE 19, 54:
    PRINT DRP1(R): COLOR 14, 1
    LOCATE 21, 10: PRINT "Decom. Rate of PCB in BS (1/d) (DRP2)": COLOR 12, 1: LOCATE 21, 54:
    PRINT DRP2(R): COLOR 14, 1
    LOCATE 22, 9: PRINT CHR$(192); STRING$(43, 196); STRING$(1, 208); STRING$(11, 196); STRING$(1,
    217)

    COLOR 12, 1
    LOCATE 5, 55: INPUT "", SEDP$(R)
    IF SEDP$(R) = "" THEN SEDP(R) = SEDP(R) ELSE SEDP(R) = VAL(SEDP$(R))
    LOCATE 7, 55: INPUT "", DBV$(R)
    IF DBV$(R) = "" THEN DBV(R) = DBV(R) ELSE DBV(R) = VAL(DBV$(R))
    LOCATE 9, 55: INPUT "", RSV$(R)
    IF RSV$(R) = "" THEN RSV(R) = RSV(R) ELSE RSV(R) = VAL(RSV$(R))
    LOCATE 11, 55: INPUT "", SRO1$(R)
    IF SRO1$(R) = "" THEN SRO1(R) = SRO1(R) ELSE SRO1(R) = VAL(SRO1$(R))
    LOCATE 13, 55: INPUT "", SRP1$(R)
    IF SRP1$(R) = "" THEN SRP1(R) = SRP1(R) ELSE SRP1(R) = VAL(SRP1$(R))
    LOCATE 15, 55: INPUT "", DECR1$(R)
    IF DECR1$(R) = "" THEN DECR1(R) = DECR1(R) ELSE DECR1(R) = VAL(DECR1$(R))
    LOCATE 17, 55: INPUT "", DECR2$(R)
    IF DECR2$(R) = "" THEN DECR2(R) = DECR2(R) ELSE DECR2(R) = VAL(DECR2$(R))
    LOCATE 19, 55: INPUT "", DRP1$(R)
    IF DRP1$(R) = "" THEN DRP1(R) = DRP1(R) ELSE DRP1(R) = VAL(DRP1$(R))
    LOCATE 21, 55: INPUT "", DRP2$(R)
    IF DRP2$(R) = "" THEN DRP2(R) = DRP2(R) ELSE DRP2(R) = VAL(DRP2$(R))

    GOSUB segment

    COLOR 11, 1: LOCATE 5, 10: PRINT "Continue Entering Data Set #3"
    COLOR 14, 1: LOCATE 6, 9: PRINT CHR$(218); STRING$(43, 196); STRING$(1, 210); STRING$(11,
    196); STRING$(1, 191)
    FOR I = 8 TO 15 STEP 2: LOCATE I, 9: PRINT CHR$(195); STRING$(43, 196); STRING$(1, 215);
    STRING$(11,196); STRING$(1, 180)
    NEXT I
    FOR I = 7 TO 16 STEP 2: LOCATE I, 9: PRINT CHR$(179)
    LOCATE I, 53: PRINT CHR$(186)
    LOCATE I, 65: PRINT CHR$(179)
    NEXT I
    COLOR 14, 1: LOCATE 7, 10: PRINT "Discription of Variable (unit) (Variable)": COLOR 12, 1:
    LOCATE 7, 55: PRINT "Input"
    COLOR 14, 1: LOCATE 8, 9: PRINT CHR$(198); STRING$(43, 205); STRING$(1, 206); STRING$(11,
    205); STRING$(1, 181)
    LOCATE 9, 10: PRINT "Partition Coef.(m3/Kg C) (PRTC)": COLOR 12, 1: LOCATE 9, 54: PRINT
    PRTC(R): COLOR 14, 1
    LOCATE 11, 10: PRINT "Volatilization Exch. Rate (m/d) (VEXR)": COLOR 12, 1: LOCATE 11, 54:
    PRINT VEXR(R): COLOR 14, 1
    LOCATE 13, 10: PRINT "Disp. Coef. b/w Sed. & Seg.#": LOCATE 13, 38: PRINT SEGNO: LOCATE 13,
    40: PRINT "(m2/d) (Esi)": COLOR 12, 1: LOCATE 13, 54: PRINT Esi(R): COLOR 14, 1
    LOCATE 15, 10: PRINT "Charc. Length b/w Sed. & Seg.#": LOCATE 15, 40: PRINT SEGNO: LOCATE 15,   42:
    PRINT " (m) (Lsi)": COLOR 12, 1: LOCATE 15, 54: PRINT Lsi(R): COLOR 14, 1
    LOCATE 16, 9: PRINT CHR$(192); STRING$(43, 196); STRING$(1, 208); STRING$(11, 196); STRING$(1,
    217)

    COLOR 12, 1
    LOCATE 9, 55: INPUT "", PRTC$(R)
    IF PRTC$(R) = "" THEN PRTC(R) = PRTC(R) ELSE PRTC(R) = VAL(PRTC$(R))
    LOCATE 11, 55: INPUT "", VEXR$(R)
    IF VEXR$(R) = "" THEN VEXR(R) = VEXR(R) ELSE VEXR(R) = VAL(VEXR$(R))
    LOCATE 13, 55: INPUT "", Esi$(R)
    IF Esi$(R) = "" THEN Esi(R) = Esi(R) ELSE Esi(R) = VAL(Esi$(R))
    LOCATE 15, 55: INPUT "", Lsi$(R)
    IF Lsi$(R) = "" THEN Lsi(R) = Lsi(R) ELSE Lsi(R) = VAL(Lsi$(R))

CHECK2:

    COLOR 12, 1: LOCATE 18, 15: PRINT "Is the Data correct for Segment #"
    LOCATE 18, 48: PRINT SEGNO: LOCATE 18, 51: PRINT "(Y/N) :"
```

```
    LOCATE 18, 57: INPUT YN$
    IF YN$ = "N" OR YN$ = "n" THEN GOTO 10 ELSE GOTO ELP1

ELP1:

    CLS
    COLOR 11, 1: LOCATE 1, 6: PRINT "Ext. Loadings of PCB (ELP)(Kg/d) for Diff. Yrs. for Seg.#"
    LOCATE 1, 64: PRINT SEGNO
    COLOR 14, 1: LOCATE 2, 5: PRINT CHR$(218); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196);
    STRING$(1, 194); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194);  STRING$(5,
    196);STRING$(1, 194); STRING$(10, 196); STRING$(1,194); STRING$(5, 196); STRING$(1,    1 9 4 ) ;
    STRING$(10, 196); STRING$(1, 191)
    FOR I = 4 TO 21 STEP 2: LOCATE I, 5: PRINT CHR$(195); STRING$(5, 196); STRING$(1, 197);
    STRING$(10,196); STRING$(1, 197); STRING$(5, 196); STRING$(1, 197); STRING$(10,
    196); STRING$(1, 197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 197);
    STRING$(5, 196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 180)
    NEXT I

    II = 0: GOSUB scrn

    COLOR 12, 1
    N = 1
    FOR j = 5 TO 22 STEP 2
    LOCATE j, 12: PRINT ELP(R, N)
    LOCATE j, 29: PRINT ELP(R, N + 9)
    LOCATE j, 46: PRINT ELP(R, N + 18)
    LOCATE j, 63: PRINT ELP(R, N + 27)
    N = N + 1
    NEXT j

    K = 13
    START = 1
    FINISH = 9

140 :

    j = 5
    FOR N = START TO FINISH
    LOCATE j, K: PRINT ELP$
    LOCATE j, K: INPUT "", ELP$
    IF ELP$ = "" THEN ELP(R, N) = ELP(R, N) ELSE ELP(R, N) = VAL(ELP$)
    j = j + 2
    ELP$ = ""
    NEXT N
    START = START + 9
    FINISH = FINISH + 9
    K = K + 17
    IF N > 36 GOTO CHECKELP1
    GOTO 140

CHECKELP1:

    COLOR 12, 1: LOCATE 24, 25: INPUT "Is  the Data correct (Y/N) :", YN$
    IF YN$ = "N" OR YN$ = "n" GOTO ELP1 ELSE GOTO ELP2

ELP2:

    CLS
    COLOR 11, 1: LOCATE 1, 6: PRINT "Ext. Loadings of PCB (ELP)(Kg/d) for Diff. Yrs. for Seg.#"
    LOCATE 1, 64: PRINT SEGNO
    COLOR 14, 1: LOCATE 2, 5: PRINT CHR$(218); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196);
    STRING$(1, 194); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194);  STRING$(5,
    196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194); STRING$(5,196); STRING$(1,    1 9 4 ) ;
    STRING$(10, 196); STRING$(1, 191)
    FOR I = 4 TO 21 STEP 2: LOCATE I, 5: PRINT CHR$(195); STRING$(5, 196); STRING$(1, 197);
    STRING$(10, 196); STRING$(1, 197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196);
    STRING$(1, 197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 197);
    STRING$(5,196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 180)
    NEXT I

    II = 36: GOSUB scrn
```

```
    COLOR 12, 1
    N = 37
    FOR j = 5 TO 22 STEP 2
    LOCATE j, 12: PRINT ELP(R, N)
    LOCATE j, 29: PRINT ELP(R, N + 9)
    LOCATE j, 46: PRINT ELP(R, N + 18)
    LOCATE j, 63: PRINT ELP(R, N + 27)
    N = N + 1
    NEXT j

    K = 13
    START = 37
    FINISH = 45

150 :

    j = 5
    FOR N = START TO FINISH
    LOCATE j, K: PRINT ELP$
    LOCATE j, K: INPUT "", ELP$
    IF ELP$ = "" THEN ELP(R, N) = ELP(R, N) ELSE ELP(R, N) = VAL(ELP$)
    j = j + 2
    ELP$ = ""
    NEXT N
    START = START + 9
    FINISH = FINISH + 9
    K = K + 17
    IF N > 72 GOTO CHECKELP2
    GOTO 150

CHECKELP2:

    COLOR 12, 1: LOCATE 24, 20: INPUT "Is  the Data correct (Y/N) :", YN$
    IF YN$ = "N" OR YN$ = "n" GOTO ELP2 ELSE GOTO ELO1

ELO1:

    CLS
    COLOR 11, 1: LOCATE 1, 6: PRINT "Ext. Loadings of POC (ELO)(Kg/d) for Diff. Yrs. for Seg.#"
    LOCATE 1, 64: PRINT SEGNO
    COLOR 14, 1: LOCATE 2, 5: PRINT CHR$(218); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196);
    STRING$(1, 194); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194);
    STRING$(5, 196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194); STRING$(5, 196);
    STRING$(1, 194); STRING$(10, 196); STRING$(1, 191)
    FOR I = 4 TO 21 STEP 2: LOCATE I, 5: PRINT CHR$(195); STRING$(5, 196); STRING$(1, 197);
    STRING$(10, 196); STRING$(1, 197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196);
    STRING$(1, 197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 197);
    STRING$(5, 196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 180)
    NEXT I

    II = 0: GOSUB scrn

    COLOR 12, 1
    N = 1
    FOR j = 5 TO 22 STEP 2
    LOCATE j, 12: PRINT ELO(R, N)
    LOCATE j, 29: PRINT ELO(R, N + 9)
    LOCATE j, 46: PRINT ELO(R, N + 18)
    LOCATE j, 63: PRINT ELO(R, N + 27)
    N = N + 1
    NEXT j

    K = 13
    START = 1
    FINISH = 9

160 :

    j = 5
    FOR N = START TO FINISH
    LOCATE j, K: PRINT ELO$
    LOCATE j, K: INPUT "", ELO$
```

```
    IF ELO$ = "" THEN ELO(R, N) = ELO(R, N) ELSE ELO(R, N) = VAL(ELO$)
    j = j + 2
    ELO$ = ""
    NEXT N
    START = START + 9
    FINISH = FINISH + 9
    K = K + 17
    IF N > 36 GOTO CHECKELO1
    GOTO 160

CHECKELO1:

    COLOR 12, 1: LOCATE 24, 20: INPUT "Is  the Data correct (Y/N) :", YN$
    IF YN$ = "N" OR YN$ = "n" GOTO ELO1 ELSE GOTO ELO2

ELO2:

    CLS
    COLOR 11, 1: LOCATE 1, 6: PRINT "Ext. Loadings of POC (ELO)(Kg/d) for Diff. Yrs. for Seg.#"
    LOCATE 1, 64: PRINT SEGNO
    COLOR 14, 1: LOCATE 2, 5: PRINT CHR$(218); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196);
    STRING$(1, 194); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194);  STRING$(5,
    196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194); STRING$(5, 196); STRING$(1,  1 9 4 ) ;
    STRING$(10, 196); STRING$(1, 191)
    FOR I = 4  TO  21  STEP  2:  LOCATE  I,  5:  PRINT  CHR$(195);  STRING$(5,  196);  STRING$(1, 197);
    STRING$(10, 196); STRING$(1, 197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196);
    STRING$(1, 197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 197); STRING$(5,
    196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 180)
    NEXT I

    II = 36: GOSUB scrn

    COLOR 12, 1
    N = 37
    FOR j = 5 TO 22 STEP 2
    LOCATE j, 12: PRINT ELO(R, N)
    LOCATE j, 29: PRINT ELO(R, N + 9)
    LOCATE j, 46: PRINT ELO(R, N + 18)
    LOCATE j, 63: PRINT ELO(R, N + 27)
    N = N + 1
    NEXT j

    K = 13
    START = 37
    FINISH = 45

170 :

    j = 5
    FOR N = START TO FINISH
    LOCATE j, K: PRINT ELO$
    LOCATE j, K: INPUT "", ELO$
    IF ELO$ = "" THEN ELO(R, N) = ELO(R, N) ELSE ELO(R, N) = VAL(ELO$)
    j = j + 2
    ELO$ = ""
    NEXT N
    START = START + 9
    FINISH = FINISH + 9
    K = K + 17
    IF N > 72 GOTO CHECKELO2
    GOTO 170

CHECKELO2:

    COLOR 12, 1: LOCATE 24, 20: INPUT "Is  the Data correct (Y/N) :", YN$
    IF YN$ = "N" OR YN$ = "n" GOTO ELO2 ELSE GOTO ILO1

ILO1:

    CLS
    COLOR 11, 1: LOCATE 1, 6: PRINT "Int. Loadings of POC (ILO)(Kg/d) for Diff. Yrs. for Seg.#"
    LOCATE 1, 64: PRINT SEGNO
```

```
    COLOR 14, 1: LOCATE 2, 5: PRINT CHR$(218); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196);
    STRING$(1, 194); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194);
    STRING$(5, 196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194); STRING$(5, 196); STRING$(1,
    194); STRING$(10, 196); STRING$(1, 191)
    FOR I = 4 TO 21 STEP 2: LOCATE I, 5: PRINT CHR$(195); STRING$(5, 196); STRING$(1, 197);
    STRING$(10, 196); STRING$(1, 197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196);
    STRING$(1, 197); STRING$(5,  196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 197); STRING$(5,
    196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 180)
    NEXT I

    II = 0: GOSUB scrn

    COLOR 12, 1
    N = 1
    FOR j = 5 TO 22 STEP 2
    LOCATE j, 12: PRINT ILO(R, N)
    LOCATE j, 29: PRINT ILO(R, N + 9)
    LOCATE j, 46: PRINT ILO(R, N + 18)
    LOCATE j, 63: PRINT ILO(R, N + 27)
    N = N + 1
    NEXT j

    K = 13
    START = 1
    FINISH = 9

180 :

    j = 5
    FOR N = START TO FINISH
    LOCATE j, K: PRINT ILO$
    LOCATE j, K: INPUT "", ILO$
    IF ILO$ = "" THEN ILO(R, N) = ILO(R, N) ELSE ILO(R, N) = VAL(ILO$)
    j = j + 2
    ILO$ = ""
    NEXT N
    START = START + 9
    FINISH = FINISH + 9
    K = K + 17
    IF N > 36 GOTO CHECKILO1
    GOTO 180

CHECKILO1:

    COLOR 12, 1: LOCATE 24, 20: INPUT "Is  the Data correct (Y/N) :", YN$
    IF YN$ = "N" OR YN$ = "n" GOTO ILO1 ELSE GOTO ILO2

ILO2:

    CLS
    COLOR 11, 1: LOCATE 1, 6: PRINT "Int. Loadings of POC (ILO)(Kg/d) for Diff. Yrs. for Seg.#"
    LOCATE 1, 64: PRINT SEGNO
    COLOR 14, 1: LOCATE 2, 5: PRINT CHR$(218); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196);
    STRING$(1, 194); STRING$(5, 196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194); STRING$(5,
    196); STRING$(1, 194); STRING$(10, 196); STRING$(1, 194); STRING$(5, 196); STRING$(1, 194);
    STRING$(10, 196); STRING$(1, 191)
    FOR I = 4 TO 21 STEP 2: LOCATE I, 5: PRINT CHR$(195); STRING$(5, 196); STRING$(1, 197);
    STRING$(10, 196); STRING$(1, 197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196);
    STRING$(1,197); STRING$(5, 196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 197); STRING$(5,
    196); STRING$(1, 197); STRING$(10, 196); STRING$(1, 180)
    NEXT I

    II = 36: GOSUB scrn

    COLOR 12, 1
    N = 37
    FOR j = 5 TO 22 STEP 2
    LOCATE j, 12: PRINT ILO(R, N)
    LOCATE j, 29: PRINT ILO(R, N + 9)
    LOCATE j, 46: PRINT ILO(R, N + 18)
    LOCATE j, 63: PRINT ILO(R, N + 27)
    N = N + 1
```

```
    NEXT j

    K = 13
    START = 37
    FINISH = 45

190 :

    j = 5
    FOR N = START TO FINISH
    LOCATE j, K: PRINT ILO$
    LOCATE j, K: INPUT "", ILO$
    IF ILO$ = "" THEN ILO(R, N) = ILO(R, N) ELSE ILO(R, N) = VAL(ILO$)
    j = j + 2
    ILO$ = ""
    NEXT N
    START = START + 9
    FINISH = FINISH + 9
    K = K + 17
    IF N > 72 GOTO CHECKILO2
    GOTO 190

CHECKILO2:

    COLOR 12, 1: LOCATE 24, 20: INPUT "Is  the Data correct (Y/N) :", YN$
    IF YN$ = "N" OR YN$ = "n" GOTO ILO2
    SEGNO = SEGNO + 1
    NEXT R

CONTINUE:

    OPEN FILEO$ FOR OUTPUT AS #1
    LOCATE 23, 64: COLOR 17, 5: PRINT "Saving Data..."
    WRITE #1, t1, t2, INC
    WRITE #1, INTA12, INTA23, INTA34, INTA4LM, CHL12, CHL23, CHL34, CHL4LM, BDSC12
    WRITE #1, BDSC23, BDSC34, BDSC4LM, QF1, Q21, Q12, Q32, Q23, Q43
    WRITE #1, QM3, QP3, QO3, Q34, QLM4, QE4, Q4LM, HEN
    FOR I = 1 TO 72
    WRITE #1, ACP(I), W1LM(I), W3LM(I)
    NEXT I
    FOR R = 1 TO 4
    WRITE #1, W1(R), W2(R), W3(R), W4(R), V1(R), V2(R), SA1(R), ASD(R), ASR(R)
    WRITE #1, SEDP(R), DBV(R), RSV(R), SRO1(R), SRP1(R), DECR1(R), DECR2(R)
    WRITE #1, DRP1(R), DRP2(R), PRTC(R), VEXR(R), Esi(R), Lsi(R)
    FOR j = 1 TO 72
    WRITE #1, ELP(R, j), ELO(R, j), ILO(R, j)
    NEXT j
    NEXT R
    CLOSE #1
    COLOR 14, 1
    GOTO MAIN

quit:

    COLOR 7, 0
    FOR I = 1 TO 12
    FOR j = 1 TO 80
    LOCATE I, j: PRINT " "
    LOCATE 24 - I, 81 - j: PRINT " "
    NEXT j
    NEXT I
    CLS
    OPEN "mstoxgb.bat" FOR OUTPUT AS #1
    PRINT #1, " "
    PRINT #1, " "
    CLOSE #1
    SYSTEM


constant:

    CLS
```

```
    COLOR 31, 4
    LOCATE 8, 4: PRINT " C "
    LOCATE 9, 4: PRINT " O "
    LOCATE 10, 4: PRINT " N "
    LOCATE 11, 4: PRINT " S "
    LOCATE 12, 4: PRINT " T "
    LOCATE 13, 4: PRINT " A "
    LOCATE 14, 4: PRINT " N "
    LOCATE 15, 4: PRINT " T "
    LOCATE 16, 4: PRINT " S "
    RETURN

scrn:

    FOR I = 3 TO 22 STEP 2: LOCATE I, 5: PRINT CHR$(179)
    LOCATE I, 11: PRINT CHR$(179)
    LOCATE I, 22: PRINT CHR$(179)
    LOCATE I, 28: PRINT CHR$(179)
    LOCATE I, 39: PRINT CHR$(179)
    LOCATE I, 45: PRINT CHR$(179)
    LOCATE I, 56: PRINT CHR$(179)
    LOCATE I, 62: PRINT CHR$(179)
    LOCATE I, 73: PRINT CHR$(179)
    NEXT I

    COLOR 14, 1: LOCATE 3, 6: PRINT "Year": COLOR 12, 1: LOCATE 3, 14: PRINT "Value"
    COLOR 14, 1: LOCATE 3, 23: PRINT "Year": COLOR 12, 1: LOCATE 3, 31: PRINT "Value"
    COLOR 14, 1: LOCATE 3, 40: PRINT "Year": COLOR 12, 1: LOCATE 3, 48: PRINT "Value"
    COLOR 14, 1: LOCATE 3, 57: PRINT "Year": COLOR 12, 1: LOCATE 3, 65: PRINT "Value"
    COLOR 14, 1: LOCATE 22, 5: PRINT CHR$(192); STRING$(5, 196); STRING$(1, 193); STRING$(10,
    196); STRING$(1, 193); STRING$(5, 196); STRING$(1, 193); STRING$(10, 196); STRING$(1, 193);
    STRING$(5, 196); STRING$(1, 193); STRING$(10, 196); STRING$ (1, 193); STRING$(5, 196); STRING$(1,
    193); STRING$(10, 196); STRING$(1, 217)

    FOR j = 5 TO 22 STEP 2
    LOCATE j, 6: PRINT II + 1
    LOCATE j, 23: PRINT II + 10
    LOCATE j, 40: PRINT II + 19
    LOCATE j, 57: PRINT II + 28
    II = II + 1
    NEXT j
    RETURN

segment:

    CLS
    COLOR 31, 4
    LOCATE 8, 4: PRINT " S "
    LOCATE 9, 4: PRINT " E "
    LOCATE 10, 4: PRINT " G "
    LOCATE 11, 4: PRINT " M "
    LOCATE 12, 4: PRINT " E "
    LOCATE 13, 4: PRINT " N "
    LOCATE 14, 4: PRINT " T "
    LOCATE 15, 4: PRINT " # "
    LOCATE 16, 4: PRINT SEGNO
    RETURN

film:

    I$ = ""
    title$ = ""
    title1$ = ""
    COLOR 15, 1
    FOR I = 1 TO 80
    LOCATE 19, I: PRINT " "
    LOCATE 20, I: PRINT " "
    NEXT I
    LOCATE 23, 65: COLOR 15, 4: PRINT "Time : "; TIME$
    COLOR 15, 1
    FOR I = 33 TO 1 STEP -1
    title$ = MID$(name$, I, 1) + title$
```

```
title1$ = MID$(name1$, I, 1) + title1$
I$ = INKEY$
LOCATE 19, 1: PRINT title$: IF LEN(I$) > 0 THEN GOTO vali
LOCATE 20, 1: PRINT title1$: IF LEN(I$) > 0 THEN GOTO vali
FOR j = 1 TO 20000: NEXT j
NEXT I

FOR I = 1 TO 47
I$ = INKEY$
title$ = " " + title$
title1$ = " " + title1$
FOR j = 1 TO 20000: NEXT j
LOCATE 19, 1: PRINT title$: IF LEN(I$) > 0 THEN GOTO vali
LOCATE 20, 1: PRINT title1$: IF LEN(I$) > 0 THEN GOTO vali
NEXT I

FOR I = 79 TO 45 STEP -1
I$ = INKEY$
ntitle$ = STRING$(80 - I, " ") + MID$(title$, 1, I)
ntitle1$ = STRING$(80 - I, " ") + MID$(title1$, 1, I)
FOR j = 1 TO 20000: NEXT j
LOCATE 19, 1: PRINT ntitle$: IF LEN(I$) > 0 THEN GOTO vali
LOCATE 20, 1: PRINT ntitle1$: IF LEN(I$) > 0 THEN GOTO vali
NEXT I
GOTO vali
```

APPENDIX B

Listing of the STOXGB Program:

```
D = 72
R = 4
DIM ACP(D), W1LM(D), W3LM(D), VV1(200), VV2(200), VV3(200), VV4(200), VV5(200)
DIM W1(R), W2(R), W3(R), W4(R), V1(R), V2(R), SA1(R), ASD(R), ASR(R), SEDP(R)
DIM DBV(R), RSV(R), SRO1(R), SRP1(R), DECR1(R), DECR2(R)
DIM DRP1(D), DRP2(D), PRTC(D), VEXR(D), Esi(R), Lsi(R)
DIM ELP(R, D), ELO(R, D), ILO(R, D)
DIM DFP1(R), DFP2(R), PFP1(R), PFP2(R)
DIM A(R, D), B(R), C(R), E(R), F(R), G(R, D), H(R, D), I(R), j(R), L(R), M(R)
DIM VAR1(200), VAR2(200), VAR3(200), VAR4(200), VAR5(200), VAR6(200)
F2$ = "####"
F$ = "###.##"
F1$ = "#.####^^^^"
Q = 1

    COLOR 0, 1
    CLS
    FOR I = 1 TO 35
    COLOR 0, 0: LOCATE 5, 25 + I: PRINT " ": NEXT I
    LOCATE 4, 59: PRINT "  "
    COLOR 15, 4
    LOCATE 3, 24: PRINT "    Simplified Toxic Model For      "
    LOCATE 4, 24: PRINT " Green Bay, Lake Michigan (STOXGB) "
    LOCATE 23, 2: COLOR 15, 4: PRINT "Date: "; DATE$
    LOCATE 23, 65: PRINT "Time : "; TIME$

Compute:

    COLOR 0, 1
    FOR I = 6 TO 12
    FOR j = 1 TO 80
    LOCATE I, j: PRINT " "
    LOCATE 25 - I, 81 - j: PRINT " "
    NEXT j
    NEXT I

    FOR I = 1 TO 50
    COLOR 0, 0: LOCATE 14, 17 + I: PRINT " "
    NEXT I

    FOR I = 1 TO 2
    COLOR 0, 0: LOCATE -I + 14, 66: PRINT "  "
    NEXT I

    COLOR 15, 4
    LOCATE 8, 30: PRINT " COMPUTATION  OPTION "
    LOCATE 11, 16: PRINT " Enter Input File Name    :                          "
    LOCATE 12, 16: PRINT "                                                      "
    LOCATE 13, 16: PRINT " Enter Output File Name   :                          "
    LOCATE 11, 43: INPUT "", FILEI$
    LOCATE 13, 43: INPUT "", FILEO$

    CLS
    OPEN FILEI$ FOR INPUT AS #1
    INPUT #1, t1, t2, INC
    INPUT #1, INTA12, INTA23, INTA34, INTA4LM, CHL12, CHL23, CHL34, CHL4LM, BDSC12
    INPUT #1, BDSC23, BDSC34, BDSC4LM, QF1, Q21, Q12, Q32, Q23, Q43
    INPUT #1, QM3, QP3, QO3, Q34, QLM4, QE4, Q4LM, HEN
    FOR I = 1 TO 72
```

```
INPUT #1, ACP(I), W1LM(I), W3LM(I)
NEXT I
FOR R = 1 TO 4
INPUT #1, W1(R), W2(R), W3(R), W4(R), V1(R), V2(R), SA1(R), ASD(R), ASR(R)
INPUT #1, SEDP(R), DBV(R), RSV(R), SRO1(R), SRP1(R), DECR1(R), DECR2(R)
INPUT #1, DRP1(R), DRP2(R), PRTC(R), VEXR(R), Esi(R), Lsi(R)
FOR j = 1 TO 72
INPUT #1, ELP(R, j), ELO(R, j), ILO(R, j)
NEXT j
NEXT R
CLOSE #1
OPEN FILEO$ FOR OUTPUT AS #1
CLOSE #1
OPEN FILEO$ FOR APPEND AS #1

X1 = (BDSC12 * INTA12 / CHL12)
X2 = (BDSC23 * INTA23 / CHL23)
X3 = (BDSC34 * INTA34 / CHL34)
X4 = (BDSC4LM * INTA4LM / CHL4LM)

FOR S = 1 TO 4
FOR Y = 1 TO 72

DFP1(S) = 1 / (1 + ((PRTC(S) / 1000000) * W1(S)))
DFP2(S) = 1 / (1 + ((PRTC(S) / 1000000) * W2(S)))
PFP1(S) = ((PRTC(S) / 1000000) * W1(S)) / (1 + ((PRTC(S) / 1000000) * W1(S)))
PFP2(S) = ((PRTC(S) / 1000000) * W2(S)) / (1 + ((PRTC(S) / 1000000) * W2(S)))

A(S, Y) = (ELO(S, Y) + ILO(S, Y))
B(S) = (SRO1(S) * SA1(S) + DECR1(S) * V1(S))
C(S) = (RSV(S) * ASR(S))
E(S) = (SRO1(S) * SA1(S))
F(S) = (ASR(S) * (RSV(S) + DBV(S))) + (DECR2(S) * V2(S))

G(S, Y) = ELP(S, Y)
H(S, Y) = ((VEXR(S) * SA1(S) * ACP(Y)) / HEN)
I(S) = (((Esi(S) / Lsi(S)) * ASR(S) * DFP1(S)) + (DRP1(S) * DFP1(S) * V1(S)) + (VEXR(S) *
SA1(S) * DFP1(S)) + (SRP1(S) * SA1(S) * PFP1(S)))
j(S) = (((Esi(S) / Lsi(S)) * ASR(S) * DFP2(S) / SEDP(S)) + (RSV(S) * ASR(S) * PFP2(S)))

L(S) = (((Esi(S) / Lsi(S)) * ASR(S) * DFP1(S)) + (SRP1(S) * SA1(S) * PFP1(S)))
M(S) = (((Esi(S) / Lsi(S)) * ASR(S) * DFP2(S) / SEDP(S)) + (DRP2(S) * DFP2(S) * V2(S)) +
(RSV(S) * ASR(S) * PFP2(S)) + (DBV(S) * ASR(S) * PFP2(S)))
NEXT Y
NEXT S

N = (t2 - t1) / INC

COLOR 14, 1
CLS
PRINT #1,
PRINT #1, TAB(32); "Data set #1"
PRINT #1,
PRINT #1, TAB(15); "==========================================="
PRINT #1, TAB(15); "Disc.of Variable (unit) (Variable)    Input"
PRINT #1, TAB(15); "==========================================="
PRINT #1, TAB(15); "Initial time(yrs) (t1)"; TAB(52); t1
PRINT #1, TAB(15); "Final time(yrs) (t2)"; TAB(52); t2
PRINT #1, TAB(15); "Time Step (yrs) (INC)"; TAB(52); INC
PRINT #1,
PRINT #1,
PRINT #1, TAB(27); "Data set #2"
PRINT #1,
PRINT #1, TAB(10); "======================================================="
PRINT #1, TAB(10); "Disc. of Variable (unit) (Variable)           Input"
PRINT #1, TAB(10); "======================================================="
PRINT #1, TAB(10); "Int. Areas, Seg.1,2 (m2) (INTA12)"; TAB(55); USING F1$; INTA12
PRINT #1, TAB(10); "Int. Areas, Seg.2,3 (m2) (INTA23)"; TAB(55); USING F1$; INTA23
PRINT #1, TAB(10); "Int. Areas, Seg.3,4 (m2) (INTA34)"; TAB(55); USING F1$; INTA34
PRINT #1, TAB(10); "Int. Areas, Seg.4,LM (m2) (INTA4LM)"; TAB(55); USING F1$; INTA4LM
PRINT #1, TAB(10); "Charac. Length, Seg.1,2 (m) (CHL12)"; TAB(55); USING F1$; CHL12
PRINT #1, TAB(10); "Charac. Length, Seg.2,3 (m) (CHL23)"; TAB(55); USING F1$; CHL23
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PRINT #1, TAB(10); "Charac. Length, Seg.3,4 (m) (CHL34)"; TAB(55); USING F1$; CHL34
PRINT #1, TAB(10); "Charac. Length, Seg.4LM (m) (CHL4LM)"; TAB(55); USING F1$; CHL4LM
PRINT #1, TAB(10); "Bulk Disp. Coeff.,Seg.1,2 (m2/d) (BDSC12)"; TAB(55); USING F1$; BDSC12
PRINT #1, TAB(10); "Bulk Disp. Coeff.,Seg.2,3 (m2/d) (BDSC23)"; TAB(55); USING F1$; BDSC23
PRINT #1, TAB(10); "Bulk Disp. Coeff.,Seg.3,4 (m2/d) (BDSC34)"; TAB(55); USING F1$; BDSC34
PRINT #1, TAB(10); "Bulk Disp. Coeff.,Seg.4LM (m2/d) (BDSC4LM)"; TAB(55); USING F1$; BDSC4LM
PRINT #1, TAB(10); "Flow from Fox to Seg.#1 (m3/d) (QF1)"; TAB(55); USING F1$; QF1
PRINT #1, TAB(10); "Flow from Seg #2 to Seg.#1 (m3/d) (Q21)"; TAB(55); USING F1$; Q21
PRINT #1, TAB(10); "Flow from Seg #1 to Seg.#2 (m3/d) (Q12)"; TAB(55); USING F1$; Q12
PRINT #1, TAB(10); "Flow from Seg #3 to Seg.#2 (m3/d) (Q32) "; TAB(55); USING F1$; Q32
PRINT #1, TAB(10); "Flow from Seg #2 to Seg.#3 (m3/d) (Q23)"; TAB(55); USING F1$; Q23
PRINT #1, TAB(10); "Flow from Seg #4 to Seg.#3 (m3/d) (Q43)"; TAB(55); USING F1$; Q43
PRINT #1, TAB(10); "Flow from Menominee to Seg.#3 (m3/d) (QM3)"; TAB(55); USING F1$; QM3
PRINT #1, TAB(10); "Flow from Peshtigo to Seg.#3 (m3/d) (QP3)"; TAB(55); USING F1$; QP3
PRINT #1, TAB(10); "Flow from Oconto to Seg.#3 (m3/d) (QO3)"; TAB(55); USING F1$; QO3
PRINT #1, TAB(10); "Flow from Seg #3 to Seg.#4 (m3/d) (Q34)"; TAB(55); USING F1$; Q34
PRINT #1, TAB(10); "Flow from LM to Seg.#4 (m3/d) (QLM4)"; TAB(55); USING F1$; QLM4
PRINT #1, TAB(10); "Flow from Escanaba to Seg.#4 (m3/d) (QE4)"; TAB(55); USING F1$; QE4
PRINT #1, TAB(10); "Flow from Seg.#4 to LM(m3/d) (Q4LM)"; TAB(55); USING F1$; Q4LM
PRINT #1, TAB(10); "Henry's Constant (atm-m3/mol) (HEN)"; TAB(55); USING F1$; HEN
PRINT #1,
PRINT #1,
PRINT #1, TAB(18); "====================================="
PRINT #1, TAB(18); "Year    ACP         W1LM        W3LM"
PRINT #1, TAB(18); "      (ng/m3)     (mg/m3)     (ng/m3)"
PRINT #1, TAB(18); "====================================="
FOR I = 1 TO 72
PRINT #1, TAB(18); I; TAB(24); USING F1$; ACP(I); TAB(35); W1LM(I); TAB(46); W3LM(I)
NEXT I
PRINT #1,
PRINT #1,
PRINT #1, TAB(30); "Data set #3"
PRINT #1,
PRINT#1,TAB(1);"=============================================================================="
PRINT #1, TAB(1); "Disc. of Variable (unit) (Variable)                  Input"
PRINT #1, TAB(1); "                                     Seg. #1    Seg. #2    Seg. #3    Seg.   #4"
PRINT#1,TAB(1);"=============================================================================="
PRINT #1, TAB(1); "Initial POC Conc.in WC (mg/m3) (W1)"; TAB(38); USING F1$; W1(1); TAB(49);
W1(2); TAB(60); W1(3); TAB(71); W1(4)
PRINT #1, TAB(1); "Initial POC Conc.in BS (mg/m3) (W2)"; TAB(38); USING F1$; W2(1); TAB(49);
W2(2); TAB(60); W2(3); TAB(71); W2(4)
PRINT #1, TAB(1); "Initial PCB Conc.in WC (ng/m3) (W3)"; TAB(38); USING F1$; W3(1); TAB(49);
W3(2); TAB(60); W3(3); TAB(71); W3(4)
PRINT #1, TAB(1); "Initial PCB Conc.in BS (ng/m3) (W4)"; TAB(38); USING F1$; W4(1); TAB(49);
W4(2); TAB(60); W4(3); TAB(71); W4(4)
PRINT #1, TAB(1); "Volume of WC(m3) (V1)"; TAB(38); USING F1$; V1(1); TAB(49); V1(2); TAB(60);
V1(3); TAB(71); V1(4)
PRINT #1, TAB(1); "Volume of BS(m3) (V2)"; TAB(38); USING F1$; V2(1); TAB(49); V2(2); TAB(60);
V2(3); TAB(71); V2(4)
PRINT #1, TAB(1); "Surface Area of WC (m2) (SA1)"; TAB(38); USING F1$; SA1(1); TAB(49);
SA1(2); TAB(60); SA1(3); TAB(71); SA1(4)
PRINT #1, TAB(1); "Area of Sediment, Dep., (m2) (ASD)"; TAB(38); USING F1$; ASD(1); TAB(49);
ASD(2); TAB(60); ASD(3); TAB(71); ASD(4)
PRINT #1, TAB(1); "Area of Sediment, Resus.(m2) (ASR)"; TAB(38); USING F1$; ASR(1); TAB(49);
ASR(2); TAB(60); ASR(3); TAB(71); ASR(4)
PRINT #1, TAB(1); "Sed. Porosity (SEDP)"; TAB(38); USING F1$; SEDP(1); TAB(49); SEDP(2);
TAB(60);SEDP(3); TAB(71); SEDP(4)
PRINT #1, TAB(1); "Deep Burial Velocity (m/d) (DBV)"; TAB(38); USING F1$; DBV(1); TAB(49);
DBV(2); TAB(60); DBV(3); TAB(71); DBV(4)
PRINT #1, TAB(1); "Resuspension Velocity (m/d) (RSV)"; TAB(38); USING F1$; RSV(1); TAB(49);
RSV(2); TAB(60); RSV(3); TAB(71); RSV(4)
PRINT #1, TAB(1); "Settling Rate of POC (m/d) (SRO1)"; TAB(38); USING F1$; SRO1(1); TAB(49);
SRO1(2); TAB(60); SRO1(3); TAB(71); SRO1(4)
PRINT #1, TAB(1); "Settling Rate of PCB (m/d) (SRP1)"; TAB(38); USING F1$; SRP1(1); TAB(49);
SRP1(2); TAB(60); SRP1(3); TAB(71); SRP1(4)
PRINT #1, TAB(1); "Decay Rate POC  WC (1/d) (DECR1)"; TAB(38); USING F1$; DECR1(1); TAB(49);
DECR1(2); TAB(60); DECR1(3); TAB(71); DECR1(4)
PRINT #1, TAB(1); "Decay Rate POC  BS (1/d) (DECR2)"; TAB(38); USING F1$; DECR2(1); TAB(49);
DECR2(2); TAB(60); DECR2(3); TAB(71); DECR2(4)
PRINT #1, TAB(1); "Decom. Rate PCB in WC (1/d) (DRP1)"; TAB(38); USING F1$; DRP1(1); TAB(49);
DRP1(2); TAB(60); DRP1(3); TAB(71); DRP1(4)
PRINT #1, TAB(1); "Decom. Rate PCB in BS (1/d) (DRP2)"; TAB(38); USING F1$; DRP2(1); TAB(49);
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DRP2(2); TAB(60); DRP2(3); TAB(71); DRP2(4)
PRINT #1, TAB(1); "Partition Coef.(m3/Kg C) (PRTC)"; TAB(38); USING F1$; PRTC(1); TAB(49);
PRTC(2); TAB(60); PRTC(3); TAB(71); PRTC(4)
PRINT #1, TAB(1); "Volat. Exch. Rate (m/d) (VEXR)"; TAB(38); USING F1$; VEXR(1); TAB(49);
VEXR(2); TAB(60); VEXR(3); TAB(71); VEXR(4)
PRINT #1, TAB(1); "Disp. Coef. Sed.Seg. (m2/d) (Esi)"; TAB(38); USING F1$; Esi(1); TAB(49);
Esi(2); TAB(60); Esi(3); TAB(71); Esi(4)
PRINT #1, TAB(1); "Charc. Length Sed.Seg. (m) (Lsi)"; TAB(38); USING F1$; Lsi(1); TAB(49);
Lsi(2); TAB(60); Lsi(3); TAB(71); Lsi(4)
PRINT #1,
PRINT #1,
PRINT #1, TAB(15); "=================================================="
PRINT #1, TAB(15); "Seg. #  Year        ELP         ELO         ILO"
PRINT #1, TAB(15); "                  (Kg/d)      (Kg/d)      (Kg/d)"
PRINT #1, TAB(15); "=================================================="
FOR S = 1 TO 4
FOR I = 1 TO 72
PRINT #1, TAB(17); S;
PRINT #1, TAB(25); I;
PRINT #1, TAB(33); USING F1$; ELP(S, I); TAB(44); ELO(S, I); TAB(55); ILO(S, I)
NEXT I
NEXT S
PRINT #1,
PRINT #1,
PRINT #1, TAB(40); "Results"
PRINT #1,
PRINT #1, TAB(10); "==================================================================="
PRINT #1, TAB(10); "                      POC-WC       POC-BS       PCB-WC       PCB-BS"
PRINT #1, TAB(10); "Time   Segment          W1           W2           W3           W4"
PRINT #1, TAB(10); "yrs      No.          (mg/l)       (mg/l)       (ng/l)       (ng/l)"
PRINT #1, TAB(10); "==================================================================="
PRINT #1,
t = t1
FOR S = 1 TO 4
PRINT #1, USING F2$; TAB(10); t; TAB(16); S; TAB(28);
PRINT #1, USING F1$; W1(S) / 1000; TAB(41); W2(S) / 1000; TAB(54); W3(S) / 1000; TAB(67);
W4(S) / 1000
NEXT S

COLOR 15, 4
COLOR 0, 0
FOR I = 3 TO 66
LOCATE 21, 6 + I: PRINT " "
NEXT I
COLOR 0, 0
FOR I = 12 TO 21
LOCATE I, 73: PRINT "  "
NEXT I
FOR I = 1 TO 35
COLOR 0, 0: LOCATE 5, 23 + I: PRINT " ": NEXT I
LOCATE 4, 57: PRINT "  "
COLOR 15, 4
LOCATE 3, 22: PRINT "    Simplified Toxic Model For     "
LOCATE 4, 22: PRINT " Green Bay, Lake Michigan (STOXGB) "
LOCATE 8, 33: PRINT "  RESULTS  "
LOCATE 11, 6: PRINT "                                                                   "
LOCATE 12, 6: PRINT "                        POC-WC       POC-BS       PCB-WC       PCB-BS  "
LOCATE 13, 6: PRINT " Time   Segment           W1           W2           W3           W4    "
LOCATE 14, 6: PRINT " yrs      No.           (mg/l)       (mg/l)       (ng/l)       (ng/l)  "
LOCATE 15, 6: PRINT "                                                                   "
t = t1
FOR S = 1 TO 4
LOCATE 15 + S, 6: PRINT USING F2$; TAB(7); t; TAB(15); S; TAB(25);
PRINT USING F1$; W1(S) / 1000; TAB(37); W2(S) / 1000; TAB(49); W3(S) / 1000; TAB(61); W4(S) /
1000;
PRINT "  "
LOCATE 20, 6: PRINT "                                                                   "
NEXT S

t = 0

FOR I = 1 TO N
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FOR S = 1 TO 4

AA(S) = A(S, INT(t + 1))
GG(S) = G(S, INT(t + 1))
HH(S) = H(S, INT(t + 1))
W1LMM = W1LM(INT(t + 1))
W3LMM = W3LM(INT(t + 1))

SELECT CASE S

CASE IS = 1

K11 = (INC * 365 / V1(S)) * ((AA(S) * 1000000) + (Q21 * W1(2)) - ((Q12 + B(S)) * W1(S)) +
(C(S) * W2(S)) - (X1 * (W1(1) - W1(2))))
K21 = (INC * 365 / V1(S)) * ((AA(S) * 1000000) + (Q21 * W1(2)) - ((Q12 + B(S)) * (W1(S) + K11 / 2))
+ (C(S) * W2(S)) - (X1 * ((W1(1) + K11 / 2) - W1(2))))
K31 = (INC * 365 / V1(S)) * ((AA(S) * 1000000) + (Q21 * W1(2)) - ((Q12 + B(S)) * (W1(S) + K21 / 2))
+ (C(S) * W2(S)) - (X1 * ((W1(1) + K21 / 2) - W1(2))))
K41 = (INC * 365 / V1(S)) * ((AA(S) * 1000000) + (Q21 * W1(2)) - ((Q12 + B(S)) * (W1(S) +
K31)) + (C(S)        * W2(S)) - (X1 * ((W1(1) + K31) - W1(2))))
W1(S) = W1(S) + ((K11 + 2 * K21 + 2 * K31 + K41) / 6)

K12 = (INC * 365 / V2(S)) * ((E(S) * W1(S)) - (F(S) * W2(S)))
K22 = (INC * 365 / V2(S)) * ((E(S) * W1(S)) - (F(S) * (W2(S) + K12 / 2)))
K32 = (INC * 365 / V2(S)) * ((E(S) * W1(S)) - (F(S) * (W2(S) + K22 / 2)))
K42 = (INC * 365 / V2(S)) * ((E(S) * W1(S)) - (F(S) * (W2(S) + K32)))
W2(S) = W2(S) + ((K12 + 2 * K22 + 2 * K32 + K42) / 6)

K13 = (INC * 365 / V1(S)) * ((GG(S) * 1E+12) + HH(S) + (Q21 * W3(2)) - ((Q12 + I(S)) * W3(S)) +
(j(S) * W4(S)) - (X1 * (W3(1) - W3(2))))
K23 = (INC * 365 / V1(S)) * ((GG(S) * 1E+12) + HH(S) + (Q21 * W3(2)) - ((Q12 + I(S)) * (W3(S) + K13
/ 2)) + (j(S) * W4(S)) - (X1 * ((W3(1) + K13 / 2) - W3(2))))
K33 = (INC * 365 / V1(S)) * ((GG(S) * 1E+12) + HH(S) + (Q21 * W3(2)) - ((Q12 + I(S)) * (W3(S) + K23
/ 2)) + (j(S) * W4(S)) - (X1 * ((W3(1) + K23 / 2) - W3(2))))
K43 = (INC * 365 / V1(S)) * ((GG(S) * 1E+12) + HH(S) + (Q21 * W3(2)) - ((Q12 + I(S)) * (W3(S) +
K33)) + (j(S) * W4(S)) - (X1 * ((W3(1) + K33) - W3(2))))
W3(S) = W3(S) + ((K13 + 2 * K23 + 2 * K33 + K43) / 6)

K14 = (INC * 365 / V2(S)) * ((L(S) * W3(S)) - (M(S) * W4(S)))
K24 = (INC * 365 / V2(S)) * ((L(S) * W3(S)) - (M(S) * (W4(S) + K14 / 2)))
K34 = (INC * 365 / V2(S)) * ((L(S) * W3(S)) - (M(S) * (W4(S) + K24 / 2)))
K44 = (INC * 365 / V2(S)) * ((L(S) * W3(S)) - (M(S) * (W4(S) + K34)))
W4(S) = W4(S) + ((K14 + 2 * K24 + 2 * K34 + K44) / 6)

CASE IS = 2

K11 = (INC * 365 / V1(S)) * ((AA(S) * 1000000) + (Q12 * W1(1)) + (Q32 * W1(3)) - ((Q23 + B(S))  *
W1(S)) + (C(S) * W2(S)) - ((X1 * (W1(1) - W1(2))) + (X2 * (W1(2) - W1(3)))))
K21 = (INC * 365 / V1(S)) * ((AA(S) * 1000000) + (Q12 * W1(1)) + (Q32 * W1(3)) - ((Q23 + B(S))  *
(W1(S) + K11 / 2)) + (C(S) * W2(S)) - ((X1 * (W1(1) - (W1(2) + K11 / 2))) + (X2 * ((W1(2) +
K11 / 2) - W1(3)))))
K31 = (INC * 365 / V1(S)) * ((AA(S) * 1000000) + (Q12 * W1(1)) + (Q32 * W1(3)) - ((Q23 + B(S))  *
(W1(S) + K21 / 2)) + (C(S) * W2(S)) - ((X1 * (W1(1) - (W1(2) + K21 / 2))) + (X2 * ((W1(2) +
K21 / 2) - W1(3)))))
K41 = (INC * 365 / V1(S)) * ((AA(S) * 1000000) + (Q12 * W1(1)) + (Q32 * W1(3)) - ((Q23 + B(S))  *
(W1(S) + K31)) + (C(S) * W2(S)) - ((X1 * (W1(1) - (W1(2) + K33))) + (X2 * ((W1(2) + K33) -
W1(3)))))
W1(S) = W1(S) + ((K11 + 2 * K21 + 2 * K31 + K41) / 6)

K12 = (INC * 365 / V2(S)) * ((E(S) * W1(S)) - (F(S) * W2(S)))
K22 = (INC * 365 / V2(S)) * ((E(S) * W1(S)) - (F(S) * (W2(S) + K12 / 2)))
K32 = (INC * 365 / V2(S)) * ((E(S) * W1(S)) - (F(S) * (W2(S) + K22 / 2)))
K42 = (INC * 365 / V2(S)) * ((E(S) * W1(S)) - (F(S) * (W2(S) + K32)))
W2(S) = W2(S) + ((K12 + 2 * K22 + 2 * K32 + K42) / 6)

K13 = (INC * 365 / V1(S)) * ((GG(S) * 1E+12) + HH(S) + (Q12 * W3(1)) + (Q32 * W3(3)) - ((Q23 +
I(S)) * W3(S)) + (j(S) * W4(S)) - ((X1 * (W3(1) - W3(2))) + (X2 * (W3(2) - W3(3)))))
K23 = (INC * 365 / V1(S)) * ((GG(S) * 1E+12) + HH(S) + (Q12 * W3(1)) + (Q32 * W3(3)) - ((Q23    +
I(S)) * (W3(S) + K13 / 2)) + (j(S) * W4(S)) - ((X1 * (W3(1) - (W3(2) + K13 / 2))) + (X2 *
((W3(2) + K13 / 2) - W3(3)))))
K33 = (INC * 365 / V1(S)) * ((GG(S) * 1E+12) + HH(S) + (Q12 * W3(1)) + (Q32 * W3(3)) - ((Q23 +
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I(S)) * (W3(S) + K23 / 2)) + (j(S) * W4(S)) - ((X1 * (W3(1) - (W3(2) + K23 / 2))) + (X2 *
((W3(2) + K23 / 2) - W3(3)))))
K43 = (INC * 365 / V1(S)) * ((GG(S) * 1E+12) + HH(S) + (Q12 * W3(1)) + (Q32 * W3(3)) - ((Q23 +
I(S)) * (W3(S) + K33)) + (j(S) * W4(S)) - ((X1 * (W3(1) - (W3(2) + K33))) + (X2 * ((W3(2) +
K33) - W3(3)))))
W3(S) = W3(S) + ((K13 + 2 * K23 + 2 * K33 + K43) / 6)

K14 = (INC * 365 / V2(S)) * ((L(S) * W3(S)) - (M(S) * W4(S)))
K24 = (INC * 365 / V2(S)) * ((L(S) * W3(S)) - (M(S) * (W4(S) + K14 / 2)))
K34 = (INC * 365 / V2(S)) * ((L(S) * W3(S)) - (M(S) * (W4(S) + K24 / 2)))
K44 = (INC * 365 / V2(S)) * ((L(S) * W3(S)) - (M(S) * (W4(S) + K34)))
W4(S) = W4(S) + ((K14 + 2 * K24 + 2 * K34 + K44) / 6)

CASE IS = 3

K11 = (INC * 365 / V1(S)) * ((AA(S) * 1000000) + (Q23 * W1(2)) + (Q43 * W1(4)) - ((Q34 + B(S))  *
W1(S)) + (C(S) * W2(S)) - ((X2 * (W1(2) - W1(3))) + (X3 * (W1(3) - W1(4)))))
K21 = (INC * 365 / V1(S)) * ((AA(S) * 1000000) + (Q23 * W1(2)) + (Q43 * W1(4)) - ((Q34 + B(S))  *
(W1(S) + K11 / 2)) + (C(S) * W2(S)) - ((X2 * (W1(2) - (W1(3) + K11 / 2))) + (X3 * ((W1(3) +
K11 / 2) - W1(4)))))
K31 = (INC * 365 / V1(S)) * ((AA(S) * 1000000) + (Q23 * W1(2)) + (Q43 * W1(4)) - ((Q34 + B(S))  *
(W1(S) + K21 / 2)) + (C(S) * W2(S)) - ((X2 * (W1(2) - (W1(3) + K21 / 2))) + (X3 * ((W1(3) +
K21 / 2) - W1(4)))))
K41 = (INC * 365 / V1(S)) * ((AA(S) * 1000000) + (Q23 * W1(2)) + (Q43 * W1(4)) - ((Q34 + B(S))  *
(W1(S) + K31)) + (C(S) * W2(S)) - ((X2 * (W1(2) - (W1(3) + K31))) + (X3 * ((W1(3) + K31) -
W1(4)))))
W1(S) = W1(S) + ((K11 + 2 * K21 + 2 * K31 + K41) / 6)

K12 = (INC * 365 / V2(S)) * ((E(S) * W1(S)) - (F(S) * W2(S)))
K22 = (INC * 365 / V2(S)) * ((E(S) * W1(S)) - (F(S) * (W2(S) + K12 / 2)))
K32 = (INC * 365 / V2(S)) * ((E(S) * W1(S)) - (F(S) * (W2(S) + K22 / 2)))
K42 = (INC * 365 / V2(S)) * ((E(S) * W1(S)) - (F(S) * (W2(S) + K32)))
W2(S) = W2(S) + ((K12 + 2 * K22 + 2 * K32 + K42) / 6)

K13 = (INC * 365 / V1(S)) * ((GG(S) * 1E+12) + HH(S) + (Q23 * W3(2)) + (Q43 * W3(4)) - ((Q34 +
I(S)) * W3(S)) + (j(S) * W4(S)) - ((X2 * (W3(2) - W3(3))) + (X3 * (W3(3) - W3(4)))))
K23 = (INC * 365 / V1(S)) * ((GG(S) * 1E+12) + HH(S) + (Q23 * W3(2)) + (Q43 * W3(4)) - ((Q34 +
I(S)) * (W3(S) + K13 / 2)) + (j(S) * W4(S)) - ((X2 * (W3(2) - (W3(3) + K13 / 2))) + (X3 *
((W3(3) + K13 / 2) - W3(4)))))
K33 = (INC * 365 / V1(S)) * ((GG(S) * 1E+12) + HH(S) + (Q23 * W3(2)) + (Q43 * W3(4)) - ((Q34 +
I(S)) * (W3(S) + K23 / 2)) + (j(S) * W4(S)) - ((X2 * (W3(2) - (W3(3) + K23 / 2))) + (X3 *
((W3(3) + K23 / 2) - W3(4)))))
K43 = (INC * 365 / V1(S)) * ((GG(S) * 1E+12) + HH(S) + (Q23 * W3(2)) + (Q43 * W3(4)) - ((Q34 +
I(S)) * (W3(S) + K33)) + (j(S) * W4(S)) - ((X2 * (W3(2) - (W3(3) + K33))) + (X3 * ((W3(3) +
K33) - W3(4)))))
W3(S) = W3(S) + ((K13 + 2 * K23 + 2 * K33 + K43) / 6)

K14 = (INC * 365 / V2(S)) * ((L(S) * W3(S)) - (M(S) * W4(S)))
K24 = (INC * 365 / V2(S)) * ((L(S) * W3(S)) - (M(S) * (W4(S) + K14 / 2)))
K34 = (INC * 365 / V2(S)) * ((L(S) * W3(S)) - (M(S) * (W4(S) + K24 / 2)))
K44 = (INC * 365 / V2(S)) * ((L(S) * W3(S)) - (M(S) * (W4(S) + K34)))
W4(S) = W4(S) + ((K14 + 2 * K24 + 2 * K34 + K44) / 6)

CASE IS = 4

K11 = (INC * 365 / V1(S)) * ((AA(S) * 1000000) + (Q34 * W1(3)) + (QLM4 * W1LMM) - ((Q4LM +
B(S)) * W1(S)) + (C(S) * W2(S)) - ((X3 * (W1(3) - W1(4))) + (X4 * (W1(4) - W1LMM))))
K21 = (INC * 365 / V1(S)) * ((AA(S) * 1000000) + (Q34 * W1(3)) + (QLM4 * W1LMM) - ((Q4LM +
B(S)) * (W1(S) + K11 / 2)) + (C(S) * W2(S)) - ((X3 * (W1(3) - (W1(4) + K11 / 2))) + (X4 *
((W1(4) + K11 / 2) - W1LMM))))
K31 = (INC * 365 / V1(S)) * ((AA(S) * 1000000) + (Q34 * W1(3)) + (QLM4 * W1LMM) - ((Q4LM +
B(S)) * (W1(S) + K21 / 2)) + (C(S) * W2(S)) - ((X3 * (W1(3) - (W1(4) + K21 / 2))) + (X4 *
((W1(4) + K21 / 2) - W1LMM))))
K41 = (INC * 365 / V1(S)) * ((AA(S) * 1000000) + (Q34 * W1(3)) + (QLM4 * W1LMM) - ((Q4LM +
B(S)) * (W1(S) + K31)) + (C(S) * W2(S)) - ((X3 * (W1(3) - (W1(4) + K31))) + (X4 * ((W1(4) +
K31) - W1LMM))))
W1(S) = W1(S) + ((K11 + 2 * K21 + 2 * K31 + K41) / 6)

K12 = (INC * 365 / V2(S)) * ((E(S) * W1(S)) - (F(S) * W2(S)))
K22 = (INC * 365 / V2(S)) * ((E(S) * W1(S)) - (F(S) * (W2(S) + K12 / 2)))
K32 = (INC * 365 / V2(S)) * ((E(S) * W1(S)) - (F(S) * (W2(S) + K22 / 2)))
K42 = (INC * 365 / V2(S)) * ((E(S) * W1(S)) - (F(S) * (W2(S) + K32)))
```

```
    W2(S) = W2(S) + ((K12 + 2 * K22 + 2 * K32 + K42) / 6)

    K13 = (INC * 365 / V1(S)) * ((GG(S) * 1E+12) + HH(S) + (Q34 * W3(3)) + (QLM4 * W3LMM) - ((Q4LM  +
    I(S)) * W3(S)) + (j(S) * W4(S)) - ((X3 * (W3(3) - W3(4))) + (X4 * (W3(4) - W3LMM))))
    K23 = (INC * 365 / V1(S)) * ((GG(S) * 1E+12) + HH(S) + (Q34 * W3(3)) + (QLM4 * W3LMM) - ((Q4LM  +
    I(S)) * (W3(S) + K13 / 2)) + (j(S) * W4(S)) - ((X3 * (W3(3) - (W3(4) + K13 / 2))) + (X4 *
    ((W3(4) + K13 / 2) - W3LMM))))
    K33 = (INC * 365 / V1(S)) * ((GG(S) * 1E+12) + HH(S) + (Q34 * W3(3)) + (QLM4 * W3LMM) - ((Q4LM  +
    I(S)) * (W3(S) + K23 / 2)) + (j(S) * W4(S)) - ((X3 * (W3(3) - (W3(4) + K23 / 2))) + (X4 *
    ((W3(4) + K23 / 2) - W3LMM))))
    K43 = (INC * 365 / V1(S)) * ((GG(S) * 1E+12) + HH(S) + (Q34 * W3(3)) + (QLM4 * W3LMM) - ((Q4LM  +
    I(S)) * (W3(S) + K33)) + (j(S) * W4(S)) - ((X3 * (W3(3) - (W3(4) + K33))) + (X4 * ((W3(4) +
    K33) - W3LMM))))
    W3(S) = W3(S) + ((K13 + 2 * K23 + 2 * K33 + K43) / 6)

    K14 = (INC * 365 / V2(S)) * ((L(S) * W3(S)) - (M(S) * W4(S)))
    K24 = (INC * 365 / V2(S)) * ((L(S) * W3(S)) - (M(S) * (W4(S) + K14 / 2)))
    K34 = (INC * 365 / V2(S)) * ((L(S) * W3(S)) - (M(S) * (W4(S) + K24 / 2)))
    K44 = (INC * 365 / V2(S)) * ((L(S) * W3(S)) - (M(S) * (W4(S) + K34)))
    W4(S) = W4(S) + ((K14 + 2 * K24 + 2 * K34 + K44) / 6)

    END SELECT

    IF INT(I / CINT(1 / INC)) <> (I / CINT(1 / INC)) THEN GOTO 30

    VAR1(Q) = t
    VAR2(Q) = S
    VAR3(Q) = W1(S) / 1000
    VAR4(Q) = W2(S) / 1000
    VAR5(Q) = W3(S) / 1000
    VAR6(Q) = W4(S) / 1000
    Q = Q + 1

    GOSUB scrn

30 :NEXT S

    t = t + INC
    NEXT I
    Z = 1

    CLS
REPEAT:
    FOR Q = Z TO 196 STEP 4

    PRINT #1, USING F2$; TAB(10); VAR1(Q) + t1; TAB(16); VAR2(Q); TAB(28);
    PRINT #1, USING F1$; VAR3(Q); TAB(41); VAR4(Q);
    PRINT #1, TAB(54); USING F1$; VAR5(Q); TAB(67); VAR6(Q)
    NEXT Q

    Z = Z + 1
    IF Z > 4 THEN GOTO quit ELSE GOTO REPEAT

quit:
CLOSE #1
SYSTEM

scrn:

    LOCATE 16, 6: PRINT USING F2$; TAB(7); t + t1; TAB(15); 1; TAB(25);
    PRINT USING F1$; W1(1) / 1000; TAB(37); W2(1) / 1000; TAB(49); W3(1) / 1000; TAB(61); W4(1) / 1000
    LOCATE 17, 6: PRINT USING F2$; TAB(7); t + t1; TAB(15); 2; TAB(25);
    PRINT USING F1$; W1(2) / 1000; TAB(37); W2(2) / 1000; TAB(49); W3(2) / 1000; TAB(61); W4(2) / 1000
    LOCATE 18, 6: PRINT USING F2$; TAB(7); t + t1; TAB(15); 3; TAB(25);
    PRINT USING F1$; W1(3) / 1000; TAB(37); W2(3) / 1000; TAB(49); W3(3) / 1000; TAB(61); W4(3) / 1000
    LOCATE 19, 6: PRINT USING F2$; TAB(7); t + t1; TAB(15); 4; TAB(25);
    PRINT USING F1$; W1(4) / 1000; TAB(37); W2(4) / 1000; TAB(49); W3(4) / 1000; TAB(61); W4(4) / 1000
    PRINT #1, USING F2$; TAB(10); t + t1; TAB(16); S; TAB(28);
    PRINT #1, USING F1$; W1(S) / 1000; TAB(41); W2(S) / 1000; TAB(54); W3(S) / 1000; TAB(67);
    W4(S) / 1000
    RETURN
```

APPENDIX C

Listing of the STOXGB Dump File:

```
                     DATA SET #1

       ==========================================
       Disc.of Variable (unit) (Variable)   Input
       ==========================================
       Initial time(yrs) (t1)               1940
       Final time(yrs) (t2)                 1990
       Time Step (yrs) (INC)                .00274


                     DATA SET #2

  =====================================================
  Disc. of Variable (unit) (Variable)          Input
  =====================================================
  Int. Areas, Seg.1,2 (m2) (INTA12)          0.5514E+05
  Int. Areas, Seg.2,3 (m2) (INTA23)          0.1410E+06
  Int. Areas, Seg.3,4 (m2) (INTA34)          0.2832E+06
  Int. Areas, Seg.4,LM (m2) (INTA4LM)        0.3300E+06
  Charac. Length, Seg.1,2 (m) (CHL12)        0.1400E+05
  Charac. Length, Seg.2,3 (m) (CHL23)        0.3500E+05
  Charac. Length, Seg.3,4 (m) (CHL34)        0.5214E+05
  Charac. Length, Seg.4LM (m) (CHL4LM)       0.1000E+05
  Bulk Disp. Coeff.,Seg.1,2 (m2/d) (BDSC12)  0.2592E+07
  Bulk Disp. Coeff.,Seg.2,3 (m2/d) (BDSC23)  0.3456E+07
  Bulk Disp. Coeff.,Seg.3,4 (m2/d) (BDSC34)  0.1728E+07
  Bulk Disp. Coeff.,Seg.4LM (m2/d) (BDSC4LM) 0.1728E+07
  Flow from Fox to Seg.#1 (m3/d) (QF1)       0.7840E+07
  Flow from Seg #2 to Seg.#1 (m3/d) (Q21)    0.1065E+08
  Flow from Seg #1 to Seg.#2 (m3/d) (Q12)    0.1849E+08
  Flow from Seg #3 to Seg.#2 (m3/d) (Q32)    0.3549E+08
  Flow from Seg #2 to Seg.#3 (m3/d) (Q23)    0.4333E+08
  Flow from Seg #4 to Seg.#3 (m3/d) (Q43)    0.1932E+09
  Flow from Menominee to Seg.#3 (m3/d) (QM3) 0.6490E+07
  Flow from Peshtigo to Seg.#3 (m3/d) (QP3)  0.1450E+07
  Flow from Oconto to Seg.#3 (m3/d) (QO3)    0.1190E+07
  Flow from Seg #3 to Seg.#4 (m3/d) (Q34)    0.2102E+09
  Flow from LM to Seg.#4 (m3/d) (QLM4)       0.8050E+09
  Flow from Escanaba to Seg.#4 (m3/d) (QE4)  0.1970E+07
  Flow from Seg.#4 to LM(m3/d) (Q4LM)        0.8239E+09
  Henry's Constant (atm-m3/mol) (HEN)        0.9400E-02


         ======================================
         Year    ACP        W1LM       W3LM
               (ng/m3)    (mg/m3)    (ng/m3)
         ======================================
          1   0.5000E-01 0.2400E+03 0.1600E+03
          2   0.1000E+00 0.2400E+03 0.3200E+03
          3   0.1500E+00 0.2400E+03 0.4800E+03
          4   0.2000E+00 0.2400E+03 0.6400E+03
          5   0.2500E+00 0.2400E+03 0.8000E+03
          6   0.3000E+00 0.2400E+03 0.9600E+03
          7   0.3500E+00 0.2400E+03 0.1120E+04
          8   0.4000E+00 0.2400E+03 0.1280E+04
          9   0.4500E+00 0.2400E+03 0.1440E+04
         10   0.5000E+00 0.2400E+03 0.1600E+04
         11   0.5500E+00 0.2400E+03 0.1760E+04
         12   0.6000E+00 0.2400E+03 0.1920E+04
         13   0.6500E+00 0.2400E+03 0.2080E+04
         14   0.7000E+00 0.2400E+03 0.2240E+04
```

```
15    0.7500E+00 0.2400E+03 0.2400E+04
16    0.8000E+00 0.2400E+03 0.2560E+04
17    0.8500E+00 0.2400E+03 0.2720E+04
18    0.9000E+00 0.2400E+03 0.2880E+04
19    0.9500E+00 0.2400E+03 0.3040E+04
20    0.1000E+01 0.2400E+03 0.3200E+04
21    0.1050E+01 0.2400E+03 0.3360E+04
22    0.1100E+01 0.2400E+03 0.3520E+04
23    0.1150E+01 0.2400E+03 0.3680E+04
24    0.1200E+01 0.2400E+03 0.3840E+04
25    0.1250E+01 0.2400E+03 0.4000E+04
26    0.1300E+01 0.2400E+03 0.4160E+04
27    0.1350E+01 0.2400E+03 0.4320E+04
28    0.1400E+01 0.2400E+03 0.4480E+04
29    0.1450E+01 0.2400E+03 0.4640E+04
30    0.1500E+01 0.2400E+03 0.4800E+04
31    0.1464E+01 0.2400E+03 0.4640E+04
32    0.1427E+01 0.2400E+03 0.4480E+04
33    0.1390E+01 0.2400E+03 0.4320E+04
34    0.1354E+01 0.2400E+03 0.4160E+04
35    0.1317E+01 0.2400E+03 0.4000E+04
36    0.1281E+01 0.2400E+03 0.3840E+04
37    0.1245E+01 0.2400E+03 0.3680E+04
38    0.1208E+01 0.2400E+03 0.3520E+04
39    0.1171E+01 0.2400E+03 0.3360E+04
40    0.1135E+01 0.2400E+03 0.3200E+04
41    0.1099E+01 0.2400E+03 0.3040E+04
42    0.1062E+01 0.2400E+03 0.2880E+04
43    0.1026E+01 0.2400E+03 0.2720E+04
44    0.9890E+00 0.2400E+03 0.2560E+04
45    0.9525E+00 0.2400E+03 0.2400E+04
46    0.9160E+00 0.2400E+03 0.2240E+04
47    0.8795E+00 0.2400E+03 0.2080E+04
48    0.8430E+00 0.2400E+03 0.1920E+04
49    0.8065E+00 0.2400E+03 0.1760E+04
50    0.7700E+00 0.2400E+03 0.1600E+04


                    DATA SET #3

==============================================================================
Disc. of Variable (unit) (Variable)            Input
                                    Seg. #1    Seg. #2    Seg. #3    Seg. #4
==============================================================================
Initial POC Conc.in WC (mg/m3) (W1)  0.2346E+04 0.2587E+34 -.2215E+30 0.1694E-09
Initial POC Conc.in BS (mg/m3) (W2)  0.7000E+07 0.2587E+34 -.2215E+30 0.1694E-09
Initial PCB Conc.in WC (ng/m3) (W3)  0.0000E+00 0.2587E+34 -.2215E+30 0.1694E-09
Initial PCB Conc.in BS (ng/m3) (W4)  0.0000E+00 0.2587E+34 -.2215E+30 0.1694E-09
Volume of WC(m3) (V1)                0.3717E+09 0.2587E+34 -.2215E+30 0.1694E-09
Volume of BS(m3) (V2)                0.4320E+07 0.2587E+34 -.2215E+30 0.1694E-09
Surface Area of WC (m2) (SA1)        0.1080E+09 0.2587E+34 -.2215E+30 0.1694E-09
Area of Sediment, Dep., (m2) (ASD)   0.1080E+09 0.2587E+34 -.2215E+30 0.1694E-09
Area of Sediment, Resus.(m2) (ASR)   0.1080E+09 0.2587E+34 -.2215E+30 0.1694E-09
Sed. Porosity (SEDP)                 0.9200E+00 0.2587E+34 -.2215E+30 0.1694E-09
Deep Burial Velocity (m/d) (DBV)     0.4850E-05 0.2587E+34 -.2215E+30 0.1694E-09
Resuspension Velocity (m/d) (RSV)    0.3890E-03 0.2587E+34 -.2215E+30 0.1694E-09
Settling Rate of POC (m/d) (SRO1)    0.1500E+01 0.2587E+34 -.2215E+30 0.1694E-09
Settling Rate of PCB (m/d) (SRP1)    0.1500E+01 0.2587E+34 -.2215E+30 0.1694E-09
Decay Rate POC  WC (1/d) (DECR1)     0.1900E-01 0.2587E+34 -.2215E+30 0.1694E-09
Decay Rate POC  BS (1/d) (DECR2)     0.1000E-02 0.2587E+34 -.2215E+30 0.1694E-09
Decom. Rate PCB in WC (1/d) (DRP1)   0.0000E+00 0.2587E+34 -.2215E+30 0.1694E-09
Decom. Rate PCB in BS (1/d) (DRP2)   0.0000E+00 0.2587E+34 -.2215E+30 0.1694E-09
Partition Coef.(m3/Kg C) (PRTC)      0.2512E+04 0.2587E+34 -.2215E+30 0.1694E-09
Volat. Exch. Rate (m/d) (VEXR)       0.1000E+00 0.2587E+34 -.2215E+30 0.1694E-09
Disp. Coef. Sed.Seg. (m2/d) (Esi)    0.3922E-03 0.2587E+34 -.2215E+30 0.1694E-09
Charc. Length Sed.Seg. (m) (Lsi)     0.4000E-01 0.2587E+34 -.2215E+30 0.1694E-09
```

Seg. #	Year	ELP (Kg/d)	ELO (Kg/d)	ILO (Kg/d)
1	1	0.4838E-01	0.1530E+05	0.6890E+05
1	2	0.9676E-01	0.1530E+05	0.6890E+05
1	3	0.1451E+00	0.1530E+05	0.6890E+05
1	4	0.1935E+00	0.1530E+05	0.6890E+05
1	5	0.2419E+00	0.1530E+05	0.6890E+05
1	6	0.2903E+00	0.1530E+05	0.6890E+05
1	7	0.3387E+00	0.1530E+05	0.6890E+05
1	8	0.3870E+00	0.1530E+05	0.6890E+05
1	9	0.4354E+00	0.1530E+05	0.6890E+05
1	10	0.4838E+00	0.1530E+05	0.6890E+05
1	11	0.5322E+00	0.1530E+05	0.6890E+05
1	12	0.5806E+00	0.1530E+05	0.6890E+05
1	13	0.6289E+00	0.1530E+05	0.6890E+05
1	14	0.6773E+00	0.1530E+05	0.6890E+05
1	15	0.7257E+00	0.1530E+05	0.6890E+05
1	16	0.7741E+00	0.1530E+05	0.6890E+05
1	17	0.8225E+00	0.1530E+05	0.6890E+05
1	18	0.8708E+00	0.1530E+05	0.6890E+05
1	19	0.9192E+00	0.1530E+05	0.6890E+05
1	20	0.9676E+00	0.1530E+05	0.6890E+05
1	21	0.1016E+01	0.1530E+05	0.6890E+05
1	22	0.1064E+01	0.1530E+05	0.6890E+05
1	23	0.1113E+01	0.1530E+05	0.6890E+05
1	24	0.1161E+01	0.1530E+05	0.6890E+05
1	25	0.1209E+01	0.1530E+05	0.6890E+05
1	26	0.1258E+01	0.1530E+05	0.6890E+05
1	27	0.1306E+01	0.1530E+05	0.6890E+05
1	28	0.1355E+01	0.1530E+05	0.6890E+05
1	29	0.1403E+01	0.1530E+05	0.6890E+05
1	30	0.1451E+01	0.1530E+05	0.6890E+05
1	31	0.1403E+01	0.1530E+05	0.6890E+05
1	32	0.1355E+01	0.1530E+05	0.6890E+05
1	33	0.1306E+01	0.1530E+05	0.6890E+05
1	34	0.1258E+01	0.1530E+05	0.6890E+05
1	35	0.1209E+01	0.1530E+05	0.6890E+05
1	36	0.1161E+01	0.1530E+05	0.6890E+05
1	37	0.1113E+01	0.1530E+05	0.6890E+05
1	38	0.1064E+01	0.1530E+05	0.6890E+05
1	39	0.1016E+01	0.1530E+05	0.6890E+05
1	40	0.9676E+00	0.1530E+05	0.6890E+05
1	41	0.9192E+00	0.1530E+05	0.6890E+05
1	42	0.8708E+00	0.1530E+05	0.6890E+05
1	43	0.8225E+00	0.1530E+05	0.6890E+05
1	44	0.7741E+00	0.1530E+05	0.6890E+05
1	45	0.7257E+00	0.1530E+05	0.6890E+05
1	46	0.6773E+00	0.1530E+05	0.6890E+05
1	47	0.6289E+00	0.1530E+05	0.6890E+05
1	48	0.5806E+00	0.1530E+05	0.6890E+05
1	49	0.5322E+00	0.1530E+05	0.6890E+05
1	50	0.4838E+00	0.1530E+05	0.6890E+05
2	1	0.2014E-03	0.0000E+00	0.9710E+05
2	2	0.4030E-03	0.0000E+00	0.9710E+05
2	3	0.6040E-03	0.0000E+00	0.9710E+05
2	4	0.8060E-03	0.0000E+00	0.9710E+05
2	5	0.1007E-02	0.0000E+00	0.9710E+05
2	6	0.1210E-02	0.0000E+00	0.9710E+05
2	7	0.1410E-02	0.0000E+00	0.9710E+05
2	8	0.1610E-02	0.0000E+00	0.9710E+05
2	9	0.1810E-02	0.0000E+00	0.9710E+05
2	10	0.2000E-02	0.0000E+00	0.9710E+05
2	11	0.2215E-02	0.0000E+00	0.9710E+05
2	12	0.2420E-02	0.0000E+00	0.9710E+05
2	13	0.2620E-02	0.0000E+00	0.9710E+05
2	14	0.2820E-02	0.0000E+00	0.9710E+05
2	15	0.3020E-02	0.0000E+00	0.9710E+05
2	16	0.3220E-02	0.0000E+00	0.9710E+05
2	17	0.3420E-02	0.0000E+00	0.9710E+05
2	18	0.3620E-02	0.0000E+00	0.9710E+05

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2        19        0.3830E-02 0.0000E+00 0.9710E+05
2        20        0.4030E-02 0.0000E+00 0.9710E+05
2        21        0.4230E-02 0.0000E+00 0.9710E+05
2        22        0.4430E-02 0.0000E+00 0.9710E+05
2        23        0.4630E-02 0.0000E+00 0.9710E+05
2        24        0.4830E-02 0.0000E+00 0.9710E+05
2        25        0.5040E-02 0.0000E+00 0.9710E+05
2        26        0.5240E-02 0.0000E+00 0.9710E+05
2        27        0.5440E-02 0.0000E+00 0.9710E+05
2        28        0.5640E-02 0.0000E+00 0.9710E+05
2        29        0.5840E-02 0.0000E+00 0.9710E+05
2        30        0.6040E-02 0.0000E+00 0.9710E+05
2        31        0.5840E-02 0.0000E+00 0.9710E+05
2        32        0.5640E-02 0.0000E+00 0.9710E+05
2        33        0.5440E-02 0.0000E+00 0.9710E+05
2        34        0.5240E-02 0.0000E+00 0.9710E+05
2        35        0.5040E-02 0.0000E+00 0.9710E+05
2        36        0.4830E-02 0.0000E+00 0.9710E+05
2        37        0.4630E-02 0.0000E+00 0.9710E+05
2        38        0.4430E-02 0.0000E+00 0.9710E+05
2        39        0.4230E-02 0.0000E+00 0.9710E+05
2        40        0.4030E-02 0.0000E+00 0.9710E+05
2        41        0.3830E-02 0.0000E+00 0.9710E+05
2        42        0.3620E-02 0.0000E+00 0.9710E+05
2        43        0.3420E-02 0.0000E+00 0.9710E+05
2        44        0.3220E-02 0.0000E+00 0.9710E+05
2        45        0.3020E-02 0.0000E+00 0.9710E+05
2        46        0.2820E-02 0.0000E+00 0.9710E+05
2        47        0.2620E-02 0.0000E+00 0.9710E+05
2        48        0.2420E-02 0.0000E+00 0.9710E+05
2        49        0.2150E-02 0.0000E+00 0.9710E+05
2        50        0.2000E-02 0.0000E+00 0.9710E+05
3        1         0.4158E-02 0.1013E+05 0.2100E+06
3        2         0.8316E-02 0.1013E+05 0.2100E+06
3        3         0.1247E-01 0.1013E+05 0.2100E+06
3        4         0.1663E-01 0.1013E+05 0.2100E+06
3        5         0.2080E-01 0.1013E+05 0.2100E+06
3        6         0.2495E-01 0.1013E+05 0.2100E+06
3        7         0.2911E-01 0.1013E+05 0.2100E+06
3        8         0.3330E-01 0.1013E+05 0.2100E+06
3        9         0.3740E-01 0.1013E+05 0.2100E+06
3        10        0.4160E-01 0.1013E+05 0.2100E+06
3        11        0.4574E-01 0.1013E+05 0.2100E+06
3        12        0.4990E-01 0.1013E+05 0.2100E+06
3        13        0.5405E-01 0.1013E+05 0.2100E+06
3        14        0.5821E-01 0.1013E+05 0.2100E+06
3        15        0.6237E-01 0.1013E+05 0.2100E+06
3        16        0.6653E-01 0.1013E+05 0.2100E+06
3        17        0.7069E-01 0.1013E+05 0.2100E+06
3        18        0.7480E-01 0.1013E+05 0.2100E+06
3        19        0.7900E-01 0.1013E+05 0.2100E+06
3        20        0.8320E-01 0.1013E+05 0.2100E+06
3        21        0.8732E-01 0.1013E+05 0.2100E+06
3        22        0.9150E-01 0.1013E+05 0.2100E+06
3        23        0.9560E-01 0.1013E+05 0.2100E+06
3        24        0.9979E-01 0.1013E+05 0.2100E+06
3        25        0.1040E+00 0.1013E+05 0.2100E+06
3        26        0.1081E+00 0.1013E+05 0.2100E+06
3        27        0.1123E+00 0.1013E+05 0.2100E+06
3        28        0.1164E+00 0.1013E+05 0.2100E+06
3        29        0.1206E+00 0.1013E+05 0.2100E+06
3        30        0.1247E+00 0.1013E+05 0.2100E+06
3        31        0.1206E+00 0.1013E+05 0.2100E+06
3        32        0.1164E+00 0.1013E+05 0.2100E+06
3        33        0.1123E+00 0.1013E+05 0.2100E+06
3        34        0.1081E+00 0.1013E+05 0.2100E+06
3        35        0.1040E+00 0.1013E+05 0.2100E+06
3        36        0.9979E-01 0.1013E+05 0.2100E+06
3        37        0.9560E-01 0.1013E+05 0.2100E+06
3        38        0.9150E-01 0.1013E+05 0.2100E+06
3        39        0.8732E-01 0.1013E+05 0.2100E+06
3        40        0.8320E-01 0.1013E+05 0.2100E+06
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3          41       0.7900E-01 0.1013E+05 0.2100E+06
3          42       0.7480E-01 0.1013E+05 0.2100E+06
3          43       0.7065E-01 0.1013E+05 0.2100E+06
3          44       0.6649E-01 0.1013E+05 0.2100E+06
3          45       0.6234E-01 0.1013E+05 0.2100E+06
3          46       0.5818E-01 0.1013E+05 0.2100E+06
3          47       0.5402E-01 0.1013E+05 0.2100E+06
3          48       0.4990E-01 0.1013E+05 0.2100E+06
3          49       0.4570E-01 0.1013E+05 0.2100E+06
3          50       0.4160E-01 0.1013E+05 0.2100E+06
4           1       0.1314E+00 0.1973E+06 0.3830E+06
4           2       0.2628E+00 0.1973E+06 0.3830E+06
4           3       0.3942E+00 0.1973E+06 0.3830E+06
4           4       0.5256E+00 0.1973E+06 0.3830E+06
4           5       0.6570E+00 0.1973E+06 0.3830E+06
4           6       0.7884E+00 0.1973E+06 0.3830E+06
4           7       0.9198E+00 0.1973E+06 0.3830E+06
4           8       0.1051E+01 0.1973E+06 0.3830E+06
4           9       0.1183E+01 0.1973E+06 0.3830E+06
4          10       0.1314E+01 0.1973E+06 0.3830E+06
4          11       0.1445E+01 0.1973E+06 0.3830E+06
4          12       0.1577E+01 0.1973E+06 0.3830E+06
4          13       0.1708E+01 0.1973E+06 0.3830E+06
4          14       0.1840E+01 0.1973E+06 0.3830E+06
4          15       0.1971E+01 0.1973E+06 0.3830E+06
4          16       0.2102E+01 0.1973E+06 0.3830E+06
4          17       0.2234E+01 0.1973E+06 0.3830E+06
4          18       0.2365E+01 0.1973E+06 0.3830E+06
4          19       0.2497E+01 0.1973E+06 0.3830E+06
4          20       0.2628E+01 0.1973E+06 0.3830E+06
4          21       0.2760E+01 0.1973E+06 0.3830E+06
4          22       0.2891E+01 0.1973E+06 0.3830E+06
4          23       0.3022E+01 0.1973E+06 0.3830E+06
4          24       0.3154E+01 0.1973E+06 0.3830E+06
4          25       0.3285E+01 0.1973E+06 0.3830E+06
4          26       0.3416E+01 0.1973E+06 0.3830E+06
4          27       0.3548E+01 0.1973E+06 0.3830E+06
4          28       0.3679E+01 0.1973E+06 0.3830E+06
4          29       0.3811E+01 0.1973E+06 0.3830E+06
4          30       0.3942E+01 0.1973E+06 0.3830E+06
4          31       0.3811E+01 0.1973E+06 0.3830E+06
4          32       0.3679E+01 0.1973E+06 0.3830E+06
4          33       0.3548E+01 0.1973E+06 0.3830E+06
4          34       0.3416E+01 0.1973E+06 0.3830E+06
4          35       0.3285E+01 0.1973E+06 0.3830E+06
4          36       0.3154E+01 0.1973E+06 0.3830E+06
4          37       0.3022E+01 0.1973E+06 0.3830E+06
4          38       0.2891E+01 0.1973E+06 0.3830E+06
4          39       0.2759E+01 0.1973E+06 0.3830E+06
4          40       0.2628E+01 0.1973E+06 0.3830E+06
4          41       0.2497E+01 0.1973E+06 0.3830E+06
4          42       0.2365E+01 0.1973E+06 0.3830E+06
4          43       0.2234E+01 0.1973E+06 0.3830E+06
4          44       0.2102E+01 0.1973E+06 0.3830E+06
4          45       0.1971E+01 0.1973E+06 0.3830E+06
4          46       0.1840E+01 0.1973E+06 0.3830E+06
4          47       0.1708E+01 0.1973E+06 0.3830E+06
4          48       0.1577E+01 0.1973E+06 0.3830E+06
4          49       0.1445E+01 0.1973E+06 0.3830E+06
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Results

Time yrs	Segment No.	POC-WC W1 (mg/l)	POC-BS W2 (mg/l)	PCB-WC W3 (ng/l)	PCB-BS W4 (ng/l)
1940	1	0.2346E+01	0.7000E+04	0.0000E+00	0.0000E+00
1941	1	0.1965E+01	0.6822E+04	0.8932E+00	0.2426E+04
1942	1	0.1948E+01	0.6748E+04	0.2114E+01	0.6142E+04
1943	1	0.1942E+01	0.6719E+04	0.3514E+01	0.1056E+05
1944	1	0.1940E+01	0.6708E+04	0.5017E+01	0.1537E+05
1945	1	0.1938E+01	0.6703E+04	0.6582E+01	0.2041E+05
1946	1	0.1938E+01	0.6700E+04	0.8188E+01	0.2560E+05
1947	1	0.1937E+01	0.6699E+04	0.9820E+01	0.3089E+05
1948	1	0.1937E+01	0.6698E+04	0.1147E+02	0.3625E+05
1949	1	0.1937E+01	0.6697E+04	0.1314E+02	0.4166E+05
1950	1	0.1937E+01	0.6697E+04	0.1482E+02	0.4712E+05
1951	1	0.1937E+01	0.6697E+04	0.1651E+02	0.5261E+05
1952	1	0.1937E+01	0.6696E+04	0.1821E+02	0.5813E+05
1953	1	0.1937E+01	0.6696E+04	0.1991E+02	0.6367E+05
1954	1	0.1937E+01	0.6696E+04	0.2162E+02	0.6924E+05
1955	1	0.1937E+01	0.6696E+04	0.2334E+02	0.7482E+05
1956	1	0.1937E+01	0.6696E+04	0.2506E+02	0.8042E+05
1957	1	0.1937E+01	0.6695E+04	0.2678E+02	0.8603E+05
1958	1	0.1936E+01	0.6695E+04	0.2851E+02	0.9165E+05
1959	1	0.1936E+01	0.6695E+04	0.3024E+02	0.9728E+05
1960	1	0.1936E+01	0.6695E+04	0.3208E+02	0.1029E+06
1961	1	0.1936E+01	0.6695E+04	0.3382E+02	0.1086E+06
1962	1	0.1936E+01	0.6695E+04	0.3556E+02	0.1142E+06
1963	1	0.1936E+01	0.6695E+04	0.3730E+02	0.1199E+06
1964	1	0.1936E+01	0.6695E+04	0.3904E+02	0.1256E+06
1965	1	0.1936E+01	0.6695E+04	0.4078E+02	0.1312E+06
1966	1	0.1936E+01	0.6695E+04	0.4253E+02	0.1369E+06
1967	1	0.1936E+01	0.6695E+04	0.4434E+02	0.1426E+06
1968	1	0.1936E+01	0.6695E+04	0.4609E+02	0.1483E+06
1969	1	0.1936E+01	0.6695E+04	0.4783E+02	0.1540E+06
1970	1	0.1936E+01	0.6695E+04	0.4924E+02	0.1596E+06
1971	1	0.1936E+01	0.6695E+04	0.4920E+02	0.1605E+06
1972	1	0.1936E+01	0.6695E+04	0.4850E+02	0.1587E+06
1973	1	0.1936E+01	0.6695E+04	0.4745E+02	0.1556E+06
1974	1	0.1936E+01	0.6695E+04	0.4619E+02	0.1517E+06
1975	1	0.1936E+01	0.6695E+04	0.4481E+02	0.1473E+06
1976	1	0.1936E+01	0.6695E+04	0.4335E+02	0.1426E+06
1977	1	0.1936E+01	0.6695E+04	0.4184E+02	0.1377E+06
1978	1	0.1936E+01	0.6695E+04	0.4029E+02	0.1327E+06
1979	1	0.1936E+01	0.6695E+04	0.3871E+02	0.1276E+06
1980	1	0.1936E+01	0.6695E+04	0.3710E+02	0.1223E+06
1981	1	0.1936E+01	0.6695E+04	0.3554E+02	0.1171E+06
1982	1	0.1936E+01	0.6695E+04	0.3390E+02	0.1117E+06
1983	1	0.1936E+01	0.6695E+04	0.3224E+02	0.1064E+06
1984	1	0.1936E+01	0.6695E+04	0.3057E+02	0.1009E+06
1985	1	0.1936E+01	0.6695E+04	0.2889E+02	0.9548E+05
1986	1	0.1936E+01	0.6695E+04	0.2720E+02	0.8999E+05
1987	1	0.1936E+01	0.6695E+04	0.2551E+02	0.8448E+05
1988	1	0.1936E+01	0.6695E+04	0.2380E+02	0.7894E+05
1989	1	0.1936E+01	0.6695E+04	0.2210E+02	0.7339E+05
1940	2	0.1072E+01	0.8080E+04	0.0000E+00	0.0000E+00
1941	2	0.8481E+00	0.8061E+04	0.4395E-01	0.2063E+03
1942	2	0.8451E+00	0.8026E+04	0.1266E+00	0.7082E+03
1943	2	0.8431E+00	0.8002E+04	0.2459E+00	0.1516E+04
1944	2	0.8418E+00	0.7987E+04	0.3981E+00	0.2608E+04
1945	2	0.8409E+00	0.7977E+04	0.5790E+00	0.3954E+04
1946	2	0.8403E+00	0.7970E+04	0.7846E+00	0.5520E+04
1947	2	0.8398E+00	0.7964E+04	0.1011E+01	0.7276E+04
1948	2	0.8394E+00	0.7960E+04	0.1256E+01	0.9195E+04
1949	2	0.8391E+00	0.7957E+04	0.1517E+01	0.1125E+05
1950	2	0.8389E+00	0.7954E+04	0.1791E+01	0.1343E+05
1951	2	0.8387E+00	0.7952E+04	0.2076E+01	0.1571E+05
1952	2	0.8385E+00	0.7950E+04	0.2372E+01	0.1808E+05
1953	2	0.8383E+00	0.7949E+04	0.2676E+01	0.2053E+05
1954	2	0.8382E+00	0.7947E+04	0.2987E+01	0.2304E+05

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1955    2          0.8381E+00   0.7946E+04   0.3305E+01   0.2562E+05
1956    2          0.8379E+00   0.7945E+04   0.3629E+01   0.2824E+05
1957    2          0.8379E+00   0.7944E+04   0.3958E+01   0.3090E+05
1958    2          0.8378E+00   0.7943E+04   0.4291E+01   0.3361E+05
1959    2          0.8377E+00   0.7942E+04   0.4628E+01   0.3635E+05
1960    2          0.8376E+00   0.7942E+04   0.4968E+01   0.3911E+05
1961    2          0.8376E+00   0.7941E+04   0.5311E+01   0.4191E+05
1962    2          0.8375E+00   0.7941E+04   0.5657E+01   0.4472E+05
1963    2          0.8375E+00   0.7941E+04   0.6005E+01   0.4756E+05
1964    2          0.8375E+00   0.7940E+04   0.6355E+01   0.5041E+05
1965    2          0.8374E+00   0.7940E+04   0.6706E+01   0.5328E+05
1966    2          0.8374E+00   0.7940E+04   0.7059E+01   0.5616E+05
1967    2          0.8374E+00   0.7940E+04   0.7414E+01   0.5905E+05
1968    2          0.8374E+00   0.7939E+04   0.7770E+01   0.6196E+05
1969    2          0.8373E+00   0.7939E+04   0.8126E+01   0.6487E+05
1970    2          0.8374E+00   0.7939E+04   0.8481E+01   0.6779E+05
1971    2          0.8374E+00   0.7939E+04   0.8751E+01   0.7030E+05
1972    2          0.8374E+00   0.7939E+04   0.8945E+01   0.7223E+05
1973    2          0.8374E+00   0.7939E+04   0.9066E+01   0.7356E+05
1974    2          0.8374E+00   0.7939E+04   0.9122E+01   0.7432E+05
1975    2          0.8374E+00   0.7939E+04   0.9122E+01   0.7458E+05
1976    2          0.8374E+00   0.7939E+04   0.9072E+01   0.7440E+05
1977    2          0.8374E+00   0.7939E+04   0.8981E+01   0.7385E+05
1978    2          0.8374E+00   0.7939E+04   0.8853E+01   0.7298E+05
1979    2          0.8374E+00   0.7939E+04   0.8695E+01   0.7183E+05
1980    2          0.8374E+00   0.7939E+04   0.8511E+01   0.7044E+05
1981    2          0.8374E+00   0.7939E+04   0.8304E+01   0.6885E+05
1982    2          0.8374E+00   0.7939E+04   0.8077E+01   0.6709E+05
1983    2          0.8374E+00   0.7939E+04   0.7833E+01   0.6517E+05
1984    2          0.8374E+00   0.7939E+04   0.7574E+01   0.6312E+05
1985    2          0.8374E+00   0.7939E+04   0.7303E+01   0.6096E+05
1986    2          0.8374E+00   0.7939E+04   0.7020E+01   0.5870E+05
1987    2          0.8374E+00   0.7939E+04   0.6727E+01   0.5635E+05
1988    2          0.8374E+00   0.7939E+04   0.6426E+01   0.5393E+05
1989    2          0.8374E+00   0.7939E+04   0.6117E+01   0.5144E+05
1940    3          0.6060E+00   0.1079E+05   0.0000E+00   0.0000E+00
1941    3          0.5951E+00   0.1075E+05   0.3307E-01   0.1407E+03
1942    3          0.5934E+00   0.1072E+05   0.7992E-01   0.4400E+03
1943    3          0.5918E+00   0.1069E+05   0.1399E+00   0.8977E+03
1944    3          0.5904E+00   0.1066E+05   0.2120E+00   0.1509E+04
1945    3          0.5892E+00   0.1063E+05   0.2955E+00   0.2268E+04
1946    3          0.5881E+00   0.1061E+05   0.3893E+00   0.3164E+04
1947    3          0.5871E+00   0.1059E+05   0.4925E+00   0.4187E+04
1948    3          0.5862E+00   0.1057E+05   0.6041E+00   0.5327E+04
1949    3          0.5855E+00   0.1055E+05   0.7233E+00   0.6572E+04
1950    3          0.5848E+00   0.1054E+05   0.8493E+00   0.7914E+04
1951    3          0.5842E+00   0.1053E+05   0.9813E+00   0.9342E+04
1952    3          0.5837E+00   0.1051E+05   0.1119E+01   0.1085E+05
1953    3          0.5833E+00   0.1050E+05   0.1261E+01   0.1242E+05
1954    3          0.5829E+00   0.1050E+05   0.1408E+01   0.1406E+05
1955    3          0.5826E+00   0.1049E+05   0.1558E+01   0.1575E+05
1956    3          0.5823E+00   0.1048E+05   0.1712E+01   0.1749E+05
1957    3          0.5821E+00   0.1048E+05   0.1868E+01   0.1927E+05
1958    3          0.5818E+00   0.1047E+05   0.2027E+01   0.2109E+05
1959    3          0.5817E+00   0.1047E+05   0.2189E+01   0.2295E+05
1960    3          0.5815E+00   0.1046E+05   0.2353E+01   0.2483E+05
1961    3          0.5814E+00   0.1046E+05   0.2518E+01   0.2674E+05
1962    3          0.5813E+00   0.1046E+05   0.2685E+01   0.2868E+05
1963    3          0.5812E+00   0.1046E+05   0.2853E+01   0.3063E+05
1964    3          0.5811E+00   0.1045E+05   0.3023E+01   0.3261E+05
1965    3          0.5810E+00   0.1045E+05   0.3193E+01   0.3460E+05
1966    3          0.5809E+00   0.1045E+05   0.3365E+01   0.3660E+05
1967    3          0.5809E+00   0.1045E+05   0.3537E+01   0.3861E+05
1968    3          0.5808E+00   0.1045E+05   0.3710E+01   0.4064E+05
1969    3          0.5808E+00   0.1045E+05   0.3884E+01   0.4267E+05
1970    3          0.5808E+00   0.1045E+05   0.4058E+01   0.4472E+05
1971    3          0.5807E+00   0.1045E+05   0.4166E+01   0.4649E+05
1972    3          0.5807E+00   0.1045E+05   0.4248E+01   0.4795E+05
1973    3          0.5807E+00   0.1044E+05   0.4304E+01   0.4910E+05
1974    3          0.5807E+00   0.1044E+05   0.4337E+01   0.4995E+05
1975    3          0.5807E+00   0.1044E+05   0.4347E+01   0.5051E+05
1976    3          0.5807E+00   0.1044E+05   0.4336E+01   0.5080E+05
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1977     3          0.5806E+00    0.1044E+05    0.4307E+01    0.5084E+05
1978     3          0.5806E+00    0.1044E+05    0.4262E+01    0.5066E+05
1979     3          0.5806E+00    0.1044E+05    0.4202E+01    0.5026E+05
1980     3          0.5806E+00    0.1044E+05    0.4128E+01    0.4968E+05
1981     3          0.5806E+00    0.1044E+05    0.4043E+01    0.4892E+05
1982     3          0.5806E+00    0.1044E+05    0.3946E+01    0.4801E+05
1983     3          0.5806E+00    0.1044E+05    0.3841E+01    0.4697E+05
1984     3          0.5806E+00    0.1044E+05    0.3726E+01    0.4581E+05
1985     3          0.5806E+00    0.1044E+05    0.3605E+01    0.4453E+05
1986     3          0.5806E+00    0.1044E+05    0.3477E+01    0.4317E+05
1987     3          0.5806E+00    0.1044E+05    0.3343E+01    0.4171E+05
1988     3          0.5806E+00    0.1044E+05    0.3204E+01    0.4018E+05
1989     3          0.5806E+00    0.1044E+05    0.3060E+01    0.3859E+05
1940     4          0.3980E+00    0.1286E+05    0.0000E+00    0.0000E+00
1941     4          0.4920E+00    0.1267E+05    0.1143E+00    0.4082E+03
1942     4          0.4886E+00    0.1254E+05    0.2455E+00    0.1146E+04
1943     4          0.4856E+00    0.1243E+05    0.3900E+00    0.2138E+04
1944     4          0.4832E+00    0.1234E+05    0.5448E+00    0.3325E+04
1945     4          0.4812E+00    0.1226E+05    0.7077E+00    0.4664E+04
1946     4          0.4794E+00    0.1220E+05    0.8770E+00    0.6121E+04
1947     4          0.4780E+00    0.1214E+05    0.1052E+01    0.7671E+04
1948     4          0.4768E+00    0.1209E+05    0.1230E+01    0.9293E+04
1949     4          0.4758E+00    0.1206E+05    0.1412E+01    0.1097E+05
1950     4          0.4749E+00    0.1202E+05    0.1597E+01    0.1270E+05
1951     4          0.4742E+00    0.1200E+05    0.1783E+01    0.1446E+05
1952     4          0.4736E+00    0.1197E+05    0.1972E+01    0.1625E+05
1953     4          0.4731E+00    0.1195E+05    0.2162E+01    0.1807E+05
1954     4          0.4726E+00    0.1194E+05    0.2353E+01    0.1990E+05
1955     4          0.4723E+00    0.1193E+05    0.2545E+01    0.2175E+05
1956     4          0.4720E+00    0.1191E+05    0.2738E+01    0.2362E+05
1957     4          0.4717E+00    0.1190E+05    0.2932E+01    0.2549E+05
1958     4          0.4715E+00    0.1190E+05    0.3127E+01    0.2737E+05
1959     4          0.4713E+00    0.1189E+05    0.3322E+01    0.2927E+05
1960     4          0.4712E+00    0.1188E+05    0.3523E+01    0.3116E+05
1961     4          0.4710E+00    0.1188E+05    0.3719E+01    0.3307E+05
1962     4          0.4709E+00    0.1187E+05    0.3915E+01    0.3498E+05
1963     4          0.4708E+00    0.1187E+05    0.4111E+01    0.3689E+05
1964     4          0.4707E+00    0.1187E+05    0.4308E+01    0.3881E+05
1965     4          0.4707E+00    0.1187E+05    0.4505E+01    0.4072E+05
1966     4          0.4706E+00    0.1186E+05    0.4702E+01    0.4264E+05
1967     4          0.4706E+00    0.1186E+05    0.4905E+01    0.4457E+05
1968     4          0.4705E+00    0.1186E+05    0.5102E+01    0.4649E+05
1969     4          0.4705E+00    0.1186E+05    0.5300E+01    0.4842E+05
1970     4          0.4705E+00    0.1186E+05    0.5476E+01    0.5035E+05
1971     4          0.4704E+00    0.1186E+05    0.5446E+01    0.5146E+05
1972     4          0.4704E+00    0.1186E+05    0.5382E+01    0.5192E+05
1973     4          0.4704E+00    0.1186E+05    0.5292E+01    0.5187E+05
1974     4          0.4704E+00    0.1185E+05    0.5180E+01    0.5143E+05
1975     4          0.4704E+00    0.1185E+05    0.5054E+01    0.5069E+05
1976     4          0.4704E+00    0.1185E+05    0.4914E+01    0.4972E+05
1977     4          0.4704E+00    0.1185E+05    0.4764E+01    0.4856E+05
1978     4          0.4704E+00    0.1185E+05    0.4606E+01    0.4725E+05
1979     4          0.4703E+00    0.1185E+05    0.4441E+01    0.4584E+05
1980     4          0.4703E+00    0.1185E+05    0.4271E+01    0.4433E+05
1981     4          0.4703E+00    0.1185E+05    0.4102E+01    0.4275E+05
1982     4          0.4703E+00    0.1185E+05    0.3925E+01    0.4112E+05
1983     4          0.4703E+00    0.1185E+05    0.3744E+01    0.3943E+05
1984     4          0.4703E+00    0.1185E+05    0.3561E+01    0.3771E+05
1985     4          0.4703E+00    0.1185E+05    0.3376E+01    0.3595E+05
1986     4          0.4703E+00    0.1185E+05    0.3189E+01    0.3417E+05
1987     4          0.4703E+00    0.1185E+05    0.3000E+01    0.3237E+05
1988     4          0.4703E+00    0.1185E+05    0.2811E+01    0.3055E+05
1989     4          0.4703E+00    0.1185E+05    0.2620E+01    0.2872E+05
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