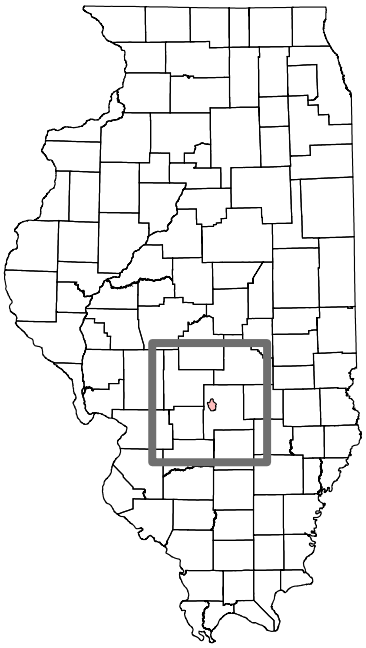
Illinois
Environmental
Protection Agency

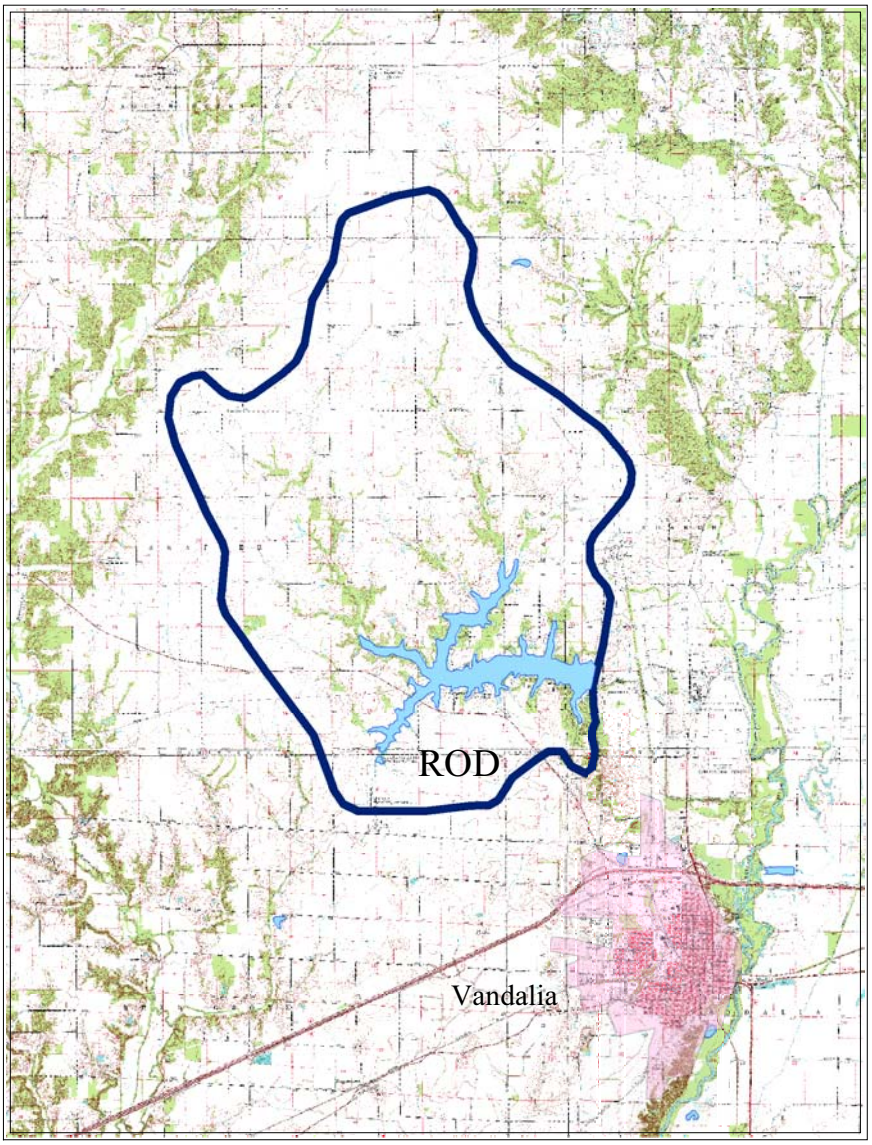
Bureau of Water
P.O. Box 19276
Springfield, IL 62794-9276

October 2004

IEPA/BOW/03-012

VANDALIA LAKE TMDL REPORT





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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

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Water Management Section
BUREAU OF WATER

REPLY TO THE ATTENTION OF
WW-16J

23 SEP 2004

Marcia T. Willhite , Chief
Bureau of Water
Illinois Environmental Protection Agency
1021 North Grand Ave. East
P.O. Box 19276
Springfield, IL 62794-9276

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BUREAU OF WATER
BUREAU CHIEF'S OFF

Dear Ms. Willhite:

The United States Environmental Protection Agency (U.S. EPA) has reviewed the final Total Maximum Daily Load (TMDL) for Vandalia Lake, including supporting documentation and follow up information. IEPA's submitted TMDL addresses the presence of elevated levels of phosphorus that impairs the General Use and the Public and Food Processing Water Supplies Use in approximately 660 acres of Vandalia Lake. Based on this review, U.S. EPA has determined that Illinois's TMDL for phosphorus meets the requirements of Section 303(d) of the Clean Water Act and U.S. EPA's implementing regulations at 40 C.F.R. Part 130. Therefore, U.S. EPA hereby approves Illinois's TMDL for the impaired Vandalia Lake, segment ROD. The statutory and regulatory requirements, and U.S. EPA's review of Illinois's compliance with each requirement, are described in the enclosed decision document.

We wish to acknowledge Illinois's effort in this submitted TMDL, and look forward to future TMDL submissions by the State of Illinois. If you have any questions, please contact Mr. Kevin Pierard, Chief of the Watersheds and Wetlands Branch at 312-886-4448.

Sincerely yours,

Jo Lynn Traub
Director, Water Division

Enclosure

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Parameter changes for developing TMDLs

In May 2001, Illinois EPA entered into a contract with Camp Dresser & McKee to develop Total Maximum Daily Loads (TMDLs) for Vandalia Lake. In the 1998 Section 303(d) List, Vandalia Lake was listed as impaired for the following parameters: phosphorus, pH, nitrogen, nitrates, siltation, total suspended solids, excessive algal growth, and chlorophyll-a. Since then, new data assessed in 2002 showed that Vandalia Lake is now impaired for phosphorus, pH, nitrogen, excessive algal growth, and chlorophyll-a.

Illinois EPA has since determined that at this time TMDLs will only be developed for those parameters with numeric water quality standards. These numeric water quality standards will serve as the target endpoints for TMDL development and provide a greater degree of clarity and certainty about the TMDL and implementation plans. As a result, this TMDL will only focus on the parameters of phosphorus and pH, for which numeric water quality standards exist.

Those parameters without established numeric water quality standards will be assigned a lower priority for TMDL development. Pending the development of numeric water quality standards for these parameters, as may be proposed by the Agency and adopted by the Illinois Pollution Control Board, Illinois EPA will continue to work toward improving water quality throughout the state by promoting and administering existing programs and working toward creating new methods for treating these potential causes of impairment.

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Appendices

Figures

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Tables

Acronyms

°F	degrees Fahrenheit
ALMP	Ambient Lake Monitoring Programs
AML	Abandoned Mined Lands
BMP	best management practices
BOD	biochemical oxygen demand
CBOD	carbonaceous biochemical oxygen demand
CCC	Commodity Credit Corporation
cfs	cubic feet per second
CO_2	carbon dioxide
CPP	Conservation Practices Program
CRP	Conservation Reserve Program
CWA	Clean Water Act
DEM	Digital Elevation Model
DO	dissolved oxygen
EQIP	Environmental Quality Incentive Program
ET	evapotranspiration
FSA	Farm Service Agency
g/day	grams per day
GIS	geographic information system
GWLF	generalized watershed loading function
HUC	Hydrologic Unit Code
IBI	Index of Biotic Integrity
ICLP	Illinois Clean Lakes Programs
IDA	Illinois Department of Agriculture
IDNR	Illinois Department of Natural Resources
Illinois EPA	Illinois Environmental Protection Agency
IPCB	Illinois Pollution Control Board
ISWS	Illinois State Water Survey
LA	load allocation
LC	loading capacity
MBI	Macroinvertebrate Biotic Index
mg/L	milligrams per liter
MOS	margin of safety

NASS	National Agricultural Statistics Service
NCDC	National Climatic Data Center
NRC	National Resources Council
NRCS	National Resource Conservation Service
NWIS	National Water Inventory System
ppm	parts per million
STATSGO	State Soil Geographic Database
STORET	USEPA *Storage and Retrieval* database
TMDL	total maximum daily load
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VLPC	Vandalia Lake Planning Committee
WASCOB	water and sediment control basin
WHIP	Wildlife Habitat Incentives Program
WLA	waste load allocation
WRP	Wetlands Reserve Program

Executive Summary
Vandalia Lake Watershed

TMDL Fact Sheet

Basin Name:	Vandalia Lake
Impaired Segments:	ROD
Location:	Fayette County, Illinois
Size:	660 acres at normal storage
Primary Watershed Land Uses:	Agriculture, grassland, and forest
Criteria of Concern:	Phosphorus and pH
Designated Uses Affected:	General use
Environmental Indicators:	Phosphorus and pH monitoring
Major Sources:	Nonpoint source loading from agriculture, internal cycling, septic systems
Loading Allocation:	10,899-pounds/year total phosphorus
Waste Load Allocation:	Zero; no point sources
Margin of Safety:	Implicit through conservative modeling; additional explicit of 5 percent (574 pounds/year)

This Total Maximum Daily Load (TMDL) assessment for impaired water bodies in the Vandalia Lake Watershed addresses the sources of water body impairments, reductions in source loading necessary to comply with water quality standards, and the implementation of procedures to mitigate the impairment.

A correlation between pH and total phosphorus was established for Vandalia Lake, and modeling demonstrates a reduction of 80 percent total phosphorus necessary so that pH and phosphorus water quality standards can be achieved. Primary sources of phosphorus loading to Vandalia Lake include internal cycling from the lake-bottom sediments and runoff from agricultural lands. Procedures outlined in the implementation plan to decrease phosphorus loading to the lake include in-lake measures as well as measures applied to the watershed to control nutrients in surface runoff and eroded sediment. In-lake mitigation practices include dredging the lake bottom and aerating the lake to eliminate internal cycling. Watershed controls include filter strips and wetlands to prevent phosphorus in surface runoff from reaching the lake, conservation tillage to decrease nutrient-rich soil erosion from agricultural fields, and development of nutrient management plans to ensure that excess phosphorus is not applied to agricultural fields.

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Section 1
Goals and Objectives for Vandalia Lake Watershed (ILO08)

1.1 Total Maximum Daily Load (TMDL) Overview

A Total Maximum Daily Load, or TMDL, is a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards. TMDLs are a requirement of Section 303(d) of the Clean Water Act (CWA). To meet this requirement, the Illinois Environmental Protection Agency (Illinois EPA) must identify water bodies not meeting water quality standards and then establish TMDLs for restoration of water quality. Illinois EPA lists water bodies not meeting water quality standards every two years. This list is called the 303(d) list and water bodies on the list are then targeted for TMDL development.

In general, a TMDL is a quantitative assessment of water quality problems, contributing sources, and pollution reductions needed to attain water quality standards. The TMDL specifies the amount of pollution or other stressor that needs to be reduced to meet water quality standards, allocates pollution control or management responsibilities among sources in a watershed, and provides a scientific and policy basis for taking actions needed to restore a water body (U.S. Environmental Protection Agency [USEPA] 1998a).

Water quality standards are laws or regulations that states authorize to enhance water quality and protect public health and welfare. Water quality standards provide the foundation for accomplishing two of the principal goals of the CWA. These goals are:

- restore and maintain the chemical, physical, and biological integrity of the nation's waters, and
- where attainable, to achieve water quality that promotes protection and propagation of fish, shellfish, and wildlife, and provides for recreation in and on the water.

Water quality standards consist of three elements:

- the designated beneficial use or uses of a water body or segment of a water body;
- the water quality criteria necessary to protect the use or uses of that particular water body;
- an antidegradation policy.

Examples of designated uses are recreation and protection of aquatic life. Water quality criteria describe the quality of water that will support a designated use. Water quality criteria can be expressed as numeric limits or as a narrative statement.

Antidegradation policies are adopted so that water quality improvements are conserved, maintained, and protected.

1.2 TMDL Goals and Objectives for Vandalia Lake Watershed

The TMDL goals and objectives for the Vandalia Lake Watershed include developing TMDLs for all impaired water bodies within the watershed, describing all of the necessary elements of the TMDL, developing an implementation plan for each TMDL, and gaining public acceptance of the process. Following is the impaired water body segment in the Vandalia Lake Watershed, which is also shown in Figure 1-1:

- Vandalia Lake (ROD)

The TMDL for each of the segments listed above will specify the following elements:

- Loading Capacity (LC) or the maximum amount of pollutant loading a water body can receive without violating water quality standards;
- Waste Load Allocation (WLA) or the portion of the TMDL allocated to existing or future point sources;
- Load Allocation (LA) or the portion of the TMDL allocated to existing or future nonpoint sources and natural background; and
- Margin of Safety (MOS) or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality.

These elements are combined into the following equation:

$$\mathbf{TMDL = LC = \Sigma WLA + \Sigma LA + MOS}$$

Each TMDL developed must also take into account the seasonal variability of pollutant loads so that water quality standards are met during all seasons of the year. Also, reasonable assurance that the TMDLs will be achieved is described in the implementation plan. The implementation plan for the Vandalia Lake Watershed describes how water quality standards will be attained. This implementation plan includes recommendations for implementing best management practices (BMPs), cost estimates, institutional needs to implement BMPs and controls throughout the watershed, and time frame for completion of implementation activities.

1.3 Report Overview

The remaining sections of this report contain:

- **Section 2 Vandalia Lake Watershed Description** provides a description of the impaired water body and general watershed characteristics.
- **Section 3 Public Participation and Involvement** discusses public participation activities that occurred throughout the TMDL development.
- **Section 4 Vandalia Lake Watershed Water Quality Standards** defines the water quality standards for the impaired water bodies. Pollution sources will also be discussed in this section.
- **Section 5 Vandalia Lake Watershed Data Review** provides an overview of available data for the Vandalia Lake Watershed.
- **Section 6 Methodologies to Complete TMDLs for the Vandalia Lake Watershed** discusses the models and analyses needed for TMDL development.
- **Section 7 Model Development for Vandalia Lake** provides an explanation of model development for Vandalia Lake.
- **Section 8 Total Maximum Daily Load for the Vandalia Lake Watershed** discusses the allowable loadings to water bodies to meet water quality standards and the reduction in existing loadings needed to meet allowable loads.
- **Section 9 Implementation Plan for Vandalia Lake** provides methods to reduce loadings to impaired water bodies.
- **Section 10 References** lists references used in this report.

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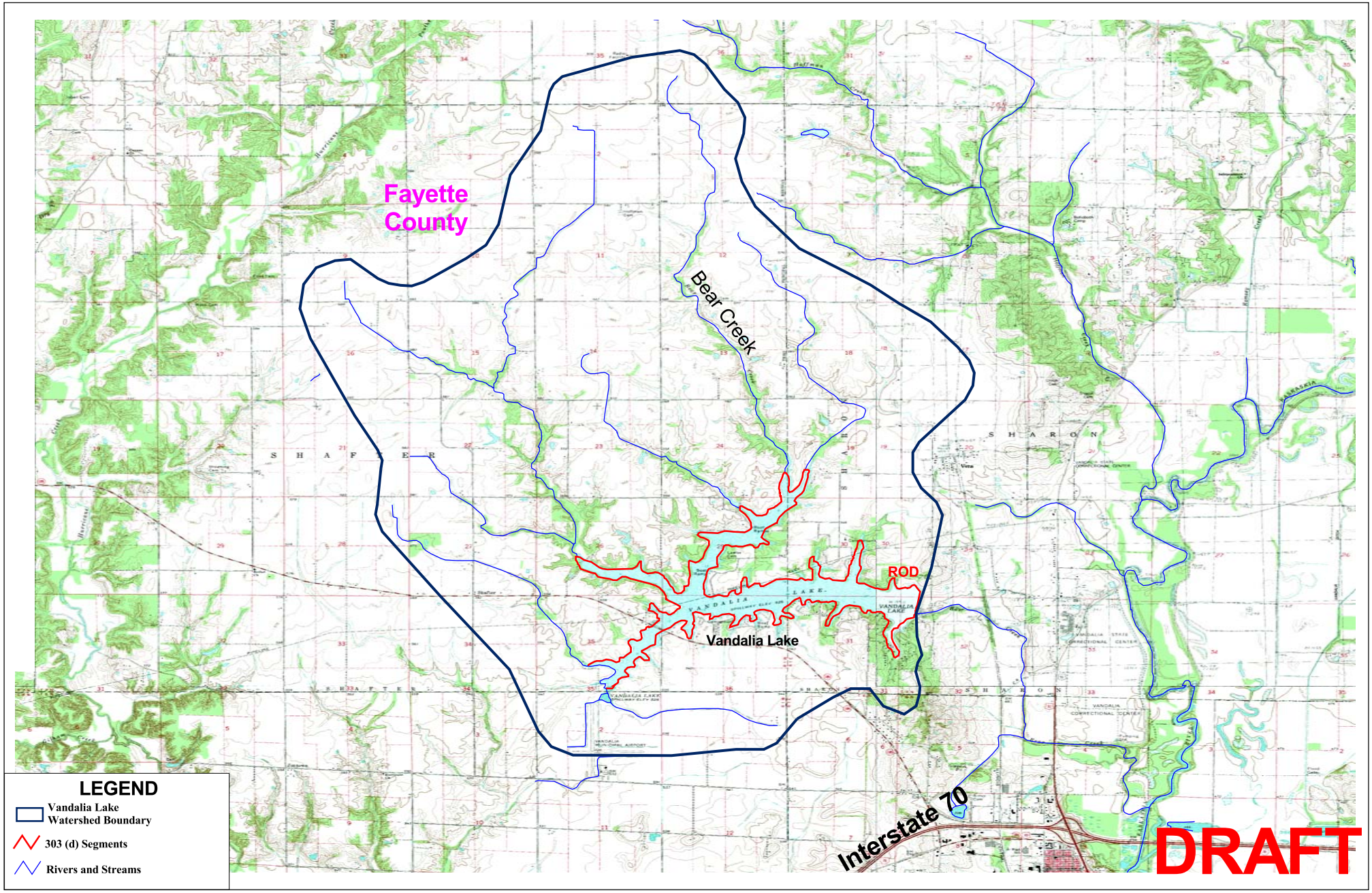

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Figure 1-1
Vandalia Lake Watershed (ILO08)
Impaired Water Bodies

CDM

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Section 2
Vandalia Lake Watershed Description

2.1 Vandalia Lake Watershed Overview

The Vandalia Lake Watershed is located in Fayette County, Illinois. The watershed is located within the U.S. Geological Survey (USGS) Kaskaskia River Basin (Hydrologic Unit Code [HUC] 07140202). The Vandalia Lake Watershed encompasses an area of approximately 25 square miles. Figure 1-1 shows the impaired lake segment within the watershed. The impaired segment is shown in red. Table 2-1 lists the water body segment, water body size, and potential causes of impairment for each water body.

Table 2-1 Impaired Water Bodies in Vandalia Lake Watershed

Water Body Segment ID	Water Body Name	Size	Potential Causes of Impairment
ROD	Vandalia Lake	660 acres	Phosphorus, pH

Land use data was obtained from the Critical Trends Assessment Land Cover Database of Illinois (Illinois Department of Natural Resources [IDNR] 1996). Land use in the watershed is predominantly agricultural followed by rural grassland and forested land uses. Farmers in the area primarily raise cash crops, such as corn and soybeans.

Soils within the Vandalia Lake Watershed are characterized as being very slowly permeable to slowly permeable. Typically, the surface layer is very dark grayish brown silt loam about seven to nine inches thick. The underlying subsurface layer is a silty clay loam (U.S. Department of Agriculture [USDA] 1997).

The climate in the Vandalia Lake Watershed is cold in the winter and warm in the summer. In the winter, October through March, the average temperature is 39 degrees Fahrenheit (°F) and the average daily minimum temperature is 29°F according to data collected at Vandalia, Illinois. Summer temperatures are typically 68°F with an average daily maximum of 79°F. Annual precipitation is 39 inches of which 22 inches, approximately 56 percent, usually falls in April through September (National Climatic Data Center [NCDC] 2002).

2.2 Lake Segment Site Reconnaissance of Vandalia Lake Watershed

The project team conducted a site reconnaissance of the Vandalia Lake Watershed on June 18, 2001. This section briefly describes the lake segment and the site reconnaissance.

Vandalia Lake at Illinois Rt. 15 crossing, looking southwest at bank erosion.

Illinois EPA has listed one lake segment as impaired based on the 1998 303(d) list in the Vandalia Lake Watershed. Vandalia Lake, Segment ROD, is located on Bear Creek, a tributary to the Kaskaskia River in south central Fayette County as shown in Figure 1-1. Vandalia Municipal Reservoir Dam was constructed on Bear Creek in 1965. The dam is owned by the city of Vandalia. The dam structure is 1,600 feet in length and 50 feet tall enabling it to store a maximum of 13,460 acre-feet, although the normal storage volume is 5,560 acre-feet. The dam inundates an area of 660 acres and is used for both recreation and water supply. The contributing drainage area of Vandalia Lake is approximately 25 square miles and is comprised of Bear Creek and two unnamed tributaries (U.S. Army Corps of Engineers [USACE] 1999a).

Small pond cut off from Vandalia Lake by a roadway was overgrown with algae.

Vandalia Lake was observed from several points around the lake, including the public boat docks, the reservoir, and the Illinois Route 185 bridge crossing. Vacation homes, trailers, and permanent residences were all evident at Vandalia Lake, with swimming and boating access also available. It appeared that no municipal sewer district provides service to the area. Several areas of the shoreline were eroded, and others were stabilized with retaining walls or riprap. A nearby section of the lake that was cut off from the main body of the lake by a low roadway was overgrown with algae.

Section 3
Public Participation and Involvement

3.1 Vandalia Lake Watershed Public Participation and Involvement

Public knowledge, acceptance, and follow through are necessary to implement a plan to meet recommended TMDLs. It was important to involve the public as early in the process as possible to achieve maximum cooperation and counter concerns as to the purpose of the process and the regulatory authority to implement the recommendations. A public meeting was held to discuss the Vandalia Lake Watershed at 6:30 p.m. on December 4, 2001 at the American Legion in Vandalia, Illinois. A total of nine interested citizens including public officials and organizations other than Illinois EPA attended the public meeting.

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Section 4
Vandalia Lake Watershed Water Quality Standards

4.1 Illinois Water Quality Standards

Water quality standards are developed and enforced by the state to protect the "designated uses" of the state's waterways. In the state of Illinois, setting the water quality standards is the responsibility of the Illinois Pollution Control Board (IPCB). Illinois is required to update water quality standards every three years in accordance with the CWA. The standards requiring modifications are identified and prioritized by Illinois EPA, in conjunction with USEPA. New standards are then developed or revised during the three-year period.

Illinois EPA is also responsible for developing scientifically based water quality criteria and proposing them to the IPCB for adoption into state rules and regulations. The Illinois water quality standards are established in the Illinois Administrative Rules Title 35, Environmental Protection; Subtitle C, Water Pollution; Chapter I, Pollution Control Board; Part 302, Water Quality Standards.

4.2 Designated Uses

The waters of Illinois are classified by designated uses, which include: General Use, Public and Food Processing Water Supplies, Lake Michigan, and Secondary Contact and Indigenous Aquatic Life Use (Illinois EPA 2000). The only designated uses applicable to the Vandalia Lake Watershed are the General Use and Public and Food Processing Water Supplies use.

4.2.1 General Use

The General Use classification provides for the protection of indigenous aquatic life, primary and secondary contact recreation (e.g., swimming or boating), and agricultural and industrial uses. The General Use is applicable to the majority of Illinois streams and lakes (Illinois EPA 2000).

4.2.2 Public and Food Processing Water Supplies

The Public and Food Processing Water Supplies use was developed for the protection of potable water supplies and water used for food processing purposes. These waters have more stringent water quality standards and apply at any point from which water is withdrawn for these uses (Illinois EPA 2000).

4.3 Illinois Water Quality Standards

To make 303(d) listing determinations, Illinois EPA compares collected data for the water body to the available water quality standards developed by Illinois EPA for assessing water body impairment. Table 4-1 presents the water quality standards of the potential causes of impairment for TMDLs that will be developed in the Vandalia Lake

Watershed. These water quality standards are further discussed in the remainder of the section.

Table 4-1 Summary of General Use Water Quality Standards for Vandalia Lake Watershed

Parameter	General Use Water Quality Standard
Phosphorous	0.05 mg/L Lakes/reservoirs >20 acres and streams entering lakes or reservoirs
pH	6.5 - 9.0

4.3.1 Phosphorus

Phosphorus is listed as a cause of impairment for Vandalia Lake. The General Use water quality standard for phosphorus shall not exceed 0.05 milligrams per liter (mg/L) in any lake or reservoir with a surface area of 20 acres or more, or in any stream at the point where it enters any such reservoir or lake. The General Use water quality standard for phosphorous does not apply to streams outside the point where the stream enters a lake or reservoir. At this time, Illinois EPA has not established phosphorus water quality standards for streams that do not enter lakes or reservoirs.

Phosphorous is listed as a cause of less than full support use attainment in lakes or reservoirs if the surface total phosphorous concentration is greater than 0.05 mg/L based on Ambient Lake Monitoring Programs (ALMP) or Illinois Clean Lakes Programs (ICLP) data. It is considered a slight impairment if it is between 0.05 mg/L and 0.140 mg/L, a moderate impairment between 0.140 mg/L and 0.400 mg/L, and a high impairment if greater than 0.400 mg/L.

4.3.2 Parameters without Water Quality Standards

It should be noted that although formal TMDLs will not be developed for parameters without water quality standards in the Vandalia Lake Watershed, many of the management measures discussed in Section 9 of this report will result in reductions of the parameters listed in the 1998 303(d) list that do not currently have adopted water quality standards. For example, many of the management measures that will be discussed in Section 9 address the other parameters of concern for the watershed. For nitrogen, management measures that control erosion will reduce these pollutants from entering the reservoir. All management measures discussed in Section 9 will help reduced chlorophyll-a and excessive algal growth within in the reservoir as the BMPs discussed are based on controlling nutrient levels in the reservoir.

4.4 Pollutant Sources

As part of the Illinois EPA use assessment presented in the annual Illinois Water Quality Report, the causes of the pollutants resulting in a less than full support use attainment are associated with a potential source, based on data, observations, and other existing information. The following is a summary of the sources associated with the listed causes for the TMDL listed segments in this watershed. They are summarized in Table 4-2.

Table 4-2 Summary of Potential Sources of Pollutants

Potential Source	Cause of Impairment
Land Disposal Onsite wastewater systems (septic tanks)	Phosphorous
Agriculture Nonirrigated crop production Pasture Land Animal Holding/Management Areas	Phosphorous
Contaminated Sediments	Phosphorous
Urban Runoff/Storm Sewers	Phosphorous

4.4.1 Land Disposal

Land disposal sources include onsite wastewater systems, mainly septic systems. Several residential/camping areas and an Old Shriners Club were observed on the banks of Vandalia Lake. Most of these areas appeared to be connected to septic systems. These systems are designed to remove solids from wastewater. The domestic waste constituents such as nitrogen, nitrate, and phosphorous pass through the septic tanks and into the leach fields. Given the close proximity to the lake, the leachate flow direction would likely be to the lake. Control of phosphorous entering the lake may reduce the amount of algal growth/chlorophyll "a."

4.4.2 Agriculture

The southern Illinois area is largely agriculture land use. Row crop agriculture is the largest single category land use in the basin. Agricultural land uses potentially contribute sediment, total suspended solids (TSS), nitrogen, phosphorus and biochemical oxygen demand (BOD) loads to the water resource loading. The amount that is contributed is a function of the soil type, slope, crop management, precipitation, total amount of cropland, and the distance to the water resource (Muir et al. 1997).

Erosion of the land and streambanks carries sediment to the streams and lakes, resulting in higher levels of TSS and siltation. This can be also be caused by livestock on pastures and feedlots. Wastes from livestock can enter streams, adding to the pollutant loadings.

4.4.3 Contaminated Sediments

Sediments are carried to streams, lakes, and reservoirs during runoff conditions and are generally deposited in streambeds or lake bottoms. Constituents contained in sediment may include nutrients, which can impact BOD loads. Both agricultural lands and urban areas contribute to the nutrient loading in the sediment.

Suspended sediments settle out to stream bottoms during periods of low flow. During periods of high flow, sediments are resuspended and carried downstream to be deposited in another location. Once the sediment reaches a lake or reservoir, the sediments are deposited and typically accumulate in these areas. The source of the contaminated sediment can therefore be located much farther upstream than the location detected.

Contaminated sediments can slowly leach contaminants to the water column, thereby being a continual source of impact to the water body. Phosphorous is commonly released from sediment into the water column especially when anoxic conditions persist.

4.4.4 Urban Runoff/Storm Sewers

Urban areas in the Vandalia Lake Watershed constitute a small percentage of land use in the watershed; however, polluted runoff from urban sections can be significant. Runoff from urban areas reaches streams or lakes either by sheet flow runoff or through storm sewer discharges. The runoff can originate from any number of areas including highways; roadways; parking lots; industrial, commercial, or residential areas; or undeveloped lands. Phosphorous can originate from fertilizer use, natural phosphorous levels in sediment, and from sanitary waste where combined sewer overflows are present.

Section 5
Vandalia Lake Watershed Data Review

5.1 Existing Data Review

The following data sources were reviewed for model selection and analysis:

- Mapping data
- Topography data
- Flow data
- Precipitation data
- Temperature data
- Evaporation data
- Existing water quality data
- Land use
- Soil data
- Cropping practices
- Reservoir characteristics
- Point sources
- Dairy and animal confinement locations
- Septic systems

5.1.1 Mapping Data

USGS quadrangle maps (scale 1:24,000) were collected for the watershed in paper and electronic form. These were utilized for base mapping.

5.1.2 Topography Data

A Digital Elevation Model (DEM) was used to delineate watersheds in a geographic information system (GIS) for Vandalia Lake segment ROD. A DEM is a digital representation of the landscape as a GIS-compatible grid in which each grid cell is assigned an elevation. DEMs of 90-meter resolution were downloaded from the *BASINS* database (USEPA 2002a) for watershed delineation. GIS watershed delineation defines the boundaries of a watershed by computing flow directions from elevations and locating elevation peaks on the DEM. The GIS-delineated watershed was checked against USGS 7.5-minute topographic maps to ensure agreement between the watershed boundaries and natural topographic boundaries. Figure 5-1 at the end of this section shows the location of historic water quality gages and the watershed boundaries for the Vandalia Lake Watershed. The watershed boundaries define the area investigated for causes of impairments in each segment.

5.1.3 Flow Data

Analyses of the Vandalia Lake Watershed require an understanding of flow into Vandalia Lake. No gage for the tributary to Vandalia Lake exists, and there is no active stream gage within the impaired segment. Therefore, the drainage area ratio method, represented by the following equation, was used to estimate flows within the watersheds.

$$Q_{gaged}\left(\frac{Area_{ungaged}}{Area_{gaged}}\right) = Q_{ungaged}$$

where Q_{gaged} = Streamflow of the gaged basin
$Q_{ungaged}$ = Streamflow of the ungaged basin
$Area_{gaged}$ = Area of the gaged basin
$Area_{ungaged}$ = Area of the ungaged basin

The assumption behind the equation is that the flow per unit area is equivalent in watersheds with similar characteristics. Therefore, the flow per unit area in the gaged watershed times the area of the ungaged watershed will result in a flow for the ungaged watershed.

USGS gage 05595820 (Casey Fork at Mount Vernon, Illinois) was chosen as an appropriate gage from which to compute flow into Vandalia Lake. Gage 05595820 captures flow from a drainage area of 77 square miles in an upstream section of the Casey Fork watershed, which is about 50 miles southeast of the Vandalia Lake watershed. Daily streamflow data for the gage were downloaded from the USGS National Water Inventory System (NWIS) for the entire period of record from October 1, 1985, to September 30, 2000 (USGS 2002a). Figure 5-2 at the end of this section shows the average monthly flow over the period of record into the Vandalia Lake calculated from the drainage area ratio method using gage 05595820. The average monthly flows into Vandalia Lake range from 5.7 cubic feet per second (cfs) to 33.4 cfs with a mean annual flow of 5.7 cfs.

5.1.4 Precipitation, Temperature, and Evaporation Data

As discussed in Section 2.1, the Vandalia Lake Watershed is located within Fayette County. Daily precipitation and temperature data for Fayette County were extracted from the NCDC database for the years of 1985 through 2001. Eighteen months of data were missing from the Fayette County gage over the period from 1985 to 2001. Missing data were supplemented with data from a gage in neighboring Effingham County. Table 5-1 lists the station details for the Effingham County and Fayette County gages.

Table 5-1 Historical Precipitation Data for the Vandalia Lake Watershed

NCDC Gage Number	Station Location	Period of Record
8781	Fayette County (Vandalia)	1948-present
2687	Effingham County (Effingham)	1901-present

Table 5-2 Average Monthly Precipitation in Fayette County from 1985 to 2001

Month	Average Precipitation (inches)
January	2.7
February	2.5
March	3.0
April	3.8
May	4.4
June	3.8
July	4.1
August	2.8
September	2.9
October	2.6
November	4.3
December	2.4
TOTAL	39.3

Table 5-2 shows the average monthly precipitation of the dataset developed for Fayette County for the years 1985 to 2001. The average annual precipitation over the same period is approximately 39 inches for Fayette County.

Pan evaporation data is available through the Illinois State Water Survey (ISWS) website at nine locations across Illinois (ISWS 2000). The Carlyle station was chosen for its proximity to the 303(d)-listed water bodies and stream segments in southern Illinois and the completeness of the dataset as compared to other stations. The Carlyle station is approximately 30 miles southwest of the Vandalia Lake Watershed. The average monthly pan evaporation for the years 1980 to 2001 at the Carlyle station was downloaded from the ISWS website and summed to produce an average annual pan evaporation of 44.2 inches. Actual evaporation is typically less than pan evaporation, so the average annual pan evaporation was multiplied by 0.75 to calculate an average annual evaporation of 33.2 inches (ISWS 2000).

5.1.5 Water Quality Data

Three historic water quality stations exist within the Vandalia Lake Watershed and are presented in Table 5-3. This table provides the location, station identification number, and the agency that collected the water quality data. Location and station identification number are also shown in Figure 5-1.

Table 5-3 Historical Water Quality Stations for Vandalia Lake Watershed

Location	Station Identification Number	Data Collection Agency
Vandalia Lake	RO-B03-D-1	Illinois EPA Division of Water Pollution Control
Vandalia Lake	RO-B03-D-2	Illinois EPA Division of Water Pollution Control
Vandalia Lake	RO-B03-D-3	Illinois EPA Division of Water Pollution Control

The impaired water body segment in the Vandalia Lake Watershed segment ROD was presented in Section 2. Table 5-4 summarizes available historic water quality data since 1990 from the USEPA *Storage and Retrieval (STORET)* database associated with impairments discussed in Section 2 for the Vandalia Lake Watershed.

Table 5-4 Summary of Constituents Associated with the Impairments for Vandalia Lake

Sample Location and Parameter	Period of Record Examined for Samples	Number of Samples
Vandalia Lake Segment ROD; Sample Location ROD-1, ROD-2, ROD-3		
ROD-1		
Phosphorus	5/23/90-10/26/99	49
pH	4/7/93-10/26/99	15
ROD-2		
Phosphorus	4/7/93-10/26/99	16
pH	4/7/93-10/26/99	15
ROD-3		
Phosphorus	5/23/90-10/26/99	22
pH	4/7/93-10/26/99	15

5.1.5.1 Vandalia Lake Water Quality Data

There are three active water quality stations in Vandalia Lake as shown in Figure 5-1 and listed in Table 5-3. The water quality station data for Vandalia Lake were downloaded from the *STORET* online database (USEPA 2002b). Data collected after 1998 were available from the Illinois EPA and were incorporated into the electronic database. The data summarized in this section include water quality data for impaired constituents in Vandalia Lake as well as constituents used in modeling efforts. The raw data are contained in Appendix A.

Constituents are sampled at various depths throughout Vandalia Lake, and compliance with water quality standards is determined by the sample at a one-foot depth from the lake surface. This section discusses the one-foot depth samples of water quality constituents used in modeling efforts for Vandalia Lake. The exception is chlorophyll "a," which was sampled at various depths at each water quality station and will be presented as an average over all sample depths. Modeling of the reservoir required use of phosphorus samples at all depths, which is discussed and presented in Section 7.3.3.2.

5.1.5.1.1 Total Phosphorus

The average total phosphorus concentrations at one-foot depth for each year of available data from 1990 to 1999 at each monitoring site in Vandalia Lake are presented in Table 5-5. At station ROD-1, samples were taken at a one-foot depth from the lake surface and at the lake bottom. Samples at stations ROD-2 and ROD-3 were only taken at a one-foot depth from the lake surface. The water quality standard for total phosphorus is less than or equal to 0.05 mg/L at a one-foot depth. The TMDL endpoint for total phosphorus in lakes is 0.05 mg/L. The raw data for all sample depths are contained in Appendix A.

Table 5-5 Average Total Phosphorus Concentrations (mg/L) in Vandalia Lake at One-Foot Depth (Illinois EPA 2002 and USEPA 2002b)

Year	ROD-1	ROD-2	ROD-3	Lake Average
1990	0.17	–	0.13	0.15
1993	0.07	0.08	0.09	0.08
1995	0.07	0.07	0.08	0.07
1996	0.11	0.12	0.14	0.12
1997	0.06	–	–	0.06
1998	0.08	–	–	0.08
1999	0.04	0.04	0.07	0.05

The annual averages for total phosphorus at all three stations and the annual lake averages are all greater than the endpoint of 0.05 mg/L except for stations ROD-1 and ROD-2 in 1999. It is apparent from Table 5-5 that concentrations at all stations repeatedly violate the phosphorus standard.

Phosphorus exists in water in either a particulate phase or a dissolved phase. Particulate matter includes living and dead plankton, precipitates of phosphorus, phosphorus adsorbed to particulates, and amorphous phosphorus. The dissolved phase includes inorganic phosphorus and organic phosphorus. Phosphorus in natural waters is usually found in the form of phosphates (PO4-3). Phosphates can be in inorganic or organic form. Inorganic phosphate is phosphate that is not associated with organic material. Types of inorganic phosphate include orthophosphate and polyphosphates. Orthophosphate is sometimes referred to as "reactive phosphorus." Orthophosphate is the most stable kind of phosphate, and is the form used by plants or algae. There are several forms of phosphorus that can be measured. Total phosphorus is a measure of all the forms of phosphorus, dissolved or particulate, that are found in a sample. Soluble reactive phosphorus is a measure of orthophosphate, the filterable (soluble, inorganic) fraction of phosphorus, the form directly taken up by plant cells.

5.1.5.1.2 pH

The average pH measurements at one-foot depth for each year of available data after 1990 at each monitoring site in Vandalia Lake are presented in Table 5-6. At station ROD-1, samples were taken at one-foot depth from the lake surface and at the lake bottom. Samples at stations ROD-2 and ROD-3 were only taken at a one-foot depth from the lake surface. The TMDL endpoints for pH are a minimum of 6.5 and a maximum of 9.0. The annual averages at all three stations and the annual lake averages are all within the endpoint limits, but individual measurements in 1996 and 1999 exceeded the upper limit. Specifically, the pH value on August 23, 1996 was 9.2 at station ROD-1 and 9.1 at stations ROD-2 and ROD-3, and on June 11, 1999, the pH value measured at ROD-2 was 9.1. The raw data are contained in Appendix A.

Table 5-6 Average pH (s.u.) Values in Vandalia Lake at One-foot Depth

	ROD-1	ROD-2	ROD-3	Lake Average
1993	8.1	8.2	8.0	8.1
1996	8.1	8.2	8.2	8.2
1999	8.5	8.6	8.5	8.5

Fluctuations in pH can be correlated to photosynthesis from algae. Chlorophyll "a" indicates presence of excessive algal or aquatic plant growth, which is a typical response to excess phosphorus loading (Wetzel 1983). Reducing total phosphorus is likely to reduce algal growth thus resulting in attainment of the pH standard. Therefore, the relationship between pH, chlorophyll "a," and total phosphorus in Vandalia Lake was investigated. The correlation between pH and chlorophyll "a" is expected to indicate a direct relationship between the two constituents. Likewise, the correlation between chlorophyll "a" and total phosphorus is expected to indicate a direct relationship. These relationships would suggest that controlling phosphorus will decrease chlorophyll "a" concentrations, which will in turn control the pH. This hypothesis is supported by Wetzel who asserts that photosynthesis and respiration are major influences on pH (1983).

5.1.5.1.3 Chlorophyll "a"

The average chlorophyll "a" concentrations for each year of available data from 1990 to 2001 at each monitoring site in Vandalia Lake are presented in Table 5-7. The raw data for all sample depths are contained in Appendix A.

Table 5-7 Chlorophyll "a" Concentrations (µg/L) in Vandalia Lake

	ROD-1	ROD-2	ROD-3	Lake Average
1993	20.4	21.2	22.4	21.3
1996	26.6	18.4	23.3	22.8
1997	26.8	–	–	26.8
1998	51.2	–	–	51.2
1999	31.7	37.0	45.3	38.0

5.1.5.1.4 Tributary Data

There is no water quality data available for the tributaries to Vandalia Lake. One tributary to Vandalia Lake is Bear Creek as shown on Figure 5-1. The remaining tributaries are unnamed. Tributary water quality data along with flow information would be useful in assessing contributing loads from the watersheds to help differentiate between external loading and internal loading. External loads are those loadings from the watershed such as nonpoint source runoff and point sources. Internal loads are caused by low DO conditions near lake sediments, which promote re-suspension of phosphorus from the sediments into the water column. External versus internal loads will be discussed further in Section 7.4.

5.1.6 Land Use

The Illinois Natural Resources Geospatial Clearinghouse distributes the Critical Trends Assessment Land Cover Database of Illinois. This database represents 23 land use classes created by satellite imagery captured between 1991 and 1995. The data were published in 1996 and are distributed by county in grid format for use in GIS. The GIS-delineated watershed for Vandalia Lake was used to obtain the land use from the Critical Trends Assessment Land Cover grid. Table 5-8 lists the land uses contributing to the Vandalia Lake Watershed as well as each land use area and percent of total area.

Table 5-8 Critical Trends Assessment Land Uses in Vandalia Lake (IDNR 1996)

Land Use	Acres	Percent of Area
Row Crop (corn, soybeans, and other tilled crops)	9,664	65%
Rural Grassland*		
CRP	1,258	9%
Waterways/Buffers	472	3%
Pasture	157	1%
Grassland	1,258	9%
Deciduous Forest	946	6%
Small Grains (wheat, oats, etc.)	842	6%
Wetlands	91	1%
Urban Grassland (parks, residential lawns, golf courses, cemeteries, and other open space)	56	0%
Urban (high and medium density)	29	0%
Total	14,773	100%

*Subclasses of rural grassland were estimated by the Fayette County NRCS (2002a)

Additional land use data were obtained from the Spatial Analysis Research Center's Cropland Data Layer to supplement the Critical Trends Assessment dataset. The data were requested from the National Agricultural Statistics Service (NASS) website for the years of 1999 and 2000 (NASS 2002). The Cropland Data Layer is also derived from satellite imagery, but the land use classes for crops are more detailed than those presented in the Critical Trends Assessment dataset. The detailing of crops in the Cropland Data Layer land use classes makes it a more accurate dataset for calculation of crop-related parameters. The dataset was also used to verify the land use obtained from the Critical Trends Assessment. Table 5-9 shows the cropland use classes of the Cropland Data Layer and the Critical Trends Assessment classes to which they were applied.

Table 5-9 Comparison of Land Use Classes in Vandalia Lake

Cropland Data Layer Land Use Class	Critical Trends Assessment Land Use Class
Corn	Row Crop
Sorghum	Small Grains
Soybeans	Row Crop
Winter Wheat	Small Grains
Other Small Grains & Hay	Small Grains
Double-Cropped Winter Wheat/Soybeans	Half to Small Grains Half to Row Crops

5.1.7 Animal Confinement Operations

There were no dairies identified in the Vandalia Lake Watershed from existing databases and communication with watershed stakeholders. The Vandalia Lake Watershed Implementation Plan identifies a hog confinement operation located on the north boundary of the watershed. It also states that the operation's waste lagoon resides outside of the watershed (2000). This operation was not modeled due to a lack of information about the size of the operation and the knowledge that the waste lagoon lies outside of the watershed. The plan also notes operations of small numbers of beef

cattle, which are primarily on pastureland. The locations of these operations are unknown and the impacts are assumed to be slight due to the small size of the operations. Therefore, the beef cattle operations were not modeled (VLPC 2000).

5.1.8 Soil Data

State Soil Geographic (*STATSGO*) Database data, created by the USDA – National Resource Conservation Service (NRCS) Soil Survey Division, are aggregated soil surveys for GIS use published for Illinois in 1994. The *STATSGO* shapefiles were downloaded by HUC from the USEPA *BASINS* website (USEPA 2002a). *STATSGO* data are presented as map units of soils in which each map unit has a unique code linking it to attribute tables listing percentages of soil types within a map unit, soil layer depths, hydrologic soil groups, and soil texture among other soil properties.

5.1.9 Cropping Practices

Tillage practices can be categorized as conventional till, reduced till, mulch-till, and no-till. The percentage of each tillage practice for corn, soybeans, and small grains by county are generated by the Illinois Department of Agriculture from County Transect Surveys. Data specific to the Vandalia Lake Watershed were not available; however, the Fayette County NRCS office verified that the percentages of each tillage practice were acceptable for application to the Vandalia Lake Watershed as shown in Table 5-10 (NRCS 2002a).

Table 5-10 Tillage Practices in Fayette County (Fayette County Soil & Water Conservation District, 2001)

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	82%	33%	25%
Reduced Till	4%	10%	3%
Mulch-Till	8%	29%	42%
No-Till	6%	28%	30%

Crop rotation practices in the Vandalia Lake Watershed were obtained from the Effingham County NRCS office (2002a). The typical rotations in the watershed are a two-year rotation of corn and soybeans and a three-year rotation of corn, soybeans, and wheat.

5.1.10 Reservoir Characteristics

Reservoir characteristics were obtained from GIS analysis, the Illinois EPA, the Vandalia Lake Watershed Water Quality Inventory, and USEPA water quality data.

The Vandalia Lake Watershed Water Quality Inventory written by the Vandalia Lake Watershed Planning Committee lists a surface area of 660 acre-feet. This value was used to validate the surface area of 677 acres obtained from GIS analysis. For modeling analyses, the area obtained through GIS analysis was scaled to equal the area from the inventory plan.

The water quality dataset described in Section 5.1.5.1 was used to determine the average depth of Vandalia Lake. On each date sampled for water quality constituents, the total depth at the site was measured. Table 5-11 lists the average depth calculated for each water quality site in Vandalia Lake for each year of available data after 1990.

Table 5-11 Average Depths (ft) for Vandalia Lake (Illinois EPA 2002 and USEPA 2002a)

	ROD-1	ROD-2	ROD-3	Lake Average
1990	28.2	21.5	14.6	21.4
1991	28.3	21.1	13.9	21.1
1992	27.7	21.3	14.7	21.2
1993	29.1	23.2	23.2	25.1
1994	27.9	23.0	14.9	21.9
1995	28.6	21.9	13.9	21.5
1996	28.5	22.4	14.0	21.6
1997	28.8	23.0	15.2	22.3
1998	28.8	22.9	13.8	21.8

Reservoir characteristics that were unavailable were flows into and out of the reservoir.

5.1.11 Septic Systems

Typically, septic systems near lake waters have greater potential for impacting water quality than systems near streams due to their proximity to the water body of concern. The Vandalia Lake Watershed contains about 400 septic systems used by seasonal and permanent residents (Vandalia Lake Planning Committee [VLPC] 2000).

5.1.12 Aerial Photography

Aerial photographs of the Vandalia Lake Watershed were obtained from the Illinois Natural Resources Geospatial Data Clearinghouse. The photographs were used to supplement the USGS quadrangle maps when locating facilities.

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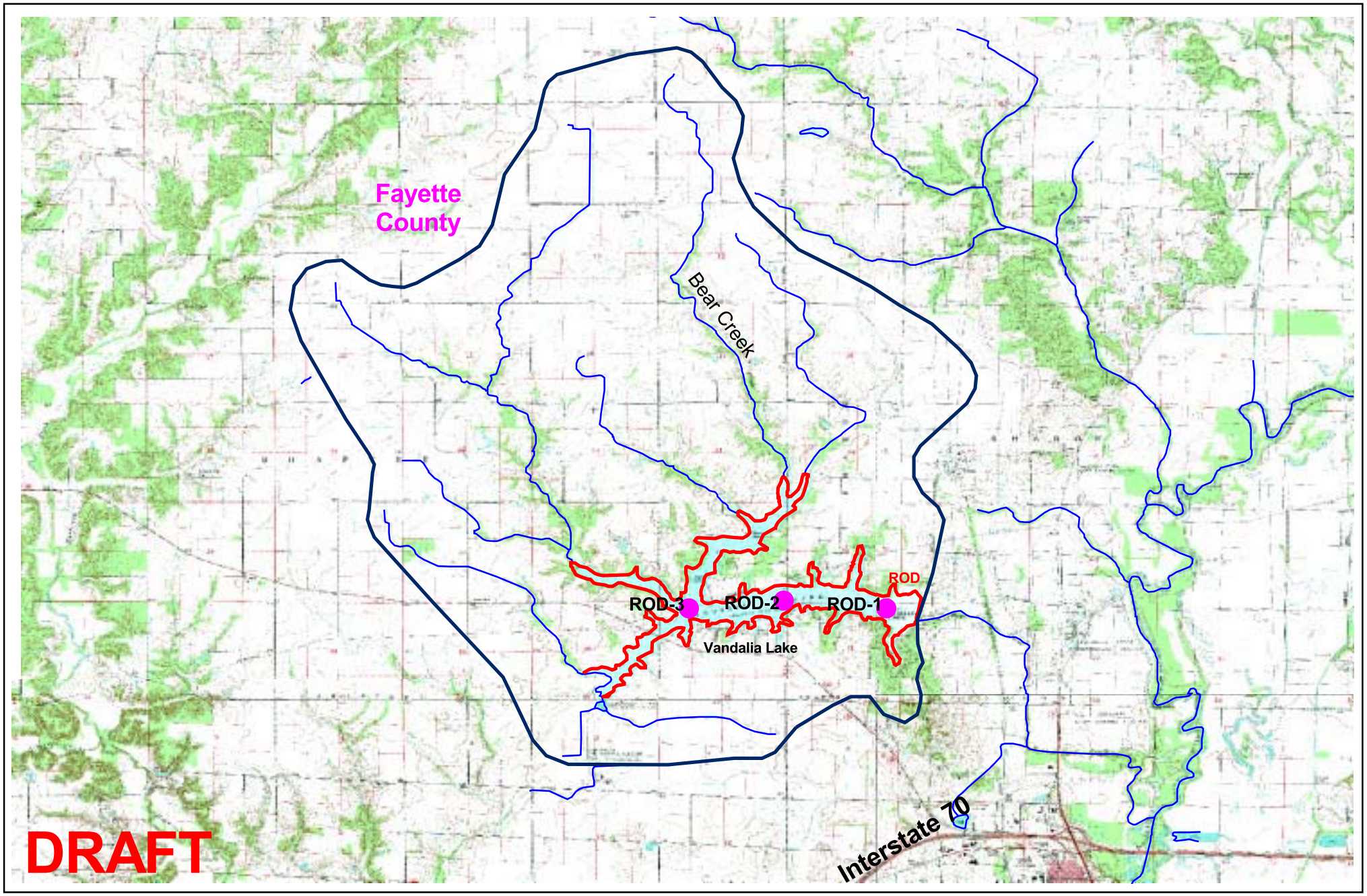

LEGEND

- Water Quality Site
- 303(d) Listed Segment
- Rivers
- Vandalia Lake Watershed Subbasin Boundaries

N

0.4 0 0.4 Miles

Figure 5-1
Vandalia Lake Watershed
and Historic Sampling Locations

CDM

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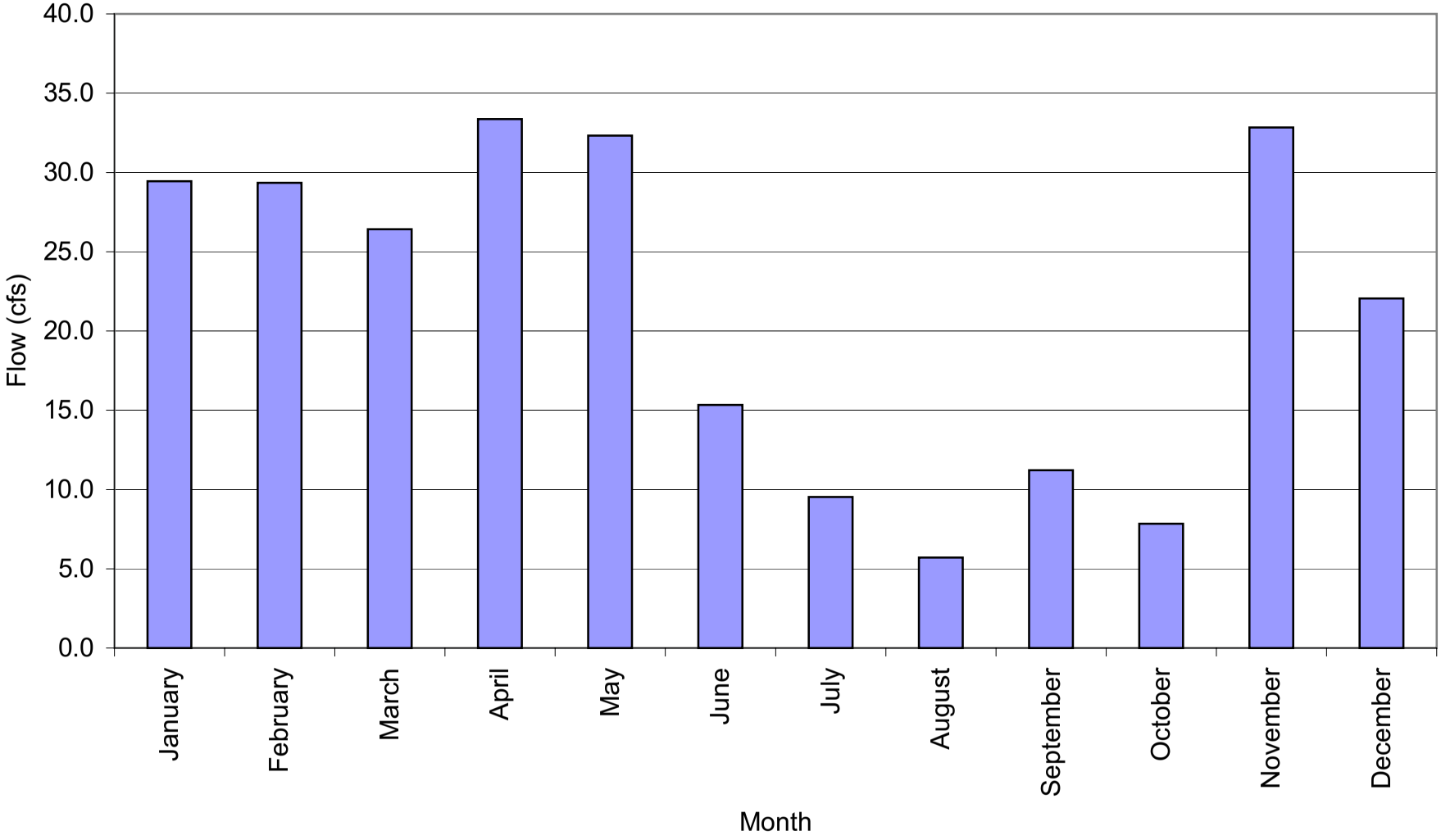
Figure 5-2: Estimated Streamflows in the Vandalia Lake Watershed Calculated from Gage 05595820



CDM

DRAFT

Period of Record
October 1, 1985, to September 30, 2000

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Section 6
Methodologies and Models to Complete TMDLs for the Vandalia Lake Watershed

6.1 Set Endpoints for TMDLs

TMDLs are used to define the total amount of pollutants that may be discharged into a particular water body within any given day based on a particular use of that water body. Developing TMDLs must, therefore, account for both present and future lake users, habitat, flow variability, and current and future point and nonpoint pollutant loadings that may impact the water body. Defining a TMDL for any particular lake segment must take into account not only the science related to physical, chemical, and biological processes that may impact water body water quality, but must also be responsive to temporal changes in the watershed and likely influences of potential solutions to water quality impairments on entities that reside in the watershed.

Stream and lake water quality standards were presented in Section 4, specifically in Table 4-1. Biological data, such as the Index of Biotic Integrity (IBI) and the Macroinvertebrate Biotic Index (MBI), are used to support 305(b) and 303(d) listing decisions; however, TMDLs were not developed specifically to meet biological endpoints for the Vandalia Lake Watershed. The endpoints presented in Section 4, which are chemical endpoints of the following constituents, were targeted: phosphorus and pH.

6.2 Methodologies and Models to Assess TMDL Endpoints

Methodologies and models were utilized to assess TMDL endpoints for the Vandalia Lake Watershed. Model development is more data intensive than using simpler methodologies or mathematical relationships for the basis of TMDL development. In situations where only limited or qualitative data exist to characterize impairments, methodologies were used to develop TMDLs and implementation plans as appropriate.

In addition to methodologies, watershed and receiving water computer models are available for TMDL development. Most models have similar overall capabilities but operate at different time and spatial scales and were developed for varying conditions. The available models range between empirical and physically based. However, all existing watershed and receiving water computer models simplify processes and often include obviously empirical components that omit the general physical laws. They are, in reality, a representation of data.

Each model has its own set of limitations on its use, applicability, and predictive capabilities. For example, watershed models may be designed to project loads within annual, seasonal, monthly, or storm event time-scales with spatial scales ranging from large watersheds to small subbasins to individual parcels such as construction sites. With regard to time, receiving water models can be steady state, quasi-dynamic, or

fully dynamic. As the level of temporal and spatial detail increases, the data requirements and level of modeling effort increase.

6.2.1 Watershed Models

Watershed or loading models can be divided into categories based on complexity, operation, time step, and simulation technique. USEPA has grouped existing watershed-scale models for TMDL development into three categories based on the number of processes they incorporate and the level of detail they provide (USEPA 1997):

- Simple models
- Mid-range models
- Detailed models

Simple models primarily implement empirical relationships between physiographic characteristics of the watershed and pollutant runoff. A list of simple category models with an indication of the capabilities of each model is shown in Table 6-1. Simple models may be used to support an assessment of the relative significance of different nonpoint sources, guide decisions for management plans, and focus continuing monitoring efforts. Generally, simple models aggregate watershed physiographic data spatially at a large-scale and provide pollutant loading estimates on large time-scales. Although they can easily be adopted to estimate storm event loading, their accuracy decreases since they cannot capture the large fluctuations of pollutant concentrations observed over smaller time-scales.

Table 6-1 Evaluation of Watershed Model Capabilities - Simple Models (USEPA 1997)

Criteria		USEPA Screening[1]	Simple Method[1]	Regression Method[1]	SLOSS-PHOSPH[2]	Watershed	FHWA	WMM
Land Uses	Urban	○	◒	◒	–	◒	○[3]	●
	Rural	◒	–	○	◒	◒	○	●
	Point Sources	–	–	–	–	○	–	○
Time-scale	Annual	●	●	●	●	●	●	●
	Single Event	○	○	○	–	–	○	–
	Continuous	–	–	–	–	–	–	–
Hydrology	Runoff	–[4]	◒	–	–	–	○	○
	Baseflow	–	–	–	–	–	–	○
Pollutant Loading	Sediment	◒	◒	◒	◒	◒	–	–
	Nutrients	◒	◒	◒	◒	◒	◒	◒
	Others	○	◒	◒	–	◒	◒	◒
Pollutant Routing	Transport	–	–	–	–	–	–	–
	Transformation	–	–	–	–	–	–	○
Model Output	Statistics	–	–	–	–	◒	○	○
	Graphics	–	–	–	–	◒	–	○
	Format Options	–	–	–	–	◒	–	○
Input Data	Requirements	○	○	○	○	○	○	○
	Calibration	–	–	–	○	◒	–	◒
	Default Data	●	●	◒	◒	○	◒	◒
	User Interface	–	–	–	–	◒	○	◒
BMPs	Evaluation	○	○	–	○	◒	◒	◒
	Design Criteria	–	–	–	–	–	–	–
Documentation		●	●	●	●	●	●	◒

[1] Not a computer program
[2] Coupled with GIS
[3] Highway drainage basins
[4] Extended Versions recommended use of SCS-curve number method for runoff estimation

● High ◒ Medium ○ Low – Not Incorporated

Mid-range models attempt a compromise between the empiricism of the simple models and complexity of detailed mechanistic models. Mid-range models are designed to estimate the importance of pollutant contributions from multiple land uses and many individual source areas in a watershed. Therefore, they require less aggregation of the watershed physiographic characteristics than the simple models. Mid-range models may be used to define large areas for pollution migration programs on a watershed basis and make qualitative evaluations of BMP alternatives. A list of models within the mid-range category and their capabilities is shown in Table 6-2.

Table 6-2 Evaluation of Watershed Model Capabilities - Mid-Range Models (USEPA 1997)

Criteria		SITEMAP	GWLF	P8-UCM	Auto-QI	AGNPS	SLAMM
Land Uses	Urban	●	●	●	●	–	●
	Rural	●	●	–	–	●	–
	Point Sources	◒	◒	●	–	●	●
Time-scale	Annual	–	–	–	–	–	–
	Single Event	○	–	●	–	●	–
	Continuous	●	●	●	●	–	●
Hydrology	Runoff	●	●	●	●	●	●
	Baseflow	○	●	○	○	–	○
Pollutant Loading	Sediment	–	●	●	●	●	●
	Nutrients	●	●	●	●	●	●
	Others	–	–	●	●	–	●
Pollutant Routing	Transport	○	○	○	◒	●	◒
	Transformation	–	–	–	–	–	–
Model Output	Statistics	◒	○	–	–	–	○
	Graphics	◒	◒	●	–	●	○
	Format Options	●	●	●	○	●	●
Input Data	Requirements	◒	◒	◒	◒	◒	◒
	Calibration	○	○	○	◒	○	◒
	Default Data	●	●	◒	○	◒	◒
	User Interface	●	●	●	◒	◒	●
BMPs	Evaluation	○	○	●	◒	◒	◒
	Design Criteria	–	–	●	◒	◒	○
Documentation		●	●	●	◒	●	◒

● High ◒ Medium ○ Low – Not Incorporated

Detailed models use storm event or continuous simulation to predict flow and pollutant concentrations for a range of flow conditions. These models explicitly simulate the physical processes of infiltration, runoff, pollutant accumulation, instream effects, and groundwater/surface water interaction. These models are complex and were not designed with emphasis on their potential use by the typical state or local planner. Many of these models were developed for research into the fundamental land surface and instream processes that influence runoff and pollutant generation rather than to communicate information to decision makers faced with planning watershed management (USEPA 1997). Although detailed or complex models provide a comparatively high degree of realism in form and function, complexity does not come without a price of data requirements for model construction, calibration, verification, and operation. If the necessary data are not available, and many inputs must be based upon professional judgment or taken from literature, the resulting uncertainty in predicted values undermine the potential benefits from greater realism. Based on the available data for the Vandalia Lake Watershed, a detailed model could not be

constructed, calibrated, and verified with certainty and the watershed model selection should focus on the simple or mid-range models.

6.2.1.1 Watershed Model Recommendation

The watershed model recommendation for Vandalia Lake is the generalized watershed loading function (GWLF) model. The GWLF model was chosen for the Vandalia Lake TMDL based on the following criteria:

- Ease of use and Illinois EPA familiarity
- Compatibility with pollutants of concern and existing data
- Provision of adequate level of detail for decision making

The GWLF manual estimates dissolved and total monthly phosphorus loads in streamflow from complex watersheds. Both surface runoff and groundwater sources are included, as well as nutrient loads from point sources and onsite wastewater disposal (septic) systems. In addition, the model provides monthly streamflow, soil erosion, and sediment yield values (Haith et al. 1996).

6.2.2 Receiving Water Quality Models

Receiving water quality models differ in many ways, but some important dimensions of discrimination include conceptual basis, input conditions, process characteristics, and output. Table 6-3 presents extremes of simplicity and complexity for each condition as a point of reference. Most receiving water quality models have some mix of simple and complex characteristics that reflect tradeoffs made in optimizing performance for a particular task.

Table 6-3 General Receiving Water Quality Model Characteristics

Model Characteristic	Simple Models	Complex Models
Conceptual Basis	Empirical	Mechanistic
Input Conditions	Steady State	Dynamic
Process	Conservative	Nonconservative
Output Conditions	Deterministic	Stochastic

The concept behind a receiving water quality model may reflect an effort to represent major processes individually and realistically in a formal mathematical manner (mechanistic), or it may simply be a "black-box" system (empirical) wherein the output is determined by a single equation, perhaps incorporating several input variables, but without attempting to portray constituent processes mechanistically.

In any natural system, important inputs such as flow in the river change over time. Most receiving water quality models assume that the change occurs sufficiently slowly so that the parameter (for example, flow) can be treated as a constant (steady state). A dynamic receiving water quality model, which can handle unsteady flow conditions, provides a more realistic representation of hydraulics, especially those conditions associated with short duration storm flows, than a steady state model. However, the

price of greater realism is an increase in model complexity that may be neither justified nor supportable.

The manner in which input data are processed varies greatly according to the purpose of the receiving water quality model. The simplest conditions involve conservative substances where the model need only calculate a new flow-weighted concentration when a new flow is added (conservation of mass). Such an approach is unsatisfactory for constituents such as DO or labile nutrients, such as nitrogen and phosphorus, which will change in concentration due to biological processes occurring in the stream.

Whereas the watershed nonpoint model's focus is the generation of flows and pollutant loads from the watershed, the receiving water models simulate the fate and transport of the pollutant in the water body. Table 6-4 presents the steady state (constant flow and loads) models applicable for this watershed. The steady state models are less complex than the dynamic models. Also, as discussed above, the dynamic models require significantly more data to develop and calibrate an accurate simulation of a water body.

Table 6-4 Descriptive List of Model Components - Steady State Water Quality Models

Model	Water Body Type	Parameters Simulated	Process Simulated	
			Physical	Chemical/Biological
USEPA Screening Methods	River, lake/ reservoir, estuary, coastal	Water body nitrogen, phosphorus, chlorophyll "a," or chemical concentrations	Dilution, advection, dispersion	First order decay - empirical relationships between nutrient loading and eutrophication indices
EUTROMOD	Lake/reservoir	DO, nitrogen, phosphorus, chlorophyll "a"	Dilution	Empirical relationships between nutrient loading and eutrophication indices
BATHTUB	Lake/reservoir	DO, nitrogen, phosphorus, chlorophyll "a"	Dilution	Empirical relationships between nutrient loading and eutrophication indices
QUAL2E	Rivers (well mixed/shallow lakes or estuaries)	DO, CBOD, arbitrary, nonconservative substances, three conservative substances	Dilution, advection, dispersion	First order decay, DO-BOD cycle, nutrient-algal cycle
EXAMSII	Rivers	Conservative and nonconservative substances	Dilution, advection, dispersion	First order decay, process kinetics, daughter products, exposure assessment
SYMPTOX3	River/reservoir	Conservative and nonconservative substances	Dilution, advection, dispersion	First order decay, sediment exchange
STREAMDO	Rivers	DO, CBOD, and ammonium	Dilution	First order decay, BOD-DO cycle, limited algal component

CBOD carbonaceous biochemical oxygen demand

6.2.2.1 Receiving Water Model Recommendation

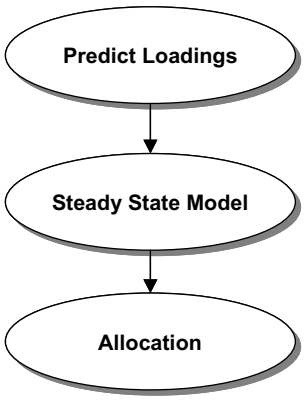
The receiving water model recommended for Vandalia Lake is BATHTUB, which applies a series of empirical eutrophication models to reservoirs and lakes. The program performs steady state water and nutrient balance calculations in a spatially segmented hydraulic network that accounts for advective and diffusive transport, and nutrient sedimentation. Eutrophication-related water quality conditions are predicted using empirical relationships (USEPA 1997).

6.2.3 Vandalia Lake TMDL

For Vandalia Lake, a TMDL for the following constituent was completed using a watershed/receiving water model combination:

- Phosphorus, pH

The strategy for completing the watershed/receiving water model TMDL for Vandalia Lake is shown in Schematic 1 to the right. This strategy applies to constituents whose loads can be predicted using GWLF. This approach allows a linkage between source and endpoint resulting in an allocation to meet water quality standards. A linkage was also made between phosphorus and DO. After phosphorus loads are predicted, the BATHTUB model was used to determine the resulting phosphorus concentrations within Vandalia Lake. Model development is discussed further in Section 7.



Schematic 1

6.2.4 Calibration and Validation of Models

The results of loading and receiving water simulations are more meaningful when they are accompanied by some sort of confirmatory analysis. The capability of any model to accurately depict water quality conditions is directly related to the accuracy of input data and the level of expertise required to operate the model. It is also largely dependent on the amount of data available. Calibration involves minimization of deviation between measured field conditions and model output by adjusting parameters of the model. Data required for this step are a set of known input values along with corresponding field observation results. Validation involves the use of a second set of independent information to check the model calibration. The data used for validation should consist of field measurements of the same type as the data output from the model. Specific features such as mean values, variability, extreme values, or all predicated values may be of interest to the modeler and require testing. Models are tested based on the levels of their predictions, whether descriptive or predictive. More accuracy is required of a model designed for absolute versus relative predictions. If the model is calibrated properly, the model predictions will be acceptably close to the field predictions.

The GWLF and BATHTUB models were calibrated based on existing data. As is outlined in Section 7, the GWLF model was calibrated based on historical flow records. The calibration factors taken into account for the GWLF model were the recession constant and seepage constant. Water quality data on the tributaries to Vandalia Lake were not available so the GWLF model could not be calibrated to tributary nutrient loads. Nutrient loads were based on literature values for Southern Illinois. GWLF model validation was not conducted as the hydrology was calibrated based on 16 years of observed flow. Data collection activities needed to calibrate nutrient loads are outlined in Section 9 Implementation Plan. The calibration process for the BATHTUB model is also outlined in Section 7. For Vandalia Lake, loads from a wet, normal, and dry precipitation year were taken from GWLF and entered into the BATHTUB model, which predicted average in-lake concentrations that were in turn compared to observed lake concentrations as the basis for calibration.

6.2.5 Seasonal Variation

Consideration of seasonal variation, such that water quality standards for the allocated pollutant will be met during all seasons of the year, is a requirement of a TMDL submittal. TMDLs must maintain or attain water quality standards throughout the year and consider variations in the water body's assimilative capacity caused by seasonal changes in temperature and flow (USEPA 1999). Seasonal variation is discussed in Section 8.

6.2.6 Allocation

Establishing a TMDL requires the determination of the LC of each stream segment. The models or methodologies were used to establish what the LC is for each segment for each pollutant. The next step was to determine the appropriate MOS for each segment. After setting the MOS, WLA of point sources and LA from the nonpoint sources were set.

The MOS can be set explicitly as a portion of the LC or implicitly through applying conservative assumptions in data analysis and modeling approaches. Data analyses and modeling limitations were taken into account when recommending a MOS. The allocation scheme (both LA and WLA) demonstrates that water quality standards will be attained and maintained and that the load reductions are technically achievable. The allocation is the foundation for the implementation and monitoring plan. Further discussion on the allocation is presented in Section 8.

6.2.7 Implementation and Monitoring

For the Vandalia Lake Watershed, a plan of implementation was produced to support the developed TMDL analyses. The plan of implementation has reasonable assurance of being achieved. The plan provides the framework for the identification of the actions that must be taken on point and nonpoint sources to achieve the desired TMDLs. The accomplishment of the necessary actions to reach these targets may involve substantial efforts and expenditures by a large number of parties within the watershed. Depending upon the specific issues and their complexity in the Vandalia

Lake Watershed, the time frame for achieving water quality standards has been developed.

The implementation plan delineates a recommended list of the sources of stressors that are contributing to the water quality impairments. The amount of the reduction needed from various sources to achieve the water quality limiting parameter was then delineated. For nonpoint sources, the use of BMPs is one way to proceed to get the desired reduction in loading. The effectiveness of various BMPs was factored into the modeling and methodologies to develop the range of options of BMPs to use. Associated with those BMPs is cost information, as available. The implementation plan for the Vandalia Lake Watershed is presented in Section 9.

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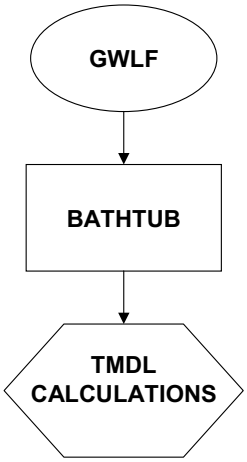
Section 7
Model Development for Vandalia Lake

7.1 Basis for pH TMDL

The relationships between pH, chlorophyll "a," and phosphorus were discussed in Section 5.1.5.1.2. Figure 7-1 shows the relationship between chlorophyll "a" and pH in Vandalia Lake. As explained in Section 5.1.5.1.2, the figure is expected to show an increase with pH as chlorophyll "a" increases. The relationship between chlorophyll "a" and phosphorus in Vandalia Lake is shown in Figure 7-2. Likewise, this figure is expected to show a direct relationship between the constituents. The relationships presented in Figures 7-1 and 7-2 provide general trends between model constituents and represent the data available from sampling. The lack of a well-defined relationship for Figure 7-2 confirms the need for a larger data set. The general relationships shown in Figures 7-1 and 7-2 suggest that controlling total phosphorus will decrease chlorophyll "a" concentrations, which will in turn bring pH into the range required for compliance with water quality standards. The TMDL will be based on the existing relationships with the knowledge that a larger data set would result in a more robust TMDL. It is therefore recommended that a TMDL endpoint of 0.05 mg/L for total phosphorus for Vandalia Lake be utilized so that the pH standard is achieved.

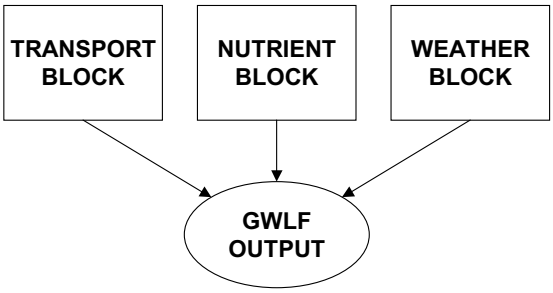
7.2 Model Overview

The models used for the TMDL analysis of Vandalia Lake were GWLF and BATHTUB. These models require input from several sources including online databases, GIS-compatible data, and hardcopy data from various agencies. This section describes the existing data reviewed for model development, model inputs, and model calibration and verification.



Schematic 1 Models used for Vandalia Lake TMDL calculation.

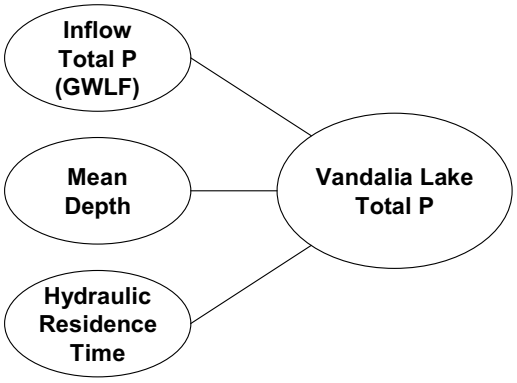
Schematic 1 shows how the GWLF model and BATHTUB model is utilized in calculating the TMDL. The GWLF model predicts phosphorus loads from the watershed. These loads are then inputted in the BATHTUB model to assess resulting phosphorus concentrations. The GWLF model outlined in Schematic 2 shows how GWLF predicts phosphorus loads from the watershed. The transport block of the GWLF model uses the Universal Soil Loss Equation to determine erosion in the watershed. The transport block also calculates runoff based on the SCS Curve Number equation. The nutrient block allows the model user to input



Schematic 2 GWLF Model.

concentrations of phosphorus contained in the soil and in the dissolved phase for runoff. These two blocks, in conjunction with the weather block, predict both solid and dissolved phosphorus loads.

Schematic 3 shows how, by using total phosphorus concentrations predicted from GWLF, the resulting in-lake total phosphorus concentrations can be predicted. The BATHTUB model uses empirical relationships between mean reservoir depth, total phosphorus inputted into the lake, and the hydraulic residence time to determine in-reservoir concentrations.



Schematic 3
BATHTUB Model Schematic.

7.3 Model Development and Inputs

The ability of the GWLF and BATHTUB models to accurately reflect natural processes depends on the quality of the input data. The following sections describe the selection, organization, and use of existing data as input to the GWLF and BATHTUB models and outline assumptions made in the process.

Due to the size of the Vandalia Lake Watershed and the multiple tributaries contributing to the lake, the watershed area was divided into seven sub-watersheds for accurate representation in the GWLF model. Flows within each of the subbasins were calculated from gage 05595820 with the drainage area ratio method presented in Section 5.1.3. To model Vandalia Lake accurately in BATHTUB, the lake was divided in three sections surrounding each of the three monitoring stations.

7.3.1 Watershed Development

Prior to developing input parameters for the GWLF or BATHTUB models, a watershed boundary for Vandalia Lake was delineated with GIS analyses through use of the DEM as discussed in Section 5.1.2. The delineation indicates that Vandalia Lake captures flows from a watershed of approximately 23.5 square miles, which is consistent with the 23.6 square miles reported in the watershed plan (VLWPC 2000). The flow through the lake is primarily from west to east. Figure 7-3 at the end of this section shows the location of each water quality station in Vandalia Lake, the boundary of the GIS-delineated watershed contributing to Vandalia Lake, the seven subbasins used in GWLF modeling, and the division of the lake for BATHTUB modeling purposes.

7.3.2 GWLF Inputs

GWLF requires input in the form of three data files that represent watershed parameters, nutrient contributions, and weather records. Each data file will be

discussed in the following sections. The input files and actual values used for each parameter are listed in Appendix B. The GWLF manual is contained in Appendix C.

DEMs of 30-meter resolution were downloaded from the USGS National Elevation Dataset for development of GWLF model parameters discussed in this section (USGS 2002b).

7.3.2.1 Transport Data File

The transport data file provides watershed parameters including land use characteristics, evapotranspiration and erosion coefficients, groundwater and streamflow characteristics, and initial soil conditions. Table 7-1 presents each transport file input parameter and its source. Those requiring further explanation are discussed in the next section.

Table 7-1 Data Needs for GWLF Transport File (Haith et al. 1996)

Input Parameter	Source
Land Use	Critical Trends Assessment Database, GIS
Land Use Area	GIS
Curve Number	*STATSGO*, GIS, Critical Trends Assessment Database, TR-55 Manual, WMM Manual
KLSCP	*STATSGO*, GIS, DEM, GWLF Manual pages 34 and 35, NRCS
Evapotranspiration Cover Coefficient	GWLF Manual page 29
Daylight Hours	GWLF Manual page 30
Growing Season	GWLF Manual Recommendation page 54
Erosivity Coefficient	GWLF Manual pages 32 and 37
Sediment Delivery Ratio	GIS, GWLF Manual page 33
5-day Antecedent Rain and Snow	GWLF Manual Recommendation page 37
Initial Unsaturated Storage	GWLF Manual Recommendation page 30
Initial Saturated Storage	GWLF Manual Recommendation page 37
Recession Constant	Calibrated
Seepage Constant	Calibrated
Initial Snow	GWLF Manual Recommendation page 37
Unsaturated Available Water Capacity	GWLF Manual Recommendation page 37

7.3.2.1.1 Land Use

Land use for the Vandalia Lake Watershed was extracted from the Critical Trends Assessment Database grid for Fayette County in GIS. Within the transport input file, each land use must be identified as urban or rural. The land uses were presented in Table 5-8.

Individually identifying each field of crops or urban community in GWLF would be time intensive, so each land use class was aggregated into one record for GIS and GWLF representation. For example, the area of each row crop field was summed to provide a single area for row crops. Additionally, the parameters for each row crop field were averaged to provide a single parameter for the row crop land use. Details of the parameter calculation are contained in the remainder of this section.

GWLF computes runoff, erosion, and pollutant loads from each land use, but it does not route flow over the watershed. For example, the model does not recognize that

runoff may flow from a field of corn over grassland and then into the river. The model assumes all runoff from the field of corn drains directly to the stream. Therefore, the location of each land use is irrelevant to the model allowing each land use class to be aggregated into a single record.

To provide accurate modeling in GWLF, the rural grassland land use class, presented in Table 5-8, was separated into four subclasses of CRP, waterways/buffer strips, pasture land, and grassland based on the recommendation of the Fayette County NRCS (2002a). The GWLF model requires nutrient runoff concentrations for each land use, and the four subclasses of rural grassland have varying concentrations. The area of each subclass was estimated from the GIS-derived rural grassland area and suggested percentages of each subclass by the Fayette County NRCS (2002a).

Due to the detailing of crops, the Cropland Data Layer land use classes, presented in Table 5-9, were used to generate evapotranspiration cover coefficients, cropping management factors, and to verify the land use obtained from the Critical Trends Assessment. Land uses used in GWLF correspond to land uses in the Critical Trends Assessment, so calculations based on the Cropland Data Layer land use classes were typically weighted by area to match the Critical Trends Assessment classes. Details of the calculations are presented in later sections and Appendix D.

7.3.2.1.2 Land Use Area

GIS was used to summarize the area of each aggregated land use in square meters as well as acres and hectares. Area in hectares was input for each land use in the transport data file.

7.3.2.1.3 Curve Number

The curve number, a value between zero and 100, represents the ability of the land surface to infiltrate water, which decreases with increasing curve number. The curve number is assigned with consideration to hydrologic soil group and land use. The hydrologic soil group, represented by the letters A through D, denotes how well a soil drains. A well-drained, sandy soil would be classified as a type A soil, whereas clay would be classified as a type D soil. This property is identified in the *STATSGO* attribute table for each soil type.

Assigning curve numbers to a large area with multiple soil types and land uses was streamlined using the GIS *ArcView* project, CRWR-PrePro (Olivera 1998), developed at the University of Texas at Austin. This process was used to develop a curve number grid. Scripts in the project intersect shapefiles of land use and soil with the *STATSGO* attribute table to create a grid in which each cell contains a curve number based on the combination.

The transport data file requires that a single curve number be associated with each land use. To accomplish this, the curve number in each grid cell was averaged over each aggregated land use area. Details of the GIS process are provided in Appendix D.

7.3.2.1.4 KLSCP

GWLF uses the Universal Soil Loss Equation, represented by the following equation (Novotny and Olem 1994), to calculate soil erosion.

$$A = (R)(K)(LS)(C)(P)$$

where A = calculated soil loss in tons/ha for a given storm or period
R = rainfall energy factor
K = soil erodibility factor
LS = slope-length factor
C = cropping management factor
P = supporting practice factor

The combined coefficient, KLSCP, is required as input to GWLF for each rural land use. The development of each factor will be discussed in the next sections. GWLF calculates the rainfall energy factor (R) with precipitation and a rainfall erosivity coefficient that will be discussed in Section 7.3.2.1.5.

Soil Erodibility Factor (K). The soil erodibility factor, K, represents potential soil erodibility. The *STATSGO* soils representation in GIS is by map unit, which incorporates multiple soil types (and K-values) in each unit, but the *STATSGO* attribute table lists the K factor for each soil type. Using this column, a weighted K factor was developed for each GIS map unit. Details of this process are provided in Appendix D.

Topographic Factor (LS). The topographic, or LS, factor represents the contribution to erosion from varying topography. This factor is independent of soil type, but dependent on land use and land surface elevations, requiring use of the DEM. Multiple equations and methodologies are used to calculate the LS factor and for this application we used methodology outlined in the *TMDL USLE* software package (USEPA 2001). The LS factor was calculated with a series of equations that compute intermediate values of slope steepness, runoff length, and rill to interill erosion before combining them into the LS factor. This process was also performed with GIS analyses to automate computational tasks. Details of the GIS computation are provided in Appendix D.

Cropping Management Factor (C). The cropping management factor, C, represents the influence of ground cover, soil condition, and management practices on erosion. The Fayette County NRCS office provided a table of C factors for various crops and tillage practices (NRCS 2002a). The table is included as Appendix E. Although the percentage of each tillage practice for corn, soybeans, and small grains in Fayette County is known, the specific locations in the watershed to which these practices are applied were unknown, so a weighted C-factor was created for these crops. In Table 7-2, the weighted C factor for corn, soybeans, and small grains and the C factor for other land uses are listed by the Cropland Data Layer land uses and areas in the Vandalia Lake Watershed.

Table 7-2 Cropland Data Layer Land Uses and C Factors

Land Use	Area (acres)	C factor
Corn	4999	0.32
Sorghum	46	0.32
Soybeans	4999	0.18
Winter Wheat	185	0.08
Other Small Grains & Hay	164	0.08
Double-Cropped WW/SB	357	0.28
Idle Cropland/CRP	112	0.004
Fallow/Idle Cropland	693	0.004
Pasture/Grassland/Nonag	1765	0.004
Woods	1197	0.003
Clouds	67	–
Urban	48	–
Water	301	–
Buildings/Homes/Subdivisions	67	–
Wetlands	41	–

The identification of crops are more detailed in the Cropland Data Layer file than the Critical Trends Land Assessment file, but the latter is used for GWLF input. Therefore, the C factor associated with the Cropland Data Layer land uses was weighted by area to create a C factor for the Critical Trends Land Assessment land uses shown in Table 7-3 at the end of this section. A more detailed description of the weighting procedure is provided in Appendix D.

Supporting Practice Factor (P). The supporting practice factor, P, represents erosion control provided by various land practices such as contouring or terracing. None of these land practices are utilized in the Vandalia Lake watershed, so a P factor of one was assigned to each land use.

7.3.2.1.5 Erosivity Coefficient

The erosivity coefficient varies spatially across the United States. Figure B-1 on page 32 of the GWLF manual places Vandalia Lake in Zone 19, which corresponds to a cool season rainfall erosivity coefficient of 0.14 and a warm season coefficient of 0.27.

7.3.2.1.6 Evapotranspiration (ET) Cover Coefficient

An ET cover coefficient for each month is required as an input parameter to GWLF representing the effects of ground cover on evapotranspiration. Ground cover changes with land use and growing season, so the computation of a single cover coefficient for each month required a series of calculations. ET cover coefficients for corn, winter wheat, sorghum, and soybeans at 10 percent increments of the growing season were obtained from GWLF Manual, page 29. These coefficients were weighted by the area of each crop in the Cropland Data Layer land use file to compute a single crop ET cover coefficient for each 10 percent increment of the growing season. The crop coefficients for each portion of the growing season were averaged to obtain a single crop coefficient for each calendar month. Monthly ET cover coefficients for pasture, woods, and urban areas were also obtained from pages 29 and 30 of the GWLF Manual. A monthly cover coefficient for water and wetlands was assumed to be 0.75.

Weighting the coefficient for each land use by the Cropland Data Layer land use area created a single ET cover coefficient for each month. Details of the ET cover coefficient calculation are provided in Appendix D.

7.3.2.1.7 Recession Constant

The recession coefficient controls the falling limb of the hydrograph in GWLF. This coefficient was calibrated to USGS streamflow and is discussed in Section 7.4.1.

7.3.2.1.8 Seepage Constant

The seepage constant controls the amount of water lost from the GWLF system by deep seepage. This value was also determined by calibration and is detailed in Section 7.4.1.

7.3.2.1.9 Sediment Delivery Ratio

The sediment delivery ratio is based on watershed area. The watershed area determined by GIS was used to obtain the corresponding sediment delivery ratio from the chart on page 33 of the GWLF manual. The sediment delivery ratios representing the annual sediment yield per annual erosion for each subbasin contributing to Vandalia Lake are presented in Table 7-4.

Table 7-4 Sediment Delivery Ratios in Vandalia Lake Watershed

Subbasin	Area (ac)	Sediment Delivery Ratio
1	4,354	0.19
2	1,550	0.25
3	2,697	0.22
4	2,217	0.23
5	2,461	0.22
6	762	0.3
7	1,001	0.28

7.3.2.2 Nutrient Data File

The nutrient input file contains information about dissolved phosphorus and nitrogen from each rural land use, solid-phase phosphorus and nitrogen from urban runoff, solid-phase nutrient concentrations in the soil and groundwater, and any point source inputs of phosphorus or nitrogen.

All solid-phase nutrient concentrations from runoff for Vandalia Lake were obtained from the GWLF manual. Figure B-4 (page 39 of Appendix C) was utilized for determining solid-phase phosphorus concentrations in the soil. A mid-range value of 0.07 percent phosphate was selected and then converted to 700 parts per million (ppm) using the relationship 0.1 percent = 1,000 ppm. Phosphate is composed of 44 percent phosphorus, so the 700 ppm phosphate was multiplied by 0.44 to obtain a value of 308 ppm phosphorus in the sediment. This solid-phase phosphorus concentration was multiplied by the recommended enrichment ratio of 2.0 and therefore a total solid-phase concentration of 616 ppm was utilized for modeling purposes. The enrichment ratio represents the ratio of phosphorus in the eroded soil to that in the non-eroded soil. Specific soil phosphorus data is not available, so the GWLF manual recommended enrichment ratio of 2.0 was used. Dissolved phosphorus concentrations in the runoff from each agricultural land use were obtained from page 41 of the GWLF manual with the exception of the three of the four rural grassland subclasses, CRP, waterways/buffers, and grassland, presented in Table 5.8. The dissolved phosphorus concentrations for these subclasses were estimated from the dissolved phosphorus concentration for pasture. CRP, waterways and buffers, and grassland are assumed to

have less animals, and therefore animal waste, than pasture land, so the concentrations were reduced for the three subclasses of CRP, waterways/buffers, and grassland. The selection of dissolved phosphorus concentrations will be confirmed in Section 7.4.1.

Table 7-5 Dissolved Phosphorus Concentrations in Runoff from the Vandalia Lake Watershed

Land Use	Phosphorus (mg/L)
Row Crop	0.26
Small Grains	0.3
Urban Grasslands	0.25
Rural Grasslands	0.25
Deciduous Forest	0.009
Urban-High Density	0.01
Urban-Medium Density	0.006

Table 7-5 lists the land uses in the Vandalia Lake Watershed and associated runoff phosphorus concentrations used in the GWLF model. It should be noted that although the majority of dissolved phosphorus concentrations in Table 7-5 exceed the endpoint of 0.05 mg/L of total phosphorus, once the surface runoff reaches Vandalia Lake or its tributaries, it mixes with water already in the stream or lake and the concentration decreases. Therefore, it cannot be concluded without analysis that constituents with dissolved concentrations above the endpoint for total phosphorus are responsible for water quality impairments.

The phosphorus contribution from septic systems is dependent on how well the system functions. GWLF classifies septic systems as normal, short-circuited, ponded, or direct discharge, and requires the population served by each type of system as input. The GWLF manual defines normal septic systems as those "whose construction and operation conforms to recommended procedures such as those suggested by the USEPA design manual for onsite wastewater disposal systems." A short-circuited septic system is one located less than 15 meters from surface waters preventing significant adsorption of phosphorus. Ponded systems are those in which the absorption field is not functioning properly and results in system effluent ponding on the field surface. A direct discharge system releases effluent directly to surface waters (Haith et al. 1996). The Vandalia Lake Watershed plan notes that the area has seasonal and permanent residents (2002). To account for seasonal variations in population, the number of persons using each septic system was assumed to be four in the summer months (May to September) and 2 in the winter months (October to April). These assumptions are based on best professional judgment that seasonal residents will arrive for the summer months, which will increase the loading to septic systems. It was assumed that 25 percent of the systems in the Vandalia Lake watershed were normal and 75 percent were short-circuited primarily due to the proximity of septic systems to the lake. The total number of systems was then divided among the seven subbasins depending on the subbasin location relative to the lake, as most residents live along the shores. The septic system input to GWLF is phosphorus loading from the system and the phosphorus uptake load by plants. The default loading value of 2.5 grams of total phosphorus per day (g/day) from the system was used to model the Vandalia Lake Watershed. The default loads for plant uptake are 0.4 g/day in the growing season and 0.0 g/day during the non-growing season.

The GWLF manual suggests nutrient concentrations in groundwater based on the percentage of agricultural versus forestlands. These percentages were calculated from the land use areas in the watershed, and the appropriate groundwater concentrations were selected from the GWLF manual, page 41. The percentage of agricultural lands in each subbasin and their corresponding groundwater dissolved phosphorus concentrations are provided in Table 7-6.

Table 7-6 Percentage of Agricultural and Forest Lands and Groundwater Phosphorus Concentrations in Vandalia Lake Watershed

Subbasin	Agriculture	Forest	Phosphorus (mg/L)
1	94%	5%	0.085
2	91%	8%	0.085
3	95%	3%	0.085
4	93%	6%	0.085
5	97%	1%	0.085
6	71%	10%	0.067
7	57%	26%	0.055

7.3.2.3 Weather Data File

The weather data file is a text file of daily precipitation and temperature and was compiled from weather data presented in Section 5.1.4. An excerpt of the weather data file is recorded in Appendix B. The precipitation data are used in GWLF to determine runoff, erosion, and evapotranspiration, and temperature data are used to compute potential evaporation and snowmelt.

7.3.3 BATHTUB Inputs

BATHTUB has three primary input interfaces: global, reservoir segment(s), and watershed inputs. The individual inputs for each of these interfaces are described in the following sections and the data input screens are provided in Appendix B.

Table 7-7 Model Year Precipitations in Fayette County

Model Year	Precipitation (inches)
1986	40
1987	31
1988	34
1989	45
1990	39
1991	36
1992	29
1993	55
1994	36
1995	41
1996	40
1997	37
1998	48
1999	41
2000	46
2001	33
Annual Average	**39**

Multiple simulations of the BATHTUB model were run to investigate variations in total phosphorus concentrations in a wet, normal, and dry year of precipitation to bracket conditions for calibration. The first step in choosing the wet, normal, and dry years was to calculate average annual precipitation. BATHTUB models lake concentrations based on a water year (October to September), so the precipitation data presented in Section 5.1.4 were averaged to coincide with the water year. Table 7-7 shows these annual and average annual precipitation values in Fayette County. Each water year was then classified as wet, dry, or normal based on a comparison to the average water year precipitation of 39 inches. Another consideration in selecting the years for

simulation was determining which years coincided with the collection dates of in-lake total phosphorus concentrations at the water quality stations within recent years. With these criteria, only a wet year and two normal years were available for the BATHTUB simulations of Vandalia Lake. Based on Table 7-7, 1996 and 1999 are designated as the normal years and 1993 is designated as the wet year.

7.3.3.1 Global Inputs

Global inputs represent atmospheric contributions of precipitation, evaporation, and atmospheric phosphorus. Precipitation was discussed in the previous section and is shown in Table 7-7 for the model years 1993, 1996, and 1999. An average annual evaporation was determined from pan evaporation data as discussed in Section 5.1.4. The default atmospheric phosphorus deposition rate suggested in the BATHTUB model was used in absence of site-specific data, which is a value of 30 kg/km^2-yr (USACE 1999b).

7.3.3.2 Reservoir Segment Inputs

The data included as segment inputs represents reservoir characteristics in BATHTUB. These data were used in BATHTUB simulations and for calibration targets. The calibration targets are observed water quality data summarized in Section 5.1.5.1.

Vandalia Lake was modeled as three segments in BATHTUB to represent the lake characteristics around each water quality station, so an average annual value of total phosphorus was calculated for each site for input of observed data. The lake segments are shown in Figure 7-3 at the end of this section. The averages of total phosphorus sampled at all depths at each station were presented in Table 5-5; however, the BATHTUB model calculates an average lake concentration. Therefore, total phosphorus samples at all depths were averaged to provide targets for the BATHTUB model. Table 7-8 shows the average annual total phosphorus concentrations for all sample depths at each station in Vandalia Lake for the modeled years. As mentioned in Section 5.1.5.1.1, station ROD-1 had samples taken at one-foot depth from the surface and at the lake bottom, whereas stations ROD-2, and ROD-3 were only sampled at one-foot depth. The raw data for all sample depths are contained in Appendix A.

Table 7-8 Total Phosphorus Concentrations in Vandalia Lake (mg/L)

Year	ROD-1	ROD-2	ROD-3	Lake Average
1993	0.15	0.08	0.09	0.11
1996	0.22	0.12	0.14	0.16
1999	0.17	0.04	0.07	0.09

Other segment inputs include lake depth, lake length, and depth to the metalimnion. The lake depth was represented by the averaged data from the water quality stations shown in Table 5-11. The lake length was determined in GIS, and the depth to the metalimnion was estimated from a chart of temperature versus depth. The charts are presented in Appendix F.

7.3.3.3 Tributary Inputs

Tributary inputs to BATHTUB are drainage area, flow, and total phosphorus (dissolved and solid-phase) loading. The drainage area of each tributary is equivalent to the basin or subbasin it represents, which was determined with GIS analyses. For the Vandalia Lake Watershed, the seven subbasins modeled in GWLF represent tributary inputs. Loadings were calculated with the monthly flow and total phosphorus concentrations obtained from GWLF output. The monthly values were summed over the water year for input to BATHTUB. To obtain flow in units of volume per time, the depth of flow was multiplied by the drainage area and divided by one year. To obtain phosphorus concentrations, the nutrient mass was divided by the volume of flow.

7.4 Model Calibration and Verification

The GWLF model was calibrated prior to BATHTUB calibration. The GWLF model for the Vandalia Lake Watershed was calibrated to flow data, as tributary phosphorus concentrations were not available. Nutrient concentrations entered into the GWLF model were calibrated based on response occurring in the BATHTUB model. Therefore, the nutrient block of the GWLF model and the BATHTUB model were calibrated together to reach agreement with observed data in Vandalia Lake.

7.4.1 GWLF Calibration

The GWLF model must run from April to March to coincide with the soil erosion cycle. GWLF does not retain erodible sediment between model years, so the model year must begin after the previous year's sediment has been washed off. The model assumes that the soil erosion cycle begins with spring runoff events in April and that erodible soil for the year has been washed off by the end of winter for the cycle to begin again the following April. GWLF generates monthly outputs including precipitation, flow, runoff and nutrient mass per watershed, and annual outputs including precipitation, flow, runoff, and nutrient mass per land use. These outputs are part of the input for the BATHTUB model.

Instream nutrient data was not available for model calibration, so GWLF was only calibrated to flow. The monthly average flow output from GWLF was compared to the monthly average streamflow calculated from USGS gage 05595820 with the drainage area ratio method presented in Section 5.1.3. The model flow was calibrated visually through the recession constant and seepage constant. Visual calibration is a subjective approach to model calibration in which the modeler varies inputs to determine the parameter combination that looks like the best fit to the observed data (Chapra 1997). According to the GWLF manual, an acceptable range for the recession constant is 0.01 to 0.2. No range suggestions are provided for the seepage constant. Figure 7-4 (at the end of this section) shows the comparison between the two flows for Vandalia Lake. The GWLF model for Vandalia Lake was visually calibrated with a resulting recession constant of 0.1 and a seepage constant of 0.15 in each subbasin. Once calibrated, the model output data could properly be included as BATHTUB inputs. The GWLF model was not validated as flow was calibrated by visually comparing 16 years of observed flow.

Although instream nutrient concentrations are not available for the tributaries to Vandalia Lake, Clean Lakes Studies have been conducted by the Illinois EPA on various Illinois lake watersheds, which do provide instream nutrient data for lake tributaries including dissolved and total phosphorus. The dissolved and total phosphorus concentrations predicted by GWLF for tributaries to the Vandalia Lake subbasins were compared to the measured dissolved and total phosphorus concentrations from tributaries to lakes observed in the Clean Lakes studies as shown in Figure 7-5. The concentrations within the Vandalia Lake Watershed are within the ranges of those in the other lake watersheds shown in Figure 7-5.

Table 7-9 shows the comparison between dissolved and total phosphorus in watersheds from Clean Lakes Studies and in the Vandalia Lake Watershed. The dissolved phosphorus concentration in Subbasin 7 in the Vandalia Lake Watershed was too low to be calculated by GWLF, so it is assumed to be negligible and is presented as zero concentration.

Table 7-9 Percentage of Dissolved Phosphorus to Total Phosphorus Concentrations in Clean Lake Study Watersheds and the Vandalia Lake Watershed

Watershed	Site	Mean Dissolved Phosphorus (mg/L)	Mean Total Phosphorus (mg/L)	Dissolved/Total Phosphorus
Nashville City	ROO 02	0.68	0.89	0.76
Paradise	RCG 02	0.06	0.07	0.87
Raccoon	RA 02	0.30	0.46	0.66
	RA 03	0.21	0.29	0.71
	RA 04	0.46	0.63	0.73
	RA 05	0.07	0.22	0.30
Lake Lou Yeager	A	0.06	0.13	0.46
	B	0.15	0.16	0.92
	C	0.05	0.25	0.20
	D	0.13	0.17	0.78
	E	0.06	0.12	0.46
	F	0.17	0.20	0.87
	G	0.33	0.41	0.79
	H	0.33	0.35	0.93
	I	0.13	0.14	0.96
Vandalia Lake	1	0.16	0.30	0.52
	2	0.12	0.36	0.34
	3	0.16	0.34	0.46
	4	0.16	0.31	0.50
	5	0.16	0.30	0.55
	6	0.02	0.15	0.13
	7	0.00	0.16	---

The ratio of dissolved to total phosphorus in the Vandalia Lake subbasin is within the range of ratios represented by the Clean Lakes Studies, except for Subbasin 7, which is below the low end of the range.

7.4.2 BATHTUB Calibration

The BATHTUB model's response to changes in the GWLF nutrient block were compared to known in-lake concentrations of total phosphorus and chlorophyll "a" for each year of simulation. These known concentrations were presented in Tables 5-5 and 5-7. The BATHTUB manual defines the limits of total phosphorus calibration factors as 0.5 and 2.0. The calibration factor accounts for sedimentation rates, and the limits were determined by error analysis calculations performed on test data sets (USACE 1999b). The calibration limits for chlorophyll "a" are not defined in the BATHTUB manual.

The GWLF model was set at a total phosphorus soil concentration of 616 ppm based on comparison with observed data in the BATHTUB model. As part of the comparison process, the watershed was also modeled with a total phosphorus soil concentration of 792 ppm to perform a sensitivity analysis on soil phosphorus. Increasing the total soil phosphorus concentration shows little impact on the estimated in-lake concentrations (Table 7-10). The calibration factor range for total phosphorus modeling in BATHTUB is 0.5 to 2 and use of the 616 ppm total phosphorus in the soil falls within this accepted range except for 1996. This calibration set (616 ppm total soil phosphorus) was still utilized as the other two years fell within the calibration range and no recent soil phosphorus test data were available to confirm use of a higher soil phosphorus. The columns labeled *target* in Table 7-10 represent the average observed in-lake concentrations. The results of the modeling sensitivity analyses are contained in Appendix G. Table 7-11 shows the chlorophyll "a" calibration factors used in each lake segment for each year modeled.

Table 7-10 Vandalia Calibration Sensitivity Analysis

Year	In-Lake Target Total Phosphorus (mg/L)	In-Lake Estimated Total Phosphorus (mg/L)	% of Total Loads from Internal Loading Required to Meet Target	Calibration Factor
Soil Total Phosphorus 616 ppm				
1993	0.10	0.076	65%	1.4
1996	0.15	0.075	81%	2.1
1999	0.09	0.076	71%	1.1
Soil Total Phosphorus 792 ppm				
1993	0.10	0.076	52%	1.4
1996	0.15	0.079	79%	2.0
1999	0.09	0.082	68%	1.1

Table 7-11 Chlorophyll "a" Calibration Factors

Lake Segment	1993	1996	1999
Near Dam	0.9	1.1	1.7
Mid Pool	1.7	1.4	2.6
Upper Pool	0.6	0.9	1.4

A robust calibration and validation of Vandalia Lake could not be completed because the following information was not available: observed nutrient concentrations in tributaries to the lake, site-specific data on internal cycling rates, reservoir outflow rates, and nutrient concentrations in reservoir releases. The analysis presented in Table 7-10 is therefore considered a preliminary calibration. However, BATHTUB modeling results indicate a fair estimate between predicted and observed

values for the years modeled based on error statistics calculated by the BATHTUB model and should be sufficient for estimating load reductions required in the watershed and from internal cycling within the reservoir. BATHTUB calculates three measures of error on each output concentration. If the absolute value of the error statistic is less than 2.0, the modeled output concentration is within the 95 percent confidence interval for that constituent (USACE 1999b). A robust calibration and validation of Vandalia Lake will be possible if data collection activities outlined in the future monitoring in Section 9 Implementation are implemented.

Based on modeling results it appears the majority of the internal cycling is occurring in the near dam pool (ROD-1) of Vandalia Lake. In the 1996 model, model results suggest internal cycling occurs in the mid pool (ROD-2) as well. The high percentage of predicted internal loading in 1996 is due to relatively high observed phosphorus concentrations in Vandalia Lake during this year. It was assumed that internal cycling or loading within Vandalia Lake could be significant due to its relatively shallow depth in comparison to the BATHTUB model empirical data set. The BATHTUB Manual notes that internal cycling can be significant in shallow prairie reservoirs and provides Lake Ashtabula (approximately 42 feet deep) as an example (USACE 1999b, 2003). Table 5-11 notes a depth of approximately 22 feet for Vandalia Lake, which places it in the category of shallow reservoir. Literature sources suggest that internal loading for deeper, more stratified lakes could be in the range of 10 to 30 percent of total loadings and that values for shallower reservoirs could be much higher (Wetzel 1983).

Because the modeling of Vandalia Lake changes based on annual loadings and climatic conditions, a validation of the model could not be completed. The model was calibrated for three climatic conditions, which will be the basis for the TMDL analysis presented in Section 8. The preliminary calibrated model was used to estimate the amount of load reductions needed from the watershed and internal loads to meet water quality standards.

Figure 7-1: Relationship between pH at One-Foot Depth and Chlorophyll "a" in Vandalia Lake

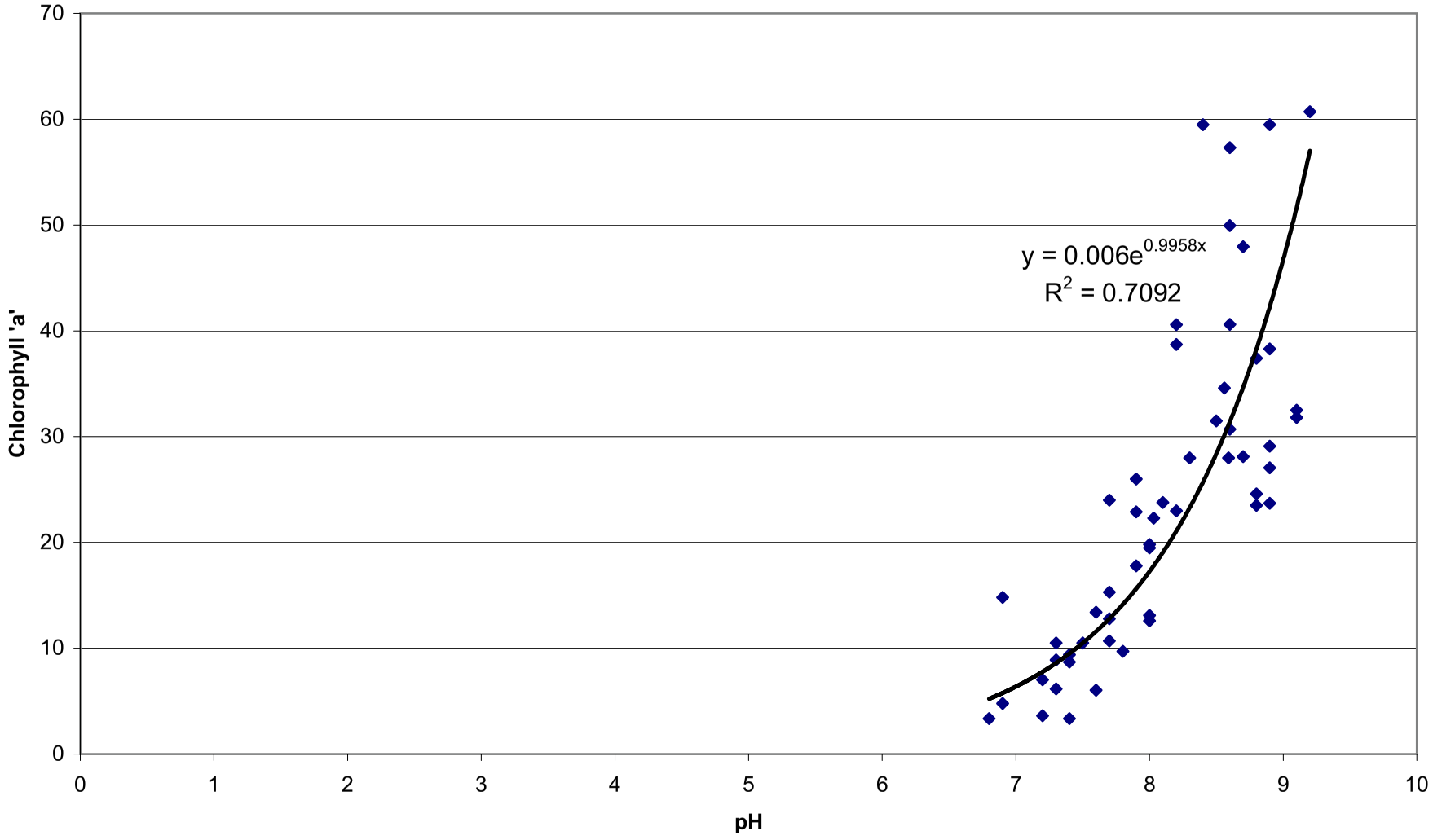


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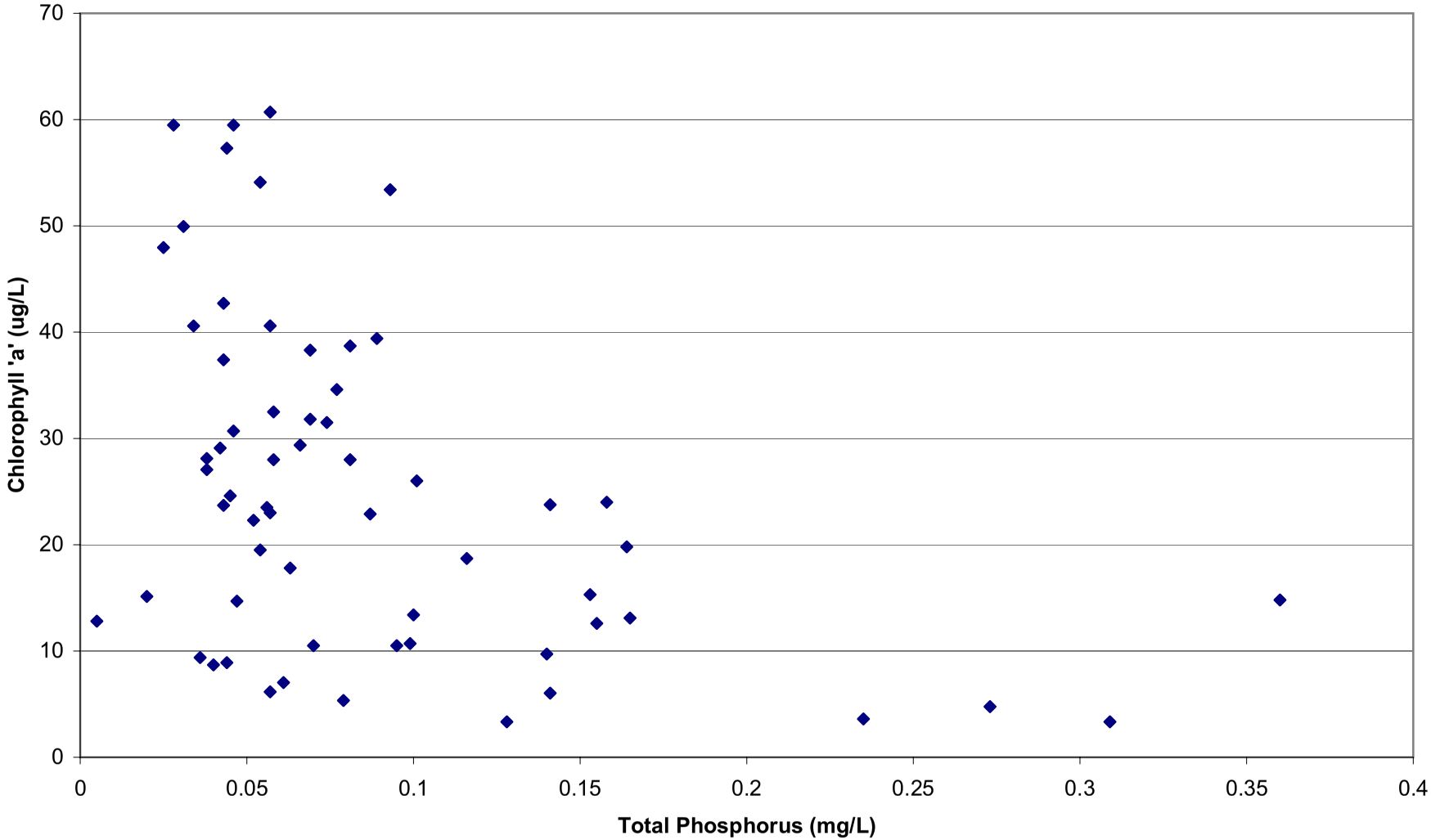
Figure 7-2: Relationship between Total Phosphorus at One-Foot Depth and Chlorophyll "a" in Vandalia Lake



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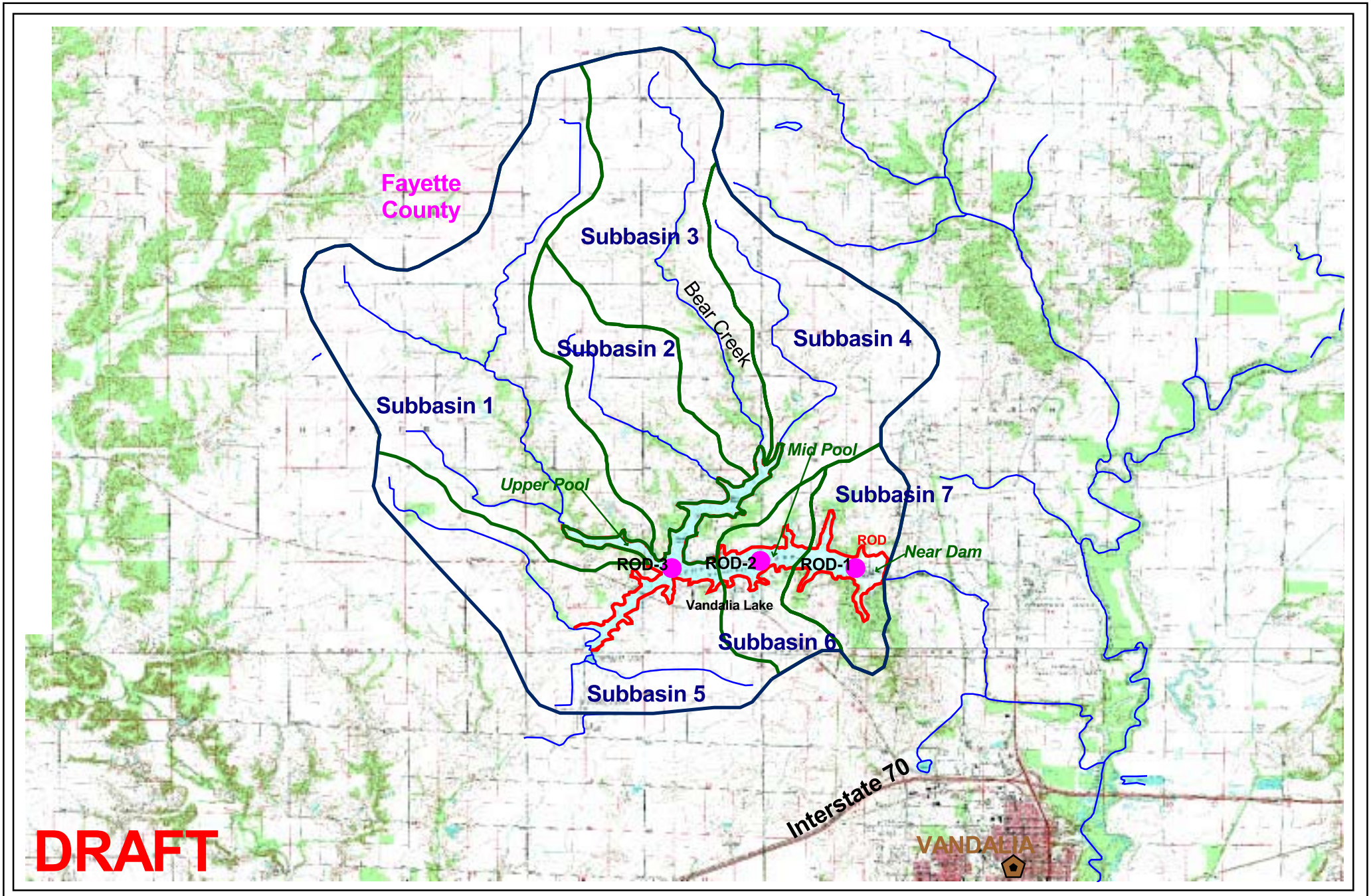

LEGEND

- Water Quality Site
- 303(d) Listed Segment
- Rivers
- Vandalia Lake Watershed Subbasin Boundaries

N

0.4 0 0.4 Miles

Figure 7-3
Vandalia Lake Historic Sampling Locations,
Watershed Subbasins, and Modeled Lake Segments

CDM

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Figure 7-4: Vandalia Lake Inflows
Monthly Flow Comparison

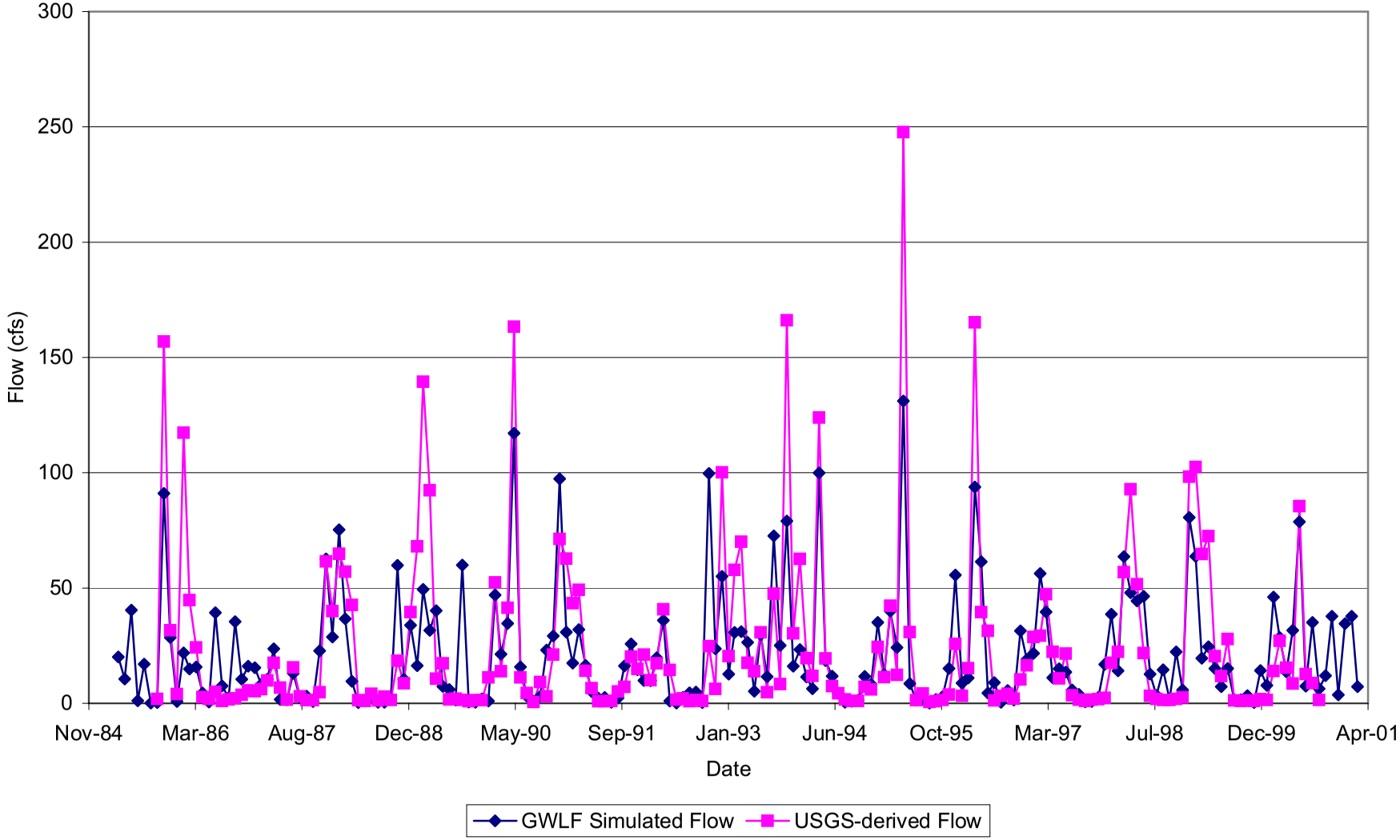

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Figure 7-5: Mean Dissolved and Mean Total Phosphorus Concentrations Measured in Clean Lake Study Tributaries and Estimated for Tributaries to Vandalia Lake

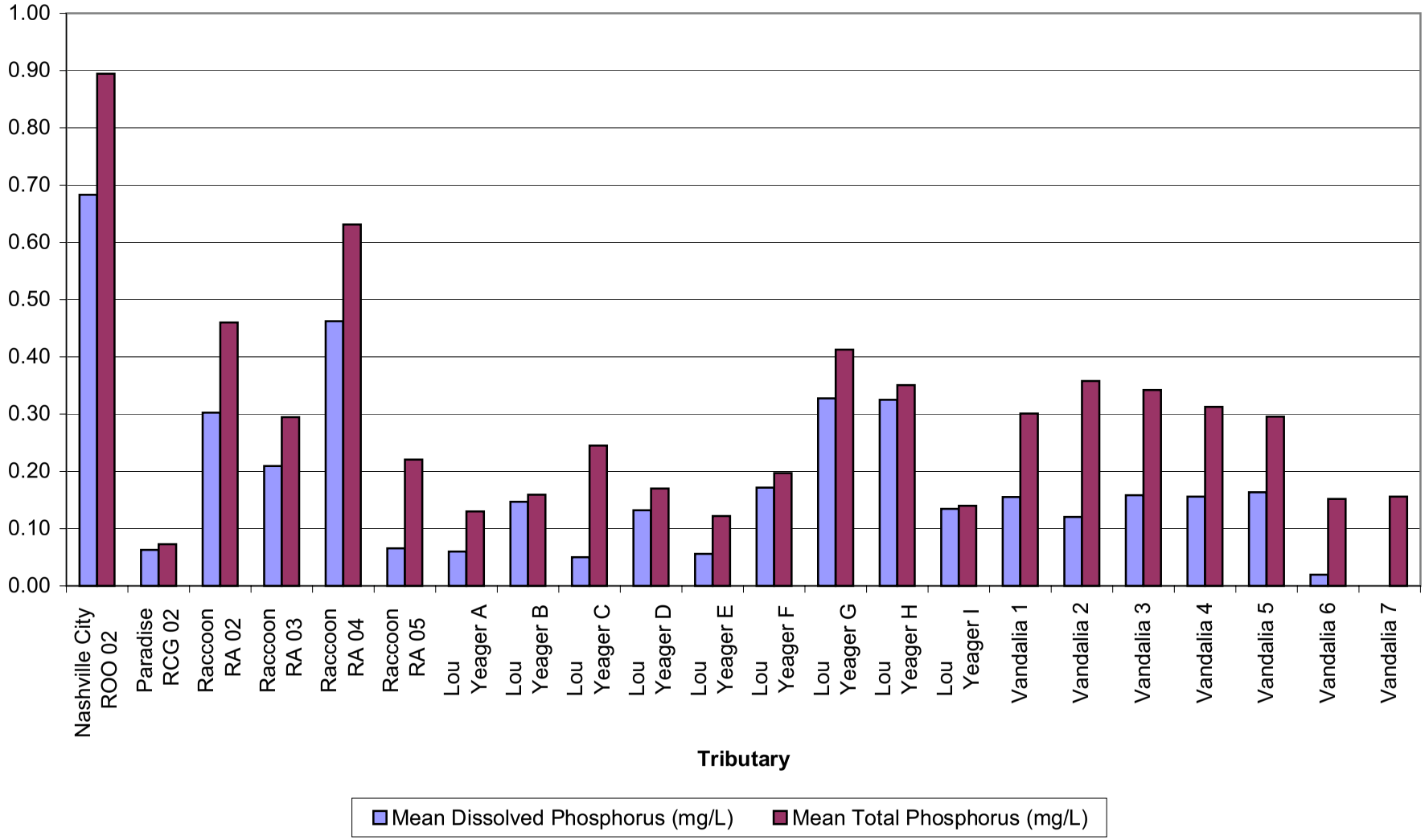

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Table 7-3 Critical Trends Land Assessment Land Uses and C factors

	Subbasin 1		Subbasin 2		Subbasin 3		Subbasin 4		Subbasin 5		Subbasin 6		Subbasin 7	
Landuse	**Area (ac)**	**C-factor**	**Area (ac)**	**C-factor**	**Area (ac)**	**C-factor**	**Area (ac)**	**C-factor**	**Area (ac)**	**C-factor**	**Area (ac)**	**C-factor**	**Area (ac)**	**C-factor**
High Density	0	---	0	---	1	---	0	---	20	---	3	---	0	---
Medium Density	0	---	0	---	0	---	0	---	4	---	0	---	0	---
Row Crop	3002	0.25	1005	0.26	2107	0.26	1318	0.24	1710	0.25	298	0.26	212	0.25
Small Grains	318	0.20	86	0.26	111	0.13	125	0.16	151	0.18	29	0.11	21	0.13
Urban Grassland	0	---	0	---	0	---	0	---	45	0.004	1	0.004	8	0.004
Rural Grassland	770	0.004	325	0.004	358	0.004	624	0.004	485	0.004	213	0.004	333	0.004
Deciduous	220	0.003	119	0.003	94	0.003	127	0.003	29	0.003	75	0.003	257	0.003
Open Water	6	---	12	---	1	---	10	---	14	---	141	---	164	---
Shallow Marsh/Wetland	4	---	0	---	1	---	0	---	2	---	1	---	4	---
Deep Marsh	1	---	0	---	1	---	0	---	0	---	0	---	0	---
Forested Wetland	27	---	1	---	20	---	8	---	0	---	0	---	1	---
Shallow Water Wetland	8	---	2	---	3	---	3	---	2	---	0	---	0	---

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Section 8
Total Maximum Daily Load for Vandalia Lake

8.1 TMDL Endpoints for Vandalia Lake

The desired in-lake water quality standard for pH is between 6.5 and 9 and less than or equal to 0.05 mg/L for total phosphorus. Tables 5-5, 5-6, and 5-7 summarized the average pH, total phosphorus, and chlorophyll "a" concentrations sampled in the Vandalia Lake Watershed. As noted in Section 5.1.5.1.1, almost all observed in-lake total phosphorus averages have exceeded the target. For pH, all observed in-lake averages meet the targets, but individual samples violate the TMDL endpoints. The range of pH values is set to prevent eutrophic conditions in Vandalia Lake and maintain aquatic life. Phosphorus is a concern as nuisance plant growth and algal concentrations in many freshwater lakes are enhanced by the availability of phosphorus. Additionally, excess phosphorus can cause large DO fluctuations.

8.2 Pollutant Sources and Linkages

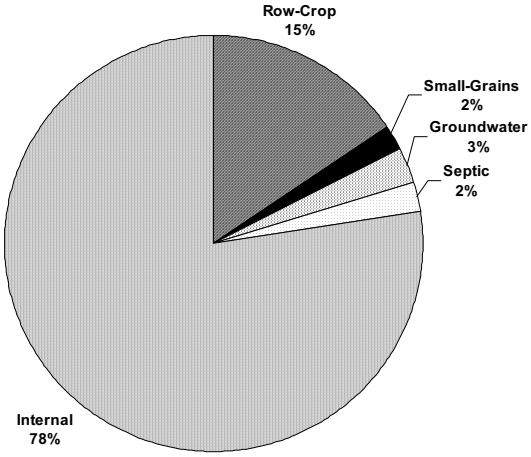
The TMDL for pH in Vandalia Lake is dependent on a relationship between pH, chlorophyll "a", and phosphorus as explained in Sections 5.1.5.1.1 and 7.1. Relationships between phosphorus, chlorophyll "a," and pH were determined, but it is recognized that they only represent general trends. This TMDL is based on the assumption that trends in Vandalia Lake will follow those observed in literature where the control of phosphorus results in acceptable pH values. The remainder of this section focuses on reductions in phosphorus to control pH.

Pollutant sources and their linkages to Vandalia Lake were established through the GWLF and BATHTUB modeling techniques described in Section 7. Pollutant sources of phosphorus include nonpoint source runoff from agriculture sources including row crops and septic tank failures. Atmospheric deposition and internal cycling are also potential sources of loads. The predicted phosphorus loads from GWLF modeling and their sources are presented in Table 8-1. The mean loads presented in Table 8-1 will be used in the overall TMDL calculation for the amount of reductions that need to occur in the Vandalia Lake watershed. These mean loads represent normal and wet years in the watershed. In addition, as explained in Section 7, 1996 was a year where in-lake phosphorus concentrations were higher than other years in the data set.

Table 8-1 Modeled Total Phosphorus Load by Source

Land Use	1993 (wet)		1996 (normal)		1999 (normal)		Mean	
	(lb/yr)	percent	(lb/yr)	percent	(lb/yr)	percent	(lb/yr)	percent
Row Crop	10,177	21%	7,323	11%	6,623	16%	8,041	15%
Small Grains	1,009	2%	725	1%	683	2%	805	2%
Urban Grassland	0	0%	0	0%	0	0%	0	0%
Rural Grassland								
CRP	151	0%	104	0%	25	0%	93	0%
Wtrwys/Buffrs	34	0%	26	0%	0	0%	20	0%
Pasture	0	0%	0	0%	0	0%	0	0%
Grassland	151	0%	104	0%	25	0%	93	0%
Deciduous	34	0%	13	0%	25	0%	24	0%
Urban	17	0%	13	0%	76	0%	35	0%
Groundwater	1,531	3%	1,281	2%	1,390	3%	1,401	3%
Septic Systems	1,009	2%	776	1%	1,517	4%	1,101	2%
Internal Cycling	34,186	72%	55,224	85%	31,556	75%	40,322	78%
Atmospheric	177	0%	177	0%	177	0%	177	0%
TOTAL	48,476	100%	65,766	100%	42,097	100%	52,112	100%

The majority of the predicted phosphorus load is from internal cycling and agricultural nonpoint sources as shown in the pie chart to the right. The loads represented in Table 8-1 and the pie chart were entered into the BATHTUB model as explained in Section 7 to determine resulting in-lake total phosphorus concentration in mg/L. As explained in Section 7, these loads result in in-lake concentrations that exceed the total phosphorus target of 0.05 mg/L. The TMDL explained throughout the remainder of this section will examine how much both the external and internal loads need to be reduced in order to meet the total phosphorus water quality standard of 0.05 mg/L in Vandalia Lake.



8.3 Allocation

As explained in Section 1, the TMDL for Vandalia Lake will address the following equation:

$$TMDL = LC = \Sigma WLA + \Sigma LA + MOS$$

where LC = Maximum amount of pollutant loading a water body can receive without violating water quality standards

WLA = The portion of the TMDL allocated to existing or future point sources

LA = Portion of the TMDL allocated to existing or future nonpoint sources and natural background

MOS = An accounting of uncertainty about the relationship between pollutant loads and receiving water quality

Each of these elements will be discussed in this section as well as consideration of seasonal variation in the TMDL calculation.

8.3.1 Loading Capacity

The loading capacity of Vandalia Lake is the pounds per year of total phosphorus that can be allowed as input to the lake and still meet the water quality standard of 0.05 mg/L total phosphorus. The allowable phosphorus loads that can be generated in the watershed and still maintain water quality standards was determined with the models that were set up and calibrated as discussed in Section 7. To accomplish this, the loads presented in Table 8-1 were reduced by a percentage and entered into the BATHTUB model until the water quality standard of 0.05 mg/L total phosphorus was met in Vandalia Lake. Table 8-2 shows the allowable phosphorus loading determined for 1993, 1996, and 1999 by reducing modeled inputs to Vandalia Lake through GWLF and BATHTUB. The output files to BATHTUB showing the results of the load reductions for 1993, 1996, and 1999 are contained in Appendix H.

Table 8-2 Allowable Phosphorus Load by Model Year

Model Year	Total Phosphorus (lb/yr)
1993	12,595
1996	8,621
1999	13,202
Mean	11,472

The allowable pounds per year resulting from the modeling show the effects of varying climatic conditions observed during these years. Therefore, an average value of these years was set as the target loading to meet the in-lake water quality standards of 0.05 mg/L.

The chlorophyll "a" concentrations predicted in BATHTUB from the allowable total phosphorus loads were used with Figure 7-1 to predict pH values. Based on this relationship, exceedances of the pH water quality standard of 6.5 to 9.0 should be avoided as shown in Table 8-3. Therefore the TMDL for Vandalia Lake will focus on phosphorus as explained throughout the remainder of this section.

Table 8-3 Predicted Chlorophyll "a" and pH Values in Vandalia Lake

Year	Chlorophyll "a" (µg/L)	pH (s.u.)
1993	14.0	7.8
1996	12.1	7.6
1999	29.1	8.5

8.3.2 Seasonal Variation

A season is represented by changes in weather; for example, a season can be classified as warm or cold as well as wet or dry. Seasonal variation is represented in the Vandalia Lake TMDL as conditions were modeled on an annual basis and by taking 15 years of daily precipitation data when calculating run-off through the GWLF model. This takes into account the seasonal effects the reservoir will undergo during a given year. Since the various pollutant sources are expected to contribute loadings in different quantities during different time periods (e.g., atmospheric deposition year round, spring run-off loads), the loadings for this TMDL will focus on average annual loadings rather than specifying different loadings by season. In addition, three data sets (wet, dry, average) were examined to assess the effects of varying precipitation on loading to the reservoir and resulting in-lake concentrations.

8.3.3 Margin of Safety

The MOS can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a combination of both. The MOS for the Vandalia Lake TMDL should be based on a combination of both. Model inputs were selected from the GWLF manual when site-specific data were unavailable. These default input values are assumed to be conservative, which implicitly includes a MOS in the modeling effort. Because the default input values are not site-specific, they are assumed more conservative and therefore a MOS can be implicitly assumed. Default input values include:

- Sediment delivery ratio – using literature value is assumed conservative as cropping practices have changed within Illinois since ratio was developed in 1975
- Soil phosphorus concentration – phosphorus concentrations in the soil were not available therefore literature values were assumed conservative as the mid-point of the range of suggested literature range was used as a starting point for analyses

In addition, averaging of a normal and dry year is assumed to be conservative and part of the implicit MOS.

Due to uncertainty with nutrient model inputs as explained in Section 7.4, an explicit MOS of 5 percent is also recommended. Due to unknowns regarding estimated versus actual measurements of loadings to the lake, an explicit MOS is included. The 5 percent MOS is appropriate based upon the generally good agreement between the GWLF loading model and observed flows, and in the BATHTUB water quality model and observed values in Vandalia Lake (Section 7.4). Since these models reasonably reflect the conditions in the watershed, a 5 percent MOS is considered to be adequate to address the uncertainty in the TMDL, based upon the data available. The MOS can be reviewed in the future as new data is developed.

8.3.4 Waste Load Allocation

There are no point sources in the watershed; therefore, no WLA (WLA = 0) is recommended at this time.

8.3.5 Load Allocation and TMDL Summary

Table 8-4 shows a summary of the TMDL for Vandalia Lake. On average, a total reduction of 80 percent of total phosphorus loads to Vandalia Lake would result in compliance with the water quality standard of 0.05 mg/L total phosphorus.

Table 8-4 TMDL Summary for Total Phosphorus in Vandalia Lake

LC (lb/yr)	WLA (lb/yr)	LA (lb/yr)	MOS (lb/yr)	Reduction Needed (lb/yr)	Reduction Needed (percent)
11,472	0	10,899	574	41,213	79%

Table 8-5 shows the respective reductions needed from internal cycling, atmospheric loads, and nonpoint sources in the watershed to meet the TMDL. The reduction of atmospheric loads is zero because atmospheric contributions cannot be controlled by watershed management measures. The percent reduction from internal cycling is estimated as 90 percent based on attainable reductions from management measures that will be discussed in Section 9. An approximate 42 percent reduction of nonpoint sources from the watershed in addition to the reduction of internal cycling would be necessary to meet the load allocation presented in Table 8-4. Methods to meet these targets will be outlined in Section 9.

Table 8-5 Sources for Total Phosphorus Reductions

Source	Current Load (lb/yr)	Load Reduction (lb/yr)	Percent Reduction
Internal Cycling	40,322	36,290	90%
Atmospheric	177	0	0%
Nonpoint Sources	11,613	4,923	42%

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Section 9
Implementation Plan for Vandalia Lake

9.1 Implementation Actions and Management Measures for Phosphorus and pH

Phosphorus loads in the Vandalia Lake Watershed originate from external and internal sources. From modeling estimates, internal phosphorus cycling from sediments accounts for approximately 78 percent of the loading to Vandalia Lake. External loads from nonpoint source runoff from agricultural crops, septic systems, and atmospheric deposition potentially account for 19 percent of the loading. Groundwater potentially contributes 3 percent of the loading to Vandalia Lake, and the remaining 1 percent is potentially due to urban, forest, and grassland land uses. To achieve the 80 percent reduction of total phosphorus established in Section 8 for Vandalia Lake (Table 8-4), management measures must address nonpoint source loading through sediment and surface runoff controls and internal nutrient cycling through in-lake management. Phosphorus sorbs readily to soil particles and controlling sediment load into the reservoir helps control phosphorus loadings. Reductions from septic systems could be achieved through system maintenance, moving systems designated as short-circuited (located less than 15 meters from surface waters) to a location greater than 15 meters from the surface water, or installing sanitary sewers around the lake.

The pH level in lakes is tied to the plant, animal, and nutrient cycles of the lake. Plants and algae use carbon dioxide (CO_2) during photosynthesis, which causes pH levels to rise. The photosynthetic rate progressively decreases as the residual CO_2 concentration declines and ceases completely with the extinction of light. During the night, reaeration and respiration replenish CO_2 causing the pH levels to decrease overnight (Welch 1980). Plant and algae growth tend to increase significantly with the addition of phosphorus to the lake; therefore, the success of controlling pH levels in Vandalia Lake is linked to the control of nonpoint source phosphorus loads. As explained in Section 8, the relationship established between chlorophyll "a" and pH showed that with reduced phosphorus loads, the pH TMDL endpoints should be met for Vandalia Lake.

Implementation actions, management measures, or BMPs are used to control the generation or distribution of pollutants. BMPs are either structural, such as wetlands, sediment basins, fencing, or filter strips; or managerial, such as conservation tillage, nutrient management plans, or crop rotation. Both types require good management to be effective in reducing pollutant loading to water resources (Osmond et al. 1995).

It is generally more effective to install a combination of BMPs or a BMP system. A BMP system is a combination of two or more individual BMPs that are used to control a pollutant from the same critical source. In other words, if the watershed has more than one identified pollutant, but the transport mechanism is the same, then a BMP

system that establishes controls for the transport mechanism can be employed. (Osmond et al. 1995).

Implementation actions and management measures are described for each phosphorus source in the watershed. Nonpoint sources include cropland and potential discharge from septic systems. The final source is internal phosphorus cycled from lake sediments.

This implementation plan should be considered a supplement to the Vandalia Lake Watershed Implementation Plan (VLPC 2000). Many of the goals outlined for erosion reduction will also have a direct impact on total phosphorus concentrations in Vandalia Lake. As explained in the Monitoring Section (9.3) of the Vandalia Lake Watershed Implementation Plan, a quantification of dissolved versus total phosphorus for the tributaries to Vandalia Lake would help in quantifying what reduction in sediment loads could also impact phosphorus reductions. The implementation measures outlined in this section and the modeling based on existing data will help to address the water quality goals and objectives of the Vandalia Lake Watershed Implementation Plan that address phosphorus concentrations, algal problems, and quantification of nonpoint sources.

9.1.1 Nonpoint Source Phosphorus and pH Management

The sources of nonpoint source pollution in the Vandalia Lake TMDL are divided between agricultural cropland and septic systems. BMPs evaluated that could be utilized to treat these nonpoint sources are:

- Conservation tillage practices
- Filter strips
- Wetlands
- Nutrient management
- Septic system maintenance or sanitary system

Total phosphorus originating from cropland is most efficiently treated with a combination of no-till or conservation tillage practices and grass filter strips. Wetlands located upstream of the reservoir provide further reductions in total and dissolved phosphorus in runoff from croplands. Nutrient management focuses on source control of nonpoint source contributions to Vandalia Lake.

9.1.1.1 Conservation Tillage Practices

For the Vandalia Lake Watershed, conservation tillage practices could help reduce nutrient loads in the lake. Nonpoint source runoff from approximately 10,500 acres of row crops and small grain agriculture were estimated to contribute 17 percent of the phosphorus load to Vandalia Lake. Total phosphorus loading from cropland is controlled through management BMPs, such as conservation tillage. Conservation tillage maintains at least 30 percent of the soil surface covered by residue after planting. Crop residuals or living vegetation cover on the soil surface protect against soil detachment from water and wind erosion. Conservation tillage practices can

remove up to 45 percent of the dissolved and total phosphorus from runoff and approximately 75 percent of the sediment. Additionally, studies have found around 93 percent less erosion occurred from no-till acreage compared to acreage subject to moldboard plowing (NCSU 2000); however, filter strips are less effective at removing dissolved phosphorus only. It is estimated that conventional till currently accounts for 82 percent of corn, 33 percent of soybean, and 25 percent of small grain tillage practices in Fayette County, and these percentages were assumed to apply to the Vandalia Lake Watershed as well. To achieve the reductions needed, erosion control through conservation tillage could reduce phosphorus loads. The watershed's modeled erosion rate from row crop and small grains averages two tons/acre/year. To achieve a 23 percent reduction in phosphorus load, the erosion rate for the watershed would need to be reduced to 1.6 tons/acre/year. Similarly, the C-factors for corn, soybeans, and small grains would need to be reduced from 0.32, 0.18, and 0.08 to 0.25, 0.14, and 0.06 respectively.

9.1.1.2 Filter Strips

Filter strips can be used as a structural control to reduce pollutant loads, including nutrients and sediment, to Vandalia Lake Watershed. Filter strips implemented along stream segments slow and filter nutrients and sediment out of runoff and provide bank stabilization decreasing erosion and deposition. Additionally, filter strips mitigate nutrient loads to lakes. The following paragraphs focus on the implementation of filter strips in the Vandalia Lake Watershed. Finally, design criteria and size selection of filter strips are detailed.

Grass and riparian buffer strips filter out nutrients and organic matter associated with sediment loads to a water body. Reduction of nutrient concentrations, specifically phosphorus, in Vandalia Lake will reduce the amount of algal growth in the lake system, which can cause more significant diurnal pH fluctuations from photosynthesis. Filter strips reduce nutrient and sediment loads to lakes by establishing ground depressions and roughness that settles sediment out of runoff and providing vegetation to filter nutrients out of overland flow. As much as 75 percent of sediment and 45 percent of total phosphorus can be removed from runoff by a grass filter strip (NCSU 2000). In addition, filter strips should be harvested periodically so that removal rate efficiencies over extended periods of time remain high (USEPA 1993).

Filter strip widths for the Vandalia Lake TMDL were estimated based on the slope. According to the NRCS Planning and Design Manual, the majority of sediment is removed in the first 25 percent of the width (NRCS 1994). Table 9-1 outlines the guidance for filter strip flow length by slope (NRCS 1999). Based on slope estimates near tributaries within the watershed filter strip, widths of 72 to 144 feet could be incorporated in locations throughout the watershed. The total acreage examined was 236 acres.

Table 9-1 Filter Strip Flow Lengths Based on Land Slope

Percent Slope	0.5%	1.0%	2.0%	3.0%	4.0%	5.0% or greater
Minimum	36	54	72	90	108	117
Maximum	72	108	144	180	216	234

The acreages provided above are used to calculate an approximation of BMP costs in Section 9.2 and should only be used as a guideline for watershed planning. It is recommended that landowners evaluate their land near streams and lakes and create or extend filter strips according to the NRCS guidance presented in Table 9-1. Programs available to fund the construction of these buffer strips are discussed in Section 9.2.

9.1.1.3 Wetlands

The use of wetlands as a structural control is applicable to nutrient reduction from agricultural lands in Vandalia Lake. To treat loads from agricultural runoff, which is estimated to contribute approximately 17 percent of the current total phosphorus load to Vandalia Lake, a wetland could be constructed on the upstream end of the reservoir. Wetlands are assumed to be an effective BMP because they:

- prevent floods by temporarily storing water, allowing the water to evaporate, or percolate into the ground;
- improve water quality through natural pollution control such as plant nutrient uptake;
- filter sediment; and
- slow overland flow of water thereby reducing soil erosion (USDA 1996).

A properly designed and functioning wetland can provide very efficient treatment of pollutants, such as phosphorus. Design of wetland systems is very important and should consider soils in the proposed location, hydraulic retention time, and space requirements. Constructed wetlands, which comprise the second or third stage of nonpoint source treatment, can be effective at improving water quality. Studies have shown that artificial wetlands designed and constructed specifically to remove pollutants from surface water runoff have removal rates for suspended solids of greater than 90 percent, for total phosphorus of 0 to 90 percent, for orthophosphate of 20 to 80 percent, and for nitrogen species from 10 to 75 percent (Johnson, Evans, and Bass 1996; Moore 1993; USEPA 1993; Kovosic et al. 2000). Although the removal rate for phosphorus is low in long-term studies, the rate can be improved if sheet flow is maintained to the wetland and vegetation and substrate are monitored to ensure the wetland is operating optimally. Sediment or vegetation removal may be necessary if the wetland removal efficiency is lessened over time. (USEPA 1993; NCSU 1994).

Guidelines for wetland design suggest a wetland to watershed ratio of 0.6 percent for nutrient and sediment removal from agricultural runoff. Table 9-2 outlines estimated wetland areas for each subbasin based on these recommendations. A wetland system to treat agricultural runoff from the seven subbasins comprising the 15,040-acre (23.5 square miles) Vandalia Lake Watershed would range between five to 26 acres (Denison and Tilton 1993).

Table 9-2 Acres of Wetland Required

Subbasin	Area (acres)	Wetland (acre)
1	4,364	26
2	1,549	9
3	2,701	16
4	2,221	13
5	2,464	15
6	761	5
7	1,003	6

9.1.1.4 Nutrient Management

Nutrient management could result in reduced phosphorus and nitrogen loads to Vandalia Lake. Crop management of nitrogen and phosphorus can be accomplished through Nutrient Management Plans, which focus on increasing the efficiency with which applied nutrients are used by crops, thereby reducing the amount available to be transported to both surface and groundwater. In the past, nutrient management focused on application rates designed to meet crop nitrogen requirements but avoid groundwater quality problems created by excess nitrogen leaching. This results in buildup of soil phosphorus above amounts sufficient for optimal crop yields. Illinois, along with most Midwestern states, demonstrates high soil test phosphorus in greater than 50 percent of soil samples analyzed (Sharpley et al. 1999).

The overall goal of phosphorus reduction from agriculture should increase the efficiency of phosphorus use by balancing phosphorus inputs in feed and fertilizer with outputs in crops and animal produce as well as managing the level of phosphorus in the soil. Reducing phosphorus loss in agricultural runoff may be brought about by source and transport control measures, such as filter strips or grassed waterways. The Nutrient Management Plans account for all inputs and outputs of phosphorus to determine reductions. Elements of a Nutrient Management Plan include:

- plan summary;
- manure summary, including annual manure generation, use, and export;
- nutrient application rates by field and crop;
- summary of excess manure utilization procedures;
- implementation schedule; and
- manure management and stormwater BMPs.

In Illinois, Nutrient Management Plans have successfully reduced phosphorus application to agricultural lands by 36-lb/acre. National reductions range from 106 to 11-lb/acre, with an average of 35-lb/acre (NCSU 2000).

9.1.1.5 Septic System Maintenance and Sanitary System

Septic systems located along the perimeter of Vandalia Lake were estimated to contribute approximately 2 percent of the dissolved phosphorus loaded to the watershed. To reduce the excessive amounts of contaminants from a faulty septic system, a regular maintenance plan that includes regular pumping and maintenance of the septic system should be followed. The majority of failures originate from excessive

suspended solids, nutrients, and BOD loading to the septic system. Reduction of solids to the tank can be achieved via limiting garbage disposals use, water conservation, and phosphate detergent restrictions. In addition, in some watersheds an approximate 40 to 50 percent reduction of phosphorus loaded to a septic system can be achieved through phosphate detergent restrictions (USEPA 1980).

Septic system management activities can extend the life and maintain the efficiency of a septic system. Water conservation practices, such as limiting daily water use or using low flow toilets and faucets, are the most effective methods to maintain a properly functioning septic system. Additionally, the system should not be used for the disposal of solids, such as cigarette butts, cat litter, cotton swabs, coffee grinds, disposable diapers, etc. Finally, physical damage to the drainfield can be prevented by:

- maintaining a vegetative cover over the drainfield to prevent erosion;
- avoiding construction over the system;
- protecting the area down slope of the system from excavation; and
- landscaping the area to divert surface flow away from the drainfield (Johnson 1998.)

The cost of each management measure is site specific; therefore, costs for these practices were not outlined in Section 9.2.

Alternatively, a long-range solution to failing septic systems is connection to a municipal sanitary sewer system. Installation of a sanitary sewer will reduce existing nutrient sources by replacing failing septic systems and will allow communities to develop without further contribution of phosphorus loads to Vandalia Lake. Costs for the installation are generally paid over a period of several years (average of 20 years) instead of forcing homeowners to shoulder the entire cost of installing a new septic system. In addition, costs are sometimes shared between the lake community and the utility responsible for treating the wastewater generated from replacing the septic tanks. The planning process is involved and requires participation from townships, cities, counties, lake associations, and citizens.

9.1.2 In-Lake Phosphorus

Internal cycling of phosphorus contributes approximately 78 percent of the phosphorus load to Vandalia Lake Watershed. Reduction of phosphorus from in-lake cycling through management strategies is necessary for attainment of the TMDL load allocation. Internal phosphorus loading occurs when the water above the sediments become anoxic causing the reduction of iron phosphate, which releases phosphate from the sediment in a form which is available for plant uptake. The addition of bioavailable phosphorus in the water column stimulates more plant growth and die-off, which perpetuates the anoxic conditions and enhances the reduction of iron and the subsequent phosphate release from ferric phosphate into the water.

Control of internal phosphorus cycling must limit release of phosphorus from the sediments either through lake oxygen concentration or sediment management. If the water column never becomes anaerobic the ferric phosphate will not be reduced to

bioavailable phosphorus. Aeration, which simulates lake mixing and keeps oxygen conditions from being depleted in the epilimnon can be very effective at preventing re-release of bound phosphorus. Reduction of internal phosphorus cycling from this measure is typically determined based on site-specific studies.

Phosphorus release from the sediment is greatest from recently deposited layers. Dredging about one meter of recently deposited phosphorus–rich sediment can remove approximately 80 to 90 percent of the internally loaded phosphorus without the addition of potentially toxic compounds to the reservoir. However, dredging is more costly than other management options (National Resources Council [NRC] 1992).

9.1.3 Implementation Actions and Management Measures Summary

To meet the reductions outlined in Section 8 for Vandalia Lake segment ROD, 47 percent of phosphorus loaded from nonpoint source pollution and 90 percent of the phosphorus from internal loading would need to be reduced in order to meet the TMDL target of a phosphorus concentration less than 0.05 mg/L. The GWLF model was used to model the following practices to estimate what reduction in total phosphorus could be achieved:

- conservation tillage;
- nutrient management (reduction of total phosphorus in sediment by 20 percent);
- septic system and leach field maintenance; and
- filter strips.

The modeling effort showed that filter strips do not provide much total phosphorus reduction, most likely due to routing constraints of the GWLF model as discussed in Section 7.3.2.1.1 and the small magnitude of area available for filter strip development. Reductions of external loads by conservation tillage, nutrient management, septic system and leach field maintenance, filter strips and wetlands are summarized in Table 9-3. Wetlands were not modeled with GWLF because wetland performance is a result of placement in the watershed, and GWLF does not recognize spatial data due to routing constraints of the model. The lower bound of the literature value for wetlands was used due to studies that have shown the long-term effectiveness of phosphorus removal in wetlands is negligible.

Table 9-3 Summary of Total Phosphorus Load Reductions

Management Measure	Potential Percent Reduction
Nutrient Management	10
Conservation Tillage Practices	11
Septic System and Leach Field Maintenance	3
Filter Strips*	22
Wetland*	5

* Literature value utilized for estimation

A combination of implementing these external reductions in load, coupled with the available treatments for internal loads, would allow the watershed to meet its total goal

of reducing loads. The next section outlines planning level costs and programs available to help with cost-sharing so that this goal can be achieved.

9.2 Reasonable Assurance

Reasonable assurance means that a demonstration is given that nonpoint source reductions in this watershed will be implemented. It should be noted that all programs discussed in this section are voluntary. The discussion in Section 9.1 provided a means for obtaining the reductions necessary. The remainder of this section discusses an estimate of costs to the watershed for implementing these practices and programs available to assist with funding.

9.2.1 Available Programs for Phosphorus TMDL

Approximately 92 percent of the Vandalia Lake Watershed is classified as rural grassland (pasture land, CRP, waterways, buffer strip, etc.), row crop, and small grains land. There are several voluntary conservation programs established through the 2002 U.S. Farm Bill, which encourage landowners to implement resource conserving practices for water quality and erosion control purposes. These programs would apply to crop fields and rural grasslands that are presently used as pasture land. Each program is discussed separately in the following paragraphs.

9.2.1.1 Illinois Department of Agriculture and Illinois EPA Nutrient Management Plan Project

The Illinois Department of Agriculture (IDA) and Illinois EPA are presently co-sponsoring a cropland Nutrient Management Plan project in watersheds that have or are developing a TMDL. Under this project, 10,500 acres of cropland have been targeted in the Vandalia Lake Watershed. This voluntary project will supply incentive payments to producers to have Nutrient Management Plans developed and implemented. Additionally, if sediments or phosphorus has been identified as a cause for impairment in the watershed, then traditional erosion control practices will be eligible for cost-share assistance through the Nutrient Management Plan project as well.

9.2.1.2 Clean Water Act Section 319 Grants

Section 319 was added to the CWA to establish a national program to address nonpoint sources of water pollution. Through this program, each state is allocated Section 319 funds on an annual basis according to a national allocation formula based on the total annual appropriation for the Section 319 grant program. The total award consists of two categories of funding; incremental funds and base funds. A state is eligible to receive EPA 319(h) grants upon USEPA's approval of the state's Nonpoint Source Assessment Report and Nonpoint Source Management Program. States may reallocate funds through subawards (e.g., contracts, subgrants) to both public and private entities, including local governments, tribal authorities, cities, counties, regional development centers, local school systems, colleges and universities, local nonprofit organizations, state agencies, federal agencies, watershed groups, for-profit groups, and individuals. Subawards to individuals are limited to demonstration projects (USEPA 2003, 2002).

USEPA designates incremental funds, a $100-million award, for the restoration of impaired water through the development and implementation of watershed-based plans and TMDLs for impaired waters. Base funds, funds other than incremental funds, are used to provide staffing and support to manage and implement the state Nonpoint Source Management Program. Section 319 funding can be used to implement activities which improve water quality, such as filter strips, streambank stabilization, etc. (USEPA 2003, 2002).

9.2.1.3 Conservation Reserve Program (CRP)

This voluntary program encourages landowners to plant long-term resource-conserving cover to improve soils, water, and wildlife resources. CRP is the USDA's single largest environmental improvement program and one of its most productive and cost-efficient. It is administered through the Farm Service Agency (FSA) by USDA's Commodity Credit Corporation (CCC). The program was initially established in the Food Security Act of 1985. The duration of the contracts under CRP range from 10 to 15 years.

Eligible land must be one of the following:

1. cropland that is planted or considered planted to an agricultural commodity two of the five most recent crop years (including field margins); must be physically and legally capable of being planted in a normal manner to an agricultural commodity, and

2. certain marginal pastureland enrolled in the Water Bank Program.

The CCC bases rental rates on the relative productivity of soils within each county and the average of the past three years of local dry land cash rent or cash-rent equivalent. The maximum rental rate is calculated in advance of enrollment. Producers may offer land at the maximum rate or at a lower rental rate to increase likelihood of offer acceptance. In addition, the CCC provides cost-share assistance for up to 50 percent of the participant's costs in establishing approved conservation practices. CCC also encourages restoration of wetlands by offering a one-time incentive payment equal to 25 percent of the costs incurred. This incentive is in addition to the 50 percent cost share provided to establish cover (USDA 1999).

Finally, CCC offers additional financial incentives of up to 20 percent of the annual payment for certain continuous sign-up practices. Continuous sign-up provides management flexibility to farmers and ranchers to implement certain high-priority conservation practices on eligible land. The land must be determined by NRCS to be eligible and suitable for any of the following practices:

- riparian buffers,
- filter strips,
- grass waterways,
- shelter belts,
- field windbreaks,
- living snow fences,

- contour grass strips,
- salt tolerant vegetation,
- shallow water areas for wildlife, and
- eligible acreage within an USEPA-designated wellhead protection area (FSA 1997).

Although CRP may be used to install filter strips, some of the land within the watershed that may need filter strips does not qualify for enrollment into the program.

9.2.1.4 Wetlands Reserve Program (WRP)

The Wetlands Reserve Program (WRP) is a voluntary program that provides technical and financial assistance to eligible landowners to restore, enhance, and protect wetlands. The goal of WRP is to achieve the greatest wetland functions and values, along with optimum wildlife habitat, on every acre enrolled in the program. At least 70 percent of each project area will be restored to the original natural condition, to the extent practicable. The remaining 30 percent of each area may be restored to other than natural conditions. Landowners have the option of enrolling eligible lands through permanent easements, 30-year easements, or restoration cost-share agreements. The program is offered on a continuous sign-up basis and is available nationwide. WRP offers landowners an opportunity to establish, at minimal cost, long-term conservation and wildlife habitat enhancement practices and protection. It is administered through the NRCS (2002b). Within the Vandalia Lake Watershed, very few areas have the characteristics necessary to qualify for the program.

The 2002 Farm Bill reauthorized the program through 2007, increasing the acreage enrollment cap to 2,275,000 acres with an annual enrollment of 250,000 acres per calendar year. The program is limited by the acreage cap and not by program funding. Since the program began in 1985, the average cost per acre is $1,100 in restorative costs and the average project size is 177 acres. The costs for each enrollment option follows in Table 9-4 (USDA 1996).

Table 9-4 Costs for Enrollment Options of WRP Program

Option	Permanent Easement	30-year Easement	Restoration Agreement
Payment for Easement	100% Agricultural Value	75% Agricultural Value	NA
Payment Options	Lump Sum	Lump Sum	NA
Restoration Payments	100% Restoration Cost Reimbursements	75% Restoration Cost Reimbursements	75% Restoration Cost Reimbursements

9.2.1.5 Environmental Quality Incentive Program (EQIP)

The Environmental Quality Incentive Program (EQIP) is a voluntary USDA conservation program for farmers and private landowners engaged in livestock or agricultural production who are faced with serious threats to soil, water, and related natural resources. It provides technical, financial, and educational assistance primarily in designated "priority areas." Priority areas are defined as watershed regions, or areas of special environmental sensitivity that have significant soil, water, or natural resource related concerns. The program goal is to maximize environmental benefits per

dollar expended and provides "(1) flexible technical and financial assistance to farmers and ranchers that face the most serious natural resource problems; (2) assistance to farmers and ranchers in complying with Federal, State, and tribal environmental laws, and encourage environmental enhancement; (3) assistance to farmers and ranchers in making beneficial, cost-effective changes to measures needed to conserve and improve natural resources; and (4) for the consolidation and simplification of the conservation planning process." As of 2001, 379,000 acres have been protected in Illinois using EQIP (NRCS 2002d,e).

Landowners, with the assistance of a local NRCS or other service provider, are responsible for development of a site-specific conservation plan, which addresses the primary natural resource concerns of the priority area. Conservation practices include but are not limited to erosion control, filter strips, buffers, and grassed waterways. If the plan is approved by NRCS, a five- to 10-year contract that provides cost-share and incentive payments is developed.

Cost-share assistance may pay landowners up to 75 percent of the costs of conservation practices, such as grassed waterways, filter strips, manure management, capping abandoned wells, and other practices important to improving and maintaining the health of natural resources in the area. Total incentive and cost-share payments are limited to $10,000 per person per year and $50,000 over the life of the contract.

9.2.1.6 Conservation Practices Program (CPP)

The Conservation Practices Program (CPP) is a 10-year program. The practices consist of waterways, water and sediment control basins (WASCOBs), pasture/hayland establishment, critical area, terrace system, no-till system, diversions, and grade stabilization structures. The CPP is state-funded through the Department of Agriculture. There is a project cap of $5,000 per landowner and costs per acre vary significantly from project to project.

9.2.1.7 Wildlife Habitat Incentives Program (WHIP)

The Wildlife Habitat Incentives Program (WHIP) is a voluntary program that encourages the creation of high quality wildlife habitat of national, state, tribal, or local significance. WHIP is administered through NRCS, which provides technical and financial assistance to landowners for development of upland, riparian, and aquatic habitat areas on their property. NRCS works with the participant to develop a wildlife habitat development plan which becomes the basis of the cost-share agreement between NRCS and the participant. Most contracts are five to 10 years in duration, depending upon the practices to be installed. However, longer-term contracts of 15 years or greater may also funded. Under the agreement:

- The landowner agrees to maintain the cost-shared practices and allow NRCS or its agent access to monitor its effectiveness.

- NRCS agrees to provide technical assistance and pay up to 75 percent of the cost of installing the wildlife habitat practices. Additional financial or technical assistance may be available through cooperating partners (NRCS 2002c).

The FSA administers the CRP. NRCS administers the EQIP, WRP, and WHIP. Local NRCS and FSA contact information in Fayette County is listed in the Table 9-5 below.

Table 9-5 Local NRCS and FSA Contact Information

Contact	Address	Phone
Local NRCS Office		
MaryAnn Hoeffliger	301 South Third Street, Vandalia, IL 62471	618-283-1095 x 3
Local FSA Office		
Vandalia Service Center	301 South Third Street, Vandalia, IL 62471	618-283-2311

9.2.2 Cost Estimates of BMPs

Cost estimates for different best management practices and individual practice prices such as filter strip installation are detailed in the following sections. Table 9-6 outlines the cost of implementation measures per acre. Finally, an estimate of the total order of magnitude costs for implementation measures in the Vandalia Lake Watershed are presented in Section 9.2.2.7 and Table 9-7.

9.2.2.1 Wetlands

The price to establish a wetland is very site specific. In general, to restore hydrology with a 6-inch to 2-foot berm the cost is $4 to $5/linear foot. A water control structure, if required, would cost approximately $500 to $1,000. Finally, tree planting using bare root stock is $350/acre or $450/acre if the trees are container grown. This equates to an average cost of $3,000/acre to construct a wetland in Fayette County.

9.2.2.2 Filter Strips and Riparian Buffers

Fayette County NRCS estimates an average cost per acre to install and maintain a grass filter strip with a 5-year life span at $54/acre. This price quote accounts for seeding and mowing every other year to remove woody sprouts. A riparian buffer strip established with bare root stock has a life span of 10 years and an installation cost of $350/acre. If the riparian zone is planted using direct seeding with acorns the cost drops to $150/acre.

9.2.2.3 Nutrient Management Plan - NRCS

A significant portion of the agricultural land in the Vandalia Lake Watershed is comprised of cropland. Therefore nutrient management concentrates on nitrogen, phosphorus, potassium, lime, and pest management residuals. The Nutrient Management Program in Fayette County consists of soil testing every three years using University of Illinois Guidelines and site specific recommendations for fertilizer application based on determined credits and realistic crop yields. The service averages $5 to $15/acre.

9.2.2.4 Nutrient Management Plan - IDA and Illinois EPA

The costs associated with development of Nutrient Management Plans co-sponsored by the IDA and the Illinois EPA are estimated as $5/acre paid to the producer and $2/acre for a third party vendor who develops the plans. The total plan development cost is estimated at $7/acre.

9.2.2.5 Conservation Tillage

Conservation tillage is assumed to include tillage practices that preserve at least 30 percent residue cover of the soil after crops are planted. The installation cost for conservation tillage is $17/acre, and the average annual cost for maintaining conservation tillage is $17.35/acre/year (NCSU 2000).

9.2.2.6 Internal Cycling

Controls of internal phosphorus cycling in lakes are costly. Dredging is typically the most expensive management practice averaging $8,000/acre; however, the practice is 80 to 90 percent effective at nutrient removal and will last for at least 50 years. An aeration system, consisting of an air compressor, pump, weighted tubing, and diffuser stations costs approximately $69,000 for material and installation. Operating costs to run the pump are estimated as $36/day for approximately 180 days/year, which totals about $6,000/year in operating costs (Cortell 2002; Geney 2002).

9.2.2.7 Planning Level Cost Estimates for Implementation Measures

Cost estimates for different implementation measures are presented in Table 9-6. The column labeled Program or Sponsor lists the financial assistance program or sponsor available for various BMPs. The programs and sponsors represented in the table are the WRP, the CRP, NRCS, Illinois EPA, and IDA.

Table 9-6 Cost Estimate of Various BMP Measures in Fayette County

Source	Program or Sponsor	BMP	Life Span	Installation Mean $/acre	Maintenance $/ac/yr
Nonpoint	CRP	Grass filter strip from seed	5	$54	$10.80
	CRP	Riparian buffer from bare root	10	$350	$35.00
	CRP	Riparian buffer from seed	10	$150	$15.00
	WRP	Wetland	10	$3,000	$300.00
	NRCS	Nutrient Management Plan		$10	
	IDA and Illinois EPA	Nutrient Management Plan		$7	
	CRP	Conservation Tillage	1	$17	$17.35
Internal Cycling	319	Dredging	50	$8,000	$160.00
	319	Aeration	20	$583	$29.15

A total order of magnitude cost for implementation measures in the watershed was estimated to be $2,445,000. The total cost is calculated as the number of acres over which a BMP or structural measure is applied by the cost per acre. Table 9-7 summarizes the number of acres each measure is applied to in the basin and the corresponding cost. The acreages reported in Table 9-7 are a preliminary estimate in

order to provide an overall understanding of cost of implementation in the watershed. The total only represents capital costs and annual maintenance costs. These do not represent the total costs of operating the measure over its life cycle. The table does not represent every measure previously discussed.

Table 9-7 Cost Estimate of Implementation Measures in the Vandalia Lake Watershed

		Capital Costs		Maintenance Costs	
BMP	**Treated Acres**	**Mean $/acre**	**Watershed $**	**$/ac/yr**	**Watershed $/yr**
Grass Filter Strips	236	$54	$12,700	$10.80	$2,500
Wetland*	300	$3,000	$900,000	$300.00	$90,000
Nutrient Management Plan	10,500	$7	$74,000		
Conservation Tillage	10,500	$17	$179,000	$17.35	$182,000
Dredging **	160	$8,000	$1,280,000		
Total			**$2,446,000**		**$22,000**

* Cost to install berm around 1/2 the perimeter and plant container plants
** One time cost

9.3 Monitoring Plan

The purpose of the monitoring plan for Vandalia Lake is to assess the overall implementation of management actions outlined in this section. This can be accomplished by conducting the following monitoring programs:

- tracking implementation of management measures in the watershed,
- estimating effectiveness of management measures,
- continuing ambient monitoring of Vandalia Lake, and
- tributary monitoring.

Tracking the implementation of management measures can be used to address the following goals (NCSU 2000):

- determine the extent to which management measures and practices have been implemented compared to action needed to meet TMDL endpoints;
- establish a baseline from which decisions can be made regarding the need for additional incentives for implementation efforts;
- measure the extent of voluntary implementation efforts;
- support work-load and costing analysis for assistance or regulatory programs; and
- determine the extent to which management measures are properly maintained and operated.

Estimating the effectiveness of the BMPs implemented in the watershed could be completed by monitoring before and after the BMP is incorporated into the watershed. Additional monitoring could be conducted on specific structural systems such as a constructed wetland. Inflow and outflow measurements could be conducted to

determine site-specific removal efficiency. If aeration is used to control internal loading, site-specific data would be needed to assess the effectiveness of this management measure. Sampling near the bottom of the reservoir could help assess whether internal loading controls are working properly.

Illinois EPA monitors Vandalia Lake from April through October approximately every three years. Continuation of this ambient monitoring will assess in-lake water quality as improvements in the watershed are completed. This data will also be used to assess whether water quality standards in the reservoir are being attained.

Tributary monitoring is needed to better assess the contribution of internal loading to Vandalia Lake. By having further knowledge of actual contributions from external loads, a better estimate of internal loads could occur. This sampling should occur on all tributaries throughout the period of the year when loading is expected to be greatest. Along with this tributary monitoring, a stage discharge relationship could be developed with the reservoir spillway so that flows into the reservoir could be paired with tributary water quality data to determine total phosphorus load from the watershed. Data on the different forms of phosphorus (dissolved, total, or orthophosphate) would also be beneficial to better assess reservoir response to phosphorus loading.

9.4 Implementation Time Line

Implementing the actions outlined in this section for the Vandalia Lake Watershed should occur in phases and assessing effectiveness of the management actions as improvements are made. It is assumed that it may take up to five years to secure funding for actions needed in the watershed and five to seven years after funding to implement the measures. Once improvements are implemented, it may take Vandalia Lake 10 years or more to reach its water quality standard target of 0.05 mg/L (Wetzel 1983). If internal loads are not effectively controlled, this time frame could be even greater as the reservoir will take time to "flush" out the phosphorus bound to bottom sediments as reductions in external loads take place. In summary, to meet water quality standards in Vandalia Lake may take up to 20 years to complete.

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Section 10
References

Bass, K.L. 2000. Evaluation of a Small In-Stream Constructed Wetland in North Carolina's Coastal Plain. North Carolina State University: Thesis. http://www.bae.ncsu.edu/research/evans_web/etd/klbass.pdf

Chapra, S.C. 1997. *Surface Water-Quality Modeling*. McGraw-Hill. New York.

Cortell, J. 2002. Personal communication regarding Marine Biochemists aeration systems. www.marinebiochemists.com

Denison, D. and D. Tilton. 1993. Rouge River National Wet Weather Demonstration Program: Technical Memorandum. Rouge River Project: RPO-NPS-TM-12.01. August.

Fayette County Soil and Water Conservation District. 2001. 2001 *County Transect Summary Reports*. Illinois Department of Agriculture.

FSA (Farm Service Agency). 1997. *Conservation Reserve Program: Continuous Sign-Up for High Priority Conservation Practices*. USDA. February.

Geney, R. 2002. Personal communication regarding GES aeration systems. www.airation.com

Haith et al. 1996. *GWLF: Generalized Watershed Loading Functions.* Department of Agricultural and Biological Engineering. Cornell University. Ithaca, New York.

IDNR (Illinois Department of Natural Resources). 1996: Illinois Clearinghouse: Natural History Data. Download: Critical Trends Assessment Land Cover Database. http://www.isgs.uiuc.edu/nsdihome/webdocs/st-naths.html

Illinois EPA (Illinois Environmental Protection Agency) 2002. *Water Quality Data.*

_____. 2000. *Annual Illinois Water Quality Report, 2000*. IEPA/BOW/00-005.

IPCB (Illinois Pollution Control Board). 1999. *Illinois Administrative Rules, Title 35: Environmental Protection; Part 302: Water Quality Standards*.

ISWS (Illinois State Water Survey). 2000. Pan Evaporation in Illinois. Download: Pan Evaporation in Illinois. http://www.sws.uiuc.edu/atmos/statecli/Pan_Evap/Panevap.htm

Johnson, B. 1998. Rouge River National Wet Weather Demonstration Program: Task Product Memorandum. Rouge River Project: RPO-NPS-TM-54.00. October.

Johnson, R., R. Evans, and K. Bass. 1996. *Constructed Wetlands Demonstration Project for NPS Pollution Control*. North Carolina Department of Natural Resources: Division of Water Quality. http://h2o.enr.state.nc.us/nps/edenton96.pdf

Kovosic, D.A., M.B. David, L.E. Gentry, K.M. Starks, and R.A. Cooke. 2000. Effectiveness of constructed wetlands in reducing N and P export from agricultural tile drainage. *J. Environmental Quality.* 29:1262-1274.

Moore, J.A. 1993. *Using Constructed Wetlands to Improve Water Quality.* Oregon State University Extension Service, EC1408: June. http://eesc.orst.edu/agcomwebfile/edmat/ec1408.pdf

Muir, D.B., M.M. King, M.R. Matson, G.L. Minton, S.P. Shasteen, M.D. Bundren, R.L. Hite, and L.J. Pitcher. 1997. An Intensive Survey of the Big Muddy River Basin – Summer 1995.

NASS (National Agricultural Statistics Service). 2002. USDA-NASS-RDD Spatial Analysis Research Section. http://www.nass.usda.gov/research/Cropland/SARS1a.htm

NCDC (National Climatic Data Center). 2002. Weather stations.

NCSU (North Carolina State University) Water Quality Group. 2000. National Management Measures to Control Nonpoint Source Pollution from Agriculture. United States Environmental Protection Agency: Contract #68-C99-249.

_____. 1994. Functions of Wetlands (Processes). WATERSHEDSS. NCSU Water Quality Group. August.

Novotny and Olem. 1994. *Water Quality: Prevention, Identification, and Management of Diffuse Pollution*. Van Nostrand Reinhold. New York.

NRC (National Research Council). 1992. "Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy." *National Academy of Sciences*. Washington, D.C.

NRCS (Natural Resources Conservation Service). 2002a. Personal Communication with MaryAnn Hoeffliger of Fayette County NRCS.

_____. 2002b. *Farm Bill 2002: Wetlands Reserve Program Fact Sheet*. May. http://www.nrcs.usda.gov/programs/farmbill/ 2002/pdf/WRPFct.pdf

_____. 2002c. *Farm Bill 2002: Wildlife Habitat Incentives Program Fact Sheet*. May. http://www.nrcs.usda.gov/programs/farmbill/2002/pdf/WHIPFct.pdf

_____. 2002d. *The Environmental Quality Incentives Program*. USDA. April.

_____. 2002e. *2001 Environmental Quality Incentives Program: Illinois Summary*. USDA. January. http://www.nrcs.usda.gov/programs/eqip/2001summaries/ILEQIP%20doc.pdf

_____. 1999. *Filter Strip Conservation Practice Standard*. National Resources Conservation Service: Code 393. May. http://www.il.nrcs.usda.gov/resources/fotg/section4/393/393.pdf

_____. 1994. *Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater.* Natural Resources Conservation Service (formerly Soil Conservation Service), U.S. Department of Agriculture, Washington, DC. http://www.abe.msstate.edu/Tools/csd/p-dm/

Olivera, Francisco et al. 1998. CRWR-PrePro: An ArcView Preprocessor for Hydrologic, Hydraulic and Environmental Modeling. Download: ArcView Project Prepro3a.apr. http://www.ce.utexas.edu/prof/olivera/prepro/prepro.htm.

Osmond, D.L., J. Spooner, and D.E. Line. 1995. *Systems of Best Management Practices for Controlling Agricultural Nonpoint Source Pollution: The Rural Clean Water Program Experience*. North Carolina State University Water Quality Control Group: brochure 6. March.

Sharpley, A.N., T. Daniel, T. Sims, J. Lemunyon, R. Stevens, and R. Parry. 1999. *Agricultural Phosphorus and Eutrophication*. United States Department of Agriculture: ARS-149. July. http://www.ars.usda.gov/is/np/Phos&Eutro/phos%26eutro.pdf

USACE (U.S. Army Corps of Engineers). 2003. *Lake Astabula/Baldhill Dam Brochure*. http://www.mvp.usace.army.mil/docs/rec/ashtabula.pdf

_____. 1999a. National Inventory of Dams. Download: Reservoir Characteristics. http://crunch.tec.army.mil/nid/webpages/nid.cfm.

_____. 1999b. *Simplified Procedures for Eutrophication Assessment and Prediction: User Manual*. William Walker. Instruction Report W-96-2. Waterways Experiment Station. USACE Headquarters.

USDA (United States Department of Agriculture). 1999. *Farm Service Agency Online: Conservation Reserve Program Fact Sheet*. October. http://www.fsa.usda.gov/pas/publications/facts/html/crp99.htm

_____. 1997. *Soil Survey of Fayette County, Illinois*. Washington, D.C.

_____. 1996. *Restoring Wetlands with the Wetland Reserve Program*. http://www.il.nrcs.udsa.gov/resources/farmbill/inahgeh.htm

USEPA (U.S. Environmental Protection Agency). 2003. *Applying for and Administering CWA Section 319 Grants: A Guide for State Nonpoint Source Agencies*. State-EPA NPS Partnership. March. http://www.epa.gov/owow/nps/319/319stateguide-revised.pdf

_____. 2002a. *BASINS - Better Assessment Science Integrating Point and Nonpoint Sources*. Download: BASINS Data. http://www.epa.gov/OST/BASINS/

_____. 2002b. *STORET – Storage and Retrieval*. Download: Water Quality Data. http://www.epa.gov/storet/

_____. 2002c. *Supplemental Guidelines for the Award of Section 319 Nonpoint Source Grants to States and Territories in FY 2003.* EPA. August. http://www.epa.gov/owow/nps/Section319/319guide03.html

_____. 2001. *EPA* Exposure Assessment Models: TMDL USLE. Download: TMDL USLE Model and User's Manual. http://www.epa.gov/ceampubl/swater/usle/index.htm

_____. 1999. *Draft Guidance for Water Quality-based Decisions: The TMDL Process* (Second Edition). Office of Water. EPA 841/D/99/001.

_____. 1998a. *Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program.* EPA/100/R/98/006. Office of Administrator. July.

_____. 1997. *Compendium of Tools for Watershed Assessment and TMDL Development*. Office of Water. EPA/841/B/97/006.

_____. 1980. *Design Manual – Onsite Wastewater Treatment and Disposal Systems.* Office of Water. Washington, DC.

USGS (U.S. Geological Survey). 2002a. Daily Streamflow. Download: Daily Flows for Stream Gage 05595820. http://waterdata.usgs.gov/nwis

_____. 2002b. Seamless Data Distribution System. Download: National Elevation Dataset. http://edcnts14.cr.usgs.gov/Website/seamless.htm

_____. 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters: Management Measures for Wetlands, Riparian Areas, and Vegetated Treatment Systems*. EPA 840-B-92-002. January. http://www.epa.gov/nps/MMGI/Chapter7/ch7-2c.html

VLPC (Vandalia Lake Planning Committee). 2000. Vandalia Lake Watershed Implementation Plan. Vandalia, Illinois.

Welch, E.B. 1980. *Ecological Effects of Wastewater: Applied Limnology and Pollutant Effects.* E&FN Spon. New York.

Wetzel, R. G. 1983. *Limnology*. Saunders College Publishing. Orlando, Florida. pp. 289–297.

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Appendix A
Historic Water Quality Data

Secondary ID .1	Start Date	Parameter Long Name	Result Value	Sample Depth (ft)
ROD-1	5/23/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.24	1
ROD-1	6/24/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.183	1
ROD-1	7/30/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.109	1
ROD-1	8/23/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.304	1
ROD-1	9/25/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.085	1
ROD-1	10/16/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.09	1
ROD-1	4/7/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.14	1
ROD-1	4/7/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.144	Lake Bottom
ROD-1	6/24/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.063	1
ROD-1	6/24/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.191	Lake Bottom
ROD-1	7/20/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.043	1
ROD-1	7/20/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.494	Lake Bottom
ROD-1	8/24/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.046	1
ROD-1	8/24/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.26	Lake Bottom
ROD-1	10/19/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.057	1
ROD-1	10/19/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.066	Lake Bottom
ROD-1	10/16/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.065	
ROD-1	5/9/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.235	1
ROD-1	5/9/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.226	Lake Bottom
ROD-1	6/21/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.165	1
ROD-1	6/21/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.286	Lake Bottom
ROD-1	7/29/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.042	1
ROD-1	7/29/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.444	Lake Bottom
ROD-1	8/23/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.057	1
ROD-1	8/23/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.628	Lake Bottom
ROD-1	10/4/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.062	1
ROD-1	10/4/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.065	Lake Bottom
ROD-1	5/22/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.079	1
ROD-1	6/10/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.047	1
ROD-1	7/10/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.02	1
ROD-1	8/25/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.066	1
ROD-1	9/15/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.093	1
ROD-1	10/14/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.043	1
ROD-1	7/13/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.116	1
ROD-1	8/12/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.076	1
ROD-1	9/10/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.054	1
ROD-1	10/9/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.089	1
ROD-1	5/12/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.095	1
ROD-1	5/12/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.122	27
ROD-1	6/11/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.025	1
ROD-1	6/11/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.25	27
ROD-1	7/15/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.038	1
ROD-1	7/15/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.077	27
ROD-1	8/26/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.028	1
ROD-1	8/26/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.025	14
ROD-1	8/26/1999	PHOSPHORUS, TOTAL (MG/L AS P)	1.31	26
ROD-1	10/26/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.034	1
ROD-1	10/26/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.032	14
ROD-1	10/26/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.04	26
ROD-2	4/7/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.153	1
ROD-2	6/24/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.074	1

ROD-2	7/20/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.045	1
ROD-2	8/24/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.047	1
ROD-2	10/19/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.061	1
ROD-2	10/16/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.069	1
ROD-2	5/9/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.273	1
ROD-2	6/21/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.155	1
ROD-2	7/29/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.043	1
ROD-2	8/23/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.058	1
ROD-2	10/4/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.072	1
ROD-2	5/12/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.087	1
ROD-2	6/11/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.033	1
ROD-2	7/15/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.038	1
ROD-2	8/26/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.025	1
ROD-2	10/26/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.031	1
ROD-3	5/23/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.124	1
ROD-3	6/24/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.228	1
ROD-3	7/30/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.121	1
ROD-3	8/23/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.18	1
ROD-3	9/25/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.071	1
ROD-3	10/16/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.053	1
ROD-3	4/7/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.158	1
ROD-3	6/24/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.101	1
ROD-3	7/20/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.056	1
ROD-3	8/24/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.081	1
ROD-3	10/19/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.07	1
ROD-3	10/16/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.08	1
ROD-3	5/9/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.309	1
ROD-3	6/21/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.164	1
ROD-3	7/29/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.069	1
ROD-3	8/23/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.069	1
ROD-3	10/4/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.079	1
ROD-3	5/12/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.141	1
ROD-3	6/11/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.044	1
ROD-3	7/15/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.057	1
ROD-3	8/26/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.046	1
ROD-3	10/26/1999	PHOSPHORUS, TOTAL (MG/L AS P)	0.044	1

Secondary ID .1	Start Date	Parameter Long Name	Result Value	Depth
ROD-1	04/24/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.4	1
ROD-1	04/24/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.1	Lake Bottom
ROD-1	06/05/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.03	1
ROD-1	06/05/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	6.9	Lake Bottom
ROD-1	07/10/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	6.9	1
ROD-1	07/10/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.2	Lake Bottom
ROD-1	08/16/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.7	1
ROD-1	08/16/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	6.8	Lake Bottom
ROD-1	10/12/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.4	1
ROD-1	10/12/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.1	Lake Bottom
ROD-1	04/07/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.8	1
ROD-1	04/07/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.6	Lake Bottom
ROD-1	06/24/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.9	1
ROD-1	06/24/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.1	Lake Bottom
ROD-1	07/20/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.8	1
ROD-1	07/20/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.1	Lake Bottom
ROD-1	08/24/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.6	1
ROD-1	08/24/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.1	Lake Bottom
ROD-1	10/19/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.3	1
ROD-1	10/19/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	7	Lake Bottom
ROD-1	05/09/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.2	1
ROD-1	05/09/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	6.8	Lake Bottom
ROD-1	06/21/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	8	1
ROD-1	06/21/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	6.9	Lake Bottom
ROD-1	07/29/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.9	1
ROD-1	07/29/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.2	Lake Bottom
ROD-1	08/23/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	9.2	1
ROD-1	08/23/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.2	Lake Bottom
ROD-1	10/04/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.2	1
ROD-1	10/04/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.9	Lake Bottom
ROD-1	5/12/1999	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.5	1
ROD-1	5/12/1999	PH (STANDARD UNITS) (standard: 6.5-9.0)	6.5	27
ROD-1	6/11/1999	PH (STANDARD UNITS) (standard: 6.5-9.0)	9	1
ROD-1	6/11/1999	PH (STANDARD UNITS) (standard: 6.5-9.0)	6.8	27
ROD-1	07/15/99	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.7	1
ROD-1	07/15/99	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.6	14
ROD-1	07/15/99	PH (STANDARD UNITS) (standard: 6.5-9.0)	7	27
ROD-1	8/26/1999	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.9	1
ROD-1	8/26/1999	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.4	14
ROD-1	8/26/1999	PH (STANDARD UNITS) (standard: 6.5-9.0)	7	26
ROD-1	10/26/1999	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.2	1
ROD-1	10/26/1999	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.5	26
ROD-2	06/26/77	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.5	1
ROD-2	08/12/78	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.2	1
ROD-2	06/14/79	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.75	1
ROD-2	06/14/79	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.8	1
ROD-2	08/29/79	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.4	1
ROD-2	05/11/82	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.1	1
ROD-2	04/24/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.7	1
ROD-2	06/05/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.59	1
ROD-2	07/10/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.2	1

ROD-2	08/16/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.6	1
ROD-2	10/12/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.4	1
ROD-2	04/07/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.7	1
ROD-2	06/24/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.5	1
ROD-2	07/20/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.8	1
ROD-2	08/24/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.7	1
ROD-2	10/19/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.2	1
ROD-2	05/09/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	6.9	1
ROD-2	06/21/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	8	1
ROD-2	07/29/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.9	1
ROD-2	08/23/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	9.1	1
ROD-2	10/04/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.3	1
ROD-2	5/12/1999	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.9	1
ROD-2	6/11/1999	PH (STANDARD UNITS) (standard: 6.5-9.0)	9.1	1
ROD-2	07/15/99	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.9	1
ROD-2	8/26/1999	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.7	1
ROD-2	10/26/1999	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.6	1
ROD-3	06/26/77	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.7	1
ROD-3	08/12/78	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.2	1
ROD-3	06/14/79	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.6	1
ROD-3	06/14/79	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.65	1
ROD-3	08/29/79	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.3	1
ROD-3	08/29/79	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.1	1
ROD-3	05/11/82	PH (STANDARD UNITS) (standard: 6.5-9.0)	6.9	1
ROD-3	04/24/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.6	1
ROD-3	06/05/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.56	1
ROD-3	07/10/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.2	1
ROD-3	08/16/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.3	1
ROD-3	10/12/89	PH (STANDARD UNITS) (standard: 6.5-9.0)	8	1
ROD-3	04/07/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.7	1
ROD-3	06/24/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.9	1
ROD-3	07/20/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.8	1
ROD-3	08/24/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.3	1
ROD-3	10/19/93	PH (STANDARD UNITS) (standard: 6.5-9.0)	7.3	1
ROD-3	05/09/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	6.8	1
ROD-3	06/21/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	8	1
ROD-3	07/29/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.9	1
ROD-3	08/23/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	9.1	1
ROD-3	10/04/96	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.4	1
ROD-3	5/12/1999	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.1	1
ROD-3	6/11/1999	PH (STANDARD UNITS) (standard: 6.5-9.0)	9	1
ROD-3	07/15/99	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.6	1
ROD-3	8/26/1999	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.4	1
ROD-3	10/26/1999	PH (STANDARD UNITS) (standard: 6.5-9.0)	8.6	1

Secondary ID .1	Start Date	Parameter Long Name	Result Value
ROD-1	5/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	5/29/1990	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	6/5/1990	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	6/26/1990	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	7/8/1990	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	7/25/1990	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	8/9/1990	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	8/25/1990	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	9/5/1990	DEPTH OF POND OR RESERVOIR IN FEET	27.5
ROD-1	9/24/1990	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	10/11/1990	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	10/21/1990	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	5/7/1991	DEPTH OF POND OR RESERVOIR IN FEET	30
ROD-1	5/23/1991	DEPTH OF POND OR RESERVOIR IN FEET	29.5
ROD-1	6/10/1991	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	6/24/1991	DEPTH OF POND OR RESERVOIR IN FEET	29.5
ROD-1	7/5/1991	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	7/30/1991	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	8/10/1991	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	8/24/1991	DEPTH OF POND OR RESERVOIR IN FEET	27
ROD-1	9/13/1991	DEPTH OF POND OR RESERVOIR IN FEET	27
ROD-1	9/28/1991	DEPTH OF POND OR RESERVOIR IN FEET	27
ROD-1	10/10/1991	DEPTH OF POND OR RESERVOIR IN FEET	27
ROD-1	10/25/1991	DEPTH OF POND OR RESERVOIR IN FEET	27
ROD-1	4/6/1992	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	4/28/1992	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	5/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	30
ROD-1	5/27/1992	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	6/12/1992	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	6/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	7/6/1992	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	7/29/1992	DEPTH OF POND OR RESERVOIR IN FEET	27
ROD-1	8/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	27
ROD-1	8/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	27
ROD-1	9/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	27
ROD-1	9/27/1992	DEPTH OF POND OR RESERVOIR IN FEET	27
ROD-1	10/13/1992	DEPTH OF POND OR RESERVOIR IN FEET	27
ROD-1	10/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	27
ROD-1	4/7/1993	DEPTH OF POND OR RESERVOIR IN FEET	28.5
ROD-1	4/7/1993	DEPTH OF POND OR RESERVOIR IN FEET	28.5
ROD-1	4/7/1993	DEPTH OF POND OR RESERVOIR IN FEET	28.5
ROD-1	6/7/1993	DEPTH OF POND OR RESERVOIR IN FEET	29.5
ROD-1	6/22/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	6/24/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	6/24/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	6/24/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	7/12/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	7/20/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	7/20/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	7/20/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	7/30/1993	DEPTH OF POND OR RESERVOIR IN FEET	29

ROD-1	8/12/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	8/24/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	8/24/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	8/24/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	8/25/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	9/10/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	9/26/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	10/11/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	10/19/1993	DEPTH OF POND OR RESERVOIR IN FEET	30
ROD-1	10/19/1993	DEPTH OF POND OR RESERVOIR IN FEET	30
ROD-1	10/19/1993	DEPTH OF POND OR RESERVOIR IN FEET	30
ROD-1	11/1/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	5/9/1994	DEPTH OF POND OR RESERVOIR IN FEET	29.5
ROD-1	5/21/1994	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	6/10/1994	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	6/22/1994	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	7/8/1994	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	7/23/1994	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	8/9/1994	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	8/20/1994	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	9/8/1994	DEPTH OF POND OR RESERVOIR IN FEET	18.5
ROD-1	9/23/1994	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	10/10/1994	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	10/29/1994	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	5/9/1995	DEPTH OF POND OR RESERVOIR IN FEET	31
ROD-1	5/24/1995	DEPTH OF POND OR RESERVOIR IN FEET	29.5
ROD-1	6/7/1995	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	6/21/1995	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	7/6/1995	DEPTH OF POND OR RESERVOIR IN FEET	28.5
ROD-1	7/23/1995	DEPTH OF POND OR RESERVOIR IN FEET	28.5
ROD-1	8/8/1995	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	8/21/1995	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	9/11/1995	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	9/21/1995	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	10/9/1995	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	10/25/1995	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	5/7/1996	DEPTH OF POND OR RESERVOIR IN FEET	30
ROD-1	5/9/1996	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	5/9/1996	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	5/9/1996	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	5/21/1996	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	6/12/1996	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	6/20/1996	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	6/21/1996	DEPTH OF POND OR RESERVOIR IN FEET	27
ROD-1	6/21/1996	DEPTH OF POND OR RESERVOIR IN FEET	27
ROD-1	6/21/1996	DEPTH OF POND OR RESERVOIR IN FEET	27
ROD-1	7/8/1996	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	7/22/1996	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	7/29/1996	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	7/29/1996	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	8/9/1996	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	8/20/1996	DEPTH OF POND OR RESERVOIR IN FEET	28

ROD-1	8/23/1996	DEPTH OF POND OR RESERVOIR IN FEET	28.5
ROD-1	8/23/1996	DEPTH OF POND OR RESERVOIR IN FEET	28.5
ROD-1	8/23/1996	DEPTH OF POND OR RESERVOIR IN FEET	28.5
ROD-1	9/13/1996	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	9/28/1996	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	10/4/1996	DEPTH OF POND OR RESERVOIR IN FEET	28.5
ROD-1	10/4/1996	DEPTH OF POND OR RESERVOIR IN FEET	28.5
ROD-1	10/4/1996	DEPTH OF POND OR RESERVOIR IN FEET	28.5
ROD-1	10/10/1996	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	10/21/1996	DEPTH OF POND OR RESERVOIR IN FEET	27
ROD-1	5/12/1997	DEPTH OF POND OR RESERVOIR IN FEET	29.5
ROD-1	5/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	28.5
ROD-1	6/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	29.5
ROD-1	6/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	7/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	7/24/1997	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	8/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	29.5
ROD-1	8/25/1997	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	9/15/1997	DEPTH OF POND OR RESERVOIR IN FEET	28.5
ROD-1	10/14/1997	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	10/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	5/10/1998	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	5/29/1998	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	6/9/1998	DEPTH OF POND OR RESERVOIR IN FEET	30
ROD-1	6/23/1998	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	7/13/1998	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	7/22/1998	DEPTH OF POND OR RESERVOIR IN FEET	29.5
ROD-1	8/12/1998	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	8/24/1998	DEPTH OF POND OR RESERVOIR IN FEET	29
ROD-1	9/10/1998	DEPTH OF POND OR RESERVOIR IN FEET	28.5
ROD-1	9/21/1998	DEPTH OF POND OR RESERVOIR IN FEET	28
ROD-1	10/9/1998	DEPTH OF POND OR RESERVOIR IN FEET	28.5
ROD-1	10/24/1998	DEPTH OF POND OR RESERVOIR IN FEET	28.5
ROD-2	5/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	5/29/1990	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	6/5/1990	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	6/26/1990	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	7/8/1990	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	7/25/1990	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	8/9/1990	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	8/25/1990	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	9/5/1990	DEPTH OF POND OR RESERVOIR IN FEET	20.5
ROD-2	9/24/1990	DEPTH OF POND OR RESERVOIR IN FEET	20
ROD-2	10/11/1990	DEPTH OF POND OR RESERVOIR IN FEET	20.5
ROD-2	10/21/1990	DEPTH OF POND OR RESERVOIR IN FEET	20.5
ROD-2	5/7/1991	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	5/23/1991	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	6/10/1991	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	6/24/1991	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	7/5/1991	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	7/30/1991	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	8/10/1991	DEPTH OF POND OR RESERVOIR IN FEET	21

ROD-2	8/24/1991	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	9/13/1991	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	9/28/1991	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	10/10/1991	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	10/25/1991	DEPTH OF POND OR RESERVOIR IN FEET	19
ROD-2	4/6/1992	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	4/28/1992	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	5/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	5/27/1992	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	6/12/1992	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	6/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	7/6/1992	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	7/29/1992	DEPTH OF POND OR RESERVOIR IN FEET	20.5
ROD-2	8/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	20.5
ROD-2	8/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	9/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	9/27/1992	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	10/13/1992	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	10/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	4/7/1993	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	4/7/1993	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	6/7/1993	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	6/22/1993	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	6/24/1993	DEPTH OF POND OR RESERVOIR IN FEET	24
ROD-2	6/24/1993	DEPTH OF POND OR RESERVOIR IN FEET	24
ROD-2	7/12/1993	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	7/20/1993	DEPTH OF POND OR RESERVOIR IN FEET	24
ROD-2	7/20/1993	DEPTH OF POND OR RESERVOIR IN FEET	24
ROD-2	7/30/1993	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	8/12/1993	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	8/24/1993	DEPTH OF POND OR RESERVOIR IN FEET	23.5
ROD-2	8/24/1993	DEPTH OF POND OR RESERVOIR IN FEET	23.5
ROD-2	8/25/1993	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	9/10/1993	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	9/26/1993	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	10/11/1993	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	10/19/1993	DEPTH OF POND OR RESERVOIR IN FEET	23.5
ROD-2	10/19/1993	DEPTH OF POND OR RESERVOIR IN FEET	23.5
ROD-2	11/1/1993	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	5/9/1994	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	5/21/1994	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	6/10/1994	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	6/22/1994	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	7/8/1994	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	7/23/1994	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	8/9/1994	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	8/20/1994	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	9/8/1994	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	9/23/1994	DEPTH OF POND OR RESERVOIR IN FEET	24
ROD-2	10/10/1994	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	10/29/1994	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	5/9/1995	DEPTH OF POND OR RESERVOIR IN FEET	23

ROD-2	5/24/1995	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	6/7/1995	DEPTH OF POND OR RESERVOIR IN FEET	21.5
ROD-2	6/21/1995	DEPTH OF POND OR RESERVOIR IN FEET	21.5
ROD-2	7/6/1995	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	7/23/1995	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	8/8/1995	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	8/21/1995	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	9/11/1995	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	9/21/1995	DEPTH OF POND OR RESERVOIR IN FEET	21.5
ROD-2	10/9/1995	DEPTH OF POND OR RESERVOIR IN FEET	21.5
ROD-2	10/25/1995	DEPTH OF POND OR RESERVOIR IN FEET	21.5
ROD-2	5/7/1996	DEPTH OF POND OR RESERVOIR IN FEET	24
ROD-2	5/9/1996	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	5/9/1996	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	5/21/1996	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	6/12/1996	DEPTH OF POND OR RESERVOIR IN FEET	24
ROD-2	6/20/1996	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	6/21/1996	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	6/21/1996	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	7/8/1996	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	7/22/1996	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	7/29/1996	DEPTH OF POND OR RESERVOIR IN FEET	24
ROD-2	8/9/1996	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	8/20/1996	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	8/23/1996	DEPTH OF POND OR RESERVOIR IN FEET	22.5
ROD-2	8/23/1996	DEPTH OF POND OR RESERVOIR IN FEET	22.5
ROD-2	9/13/1996	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	9/28/1996	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	10/4/1996	DEPTH OF POND OR RESERVOIR IN FEET	21.5
ROD-2	10/4/1996	DEPTH OF POND OR RESERVOIR IN FEET	21.5
ROD-2	10/10/1996	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	10/21/1996	DEPTH OF POND OR RESERVOIR IN FEET	21
ROD-2	5/12/1997	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	5/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	24.5
ROD-2	6/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	6/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	23.5
ROD-2	7/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	7/24/1997	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	8/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	8/25/1997	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	9/15/1997	DEPTH OF POND OR RESERVOIR IN FEET	22.5
ROD-2	10/14/1997	DEPTH OF POND OR RESERVOIR IN FEET	22.5
ROD-2	10/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	22.5
ROD-2	5/10/1998	DEPTH OF POND OR RESERVOIR IN FEET	23.5
ROD-2	5/29/1998	DEPTH OF POND OR RESERVOIR IN FEET	24
ROD-2	6/9/1998	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	6/23/1998	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	7/13/1998	DEPTH OF POND OR RESERVOIR IN FEET	22.5
ROD-2	7/22/1998	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	8/12/1998	DEPTH OF POND OR RESERVOIR IN FEET	23.5
ROD-2	8/24/1998	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	9/10/1998	DEPTH OF POND OR RESERVOIR IN FEET	22.5

ROD-2	9/21/1998	DEPTH OF POND OR RESERVOIR IN FEET	23
ROD-2	10/9/1998	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-2	10/24/1998	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-3	5/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	5/29/1990	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	6/5/1990	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	6/26/1990	DEPTH OF POND OR RESERVOIR IN FEET	18
ROD-3	7/8/1990	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	7/25/1990	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	8/9/1990	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	8/25/1990	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	9/5/1990	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	9/24/1990	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	10/11/1990	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	10/21/1990	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	5/7/1991	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	5/23/1991	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	6/10/1991	DEPTH OF POND OR RESERVOIR IN FEET	16
ROD-3	6/24/1991	DEPTH OF POND OR RESERVOIR IN FEET	15.5
ROD-3	7/5/1991	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	7/30/1991	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	8/10/1991	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	8/24/1991	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	9/13/1991	DEPTH OF POND OR RESERVOIR IN FEET	12
ROD-3	9/28/1991	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	10/10/1991	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	10/25/1991	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	4/6/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	4/28/1992	DEPTH OF POND OR RESERVOIR IN FEET	16
ROD-3	5/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	22
ROD-3	5/27/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	6/12/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	6/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	7/6/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	7/29/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	8/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	8/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	9/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	9/27/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	10/13/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	10/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	4/7/1993	DEPTH OF POND OR RESERVOIR IN FEET	14.5
ROD-3	4/7/1993	DEPTH OF POND OR RESERVOIR IN FEET	14.5
ROD-3	6/7/1993	DEPTH OF POND OR RESERVOIR IN FEET	14.5
ROD-3	6/22/1993	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	6/24/1993	DEPTH OF POND OR RESERVOIR IN FEET	16
ROD-3	6/24/1993	DEPTH OF POND OR RESERVOIR IN FEET	16
ROD-3	7/12/1993	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	7/20/1993	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	7/20/1993	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	7/30/1993	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	8/12/1993	DEPTH OF POND OR RESERVOIR IN FEET	13

ROD-3	8/24/1993	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	8/24/1993	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	8/25/1993	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	9/10/1993	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	9/26/1993	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	10/11/1993	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	10/19/1993	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	10/19/1993	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	11/1/1993	DEPTH OF POND OR RESERVOIR IN FEET	16
ROD-3	5/9/1994	DEPTH OF POND OR RESERVOIR IN FEET	15.5
ROD-3	5/21/1994	DEPTH OF POND OR RESERVOIR IN FEET	15.5
ROD-3	6/10/1994	DEPTH OF POND OR RESERVOIR IN FEET	15.5
ROD-3	6/22/1994	DEPTH OF POND OR RESERVOIR IN FEET	15.5
ROD-3	7/8/1994	DEPTH OF POND OR RESERVOIR IN FEET	15.5
ROD-3	7/23/1994	DEPTH OF POND OR RESERVOIR IN FEET	15.5
ROD-3	8/9/1994	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	8/20/1994	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	9/8/1994	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	9/23/1994	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	10/10/1994	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	10/29/1994	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	5/9/1995	DEPTH OF POND OR RESERVOIR IN FEET	16
ROD-3	5/24/1995	DEPTH OF POND OR RESERVOIR IN FEET	14.5
ROD-3	6/7/1995	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	6/21/1995	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	7/6/1995	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	7/23/1995	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	8/8/1995	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	8/21/1995	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	9/11/1995	DEPTH OF POND OR RESERVOIR IN FEET	13.5
ROD-3	9/21/1995	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	10/9/1995	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	10/25/1995	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	5/7/1996	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	5/9/1996	DEPTH OF POND OR RESERVOIR IN FEET	15.5
ROD-3	5/9/1996	DEPTH OF POND OR RESERVOIR IN FEET	15.5
ROD-3	5/21/1996	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	6/12/1996	DEPTH OF POND OR RESERVOIR IN FEET	14.5
ROD-3	6/20/1996	DEPTH OF POND OR RESERVOIR IN FEET	14.5
ROD-3	6/21/1996	DEPTH OF POND OR RESERVOIR IN FEET	14.5
ROD-3	6/21/1996	DEPTH OF POND OR RESERVOIR IN FEET	14.5
ROD-3	7/8/1996	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	7/22/1996	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	7/29/1996	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	8/9/1996	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	8/20/1996	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	8/23/1996	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	8/23/1996	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	9/13/1996	DEPTH OF POND OR RESERVOIR IN FEET	13.5
ROD-3	9/28/1996	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	10/4/1996	DEPTH OF POND OR RESERVOIR IN FEET	13.5
ROD-3	10/4/1996	DEPTH OF POND OR RESERVOIR IN FEET	13.5

ROD-3	10/10/1996	DEPTH OF POND OR RESERVOIR IN FEET	13.5
ROD-3	10/21/1996	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	5/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	13.5
ROD-3	6/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	6/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	7/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	15
ROD-3	7/24/1997	DEPTH OF POND OR RESERVOIR IN FEET	11
ROD-3	8/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	8/25/1997	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	9/15/1997	DEPTH OF POND OR RESERVOIR IN FEET	13.5
ROD-3	10/14/1997	DEPTH OF POND OR RESERVOIR IN FEET	13.5
ROD-3	10/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	27
ROD-3	5/10/1998	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	5/29/1998	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	6/9/1998	DEPTH OF POND OR RESERVOIR IN FEET	14.5
ROD-3	6/23/1998	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	7/13/1998	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	7/22/1998	DEPTH OF POND OR RESERVOIR IN FEET	14.5
ROD-3	8/12/1998	DEPTH OF POND OR RESERVOIR IN FEET	13.5
ROD-3	8/24/1998	DEPTH OF POND OR RESERVOIR IN FEET	14
ROD-3	9/10/1998	DEPTH OF POND OR RESERVOIR IN FEET	13.5
ROD-3	9/21/1998	DEPTH OF POND OR RESERVOIR IN FEET	13
ROD-3	10/9/1998	DEPTH OF POND OR RESERVOIR IN FEET	13.5
ROD-3	10/24/1998	DEPTH OF POND OR RESERVOIR IN FEET	13.5

Secondary ID .1	Start Date	Parameter Long Name	Result Value
ROD-1	4/7/1993	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	9.71
ROD-1	6/24/1993	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	17.8
ROD-1	7/20/1993	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	37.4
ROD-1	8/24/1993	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	30.7
ROD-1	10/19/1993	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	6.16
ROD-1	5/9/1996	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	3.61
ROD-1	6/21/1996	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	13.1
ROD-1	7/29/1996	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	29.1
ROD-1	8/23/1996	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	60.7
ROD-1	5/22/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	5.34
ROD-1	6/10/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	14.69
ROD-1	7/10/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	15.13
ROD-1	8/25/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	29.37
ROD-1	9/15/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	53.4
ROD-1	10/14/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	42.72
ROD-1	6/9/1998	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	10.68
ROD-1	6/22/1998	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	5.34
ROD-1	7/13/1998	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	18.7
ROD-1	8/12/1998	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	179
ROD-1	9/10/1998	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	54.1
ROD-1	10/9/1998	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	39.4
ROD-1	5/12/1999	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	10.5
ROD-1	7/15/1999	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	28.11
ROD-1	8/26/1999	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	47.74
ROD-1	10/26/1999	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	40.58
ROD-2	4/7/1993	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	15.3
ROD-2	6/24/1993	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	31.5
ROD-2	7/20/1993	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	24.6
ROD-2	9/24/1993	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	27.8
ROD-2	10/19/1993	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	7.03
ROD-2	5/9/1996	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	4.77
ROD-2	6/21/1996	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	12.6
ROD-2	7/29/1996	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	23.7
ROD-2	8/23/1996	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	32.5
ROD-2	5/12/1999	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	22.89
ROD-2	7/15/1999	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	27.06
ROD-2	8/26/1999	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	47.96
ROD-2	10/26/1999	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	49.94
ROD-3	4/7/1993	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	24
ROD-3	6/24/1993	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	26
ROD-3	7/20/1993	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	23.5
ROD-3	8/24/1993	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	28
ROD-3	10/19/1993	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	10.5
ROD-3	5/9/1996	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	3.34
ROD-3	6/21/1996	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	19.8
ROD-3	7/29/1996	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	38.3
ROD-3	8/23/1996	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	31.8
ROD-3	5/12/1999	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	23.77
ROD-3	7/15/1999	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	40.6
ROD-3	8/26/1999	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	59.48
ROD-3	10/26/1999	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	57.31

Appendix B
GWLF Input Files and
BATHTUB Input and Output Files

GWLF Data Input File Template

Transprt.dat

number of rural landuses, number of urban landuses
recession coefficient, seepage constant, initial unsaturated storage, initial saturated storage, initial snow, sediment delivery ratio, unsaturated available capacity
1-day antecedent precipitation
2-day antecedent precipitation
3-day antecedent precipitation
4-day antecedent precipitation
5-day antecedent precipitation
month1, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month2, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month3, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month4, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month5, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month6, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month7, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month8, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month9, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month10, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month11, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month12, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
rural_landuse_1, hectares, curve number, KLSCP coefficient
rural_landuse_2, hectares, curve number, KLSCP coefficient
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rural_landuse_n, hectares, curve number, KLSCP coefficient
urban_landuse_1, hectares, curve number, KLSCP coefficient
urban_landuse_2, hectares, curve number, KLSCP coefficient
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urban_landuse_n, hectares, curve number, KLSCP coefficient

Nutrient.dat

nitrogen in sediment, phosphorus in sediment, nitrogen in groundwater, phosphorus in groundwater
number of land uses over which manure is spread, first month of manure spread, last month of manure spread
rural_landuse_1 dissolved nitrogen, rural_landuse_1 dissolved phosphorus
rural_landuse_2 dissolved nitrogen, rural_landuse_2 dissolved phorphorus
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rural_landuse_n dissolved nitrogen, rural_landuse_n dissolved phosphorus
urban_landuse_1 total nitrogen buildup, urban_landuse_1 total phosphorus buildup
urban_landuse_2 total nitrogen buildup, urban_landuse_2 total phosphorus buildup
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urban_landuse_n total nitrogen buildup, urban_landuse_n total phosphorus buildup
manure nitrogen concentration, manure phosphorus concentration (if applicable)
point_source_1 nitrogen, point_source_1 phosphorus (if applicable)
point_source_2 nitrogen, point_source_2 phosphorus (if applicable)
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point_source_n nitrogen, point_source_n phosphorus (if applicable)
model septic systems (0 = no, 1 = yes)
# of septic systems month1, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month2, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month3, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month4, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month5, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month6, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month7, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month8, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month9, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month10, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month11, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month12, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
per capita septic nitrogen effluent, per capita septic phorphorus effluent, plant nitrogen uptake, plant phosphorus uptake (if applicable)

Weather.dat

# of days in month1
average temperature in Centigrade, total precipitation (cm) on day 1
average temperature in Centigrade, total precipitation (cm) on day 2
average temperature in Centigrade, total precipitation (cm) on day 3
average temperature in Centigrade, total precipitation (cm) on day 4
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average temperature in Centigrade, total precipitation (cm) on day n
# of days in month 2
average temperature in Centigrade, total precipitation (cm) on day 1
average temperature in Centigrade, total precipitation (cm) on day 2
average temperature in Centigrade, total precipitation (cm) on day 3
average temperature in Centigrade, total precipitation (cm) on day 4
.
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average temperature in Centigrade, total precipitation (cm) on day n

GWLF Input Data Files

Subbasin 1

Transprt.dat

```
7,5
0.1,0.15,10,0,0,0.19,10
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0
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"APR",0.45,13,0,0.27
"MAY",0.60,14.1,1,0.27
"JUNE",0.90,14.6,1,0.27
"JULY",0.90,14.4,1,0.27
"AUG",0.88,13.5,1,0.27
"SEPT",0.83,12.2,1,0.27
"OCT",0.55,11,1,0.14
"NOV",0.43,9.9,0,0.14
"DEC",0.41,9.3,0,0.14
"JAN",0.46,9.6,0,0.14
"FEB",0.47,10.6,0,0.14
"MAR",0.47,11.8,0,0.14
"Row-Crop",1214.7,87.4,0.0114
"Small-Grains",128.6,85.0,0.0210
"CRP",124.7,76.5,0.0006
"Wtrwys/Buffrs",46.8,76.5,0.0006
"Pasture",15.6,76.5,0.0006
"Grassland",124.7,76.5,0.0006
"Deciduous",89.1,71.8,0.0009
"Open-Water",2.3,100.0,0.0000
"Shallow-Mar",1.4,100.0,0.0000
"Deep-Marsh",0.2,100.0,0.0000
"Forested-Wetl",10.8,100.0,0.0000
"Shallow-Wat",3.3,97.8,0.0000
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Nutrient.dat

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3000,616,0.77,0.085
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2.9,0.26
1.8,0.3
3,0.15
3,0.15
3,0.25
3,0.15
0.06,0.009
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
1
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
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17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
12,2.5,1.6,0.4
```

Subbasin 2

Transprt.dat

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7,3
0.1,0.15,10,0,0,0.25,10
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0
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"APR",0.51,13,0,0.27
"MAY",0.65,14.1,1,0.27
"JUNE",0.87,14.6,1,0.27
"JULY",0.89,14.4,1,0.27
"AUG",0.90,13.5,1,0.27
"SEPT",0.88,12.2,1,0.27
"OCT",0.61,11,1,0.14
"NOV",0.46,9.9,0,0.14
"DEC",0.44,9.3,0,0.14
"JAN",0.52,9.6,0,0.14
"FEB",0.54,10.6,0,0.14
"MAR",0.53,11.8,0,0.14
"Row-Crop",406.8,87.1,0.0155
"Small-Grains",35.0,84.6,0.0289
"CRP",52.6,75.5,0.0006
"Wtrwys/Buffrs",19.7,75.5,0.0006
"Pasture",6.6,75.5,0.0006
"Grassland",52.6,75.5,0.0006
"Deciduous",48.0,71.6,0.0008
"Open-Water",4.7,100.0,0.0000
"Forested-Wetl",0.3,100.0,0.0000
"Shallow-Wat",0.8,100.0,0.0000
```

Nutrient.dat

```
3000,616,0.77,0.085
0,0,0
2.9,0.26
1.8,0.3
3,0.15
3,0.15
3,0.25
3,0.15
0.06,0.009
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
1
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
12,2.5,1.6,0.4
```

Subbasin 3

Transprt.dat

```
7,6
0.1,0.15,10,0,0,0.22,10
0
0
0
0
0
"APR",0.52,13,0,0.27
"MAY",0.65,14.1,1,0.27
"JUNE",0.90,14.6,1,0.27
"JULY",0.91,14.4,1,0.27
"AUG",0.89,13.5,1,0.27
"SEPT",0.85,12.2,1,0.27
"OCT",0.58,11,1,0.14
"NOV",0.48,9.9,0,0.14
"DEC",0.45,9.3,0,0.14
"JAN",0.53,9.6,0,0.14
"FEB",0.54,10.6,0,0.14
"MAR",0.53,11.8,0,0.14
"Row-Crop",852.7,87.4,0.0134
"Small-Grains",44.8,85.3,0.0114
"CRP",57.9,76.8,0.0005
"Wtrwys/Buffrs",21.7,76.8,0.0005
"Pasture",7.2,76.8,0.0005
"Grassland",57.9,76.8,0.0005
"Deciduous",38.1,71.5,0.0009
"Open-Water",0.4,100.0,0.0000
"Shallow-Mar",0.5,100.0,0.0000
"Deep-Marsh",0.4,100.0,0.0000
"Forested-Wetl",8.1,100.0,0.0000
"Shallow-Wat",1.3,100.0,0.0000
"High-Density",0.5,91.3,0.0000
```

Nutrient.dat

```
3000,616,0.77,0.085
0,0,0
2.9,0.26
1.8,0.3
3,0.15
3,0.15
3,0.25
3,0.15
0.06,0.009
0,0
0,0
0,0
0,0
0,0
0.0756,0.0101
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
1
17.5,0,52.5,0
43.75,0,131.25,0
43.75,0,131.25,0
43.75,0,131.25,0
43.75,0,131.25,0
43.75,0,131.25,0
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
17.5,0,52.5,0
12,2.5,1.6,0.4
```

Subbasin 4

Transprt.dat

```
7,3
0.1,0.15,10,0,0,0.23,10
0
0
0
0
0
"APR",0.54,13,0,0.27
"MAY",0.65,14.1,1,0.27
"JUNE",0.91,14.6,1,0.27
"JULY",0.90,14.4,1,0.27
"AUG",0.86,13.5,1,0.27
"SEPT",0.81,12.2,1,0.27
"OCT",0.58,11,1,0.14
"NOV",0.48,9.9,0,0.14
"DEC",0.45,9.3,0,0.14
"JAN",0.55,9.6,0,0.14
"FEB",0.57,10.6,0,0.14
"MAR",0.56,11.8,0,0.14
"Row-Crop",533.5,86.6,0.0134
"Small-Grains",50.6,84.3,0.0129
"CRP",101.1,75.5,0.0003
"Wtrwys/Buffrs",37.9,75.5,0.0003
"Pasture",12.6,75.5,0.0003
"Grassland",101.1,75.5,0.0003
"Deciduous",51.5,71.6,0.0005
"Open-Water",4.1,100.0,0.0000
"Forested-Wetl",3.4,100.0,0.0000
"Shallow-Wat",1.2,100.0,0.0000
```

Nutrient.dat

```
3000,616,0.77,0.085
0,0,0
2.9,0.26
1.8,0.3
3,0.15
3,0.15
3,0.25
3,0.15
0.06,0.009
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
1
0,0,0,0
113.75,0,341.25,0
113.75,0,341.25,0
113.75,0,341.25,0
113.75,0,341.25,0
113.75,0,341.25,0
0,0,0,0
0,0,0,0
0,0,0,0
0,0,0,0
0,0,0,0
0,0,0,0
12,2.5,1.6,0.4
```

Subbasin 5

Transprt.dat

```
8,5
0.1,0.15,10,0,0,0.22,10
0
0
0
0
0
"APR",0.51,13,0,0.27
"MAY",0.61,14.1,1,0.27
"JUNE",0.89,14.6,1,0.27
"JULY",0.89,14.4,1,0.27
"AUG",0.86,13.5,1,0.27
"SEPT",0.81,12.2,1,0.27
"OCT",0.55,11,1,0.14
"NOV",0.47,9.9,0,0.14
"DEC",0.45,9.3,0,0.14
"JAN",0.53,9.6,0,0.14
"FEB",0.54,10.6,0,0.14
"MAR",0.53,11.8,0,0.14
"Row-Crop",692.0,87.5,0.0104
"Small-Grains",61.0,85.3,0.0088
"Urban-Grass",18.2,78.0,0.0001
"CRP",78.5,76.7,0.0002
"Wtrwys/Buffrs",29.4,76.7,0.0002
"Pasture",9.8,76.7,0.0002
"Grassland",78.5,76.7,0.0002
"Deciduous",11.7,72.9,0.0005
"Open-Water",5.5,99.5,0.0000
"Shallow-Mar",0.9,100.0,0.0000
"Shallow-Wat",0.7,100.0,0.0000
"High-Density",8.1,91.3,0.0000
"Med-Density",1.5,84.3,0.0000
```

Nutrient.dat

```
3000,616,0.77,0.085
0,0,0
2.9,0.26
1.8,0.3
3,0.25
3,0.15
3,0.15
3,0.25
3,0.15
0.06,0.009
0,0
0,0
0,0
0.0756,0.0101
0.0424,0.0061
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
1
40.25,0,120.75,0
75.25,0,225.75,0
75.25,0,225.75,0
75.25,0,225.75,0
75.25,0,225.75,0
75.25,0,225.75,0
40.25,0,120.75,0
40.25,0,120.75,0
40.25,0,120.75,0
40.25,0,120.75,0
40.25,0,120.75,0
40.25,0,120.75,0
12,2.5,1.6,0.4
```

Subbasin 6

Transprt.dat

```
8,3
0.1,0.15,10,0,0,0.3,10
0
0
0
0
0
"APR",0.63,13,0,0.27
"MAY",0.73,14.1,1,0.27
"JUNE",0.86,14.6,1,0.27
"JULY",0.86,14.4,1,0.27
"AUG",0.86,13.5,1,0.27
"SEPT",0.85,12.2,1,0.27
"OCT",0.69,11,1,0.14
"NOV",0.56,9.9,0,0.14
"DEC",0.53,9.3,0,0.14
"JAN",0.64,9.6,0,0.14
"FEB",0.66,10.6,0,0.14
"MAR",0.65,11.8,0,0.14
"Row-Crop",120.5,86.6,0.0100
"Small-Grains",11.9,83.7,0.0090
"Urban-Grass",0.3,75.8,0.0001
"CRP",34.5,75.3,0.0003
"Wtrwys/Buffrs",13.0,75.3,0.0003
"Pasture",4.3,75.3,0.0003
"Grassland",34.5,75.3,0.0003
"Deciduous",30.3,71.3,0.0006
"Open-Water",57.1,99.8,0.0000
"Shallow-Mar",0.4,100.0,0.0000
"High-Density",1.4,90.5,0.0000
```

Nutrient.dat

```
3000,616,0.8,0.067
0,0,0
2.9,0.26
1.8,0.3
3,0.25
3,0.15
3,0.15
3,0.25
3,0.15
0.06,0.009
0,0
0,0
0.0756,0.010112
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
1
41,0,123,0
41,0,123,0
41,0,123,0
41,0,123,0
41,0,123,0
41,0,123,0
41,0,123,0
41,0,123,0
41,0,123,0
41,0,123,0
41,0,123,0
41,0,123,0
12,2.5,1.6,0.4
```

***Subbasin* 7**

Transprt.dat

```
8,4
0.1,0.15,10,0,0,0.28,10
0
0
0
0
0
"APR",0.66,13,0,0.27
"MAY",0.82,14.1,1,0.27
"JUNE",0.88,14.6,1,0.27
"JULY",0.88,14.4,1,0.27
"AUG",0.87,13.5,1,0.27
"SEPT",0.87,12.2,1,0.27
"OCT",0.78,11,1,0.14
"NOV",0.57,9.9,0,0.14
"DEC",0.52,9.3,0,0.14
"JAN",0.68,9.6,0,0.14
"FEB",0.70,10.6,0,0.14
"MAR",0.69,11.8,0,0.14
"Row-Crop",85.8,85.7,0.0278
"Small-Grains",8.7,83.7,0.0208
"Urban-Grass",3.3,75.0,0.0011
"CRP",53.9,75.0,0.0007
"Wtrwys/Buffrs",20.2,75.0,0.0007
"Pasture",6.7,75.0,0.0007
"Grassland",53.9,75.0,0.0007
"Deciduous",104.0,71.2,0.0011
"Open-Water",66.5,99.9,0.0000
"Shallow-Mar",1.5,100.0,0.0000
"Forested-Wetl",0.5,100.0,0.0000
"Med-Density",0.1,81.9,0.0000
```

Nutrient.dat

```
3000,616,0.65,0.055
0,0,0
2.9,0.26
1.8,0.3
3,0.25
3,0.15
3,0.15
3,0.25
3,0.15
0.06,0.009
0,0
0,0
0,0
0.0424,0.0061
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
1
41.25,0,123.75,0
41.25,0,123.75,0
41.25,0,123.75,0
41.25,0,123.75,0
41.25,0,123.75,0
41.25,0,123.75,0
41.25,0,123.75,0
41.25,0,123.75,0
41.25,0,123.75,0
41.25,0,123.75,0
41.25,0,123.75,0
41.25,0,123.75,0
12,2.5,1.6,0.4
```

Weather.dat (excerpt)

```
30
5.28,0.00
3.61,0.00
8.06,0.00
14.44,0.00
15.00,2.13
5.56,1.57
7.78,0.51
4.44,0.10
2.78,0.00
5.00,0.00
5.56,0.64
14.44,0.00
16.39,0.00
17.22,0.33
13.33,1.22
13.33,0.00
13.06,0.00
18.61,0.00
22.22,0.00
22.78,0.00
21.67,0.00
23.06,0.00
21.94,0.00
20.28,0.00
14.17,0.00
18.06,0.00
20.28,0.00
20.56,0.00
15.28,0.00
17.50,0.00
31
18.89,0.38
15.56,3.56
15.28,0.25
14.17,0.00
14.44,0.00
19.44,0.00
15.56,0.00
15.00,0.00
15.28,0.00
19.17,0.00
18.61,0.00
19.44,0.00
23.33,0.00
20.00,1.22
19.44,0.00
17.50,0.00
14.72,0.25
10.00,0.00
16.67,0.00
20.28,0.00
20.83,2.69
20.28,0.00
14.44,0.00
16.11,0.00
```

17.78,0.00
21.67,0.00
26.39,0.00
20.56,0.00
18.06,0.00
20.28,0.00
21.67,0.00
30
23.06,0.00
22.22,3.18
22.78,0.46
20.28,0.00
19.44,2.57
21.39,0.25
22.22,1.91
20.83,0.00
20.83,0.00
21.67,0.18
23.06,4.55
16.94,0.76
12.50,0.00
15.83,0.00
19.17,0.00
20.83,0.00
25.00,1.12
17.78,0.00
18.33,0.00
18.33,0.00
21.67,0.00
23.33,0.30
23.06,0.00
24.44,0.48
24.72,0.13
26.39,0.00
27.22,0.00
24.72,1.83
19.44,0.81
20.83,0.00

GLWF Output Files

Subbasin 1

rod1 16 -year means

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	9.6	2.5	2.2	1.9	4.1
MAY	11.3	5.6	2.2	1.9	4.1
JUNE	9.7	11.1	0.7	1.1	1.8
JULY	10.4	11.7	0.1	1.0	1.1
AUG	7.1	6.7	0.1	0.6	0.6
SEPT	7.4	4.4	0.2	1.1	1.3
OCT	6.7	2.3	0.3	0.6	0.9
NOV	10.9	0.9	1.4	2.6	4.0
DEC	6.2	0.4	1.5	1.2	2.8
JAN	6.9	0.3	1.7	2.0	3.7
FEB	6.4	0.6	1.9	1.4	3.3
MAR	7.6	1.4	2.1	1.3	3.3
ANNUAL	100.2	47.8	14.3	16.7	31.0

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	0.7	0.0	1.2	1.3	0.1	0.1
MAY	1.0	0.1	1.2	1.4	0.1	0.2
JUNE	0.7	0.0	0.6	0.7	0.1	0.1
JULY	0.8	0.0	0.5	0.6	0.0	0.1
AUG	0.5	0.0	0.3	0.4	0.0	0.0
SEPT	0.8	0.1	0.5	0.9	0.1	0.1
OCT	0.2	0.0	0.3	0.5	0.0	0.1
NOV	0.4	0.2	1.4	2.0	0.1	0.2
DEC	0.1	0.1	0.8	1.1	0.1	0.1
JAN	0.1	0.2	1.2	1.7	0.1	0.2
FEB	0.2	0.2	0.9	1.4	0.1	0.2
MAR	0.2	0.1	0.9	1.3	0.1	0.2
ANNUAL	5.9	1.1	9.9	13.3	1.0	1.6

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
				(Mg)			
Row-Crop	1215.	18.87	3.98	6.65	9.40	0.60	1.16
Small-Grains	129.	15.25	7.33	0.35	0.89	0.06	0.17
CRP	125.	7.64	0.21	0.29	0.30	0.01	0.02
Wtrwys/Buffrs	47.	7.64	0.21	0.11	0.11	0.01	0.01
Pasture	16.	7.64	0.21	0.04	0.04	0.00	0.00
Grassland	125.	7.64	0.21	0.29	0.30	0.01	0.02
Deciduous	89.	5.29	0.31	0.00	0.02	0.00	0.00
Open-Water	2.	100.19	0.00	0.00	0.00	0.00	0.00
Shallow-Mar	1.	100.19	0.00	0.00	0.00	0.00	0.00
Deep-Marsh	0.	100.19	0.00	0.00	0.00	0.00	0.00
Forested-Wetl	11.	100.19	0.00	0.00	0.00	0.00	0.00
Shallow-Wat	3.	63.42	0.00	0.00	0.00	0.00	0.00
GROUNDWATER				1.94	1.94	0.21	0.21
POINT SOURCE				0.00	0.00	0.00	0.00
SEPTIC SYSTEMS				0.29	0.29	0.04	0.04
TOTAL				9.94	13.29	0.95	1.64

Subbasin 2

rod2 16 -year means

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	9.6	2.8	2.2	1.8	3.9
MAY	11.3	6.1	2.1	1.8	3.9
JUNE	9.7	10.7	0.7	1.0	1.7
JULY	10.4	11.6	0.1	0.9	1.0
AUG	7.1	6.9	0.1	0.5	0.6
SEPT	7.4	4.6	0.2	1.0	1.2
OCT	6.7	2.5	0.3	0.6	0.9
NOV	10.9	1.0	1.4	2.4	3.8
DEC	6.2	0.4	1.5	1.1	2.7
JAN	6.9	0.4	1.7	1.9	3.6
FEB	6.4	0.7	1.9	1.3	3.2
MAR	7.6	1.6	2.1	1.2	3.2
ANNUAL	100.2	49.2	14.2	15.5	29.7

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	0.3	0.0	0.4	0.5	0.0	0.1
MAY	0.4	0.0	0.4	0.5	0.0	0.1
JUNE	0.3	0.0	0.2	0.3	0.0	0.0
JULY	0.4	0.0	0.2	0.2	0.0	0.0
AUG	0.2	0.0	0.1	0.2	0.0	0.0
SEPT	0.3	0.1	0.2	0.4	0.0	0.1
OCT	0.1	0.0	0.1	0.2	0.0	0.0
NOV	0.2	0.1	0.5	0.8	0.0	0.1
DEC	0.1	0.1	0.3	0.4	0.0	0.1
JAN	0.1	0.1	0.4	0.7	0.0	0.1
FEB	0.1	0.1	0.3	0.6	0.0	0.1
MAR	0.1	0.1	0.3	0.6	0.0	0.1
ANNUAL	2.6	0.6	3.5	5.5	0.3	0.7

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
				(Mg)			
Row-Crop	407.	18.36	5.41	2.17	3.82	0.19	0.53
Small-Grains	35.	14.73	10.09	0.09	0.36	0.02	0.07
CRP	53.	7.06	0.24	0.11	0.12	0.01	0.01
Wtrwys/Buffrs	20.	7.06	0.24	0.04	0.05	0.00	0.00
Pasture	7.	7.06	0.24	0.01	0.02	0.00	0.00
Grassland	53.	7.06	0.24	0.11	0.12	0.01	0.01
Deciduous	48.	5.21	0.28	0.00	0.01	0.00	0.00
Open-Water	5.	100.19	0.00	0.00	0.00	0.00	0.00
Forested-Wetl	0.	100.19	0.00	0.00	0.00	0.00	0.00
Shallow-Wat	1.	100.19	0.00	0.00	0.00	0.00	0.00
GROUNDWATER				0.68	0.68	0.08	0.08
POINT SOURCE				0.00	0.00	0.00	0.00
SEPTIC SYSTEMS				0.29	0.29	0.04	0.04
TOTAL				3.51	5.46	0.34	0.74

Subbasin 3

rod3 16 -year means

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	9.6	2.8	2.1	2.0	4.0
MAY	11.3	6.1	2.0	2.0	4.0
JUNE	9.7	11.0	0.6	1.2	1.8
JULY	10.4	11.7	0.1	1.1	1.1
AUG	7.1	6.6	0.0	0.6	0.7
SEPT	7.4	4.4	0.2	1.1	1.3
OCT	6.7	2.4	0.3	0.7	0.9
NOV	10.9	1.0	1.3	2.7	4.0
DEC	6.2	0.4	1.5	1.3	2.7
JAN	6.9	0.4	1.6	2.1	3.7
FEB	6.4	0.7	1.9	1.4	3.3
MAR	7.6	1.6	2.0	1.3	3.3
ANNUAL	100.2	49.0	13.4	17.6	31.0

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	0.5	0.0	0.8	0.9	0.1	0.1
MAY	0.7	0.1	0.8	1.0	0.1	0.1
JUNE	0.5	0.0	0.4	0.5	0.0	0.1
JULY	0.6	0.0	0.4	0.5	0.0	0.1
AUG	0.4	0.0	0.2	0.3	0.0	0.0
SEPT	0.5	0.1	0.4	0.6	0.0	0.1
OCT	0.2	0.0	0.2	0.3	0.0	0.0
NOV	0.3	0.2	0.9	1.4	0.1	0.2
DEC	0.1	0.1	0.5	0.7	0.1	0.1
JAN	0.1	0.1	0.8	1.2	0.1	0.2
FEB	0.2	0.1	0.6	1.0	0.1	0.1
MAR	0.2	0.1	0.6	1.0	0.1	0.1
ANNUAL	4.2	0.9	6.7	9.5	0.7	1.2

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR (Mg)	TOT.NITR (Mg)	DIS.PHOS (Mg)	TOT.PHOS (Mg)
Row-Crop	853.	18.87	4.68	4.67	7.30	0.42	0.96
Small-Grains	45.	15.65	3.98	0.13	0.24	0.02	0.05
CRP	58.	7.82	0.21	0.14	0.14	0.01	0.01
Wtrwys/Buffrs	22.	7.82	0.21	0.05	0.05	0.00	0.00
Pasture	7.	7.82	0.21	0.02	0.02	0.00	0.00
Grassland	58.	7.82	0.21	0.14	0.14	0.01	0.01
Deciduous	38.	5.17	0.31	0.00	0.01	0.00	0.00
Open-Water	0.	100.19	0.00	0.00	0.00	0.00	0.00
Shallow-Mar	1.	100.19	0.00	0.00	0.00	0.00	0.00
Deep-Marsh	0.	100.19	0.00	0.00	0.00	0.00	0.00
Forested-Wetl	8.	100.19	0.00	0.00	0.00	0.00	0.00
Shallow-Wat	1.	100.19	0.00	0.00	0.00	0.00	0.00
High-Density	1.	27.55	0.00	0.00	0.00	0.00	0.00
GROUNDWATER				1.13	1.13	0.12	0.12
POINT SOURCE				0.00	0.00	0.00	0.00
SEPTIC SYSTEMS				0.45	0.45	0.07	0.07
TOTAL				6.71	9.50	0.65	1.22

Subbasin 4

rod4 16 -year means

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	9.6	2.9	2.1	1.6	3.8
MAY	11.3	6.1	2.1	1.7	3.8
JUNE	9.7	11.1	0.7	0.9	1.6
JULY	10.4	11.7	0.1	0.8	0.9
AUG	7.1	6.6	0.1	0.5	0.6
SEPT	7.4	4.4	0.2	0.9	1.2
OCT	6.7	2.4	0.3	0.6	0.9
NOV	10.9	1.0	1.5	2.3	3.8
DEC	6.2	0.4	1.6	1.1	2.7
JAN	6.9	0.4	1.7	1.8	3.5
FEB	6.4	0.7	2.0	1.2	3.2
MAR	7.6	1.6	2.1	1.1	3.1
ANNUAL	100.2	49.4	14.5	14.5	29.0

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	0.3	0.0	0.6	0.6	0.0	0.1
MAY	0.5	0.0	0.7	0.8	0.1	0.1
JUNE	0.3	0.0	0.4	0.4	0.0	0.1
JULY	0.4	0.0	0.3	0.4	0.0	0.1
AUG	0.2	0.0	0.2	0.3	0.0	0.0
SEPT	0.4	0.1	0.3	0.5	0.0	0.1
OCT	0.1	0.0	0.1	0.2	0.0	0.0
NOV	0.2	0.1	0.7	1.0	0.1	0.1
DEC	0.1	0.0	0.4	0.5	0.0	0.1
JAN	0.1	0.1	0.6	0.8	0.0	0.1
FEB	0.1	0.1	0.4	0.7	0.0	0.1
MAR	0.1	0.1	0.4	0.7	0.0	0.1
ANNUAL	2.8	0.6	5.1	7.0	0.5	0.9

SOURCE	AREA	RUNOFF	EROSION	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(ha)	(cm)	(Mg/ha)	(Mg)			
Row-Crop	534.	17.55	4.68	2.72	4.44	0.24	0.60
Small-Grains	51.	14.36	4.50	0.13	0.29	0.02	0.05
CRP	101.	7.06	0.14	0.21	0.22	0.01	0.01
Wtrwys/Buffrs	38.	7.06	0.14	0.08	0.08	0.00	0.00
Pasture	13.	7.06	0.14	0.03	0.03	0.00	0.00
Grassland	101.	7.06	0.14	0.21	0.22	0.01	0.01
Deciduous	52.	5.21	0.17	0.00	0.01	0.00	0.00
Open-Water	4.	100.19	0.00	0.00	0.00	0.00	0.00
Forested-Wetl	3.	100.19	0.00	0.00	0.00	0.00	0.00
Shallow-Wat	1.	100.19	0.00	0.00	0.00	0.00	0.00
GROUNDWATER				1.00	1.00	0.11	0.11
POINT SOURCE				0.00	0.00	0.00	0.00
SEPTIC SYSTEMS				0.72	0.72	0.11	0.11
TOTAL				5.11	7.02	0.51	0.91

Subbasin 5

rod5 16 -year means

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	9.6	2.8	2.1	1.9	4.0
MAY	11.3	5.7	2.1	2.0	4.0
JUNE	9.7	11.0	0.7	1.1	1.8
JULY	10.4	11.6	0.1	1.0	1.1
AUG	7.1	6.7	0.1	0.6	0.6
SEPT	7.4	4.4	0.2	1.1	1.3
OCT	6.7	2.3	0.3	0.6	0.9
NOV	10.9	1.0	1.4	2.6	4.0
DEC	6.2	0.4	1.5	1.2	2.8
JAN	6.9	0.4	1.6	2.0	3.7
FEB	6.4	0.7	1.9	1.4	3.3
MAR	7.6	1.6	2.0	1.3	3.3
ANNUAL	100.2	48.4	14.0	16.8	30.8

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	0.3	0.0	0.7	0.8	0.1	0.1
MAY	0.5	0.0	0.8	0.9	0.1	0.1
JUNE	0.3	0.0	0.4	0.5	0.0	0.1
JULY	0.4	0.0	0.3	0.4	0.0	0.1
AUG	0.2	0.0	0.2	0.3	0.0	0.0
SEPT	0.4	0.1	0.4	0.5	0.0	0.1
OCT	0.1	0.0	0.2	0.3	0.0	0.0
NOV	0.2	0.1	0.9	1.2	0.1	0.1
DEC	0.1	0.0	0.5	0.7	0.1	0.1
JAN	0.1	0.1	0.7	1.0	0.1	0.1
FEB	0.1	0.1	0.6	0.9	0.1	0.1
MAR	0.1	0.1	0.6	0.8	0.1	0.1
ANNUAL	2.7	0.6	6.5	8.3	0.7	1.0

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
				(Mg)			
Row-Crop	692.	19.04	3.63	3.82	5.48	0.34	0.68
Small-Grains	61.	15.65	3.07	0.17	0.30	0.03	0.05
Urban-Grass	18.	8.59	0.03	0.05	0.05	0.00	0.00
CRP	79.	7.76	0.10	0.18	0.19	0.01	0.01
Wtrwys/Buffrs	29.	7.76	0.10	0.07	0.07	0.00	0.00
Pasture	10.	7.76	0.10	0.02	0.02	0.00	0.00
Grassland	79.	7.76	0.10	0.18	0.19	0.01	0.01
Deciduous	12.	5.77	0.17	0.00	0.00	0.00	0.00
Open-Water	6.	86.89	0.00	0.00	0.00	0.00	0.00
Shallow-Mar	1.	100.19	0.00	0.00	0.00	0.00	0.00
Shallow-Wat	1.	100.19	0.00	0.00	0.00	0.00	0.00
High-Density	8.	27.55	0.00	0.00	0.06	0.00	0.01
Med-Density	2.	14.36	0.00	0.00	0.00	0.00	0.00
GROUNDWATER				1.07	1.07	0.12	0.12
POINT SOURCE				0.00	0.00	0.00	0.00
SEPTIC SYSTEMS				0.88	0.88	0.14	0.14
TOTAL				6.45	8.31	0.65	1.03

Subbasin 6

rod6 16 -year means

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	9.6	3.4	1.5	2.8	4.4
MAY	11.3	6.8	1.4	3.1	4.5
JUNE	9.7	10.0	0.4	2.3	2.7
JULY	10.4	10.7	0.0	2.3	2.4
AUG	7.1	5.7	0.0	1.5	1.5
SEPT	7.4	4.0	0.1	1.9	2.0
OCT	6.7	2.7	0.1	1.5	1.6
NOV	10.9	1.2	0.7	3.6	4.2
DEC	6.2	0.5	1.0	1.7	2.8
JAN	6.9	0.5	1.4	2.5	3.9
FEB	6.4	0.9	1.5	2.1	3.6
MAR	7.6	1.9	1.6	2.1	3.7
ANNUAL	100.2	48.4	9.8	27.5	37.2

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	0.1	0.0	0.2	0.2	0.0	0.0
MAY	0.1	0.0	0.2	0.2	0.0	0.0
JUNE	0.1	0.0	0.1	0.1	0.0	0.0
JULY	0.1	0.0	0.1	0.1	0.0	0.0
AUG	0.0	0.0	0.1	0.1	0.0	0.0
SEPT	0.1	0.0	0.1	0.1	0.0	0.0
OCT	0.0	0.0	0.1	0.1	0.0	0.0
NOV	0.0	0.0	0.2	0.3	0.0	0.0
DEC	0.0	0.0	0.2	0.2	0.0	0.0
JAN	0.0	0.0	0.2	0.3	0.0	0.0
FEB	0.0	0.0	0.2	0.2	0.0	0.0
MAR	0.0	0.0	0.2	0.2	0.0	0.0
ANNUAL	0.5	0.1	1.7	2.2	0.2	0.3

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
				(Mg)			
Row-Crop	121.	17.55	3.49	0.61	0.99	0.05	0.13
Small-Grains	12.	13.65	3.14	0.03	0.06	0.00	0.01
Urban-Grass	0.	7.23	0.07	0.00	0.00	0.00	0.00
CRP	35.	6.95	0.14	0.07	0.08	0.00	0.00
Wtrwys/Buffrs	13.	6.95	0.14	0.03	0.03	0.00	0.00
Pasture	4.	6.95	0.14	0.01	0.01	0.00	0.00
Grassland	35.	6.95	0.14	0.07	0.08	0.00	0.00
Deciduous	30.	5.09	0.21	0.00	0.01	0.00	0.00
Open-Water	57.	93.80	0.00	0.00	0.00	0.00	0.00
Shallow-Mar	0.	100.19	0.00	0.00	0.00	0.00	0.00
High-Density	1.	25.38	0.00	0.00	0.01	0.00	0.00
GROUNDWATER				0.24	0.24	0.02	0.02
POINT SOURCE				0.00	0.00	0.00	0.00
SEPTIC SYSTEMS				0.67	0.67	0.10	0.10
TOTAL				1.74	2.17	0.19	0.28

Subbasin 7

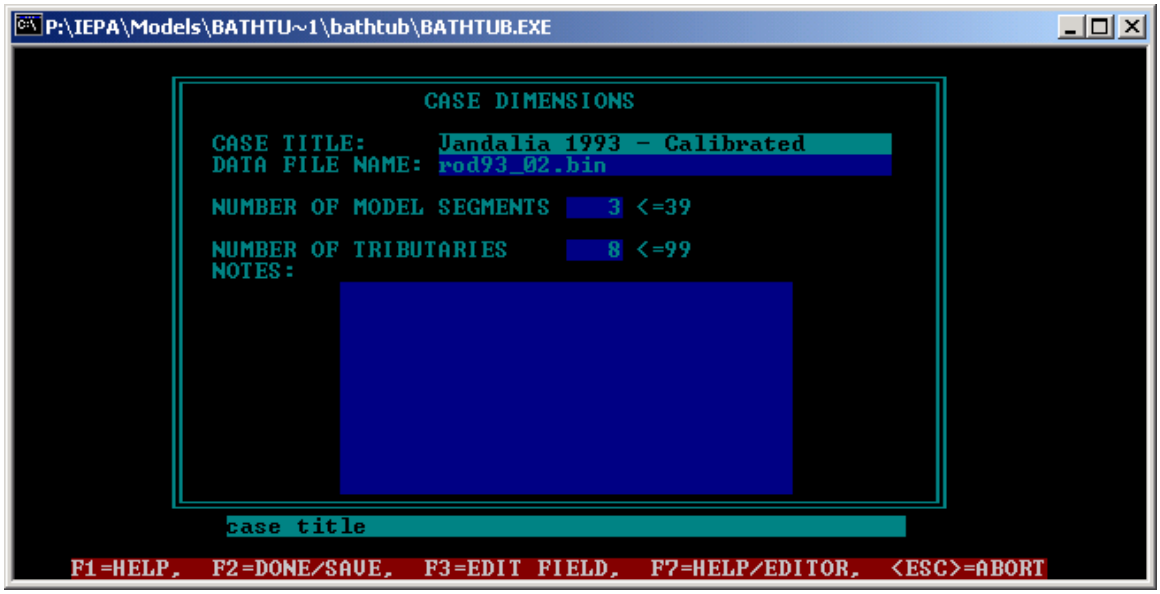
rod7 16 -year means

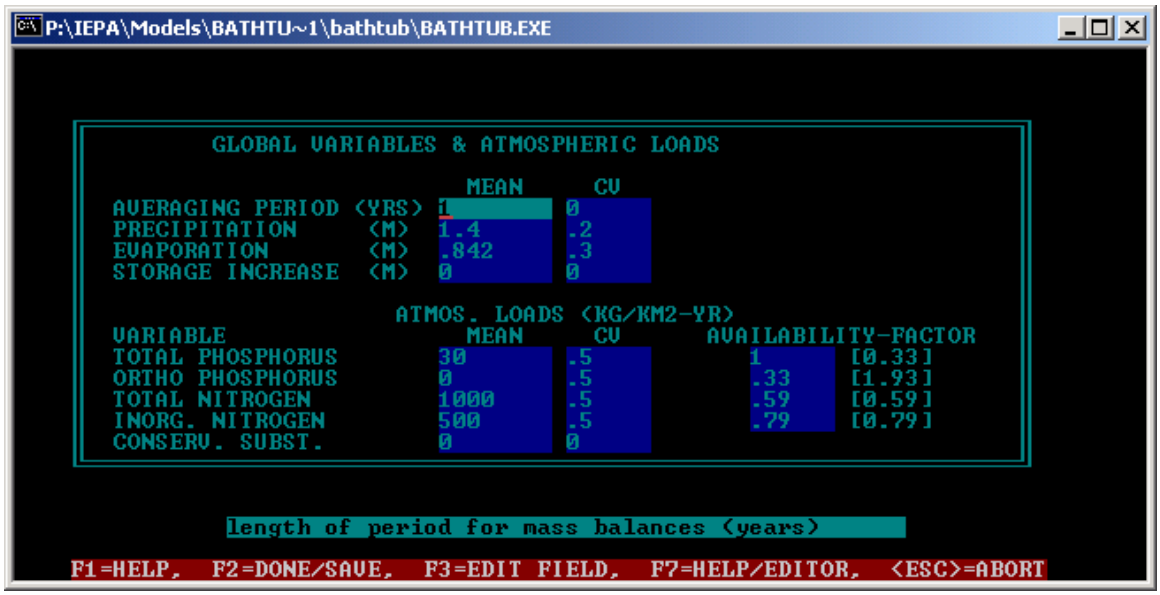
	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	9.6	3.6	1.6	2.4	4.1
MAY	11.3	7.7	1.4	2.7	4.1
JUNE	9.7	9.9	0.4	2.0	2.4
JULY	10.4	10.8	0.0	2.0	2.0
AUG	7.1	5.8	0.0	1.3	1.3
SEPT	7.4	4.1	0.2	1.7	1.9
OCT	6.7	3.1	0.1	1.3	1.5
NOV	10.9	1.2	0.8	3.0	3.9
DEC	6.2	0.5	1.1	1.5	2.6
JAN	6.9	0.5	1.5	2.1	3.6
FEB	6.4	0.9	1.6	1.7	3.4
MAR	7.6	2.0	1.7	1.8	3.4
ANNUAL	100.2	50.1	10.6	23.7	34.3

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	0.1	0.0	0.2	0.2	0.0	0.0
MAY	0.2	0.0	0.2	0.2	0.0	0.0
JUNE	0.1	0.0	0.1	0.1	0.0	0.0
JULY	0.1	0.0	0.1	0.1	0.0	0.0
AUG	0.1	0.0	0.1	0.1	0.0	0.0
SEPT	0.1	0.0	0.1	0.2	0.0	0.0
OCT	0.0	0.0	0.1	0.1	0.0	0.0
NOV	0.1	0.0	0.2	0.3	0.0	0.0
DEC	0.0	0.0	0.2	0.2	0.0	0.0
JAN	0.0	0.0	0.2	0.3	0.0	0.0
FEB	0.0	0.0	0.2	0.3	0.0	0.0
MAR	0.0	0.0	0.2	0.3	0.0	0.0
ANNUAL	1.0	0.3	1.7	2.5	0.2	0.4

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
				(Mg)			
Row-Crop	86.	16.20	9.71	0.40	1.10	0.04	0.18
Small-Grains	9.	13.65	7.26	0.02	0.07	0.00	0.01
Urban-Grass	3.	6.79	0.52	0.01	0.01	0.00	0.00
CRP	54.	6.79	0.35	0.11	0.13	0.01	0.01
Wtrwys/Buffrs	20.	6.79	0.35	0.04	0.05	0.00	0.00
Pasture	7.	6.79	0.35	0.01	0.02	0.00	0.00
Grassland	54.	6.79	0.35	0.11	0.13	0.01	0.01
Deciduous	104.	5.05	0.38	0.00	0.04	0.00	0.01
Open-Water	67.	96.70	0.00	0.00	0.00	0.00	0.00
Shallow-Mar	2.	100.19	0.00	0.00	0.00	0.00	0.00
Forested-Wetl	1.	100.19	0.00	0.00	0.00	0.00	0.00
Med-Density	0.	11.75	0.00	0.00	0.00	0.00	0.00
GROUNDWATER				0.28	0.28	0.02	0.02
POINT SOURCE				0.00	0.00	0.00	0.00
SEPTIC SYSTEMS				0.67	0.67	0.10	0.10
TOTAL				1.66	2.49	0.18	0.35

BATHTUB Input Screens for 1993 Simulation





P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

SEGMENT: 1 NAME: Upper Pool OUTFLOW SEG: 2 GROUP: 1
AREA (KM2):1.472 MEAN DEPTH (M):4.36 LENGTH (KM):3.5

VARIABLE	UNITS	MEAN	CV	CALIBRATION FACTORS	
MIXED LAYER DEPTH	(M)	1.83	0		
HYPOLIMNETIC DEPTH	(M)	0	0		
DISPERSION FACTOR	-			1	0
OBSERVED WATER QUALITY...					
NON-ALGAL TURBIDITY	(1/M)	0	0		
TOTAL PHOSPHORUS	(PPB)	93.2	.427	.8	0
TOTAL NITROGEN	(PPB)	0	0	1	0
CHLOROPHYLL-A	(PPB)	22.4	.307	.7	0
SECCHI DEPTH	(M)	.528	.357	1	0
ORGANIC NITROGEN	(PPB)	0	0		
TOTAL P - ORTHO P	(PPB)	0	0		
HYPOL. O2 DEPL.	(PPB/DAY)	0	0	1	0
METAL. O2 DEPL.	(PPB/DAY)	0	0		
CONSERVATIVE SUBST.	-	0	0		

segment label

F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

SEGMENT: 2 NAME: Mid Pool OUTFLOW SEG: 3 GROUP: 1
AREA (KM2):.546 MEAN DEPTH (M):7.1 LENGTH (KM):1.15

VARIABLE	UNITS	MEAN	CV	CALIBRATION FACTORS	
MIXED LAYER DEPTH	(M)	4.57	0		
HYPOLIMNETIC DEPTH	(M)	0	0		
DISPERSION FACTOR	-			1	0
OBSERVED WATER QUALITY...					
NON-ALGAL TURBIDITY	(1/M)	0	0		
TOTAL PHOSPHORUS	(PPB)	76	.587	.7	0
TOTAL NITROGEN	(PPB)	0	0	1	0
CHLOROPHYLL-A	(PPB)	21.246	.469	1.4	0
SECCHI DEPTH	(M)	.643	.311	1	0
ORGANIC NITROGEN	(PPB)	0	0		
TOTAL P - ORTHO P	(PPB)	0	0		
HYPOL. O2 DEPL.	(PPB/DAY)	0	0	1	0
METAL. O2 DEPL.	(PPB/DAY)	0	0		
CONSERVATIVE SUBST.	-	0	0		

segment label

F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

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SEGMENT:    3 NAME: Near Dam          OUTFLOW SEG:  0 GROUP:  1
AREA (KM2):.653     MEAN DEPTH (M):8.87    LENGTH (KM):1.17

 VARIABLE              UNITS       MEAN      CV      CALIBRATION
 MIXED LAYER DEPTH      (M)       5.49      0          FACTORS
 HYPOLIMNETIC DEPTH     (M)       0         0
 DISPERSION FACTOR       -                            1        0
 OBSERVED WATER QUALITY...
 NON-ALGAL TURBIDITY (1/M)        0         0
 TOTAL PHOSPHORUS      (PPB)      150.4     .935      1        0
 TOTAL NITROGEN        (PPB)      0         0         1        0
 CHLOROPHYLL-A         (PPB)      20.354    .659      1.3      0
 SECCHI DEPTH           (M)       .724      .305      1        0
 ORGANIC NITROGEN      (PPB)      0         0
 TOTAL P - ORTHO P     (PPB)      0         0
 HYPOL. O2 DEPL.    (PPB/DAY)     0         0         1        0
 METAL. O2 DEPL.    (PPB/DAY)     0         0
 CONSERVATIVE SUBST.     -        0         0

          segment label

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
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P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

```
TRIBUTARY NUMBER:   1    LABEL: Subbasin 1

SEGMENT NUMBER:     1    TYPE CODE:     1

                                      MEAN        CV
 DRAINAGE AREA          (KM2)       17.66
 FLOW                 (HM3/YR)      8.568       0
 TOTAL PHOSPHORUS       (PPB)       280.148     0
 ORTHO PHOSPHORUS       (PPB)       0           0
 TOTAL NITROGEN         (PPB)       0           0
 INORGANIC NITROGEN     (PPB)       0           0
 CONSERVATIVE SUBST.      -         0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1   landuse2   landuse3   landuse4
AREA (KM2) 0          0          0          0
CATEGORY:
AREA (KM2) 0          0          0          0

     tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

```
P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

TRIBUTARY NUMBER:   2   LABEL: Subbasin 2

SEGMENT NUMBER:     1   TYPE CODE:     1

                                   MEAN        CV
 DRAINAGE AREA        (KM2)       6.27
 FLOW                (HM3/YR)     2.921       0
 TOTAL PHOSPHORUS     (PPB)       342.374     0
 ORTHO PHOSPHORUS     (PPB)       0           0
 TOTAL NITROGEN       (PPB)       0           0
 INORGANIC NITROGEN   (PPB)       0           0
 CONSERVATIVE SUBST.    -         0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1  landuse2  landuse3  landuse4
AREA (KM2) 0         0         0         0
CATEGORY:
AREA (KM2) 0         0         0         0

  tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

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P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

TRIBUTARY NUMBER:   3   LABEL: Subbasin 3

SEGMENT NUMBER:     1   TYPE CODE:     1

                                   MEAN        CV
 DRAINAGE AREA        (KM2)       10.93
 FLOW                (HM3/YR)     5.302       0
 TOTAL PHOSPHORUS     (PPB)       339.563     0
 ORTHO PHOSPHORUS     (PPB)       0           0
 TOTAL NITROGEN       (PPB)       0           0
 INORGANIC NITROGEN   (PPB)       0           0
 CONSERVATIVE SUBST.    -         0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1  landuse2  landuse3  landuse4
AREA (KM2) 0         0         0         0
CATEGORY:
AREA (KM2) 0         0         0         0

  tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

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P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

TRIBUTARY NUMBER:   4   LABEL: Subbasin 4

SEGMENT NUMBER:     1   TYPE CODE:     1

                                   MEAN        CV
 DRAINAGE AREA        (KM2)       8.99
 FLOW               (HM3/YR)      4.144       0
 TOTAL PHOSPHORUS     (PPB)       265.5       0
 ORTHO PHOSPHORUS     (PPB)       0           0
 TOTAL NITROGEN       (PPB)       0           0
 INORGANIC NITROGEN   (PPB)       0           0
 CONSERVATIVE SUBST.    -         0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1  landuse2  landuse3  landuse4
AREA (KM2) 0         0         0         0
CATEGORY:
AREA (KM2) 0         0         0         0

  tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

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P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

TRIBUTARY NUMBER:   5   LABEL: Subbasin 5

SEGMENT NUMBER:     1   TYPE CODE:     1

                                   MEAN        CV
 DRAINAGE AREA        (KM2)       9.97
 FLOW               (HM3/YR)      4.867       0
 TOTAL PHOSPHORUS     (PPB)       287.707     0
 ORTHO PHOSPHORUS     (PPB)       0           0
 TOTAL NITROGEN       (PPB)       0           0
 INORGANIC NITROGEN   (PPB)       0           0
 CONSERVATIVE SUBST.    -         0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1  landuse2  landuse3  landuse4
AREA (KM2) 0         0         0         0
CATEGORY:
AREA (KM2) 0         0         0         0

  tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

```
TRIBUTARY NUMBER:   6   LABEL: Subbasin 6

SEGMENT NUMBER:     2   TYPE CODE:     1

                                   MEAN        CV
 DRAINAGE AREA        (KM2)       3.08
 FLOW                (HM3/YR)     1.697       0
 TOTAL PHOSPHORUS     (PPB)       117.849     0
 ORTHO PHOSPHORUS     (PPB)       0           0
 TOTAL NITROGEN       (PPB)       0           0
 INORGANIC NITROGEN   (PPB)       0           0
 CONSERVATIVE SUBST.    -         0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1  landuse2  landuse3  landuse4
AREA (KM2) 0         0         0         0
CATEGORY:
AREA (KM2) 0         0         0         0

  tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

```
TRIBUTARY NUMBER:   7   LABEL: Subbasin 7

SEGMENT NUMBER:     3   TYPE CODE:     1

                                   MEAN        CV
 DRAINAGE AREA        (KM2)       4.06
 FLOW                (HM3/YR)     2.046       0
 TOTAL PHOSPHORUS     (PPB)       146.61      0
 ORTHO PHOSPHORUS     (PPB)       0           0
 TOTAL NITROGEN       (PPB)       0           0
 INORGANIC NITROGEN   (PPB)       0           0
 CONSERVATIVE SUBST.    -         0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1  landuse2  landuse3  landuse4
AREA (KM2) 0         0         0         0
CATEGORY:
AREA (KM2) 0         0         0         0

  tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
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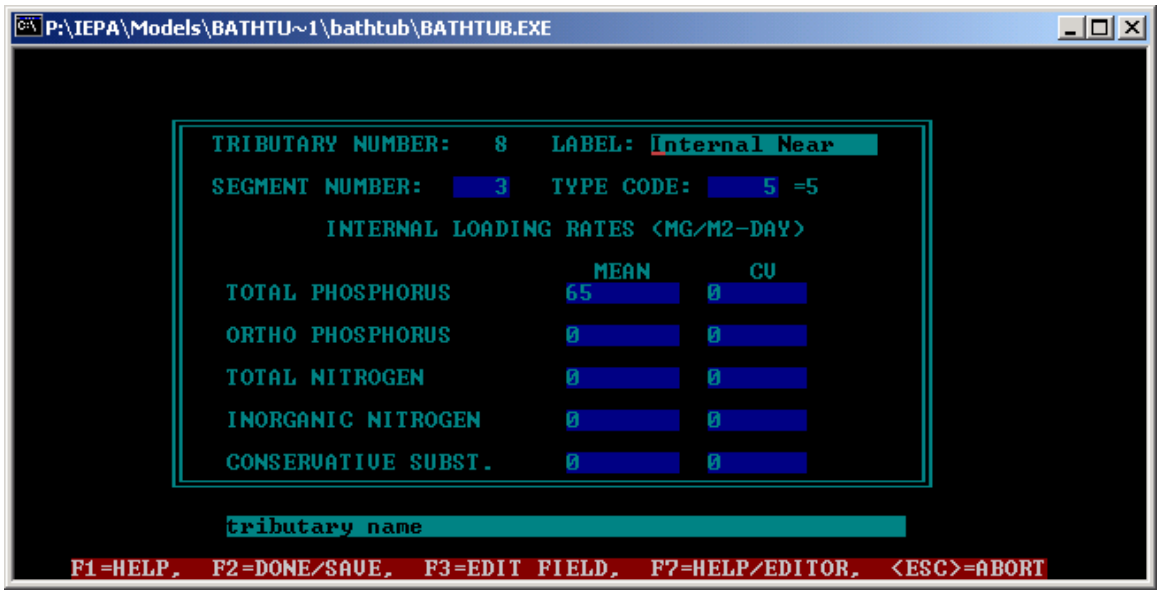

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 8 LABEL: Internal Near
SEGMENT NUMBER: 3 TYPE CODE: 5 =5
INTERNAL LOADING RATES (MG/M2-DAY)
MEAN CV
TOTAL PHOSPHORUS 65 0
ORTHO PHOSPHORUS 0 0
TOTAL NITROGEN 0 0
INORGANIC NITROGEN 0 0
CONSERVATIVE SUBST. 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

BATHTUB Output for 1993 Simulation

CASE: Vandalia 1993 - Calibrated

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	93.2	.43	81.0	.45	1.15	.33	.52	.22
CHL-A	MG/M3	22.4	.31	22.6	.46	.99	-.02	-.02	-.01
SECCHI	M	.5	.36	.5	.35	1.00	.01	.01	.00
ORGANIC N	MG/M3	.0	.00	772.0	.32	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	67.7	.33	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	76.0	.59	75.6	.46	1.01	.01	.02	.01
CHL-A	MG/M3	21.2	.47	20.4	.43	1.04	.09	.12	.07
SECCHI	M	.6	.31	.7	.31	.99	-.05	-.05	-.03
ORGANIC N	MG/M3	.0	.00	698.6	.28	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	56.4	.28	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	150.4	.94	150.0	.45	1.00	.00	.01	.00
CHL-A	MG/M3	20.4	.66	20.7	.41	.99	-.02	-.04	-.02
SECCHI	M	.7	.31	.7	.31	1.01	.02	.02	.01
ORGANIC N	MG/M3	.0	.00	693.8	.26	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	53.4	.25	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	103.7	.63	96.8	.45	1.07	.11	.26	.09
CHL-A	MG/M3	21.7	.42	21.7	.39	1.00	.00	.00	.00
SECCHI	M	.6	.33	.6	.24	1.00	.00	.00	.00
ORGANIC N	MG/M3	.0	.00	737.9	.28	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	61.9	.29	.00	.00	.00	.00

CASE: Vandalia 1993 - Calibrated

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	17.660	8.568	.000E+00	.000	.485
2	1	Subbasin 2	6.270	2.921	.000E+00	.000	.466
3	1	Subbasin 3	10.930	5.302	.000E+00	.000	.485
4	1	Subbasin 4	8.990	4.144	.000E+00	.000	.461
5	1	Subbasin 5	9.970	4.867	.000E+00	.000	.488
6	1	Subbasin 6	3.080	1.697	.000E+00	.000	.551
7	1	Subbasin 7	4.060	2.046	.000E+00	.000	.504
PRECIPITATION			2.671	3.739	.559E+00	.200	1.400
TRIBUTARY INFLOW			60.960	29.545	.000E+00	.000	.485
***TOTAL INFLOW			63.631	33.284	.559E+00	.022	.523
ADVECTIVE OUTFLOW			63.631	31.035	.101E+01	.032	.488
***TOTAL OUTFLOW			63.631	31.035	.101E+01	.032	.488
***EVAPORATION			.000	2.249	.455E+00	.300	.000

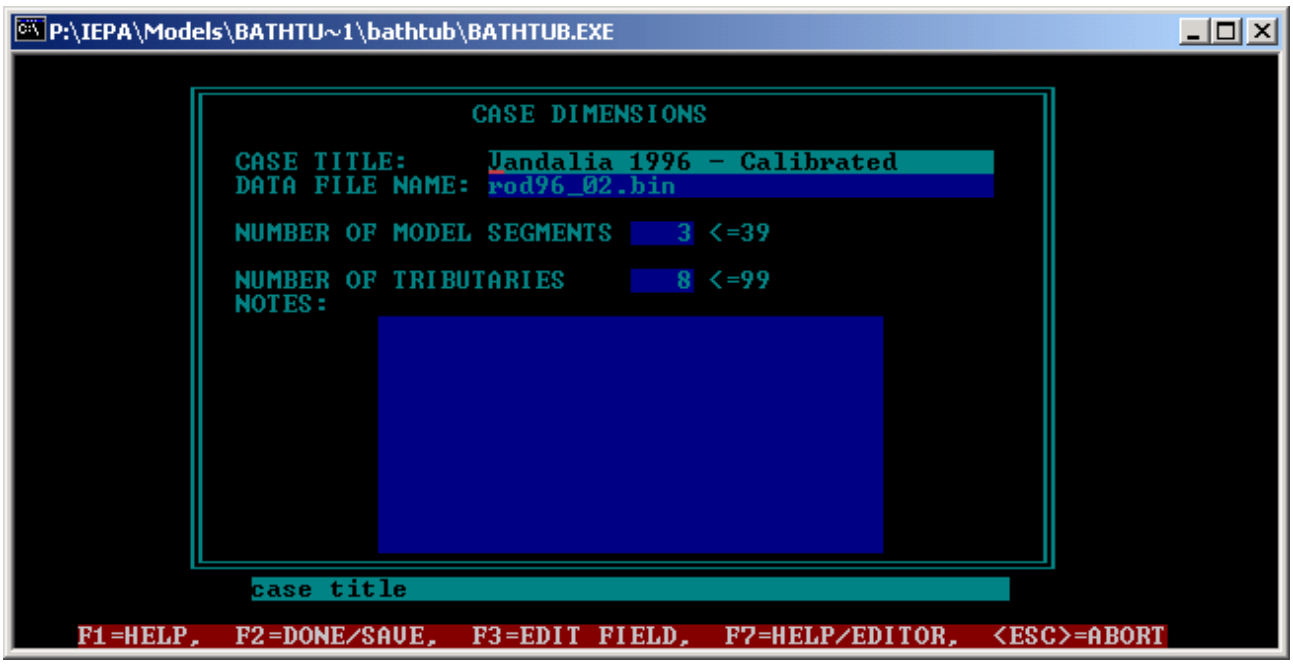
GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

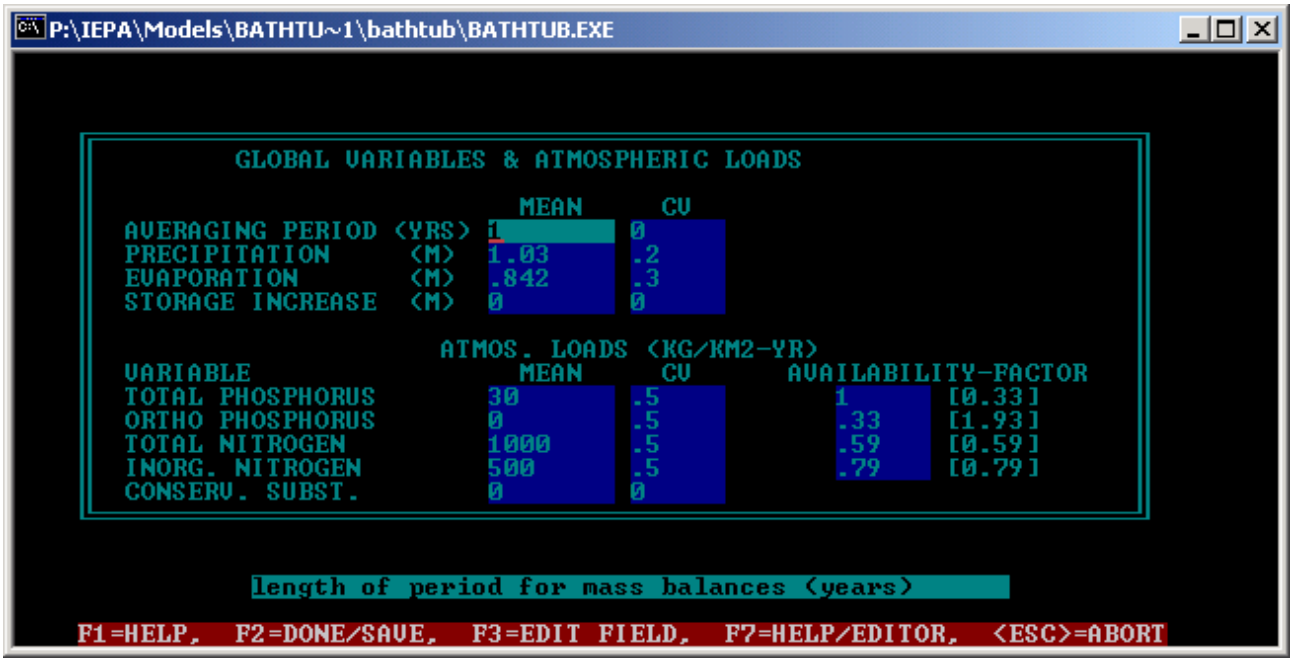
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	2400.3	10.1	.000E+00	.0	.000	280.1	135.9
2	1	Subbasin 2	1000.1	4.2	.000E+00	.0	.000	342.4	159.5
3	1	Subbasin 3	1800.4	7.6	.000E+00	.0	.000	339.6	164.7
4	1	Subbasin 4	1100.2	4.6	.000E+00	.0	.000	265.5	122.4
5	1	Subbasin 5	1400.3	5.9	.000E+00	.0	.000	287.7	140.4
6	1	Subbasin 6	200.0	.8	.000E+00	.0	.000	117.8	64.9
7	1	Subbasin 7	300.0	1.3	.000E+00	.0	.000	146.6	73.9
PRECIPITATION			80.1	.3	.161E+04	100.0	.500	21.4	30.0
INTERNAL LOAD			15503.0	65.2	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW			8201.2	34.5	.000E+00	.0	.000	277.6	134.5
***TOTAL INFLOW			23784.4	100.0	.161E+04	100.0	.002	714.6	373.8
ADVECTIVE OUTFLOW			4654.0	19.6	.444E+07*******		.453	150.0	73.1
***TOTAL OUTFLOW			4654.0	19.6	.444E+07*******		.453	150.0	73.1
***RETENTION			19130.4	80.4	.444E+07*******		.110	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
11.62	.5183	103.7	.0701	14.2620	.8043

BATHTUB Model Input Screens for 1996 Simulation





P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

SEGMENT: 1 NAME: Upper Pool OUTFLOW SEG: 2 GROUP: 1
AREA (KM2):1.472 MEAN DEPTH (M):4.27 LENGTH (KM):3.5

VARIABLE	UNITS	MEAN	CV	CALIBRATION FACTORS	
MIXED LAYER DEPTH	(M)	2.13	0		
HYPOLIMNETIC DEPTH	(M)	0	0		
DISPERSION FACTOR	-			1	0
OBSERVED WATER QUALITY...					
NON-ALGAL TURBIDITY	(1/M)	0	0		
TOTAL PHOSPHORUS	(PPB)	138	.751	1	0
TOTAL NITROGEN	(PPB)	0	0	1	0
CHLOROPHYLL-A	(PPB)	23.31	.659	.8	0
SECCHI DEPTH	(M)	.385	.458	1	0
ORGANIC NITROGEN	(PPB)	0	0		
TOTAL P - ORTHO P	(PPB)	0	0		
HYPOL. O2 DEPL.	(PPB/DAY)	0	0	1	0
METAL. O2 DEPL.	(PPB/DAY)	0	0		
CONSERVATIVE SUBST.	-	0	0		

segment label

F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

SEGMENT: 2 NAME: Mid Pool OUTFLOW SEG: 3 GROUP: 1
AREA (KM2):.546 MEAN DEPTH (M):6.83 LENGTH (KM):1.15

VARIABLE	UNITS	MEAN	CV	CALIBRATION FACTORS	
MIXED LAYER DEPTH	(M)	3.35	0		
HYPOLIMNETIC DEPTH	(M)	0	0		
DISPERSION FACTOR	-			1	0
OBSERVED WATER QUALITY...					
NON-ALGAL TURBIDITY	(1/M)	0	0		
TOTAL PHOSPHORUS	(PPB)	120.2	.797	1	0
TOTAL NITROGEN	(PPB)	0	0	1	0
CHLOROPHYLL-A	(PPB)	18.393	.663	.8	0
SECCHI DEPTH	(M)	.458	.49	1	0
ORGANIC NITROGEN	(PPB)	0	0		
TOTAL P - ORTHO P	(PPB)	0	0		
HYPOL. O2 DEPL.	(PPB/DAY)	0	0	1	0
METAL. O2 DEPL.	(PPB/DAY)	0	0		
CONSERVATIVE SUBST.	-	0	0		

segment label

F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

```
SEGMENT:    3 NAME: Near Dam          OUTFLOW SEG:  0 GROUP:  1
AREA (KM2):.653     MEAN DEPTH (M):8.69     LENGTH (KM):1.17

 VARIABLE                UNITS       MEAN      CV      CALIBRATION
 MIXED LAYER DEPTH        (M)       3.96      0         FACTORS
 HYPOLIMNETIC DEPTH       (M)       0         0
 DISPERSION FACTOR         -                           1        0
 OBSERVED WATER QUALITY...
 NON-ALGAL TURBIDITY (1/M)          0         0
 TOTAL PHOSPHORUS        (PPB)      221       .868     1        0
 TOTAL NITROGEN          (PPB)      0         0        1        0
 CHLOROPHYLL-A           (PPB)      26.628    .94      1.3      0
 SECCHI DEPTH             (M)       .454      .514     1        0
 ORGANIC NITROGEN        (PPB)      0         0
 TOTAL P - ORTHO P       (PPB)      0         0
 HYPOL. O2 DEPL.      (PPB/DAY)     0         0        1        0
 METAL. O2 DEPL.      (PPB/DAY)     0         0
 CONSERVATIVE SUBST.       -        0         0

          segment label

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

```
TRIBUTARY NUMBER:   1    LABEL: Subbasin 1

SEGMENT NUMBER:     1    TYPE CODE:     1

                                      MEAN        CV
 DRAINAGE AREA          (KM2)       17.66
 FLOW                 (HM3/YR)      5.777       0
 TOTAL PHOSPHORUS       (PPB)       311.632     0
 ORTHO PHOSPHORUS       (PPB)       0           0
 TOTAL NITROGEN         (PPB)       0           0
 INORGANIC NITROGEN     (PPB)       0           0
 CONSERVATIVE SUBST.      -         0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1   landuse2   landuse3   landuse4
AREA (KM2) 0          0          0          0
CATEGORY:
AREA (KM2) 0          0          0          0

     tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

```
TRIBUTARY NUMBER:   2   LABEL: Subbasin 2

SEGMENT NUMBER:     1   TYPE CODE:     1

                                   MEAN        CV
 DRAINAGE AREA        (KM2)       6.27
 FLOW                (HM3/YR)     1.981       0
 TOTAL PHOSPHORUS      (PPB)      302.936     0
 ORTHO PHOSPHORUS      (PPB)      0           0
 TOTAL NITROGEN        (PPB)      0           0
 INORGANIC NITROGEN    (PPB)      0           0
 CONSERVATIVE SUBST.     -        0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1   landuse2   landuse3   landuse4
AREA (KM2) 0          0          0          0
CATEGORY:
AREA (KM2) 0          0          0          0

  tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

```
TRIBUTARY NUMBER:   3   LABEL: Subbasin 3

SEGMENT NUMBER:     1   TYPE CODE:     1

                                   MEAN        CV
 DRAINAGE AREA        (KM2)       10.93
 FLOW                (HM3/YR)     3.607       0
 TOTAL PHOSPHORUS      (PPB)      332.703     0
 ORTHO PHOSPHORUS      (PPB)      0           0
 TOTAL NITROGEN        (PPB)      0           0
 INORGANIC NITROGEN    (PPB)      0           0
 CONSERVATIVE SUBST.     -        0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1   landuse2   landuse3   landuse4
AREA (KM2) 0          0          0          0
CATEGORY:
AREA (KM2) 0          0          0          0

  tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

```
TRIBUTARY NUMBER:   4   LABEL: Subbasin 4

SEGMENT NUMBER:     1   TYPE CODE:     1

                                   MEAN        CV
 DRAINAGE AREA        (KM2)       8.99
 FLOW                (HM3/YR)     2.741       0
 TOTAL PHOSPHORUS     (PPB)       328.334     0
 ORTHO PHOSPHORUS     (PPB)       0           0
 TOTAL NITROGEN       (PPB)       0           0
 INORGANIC NITROGEN   (PPB)       0           0
 CONSERVATIVE SUBST.    -         0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1   landuse2   landuse3   landuse4
AREA (KM2) 0          0          0          0
CATEGORY:
AREA (KM2) 0          0          0          0

  tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

```
TRIBUTARY NUMBER:   5   LABEL: Subbasin 5

SEGMENT NUMBER:     1   TYPE CODE:     1

                                   MEAN        CV
 DRAINAGE AREA        (KM2)       9.97
 FLOW                (HM3/YR)     3.261       0
 TOTAL PHOSPHORUS     (PPB)       306.686     0
 ORTHO PHOSPHORUS     (PPB)       0           0
 TOTAL NITROGEN       (PPB)       0           0
 INORGANIC NITROGEN   (PPB)       0           0
 CONSERVATIVE SUBST.    -         0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1   landuse2   landuse3   landuse4
AREA (KM2) 0          0          0          0
CATEGORY:
AREA (KM2) 0          0          0          0

  tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

```
TRIBUTARY NUMBER:   6   LABEL: Subbasin 6

SEGMENT NUMBER:     2   TYPE CODE:     1

                                   MEAN        CV
 DRAINAGE AREA        (KM2)       3.08
 FLOW                (HM3/YR)     1.201       0
 TOTAL PHOSPHORUS     (PPB)       166.5       0
 ORTHO PHOSPHORUS     (PPB)       0           0
 TOTAL NITROGEN       (PPB)       0           0
 INORGANIC NITROGEN   (PPB)       0           0
 CONSERVATIVE SUBST.    -         0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1   landuse2   landuse3   landuse4
AREA (KM2) 0          0          0          0
CATEGORY:
AREA (KM2) 0          0          0          0

  tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

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```
TRIBUTARY NUMBER:   7   LABEL: Subbasin 7

SEGMENT NUMBER:     3   TYPE CODE:     1

                                   MEAN        CV
 DRAINAGE AREA        (KM2)       4.06
 FLOW                (HM3/YR)     1.106       0
 TOTAL PHOSPHORUS     (PPB)       180.878     0
 ORTHO PHOSPHORUS     (PPB)       0           0
 TOTAL NITROGEN       (PPB)       0           0
 INORGANIC NITROGEN   (PPB)       0           0
 CONSERVATIVE SUBST.    -         0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1   landuse2   landuse3   landuse4
AREA (KM2) 0          0          0          0
CATEGORY:
AREA (KM2) 0          0          0          0

  tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

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TRIBUTARY NUMBER: 8 LABEL: Internal Near

SEGMENT NUMBER: 3 TYPE CODE: 5 =5

INTERNAL LOADING RATES (MG/M2-DAY)

	MEAN	CV
TOTAL PHOSPHORUS	105	0
ORTHO PHOSPHORUS	0	0
TOTAL NITROGEN	0	0
INORGANIC NITROGEN	0	0
CONSERVATIVE SUBST.	0	0

tributary name

F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

BATHTUB Model Output for 1996 Simulation

CASE: Vandalia 1996 - Calibrated

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	138.0	.75	105.2	.46	1.31	.36	1.01	.31
CHL-A	MG/M3	23.3	.66	23.3	.47	1.00	.00	.00	.00
SECCHI	M	.4	.46	.4	.43	1.00	.00	.00	.00
ORGANIC N	MG/M3	.0	.00	839.4	.27	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	85.1	.32	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	120.2	.80	138.9	.47	.87	-.18	-.54	-.16
CHL-A	MG/M3	18.4	.66	17.1	.46	1.08	.11	.22	.09
SECCHI	M	.5	.49	.5	.46	.98	-.03	-.05	-.02
ORGANIC N	MG/M3	.0	.00	675.9	.22	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	67.1	.32	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	221.0	.87	225.5	.45	.98	-.02	-.07	-.02
CHL-A	MG/M3	26.6	.94	26.7	.53	1.00	.00	-.01	.00
SECCHI	M	.5	.51	.5	.46	1.00	.00	.00	.00
ORGANIC N	MG/M3	.0	.00	880.9	.30	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	79.8	.25	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	154.7	.80	141.5	.45	1.09	.11	.33	.10
CHL-A	MG/M3	23.1	.74	22.8	.39	1.01	.02	.03	.01
SECCHI	M	.4	.48	.4	.29	1.00	-.01	-.01	-.01
ORGANIC N	MG/M3	.0	.00	816.1	.25	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	80.1	.26	.00	.00	.00	.00

CASE: Vandalia 1996 - Calibrated
GROSS WATER BALANCE:

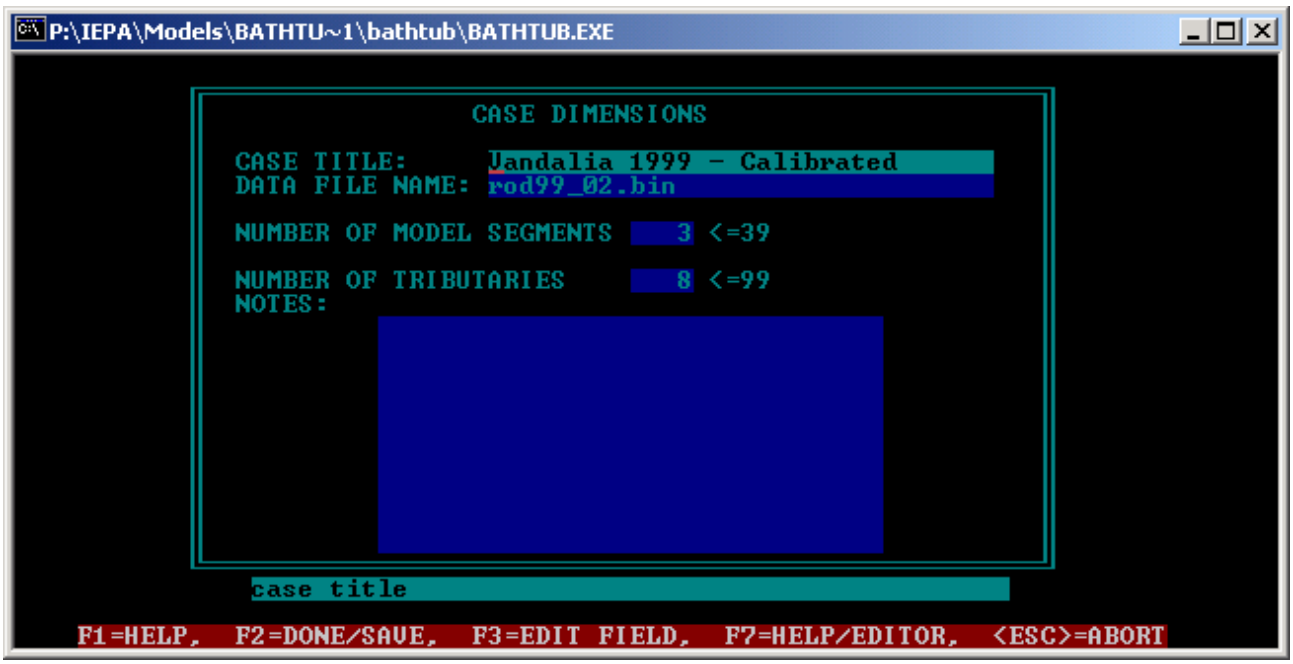
ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	17.660	5.777	.000E+00	.000	.327
2	1	Subbasin 2	6.270	1.981	.000E+00	.000	.316
3	1	Subbasin 3	10.930	3.607	.000E+00	.000	.330
4	1	Subbasin 4	8.990	2.741	.000E+00	.000	.305
5	1	Subbasin 5	9.970	3.261	.000E+00	.000	.327
6	1	Subbasin 6	3.080	1.201	.000E+00	.000	.390
7	1	Subbasin 7	4.060	1.106	.000E+00	.000	.272
PRECIPITATION			2.671	2.751	.303E+00	.200	1.030
TRIBUTARY INFLOW			60.960	19.674	.000E+00	.000	.323
***TOTAL INFLOW			63.631	22.425	.303E+00	.025	.352
ADVECTIVE OUTFLOW			63.631	20.176	.758E+00	.043	.317
***TOTAL OUTFLOW			63.631	20.176	.758E+00	.043	.317
***EVAPORATION			.000	2.249	.455E+00	.300	.000

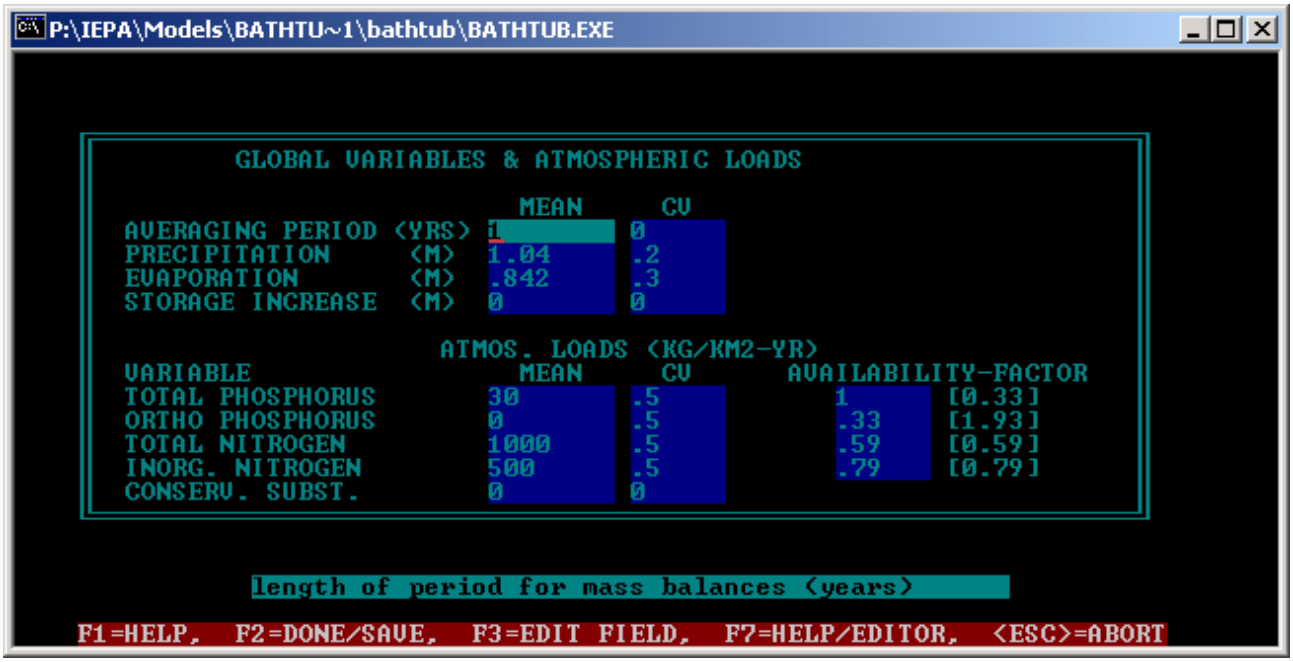
GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	1800.3	5.8	.000E+00	.0	.000	311.6	101.9
2	1	Subbasin 2	600.1	1.9	.000E+00	.0	.000	302.9	95.7
3	1	Subbasin 3	1200.1	3.9	.000E+00	.0	.000	332.7	109.8
4	1	Subbasin 4	900.0	2.9	.000E+00	.0	.000	328.3	100.1
5	1	Subbasin 5	1000.1	3.2	.000E+00	.0	.000	306.7	100.3
6	1	Subbasin 6	200.0	.6	.000E+00	.0	.000	166.5	64.9
7	1	Subbasin 7	200.1	.6	.000E+00	.0	.000	180.9	49.3
PRECIPITATION			80.1	.3	.161E+04	100.0	.500	29.1	30.0
INTERNAL LOAD			25043.4	80.7	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW			5900.6	19.0	.000E+00	.0	.000	299.9	96.8
***TOTAL INFLOW			31024.1	100.0	.161E+04	100.0	.001	1383.5	487.6
ADVECTIVE OUTFLOW			4549.1	14.7	.426E+07*******		.453	225.5	71.5
***TOTAL OUTFLOW			4549.1	14.7	.426E+07*******		.453	225.5	71.5
***RETENTION			26474.9	85.3	.426E+07*******		.078	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.55	.7776	154.7	.0782	12.7861	.8534

BATHTUB Model Input Screens for 1999 Simulation





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SEGMENT: 1 NAME: Upper Pool OUTFLOW SEG: 2 GROUP: 1
AREA (KM2):1.472 MEAN DEPTH (M):4.24 LENGTH (KM):3.5

VARIABLE	UNITS	MEAN	CV	CALIBRATION FACTORS	
MIXED LAYER DEPTH	(M)	2.13	0		
HYPOLIMNETIC DEPTH	(M)	0	0		
DISPERSION FACTOR	-			1	0
OBSERVED WATER QUALITY...					
NON-ALGAL TURBIDITY	(1/M)	0	0		
TOTAL PHOSPHORUS	(PPB)	66.4	.633	.6	0
TOTAL NITROGEN	(PPB)	0	0	1	0
CHLOROPHYLL-A	(PPB)	45.29	.367	1.9	0
SECCHI DEPTH	(M)	.422	.324	1	0
ORGANIC NITROGEN	(PPB)	0	0		
TOTAL P - ORTHO P	(PPB)	0	0		
HYPOL. O2 DEPL.	(PPB/DAY)	0	0	1	0
METAL. O2 DEPL.	(PPB/DAY)	0	0		
CONSERVATIVE SUBST.	-	0	0		

segment label

F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

SEGMENT: 2 NAME: Mid Pool OUTFLOW SEG: 3 GROUP: 1
AREA (KM2):.546 MEAN DEPTH (M):6.98 LENGTH (KM):1.15

VARIABLE	UNITS	MEAN	CV	CALIBRATION FACTORS	
MIXED LAYER DEPTH	(M)	4.27	0		
HYPOLIMNETIC DEPTH	(M)	0	0		
DISPERSION FACTOR	-			1	0
OBSERVED WATER QUALITY...					
NON-ALGAL TURBIDITY	(1/M)	0	0		
TOTAL PHOSPHORUS	(PPB)	42.8	.587	.5	0
TOTAL NITROGEN	(PPB)	0	0	1	0
CHLOROPHYLL-A	(PPB)	36.963	.378	2	0
SECCHI DEPTH	(M)	.533	.316	1	0
ORGANIC NITROGEN	(PPB)	0	0		
TOTAL P - ORTHO P	(PPB)	0	0		
HYPOL. O2 DEPL.	(PPB/DAY)	0	0	1	0
METAL. O2 DEPL.	(PPB/DAY)	0	0		
CONSERVATIVE SUBST.	-	0	0		

segment label

F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

```
SEGMENT:    3 NAME: Near Dam          OUTFLOW SEG:  0 GROUP:  1
AREA (KM2):.653    MEAN DEPTH (M):8.66    LENGTH (KM):1.17

 VARIABLE                UNITS      MEAN      CV      CALIBRATION
 MIXED LAYER DEPTH        (M)      4.57      0         FACTORS
 HYPOLIMNETIC DEPTH       (M)      0         0
 DISPERSION FACTOR         -                          1        0
 OBSERVED WATER QUALITY...
 NON-ALGAL TURBIDITY (1/M)         0         0
 TOTAL PHOSPHORUS        (PPB)     173       2.103    1        0
 TOTAL NITROGEN          (PPB)     0         0        1        0
 CHLOROPHYLL-A           (PPB)     31.733    .514     1.6      0
 SECCHI DEPTH             (M)      .561      .32      1        0
 ORGANIC NITROGEN        (PPB)     0         0
 TOTAL P - ORTHO P       (PPB)     0         0
 HYPOL. O2 DEPL.      (PPB/DAY)    0         0        1        0
 METAL. O2 DEPL.      (PPB/DAY)    0         0
 CONSERVATIVE SUBST.       -       0         0

          segment label

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

```
TRIBUTARY NUMBER:   1    LABEL: Subbasin 1

SEGMENT NUMBER:     1    TYPE CODE:     1

                                      MEAN        CV
 DRAINAGE AREA            (KM2)      17.66
 FLOW                   (HM3/YR)     5.459       0
 TOTAL PHOSPHORUS         (PPB)      311.464     0
 ORTHO PHOSPHORUS         (PPB)      0           0
 TOTAL NITROGEN           (PPB)      0           0
 INORGANIC NITROGEN       (PPB)      0           0
 CONSERVATIVE SUBST.        -        0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1   landuse2   landuse3   landuse4
AREA (KM2) 0          0          0          0
CATEGORY:
AREA (KM2) 0          0          0          0

     tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

```
TRIBUTARY NUMBER:   2   LABEL: Subbasin 2

SEGMENT NUMBER:     1   TYPE CODE:     1

                                   MEAN        CV
 DRAINAGE AREA        (KM2)       6.27
 FLOW                (HM3/YR)     1.868       0
 TOTAL PHOSPHORUS     (PPB)       428.312     0
 ORTHO PHOSPHORUS     (PPB)       0           0
 TOTAL NITROGEN       (PPB)       0           0
 INORGANIC NITROGEN   (PPB)       0           0
 CONSERVATIVE SUBST.    -         0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1   landuse2   landuse3   landuse4
AREA (KM2) 0          0          0          0
CATEGORY:
AREA (KM2) 0          0          0          0

  tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

```
TRIBUTARY NUMBER:   3   LABEL: Subbasin 3

SEGMENT NUMBER:     1   TYPE CODE:     1

                                   MEAN        CV
 DRAINAGE AREA        (KM2)       10.93
 FLOW                (HM3/YR)     3.389       0
 TOTAL PHOSPHORUS     (PPB)       354.168     0
 ORTHO PHOSPHORUS     (PPB)       0           0
 TOTAL NITROGEN       (PPB)       0           0
 INORGANIC NITROGEN   (PPB)       0           0
 CONSERVATIVE SUBST.    -         0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1   landuse2   landuse3   landuse4
AREA (KM2) 0          0          0          0
CATEGORY:
AREA (KM2) 0          0          0          0

  tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

```
TRIBUTARY NUMBER:   4   LABEL: Subbasin 4

SEGMENT NUMBER:     1   TYPE CODE:     1

                                   MEAN        CV
 DRAINAGE AREA        (KM2)       8.99
 FLOW                (HM3/YR)     2.616       0
 TOTAL PHOSPHORUS     (PPB)       344.13      0
 ORTHO PHOSPHORUS     (PPB)       0           0
 TOTAL NITROGEN       (PPB)       0           0
 INORGANIC NITROGEN   (PPB)       0           0
 CONSERVATIVE SUBST.    -         0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1   landuse2   landuse3   landuse4
AREA (KM2) 0          0          0          0
CATEGORY:
AREA (KM2) 0          0          0          0

  tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

```
TRIBUTARY NUMBER:   5   LABEL: Subbasin 5

SEGMENT NUMBER:     1   TYPE CODE:     1

                                   MEAN        CV
 DRAINAGE AREA        (KM2)       9.97
 FLOW                (HM3/YR)     3.082       0
 TOTAL PHOSPHORUS     (PPB)       292.096     0
 ORTHO PHOSPHORUS     (PPB)       0           0
 TOTAL NITROGEN       (PPB)       0           0
 INORGANIC NITROGEN   (PPB)       0           0
 CONSERVATIVE SUBST.    -         0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1   landuse2   landuse3   landuse4
AREA (KM2) 0          0          0          0
CATEGORY:
AREA (KM2) 0          0          0          0

  tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

```
TRIBUTARY NUMBER:   6   LABEL: Subbasin 6

SEGMENT NUMBER:     2   TYPE CODE:     1

                                   MEAN        CV
 DRAINAGE AREA        (KM2)       3.08
 FLOW                (HM3/YR)     1.167       0
 TOTAL PHOSPHORUS      (PPB)      171.333     0
 ORTHO PHOSPHORUS      (PPB)      0           0
 TOTAL NITROGEN        (PPB)      0           0
 INORGANIC NITROGEN    (PPB)      0           0
 CONSERVATIVE SUBST.     -        0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1   landuse2   landuse3   landuse4
AREA (KM2) 0          0          0          0
CATEGORY:
AREA (KM2) 0          0          0          0

  tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

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```
TRIBUTARY NUMBER:   7   LABEL: Subbasin 7

SEGMENT NUMBER:     3   TYPE CODE:     1

                                   MEAN        CV
 DRAINAGE AREA        (KM2)       4.06
 FLOW                (HM3/YR)     1.425       0
 TOTAL PHOSPHORUS      (PPB)      140.345     0
 ORTHO PHOSPHORUS      (PPB)      0           0
 TOTAL NITROGEN        (PPB)      0           0
 INORGANIC NITROGEN    (PPB)      0           0
 CONSERVATIVE SUBST.     -        0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1   landuse2   landuse3   landuse4
AREA (KM2) 0          0          0          0
CATEGORY:
AREA (KM2) 0          0          0          0

  tributary name

F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
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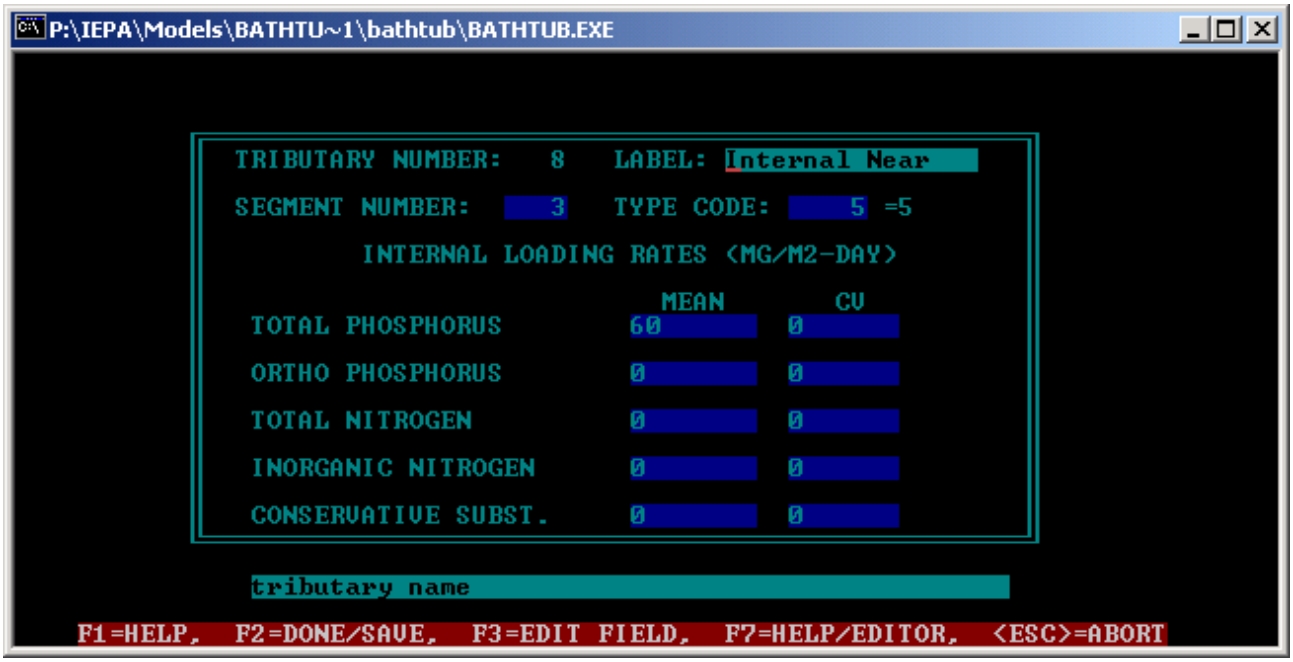

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 8 LABEL: Internal Near
SEGMENT NUMBER: 3 TYPE CODE: 5 =5
INTERNAL LOADING RATES (MG/M2-DAY)
MEAN CV
TOTAL PHOSPHORUS 60 0
ORTHO PHOSPHORUS 0 0
TOTAL NITROGEN 0 0
INORGANIC NITROGEN 0 0
CONSERVATIVE SUBST. 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

BATHTUB Model Output for 1999 Simulation

CASE: Vandalia 1999 - Calibrated

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	66.4	.63	61.9	.45	1.07	.11	.26	.09
CHL-A	MG/M3	45.3	.37	45.6	.52	.99	-.02	-.02	-.01
SECCHI	M	.4	.32	.4	.35	1.00	.01	.01	.01
ORGANIC N	MG/M3	.0	.00	1289.9	.42	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	106.4	.38	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	42.8	.59	57.4	.47	.75	-.50	-1.09	-.39
CHL-A	MG/M3	37.0	.38	28.0	.51	1.32	.74	.80	.44
SECCHI	M	.5	.32	.6	.34	.88	-.40	-.46	-.27
ORGANIC N	MG/M3	.0	.00	866.7	.36	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	68.3	.33	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	173.0	2.10	170.5	.45	1.01	.01	.05	.01
CHL-A	MG/M3	31.7	.51	32.0	.43	.99	-.01	-.02	-.01
SECCHI	M	.6	.32	.6	.29	1.00	.01	.01	.01
ORGANIC N	MG/M3	.0	.00	960.6	.31	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	76.3	.26	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	87.6	1.34	87.6	.45	1.00	.00	.00	.00
CHL-A	MG/M3	40.3	.40	38.7	.44	1.04	.10	.12	.07
SECCHI	M	.5	.32	.5	.25	.97	-.09	-.10	-.07
ORGANIC N	MG/M3	.0	.00	1122.9	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	91.2	.34	.00	.00	.00	.00

CASE: Vandalia 1999 - Calibrated
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	17.660	5.459	.000E+00	.000	.309
2	1	Subbasin 2	6.270	1.868	.000E+00	.000	.298
3	1	Subbasin 3	10.930	3.389	.000E+00	.000	.310
4	1	Subbasin 4	8.990	2.616	.000E+00	.000	.291
5	1	Subbasin 5	9.970	3.082	.000E+00	.000	.309
6	1	Subbasin 6	3.080	1.167	.000E+00	.000	.379
7	1	Subbasin 7	4.060	1.425	.000E+00	.000	.351
PRECIPITATION			2.671	2.778	.309E+00	.200	1.040
TRIBUTARY INFLOW			60.960	19.006	.000E+00	.000	.312
***TOTAL INFLOW			63.631	21.784	.309E+00	.026	.342
ADVECTIVE OUTFLOW			63.631	19.535	.764E+00	.045	.307
***TOTAL OUTFLOW			63.631	19.535	.764E+00	.045	.307
***EVAPORATION			.000	2.249	.455E+00	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	1700.3	8.4	.000E+00	.0	.000	311.5	96.3
2	1	Subbasin 2	800.1	3.9	.000E+00	.0	.000	428.3	127.6
3	1	Subbasin 3	1200.3	5.9	.000E+00	.0	.000	354.2	109.8
4	1	Subbasin 4	900.2	4.4	.000E+00	.0	.000	344.1	100.1
5	1	Subbasin 5	900.2	4.4	.000E+00	.0	.000	292.1	90.3
6	1	Subbasin 6	199.9	1.0	.000E+00	.0	.000	171.3	64.9
7	1	Subbasin 7	200.0	1.0	.000E+00	.0	.000	140.3	49.3
PRECIPITATION			80.1	.4	.161E+04	100.1	.500	28.8	30.0
INTERNAL LOAD			14310.5	70.5	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW			5901.1	29.1	.000E+00	.0	.000	310.5	96.8
***TOTAL INFLOW			20291.7	100.0	.160E+04	100.0	.002	931.5	318.9
ADVECTIVE OUTFLOW			3331.5	16.4	.228E+07	*******	.453	170.5	52.4
***TOTAL OUTFLOW			3331.5	16.4	.228E+07	*******	.453	170.5	52.4
***RETENTION			16960.2	83.6	.228E+07	*******	.089	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.31	.8041	87.6	.0678	14.7410	.8358

Appendix C
GWLF Manual

G W L F

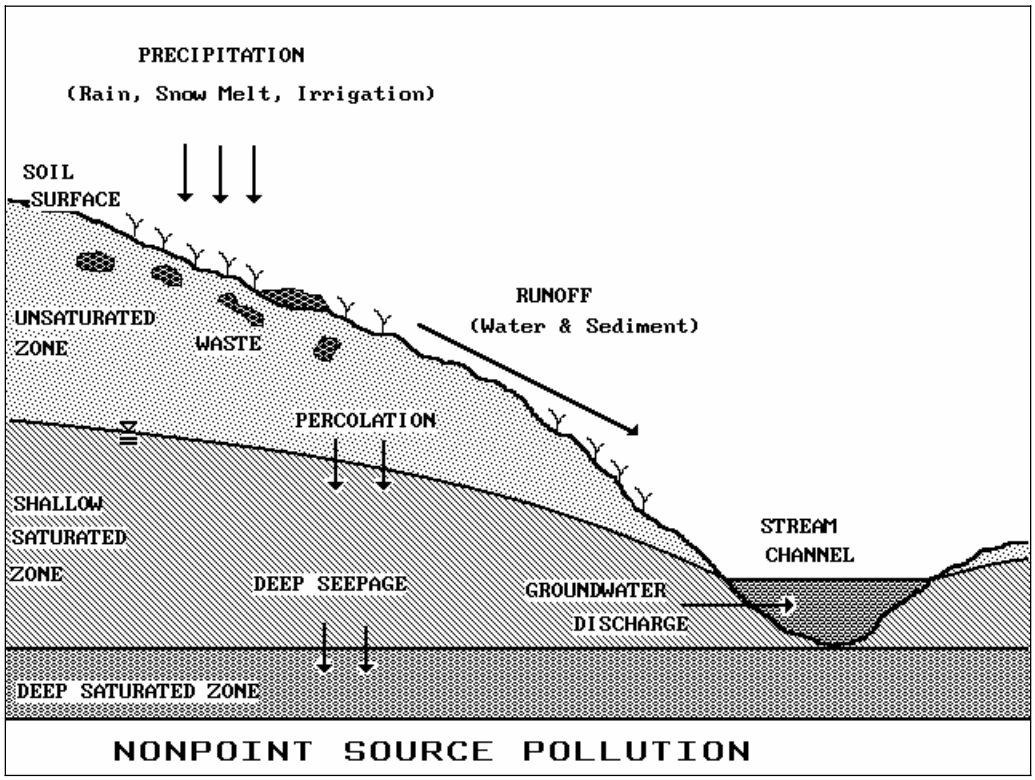
GENERALIZED WATERSHED LOADING FUNCTIONS

VERSION 2.0

USER'S MANUAL

December, 1992
(Corrected & reprinted: January, 1996)

Douglas A. Haith, Ross Mandel & Ray Shyan Wu



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INTRODUCTION

Mathematical models for estimating nonpoint sources of nitrogen and phosphorus in streamflow include export coefficients, loading functions and chemical simulation models. Export coefficients are average annual unit area nutrient loads associated with watershed land uses. Coefficients provide gross estimates of nutrient loads, but are of limited value for determining seasonal loads or evaluating water pollution control measures. Chemical simulation models are mechanistic (mass balance) descriptions of nutrient availability, wash off, transport and losses. Chemical simulation models provide the most complete descriptions of nutrient loads, but they are too data intensive for use in many water quality studies.

Loading functions are engineering compromises between the empiricism of export coefficients and the complexity of chemical simulation models. Mechanistic modeling is limited to water and/or sediment movement. Chemical behavior of nutrients is either ignored or described by simple empirical relationships. Loading functions provide useful means of estimating nutrient loads when chemical simulation models are impractical.

The Generalized Watershed Loading Functions (GWLF) model described in this manual estimates dissolved and total monthly nitrogen and phosphorus loads in streamflow from complex watersheds. Both surface runoff and groundwater sources are included, as well as nutrient loads from point sources and on-site wastewater disposal (septic) systems. In addition, the model provides monthly streamflow, soil erosion and sediment yield values. The model does not require water quality data for calibration, and has been validated for an 85,000 ha watershed in upstate New York.

The model described in this manual is a based on the original GWLF model as described by Haith & Shoemaker (1987). However, the current version (Version 2.0) contains several enhancements. Nutrient loads from septic systems are now included and the urban runoff model has been modified to more closely approximate procedures used in the Soil Conservation Service's Technical Release 55 (Soil Conservation Service, 1986) and models such as SWMM (Huber & Dickinson, 1988) and STORM (Hydrologic Engineering Center, 1977). The groundwater model has been given a somewhat stronger conceptual basis by limiting the unsaturated zone moisture storage capacity. The graphics outputs have been converted to VGA and color has been used more extensively.

The most significant changes in the manual are an expanded mathematical description of the model (Appendix A) and much more detailed guidance on parameter estimation (Appendix B). Both changes are in response to suggestions by many users. The extra mathematical details are for the benefit of researchers who wish to modify (and improve) GWLF for their own purposes. The new sections on parameter estimation (and the many new tables) are for users who may not be familiar with curve numbers, erosivity coefficients, etc., or who do not have access to some of the primary sources. The general intent has been to make the manual self-contained.

This manual describes the computer software package which can be used to implement GWLF. The associated programs are written in QuickBASIC 4.5 for personal computers using the MS-DOS operating system and VGA graphics. The manual and associated programs (on floppy disk) are available without charge from the senior author. The programs are distributed in both executable (.EXE) and source code form (.BAS). Associated example data files and outputs for Example 1 and a 30-yr weather set for Walton NY used in Example 3 are also included on the disk.

The main body of this manual describes the program structures and input and output files and options. Three examples are also presented. Four appendices present the mathematical structure of GWLF, methods for estimation of model parameters, results of a validation study, and sample listings of input and output files.

In this manual, the program name, options in the menu page, and input by the user are written in **bold**, <u>underline</u> and *italic*, respectively.

MODEL DESCRIPTION

Model Structure

The GWLF model includes dissolved and solid-phase nitrogen and phosphorus in streamflow from the sources shown in Figure 1. Rural nutrient loads are transported in runoff water and eroded soil from numerous source areas, each of which is considered uniform with respect to soil and cover. Dissolved loads from each source area are obtained by multiplying runoff by dissolved concentrations. Runoff is computed by using the Soil Conservation Service Curve Number Equation. Solid-phase rural nutrient loads are given by the product of monthly sediment yield and average sediment nutrient concentrations. Erosion is computed using the Universal Soil Loss Equation and the sediment yield is the product of erosion and sediment delivery ratio. The yield in any month is proportional to the total transport capacity of daily runoff during the month. Urban nutrient loads, assumed to be entirely solid-phase, are modeled by exponential accumulation and washoff functions. Septic systems are classified according to four types: normal systems, ponding systems, short-circuiting systems, and direct discharge systems. Nutrient loads from septic systems are calculated by estimating the per capita daily load from each type of system and the number of people in the watershed served by each type. Daily evapotranspiration is given by the product of a cover factor and potential evapotranspiration. The latter is estimated as a function of daylight hours, saturated water vapor pressure and daily temperature.

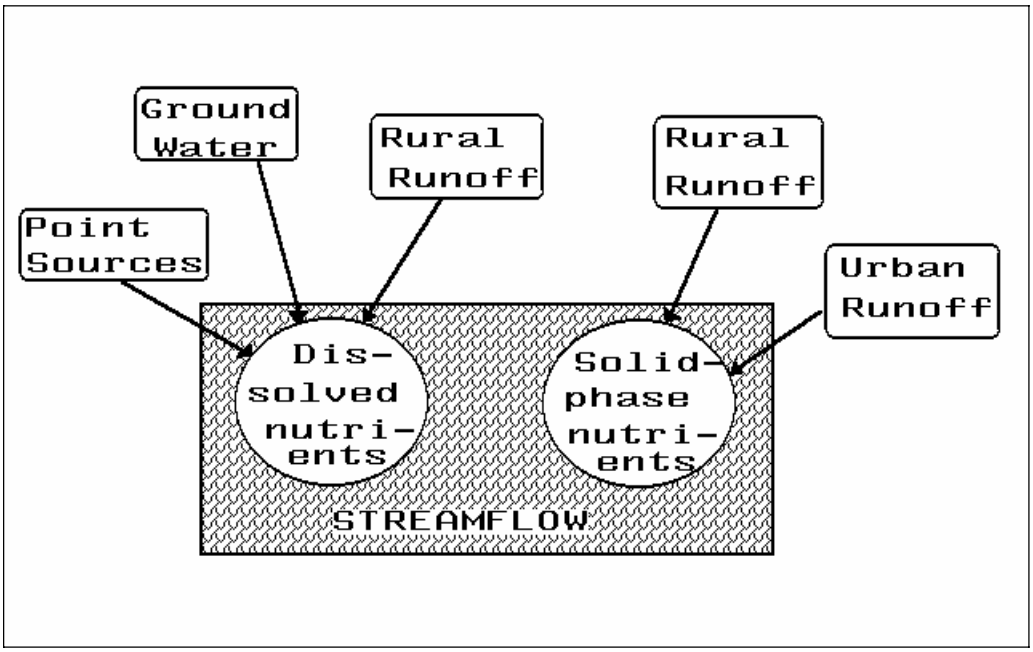

Figure 1. Nutrient Sources in GWLF.

Streamflow consists of runoff and discharge from groundwater. The latter is obtained from a lumped parameter watershed water balance. Daily water balances are calculated for unsaturated and shallow saturated zones. Infiltration to the unsaturated and shallow saturated zones equals the excess, if any, of rainfall and snowmelt less runoff and evapotranspiration. Percolation occurs when unsaturated zone water exceeds field capacity. The shallow saturated zone is modeled as a linear groundwater reservoir.

Model structure, including mathematics, is discussed in more detail in Appendix A.

Input Data

The GWLF model requires daily precipitation and temperature data, runoff sources and transport and chemical parameters. Transport parameters include areas, runoff curve numbers for antecedent moisture condition II and the erosion product ḲLṢÇP for each runoff source. Required watershed transport parameters are groundwater recession and seepage coefficients, the available water capacity of the unsaturated zone, the

sediment delivery ratio and monthly values for evapotranspiration cover factors, average daylight hours, growing season indicators and rainfall erosivity coefficients. Initial values must also be specified for unsaturated and shallow saturated zones, snow cover and 5-day antecedent rain fall plus snowmelt.

Input nutrient data for rural source areas are dissolved nitrogen and phosphorus concentrations in runoff and solid-phase nutrient concentrations in sediment. If manure is spread during winter months on any rural area, dissolved concentrations in runoff are also specified for each manured area. Daily nutrient accumulation rates are required for each urban land use. Septic systems need estimates of the per capita nutrient load in septic system effluent and per capita nutrient losses due to plant uptake, as well as the number of people served by each type of system. Point sources of nitrogen and phosphorus are assumed to be in dissolved form and must be specified for each month. The remaining nutrient data are dissolved nitrogen and phosphorus concentrations in groundwater.

Procedures for estimating transport and nutrient parameters are described in Appendix B. Examples are given in Appendix C and in subsequent sections of this manual.

Model Output

The GWLF program provides its simulation results in tables as well as in graphs. The following principal variables are given:

Monthly Streamflow
Monthly Watershed Erosion and Sediment Yield
Monthly Total Nitrogen and Phosphorus Loads in Streamflow
Annual Erosion from Each Land Use
Annual Nitrogen and Phosphorus Loads from Each Land Use

The program also provides

Monthly Precipitation and Evapotranspiration
Monthly Ground Water Discharge to Streamflow
Monthly Watershed Runoff
Monthly Dissolved Nitrogen and Phosphorus Loads in Streamflow
Annual Dissolved Nitrogen and Phosphorus Loads from Each Land Use
Annual Dissolved Nitrogen and Phosphorus Loads from Septic Systems

GWLF PROGRAM

Required Files

Simulations by GWLF require four program modules and three data files on the default drive. The three necessary data files are **WEATHER.DAT**, **TRANSPRT.DAT** and **NUTRIENT.DAT**. The four compiled modules, **GWLF20.EXE**, **TRAN20.EXE**, **NUTR20.EXE**, and **OUTP20.EXE** are run by typing *GWLF20*.

Two daily weather files for Walton, NY are included on the disks. **WALT478.382** is the four year (4/78-3/92) record used for model validation and in Examples 1 and 2. **WALT462.392** is the 30 year (4/62- 3/92) record used in Example 3. Prior to running the programs, the appropriate weather record should be copied to **WEATHER.DAT**.

The final two data files on the disks (**RESULTS.DAT**, and **SUMMARY.DAT**) are output files from Example 1. **GWLF20.BAS**, **TRAN20.BAS**, **NUTR20.BAS**, and **OUTP20.BAS** are the uncompiled, Quick-BASIC files for the modules, and can be used to modify the existing program.

Program Structure

The structure of GWLF is illustrated in Figure 2. Once the program has been activated, the main control page appears on the screen, as shown in DISPLAY 1.This page is the main menu page that leads to the four major options of the program. The selection of a program option provides access to another set of menu pages within the chosen option. After completing an option, the program returns the user to the main menu page for further actions.

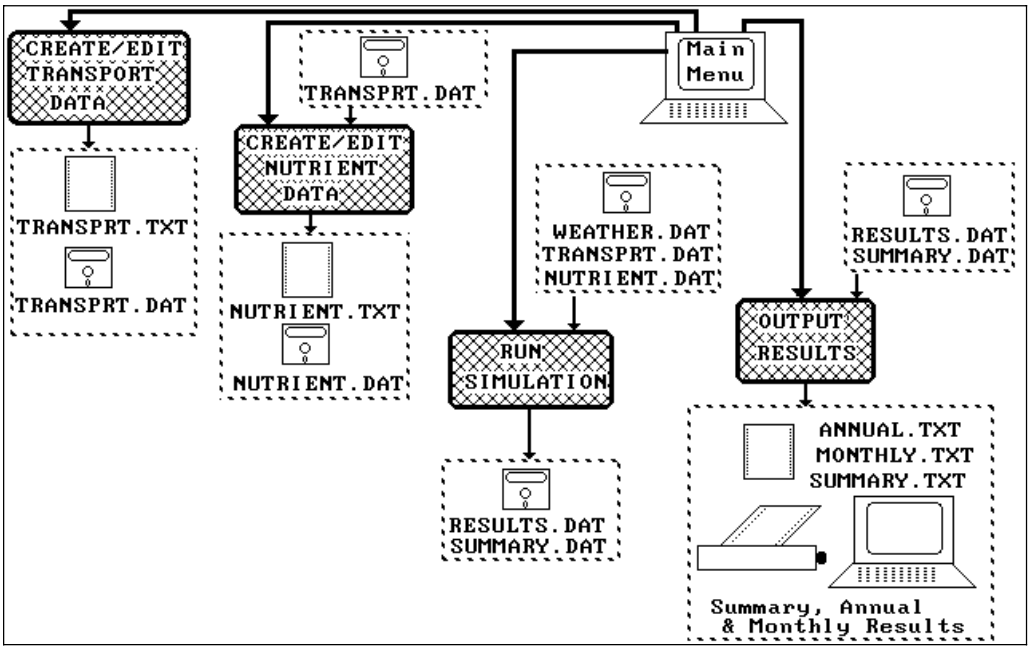

Figure 2. Structure of the GWLF Program.

The selection of the menu options is done by typing the number indicating a choice and then *Enter*. For example, selection of Run simulation is done by typing *3* and *Enter*.

```
Select one of the following :
      1      Create or print TRANSPRT.DAT (Transport parameters)
      2      Create or print NUTRIENT.DAT (nutrient parameters)
               (TRANSPRT.DAT must be created before NUTRIENT.DAT)
      3      Run simulation
      4      Obtain output
      5      Stop (End)
?
```

DISPLAY 1. The Main Menu Page of the GWLF Program.

Transport Data Manipulation

The first step in using the program is to define transport parameters either by creating a new transport data file or modifying an existing one. Options are shown in DISPLAY 2. If the user wishes to create a new transport data file, selection of Create new TRANSPRT.DAT file leads to the input mode. On the other hand, if the user wishes to modify an existing transport data file, selection of Modify existing TRANSPRT.DAT file leads to the modification mode. After input/modification, the user can obtain a hard copy of the transport data by selecting Print TRANSPORT data.

```
Select :
      1        Create new TRANSPRT.DAT file
      2        Modify existing TRANSPRT.DAT file
      3        Print TRANSPORT data
  otherwise    Return
?
```

DISPLAY 2. The Menu Page for Manipulation of Transport Parameters.

Create a New TRANSPRT.DAT File. New values of transport parameters are input one by one in this mode. Values are separated by *Enter* keys. After the number of land uses are input, a table is displayed in the screen to help the user to input data. The line in the bottom of the screen provides on-line help which indicates the expected input data type.

In cases when a serious error has been made, the user can always restart this process by hitting *F1*, then *Enter*. Alternatively, the user may save current input and modify the data in the modification mode.

After all input is complete, the user is asked whether to save or abort the changes. An input of *Y* will overwrite the existing, if any, transport data file.

Modify an Existing TRANSPRT.DAT File. An existing transport data file can be modified in this mode. This is convenient when only minor modification of transport data is needed, e.g., in the case of studying impacts of changes of land use on a watershed.

In this mode, the user is expected to hit *Enter* if no change would be made and *Space bar* if a new value would be issued. The two lines at the bottom of screen provide on-line help.

Print TRANSPORT Data. The user can choose one or more of the three types of print out of transport parameters, namely, to display to screen, print a hard copy, or create a ASCII text file named **TRANSPRT.TXT**. The text file can later be imported to a word processor to generate reports.

Nutrient Data Manipulation

0When nutrient loads are of concern, the nutrient data file (**NUTRIENT.DAT**) must be available before a simulation can be run. This is done by either creating a new nutrient data file or modifying an existing one. Options are shown in DISPLAY 3. Procedures for creating, modifying or printing nutrient data are similar to those described for the transport data. The ASCII text file is **NUTRIENT.TXT**.

```
Select :
      1        Create new NUTRIENT.DAT file
      2        Modify existing NUTRIENT.DAT file
      3        Print NUTRIENT data
      4        Return
?
```

DISPLAY 3. The Menu Page for Manipulation of Nutrient Parameters.

Simulation

Four categories of simulation can be performed, as shown in DISPLAY 4. To simulate streamflow or sediment yield, two data files, **WEATHER.DAT** and **TRANSPRT.DAT** must be in the default directory. An additional data file, **NUTRIENT.DAT**, is required when nutrient loads are simulated.

```
Select program options:
      1      Streamflow simulation only
      2      Streamflow and sediment yield only
      3      Streamflow, sediment yield, and nutrient loads
      4      Streamflow, sediment yield, nutrient loads, and septic systems
  otherwise  Return
?
```

DISPLAY 4. The Menu Page for Simulation Options.

After choosing the type of simulation, the user inputs the title of this specific simulation. This title can be a word, a sentence, or a group of words. The user then decides the length, in years, of the simulation run (not to exceed the number of years of weather data in **WEATHER.DAT**).

Results Output

Simulation output can be reported in three categories, namely, overall means, annual values, and monthly values. Either tables or graphs can be generated, as shown in DISPLAY 5. In producing tables, i.e., when one of the first three options is selected, the user can choose to display it on screen, print it on a printer, or save it as an ASCII text file. When one of the graph options is selected, the user is able to see the graph on the screen. If the computer has suitable printer driver, a hard copy of the graph can be obtained by pressing *Shift-PrtSc* keys together.

```
Select :
      1       Print summary
      2       Print annual results
      3       Print monthly results
      4       Graph summary (average)
      5       Graph annual results
      6       Graph monthly results
              (PrtSc for hard copy, carriage return to continue)
  otherwise   Return
?
```

DISPLAY 5. The Menu Page for Output Generation.

EXAMPLE 1: 4-YEAR STUDY IN WEST BRANCH DELAWARE BASIN

This example is designed to allow the user to become familiar with the operation of the program and the way results are presented. The data set and results are those described in Appendix C for the GWLF validation for the West Branch Delaware River Watershed in New York.

The programs **GWLF20.EXE, TRAN20.EXE, NUTR20.EXE,** and **OUTP20.EXE**, and the data files **WEATHER.DAT, TRANSPRT.DAT,** and **NUTRIENT.DAT** must be on the default drive. The weather file can be obtained by copying **WALT478.382** to **WEATHER.DAT**.

Simulation

To start the program, type *GWLF20* then *Enter*. The first screen is the main menu (see DISPLAY 1). To select Run simulation, type *3* and *Enter*. This will lead to the simulation option menu (see DISPLAY 4). Since nutrient fluxes and septic system loads are of interest, type *4* and *Enter*. This will start the simulation.

The user is then asked to input the title of this simulation. Type *Example 1* and *Enter*. Finally the user is expected to specify the length of the simulation. Type *4*, then *Enter*. This concludes the information required for a simulation run. The input section described above is shown in DISPLAY 6.

```
Select one of the following :
      1     Create or print TRANSPRT.DAT (Transport parameters)
      2     Create or print NUTRIENT.DAT (nutrient parameters)
              (TRANSPRT.DAT must be created before NUTRIENT.DAT)
      3     Run simulation
      4     Obtain output
      5     Stop (End)
? 3

Select program options:
      1     Streamflow simulation only
      2     Streamflow and sediment yield only
      3     Streamflow, sediment yield, and nutrient loads
      4     Streamflow, sediment yield, nutrient loads, and septic systems
  otherwise Return
? 3

TITLE OF SIMULATION? Example 1
LENGTH OF RUN IN YEARS? 4
```

DISPLAY 6. Input Section in Example 1. User Input is Indicated by Italics.

The screen is now switched to graphic mode. During the computation, part of the result will be displayed. This is to provide a sample of the result and to monitor the progress of the simulation. As shown in Figure 3, the line on the top of the screen reports the length of simulation and the current simulated month/year.

The main menu is displayed at the end of the simulation. From here, the user can generate several types of results.

Results Generation

Type *4*, then *Enter* to generate results. For printing out monthly streamflows, sediment yields, and nutrient loads, type *3*, then *Enter*. The user is asked whether to specify the range of the period to be reported. Type *N*, then *Enter* to select the default full period.

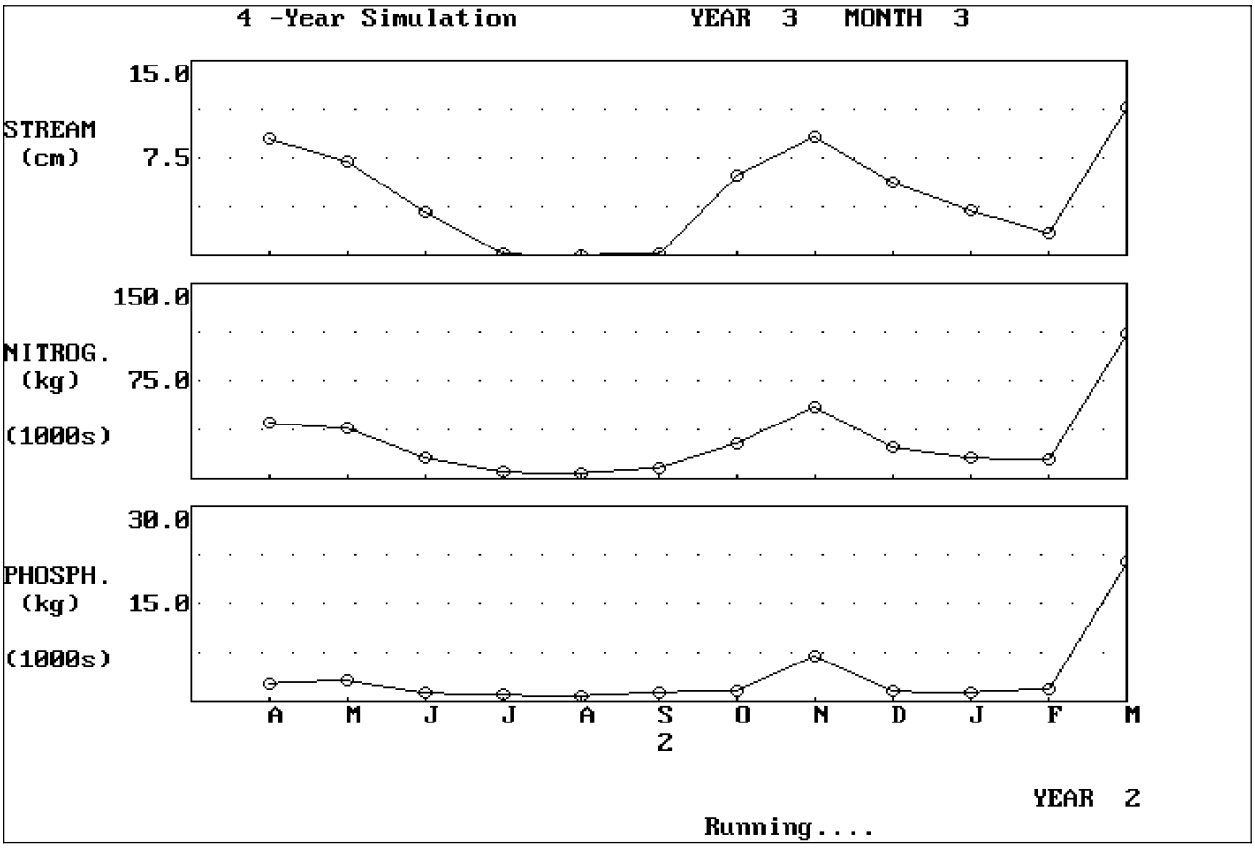

Figure 3. Screen Display during Simulation.

The user decides on the type of output. Type *1*, then *Enter* to print to the screen. The result is displayed in nine screens. After reading a screen, press *Enter* to bring up the next screen. To generate a hard copy, turn on the printer, type *2* and *Enter*. Alternatively, the user can save the result in a text file, **MONTHLY.TXT**. The user can go back to the previous page menu to select another option of results generation by pressing *Enter*. Part of the process described above is shown in DISPLAY 7. To generate graphs of the monthly results, type *6* and *Enter*. This produces graphs such as Figure 4 and Figure 5. The user can call up the main menu again by pressing *Enter* keys. The data input files **TRANSPRT.DAT**, **NUTRIENT.DAT** and **WEATHER.DAT** for this example are listed in Appendix E with the various **.TXT** files that may be generated.

EXAMPLE 2: EFFECTS OF ELIMINATION OF WINTER MANURE SPREADING

In this example, nutrient parameters are modified to investigate effects of winter manure applications. The example involves manipulation of the data file **NUTRIENT.DAT**. If the user wishes to save the original file, it should first be copied to a new file, say **NUTRIENT.EX1**.

Nutrient Parameters Modification

From the main menu, type *2*, *Enter*. This leads to the nutrient data manipulation option. Type *2*, *Enter* to modify **NUTRIENT.DAT** (see DISPLAY 8).

Type *Enter* to accept the original dissolved nutrient concentrations. Repeat this procedure until the cursor is in the line, Number of Land Uses on Which Manure is Spread (see DISPLAY 9), hit *Space-bar*, type *0*, and hit *Enter*.

Accept all the rest of original data by hitting *Enter* key until the end of the file. Type *Y* to save the

changes. This concludes the modification of **NUTRIENT.DAT**.

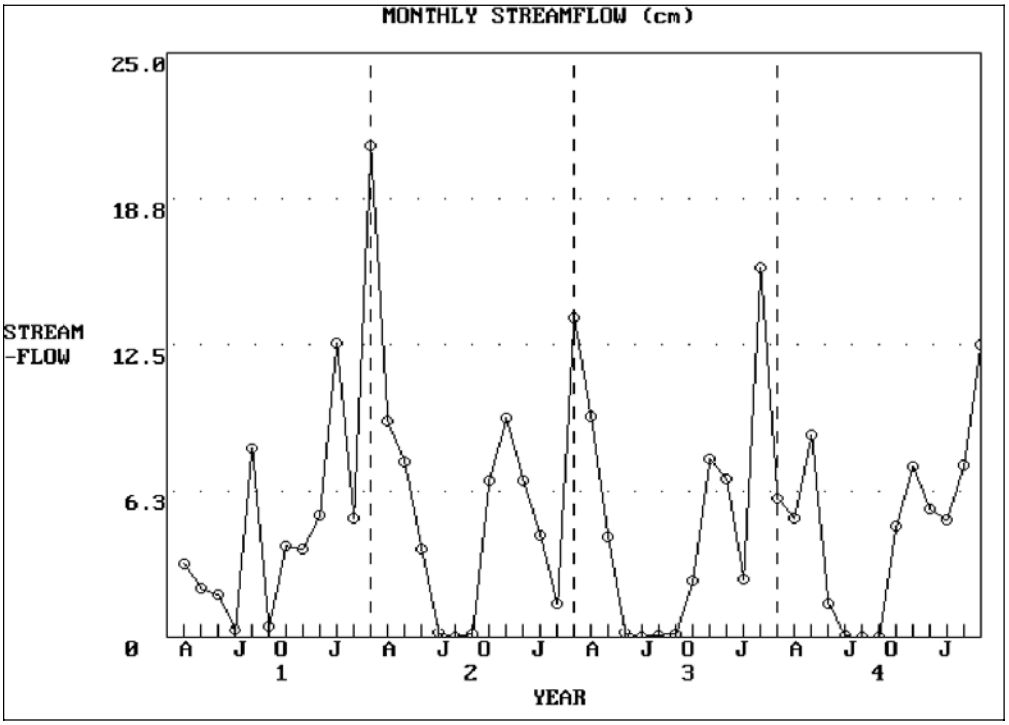

Figure 4. Monthly Streamflows for Example 1.

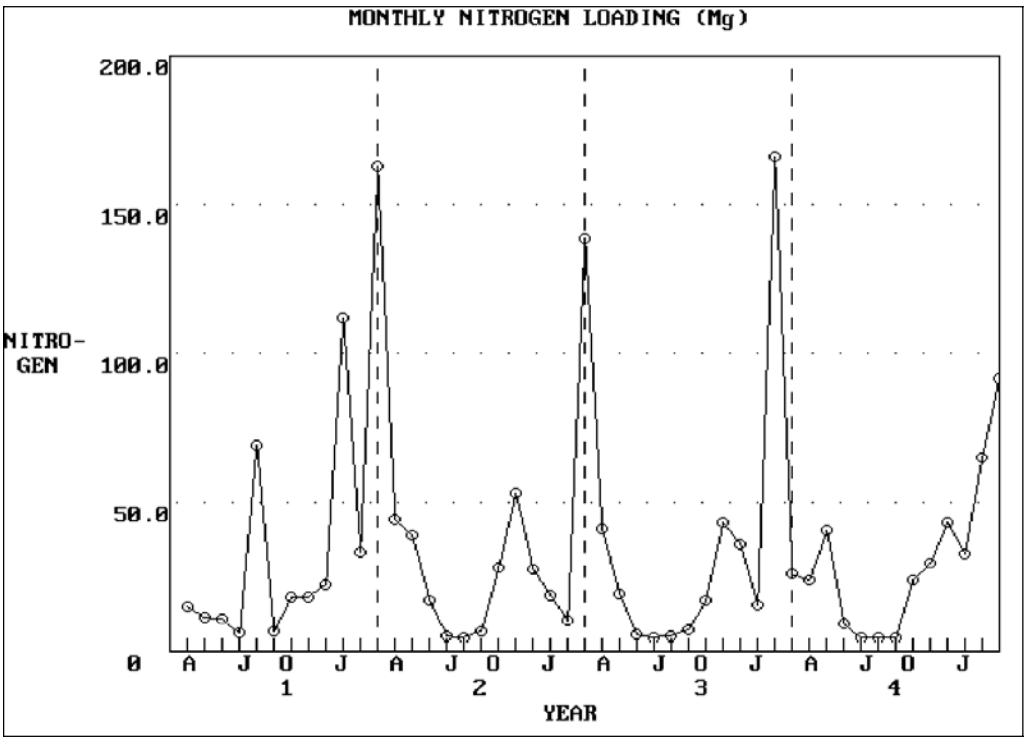

Figure 5. Monthly Nitrogen Loads for Example 1.

The user may print out nutrient data to make sure these changes have been made. To do so, the user selects Print NUTRIENT data in the nutrient data manipulation page (see DISPLAY 3). Then select Print to screen to display the current nutrient parameters.

```
Select one of the following :
      1       Create or print TRANSPRT.DAT (Transport parameters)
      2       Create or print NUTRIENT.DAT (nutrient parameters)
                (TRANSPRT.DAT must be created before NUTRIENT.DAT)
      3       Run simulation
      4       Obtain output
      5       Stop (End)
? 4

Select :
      1       Print summary
      2       Print annual results
      3       Print monthly results
      4       Graph summary (average)
      5       Graph annual results
      6       Graph monthly results
              (PrtSc for hard copy, carriage return to continue)
  otherwise   Return
? 3
      Want to specify the range of years in output?   ( Type  Y  or  N )
? N

Select : (For printing MONTHLY data)
      1       Print to screen (carriage return to continue)
      2       Print a hard copy (turn on printer first)
      3       Print to a file named MONTHLY.TXT
  otherwise   Return
? 1
```

DISPLAY 7. Result Generating Menu in Example 1.

```
Select one of the following :
      1       Create or print TRANSPRT.DAT (Transport parameters)
      2       Create or print NUTRIENT.DAT (nutrient parameters)
                (TRANSPRT.DAT must be created before NUTRIENT.DAT)
      3       Run simulation
      4       Obtain output
      5       Stop (End)
? 2

Select :
      1       Create new NUTRIENT.DAT file
      2       Modify existing NUTRIENT.DAT file
      3       Print NUTRIENT data
  otherwise   Return
? 2
```

DISPLAY 8. Modification of Nutrient Parameters.

Simulation and Results Generation

Following the procedures described in Example 1, the results of a 3-year simulation are shown in Figure 6.

```
Number of Land Uses on Which Manure is Spread: -1

                    To redo from start, Hit <F1> then <ENTER> key
Hint: Press Space-Bar to Input Value or Enter-Key to Accept Current Value
```

DISPLAY 9. The First Screen for Modifying Nutrient Parameters. The Original Number is 1. Hit the *Space Bar*, Type *0*, and then Hit *Enter* Key to Change this Number to 0.

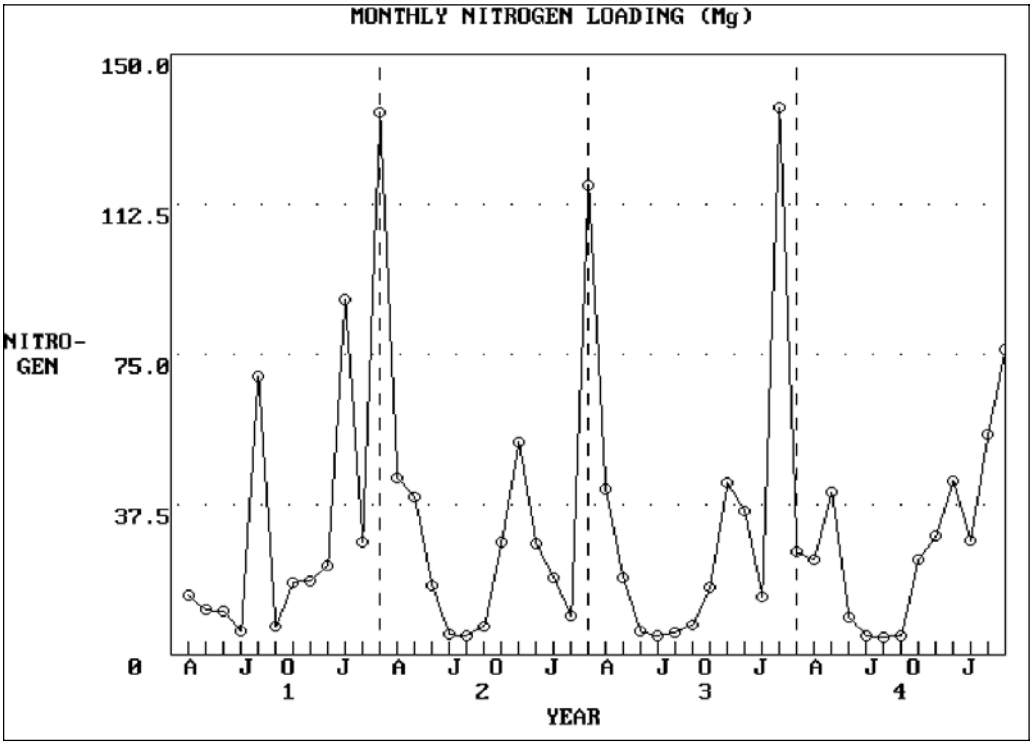

Figure 6. Monthly Nitrogen Loads with no Manure Spreading .

EXAMPLE 3: A 30-YEAR SIMULATION STUDY

In Example 3, a simulation of the West Branch Delaware River Basin is based on a 30-yr (4/62-3/92) weather record given in the file **WALT462.392**.

Simulation and Results Generation

The simulation is run by following procedures as in Example 1 (see DISPLAY 6). Answer LENGTH OF RUN IN YEARS by typing *30* and then *Enter*.

At the end of the computation, the main menu is displayed. From here, the user can generate several types of results by typing *4*, then *Enter*. For a summary of the results, type *1* and *Enter*. To display the summary in screen, type *1* and *Enter*. The summary is displayed in three screens. After reading a screen, press *Enter* to bring up next screen. To generate a hard copy from the printer, turn on the printer, select Print a hard copy. Hit *Enter* to obtain the output option menu.

From the output generation menu (see DISPLAY 5), to obtain a graphical description of the summary, type *4* and then *Enter*. This brings up a screen of options (see DISPLAY 10). Eighteen types of graphs can be generated. For example, to investigate the relative magnitudes of average monthly streamflow, type *5* and *Enter*. This produces the bar chart shown in Figure 7. Similarly, to investigate the nitrogen loads from each source, type *15* and then *Enter*. This generates another bar chart as shown in Figure 8.

```
Select :
    1     Mean Monthly Precipitation
    2     Mean Monthly Evapotranspiration
    3     Mean Monthly Groundwater Flow
    4     Mean Monthly Runoff
    5     Mean Monthly Streamflow
    6     Mean Monthly Erosion
    7     Mean Monthly Sediment
    8     Mean Monthly Dissolved Nitrogen
    9     Mean Monthly Total Nitrogen
   10     Mean Monthly Dissolved Phosphorus
   11     Mean Monthly Total Phosphorus
   12     Mean Annual Runoff from Sources
   13     Mean Annual Erosion from Sources
   14     Mean Annual Dissolved Nitrogen Loads from Sources
   15     Mean Annual Total Nitrogen Loads from Sources
   16     Mean Annual Dissolved Phosphorus Loads from Sources
   17     Mean Annual Total Phosphorus Loads from Sources
   18     Areas of Sources
otherwise Return
?
```

DISPLAY 10. The Options for Plotting Summary

For plotting annual streamflows, sediment yields and nutrient loads, type *5*, then *Enter*. The graphs will be displayed on several screens. For example, Figure 9 shows the predicted annual streamflows.

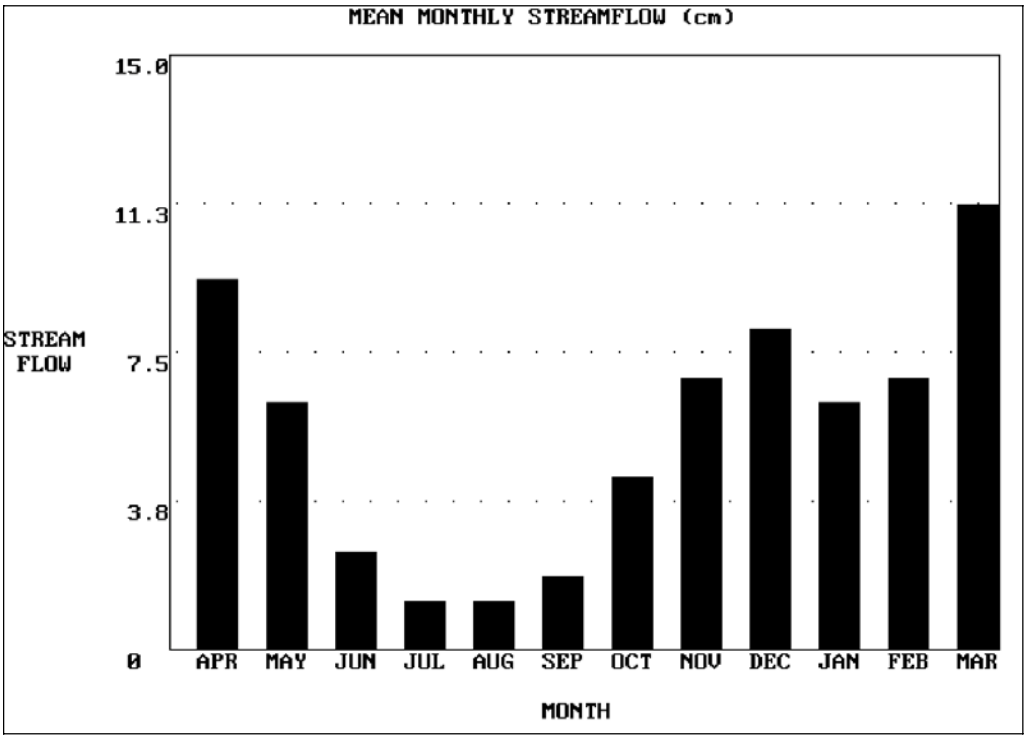

Figure 7. Mean Monthly Streamflows for 30-yr Simulation.

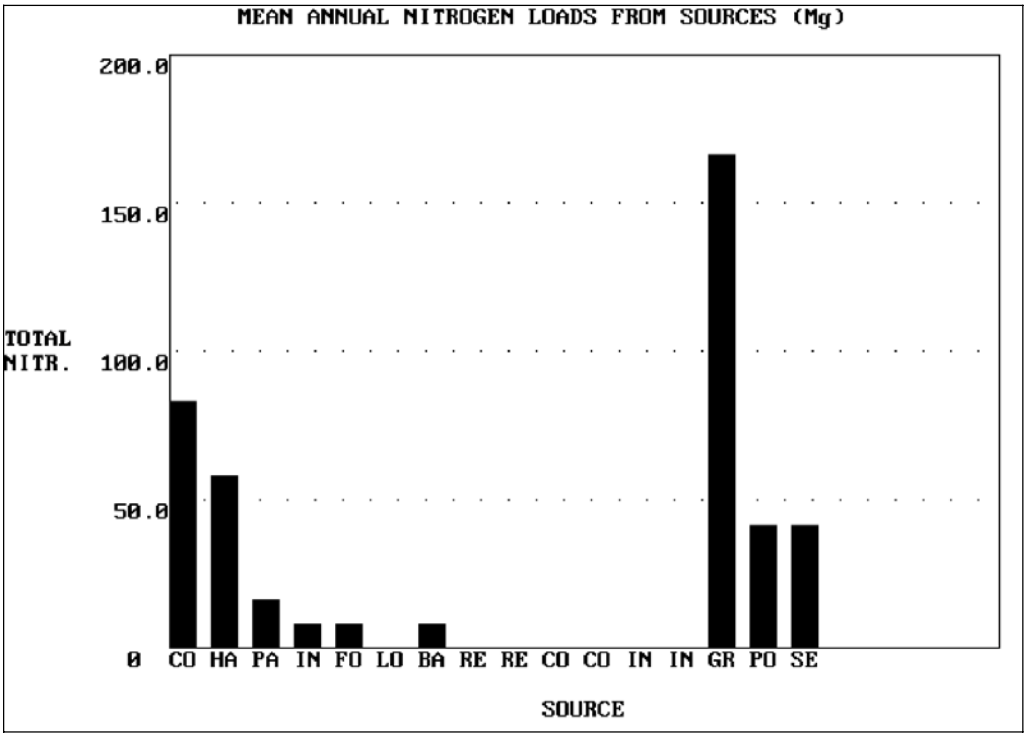

Figure 8. Mean Annual Nitrogen Load from Sources for 30-yr Simulation.

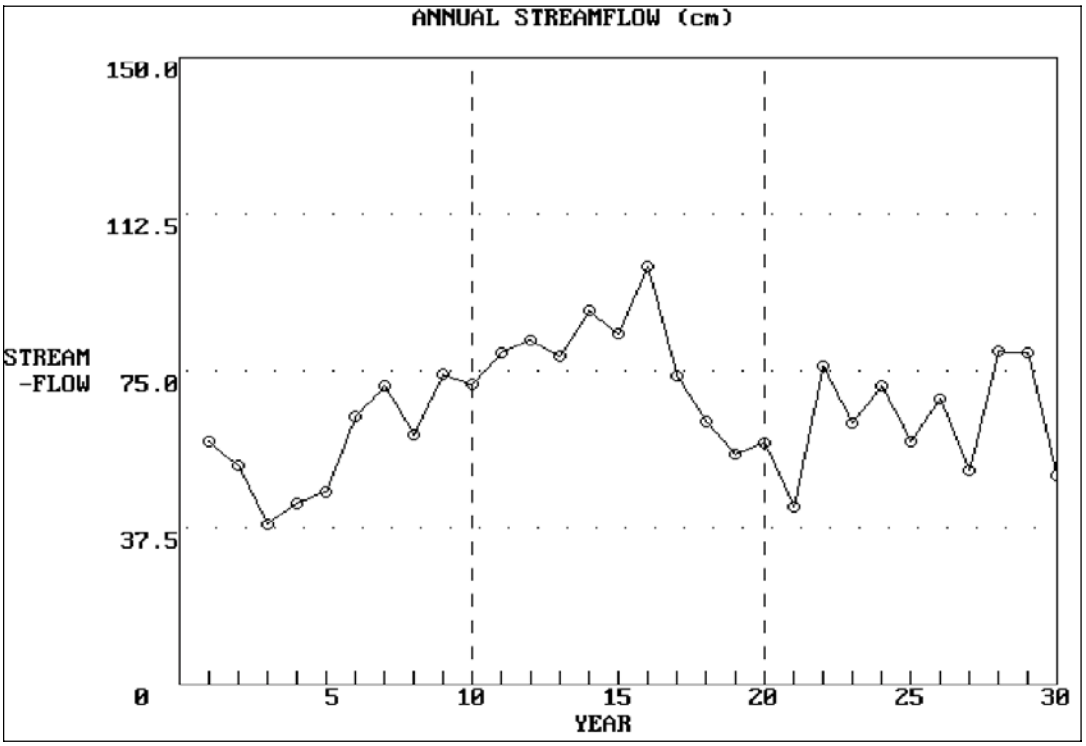

Figure 9. Annual Streamflows for 30-yr Simulation.

APPENDIX A: MATHEMATICAL DESCRIPTION OF GWLF

General Structure

Streamflow nutrient flux contains dissolved and solid phases. Dissolved nutrients are associated with runoff, point sources and groundwater discharges to the stream. Solid-phase nutrients are due to point sources, rural soil erosion or wash off of material from urban surfaces. The GWLF model describes nonpoint sources with a distributed model for runoff, erosion and urban wash off, and a lumped parameter linear reservoir groundwater model. Point sources are added as constant mass loads which are assumed known. Water balances are computed from daily weather data but flow routing is not considered. Hence, daily values are summed to provide monthly estimates of streamflow, sediment and nutrient fluxes (It is assumed that streamflow travel times are much less than one month).

Monthly loads of nitrogen or phosphorus in streamflow in any year are

$$LD_m = DP_m + DR_m + DG_m + DS_m \qquad \text{(A-1)}$$

$$LS_m = SP_m + SR_m + SU_m \qquad \text{(A-2)}$$

In these equations, LD_m is dissolved nutrient load, LS_m is solid-phase nutrient load, DP_m, DR_m, DG_m and DS_m are point source, rural runoff, groundwater and septic system dissolved nutrient loads, respectively, and SP_m, SR_m and SU_m and are solid-phase point source, rural runoff and urban runoff nutrient loads (kg), respectively, in month m (m = 1,2,...12). Note that the equations assume (i) point source, groundwater and septic system loads are entirely dissolved; and (ii) urban nutrient loads are entirely solid.

Rural Runoff Loads

Rural nutrient loads are transported in runoff water and eroded soil from numerous source areas, each of which is considered uniform with respect to soil and cover.

Dissolved Loads. Dissolved loads from each source area are obtained by multiplying runoff by dissolved concentrations. Monthly loads for the watershed are obtained by summing daily loads over all source areas:

$$LD_m = 0.1 \sum_k \sum_{t=1}^{d_m} Cd_k \, Q_{kt} \, AR_k \qquad \text{(A-3)}$$

where Cd_k = nutrient concentration in runoff from source area k (mg/*l*), Q_{kt} = runoff from source area k on day t (cm) and AR_k = area of source area k (ha) and d_m = number of days in month m.

Runoff is computed from daily weather data by the U.S. Soil Conservation Service's Curve Number Equation (Ogrosky & Mockus, 1964):

$$Q_{kt} = \frac{(R_t + M_t - 0.2\, DS_{kt})^2}{R_t + M_t + 0.8\, DS_{kt}} \qquad \text{(A-4)}$$

Rainfall R_t (cm) and snowmelt M_t (cm of water) on day t are estimated from daily precipitation and temperature data. Precipitation is assumed to be rain when daily mean air temperature T_t (°C) is above 0 and snow fall otherwise. Snowmelt water is computed by a degree-day equation (Haith, 1985):

$$M_t = 0.45\, T_t, \text{ for } T_t > 0 \qquad \text{(A-5)}$$

The detention parameter DS_{kt} (cm) is determined from a curve number CN_{kt} as

$$DS_{kt} = \frac{2540}{CN_{kt}} - 25.4 \qquad \text{(A-6)}$$

Curve numbers are selected as functions of antecedent moisture as described in Haith (1985), and shown in Figure A-1. Curve numbers for antecedent moisture conditions 1 (driest), 2 (average) and 3 (wettest) are $CN1_k$, $CN2_k$ and $CN3_k$ respectively. The actual curve number for day t, CN_{kt}, is selected as a linear function of A_t, 5-day antecedent precipitation (cm):

$$A_t = \sum_{n=t-5}^{t-1} (R_n + M_n) \qquad \text{(A-7)}$$

Recommended values (Ogrosky & Mockus, 1964) for the break points in Figure A-1 are AM1 = 1.3, 3.6 cm, and AM2 = 2.8, 5.3 cm, for dormant and growing seasons, respectively. For snowmelt conditions, it is assumed that the wettest antecedent moisture conditions prevail and hence regardless of A_t, $CN_{kt} = CN3_k$ when $M_t > 0$.

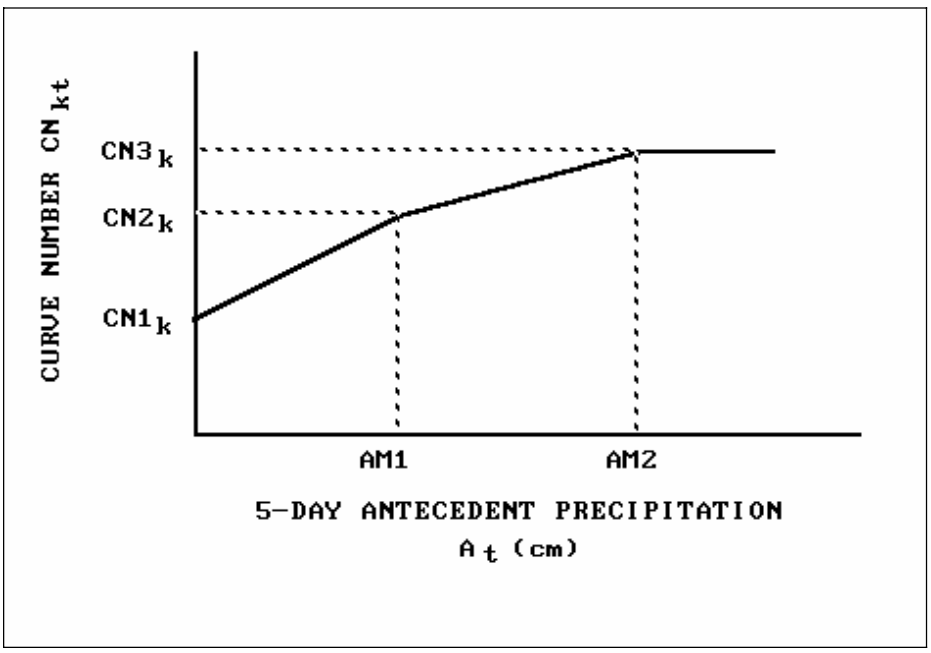

Figure A-1. Curve Number as Function of Antecedent Moisture.

The model requires specification of $CN2_k$. Values for $CN1_k$ and $CN3_k$ are computed from Hawkins (1978) approximations:

$$CN1_k = \frac{CN2_k}{2.334 - 0.01334\, CN2_k} \qquad \text{(A-8)}$$

$$CN3_k = \frac{CN2_k}{\quad} \qquad \text{(A-9)}$$

$$0.4036 + 0.0059\ CN2_k$$

Solid-Phase Loads. Solid-phase rural nutrient loads (SR_m) are given by the product of monthly watershed sediment yields (Y_m, Mg) and average sediment nutrient concentrations (c_s, mg/kg):

$$SR_m = 0.001\ c_s\ Y_m \qquad \text{(A-10)}$$

Monthly sediment yields are determined from the model developed by Haith (1985). The model is based on three principal assumptions: (i) sediment originates from sheet and rill erosion (gully and stream bank erosion are neglected); (ii) sediment transport capacity is proportional to runoff to the 5/3 power (Meyer & Wischmeier, 1969); and (iii) sediment yields are produced from soil which erodes in the current year (no carryover of sediment supply from one year to the next).

Erosion from source area k on day t (Mg) is given by

$$X_{kt} = 0.132\ RE_t\ K_k\ (LS)_k\ C_k\ P_k\ AR_k \qquad \text{(A-11)}$$

in which K_k, $(LS)_k$, C_k and P_k are the standard values for soil erodibility, topographic, cover and management and supporting practice factors as specified for the Universal Soil Loss Equation (Wischmeier & Smith, 1978). RE_t is the rainfall erosivity on day t (MJ-mm/ha-h). The constant 0.132 is a dimensional conversion factor associated with the SI units of rainfall erosivity. Erosivity can be estimated by the deterministic portion of the empirical equation developed by Richardson et al. (1983) and subsequently tested by Haith & Merrill (1987):

$$RE_t = 64.6\ a_t\ R_t^{1.81} \qquad \text{(A-12)}$$

where the coefficient a_t varies with season and geographical location.

The total watershed sediment supply generated in month j (Mg) is

$$SX_j = DR \sum_k \sum_{t=1}^{d_j} X_{kt} \qquad \text{(A-13)}$$

where DR is the watershed sediment delivery ratio. The transport of this sediment from the watershed is based on the transport capacity of runoff during that month. A transport factor TR_j is defined as

$$TR_j = \sum_{t=1}^{d_j} Q_t^{5/3} \qquad \text{(A-14)}$$

The sediment supply SX_j is allocated to months j, j + 1, ... , 12 in proportion to the transport capacity for each month. The total transport capacity for months j, j + 1, ... , 12 is proportional to B_j, where

$$B_j = \sum_{h=j}^{12} TR_h \qquad \text{(A-15)}$$

For each month m, the fraction of available sediment X_j which contributes to Y_m, the monthly sediment yield (Mg), is TR_m/B_j. The total monthly yield is the sum of all contributions from preceding months:

$$Y_m = TR_m \sum_{j=1}^{m} (X_j/B_j) \qquad \text{(A-16)}$$

Urban Runoff

The urban runoff model is based on general accumulation and wash off relationships proposed by Amy et al. (1974) and Sartor & Boyd (1972). The exponential accumulation function was subsequently used in SWMM (Huber & Dickinson, 1988) and the wash off function is used in both SWMM and STORM (Hydrologic Engineering Center, 1977). The mathematical development here follows that of Overton and Meadows (1976).

Nutrients accumulate on urban surfaces over time and are washed off by runoff events. Runoff volumes are computed by equations A-4 through A-7.

If $N_k(t)$ is the accumulated nutrient load on source area (land use) k on day t (kg/ha), then the rate of accumulation during dry periods is

$$\frac{dN_k}{dt} = n_k - \beta N_k \qquad \text{(A-17)}$$

where n_k is a constant accumulation rate (kg/ha-day) and β is a depletion rate constant (day^{-1}). Solving equation A-17, we obtain

$$N_k(t) = N_{k0}\, e^{-\beta t} + (n_k/\beta)\,(1 - e^{-\beta t}) \qquad \text{(A-18)}$$

in which $N_{k0} = N_k(t)$ at time t = 0.

Equation A-18 approaches an asymptotic value $N_{k,max}$:

$$N_{k,max} = \lim_{t \to \infty} N_k(t) = n_k/\beta \qquad \text{(A-19)}$$

Data given in Sartor & Boyd (1972) and shown in Figure A-2 indicates that $N_k(t)$ approaches its maximum value in approximately 12 days. If we conservatively assume that $N_k(t)$ reaches 90% of $N_{k,max}$ in 20 days, then for $N_{k0} = 0$,

$$0.90\,(n_k/\beta) = (n_k/\beta)\,(1 - e^{-20\beta}), \text{ or } \beta = 0.12$$

Equation A-18 can also be written for a time interval $\Delta t = t_2 - t_1$ as

$$N_k(t_2) = N_k(t_1)\, e^{-0.12\Delta t} + (n_k/0.12)\,(1 - e^{-0.12\Delta t}) \qquad \text{(A-20)}$$

or, for a time interval of one day,

$$N_{k,t+1} = N_{kt}\, e^{-0.12} + (n_k/0.12)\,(1 - e^{-0.12}) \qquad \text{(A-21)}$$

where N_{kt} is the nutrient accumulation at the beginning of day t (kg/ha).

Equation A-21 can be modified to include the effects of wash off:

$$N_{k,t+1} = N_{kt}\, e^{-0.12} + (n_k/0.12)\,(1 - e^{-0.12}) - W_{kt} \qquad \text{(A-22)}$$

in which W_{kt} = runoff nutrient load from land use k on day t(kg/ha).

The runoff load is

$$W_{kt} = w_{kt}\,[N_{kt}\, e^{-0.12} + (n_k/0.12)\,(1 - e^{-0.12})] \qquad \text{(A-23)}$$

where w_{kt} is the first-order wash off function suggested by Amy et al. (1974):

$$w_{kt} = 1 - e^{-1.81Q_{kt}} \qquad \text{(A-24)}$$

Equation A-24 is based on the assumption that 1.27 cm (0.5 in) of runoff will wash off 90% of accumulated pollutants. Monthly runoff loads of urban nutrients are thus given by

$$SU_m = \sum_k \sum_{t=1}^{d_m} W_{kt} AR_k \qquad \text{(A-25)}$$

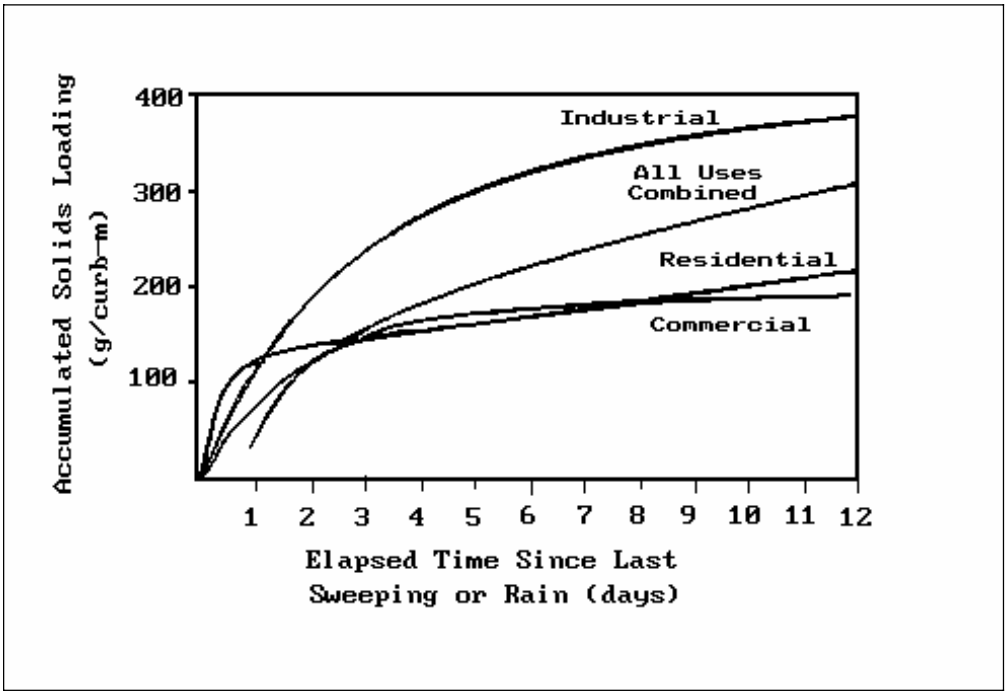

Figure A-2. Accumulation of Pollutants on Urban Surfaces (Sartor & Boyd, 1972; redrawn in Novotny & Chesters, 1981).

Groundwater Sources

The monthly groundwater nutrient load to the stream is

$$DG_m = 0.1\, C_g\, AT \sum_{t=1}^{d_m} G_t \qquad \text{(A-26)}$$

in which C_g = nutrient concentration in groundwater (mg/l), AT = watershed area (ha), and G_t = groundwater discharge to the stream on day t (cm).

Groundwater discharge is described by the lumped parameter model shown in Figure A-3. Streamflow consists of total watershed runoff from all source areas plus groundwater discharge from a shallow saturated zone. The division of soil moisture into unsaturated, shallow saturated and deep saturated zones is similar to that used by Haan (1972).

Daily water balances for the unsaturated and shallow saturated zones are

$$U_{t+1} = U_t + R_t + M_t - Q_t - E_t - PC_t \quad \text{(A-27)}$$

$$S_{t+1} = S_t + PC_t - G_t - D_t \quad \text{(A-28)}$$

In these equations, U_t and S_t are the unsaturated and shallow saturated zone soil moistures at the beginning of day t and Q_t, E_t, PC_t, G_t and D_t are watershed runoff, evapotranspiration, percolation into the shallow saturated zone, groundwater discharge to the stream and seepage flow to the deep saturated zone, respectively, on day t (cm).

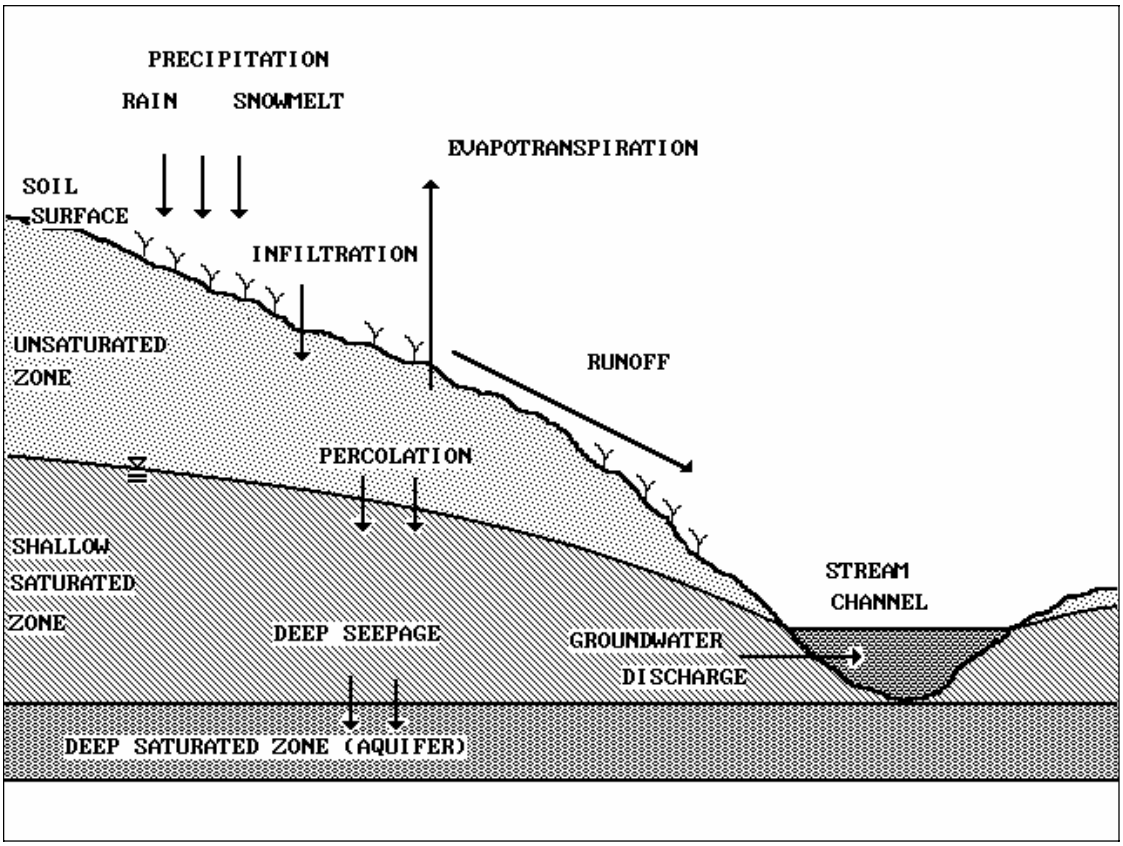

Figure A-3. Lumped Parameter Model for Groundwater Discharge.

Percolation occurs when unsaturated zone water exceeds available soil water capacity U^* (cm):

$$PC_t = \text{Max}\,(0;\ U_t + R_t + M_t - Q_t - E_t - U^*) \quad \text{(A-29)}$$

Evapotranspiration is limited by available moisture in the unsaturated zone:

$$E_t = \text{Min}\,(CV_t\ PE_t;\ U_t + R_t + M_t - Q_t) \quad \text{(A-30)}$$

for which CV_t is a cover coefficient and PE_t is potential evapotranspiration (cm) as given by Hamon (1961):

$$PE_t = \frac{0.021\ H_t^2\ e_t)}{T_t + 273} \quad \text{(A-31)}$$

In this equation, H_t is the number of daylight hours per day during the month containing day t, e_t is the saturated water vapor pressure in millibars on day t and T_t is the temperature on day t (°C). When $T_t \leq 0$, PE_t is set to zero. Saturated vapor pressure can be approximated as in (Bosen, 1960):

$$e_t = 33.8639 \, [\, (0.00738 \, T_t + 0.8072)^8 - 0.000019 \, (1.8 \, T_t + 48) + 0.001316 \,] \, , \quad T_t \geq 0 \qquad \text{(A-32)}$$

As in Haan (1972), the shallow unsaturated zone is modeled as a simple linear reservoir. Groundwater discharge and deep seepage are

$$G_t = r \, S_t \qquad \text{(A-33)}$$

and

$$D_t = s \, S_t \qquad \text{(A-34)}$$

where r and s are groundwater recession and seepage constants, respectively (day^{-1}).

Septic (On-site Wastewater Disposal) Systems

The septic system component of GWLF is based on the model developed by Mandel (1993). For purposes of assessing watershed water quality impacts, septic systems loads can be divided into four types:

$$DS_m = DS_{1m} + DS_{2m} + DS_{3m} + DS_{4m} \qquad \text{(A-35)}$$

where DS_{1m}, DS_{2m}, DS_{3m} and DS_{4m} are the dissolved nutrient load to streamflow from normal, short-circuited, ponded and direct discharge systems, respectively in month m (kg). These loads are computed from per capita daily effluent loads and monthly populations served a_{jm} for each system (j =1,2,3,4).

Normal Systems. A normal septic system is a system whose construction and operation conforms to recommended procedures such as those suggested by the EPA design manual for on-site wastewater disposal systems (U. S. Environmental Protection Agency, 1980). Effluents from such systems infiltrate into the soil and enter the shallow saturated zone. Effluent nitrogen is converted to nitrate, and except for removal by plant uptake, the nitrogen is transported to the stream by groundwater discharge. Conversely, phosphates in the effluent are adsorbed and retained by the soil and hence normal systems provide no phosphorus loads to streamflow. The nitrogen load to groundwater from normal systems in month m (kg) is

$$SL_{1m} = 0.001 \; a_{1m} \, d_m \, (e - u_m) \qquad \text{(A-36)}$$

in which e = per capita daily nutrient load in septic tank effluent (g/day) and u_m = per capita daily nutrient uptake by plants in month m (g/day).

Normal systems are generally some distance from streams and their effluent mixes with other groundwater. Monthly nutrient loads are thus proportional to groundwater discharge to the stream. The portion of the annual load delivered in month m is equivalent to the portion of annual groundwater discharge which occurs in that month. Thus the load in month m of any year is

$$DS_{1m} = \frac{GR_m \sum_{m=1}^{12} SL_{1m}}{\sum_{m=1}^{12} GR_m} \qquad \text{(A-37)}$$

where GR_m = total groundwater discharge to streamflow in month m (cm), obtained by summing the daily values G_t for the month. Equation A-37 applies only for nitrogen. In the case of phosphorus, $DS_{1m} = 0$.

Short-Circuited Systems. These systems are located close enough to surface waters (< 15 m) so that negligible adsorption of phosphorus takes place. The only nutrient removal mechanism is plant uptake, and the watershed load for both nitrogen and phosphorus is

$$DS_{2m} = 0.001\ a_{2m}\ d_m\ (e - u_m) \qquad \text{(A-38)}$$

Ponded Systems. These systems exhibit hydraulic failure of the tank's absorption field and resulting surfacing of the effluent. Unless the surfaced effluent freezes, ponding systems deliver their nutrient loads to surface waters in the same month that they are generated through overland flow. If the temperature is below freezing, the surfacing effluent is assumed to freeze in a thin layer at the ground surface. The accumulated frozen effluent melts when the snowpack disappears and the temperature is above freezing. The monthly nutrient load is

$$DS_{3m} = 0.001 \sum_{t=1}^{d_m} PN_t \qquad \text{(A-39)}$$

where PN_t = watershed nutrient load in runoff from ponded systems on day t (g). Nutrient accumulation under freezing conditions is

$$FN_{t+1} = \begin{cases} FN_t + a_{3m}\ e\ , & SN_t > 0 \text{ or } T_t \leq 0 \\ 0\ , & \text{otherwise} \end{cases} \qquad \text{(A-40)}$$

where FN_t = frozen nutrient accumulation in ponded systems at the beginning of day t (g). The runoff load is thus

$$PN_t = \begin{cases} a_{3m}\ e + FN_t - u_m\ , & SN_t = 0 \text{ and } T_t > 0 \\ 0\ , & \text{otherwise} \end{cases} \qquad \text{(A-41)}$$

Direct Discharge Systems. These illegal systems discharge septic tank effluent directly into surface waters. Thus,

$$DS_{4m} = 0.001\ a_{4m}\ d_m\ e \qquad \text{(A-42)}$$

APPENDIX B: DATA SOURCES & PARAMETER ESTIMATION

Four types of information must be assembled for GWLF model runs. Land use data consists of the areas of the various rural and urban runoff sources. Required weather data are daily temperature (°C) and precipitation (cm) records for the simulation period. Transport parameters are the necessary hydrologic, erosion and sediment data and nutrient parameters are the various nitrogen and phosphorus data required for loading calculations. This appendix discusses general procedures for estimation of these parameters. Examples of parameter estimation are provided in Appendix C.

Land Use Data

Runoff source areas are identified from land use maps, soil surveys and aerial or satellite photography (Haith & Tubbs, 1981; Delwiche & Haith, 1983). In principle, each combination of soil, surface cover and management must be designated. For example, each corn field in the watershed can be considered a source area, and its area determined and estimates made for runoff curve number and soil erodibility and topographic, cover and supporting practice factors. In practice, these fields can often be aggregated, as in Appendix C into one "corn" source area with area-weighted parameters. Each urban land use is broken down into impervious and pervious areas. The former are solid surfaces such as streets, driveways, parking lots and roofs.

Weather Data

Daily precipitation and temperature data are obtained from meteorological records and assembled in the data file **WEATHER.DAT**. An example of this file is given in Appendix D. Weather data must be organized in "weather years" which are consistent with model assumptions. Both the groundwater and sediment portions of GWLF require that simulated years begin at a time when soil moisture conditions are known and runoff events have "flushed" the watershed of the previous year's accumulated sediment. In the eastern U.S. this generally corresponds to early spring and hence in such locations an April - March weather year is appropriate.

Transport Parameters

A sample set of hydrologic, erosion and sediment parameters required for the data file **TRANSPRT.DAT** is given in Appendix D.

Runoff Curve Numbers. Runoff curve numbers for rural and urban land uses have been assembled in the U.S. Soil Conservation Service's Technical Release No. 55, 2nd edition (Soil Conservation Service, 1986). These curve numbers are based on the soil hydrologic groups given in Table B-1. Curve numbers for average antecedent moisture conditions ($CN2_k$) are listed in Tables B-2 through B-5. Barnyard curve numbers are given by Overcash & Phillips (1978) as $CN2_k$ = 90, 98 and 100 for earthen areas, concrete pads and roof areas draining into the barnyard, respectively.

Evapotranspiration Cover Coefficients. Estimation of evapotranspiration cover coefficients for watershed studies is problematic. Cover coefficients may be determined from published seasonal values such as those given in Tables B-6 and B-7. However, their use often requires estimates of crop development (planting dates, time to maturity, etc.) which may not be available. Moreover, a single set of consistent values is seldom available for all of a watershed's land uses.

Soil Hydrologic Group	Description
A	Low runoff potential and high infiltration rates even when thoroughly wetted. Chiefly deep, well to excessively drained sands or gravels. High rate of water transmission (> 0.75 cm/hr).
B	Moderate infiltration rates when thoroughly wetted. Chiefly moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. Moderate rate of water transmission (0.40-0.75 cm/hr).
C	Low infiltration rates when thoroughly wetted. Chiefly soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. Low rate of water transmission (0.15-0.40 cm/hr).
D	High runoff potential. Very low infiltration rates when thoroughly wetted. Chiefly clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, or shallow soils over nearly impervious material. Very low rate of water transmission (0-0.15 cm/hr).

Disturbed Soils (Major altering of soil profile by construction, development):

A	Sand, loamy sand, sandy loam.
B	Silt loam, loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay, clay.

Table B-1. Descriptions of Soil Hydrologic Groups (Soil Conservation Service, 1986)

A simplified procedure can be developed, however, based on a few general observations:

1. Cover coefficients should in principle vary between 0 and 1.

2. Cover coefficients will approach their maximum value when plants have developed full foliage.

3. Because evapotranspiration measures both transpiration and evaporation of soil water, the lower limit for cover coefficients will be greater than zero. This lower limit essentially represents a situation without any plant cover.

4. The protection of soil by impervious surfaces prevents evapotranspiration.

The cover coefficients given for annual crops in Table B-6 fall to approximately 0.3 before planting and after harvest. Similarly, cover coefficients for forests reach minimum values of 0.2 to 0.3 when leaf area indices approach zero. This suggests that monthly cover coefficients for can be given the value 0.3 when foliage is absent and 1.0 otherwise. Perennial crops, such as grass, hay, meadow, and pasture, crops grown in flooded soil, such as rice, and conifers can be given a cover coefficient of 1.0 year round.

Land Use/Cover		Hydrologic Condition	Soil Hydrologic Group A	B	C	D
Fallow	Bare Soil	-	77	86	91	94
Crop residue cover (CR)		Poor[a/]	76	85	90	93
		Good	74	83	88	90
Row Crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small Grains	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

[a/] Hydrologic condition is based on a combination of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of close-seeded legumes in rotations, (d) percent of residue cover on the land surface (good $ 20%), and (e) degree of surface roughness.

Table B-2. Runoff Curve Numbers (Antecedent Moisture Condition II) for Cultivated Agricultural Land (Soil Conservation Service, 1986).

Land Use/Cover	Hydrologic Condition	Soil Hydrologic Group A	B	C	D
Pasture, grassland or range - continuous forage for grazing	Poor[a/]	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow - continuous grass, protected from grazing, generally mowed for hay	-	30	58	71	78
Brush - brush/weeds/grass mixture with brush the major element	Poor[b/]	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods/grass combination (orchard or tree farm)[c/]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods	Poor[/d]	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads - buildings, lanes, driveways and surrounding lots	-	59	74	82	86

[a/] Poor: < 50% ground cover or heavily grazed with no mulch; Fair: 50 to 75% ground cover and not heavily grazed; Good: > 75% ground cover and lightly or only occasionally grazed.

[b/] Poor: < 50% ground cover; Fair: 50 to 75% ground cover; Good: > 75% ground cover.

[c/] Estimated as 50% woods, 50% pasture.

[d/] Poor: forest litter, small trees and brush are destroyed by heavy grazing or regular burning; Fair: woods are grazed but not burned and some forest litter covers the soil; Good: Woods are protected from grazing and litter and brush adequately cover the soil.

Table B-3. Runoff Curve Numbers (Antecedent Moisture Condition II) for other Rural Land (Soil Conservation Service, 1986).

Land Use/Cover	Hydrologic Condition	Soil Hydrologic Group A	B	C	D
Herbaceous - grass, weeds & low-growing brush; brush the minor component	Poor[a/]	-	80	87	93
	Fair	-	71	81	89
	Good	-	62	74	85
Oak/aspen - oak brush, aspen, mountain mahogany, bitter brush, maple and other brush	Poor	-	66	74	79
	Fair	-	48	57	63
	Good	-	30	41	48
Pinyon/juniper - pinyon, juniper or both; grass understory	Poor	-	75	85	89
	Fair	-	58	73	80
	Good	-	41	61	71
Sagebrush with grass understory	Poor	-	67	80	85
	Fair	-	51	63	70
	Good	-	35	47	55
Desert scrub - saltbush, greasewood, creosotebrush, blackbrush, bursage, palo verde, mesquite and cactus	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

[a/] Poor: < 30% ground cover (litter, grass and brush overstory); Fair: 30 to 70% ground cover; Good: > 70% ground cover.

Table B-4. Runoff Curve Numbers (Antecedent Moisture Condition II) for Arid and Semiarid Rangelands (Soil Conservation Service, 1986).

Land Use	Soil Hydrologic Group A	B	C	D
Open space (lawns, parks, golf courses, cemeteries, etc.):				
Poor condition (grass cover < 50%)	68	79	86	89
Fair condition (grass cover 50-75%)	49	69	79	84
Good condition (grass cover > 75%)	39	61	74	80
Impervious areas:				
Paved parking lots, roofs, driveways, etc.)	98	98	98	98
Streets and roads:				
Paved with curbs & storm sewers	98	98	98	98
Paved with open ditches	83	89	92	93
Gravel	76	85	89	91
Dirt	72	82	87	89
Western desert urban areas:				
Natural desert landscaping (pervious areas, only)	63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1-2 in sand or gravel mulch and basin borders)	96	96	96	96

Table B-5. Runoff Curve Numbers (Antecedent Moisture Condition II) for Urban Areas (Soil Conservation Service, 1986).

	% of Growing Season										
Crop	0	10	20	30	40	50	60	70	80	90	100

Field corn	0.45	0.51	0.58	0.66	0.75	0.85	0.96	1.08	1.20	1.08	0.70
Grain sorghum	0.30	0.40	0.65	0.90	1.10	1.20	1.10	0.95	0.80	0.65	0.50
Winter wheat	1.08	1.19	1.29	1.35	1.40	1.38	1.36	1.23	1.10	0.75	0.40
Cotton	0.40	0.45	0.56	0.76	1.00	1.14	1.19	1.11	0.83	0.58	0.40
Sugar beets	0.30	0.35	0.41	0.56	0.73	0.90	1.08	1.26	1.44	1.30	1.10
Cantaloupe	0.30	0.30	0.32	0.35	0.46	0.70	1.05	1.22	1.13	0.82	0.44
Potatoes	0.30	0.40	0.62	0.87	1.06	1.24	1.40	1.50	1.50	1.40	1.26
Papago peas	0.30	0.40	0.66	0.89	1.04	1.16	1.26	1.25	0.63	0.28	0.16
Beans	0.30	0.35	0.58	1.05	1.07	0.94	0.80	0.66	0.53	0.43	0.36
Rice	1.00	1.06	1.13	1.24	1.38	1.55	1.58	1.57	1.47	1.27	1.00

Table B-6. Evapotranspiration Cover Coefficients for Annual Crops - Measured as Ratio of Evapotranspiration to Lake Evaporation (Davis & Sorensen, 1969; cited in Novotny & Chesters, 1981).

	Alfalfa	Pasture	Grapes	Citrus Orchards		Deciduous Orchards	Sugarcane
Jan	0.83		1.16	-	0.58	-	0.65
Feb	0.90		1.23	-	0.53	-	0.50
Mar	0.96		1.19	0.15	0.65	-	0.80
Apr	1.02		1.09	0.50	0.74	0.60	1.17
May	1.08		0.95	0.80	0.73	0.80	1.21
June	1.14		0.83	0.70	0.70	0.90	1.22
July	1.20		0.79	0.45	0.81	0.90	1.23
Aug	1.25		0.80	-	0.96	0.80	1.24
Sept	1.22		0.91	-	1.08	0.50	1.26
Oct	1.18		0.91	-	1.03	0.20	1.27
Nov	1.12		0.83	-	0.82	0.20	1.28
Dec	0.86		0.69	-	0.65	-	0.80

Table B-7. Evapotranspiration Cover Coefficients for Perennial Crops - Measured as Ratio of Evapotranspiration to Lake Evaporation (Davis & Sorensen, 1969; cited in Novotny & Chesters, 1981).

In urban areas, ground cover is a mixture of trees and grass. It follows that cover factors for pervious areas are weighted averages of the perennial crop, hardwood, and softwood cover factors. It may be difficult to determine the relative fractions of urban areas with these covers. Since these covers would have different values only during dormant seasons, it is reasonable to assume a constant month value of 1.0 for urban pervious surfaces and zero for impervious surfaces.

These approximate cover coefficients are given in Table B-8. Table B-9 list mean monthly values of daylight hours (H_t) for use in Equation A-31.

Cover	Dormant Season	Growing Season
Annual crops (foliage only in growing season)	0.3	1.0
Perennial crops (year-round foliage: grass, pasture, meadow, etc.)	1.0	1.0

Saturated crops (rice)	1.0	1.0
Hardwood (deciduous) forests & orchards	0.3	1.0
Softwood (conifer) forests & orchards	1.0	1.0
Disturbed areas & bare soil (barn yards, fallow, logging trails, construction and mining)	0.3	0.3
Urban areas (I = impervious fraction)	1 - I	1 - I

Table B-8. Approximate Values for Evapotranspiration Cover Coefficients.

	Latitude North (E)						
	48	46	44	42	40	38	36
	(---------- hr/day ----------)						
Jan	8.7	8.9	9.2	9.3	9.5	9.7	9.9
Feb	10.0	10.2	10.3	10.4	10.5	10.6	10.7
Mar	11.7	11.7	11.7	11.7	11.8	11.8	11.8
Apr	13.4	13.3	13.2	13.1	13.0	13.0	12.9
May	14.9	14.7	14.5	14.3	14.1	14.0	13.8
Jun	15.7	15.4	15.2	15.0	14.7	14.5	14.3
Jul	15.3	15.0	14.8	14.6	14.4	14.3	14.1
Aug	14.0	13.8	13.7	13.6	13.6	13.4	13.3
Sep	12.3	12.3	12.3	12.3	12.2	12.2	12.2
Oct	10.6	10.7	10.8	10.9	11.0	11.0	11.1
Nov	9.1	9.3	9.5	9.7	9.8	10.0	10.1
Dec	8.3	8.5	8.8	9.0	9.2	9.4	9.6
	34	32	30	28	26	24	
Jan	10.0	10.2	10.3	10.5	10.6	10.7	
Feb	10.8	10.9	11.0	11.1	11.1	11.2	
Mar	11.8	11.8	11.8	11.8	11.8	11.9	
Apr	12.8	12.8	12.7	12.7	12.6	12.6	
May	13.7	13.6	13.5	13.4	13.2	13.1	
Jun	14.2	14.0	13.9	13.7	13.6	13.4	
Jul	14.0	13.8	13.7	13.5	13.4	13.3	
Aug	13.2	13.3	13.0	13.0	12.9	12.8	
Sep	12.2	12.2	12.2	12.1	12.1	12.1	
Oct	11.2	11.2	11.3	11.3	11.4	11.4	
Nov	10.2	10.4	10.5	10.6	10.7	10.9	
Dec	9.8	10.0	10.1	10.3	10.4	10.6	

Table B-9. Mean Daylight Hours (Mills et al., 1985).

Groundwater. The groundwater portion of GWLF requires estimates of available unsaturated zone available soil moisture capacity U^*, recession constant r and seepage constant s.

In principle, U^* is equivalent to a mean watershed maximum rooting depth multiplied by a mean volumetric soil available water capacity. The latter also requires determination of a mean unsaturated zone depth, and this is probably impractical for most watershed studies. A default value of 10 cm can be assumed for pervious areas, corresponding to a 100 cm rooting depth and a 0.1 cm/cm volumetric available water

capacity. These values appear typical for a wide range of plants (Jensen et al., 1989; U.S. Forest Service, 1980) and soils (Rawls et al., 1982).

Estimates of the recession constant r can be estimated from streamflow records by standard hydrograph separation techniques (Chow, 1964). During a period of hydrograph recession, the rate of change in shallow saturated zone water S(t) (cm) is given by the linear reservoir relationship

$$\frac{dS}{dt} = -r S \qquad \text{(B-1)}$$

or,

$$S(t) = S(0)\, e^{-rt} \qquad \text{(B-2)}$$

where S(0) is the shallow saturated zone moisture at t = 0. Groundwater discharge to the stream G(t) (cm) at time t is

$$G(t) = r\, S(t) = r\, S(0)\, e^{-rt} \qquad \text{(B-3)}$$

During periods of streamflow recession, it is assumed that runoff is negligible, and hence streamflow F(t) (cm) consists of groundwater discharge given by Equation B-3; i.e., F(t) = G(t). A recession constant can be estimated from two streamflows $F(t_1)$, $F(t_2)$ measured on days t_1 and t_2 ($t_2 > t_1$) during the hydrograph recession. The ratio $F(t_1)/F(t_2)$ is

$$\frac{F(t_1)}{F(t_2)} = \frac{r\, S(0)\, e^{-rt_1}}{r\, S(0)\, e^{-rt_2}} = e^{r(t_2 - t_1)} \qquad \text{(B-4)}$$

The recession constant is thus given by

$$r = \frac{\ln\,[F(t_1)/F(t_2)]}{t_2 - t_1} \qquad \text{(B-5)}$$

Recession constants are measured for a number of hydrographs and an average value is used for the simulations. Typical values range from 0.01 to 0.2

No standard techniques are available for estimating the rate constant for deep seepage loss (s). The most conservative approach is to assume that s = 0 (all precipitation exits the watershed in evapotranspiration or streamflow). Otherwise the constant must be determined by calibration.

Erosion and Sediment. The factors K_k, $(LS)_k$, C_k and P_k for the Universal Soil Loss Equation must be specified as the product $K_k\,(LS)_k\,C_k\,P_k$ for each rural runoff source area. Values K_k, C_k and P_k are given for a range of soils and conditions in Tables B-10 - B-13. More complete sets of values are provided in Mills et al. (1985) and Wischmeier & Smith (1978). The $(LS)_k$ factor is calculated for each source area k as in Wischmeier & Smith (1978):

$$LS = (0.045x_k)^b\,(65.41 \sin^2 \theta_k + 4.56 \sin \theta_k + 0.065) \qquad \text{(B-6)}$$

$$\theta_k = \tan^{-1}(ps_k/100) \qquad \text{(B-7)}$$

in which x_k = slope length (m) and ps_k = per cent slope. The exponent in Equation B-6 is given by b = 0.5 for ps_k $ 5, b = 0.4 for $5 < ps_k < 3$, b = 0.3 for $3 \le ps_k \le 1$, and b = 0.2 for $ps_k < 1$ (Wischmeier & Smith, 1978).

The rainfall erosivity coefficient a_t for Equation A-12 can be estimated using methods developed by Selker et al. (1990). General values for the rainfall erosivity zones shown in Figure B-1 are given in Table B-14. Watershed sediment delivery ratios are most commonly obtained from the area-based relationship shown in

Figure B-2.

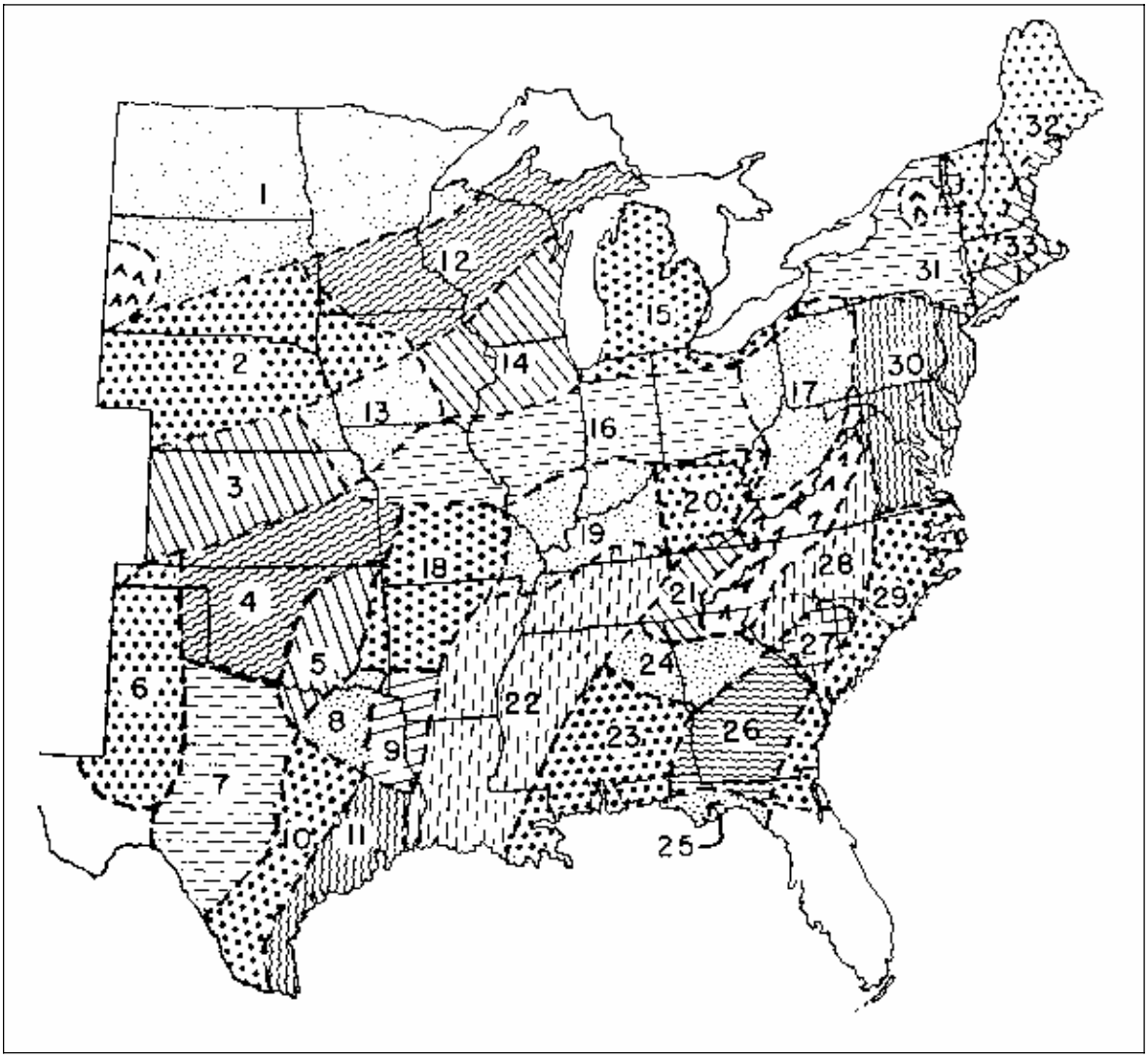

Figure B-1. Rainfall Erosivity Zones in Eastern U.S. (Wischmeier & Smith, 1978).

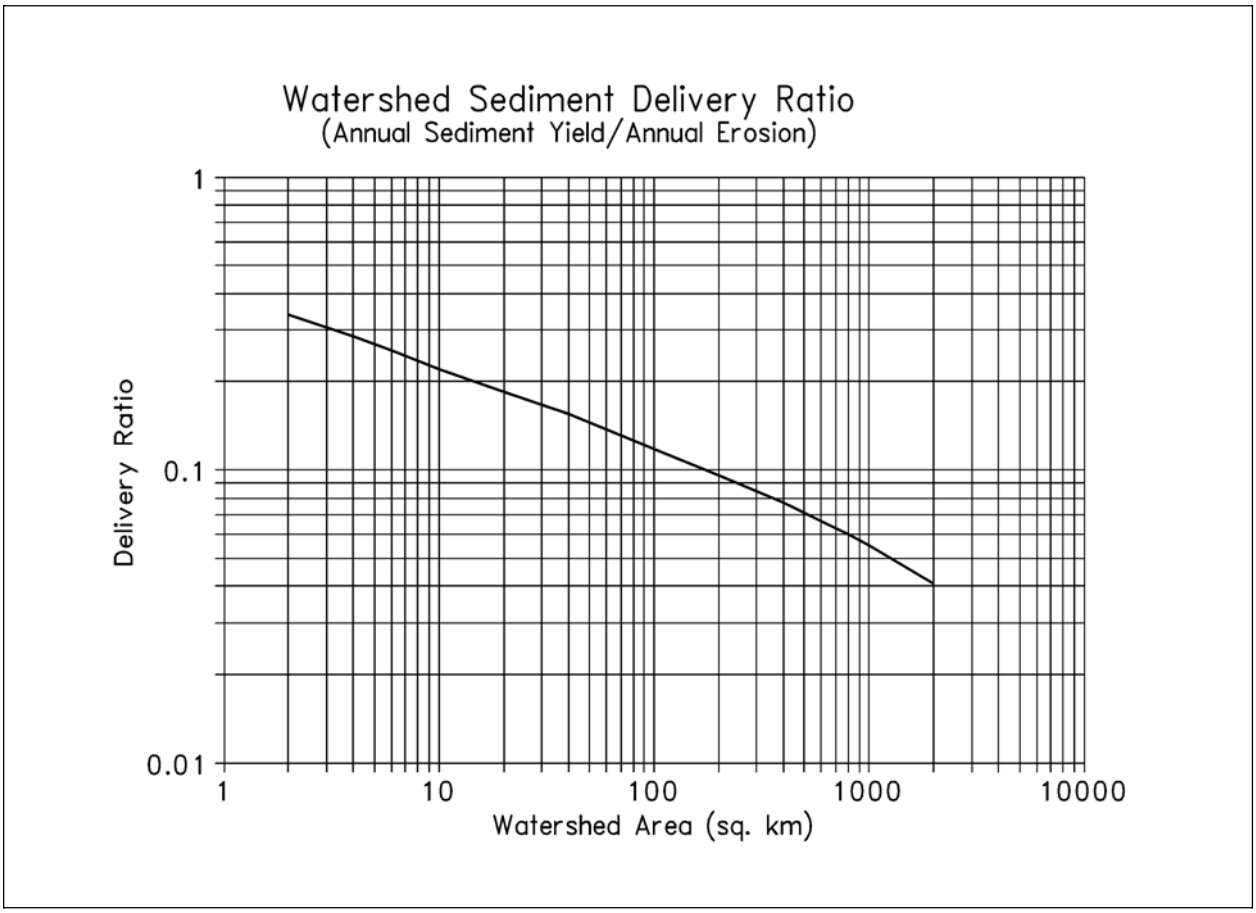

Figure B-2. Watershed Sediment Delivery Ratios (Vanoni, 1975).

	Organic Matter Content (%)		
Texture	<0.5	2	4
Sand	0.05	0.03	0.02
Fine sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.08
Loamy fine sand	0.24	0.20	0.16
Loamy very fine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Fine sandy loam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.33
Loam	0.38	0.34	0.29
Silt loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy clay loam	0.27	0.25	0.21
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay	-	0.13-0.29	-

Table B-10. Values of Soil Erodibility Factor (K) (Stewart et al., 1975).

	Crop, rotation & management[b/]	Productivity[a/] High	Moderate
	Continuous fallow, tilled up and down slope	1.00	1.00
	CORN		
1	C, RdR, fall TP, conv (1)	0.54	0.62
2	C, RdR, spring TP, conv (1)	0.50	0.59
3	C, RdL, fall TP, conv (1)	0.42	0.52
4	C, RdR, wc seeding, spring TP, conv (1)	0.40	0.49
5	C, RdL, standing, spring TP, conv (1)	0.38	0.48
6	C, fall shred stalks, spring TP, conv (1)	0.35	0.44
7	C(silage)-W(RdL,fall TP) (2)	0.31	0.35
8	C, RdL, fall chisel, spring disk, 40-30% re (1)	0.24	0.30
9	C(silage), W wc seeding, no-till pl in c-k W (1)	0.20	0.24
10	C(RdL)-W(RdL,spring TP) (2)	0.20	0.28
11	C, fall shred stalks, chisel pl, 40-30% re (1)	0.19	0.26
12	C-C-C-W-M, RdL, TP for C, disk for W (5)	0.17	0.23
13	C, RdL, strip till row zones, 55-40% re (1)	0.16	0.24
14	C-C-C-W-M-M, RdL, TP for C, disk for W (6)	0.14	0.20
15	C-C-W-M, RdL, TP for C, disk for W (4)	0.12	0.17
16	C, fall shred, no-till pl, 70-50% re (1)	0.11	0.18
17	C-C-W-M-M, RdL, TP for C, disk for W (5)	0.087	0.14
18	C-C-C-W-M, RdL, no-till pl 2nd & 3rd C (5)	0.076	0.13
19	C-C-W-M, RdL, no-till pl 2d C (4)	0.068	0.11
20	C, no-till pl in c-k wheat, 90-70% re (1)	0.062	0.14
21	C-C-C-W-M-M, no-till pl 2d & 3rd C (6)	0.061	0.11
22	C-W-M, RdL, TP for C, disk for W (3)	0.055	0.095
23	C-C-W-M-M, RdL, no-till pl 2d C (5)	0.051	0.094
24	C-W-M-M, RdL, TP for C, disk for W (4)	0.039	0.074
25	C-W-M-M-M, RdL, TP for C, disk for W (5)	0.032	0.061
26	C, no-till pl in c-k sod, 95-80% re (1)	0.017	0.053
	COTTON[/c]		
27	Cot, conv (western plains) (1)	0.42	0.49
28	Cot, conv (south) (1)	0.34	0.40
	MEADOW (HAY)		
29	Grass & legume mix	0.004	0.01
30	Alfalfa, lespedeza or sericia	0.020	-
31	Sweet clover	0.025	-
	SORGHUM, GRAIN (western plains)		
32	RdL, spring TP, conv (1)	0.43	0.53
33	No-till pl in shredded 70-50% re	0.11	0.18
	SOYBEANS[/c]		
34	B, RdL, spring TP, conv (1)	0.48	0.54
35	C-B, TP annually, conv (2)	0.43	0.51
36	B, no-till pl	0.22	0.28
37	C-B, no-till pl, fall shred C stalks (2)	0.18	0.22

Table B-11. CONTINUED

Crop, rotation & management[b/]	Productivity[a/] High	Moderate
WHEAT		
38 W-F, fall TP after W (2)	0.38	-
39 W-F, stubble mulch, 500 lb re (2)	0.32	-
40 W-F, stubble mulch, 1000 Lb re (2)	0.21	-
41 Spring W, RdL, Sept TP, conv (ND,SD) (1)	0.23	-
42 Winter W, RdL, Aug TP, conv (KS) (1)	0.19	-
43 Spring W, stubble mulch, 750 lb re (1)	0.15	-
44 Spring W, stubble mulch, 1250 lb re (1)	0.12	-
45 Winter W, stubble mulch, 750 lb re (1)	0.11	-
46 Winter W, stubble mulch, 1250 lb re (1)	0.10	-
47 W-M, conv (2)	0.054	-
48 W-M-M, conv (3)	0.026	-
49 W-M-M-M, conv (4)	0.021	-

[a/] High level exemplified by long-term yield averages greater than 75 bu/ac corn or 3 ton/ac hay or cotton management that regularly provides good stands and growth.

[b/] Numbers in parentheses indicate numbers of years in the rotation cycle. (1) indicates a continuous one-crop system.

[c/] Grain sorghum, soybeans or cotton may be substituted for corn in lines 12, 14, 15, 17-19, 21-25 to estimate values for sod-based rotations.

Abbreviations:

B	soybeans	F	fallow
C	corn	M	grass & legume hay
c-k	chemically killed	pl	plant
conv	conventional	W	wheat
cot	cotton	wc	winter cover

lb re	pounds of residue per acre remaining on surface after new crop seeding
% re	percentage of soil surface covered by residue mulch after new crop seeding
xx-yy% re	xx% cover for high productivity, yy% for moderate
RdR	residues (corn stover, straw, etc.) removed or burned
RdL	residues left on field (on surface or incorporated)
TP	turn plowed (upper 5 or more inches of soil inverted, covering residues

Table B-11. Generalized Values of Cover and Management Factor (C) for Field Crops East of the Rocky Mountains (Stewart et al., 1975).

Cover	Value
Permanent pasture, idle land, unmanaged woodland	
95-100% ground cover	
as grass	0.003
as weeds	0.01
80% ground cover	
as grass	0.01
as weeds	0.04
60% ground cover	
as grass	0.04
as weeds	0.09
Managed woodland	
75-100% tree canopy	0.001
40-75% tree canopy	0.002-0.004
20-40% tree canopy	0.003-0.01

Table B-12. Values of Cover and Management Factor (C) for Pasture and Woodland (Novotny & Chesters, 1981).

Practice Slope(%):	1.1-2	2.1-7	7.1-12	12.1-18	18.1-24
No support practice	1.00	1.00	1.00	1.00	1.00
Contouring	0.60	0.50	0.60	0.80	0.90
Contour strip cropping					
R-R-M-M[a/]	0.30	0.25	0.30	0.40	0.45
R-W-M-M	0.30	0.25	0.30	0.40	0.45
R-R-W-M	0.45	0.38	0.45	0.60	0.68
R-W	0.52	0.44	0.52	0.70	0.90
R-O	0.60	0.50	0.60	0.80	0.90
Contour listing or ridge planting	0.30	0.25	0.30	0.40	0.45
Contour terracing[b/]	0.6/%n	0.5/%n	0.6/%n	0.8/%n	0.9/%n

[a/] R = row crop, W = fall-seeded grain, M = meadow. The crops are grown in rotation and so arranged on the field that row crop strips are always separated by a meadow or winter-grain strip.

[b/] These factors estimate the amount of soil eroded to the terrace channels. To obtain off-field values, multiply by 0.2. n = number of approximately equal length intervals into which the field slope is divided by the terraces. Tillage operations must be parallel to the terraces.

Table B-13. Values of Supporting Practice Factor (P) (Stewart et al., 1975).

Zone[a/]	Location	Season[b/] Cool	Warm
1	Fargo ND	0.08	0.30
2	Sioux City IA	0.13	0.35
3	Goodland KS	0.07	0.15
4	Wichita KS	0.20	0.30
5	Tulsa OK	0.21	0.27
6	Amarillo TX	0.30	0.34
7	Abilene TX	0.26	0.34
8	Dallas TX	0.28	0.37
9	Shreveport LA	0.22	0.32
10	Austin TX	0.27	0.41
11	Houston TX	0.29	0.42
12	St. Paul MN	0.10	0.26
13	Lincoln NE	0.26	0.24
14	Dubuque IA	0.14	0.26
15	Grand Rapids MI	0.08	0.23
16	Indianapolis IN	0.12	0.30
17	Parkersburg WV	0.08	0.26
18	Springfield MO	0.17	0.23
19	Evansville IN	0.14	0.27
20	Lexington KY	0.11	0.28
21	Knoxville TN	0.10	0.28
22	Memphis TN	0.11	0.20
23	Mobile AL	0.15	0.19
24	Atlanta GA	0.15	0.34
25	Apalachacola FL	0.22	0.31
26	Macon GA	0.15	0.40
27	Columbia SC	0.08	0.25
28	Charlotte NC	0.12	0.33
29	Wilmington NC	0.16	0.28
30	Baltimore MD	0.12	0.30
31	Albany NY	0.06	0.25
32	Caribou ME	0.07	0.13
33	Hartford CN	0.11	0.22

[a/] Zones given in Figure B-1.

[b/] Cool season: Oct - Mar; Warm season: Apr - Sept.

Table B-14. Rainfall Erosivity Coefficients (a) for Erosivity Zones in Eastern U.S. (Selker et al., 1990).

Initial Conditions. Several initial conditions must be provided in the **TRANSPRT.DAT** file: initial unsaturated and shallow saturated zone soil moistures (U_1 and S_1), snowmelt water (SN_1) and antecedent rain + snowmelt for the five previous days. It is likely that these values will be uncertain in many applications. However, they will not affect model results for more than the first month or two of the simulation period. It is generally most practical to assign arbitrary initial values (U^* for U_1 and zero for the remaining variables) and to discard the first year of the simulation results.

Nutrient Parameters

A sample set of nutrient parameters required for the data file **NUTRIENT.DAT** is given in Appendix D.

Although the GWLF model will be most accurate when nutrient data are calibrated to local conditions, a set of default parameters has been developed to facilitate uncalibrated applications. Obviously these parameters, which are average values obtained from published water pollution monitoring studies, are only approximations of conditions in any watershed.

Rural and Groundwater Sources. Solid-phase nutrients in sediment from rural sources can be estimated as the average soil nutrient content multiplied by an enrichment ratio. Soil nutrient levels can be determined from soil samples, soil surveys or general maps such as those given in Figures B-3 and B-4. A value of 2.0 for the enrichment ratio falls within the mid-range of reported ratios and can be used in absence of more specific data (McElroy et al., 1976; Mills et al., 1985).

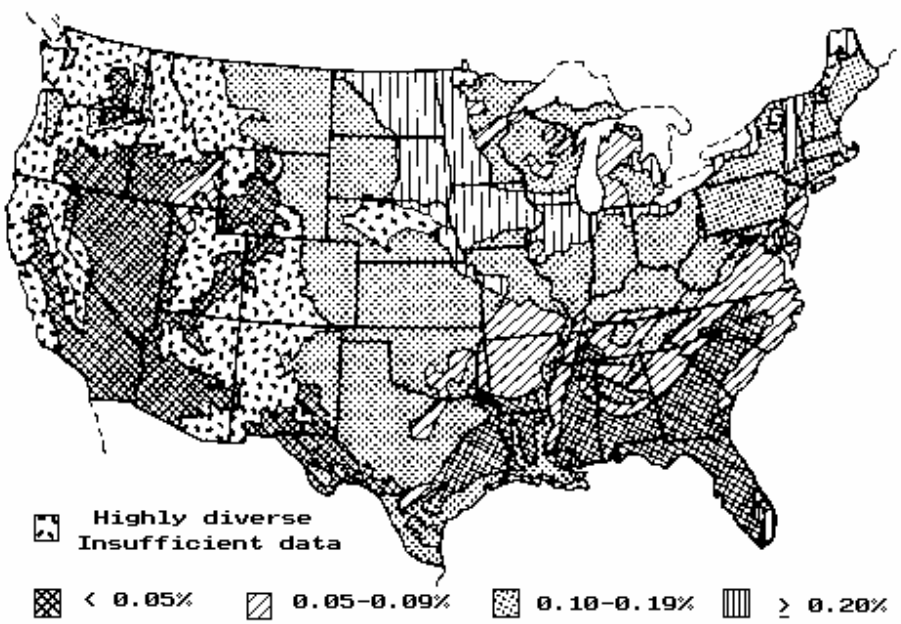

Figure B-3. Nitrogen in Surface 30 cm of Soils (Parker, *et al*., 1946; Mills, *et al*., 1985).

Default flow-weighted mean concentrations of dissolved nitrogen and phosphorus in agricultural runoff are given in Table B-15. The cropland and barnyard data are from multi-year storm runoff sampling studies in South Dakota (Dornbush et al., 1974) and Ohio (Edwards et al., 1972). The concentrations for snowmelt runoff from fields with manure on the soil surface are taken from a manual prepared by U. S. Department of Agriculture scientists (Gilbertson et al., 1979).

Default values for nutrient concentrations in groundwater discharge can be inferred from the U.S. Eutrophication Survey results (Omernik, 1977) given in Table B-16. These data are mean concentrations

computed from 12 monthly streamflow samples in watersheds free of point sources. Since such limited sampling is unlikely to capture nutrient fluxes from storm runoff, the streamflow concentrations can be assumed to represent groundwater discharges to streams.

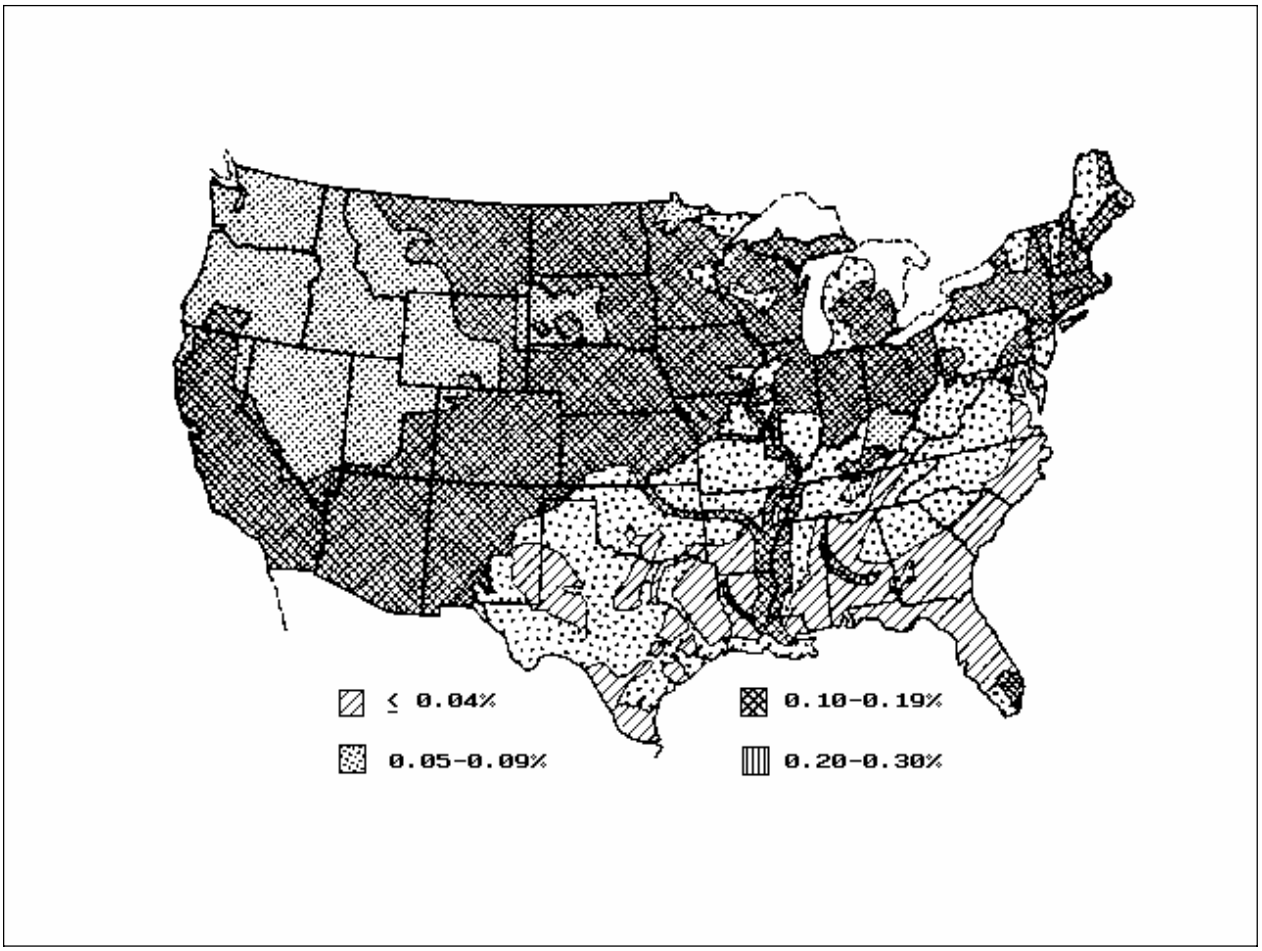

Figure B-4. P_2O_5 (44% phosphorus) in Surface 30 cm of Soils (Parker, *et al.*, 1946; Mills, *et al.*, 1985).

Dissolved nutrient data for forest runoff are essentially nonexistent. Runoff is a small component of streamflow from forest areas and studies of forest nutrient flux are based on streamflow rather than runoff sampling. Hence the only possible default option is the use of the streamflow concentrations from the "$ 90% Forest" category in Table B-16 as estimates of runoff concentrations.

Default values for urban nutrient accumulation rates are provided in Table B-17. These values were developed for Northern Virginia conditions and are probably suitable for smaller and relatively new urban areas. They would likely underestimate accumulations in older large cities.

Septic Systems. Representative values for septic system nutrient parameters are given in Table B-18. Per capita nutrient loads in septic tank effluent were estimated from typical flows and concentrations. The EPA Design Manual (U.S. Environmental Protection Agency, 1980) indicates 170 *l*/day as a representative wastewater flow from on-site wastewater disposal systems. Alhajjar et al. (1989) measured mean nitrogen and phosphorus concentrations in septic tank effluents of 73 and 14 mg/*l*, respectively. The latter concentration is based on use of phosphate detergents. When non-phosphate detergents are used, the concentration dropped to 7.9 mg/*l*. These concentrations were combined with the 170 *l*/day flow to produce the effluent nutrient loads given in Table B-18.

Nutrient uptake by plants (generally grasses) growing over the septic system adsorption field are frankly speculative. Brown & Thomas (1978) suggest that if the grass clippings are harvested, nutrients from a septic system effluent can support at least twice the normal yield of grass over the absorption field. Petrovic & Cornman (1982) suggest that retention of turf grass clippings can reduce required fertilizer applications by 25%, thus implying nutrient losses of 75% of uptakes. It appears that a conservative estimate of nutrient losses from plant cover would be 75% of the nutrient uptake of from a normal annual yield of grass. Reed et al. (1988) reported that Kentucky bluegrass annually utilizes 200-270 kg/ha nitrogen and 45 kg/ha phosphorus. Using the 200 kg/ha nitrogen value, and assuming a six month growing season and a 20 m^2 per capita absorption area, an estimated 1.6 g/day nitrogen and 0.4 g/day phosphorus are lost by plant uptake on a per capita basis during the growing season. The 20 m^2 adsorption area was based on per bedroom adsorption area recommendations by the U.S. Public Health Service for a soil with average percolation rate (.12 min/cm) (U.S. Public Health Service, 1967).

The remaining information needed are the numbers of people served by the four different types of septic systems (normal, short-circuited, ponded and direct discharge). A starting point for this data will generally be estimates of the unsewered population in the watershed. Local public health officials may be able to estimate the fractions of systems within the area which are of each type. However, the most direct way of generating the information is through a septic systems survey.

Land Use	Nitrogen	Phosphorus
	(----------(mg/*l*)----------	)
Fallow[a/]	2.6	0.10
Corn[a/]	2.9	0.26
Small grains[a/]	1.8	0.30
Hay[a/]	2.8	0.15
Pasture[a/]	3.0	0.25
Barn yards[b/]	29.3	5.10
Snowmelt runoff from manured land[c/]:		
Corn	12.2	1.90
Small grains	25.0	5.00
Hay	36.0	8.70

[a/]Dornbush et al. (1974)

[b/]Edwards et al. (1972)

[c/]Gilbertson et al. (1979); manure left on soil surface.

Table B-15. Dissolved Nutrients in Agricultural Runoff.

Watershed Type	Concentrations (mg/*l*) Eastern U.S.	Central U.S.	Western U.S.
Nitrogen[a/]:			
$ 90% Forest	0.19	0.06	0.07
$ 75% Forest	0.23	0.10	0.07
$ 50% Forest	0.34	0.25	0.18
$ 50% Agriculture	1.08	0.65	0.83
$ 75% Agriculture	1.82	0.80	1.70
$ 90% Agriculture	5.04	0.77	0.71
Phosphorus[b/]:			
$ 90% Forest	0.006	0.009	0.012
$ 75% Forest	0.007	0.012	0.015
$ 50% Forest	0.013	0.015	0.015
$ 50% Agriculture	0.029	0.055	0.083
$ 75% Agriculture	0.052	0.067	0.069
$ 90% Agriculture	0.067	0.085	0.104

[a/]Measured as total inorganic nitrogen.

[b/]Measured as total orthophosphorus

Table B-16. Mean Dissolved Nutrients Measured in Streamflow by the National Eutrophication Survey (Omernik, 1977).

Land Use	Sus-pended Solids	BOD	Total Nitrogen	Total Phosphorus
	(---------- kg/ha-day ----------)			
Impervious Surfaces				
Single family residential				
Low density (units/ha < 1.2)	2.5	0.15	0.045	0.0045
Medium density (units/ha ≥ 1.2)	6.2	0.22	0.090	0.0112
Townhouses & apartments	6.2	0.22	0.090	0.0112
High rise residential	3.9	0.71	0.056	0.0067
Institutional	2.8	0.39	0.056	0.0067
Industrial	2.8	0.71	0.101	0.0112
Suburban shopping center	2.8	0.71	0.056	0.0067
Central business district	2.8	0.85	0.101	0.0112
Pervious Surfaces				
Single family residential				
Low density (units/ha < 1.2)	1.3	0.08	0.012	0.0016
Medium density (units/ha ≥ 1.2)	1.1	0.15	0.022	0.0039
Townhouses & apartments	2.2	0.29	0.045	0.0078
High rise residential	0.8	0.08	0.012	0.0019
Institutional	0.8	0.08	0.012	0.0019
Industrial	0.8	0.08	0.012	0.0019
Suburban shopping center	0.8	0.08	0.012	0.0019
Central business district	0.8	0.08	0.012	0.0019

Table B-17. Contaminant Accumulation Rates for Northern Virginia Urban Areas (Kuo, et al., 1988).

Parameter		Value
e, per capita daily nutrient load in septic tank effluent (g/day)		
Nitrogen		12.0
Phosphorus		
Phosphate detergents use		2.5
Non-phosphate detergents use		1.5
u_m, per capita daily nutrient uptake by plants during month m (g/day)		
Nitrogen:	Growing season	1.6
	Non-growing season	0.0
Phosphorus:	Growing season	0.4
	Non-growing season	0.0

Table B-18. Default Parameter Values for Septic Systems.

APPENDIX C: VALIDATION STUDY

The GWLF model was tested by comparing model predictions with measured streamflow, sediment and nutrient loads from the West Branch Delaware River Basin during a three-year period (April, 1979 - March, 1982). The model was run using the four-year period April, 1978 - March, 1982 and first year results were ignored to eliminate effects of arbitrary initial conditions.

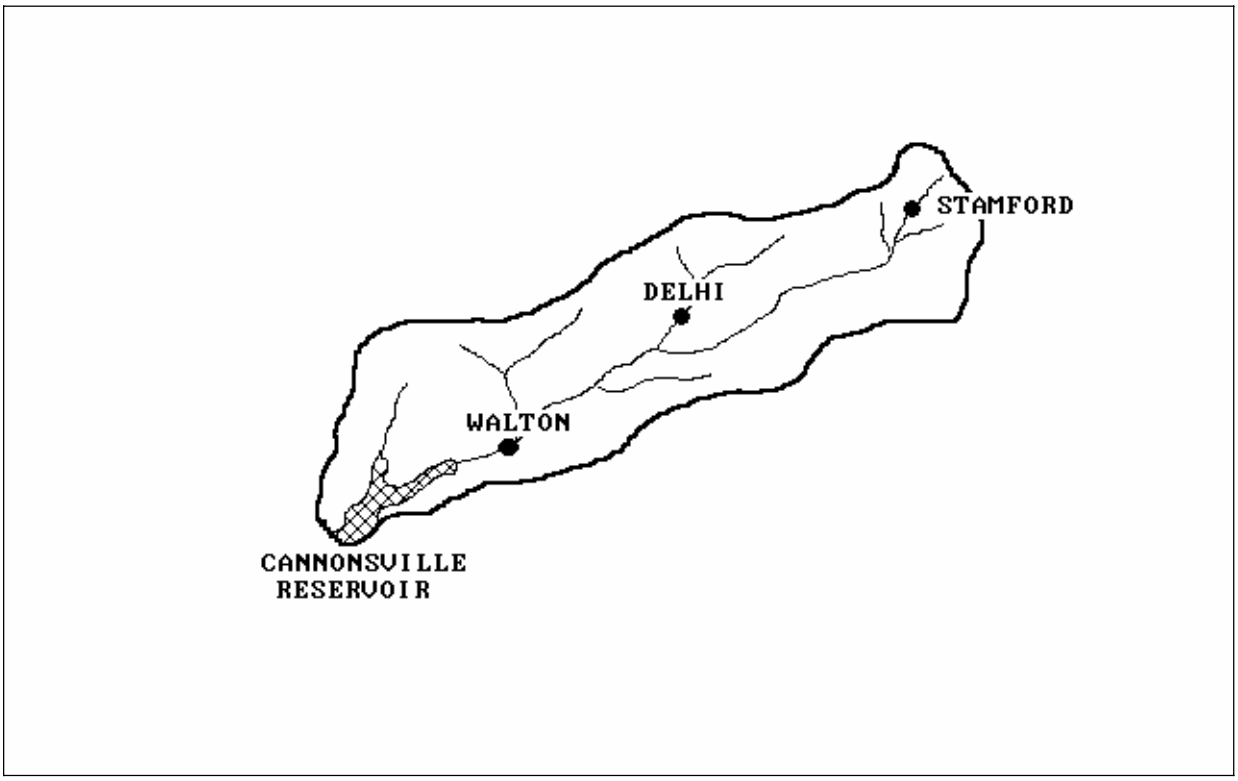

Figure C-1. West Branch Delaware River Watershed.

The 850 km^2 watershed, which is shown in Figure C-1, is in a dairy farming area in southeast New York which consists of 30% agricultural, 67% forested and 2% urban land uses. The river empties into Cannonsville Reservoir, which is a water supply source for the City of New York.

The model was run for the four-year period using daily precipitation and temperature records from the U.S. Environmental Data and Information service weather station at Walton, NY. To test the usefulness of the default parameters presented previously, no attempt was made to calibrate the model. No water quality data from the watershed were used to estimate parameters. All transport and chemical parameters were obtained by the general procedures described in the Appendix B.

Water Quality Observations

Continuous streamflow records were available from a U.S. Geological Survey gauging station at Walton, NY. Nutrient and sediment data were collected, analyzed and summarized by the N.Y. State Department of Environmental Conservation (Brown et al., 1985). During base flow conditions, samples were collected at approximately one-week intervals. During storm events, samples were collected at 2-4 hour intervals during hydrograph rise and at 6-8 hour intervals in the 2-3 days following flow peak. More frequent sampling was carried out during major snowmelt events. Total and dissolved phosphorus and sediment (suspended solids) data were collected from March, 1980 through March, 1982. The sampling periods for dissolved and total nitrogen were less extensive: March, 1980 - September, 1981 and January, 1981 - September, 1981, respectively.

Mass fluxes were computed by multiplying sediment or nutrient concentrations in a sample by "a volume of water determined by numerically integrating flow over the period of time from half of the preceding sampling time interval through half of the following sampling time interval" (Brown et al., 1985).

Watershed Data

Land Uses. The parameters needed for the agricultural and forest source areas were estimated from a land use sampling procedure similar to that described by Haith & Tubbs (1981). U.S. Geological Survey 1:24,000 topographic maps of the watershed were overlain by land use maps derived from 1971-1974 aerial photography. The maps were then overlain by a grid with 1-ha cells which was the basis of the sampling procedure. The land uses were divided into two general categories: forest and agriculture. Forest areas were subdivided into forest brushland and mature forest, and agricultural areas were subdivided into cropland, pasture and inactive agriculture. A random sample of 500 cells was taken, stratified over the two major land uses to provide more intense sampling of agricultural areas (390 samples vs. 110 for forest).

For each agricultural sample, the following were recorded: land use (cropland, pasture or inactive), soil type and length and gradient of the slope of the field in which the 1-ha sample was located. Crops were separated into two categories, corn or hay, since these two crops make up 99% of the county cropland.

Barnyard areas were identified from examination of conservation plans for 30 watershed dairy farm barnyards. Average earthen and roof drainage areas were 0.1306 ha and 0.0369 ha, respectively. These values were assumed representative of the watershed's 245 barnyards, producing total earth and roof drainage areas of 32 and 9 ha, respectively.

Urban land uses (low-density residential, commercial and industrial) were calculated from Delaware County tax maps. The impervious portions of these areas were 16%, 54% and 34% for residential, commercial and industrial land uses, respectively.

Runoff Curve Numbers. In forest areas, curve numbers were selected by soil type, assuming "good" hydrologic condition. Agricultural curve numbers were selected based on soil type, crop, management practice (e.g., strip cropping) and hydrologic condition. All pasture, hay and corn-hay rotations were assumed to be in good condition. Inactive agricultural areas were assumed to be the same as pasture. Corn grown in continuous rotation was considered in poor condition. Cropland breakdown into hay, continuous corn and rotated corn was determined from county data assembled by Soil Conservation Service (1976) and confirmed from Bureau of the Census (1980).

Rural source areas and curve numbers are listed in Table C-1. These areas were subsequently aggregated for the GWLF input files into the large areas given in Table C-2. Urban and barnyard areas are also given in Table C-2. Curve numbers are area-weighted averages for each source area.

Erosion and Sediment Parameters. Data required for estimation of soil loss parameters for logging sites were obtained from a forestry survey (Slavicek, 1980). Logging areas were located from a 1979 aerial survey. Transects of the logging roads at these sites were measured for soil loss parameters K_k, $(LS)_k$, C_k and P_k, and from this information an average K_k $(LS)_k$ C_k P_k value was calculated.

Soil erodibility factors (K_k) for agricultural land were obtained from the Soil Conservation Service. Cover factors (C) were selected Table B-10 based on several assumptions. For corn, the assumptions were that all residues are removed from the fields (91% of the corn in the county is used for silage (Bureau of the Census, 1980)), and all fields are spring turn-plowed and in the high productivity class (Knoblauch, 1976). A moderate productivity was assumed for hay (Knoblauch, 1976). Supporting practice factors of P = 1 were used for all source areas except strip crop corn. Area-weighted K_k $(LS)_k$ C_k P_k values are given in Table C-2. Coefficients for daily rainfall erosivity were selected from Table B-13 for Zone 31 (Figure B-1) . A watershed sediment delivery ratio of 0.065 was determined from Figure B-2.

Source Area	Soil Hydrologic Group	Area(ha)	Curve Number[a]
Continuous corn	B	414	81
	C	878	88
Rotated corn	B	620	78
	C	1316	85
Strip crop corn	C	202	82
Hay	B	2319	72
	C	10690	81
	D	76	85
Pasture	B	378	61
	C	4639	74
	D	76	80
Inactive agriculture	B	328	61
	C	3227	74
	D	126	80
Forest brushland	B	3118	48
	C	24693	65
	D	510	73
Mature forest	B	510	55
	C	27851	70

[a/] Antecedent moisture condition 2 ($CN2_k$)

Table C-1. Areas and Curve Numbers for Agricultural and Forest Runoff Sources for West Branch Delaware River Basin.

Land Use	Area(ha)	Curve Number[a/]	Erosion Product[b/]
Corn	3430	83.8	0.214
Hay	13085	79.4	0.012
Pasture	5093	73.1	0.016
Inactive Agriculture	3681	73.1	0.017
Barnyards	41	92.2	--
Forest	56682	66.5	--
Logging Trails	20	--	0.217
Residential (Low Density)			
Impervious	104	98.0	--
Pervious	546	74.0	--
Commercial			
Impervious	49	98.0	--
Pervious	41	74.0	--
Industrial			
Impervious	34	98.0	--
Pervious	67	74.0	--

[a/]Antecedent moisture condition 2 ($CN2_k$).

[b/]K_k $(LS)_k$ C_k P_k

Table C-2. Aggregated Runoff Source Areas in West Branch Delaware River Basin.

Land Use	Area(ha)	Cover Coefficient May-Oct	Cover Coefficient Nov-Apr
Corn	3430	1.0	0.3
Hay	13085	1.0	1.0
Pasture	5093	1.0	1.0
Inactive Agriculture	3681	1.0	1.0
Forest	56682	1.0	0.3
Logging	20	0.3	0.3
Barn Yards	41	0.3	0.3
Residential	650	0.84	0.84
Commercial	90	0.46	0.46
Industrial	101	0.66	0.66
Watershed Weighted Mean	82873	1.00	0.49

Table C-3. Evapotranspiration Cover Coefficients for West Branch Delaware River Basin.

Other Transport Parameters. For purpose of curve number and evapotranspiration cover coefficient selection, the growing season was assumed to correspond to months during which mean air temperature is at least 10EC (May-October). Cover coefficients were selected from Table B-8 and are listed in Table C-3 along with the area-weighted watershed values. An average groundwater recession constant of r = 0.1 was determined from analysis of 30 hydrograph recessions from the period 1971 - 1978. The seepage constant (s) was assumed to be zero, and the default value of 10 cm was used for unsaturated zone available soil moisture capacity U^*.

Nutrient Concentrations and Accumulation Rates. Using the soil nutrient values given in Figures B-3 and B-4 and the previously suggested enrichment ratio of 2.0 produced sediment nutrient concentrations of 3000 mg/kg nitrogen and 1300 mg/kg phosphorus. Rural dissolved nutrient concentrations were selected from Tables B-15 and B-16. Manure is spread on corn land in the watershed and hence the manured land concentrations were used for corn land runoff in snowmelt months (January - March). Inactive agricultural land was assumed to have nutrient concentrations midway between pasture and forest values. Urban nutrient accumulation rates from Table B-17 were used, with "Central business district" values used for commercial land.

Septic System Parameters. The default values for nutrient loads and plant uptake given in Table B-18 were used to model septic systems. The population served by each type of septic system was estimated by determining the percentage of the total number of systems falling within each class and multiplying by the year-round and seasonal (June - August) unsewered populations in the watershed. Table C-4 summarizes the population data for septic systems.

System Type	Percent of Total Population Served		
	Population	Year-round	Seasonal[a/]
Normal	86	7572	1835
Short-circuited	1	88	21
Ponded	10	881	213
Direct discharge	3	264	64

[a/] June - August

Table C-4. Estimated Populations Served by Different Septic System Types in West Branch Delaware River Basin.

The year-round unsewered population estimate for the watershed was based on 1980 Census data. These data were also used to determine the average number of people per household and the number of housing units used on a part-time basis. The seasonal population was then calculated by assuming the number of people per household was the same for seasonal and year-round residents.

A range of values for the current (1991) percentage of each type of system was supplied by the New York City Department of Environmental Protection (Personal Communication, J. Kane, New York City Department of Environmental Protection). A estimate of the percentages for the study period was determined by comparing the range of current values with the percentages from a survey of a neighboring area of Delaware County with construction practices and code enforcement similar to the West Branch Delaware River Watershed at the time of the study (Personal Communication, A. Lemley, Cornell University).

Point Sources. Point sources of nutrients are dissolved loads from five municipal and two industrial wastewater treatment plants. These inputs are 3800 kg/mo nitrogen and 825 kg/mo phosphorus (Brown & Rafferty, 1980; Dickerhoff, 1981).

Complete data inputs for the validation simulation run are given in Appendix D.

Validation Results

The GWLF streamflow predictions are compared with observations in Figure C-2. It is apparent that although the model mirrors the timing of observed streamflow, predictions for any particular month may have substantial errors. Accuracy is poorest for low flows, when predicted streamflows are essentially zero due to the very simple lumped parameter groundwater model.

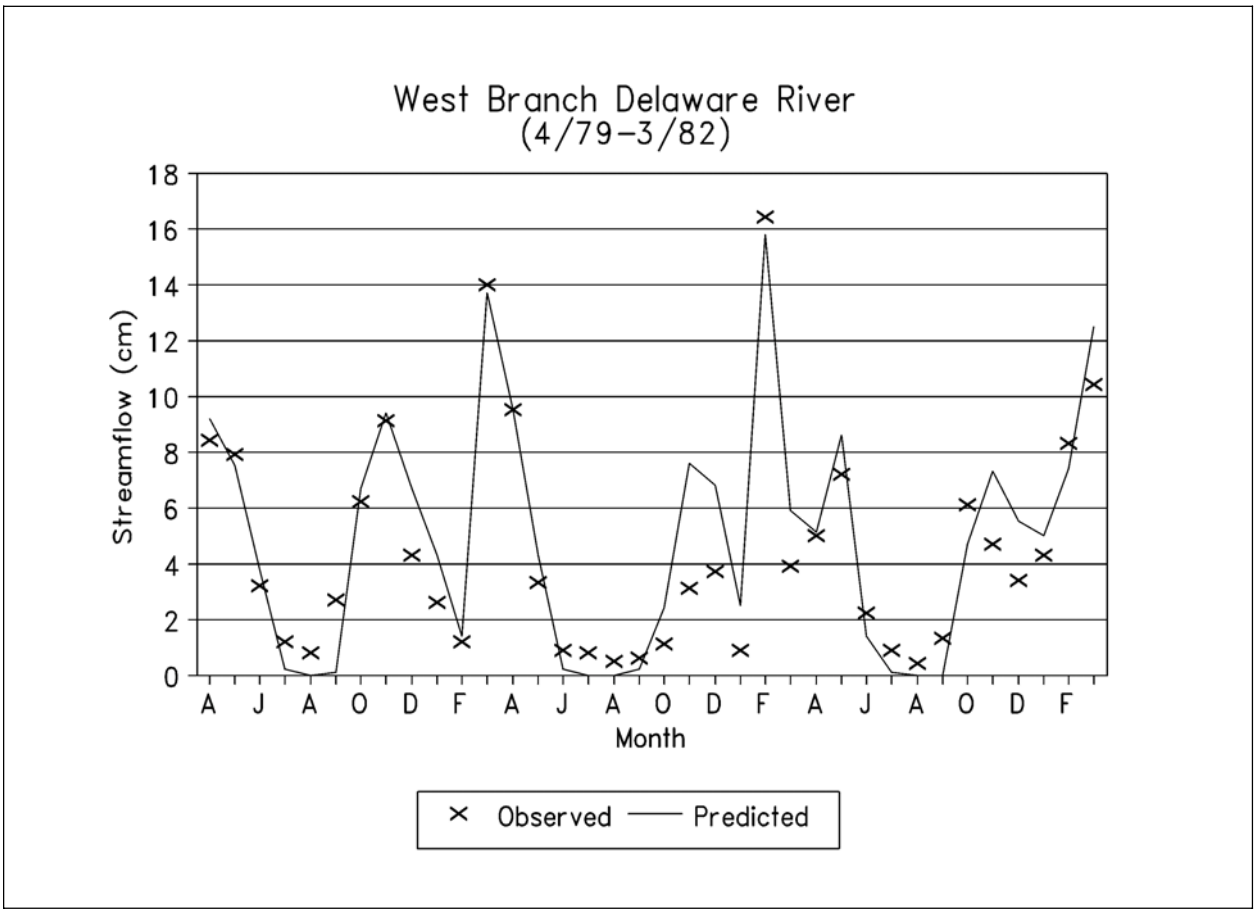

Figure C-2. Observed and Predicted Monthly Streamflow.

Model predictions and observations for total phosphorus and nitrogen are compared in Figures C-3 and C-4. Both sets of predictions match the variations in observations but under-predict the February, 1981 peak values by 35% and 26% for phosphorus and nitrogen, respectively. A quantitative summary of the comparisons of predictions with observations is given in Table C-5. Monthly mean predictions are within 10% of observation means for five of the six model outputs. The predicted mean total nitrogen flux is 73% of the observed mean. No coefficient of determination (R^2) is less than 0.88, indicating that the model explains at least 88% of the observed monthly variation in streamflow, sediment yield and nutrient fluxes.

Mean annual nutrient loads from each source for the four-year simulation period are provided in Table C-6. It is apparent that cropland runoff is a major source of streamflow nitrogen and phosphorus. Groundwater discharge is the largest source of nitrogen, accounting for 41% of dissolved and 36% of total nitrogen loads. Point sources constitute 11% of total nitrogen and 20% of total phosphorus. Septic tank drainage provides nearly as much nitrogen as point sources, but is a minor phosphorus source.

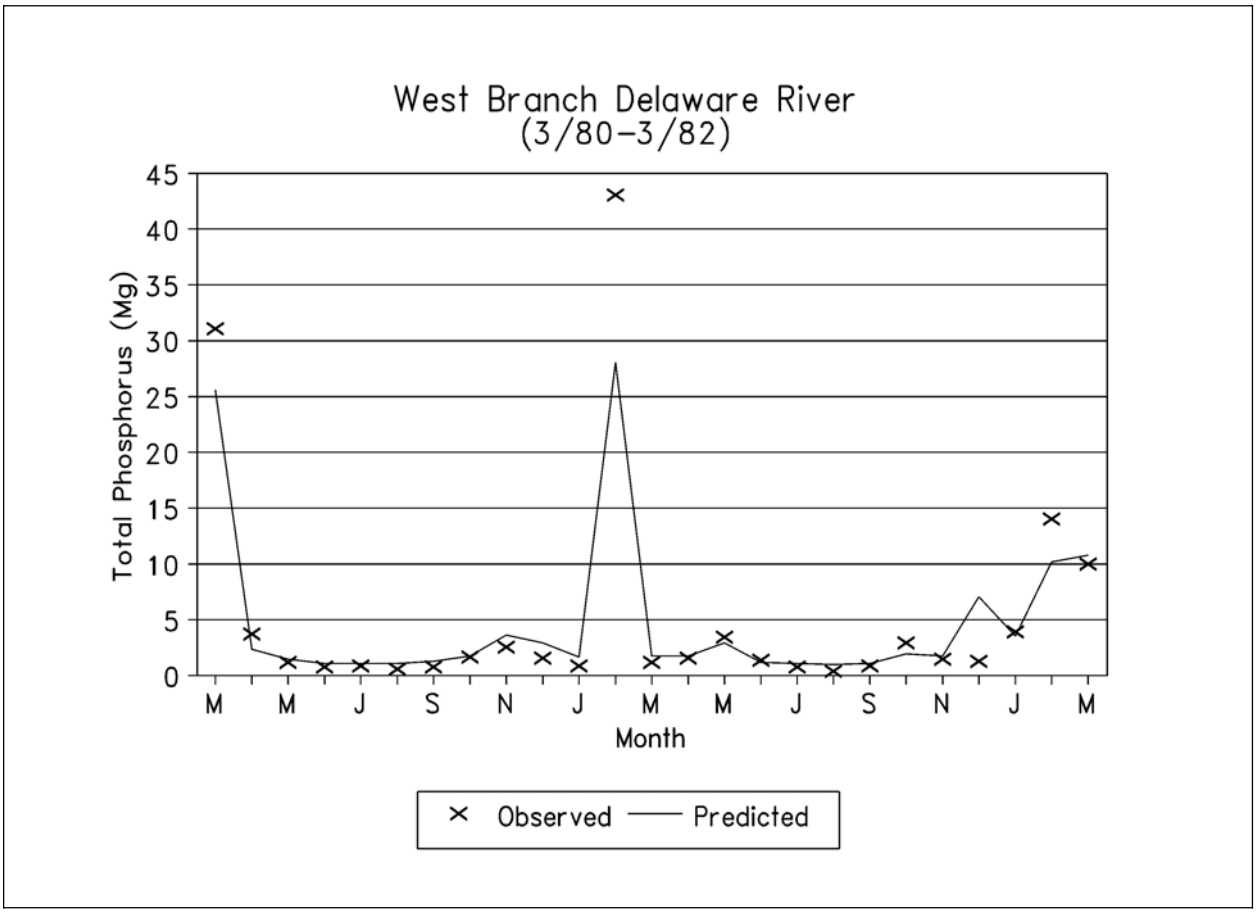

Figure C-3. Observed and Predicted Total Phosphorus in Streamflow.

Constituent	Validation Period	Monthly Means Predicted	Monthly Means Observed	Coefficient of Determination (R^2)
Streamflow (cm)	4/79-3/82	4.9	4.5	0.88
Sediment (1000 Mg)	3/80-3/82	1.6	1.7	0.95
Nitrogen (Mg)				
Dissolved	3/80-9/81	27.8	27.8	0.94
Total	1/81-9/81	32.9	44.8	0.99
Phosphorus (Mg)				
Dissolved	3/80-3/82	2.6	2.4	0.95
Total	3/80-3/82	4.7	5.2	0.95

Table C-5. Comparison of GWLF Predictions and Observations for the West Branch Delaware River Watershed.

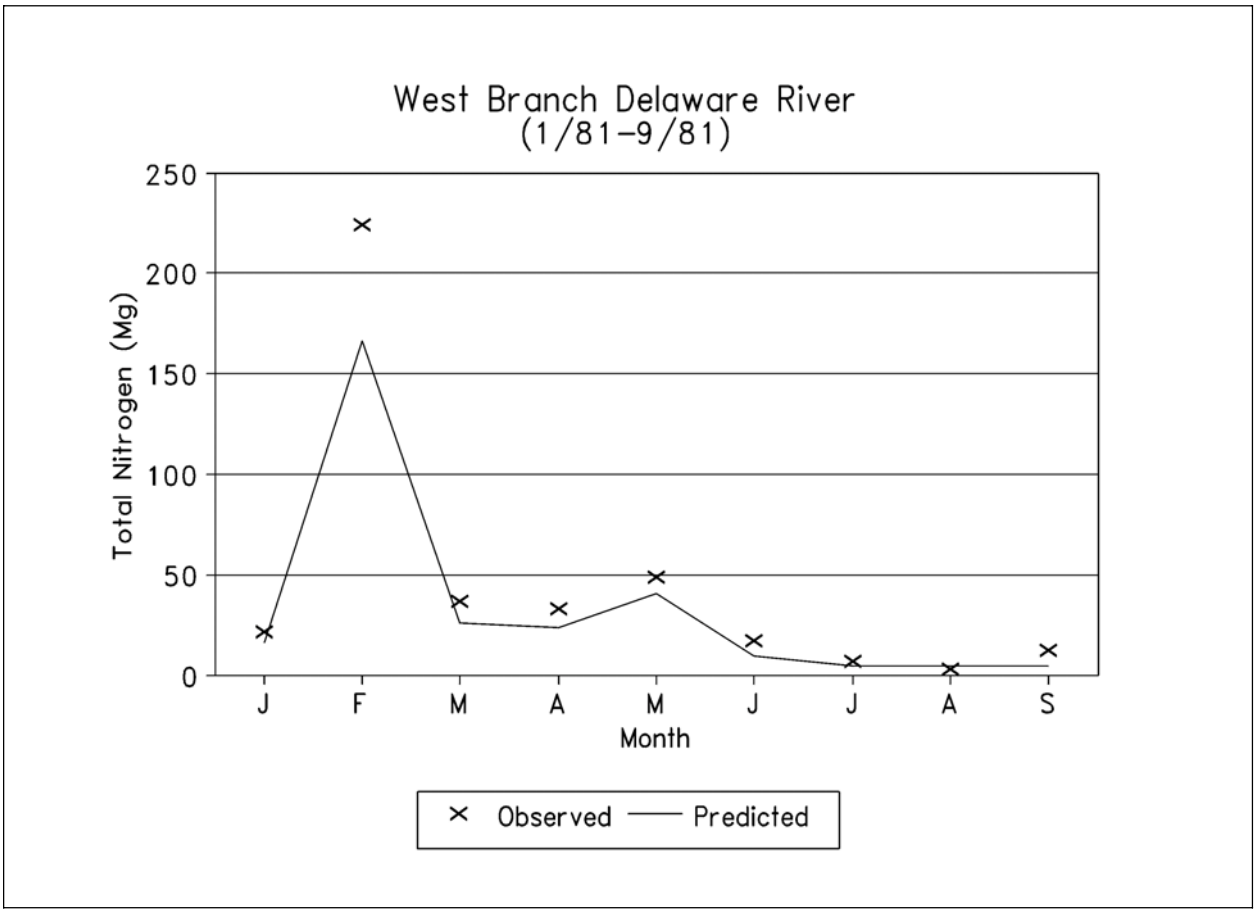

Figure C-4. Observed and Predicted Total Nitrogen in Streamflow.

Conclusions

The watershed loading functions model GWLF is based on simple runoff, sediment and groundwater relationships combined with empirical chemical parameters. The model is unique in its ability to estimate monthly nutrient fluxes in streamflow without calibration. Validation studies in a large New York watershed indicated that the model possesses a high degree of predictive accuracy. Although better results could perhaps be obtained by more detailed chemical simulation models, such models have substantially greater data and computational requirements and must be calibrated from water quality sampling data.

The GWLF model has several limitations. Peak monthly nutrient fluxes were underestimated by as much as 35%. Since nutrient chemistry is not modeled explicitly, the model cannot be used to estimate the effects of fertilizer management or urban storm water storage and treatment. The model has only been validated for a largely rural watershed in which agricultural runoff and groundwater discharge provided most of the nutrient load. Although the urban runoff component is based on well-known relationships which have been used previously in such models as STORM and SWMM, GWLF performance in more urban watersheds is uncertain.

Source	Nitrogen (Mg) Dissolved	Nitrogen (Mg) Total	Phosphorus (Mg) Dissolved	Phosphorus (Mg) Total
Runoff				
Corn	52.9	84.6	7.8	21.5
Hay	48.6	55.4	2.6	5.5
Pasture	13.2	16.7	1.1	2.6
Inactive Agriculture	5.1	7.8	0.4	1.6
Forest & logging	5.9	6.1	0.2	0.3
Barn yards	4.3	4.3	0.8	0.8
Urban	--	2.8	--	0.3
Groundwater, Point Sources, & Septic Systems				
Groundwater Discharge	149.6	149.6	5.7	5.7
Point sources	45.6	45.6	9.9	9.9
Septic systems	38.1	38.1	1.1	1.1
Watershed Total	363.4	411.1	29.6	48.3

Table C-6. Mean Annual Nutrient Loads Estimated from GWLF for the West Branch Delaware River Watershed: 4/78 - 3/82.

APPENDIX D: DATA AND OUTPUT LISTINGS FOR VALIDATION STUDY (EXAMPLE 1)

The first listing in this appendix is the set of sequential data input files **TRANSPRT.DAT**, **NUTRIENT.DAT** and **WEATHER.DAT** used in the validation study and Example 1. The first two files are constructed by selecting the appropriate option from GWLF menus. The weather file is arranged by months (April - March, in this application) with the first entry for each month being the number of days in the month, and subsequent entries being temperature (EC) and precipitation (cm) for each day. Only a partial listing of **WEATHER.DAT** is given. The next listings are the text files for the transport and nutrient data (**TRANSPRT.TXT** and **NUTRIENT.TXT**). The remaining listings are text files of the several program outputs (**SUMMARY.TXT** and **MONTHLY.TXT**).

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"LOGGING",20,0,.217
"BARN YARDS",41,92.2,0
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TRANSPRT.TXT

TRANSPRT DATA

LAND USE	AREA(ha)	CURVE NO	KLSCP
CORN	3430.	83.8	0.21400
HAY	13085.	79.4	0.01200
PASTURE	5093.	73.1	0.01600
INACTIVE	3681.	73.1	0.01700
FOREST	56682.	66.5	0.00000
LOGGING	20.	0.0	0.21700
BARN YARDS	41.	92.2	0.00000
RES-imperv	104.	98.0	0.00000
RES-perv	546.	74.0	0.00000
COMM-imperv	49.	98.0	0.00000
COMM-perv	41.	74.0	0.00000
INDUS-imperv	34.	98.0	0.00000
INDUS-perv	67.	74.0	0.00000

MONTH	ET CV()	DAY HRS	GROW. SEASON	EROS. COEF
APR	0.490	13.1	0	.25
MAY	1.000	14.3	1	.25
JUNE	1.000	15	1	.25
JULY	1.000	14.6	1	.25
AUG	1.000	13.6	1	.25
SEPT	1.000	12.3	1	.25
OCT	1.000	10.9	1	.06
NOV	0.490	9.7	0	.06
DEC	0.490	9	0	.06
JAN	0.490	9.3	0	.06
FEB	0.490	10.4	0	.06
MAR	0.490	11.7	0	.06

ANTECEDENT RAIN+MELT FOR DAY -1 TO DAY -5
0 0 0 0 0
INITIAL UNSATURATED STORAGE (cm) = 10
INITIAL SATURATED STORAGE (cm) = 0
RECESSION COEFFICIENT (1/day) = .1
SEEPAGE COEFFICIENT (1/day) = 0
INITIAL SNOW (cm water) = 0
SEDIMENT DELIVERY RATIO = 0.065
UNSAT AVAIL WATER CAPACITY (cm) = 10

NUTRIENT.TXT

NUTRIENT DATA

RURAL LAND USE	DIS.NITR IN RUNOFF(mg/l)	DIS.PHOS IN RUNOFF(mg/l)
CORN	2.9	.26
HAY	2.8	.15
PASTURE	3	.25
INACTIVE	1.6	.13
FOREST	.19	.006
LOGGING	0	0
BARN YARDS	29.3	5.1

NUTRIENT CONCENTRATIONS IN RUNOFF FROM MANURED AREAS

LAND USE	NITROGEN(mg/l)	PHOSPHORUS(mg/l)
CORN	12.2	1.9

URBAN LAND USE	NITR.BUILD-UP(kg/ha-day)	PHOS.BUILD-UP(kg/ha-day)
RES-imperv	.045	.0045
RES-perv	.012	.0016
COMM-imperv	.101	.0112
COMM-perv	.012	.0019
INDUS-imperv	.101	.0112
INDUS-perv	.012	.0019

MONTH	POINT SOURCE NITR.(kg)	POINT SOURCE PHOS.(kg)
APR	3800	825
MAY	3800	825
JUNE	3800	825
JULY	3800	825
AUG	3800	825
SEPT	3800	825
OCT	3800	825
NOV	3800	825
DEC	3800	825
JAN	3800	825
FEB	3800	825
MAR	3800	825

NITROGEN IN GROUNDWATER (mg/l): 0.340
PHOSPHORUS IN GROUNDWATER (mg/l): 0.013
NITROGEN IN SEDIMENT (mg/kg): 3000
PHOSPHORUS IN SEDIMENT (mg/kg): 1300

MANURE SPREADING JAN THRU MAR

SEPTIC SYSTEMS

	POPULATION SERVED			
MONTH	NORMAL SYSTEMS	PONDING SYSTEMS	SHORT-CIRCUIT SYSTEMS	DISCHARGE SYSTEMS
APR	7572	881	88	264
MAY	7572	881	88	264
JUNE	9407	1094	109	328
JULY	9407	1094	109	328
AUG	9407	1094	109	328
SEPT	7572	881	88	264
OCT	7572	881	88	264
NOV	7572	881	88	264
DEC	7572	881	88	264
JAN	7572	881	88	264
FEB	7572	881	88	264
MAR	7572	881	88	264

PER CAPITA TANK EFFLUENT NITROGEN (g/day) = 12
PER CAPITA TANK EFFLUENT PHOSPHORUS (g/day) = 2.5
PER CAPITA GROWING SEASON NITROGEN UPTAKE (g/day) = 1.6
PER CAPITA GROWING SEASON PHOSPHORUS UPTAKE (g/day) = .4

SUMMARY.TXT

W. Branch Delaware River 4/78-3/82 4 -year means

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	9.6	1.9	6.5	0.3	6.7
MAY	9.8	7.5	5.3	0.3	5.6
JUNE	8.3	9.7	1.8	0.0	1.8
JULY	8.6	11.3	0.1	0.0	0.2
AUG	10.4	9.2	1.2	0.9	2.0
SEPT	11.6	5.8	0.1	0.1	0.2
OCT	11.5	3.1	4.3	0.1	4.4
NOV	8.2	0.7	6.6	0.4	7.0
DEC	8.0	0.2	5.6	0.4	6.0
JAN	8.1	0.1	5.0	1.1	6.1
FEB	8.5	0.2	5.7	1.8	7.4
MAR	9.8	0.8	10.9	2.4	13.3
ANNUAL	112.3	50.7	53.1	7.8	60.8

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	29.2	0.0	30.7	31.1	1.9	2.0
MAY	35.7	0.2	26.9	27.7	1.8	2.1
JUNE	23.5	0.0	10.7	10.9	1.1	1.2
JULY	28.1	0.0	4.9	5.2	1.0	1.0
AUG	45.8	1.2	17.2	21.0	1.7	3.2
SEPT	45.0	0.0	6.2	6.6	1.1	1.1
OCT	11.2	0.1	21.3	21.8	1.6	1.7
NOV	6.3	0.9	33.3	36.1	2.1	3.2
DEC	0.8	1.1	28.9	32.3	1.9	3.3
JAN	0.4	1.1	41.4	45.0	3.6	5.1
FEB	0.5	4.4	55.4	68.8	4.9	10.6
MAR	3.7	6.0	86.6	104.8	7.0	14.8
ANNUAL	230.4	15.0	363.4	411.0	29.6	49.3

SOURCE	AREA	RUNOFF	EROSION	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(ha)	(cm)	(Mg/ha)	(Mg)			
CORN	3430.	18.03	47.43	52.92	84.64	7.78	21.52
HAY	13085.	13.27	2.66	48.60	55.39	2.60	5.54
PASTURE	5093.	8.65	3.55	13.22	16.74	1.10	2.63
INACTIVE	3681.	8.65	3.77	5.10	7.80	0.41	1.59
FOREST	56682.	5.47	0.00	5.89	5.89	0.19	0.19
LOGGING	20.	0.00	48.10	0.00	0.19	0.00	0.08
BARN YARDS	41.	36.11	0.00	4.34	4.34	0.76	0.76
RES-imperv	104.	74.11	0.00	0.00	0.86	0.00	0.09
RES-perv	546.	9.20	0.00	0.00	0.29	0.00	0.04
COMM-imperv	49.	74.11	0.00	0.00	0.91	0.00	0.10
COMM-perv	41.	9.20	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	74.11	0.00	0.00	0.63	0.00	0.07
INDUS-perv	67.	9.20	0.00	0.00	0.04	0.00	0.01
GROUNDWATER				149.58	149.58	5.72	5.72
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.13	38.13	1.11	1.11
TOTAL				363.37	411.05	29.57	49.34

MONTHLY.TXT

W. Branch Delaware River 4/78-3/82 YEAR 1

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	5.2	1.7	3.1	0.0	3.1
MAY	7.9	7.4	2.1	0.0	2.1
JUNE	10.5	9.7	1.8	0.0	1.8
JULY	10.8	10.9	0.3	0.0	0.4
AUG	17.0	10.4	4.6	3.4	8.1
SEPT	7.6	5.5	0.4	0.1	0.4
OCT	11.6	3.1	3.9	0.0	3.9
NOV	4.7	0.7	3.7	0.1	3.8
DEC	12.6	0.2	5.2	0.0	5.2
JAN	19.1	0.2	8.7	3.8	12.6
FEB	4.0	0.1	4.6	0.5	5.1
MAR	10.9	1.1	16.5	4.6	21.0
YEAR	121.9	50.9	54.9	12.6	67.4

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	8.3	0.0	14.9	15.0	1.3	1.3
MAY	13.3	0.0	11.3	11.5	1.1	1.2
JUNE	29.3	0.0	10.8	11.0	1.2	1.2
JULY	39.4	0.0	5.8	6.1	1.0	1.0
AUG	109.6	4.7	54.9	69.5	3.8	10.0
SEPT	35.4	0.0	6.8	6.9	1.1	1.1
OCT	10.3	0.0	17.8	18.1	1.4	1.4
NOV	1.4	0.0	18.2	18.4	1.4	1.4
DEC	1.8	0.0	22.1	22.3	1.5	1.5
JAN	0.0	3.8	100.4	112.2	8.9	13.9
FEB	0.0	0.2	32.7	33.5	2.8	3.1
MAR	5.0	7.7	139.6	163.2	11.2	21.3
YEAR	253.8	16.5	435.3	487.5	36.6	58.3

SOURCE	AREA	RUNOFF	EROSION	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(ha)	(cm)	(Mg/ha)	(Mg)			
CORN	3430.	24.70	52.26	81.18	116.13	12.18	27.33
HAY	13085.	19.27	2.93	70.59	78.06	3.78	7.02
PASTURE	5093.	13.86	3.91	21.18	25.06	1.76	3.45
INACTIVE	3681.	13.86	4.15	8.16	11.14	0.66	1.95
FOREST	56682.	9.81	0.00	10.57	10.57	0.33	0.33
LOGGING	20.	0.00	52.99	0.00	0.21	0.00	0.09
BARN YARDS	41.	44.22	0.00	5.31	5.31	0.92	0.92
RES-imperv	104.	82.95	0.00	0.00	0.86	0.00	0.09
RES-perv	546.	14.52	0.00	0.00	0.30	0.00	0.04
COMM-imperv	49.	82.95	0.00	0.00	0.90	0.00	0.10
COMM-perv	41.	14.52	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	82.95	0.00	0.00	0.63	0.00	0.07
INDUS-perv	67.	14.52	0.00	0.00	0.04	0.00	0.01
GROUNDWATER				154.61	154.61	5.91	5.91
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.10	38.10	1.11	1.11
TOTAL				435.30	487.55	36.58	58.33

W. Branch Delaware River 4/78-3/82 YEAR 2

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	11.0	1.8	8.5	0.7	9.2
MAY	15.3	7.6	6.8	0.6	7.5
JUNE	4.2	9.6	3.8	0.0	3.8
JULY	7.2	11.5	0.2	0.0	0.2
AUG	9.2	7.6	0.0	0.0	0.0
SEPT	14.3	6.0	0.0	0.1	0.1
OCT	11.2	3.4	6.7	0.1	6.7
NOV	13.5	0.9	8.6	0.8	9.4
DEC	5.0	0.4	6.7	0.0	6.7
JAN	3.7	0.2	4.3	0.0	4.3
FEB	4.0	0.1	1.4	0.0	1.4
MAR	14.8	0.7	10.7	3.0	13.7
YEAR	113.4	49.8	57.6	5.4	63.0

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	35.1	0.2	43.4	44.2	2.6	2.8
MAY	66.9	0.5	37.6	39.3	2.4	3.1
JUNE	11.2	0.0	17.2	17.3	1.3	1.4
JULY	15.4	0.0	4.9	5.1	0.9	1.0
AUG	19.1	0.0	4.4	4.6	0.9	1.0
SEPT	64.7	0.1	6.5	7.0	1.1	1.2
OCT	8.2	0.0	27.9	28.2	1.7	1.8
NOV	21.0	2.6	45.2	53.3	2.7	6.1
DEC	0.7	0.0	27.6	27.9	1.7	1.7
JAN	1.7	0.0	18.9	19.0	1.4	1.4
FEB	0.0	0.0	10.2	10.3	1.2	1.2
MAR	8.6	13.0	99.0	138.5	8.5	25.5
YEAR	252.7	16.4	342.6	394.6	26.4	48.1

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR (Mg)	TOT.NITR (Mg)	DIS.PHOS (Mg)	TOT.PHOS (Mg)
CORN	3430.	15.22	52.02	37.28	72.08	5.26	20.34
HAY	13085.	10.54	2.92	38.60	46.05	2.07	5.29
PASTURE	5093.	6.11	3.89	9.33	13.19	0.78	2.45
INACTIVE	3681.	6.11	4.13	3.60	6.56	0.29	1.58
FOREST	56682.	3.26	0.00	3.51	3.51	0.11	0.11
LOGGING	20.	0.00	52.75	0.00	0.21	0.00	0.09
BARN YARDS	41.	33.71	0.00	4.05	4.05	0.70	0.70
RES-imperv	104.	74.86	0.00	0.00	0.88	0.00	0.09
RES-perv	546.	6.62	0.00	0.00	0.28	0.00	0.04
COMM-imperv	49.	74.86	0.00	0.00	0.93	0.00	0.10
COMM-perv	41.	6.62	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	74.86	0.00	0.00	0.64	0.00	0.07
INDUS-perv	67.	6.62	0.00	0.00	0.03	0.00	0.01
GROUNDWATER				162.40	162.40	6.21	6.21
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.21	38.21	1.12	1.12
TOTAL				342.59	394.64	26.44	48.10

W. Branch Delaware River 4/78-3/82 YEAR 3

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	11.9	2.1	9.3	0.2	9.5
MAY	3.2	7.6	4.3	0.0	4.3
JUNE	10.4	9.1	0.2	0.0	0.2
JULY	9.5	11.5	0.0	0.0	0.0
AUG	9.9	10.3	0.0	0.0	0.0
SEPT	10.7	6.3	0.0	0.2	0.2
OCT	10.0	3.0	2.2	0.2	2.4
NOV	8.8	0.5	6.7	0.9	7.6
DEC	6.3	0.1	6.2	0.6	6.8
JAN	2.8	0.0	2.4	0.1	2.5
FEB	16.8	0.6	10.7	5.1	15.8
MAR	4.3	0.8	5.9	0.0	5.9
YEAR	104.6	52.0	47.8	7.4	55.2

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	45.5	0.0	40.9	41.2	2.2	2.3
MAY	6.7	0.0	19.2	19.3	1.4	1.4
JUNE	38.2	0.0	5.4	5.7	1.0	1.0
JULY	37.6	0.0	4.5	4.7	1.0	1.0
AUG	41.7	0.0	5.2	5.4	1.0	1.0
SEPT	36.6	0.1	7.1	7.5	1.1	1.2
OCT	15.9	0.1	16.3	17.0	1.5	1.7
NOV	0.5	0.8	40.3	43.1	2.5	3.6
DEC	0.2	0.6	33.9	35.8	2.1	2.9
JAN	0.0	0.0	15.6	15.8	1.5	1.6
FEB	2.1	13.0	126.8	166.2	11.1	28.0
MAR	0.7	0.0	25.7	26.0	1.7	1.7
YEAR	225.7	14.7	340.9	387.6	28.1	47.5

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR (Mg)	TOT.NITR (Mg)	DIS.PHOS (Mg)	TOT.PHOS (Mg)
CORN	3430.	17.55	46.48	48.63	79.72	7.06	20.53
HAY	13085.	12.74	2.61	46.69	53.34	2.50	5.38
PASTURE	5093.	8.17	3.47	12.48	15.93	1.04	2.54
INACTIVE	3681.	8.17	3.69	4.81	7.46	0.39	1.54
FOREST	56682.	5.14	0.00	5.54	5.54	0.17	0.17
LOGGING	20.	0.00	47.13	0.00	0.18	0.00	0.08
BARN YARDS	41.	35.45	0.00	4.26	4.26	0.74	0.74
RES-imperv	104.	70.37	0.00	0.00	0.85	0.00	0.08
RES-perv	546.	8.69	0.00	0.00	0.28	0.00	0.04
COMM-imperv	49.	70.37	0.00	0.00	0.90	0.00	0.10
COMM-perv	41.	8.69	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	70.37	0.00	0.00	0.62	0.00	0.07
INDUS-perv	67.	8.69	0.00	0.00	0.03	0.00	0.01
GROUNDWATER				134.79	134.79	5.15	5.15
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.10	38.10	1.11	1.11
TOTAL				340.89	387.61	28.08	47.45

W. Branch Delaware River 4/78-3/82 YEAR 4

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	10.3	2.1	5.0	0.1	5.1
MAY	13.0	7.4	8.1	0.5	8.6
JUNE	8.1	10.4	1.4	0.0	1.4
JULY	7.0	11.4	0.1	0.0	0.1
AUG	5.4	8.7	0.0	0.0	0.0
SEPT	13.7	5.4	0.0	0.0	0.0
OCT	13.1	2.9	4.6	0.2	4.7
NOV	5.9	0.7	7.3	0.0	7.3
DEC	8.2	0.1	4.3	1.1	5.5
JAN	6.6	0.1	4.6	0.4	5.0
FEB	9.1	0.1	5.9	1.5	7.4
MAR	9.0	0.7	10.7	1.8	12.5
YEAR	109.4	50.0	52.0	5.7	57.7

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	28.0	0.0	23.5	23.9	1.6	1.7
MAY	55.8	0.4	39.3	40.8	2.3	2.9
JUNE	15.4	0.0	9.3	9.4	1.1	1.1
JULY	20.1	0.0	4.6	4.8	0.9	1.0
AUG	12.7	0.0	4.3	4.5	0.9	0.9
SEPT	43.2	0.0	4.6	4.9	1.0	1.0
OCT	10.5	0.2	23.0	23.8	1.6	1.9
NOV	2.4	0.0	29.5	29.7	1.7	1.7
DEC	0.5	3.6	32.0	43.2	2.2	7.0
JAN	0.0	0.7	30.6	32.9	2.6	3.5
FEB	0.0	4.3	51.9	65.1	4.5	10.1
MAR	0.7	3.1	82.0	91.6	6.7	10.7
YEAR	189.3	12.3	334.7	374.4	27.2	43.5

SOURCE	AREA	RUNOFF	EROSION	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(ha)	(cm)	(Mg/ha)	(Mg)			
CORN	3430.	14.66	38.98	44.57	70.64	6.60	17.89
HAY	13085.	10.52	2.19	38.54	44.12	2.06	4.48
PASTURE	5093.	6.48	2.91	9.90	12.79	0.82	2.08
INACTIVE	3681.	6.48	3.10	3.81	6.04	0.31	1.27
FOREST	56682.	3.67	0.00	3.95	3.95	0.12	0.12
LOGGING	20.	0.00	39.52	0.00	0.15	0.00	0.07
BARN YARDS	41.	31.05	0.00	3.73	3.73	0.65	0.65
RES-imperv	104.	68.27	0.00	0.00	0.87	0.00	0.09
RES-perv	546.	6.96	0.00	0.00	0.30	0.00	0.04
COMM-imperv	49.	68.27	0.00	0.00	0.92	0.00	0.10
COMM-perv	41.	6.96	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	68.27	0.00	0.00	0.64	0.00	0.07
INDUS-perv	67.	6.96	0.00	0.00	0.04	0.00	0.01
GROUNDWATER				146.50	146.50	5.60	5.60
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.10	38.10	1.11	1.11
TOTAL				334.70	374.40	27.18	43.49

REFERENCES

Alhajjar, B. J., Harkin, J. H., Chesters, G. 1989. Detergent formula and characteristics of wastewater in septic tanks. Journal of the Water Pollution Control Federation 61(5): 605-613.

Amy, G., Pitt, R., Singh, R., Bradford, W. L., LaGraffi, M. B. 1974. Water quality management planning for urban runoff. EPA-440/9-75-004. U.S. Environmental Protection Agency, Washington DC.

Bosen, J. F. 1960. A formula for approximation of saturation vapor pressure over water. Monthly Weather Reviews 88(8):275-276).

Brown, K. W., Thomas, J. C. 1978. Uptake of N by grass from septic fields in three soils. Agronomy Journal 70(6): 1037-1040.

Brown, M. P., Rafferty, M.R. 1980. A historical perspective of phosphorus loading to the Cannonsville Reservoir as it relates to the West Branch Delaware River Model Implementation Program. Technical Report 62. N.Y. Department of Environmental Conservation, Albany NY.

Brown, M. P., Rafferty, M. R., Longabucco, P. 1985. Nonpoint source control of phosphorus - a watershed evaluation. Report to the U.S. Environmental Protection Agency, Ada, OK.

Bureau of the Census. 1980. 1978 census of agriculture, Delaware County, NY. U.S. Department of Commerce, Washington, DC.

Chow, V. T. 1964. Runoff. In: V. T. Chow (ed.). Handbook of Applied Hydrology. McGraw-Hill, New York NY, Chapter 14.

Davis, C. V., Sorensen, K. E. 1969. Handbook of Applied Hydraulics. McGraw-Hill, New York NY.

Delwiche, L. L. D., Haith, D. A. 1983. Loading functions for predicting nutrient losses from complex watersheds. Water Resources Bulletin 19(6):951-959.

Dickerhoff, L. L. 1981. A methodology for predicting runoff and nutrient losses from a heterogeneous watershed. M. S. Dissertation. Department of Agricultural Engineering, Cornell University, Ithaca NY.

Dornbush, J. N., Anderson, J. R., Harms L. L. 1974. Quantification of pollutants in agricultural runoff. EPA-660/2-74-005, U. S. Environmental Protection Agency, Washington DC.

Edwards, W. M., Simpson, E. C, Frere, M. H. 1972. Nutrient content of barnyard runoff water. Journal of Environmental Quality 1(4): 401-405.

Gilbertson, C. B., Norstadt, F. A., Mathers, A. C., Holt, R. F., Barnett, A. P., McCalla, T. M., Onstadt, C. A., Young, R. A. 1979. Animal waste utilization on crop land and pasture land. EPA-600/2-79-059, U. S. Environmental Protection Agency, Washington DC.

Haan, C. T. 1972. A water yield model for small watersheds. Water Resources Research 8(1): 58-69.

Haith, D. A. 1985. An event-based procedure for estimating monthly sediment yields. Transactions of the American Society of Agricultural Engineers 28(6): 1916-1920.

Haith, D. A., Merrill, D. E. 1987. Evaluation of a daily rainfall erosivity model. Transactions of the American Society of Agricultural Engineers 30(1):90-93.

Haith, D. A., Shoemaker, L. L. 1987. Generalized watershed loading functions for stream flow nutrients. Water Resources Bulletin 23(3):471-478.

Haith, D. A., Tubbs, L. J. 1981. Watershed loading functions for nonpoint sources. Proceedings of the

American Society of Civil Engineers, Journal of the Environmental Engineering Division 107(EE1):121-137.

Hamon, W. R. 1961. Estimating potential evapotranspiration. Proceedings of the American Society of Civil Engineers, Journal of the Hydraulics Division 87(HY3):107-120.

Hawkins, R. H. 1978. Runoff curve numbers with varying site moisture. Proceedings of the American Society of Civil Engineers, Journal of the Irrigation and Drainage Division 104(IR4):389-398.

Huber, W. C., Dickinson, R. E. 1988. Storm water management model, version 4: User's manual. Cooperative agreement CR-811607. U.S. Environmental Protection Agency, Athens, GA.

Hydrologic Engineering Center. 1977. Storage, treatment, overflow, runoff model `STORM'. 723-S8-L7520. U.S. Army Corps of Engineers, Davis CA.

Jensen, M. E., Burman, R. D., Allen, R. G. (ed.) 1989. Evapotranspiration and irrigation water requirements. ASCE Manual No. 70. American Society of Civil Engineers, New York, NY.

Knoblauch, W. 1976. New York's changing agriculture census data. Extension Bulletin 76-35. Department of Agricultural Economics, Cornell University, Ithaca, NY.

Kuo, C. Y., Cave, K. A., Loganathan, G. V. 1988. Planning of urban best management practices. Water Resources Bulletin 24(1):125-132.

Mandel, R. 1993. The impact of septic systems on surface water quality. Unpublished M.S. dissertation. School of Civil & Environmental Engineering, Cornell University, Ithaca, NY.

McElroy, A. D., Chiu, S. Y., Nebgen, J. W., Aleti, A., Bennett, F. W. 1976. Loading functions for assessment of water pollution from nonpoint sources. EPA-600/2-76-151. U.S. Environmental Protection Agency, Washington DC.

Meyer, L. D., Wischmeier, W. H. 1969. Mathematical simulation of the process of soil erosion by water. Transactions of the American Society of Agricultural Engineers 12(6):754-758.

Mills, W. B., Porcella, D. B, Ungs, M. J., Gherini, S. A., Summers, K. V., Mok, L., Rupp, G. L., Bowie, G. L., Haith, D. A. 1985. Water quality assessment: A screening procedure for toxic and conventional pollutants in surface and ground water. EPA/600/6-85/002, U. S. Environmental Protection Agency, Athens GA.

Novotny, V., Chesters, G. 1981. Handbook of Nonpoint Pollution. Van Nostrand Reinhold, New York NY.

Ogrosky, H. O., Mockus, V. 1964. Hydrology of agricultural lands. In: V. T. Chow (ed.). Handbook of Applied Hydrology. McGraw-Hill, New York. Ch. 21.

Omernik, J. M. 1977. Nonpoint source - stream nutrient level relationships: a nationwide study. EPA-600/3-77-105. U.S. Environmental Protection Agency, Corvallis OR.

Overcash, M. R., Phillips, R. L. 1978. Dairy feedlot hydrology. Transactions of the American Society of Agricultural Engineers 21(5):1193-1198.

Overton, D. E., Meadows, M. E. 1976. Stormwater Modeling. Academic Press. New York, NY.

Parker, C. A., et al. 1946. Fertilizers and lime in the United States. Misc. Publication No. 586. U.S. Department of Agriculture, Washington, DC.

Petrovic, A. M., Cornman, J. F. 1982. Home lawns. Information Bulletin 185. Cornell Cooperative Extension, Cornell University, Ithaca, NY.

Reed, S. C., Middlebrooks, E. J., Crites, R. W. 1988. Natural Systems for Waste Management and Treatment.

McGraw-Hill, New York.

Rawls, W. J., Brakensiek, D. L. , Saxton, K. E. 1982. Estimation of soil water properties. Transactions of the American Society of Agricultural Engineers 25(5): 1316-1320, 1328.

Richardson, C. W., Foster, G. R., Wright, D. A. 1983. Estimation of erosion index from daily rainfall amount. Transactions of the American Society of Agricultural Engineers 26(1):153-157,160.

Sartor, J. D., Boyd, G. B. 1972. Water pollution aspects of street surface contaminants. EPA-R2/72-081. U.S. Environmental Protection Agency, Washington DC.

Selker, J. S., Haith, D. A., Reynolds, J. E. 1990. Calibration and testing of daily rainfall erosivity model. Transactions of the American Society of Agricultural Engineers 33(5): 1612-1618.

Slavicek, R. L. 1980. The West Branch of the Delaware River model implementation program, survey of logging road erosion and sediment production. U.S. Forest Service, Stamford, NY.

Soil Conservation Service. 1976. Potential nonpoint sources of agricultural pollution, West Branch Delaware River watershed. U.S. Department of Agriculture, Syracuse, NY.

Soil Conservation Service. 1986. Urban hydrology for small watersheds. Technical Release No. 55 (2nd edition). U.S. Department of Agriculture, Washington, DC.

Stewart, B. A., Woolhiser, D. A., Wischmeier, W. H., Caro, J. H., Frere, M. H. 1975. Control of water pollution from cropland. Volume I: A manual for guideline development. EPA-600/2-75-026a. U.S. Environmental Protection Agency, Washington DC.

U. S. Environmental Protection Agency. 1980. Design manual: Onsite wastewater treatment and disposal systems. EPA-625/1-80-012. U. S. Environmental Protection Agency, Washington DC.

U. S. Forest Service. 1980. An approach to water resources evaluation of nonpoint silvicultural sources. EPA-600/8-80-012. U.S. Environmental Protection Agency, Athens GA.

U. S. Public Health Service. 1967. Manual of septic tank practice. National Center for Urban and Industrial Health, Cincinnati, OH.

Vanoni, V. A. (Ed.). 1975. Sedimentation Engineering. American Society of Civil Engineers, New York NY.

Wischmeier, W. H., Smith, D. D. 1978. Predicting rainfall erosion losses - a guide to conservation planning. Agricultural Handbook 537, U.S. Department of Agriculture, Washington DC.

Appendix D
Calculation Details

This appendix provides details for the computation of GWLF input parameters requiring multiple steps.

Curve Number

The curve number must be developed within an ArcView project named *iepa_prepro.apr*, which contains all of the necessary extensions except Spatial Analyst. The Spatial Analyst extension of ArcView must be available for this calculation.

1. Add the landuse and STATSGO shapefiles and the landuse grid to the View. Open the attribute table for the STATSGO shapefile.
2. Add the attribute tables lookup.dbf and statsgoc.dbf to the project. The lookup table is common to any soil/landuse combination, but the STATSGO table must reflect the area for which the curve number is being calculated. In the statsgoc.dbf table, the field *comppct* identifies the percentage of each soil type in a map unit. This field is a string field and must be converted to a number field.
3. To convert the string field to a number field: add a new number field to the statsgoc.dbf attribute table named *comppct2*, and fill it with the values of the field *comppct* (to fill a number field with values from a string field, the calculation should read "*comppct.AsNumber*"). Delete the field *comppct*. Create a new number field, *comppct*, and fill it with the values of *comppct2*. Delete the field *commct2*. The *comppct* field now exists as a number field.
4. From the CRWR-PrePro menu, select "Soil Group Percentages". When prompted, input statsgo.dbf for the map unit table and statsgoc.dbf for the component table. The script will automatically create an output table, muidjoin.dbf, listing the percentage of each hydrologic soil group in each map unit.
5. From the CRWR-PrePro menu, select "Curve Number Grid". When prompted, select the STATSGO shapefile as the soils theme, the landuse shapefile as the landuse theme, lookup.dbf as the lookup table, muidjoin.dbf as the table with the soil group percentages, and set the analysis extent and the cell size to the landuse grid. The curve number grid can take between 2 and 15 minutes to compute depending on the computer speed and size of the basin.
6. Save the temporary curve number grid as a permanent grid named *CN_grid*.
7. To average the curve number grid over the landuse shapefile polygons, select "Average grid value on polygon" from the CRWR-Raster menu.

Table D-1 presents the resulting curve numbers associated with each landuse and used in the GWLF program.

Table D-1 Weighted Curve Numbers in the Vandalia Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4	Subbasin 5	Subbasin 6	Subbasin 7
High Density	---	---	91.3	---	91.3	90.5	---
Medium Density	---	---	---	---	84.3	---	81.9
Row Crop	87.4	87.1	87.4	86.6	87.5	86.6	85.7
Small Grains	85.0	84.6	85.3	84.3	85.3	83.7	83.7
Urban Grassland	---	---	---	---	78.0	75.8	75.0
Rural Grassland	76.5	75.5	76.8	75.5	76.7	75.3	75.0
Deciduous	71.8	71.6	71.5	71.6	72.9	71.3	71.2
Open Water	100.0	100.0	100.0	100.0	99.5	99.8	99.9
Shallow Marsh/ Wetland	100.0	---	100.0	---	100.0	100.0	100.0
Deep Marsh	100.0	---	100.0	---	---	---	---
Forested Wetland	100.0	100.0	100.0	100.0	---	---	100.0
Shallow Water Wetland	97.8	100.0	100.0	100.0	100.0	---	---

Soil Erodibility Factor (K)

The K factor is developed in ArcView and Excel.

1. In ArcView, add the attribute tables statsgoc.dbf and statsgol.dbf to the Table list. Join the statsgoc.dbf table to the statsgol.dbf table by field *muidsegnum*. This appends the percentage of each soil type to the soils in each layer. Export the joined table as a .dbf named statsgo_kf.dbf.
   1. Open the table statsgo_kf.dbf in Excel. Remove all fields except *muid, layernum, kffact, kfact,* and *comppct*.
   2. Sort the entire table by *layernum* then by *muid*. This promotes all soils in layer 1 to the top of the spreadsheet.
   3. Remove all records for soils below layer 1.
   4. Ensure the sum of the *comppct* field for each muid is equal to 100.
   5. In a new column labeled *product*, multiply *kffact* by *comppct* and divide by 100 for each record. If the value in the *kffact* field is zero, use the value in the *kfact* field
   6. In a new column labeled *kffact_r* (revised), sum *product* over each muid to obtain the revised K factor for each muid.
   7. Copy the *kffact_r* column and use the "Paste Special/Values" option to paste the column into the *layernum* column. This is done so that the *kffact_r* values will be retained when the statsgo_kf.dbf table is saved and used again in ArcView.
   8. Delete all columns except for *muid* and *kffact_r*. Delete any rows without a value in the *kffact_r* field.
   9. Save the table.
   10. In ArcView, add the table statsgo_kf.dbf, the STATSGO shapefile in UTM 16 projection, and the landuse grid. Join the statsgo_kf.dbf table to the statsgo.dbf table by *muid*. This attaches the average K factor to each muid in statsgo.dbf.
   11. Set the analysis extent and cell size to the landuse grid.
   12. Convert the SATSGO shapefile to a grid using the *kffact_r* field as the grid value.

13. To average the K factor grid over the landuse shapefile polygons, select "Average grid value on polygon" from the CRWR-Raster menu.

Table D-2 presents the resulting K factors associated with each landuse and used in the GWLF program.

Table D-2 Weighted K factors for the Vandalia Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4	Subbasin 5	Subbasin 6	Subbasin 7
High Density	---	---	0.37	---	0.37	0.41	---
Medium Density	---	---	---	---	0.37	---	0.42
Row Crop	0.38	0.38	0.38	0.40	0.37	0.40	0.42
Small Grains	0.39	0.40	0.38	0.40	0.38	0.42	0.42
Urban Grassland	---	---	---	---	0.37	0.41	0.42
Rural Grassland	0.40	0.41	0.39	0.41	0.39	0.41	0.42
Deciduous	0.41	0.42	0.42	0.42	0.40	0.42	0.42
Open Water	0	0	0	0	0	0	0
Shallow Marsh/ Wetland	0.38	---	0.37	---	0.37	0.37	0.42
Deep Marsh	0.42	---	0.42	---	---	---	---
Forested Wetland	0.42	0.42	0.42	0.42	---	---	0.42
Shallow Water Wetland	0	0	0	0	0	---	---

Topographic Factor (LS)

Computation of the LS factor is done in the ArcView project *iepa_prepro.apr*.

1. In ArcView, add the Digital Elevation Model (DEM) to the View
2. Set the analysis extent and cell size to the DEM.
3. Select "Fill Sinks" from the CRWR-PrePro menu to fill sinks in the DEM. Save the temporary grid as a permanent grid named *Fill_grid*.
4. Open the script "New_Slope" from the project window, and press the "Run" button to compute percent slopes from the filled DEM. Save the temporary grid as a permanent grid named *Slope_grid*.
5. Select "Flow Direction" from the CRWR-PrePro menu to derive the direction of flow through each grid cell. Save the temporary grid as a permanent grid named *Fdr_grid*.
6. Compute the theta grid (in radians) with the map calculator.
   Map Calc. Statement: (([slope_grid] / 100)).Atan
   Save Map Calc 1 as a permanent grid named *Theta_grid*.
7. Compute the S grid with the map calculator and a succession of calculations
   Map Calc. 1: ([slope_grid] <= 9)
   Output: 1 in cells where slope is less or equal to 9; zero elsewhere
   Map Calc. 2: ((([theta_grid].Sin) * 10.8) + 0.03)
   Output: S-value computed for slopes <= 9 in all cells
   Map Calc. 3: ([Map Calculation 2 * [Map Calculation 1])

Output: Correct S-value in cells with slope <= 9; zero elsewhere

Map Calc. 4: ([slope_grid] > 9)

Output: 1 in cells where slope > 9, zero elsewhere

Map Calc. 5: ((([theta_grid].Sin) * 16.8) – 0.5)

Output: S-value computed for slopes > 9 in all cells

Map Calc. 6: ([Map Calculation 5] * [Map Calculation 4])

Output: Correct S-value in cells with slope > 9; zero elsewhere

Map Calc. 7: ([Map Calculation 3] + [Map Calculation 6])

Output: Correct S-value in each cell

Save Map Calculation 7 as a permanent grid named *S_grid*.

8. Compute the Beta grid with the map calculator.

Map Calc. 1: (([theta_grid].Sin) / 0.0896) / ((([theta_grid].Sin).Pow(0.8)) * 3.0 + 0.56)

Save Map Calculation 1 as a permanent grid named *Beta_grid*.

9. Compute the M grid with the map calculator.

Map Calc. 1: ([beta_grid] / ([beta_grid] + 1))

Save Map Calculation 1 as permanent grid named *M_grid*.

10. Compute the flow length (Lambda) grid with the map calculator and a succession of calculations

Map Calc. 1: ([fdr] = 1 OR [fdr] = 4 OR [fdr] = 16 OF [fdr] = 64)

Output: 1 in cells flowing in cardinal direction and 0 in other cells

Map Calc. 2: ([Map Calculation 1] * 30.8875)

{30.885 = cell length}

Output: 30.885 in cells flowing in cardinal direction and 0 in others.

Map Calc. 3: ([Map Calculation 2] = 0)

Output: 0 in cells flowing in cardinal direction and 1 in others

Map Calc. 4: ([Map Calculation 3] * 43.682)

{43.682= length across cell diagonal}

Output: 43.682 in cells flowing in non-cardinal direction, 0 in others.

Map Calc. 5: ([Map Calculation 4] + [Map Calculation 2])

Output: correct flow lengths in each cell – 30.885 in cardinal, 43.682 in others

Map Calc. 6: ([Map Calculation 5] * 100 / 2.54 / 12

Output: flow length grid in feet

Save Map Calculation 6 as a permanent grid named *Lambda_grid*

11. Compute the L with the map calculator.

Map Calc. Statement: ([lambda_grid] / 72.6).Pow([m_grid])

Save Map Calculation 1 as a permanent grid named *L_grid*.

12. Compute the LS grid with the map calculator.

Map Calc. Statement: ([L-grid] * [S_grid])

Save Map Calculation 1 as a permanent grid named *LS_grid*.

13. To average the LS grid over the landuse shapefile polygons, select "Average grid value on polygon" from the CRWR-Raster menu.

Table D-3 presents the resulting LS factors for each landuse used in GWLF.

Table D-3 Weighted LS factors for the Vandalia Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4	Subbasin 5	Subbasin 6	Subbasin 7
High Density	---	---	0.051	---	0.060	0.076	---
Medium Density	---	---	---	---	0.031	---	0.402
Row Crop	0.121	0.153	0.139	0.140	0.112	0.097	0.265
Small Grains	0.273	0.279	0.229	0.201	0.132	0.205	0.385
Urban Grassland	---	---	---	---	0.059	0.114	0.875
Rural Grassland	0.402	0.452	0.408	0.233	0.193	0.233	0.571
Deciduous	0.692	0.615	0.689	0.366	0.419	0.460	0.887
Open Water	0	0	0	0	0	0	0
Shallow Marsh/ Wetland	0.699	---	0.067	---	0.084	0.044	0.714
Deep Marsh	0.413	---	0.561	---	---	---	---
Forested Wetland	0.531	0.532	0.618	0.199	---	---	1.365
Shallow Water Wetland	0	0	0	0	0	---	---

In the following discussions, fields in bold type represent calculations in Excel. Fields in non-bold type are input fields.

Cropping Management Factor (C factor)

The C factor is calculated in Excel. C factors were selected for each crop by tillage practice and crop rotation from the table provided by the Fayette County NRCS office included as Appendix E. The spreadsheet used to calculate a weighted c-factor for corn, soybeans, and small grains is shown at the end of this appendix. The values in the Table 1 of the spreadsheet are a weighted average of values from columns C and F. This weighted average allows the influence of crop rotations to be included in the c-factors for the Vandalia Lake Watershed. The values in the Table 1 are then weighted by the percentage of each tillage practice in Table 2 to determine a single c-factor for corn, soybeans, and small grains.

The weighted C factor for each crop is then appended to the table of Cropland Data Layer landuses and areas in the Altamont New Reservoir Watershed. Table D-4 shows the Cropland Data Layer landuse areas, and C factors. C factors for landuses other than corn, soybean, and small grains were obtained from the table included as Appendix E.

Table D-4 Cropland Data Layer C factors for the Vandalia Lake Watershed

Landuse	C-factor
Corn	0.32
Sorghum	0.32
Soybeans	0.18
Winter Wheat	0.08
Other Small Grains & Hay	0.08
Double-Cropped WW/SB	0.28
Idle Cropland/CRP	0.004
Fallow/Idle Cropland	0.004
Pasture/Grassland/Nonagriculture	0.004
Woods	0.003

The landuse classes in GWLF are represented by the Critical Trends Land Assessment classes rather than the Cropland Data Layer classes, so an area-weighted average was used to calculate the C factor coefficients for "Row Crop" and "Small Grains" in the Critical Trends Land Assessment landuse file. Table D-5 shows the Critical Trends Land Assessment landuse classes and the calculated C factor coefficients. The coefficient for "Row Crop" was calculated with an area-weighed average of the C factors for corn, soybeans, and half of the double-cropped WW/SB area in the Cropland Data Layer. The coefficient for "Small Grains" was calculated with an area-weighted average of the C factors for winter wheat, other small grains and hay, and half of double-cropped WW/SB area from the Cropland Data Layer.

Table D-5 C Factors by Critical Trends Assessment Landuse Classes in the Vandalia Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4	Subbasin 5	Subbasin 6	Subbasin 7
High Density	---	---	---	---	---	---	---
Medium Density	---	---	---	---	---	---	---
Row Crop	0.249	0.262	0.255	0.240	0.248	0.259	0.250
Small Grains	0.200	0.262	0.131	0.161	0.176	0.105	0.128
Urban Grassland	---	---	---	---	0.004	0.004	0.004
Rural Grassland	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Deciduous	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Open Water	---	---	---	---	---	---	---
Shallow Marsh/ Wetland	---	---	---	---	---	---	---
Deep Marsh	---	---	---	---	---	---	---
Forested Wetland	---	---	---	---	---	---	---
Shallow Water Wetland	---	---	---	---	---	---	---

Evapotranspiration (ET) Cover Coefficient

The ET cover coefficient was calculated in an Excel spreadsheet. The cover coefficients for crops available in the GWLF Manual and the crops listed in the Cropland Data Layer landuse file differ. Therefore, crops in the Cropland Data Layer file were summed into classes matching the available crop cover coefficients. Table D-6 (at the end of this section) shows the original and adjusted areas for Vandalia Lake. The adjusted sorghum area is the sum of sorghum and other small grains and hay, and the adjusted soybean area represents soybeans plus half of the double-cropped WW/SB area. Adjusted area from winter wheat represents winter wheat plus half the double-cropped WW/SB area.

Table D-7 shows the calculation of a single crop coefficient for each 10% of the growing season and for each calendar month. The ET cover coefficients for each crop were obtained from page 29 of the GWLF Manual. To create the coefficient for each 10% of the growing season, each crop coefficient in columns B-E was weighted by its corresponding area in Table D-6. An average monthly ET coefficient (column G) was calculated from the coefficients in Column F, and then each growing season was assigned to a calendar month (Column H).

Table D-7 Calculation of a Monthly Crop Evapotranspiration Cover Coefficient

A	B	C	D	E	**F**	**G**	H
% of Growing Season	Field Corn	Grain Sorghum	Winter Wheat	Soybeans	**Weighted Average ET Coeff.**	**Average Monthly ET Coeff.**	Month
0	0.45	0.3	1.08	0.3	**0.39**	**0.39**	Nov - Apr
10	0.51	0.4	1.19	0.35	**0.45**		
20	0.58	0.65	1.29	0.58	**0.62**	**0.53**	May
30	0.66	0.9	1.35	1.05	**0.89**		
40	0.75	1.1	1.4	1.07	**0.96**	**0.93**	June
50	0.85	1.2	1.38	0.94	**0.95**	**0.95**	July
60	0.96	1.1	1.36	0.8	**0.92**		
70	1.08	0.95	1.23	0.66	**0.88**	**0.90**	Aug
80	1.2	0.8	1.1	0.53	**0.85**		
90	1.08	0.65	0.75	0.43	**0.72**	**0.79**	Sep
100	0.7	0.5	0.4	0.36	**0.51**		
					0.39	**0.45**	Oct

Finally, a single area-weighted crop coefficient for each month was calculated from the monthly crop cover coefficients in Table D-7 and the adjusted areas in Table D-6. This calculation is shown in Table D-8.

Table D-8 Calculation of a Monthly ET Cover Coefficient in the Vandalia Lake Watershed

	Crop	Pasture	Forest	Urban 68%	Urban 30%	Water/ Wetland	**Weighted Average ET**
Apr	0.39	1.09	0.3	0.32	0.7	0.75	**0.66**
May	0.53	0.95	1	0.32	0.7	0.75	**0.82**
Jun	0.93	0.83	1	0.32	0.7	0.75	**0.88**
Jul	0.95	0.79	1	0.32	0.7	0.75	**0.88**
Aug	0.90	0.8	1	0.32	0.7	0.75	**0.87**
Sep	0.79	0.91	1	0.32	0.7	0.75	**0.87**
Oct	0.45	0.91	1	0.32	0.7	0.75	**0.78**
Nov	0.39	0.83	0.3	0.32	0.7	0.75	**0.57**
Dec	0.39	0.69	0.3	0.32	0.7	0.75	**0.52**
Jan	0.39	1.16	0.3	0.32	0.7	0.75	**0.68**
Feb	0.39	1.23	0.3	0.32	0.7	0.75	**0.70**
Mar	0.39	1.19	0.3	0.32	0.7	0.75	**0.69**

A	B	C
Corn-Soybean Rotation		
85% of watershed		
Conventional Till (Spring Plow)		
	Corn after Soybean	0.36
	Soybean after Corn[1]	0.33
Reduced-Till (30% Cover)		
	Corn after Soybean[2]	0.25
	Soybean after Corn[1]	0.17
Mulch-Till (50% cover)		
	Corn after Soybean[2]	0.25
	Soybean after Corn[1]	0.12
No-Till (70% Cover)		
	Corn after Soybean[3]	0.14
	Soybean after Corn[1]	0.07

D	E	F
Corn-Soybean-Wheat Rotation		
15% of watershed		
Conventional Till (Spring Plow)		
	Corn after Wheat[4]	0.30
	Soybean after Corn[1]	0.33
	Wheat after Soybean[5]	0.12
Reduced-Till (30% Cover)		
	Corn after Wheat[4]	0.2
	Soybean after Corn[1]	0.17
	Wheat after Soybean[35]	0.07
Mulch-Till (50% cover)		
	Corn after Wheat[4]	0.13
	Soybean after Corn[1]	0.12
	Wheat after Soybean[35]	0.07
No-Till (70% Cover)		
	Corn after Wheat[4]	0.06
	Soybean after Corn[1]	0.07
	Wheat after Soybean[35]	0.05

[1]Assumed Wide-Row
[2]Used 20% Residue
[3]Used 40% Residue
[4]Used Corn after Small Grain
[5]Used Small Grain after Soybean
[6]Used 30% Residue

G H I J

C-factors Weighted by Percent of Crop Rotation in the Watersl

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	0.35	0.33	0.12
Reduced Till	0.24	0.17	0.07
Mulch-Till	0.23	0.12	0.07
No-Till	0.13	0.07	0.05

Percent of Each Tillage Practice in Fayette County

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	82%	33%	25%
Reduced Till	4%	10%	3%
Mulch-Till	8%	29%	43%
No-Till	6%	28%	30%

C-factors Weighted by Percent of Each Tillage Practice

Corn	Soybeans	Small Grains
0.32	0.18	0.08

Table D-6 Cropland Data Layer Adjusted Landuse Areas

	Subbasin 1		Subbasin 2		Subbasin 3		Subbasin 4		Subbasin 5		Subbasin 6		Subbasin 7	
ERDAS Landuse	**Area (m2)**	**Adjusted Area (m2)**	**Area (m2)**	**Adjusted Area (m2)**	**Area (m2)**	**Adjusted Area (m2)**	**Area (m2)**	**Adjusted Area (m2)**	**Area (m2)**	**Adjusted Area (m2)**	**Area (m2)**	**Adjusted Area (m2)**	**Area (m2)**	**Adjusted Area (m2)**
Corn	7407	7407	2475900	2475900	3987900	3987900	2474100	2474100	3501000	3501000	700200	700200	425700	425700
Sorghum		141	99000	135900	2700	145800	19800	106200	58500	153900	---	42300	4500	138600
Soybeans	7637	7871.5	1741500	1801350	3492900	3653550	3366000	3495600	3771900	3879000	540000	555300	446400	484650
Winter Wheat	16	250.5	900	60750	342000	502650	141300	270900	181800	288900	64800	80100	3600	41850
Other Small Grains & Hay	141	---	36900	---	143100	---	86400	---	95400	---	42300	---	134100	---
Double-Cropped WW/SB	469	---	119700	---	321300	---	259200	---	214200	---	30600	---	76500	---
Other Crops	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Idle Cropland/CRP	---	---	29700	29700	12600	12600	18000	18000	5400	5400	---	---	2700	2700
Fallow/Idle Cropland	429	429	413100	413100	386100	386100	922500	922500	459000	459000	137700	137700	485100	485100
Pasture/Grassland/Nonag	1633	1633	661500	661500	1350900	1350900	966600	966600	1236600	1236600	608400	608400	850500	850500
Woods	1496	1496	624600	624600	766800	766800	574200	574200	207000	207000	359100	359100	965700	965700
Clouds	220	220	7200	7200	18000	18000	27000	27000	10800	10800	---	---	9900	9900
Urban	77	77	900	900	14400	14400	18000	18000	46800	46800	25200	25200	18900	18900
Water	46	46	35100	35100	8100	8100	27000	27000	30600	30600	502200	502200	575100	575100
Buildings/Homes/Subdivisions	---	---	7200	7200	51300	51300	39600	39600	130500	130500	30600	30600	11700	11700
Wetlands	---	---	23400	23400	19800	19800	23400	23400	21600	21600	36000	36000	42300	42300
Total	19571	19571	6276600	6276600	10917900	10917900	8963100	8963100	9971100	9971100	3077100	3077100	4052700	4052700

Appendix E
Crop Management "C" Factor Values for Rainfall E.I. Distribution Curve #16

TABLE 2 - CROP MANAGEMENT "C" FACTOR VALUES FOR RAINFALL "E.I." DISTRIBUTION CURVE #16 1/

CROP SEQUENCE		FALL PLOW	SPRING PLOW	CHISEL - DISK - RIDGE 2/ % Cover After Plant 20%	30%	40%	50%	NO-Till % Cover After Plant 60%	70%	80%	90%
CORN after Soybeans		.42	.36	.36	.30	.25	---	20% .25	30% .19	40% .14	3/ --
CORN after Corn		.36	.29	.21	.18	.15	.12	.09	.06	.05	.03
CORN after Small Grain		.37	.30	.23	.20	.16	.13	.09	.06	.05	.03
CORN after Meadow 4/		.17	.13	.12	.10	.09	.08	---	.02	.02	.01
CORN 2nd yr. after Meadow 4/		.32	.24	.19	.16	.15	.14	.06	.05	.04	.03
SOYBEANS after Soybeans 5/	Wide Row	.48	.41	.37	.35	---	---	20% .26	30% .20	40% .16	3/
	Drill	.38	.30	.31	.30	---	---	.20	.16	.13	
SOYBEANS after Corn 5/	Wide Row	.40	.33	.20	.17	.14	.12	.10	.07	.05	.03
	Drill	.30	.25	.18	.15	.13	.10	.08	.06	.04	.03
SOYBEANS after Sm. Grain 5/	Wide Row	.42	.30	.24	.20	.17	.14	.09	.06	.04	.03
	Drill	.32	.23	.19	.16	.14	.12	.08	.06	.04	.03
SOYBEANS after Meadow 4,5/	Wide Row	.20	.15	.12	.10	.09	.08	.03	.02	.01	.01
	Drill	.15	.12	.11	.09	.08	.08	.03	.02	.01	.01
SOYBEANS after Corn 2nd year after meadow 5/	Wide Row	.36	.27	.18	.15	.12	.10	.08	.06	.04	.03
	Drill	.27	.22	.15	.13	.11	.10	.08	.06	.04	.03
SMALL GRAIN after Corn (Grain) 6/		.12	.11	.09	.08	.07	.06	.08	.06	.04	.03
SMALL GRAIN after Corn (Silage) 7/		.17	---	.17	---	---	---	.13	---	---	---
SMALL GRAIN after Soybeans 6/		.13	.12	.10	.09	.08	.07	20% .09	30% .07	40% .05	3/ ---

WHEAT/SOYBEANS (Double Crop)

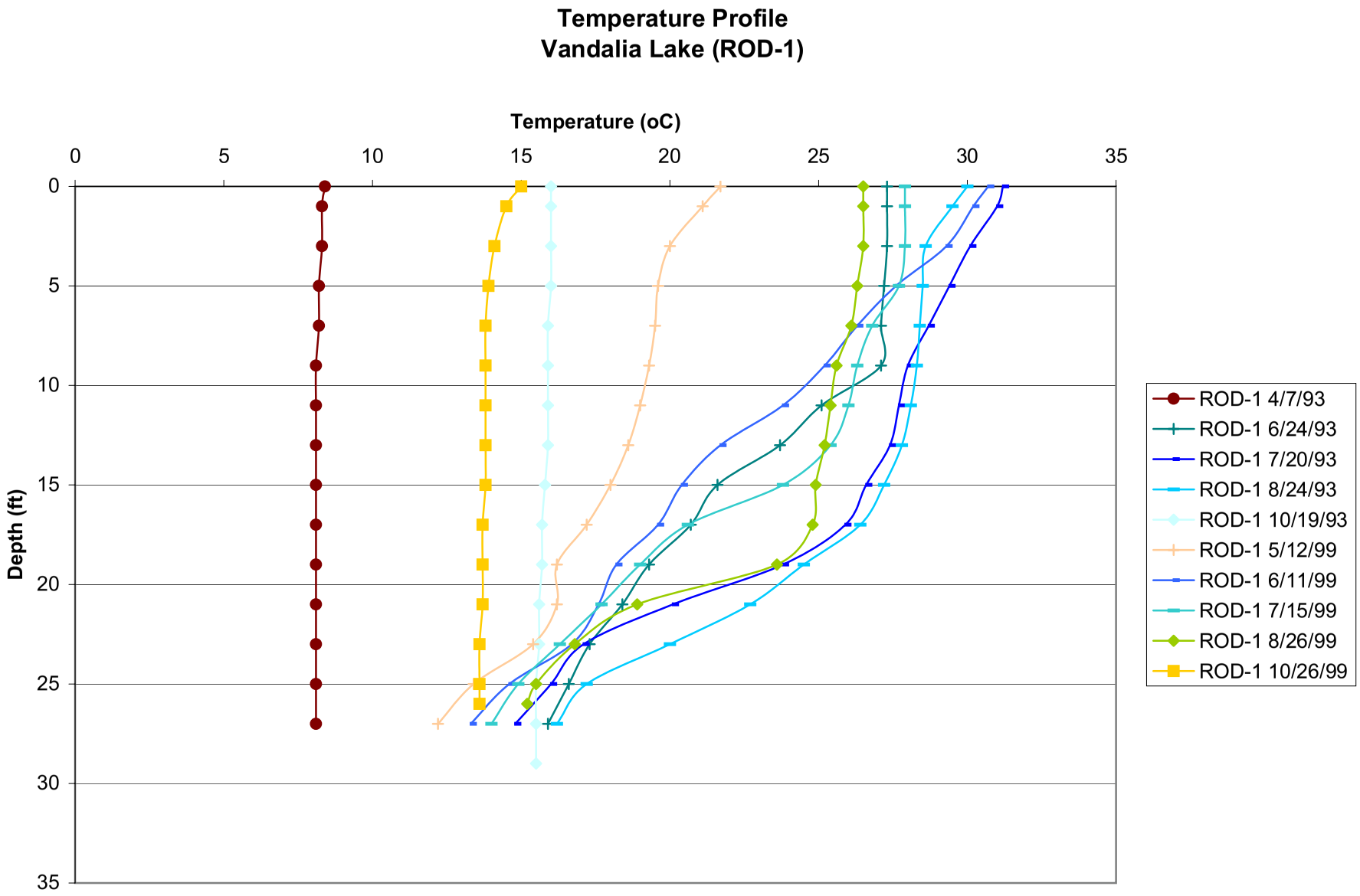
		Tillage for Soybeans Plow	Disk	No-Till
Tillage	Plow	.28	.16	.13
for	Disk	.23	.10	.07
Wheat	No-Till	.20	.08	.04

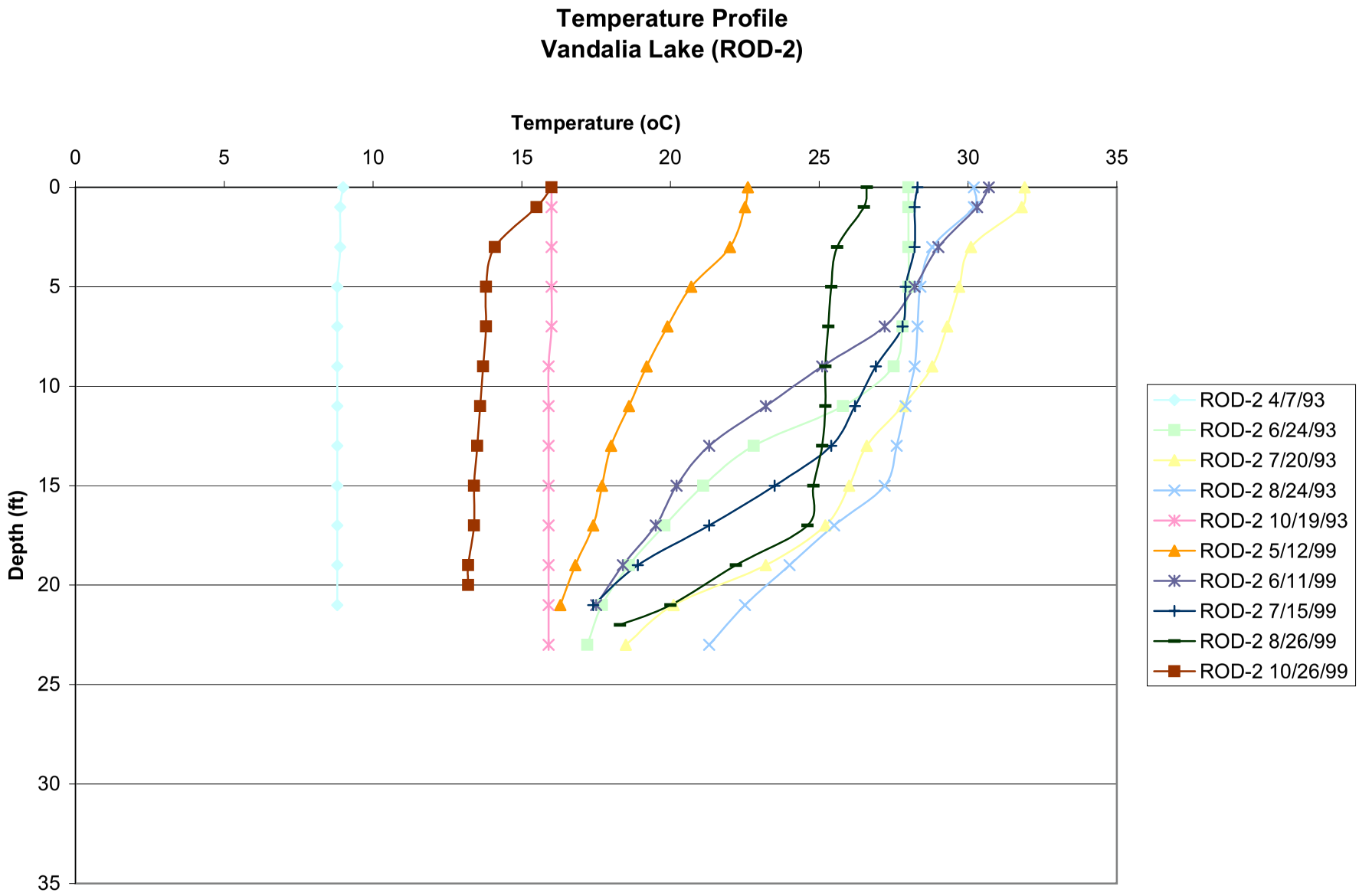
Meadow (Full year-Established)

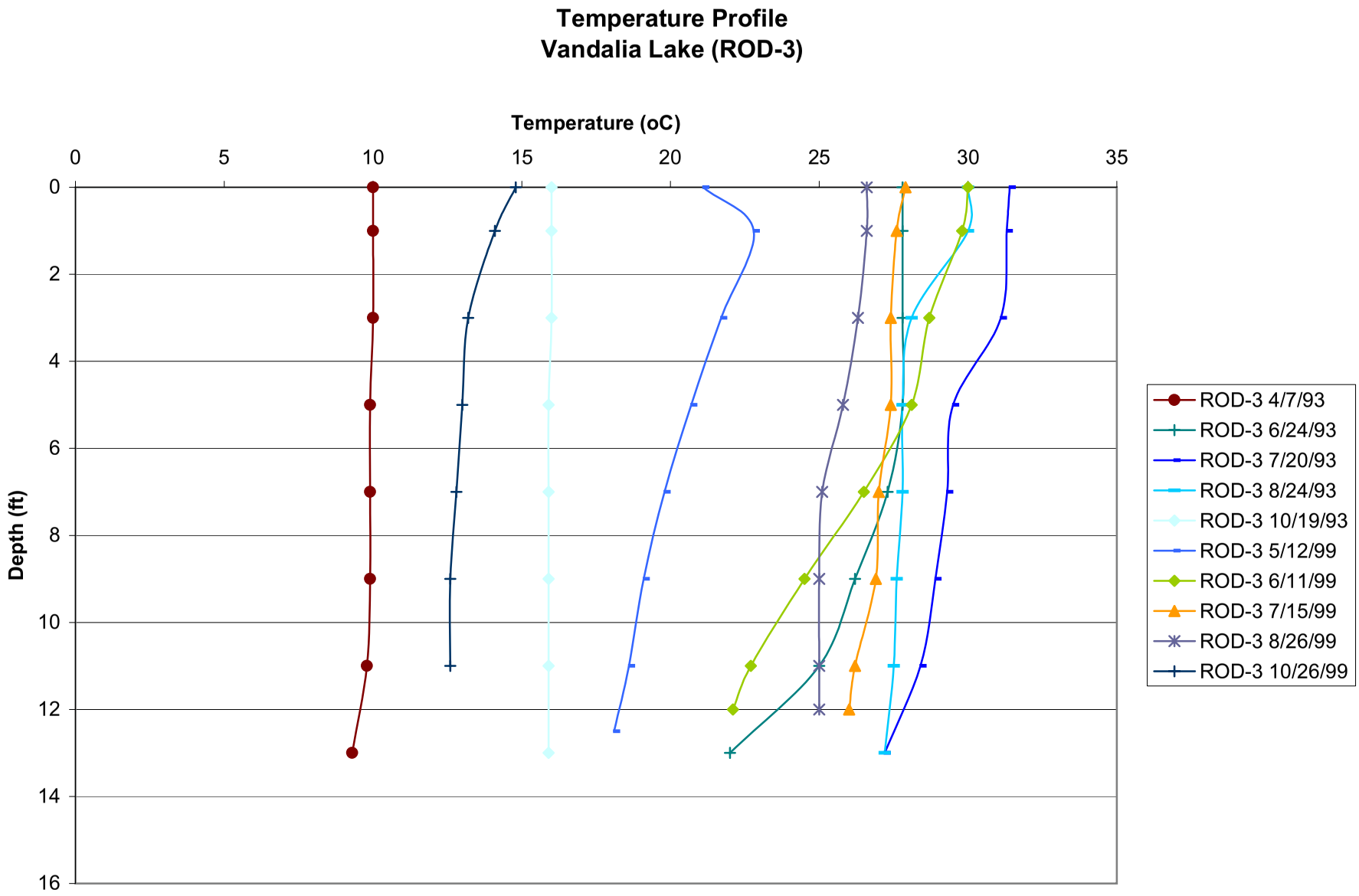
Grass-Legume	.004
Legume only	.02

SCS-IL, September, 1992

Appendix F
Metalimnion Charts


Temperature Profile
Vandalia Lake (ROD-1)
Temperature (oC)
0
5
10
15
20
25
30
35
Depth (ft)
ROD-1 4/7/93
ROD-1 6/24/93
ROD-1 7/20/93
ROD-1 8/24/93
ROD-1 10/19/93
ROD-1 5/12/99
ROD-1 6/11/99
ROD-1 7/15/99
ROD-1 8/26/99
ROD-1 10/26/99


Temperature Profile
Vandalia Lake (ROD-2)
Temperature (oC)
0
5
10
15
20
25
30
35
Depth (ft)
ROD-2 4/7/93
ROD-2 6/24/93
ROD-2 7/20/93
ROD-2 8/24/93
ROD-2 10/19/93
ROD-2 5/12/99
ROD-2 6/11/99
ROD-2 7/15/99
ROD-2 8/26/99
ROD-2 10/26/99


Temperature Profile
Vandalia Lake (ROD-3)
Temperature (oC)
0
5
10
15
20
25
30
35
Depth (ft)
0
2
4
6
8
10
12
14
16
ROD-3 4/7/93
ROD-3 6/24/93
ROD-3 7/20/93
ROD-3 8/24/93
ROD-3 10/19/93
ROD-3 5/12/99
ROD-3 6/11/99
ROD-3 7/15/99
ROD-3 8/26/99
ROD-3 10/26/99

Station	Date	Temp	Depth
ROD-1	4/24/1989	16.8	0
ROD-1	4/24/1989	16.7	1
ROD-1	4/24/1989	15.4	3
ROD-1	4/24/1989	13.8	5
ROD-1	4/24/1989	13.5	7
ROD-1	4/24/1989	13.3	9
ROD-1	4/24/1989	13.1	11
ROD-1	4/24/1989	12.9	13
ROD-1	4/24/1989	12.8	15
ROD-1	4/24/1989	12.7	17
ROD-1	4/24/1989	12.5	19
ROD-1	4/24/1989	12.2	21
ROD-1	4/24/1989	12	23
ROD-1	4/24/1989	11.2	25
ROD-1	4/24/1989	10.3	27
ROD-1	4/24/1989	10	29
ROD-1	6/5/1989	23.9	0
ROD-1	6/5/1989	23.5	1
ROD-1	6/5/1989	23.2	3
ROD-1	6/5/1989	23.1	5
ROD-1	6/5/1989	22	7
ROD-1	6/5/1989	20.1	9
ROD-1	6/5/1989	17.6	11
ROD-1	6/5/1989	16.2	13
ROD-1	6/5/1989	24.1	15
ROD-1	6/5/1989	24.1	17
ROD-1	6/5/1989	24.1	19
ROD-1	6/5/1989	16.1	21
ROD-1	6/5/1989	15	23
ROD-1	6/5/1989	14	25
ROD-1	6/5/1989	13.6	27
ROD-1	6/5/1989	13.4	29
ROD-1	7/10/1989	15	0
ROD-1	7/10/1989	13.8	1
ROD-1	7/10/1989	13.5	3
ROD-1	7/10/1989	30.4	5
ROD-1	7/10/1989	30.4	7
ROD-1	7/10/1989	30.4	9
ROD-1	7/10/1989	30.1	11
ROD-1	7/10/1989	30.1	13
ROD-1	7/10/1989	30.2	15
ROD-1	7/10/1989	28.4	17
ROD-1	7/10/1989	26.8	19
ROD-1	7/10/1989	24.4	21
ROD-1	7/10/1989	22.4	23
ROD-1	7/10/1989	19.4	25
ROD-1	7/10/1989	17.5	27
ROD-1	7/10/1989	16.1	29
ROD-1	8/16/1989	26.2	0
ROD-1	8/16/1989	26.3	1

Depth	ROD-1 4/2	ROD-1 6/5/8
0	16.8	24.1
1	16.7	24.1
3	15.4	24.1
5	13.8	23.9
7	13.5	23.5
9	13.3	23.2
11	13.1	23.1
13	12.9	22
15	12.8	20.1
17	12.7	17.6
19	12.5	16.2
21	12.2	16.1
23	12	15
25	11.2	14
27	10.3	13.6
29	10	13.4

Depth	ROD-2 4/2	ROD-2 6/5/8
0	19.5	25.2
1	19.4	25.2
3	18.8	24.4
5	17.3	24
7	15.8	23.6
9	15.4	23.4
11	15	23.3
13	13.8	22.4
15	13.2	20.3
17	12.7	19.4
19	11.4	16.4
21	10.8	15.6
23	10.7	15.3
25	10.6	
27	10.6	
29		

Depth	ROD-3 4/2	ROD-3 6/5/8
0	19	25.6
1	18.9	25.5
3	18.9	25.4
5	18.6	24.9
7	17.1	24.7
9	16.7	24.6
11	15	24.3

ROD-1	8/16/1989	23.4	3	13	13.9	23.2
ROD-1	8/16/1989	21.4	5	15	13.8	22.5
ROD-1	8/16/1989	16.8	7			
ROD-1	8/16/1989	15.3	9			
ROD-1	8/16/1989	14.4	11			
ROD-1	8/16/1989	26.3	13			
ROD-1	8/16/1989	26.3	15			
ROD-1	8/16/1989	26.3	17			
ROD-1	8/16/1989	26.3	19			
ROD-1	8/16/1989	26.3	21			
ROD-1	8/16/1989	26.3	23			
ROD-1	8/16/1989	25.5	25			
ROD-1	8/16/1989	24.7	27			
ROD-1	10/12/1989	21	0			
ROD-1	10/12/1989	20.4	1			
ROD-1	10/12/1989	18.1	3			
ROD-1	10/12/1989	17.9	5			
ROD-1	10/12/1989	17.4	7			
ROD-1	10/12/1989	17.3	9			
ROD-1	10/12/1989	17.2	11			
ROD-1	10/12/1989	17.1	13			
ROD-1	10/12/1989	17.1	15			
ROD-1	10/12/1989	17.1	17			
ROD-1	10/12/1989	17.1	19			
ROD-1	10/12/1989	17.1	21			
ROD-1	10/12/1989	17	23			
ROD-1	10/12/1989	17	25			
ROD-1	10/12/1989	17	27			
ROD-1	10/12/1989	17	29			
ROD-1	4/7/1993	8.4	0			
ROD-1	4/7/1993	8.3	1			
ROD-1	4/7/1993	8.3	3			
ROD-1	4/7/1993	8.2	5			
ROD-1	4/7/1993	8.2	7			
ROD-1	4/7/1993	8.1	9			
ROD-1	4/7/1993	8.1	11			
ROD-1	4/7/1993	8.1	13			
ROD-1	4/7/1993	8.1	15			
ROD-1	4/7/1993	8.1	17			
ROD-1	4/7/1993	8.1	19			
ROD-1	4/7/1993	8.1	21			
ROD-1	4/7/1993	8.1	23			
ROD-1	4/7/1993	8.1	25			
ROD-1	4/7/1993	8.1	27			
ROD-1	6/24/1993	27.3	0			
ROD-1	6/24/1993	27.3	1			
ROD-1	6/24/1993	27.3	3			
ROD-1	6/24/1993	27.2	5			
ROD-1	6/24/1993	27.1	7			
ROD-1	6/24/1993	27.1	9			
ROD-1	6/24/1993	25.1	11			

ROD-1	6/24/1993	23.7	13
ROD-1	6/24/1993	21.6	15
ROD-1	6/24/1993	20.7	17
ROD-1	6/24/1993	19.3	19
ROD-1	6/24/1993	18.4	21
ROD-1	6/24/1993	17.3	23
ROD-1	6/24/1993	16.6	25
ROD-1	6/24/1993	15.9	27
ROD-1	7/20/1993	31.2	0
ROD-1	7/20/1993	31	1
ROD-1	7/20/1993	30.1	3
ROD-1	7/20/1993	29.4	5
ROD-1	7/20/1993	28.7	7
ROD-1	7/20/1993	28	9
ROD-1	7/20/1993	27.7	11
ROD-1	7/20/1993	27.4	13
ROD-1	7/20/1993	26.6	15
ROD-1	7/20/1993	25.9	17
ROD-1	7/20/1993	23.8	19
ROD-1	7/20/1993	20.1	21
ROD-1	7/20/1993	17.1	23
ROD-1	7/20/1993	16	25
ROD-1	7/20/1993	14.8	27
ROD-1	8/24/1993	30	0
ROD-1	8/24/1993	29.5	1
ROD-1	8/24/1993	28.6	3
ROD-1	8/24/1993	28.5	5
ROD-1	8/24/1993	28.4	7
ROD-1	8/24/1993	28.3	9
ROD-1	8/24/1993	28.1	11
ROD-1	8/24/1993	27.8	13
ROD-1	8/24/1993	27.2	15
ROD-1	8/24/1993	26.4	17
ROD-1	8/24/1993	24.5	19
ROD-1	8/24/1993	22.7	21
ROD-1	8/24/1993	20	23
ROD-1	8/24/1993	17.2	25
ROD-1	8/24/1993	16.2	27
ROD-1	10/19/1993	16	0
ROD-1	10/19/1993	16	1
ROD-1	10/19/1993	16	3
ROD-1	10/19/1993	16	5
ROD-1	10/19/1993	15.9	7
ROD-1	10/19/1993	15.9	9
ROD-1	10/19/1993	15.9	11
ROD-1	10/19/1993	15.9	13
ROD-1	10/19/1993	15.8	15
ROD-1	10/19/1993	15.7	17
ROD-1	10/19/1993	15.7	19
ROD-1	10/19/1993	15.6	21
ROD-1	10/19/1993	15.6	23

ROD-1	10/19/1993	15.5	25
ROD-1	10/19/1993	15.5	27
ROD-1	10/19/1993	15.5	29
ROD-1	5/9/1996	18.7	0
ROD-1	5/9/1996	18.4	1
ROD-1	5/9/1996	18.2	3
ROD-1	5/9/1996	18.1	5
ROD-1	5/9/1996	17.8	7
ROD-1	5/9/1996	17.2	9
ROD-1	5/9/1996	15.6	11
ROD-1	5/9/1996	15.2	13
ROD-1	5/9/1996	14.8	15
ROD-1	5/9/1996	13.9	17
ROD-1	5/9/1996	13.5	19
ROD-1	5/9/1996	13.3	21
ROD-1	5/9/1996	13.1	23
ROD-1	5/9/1996	12.9	25
ROD-1	5/9/1996	12.8	27
ROD-1	6/21/1996	26.2	0
ROD-1	6/21/1996	28.8	1
ROD-1	6/21/1996	27.1	3
ROD-1	6/21/1996	25.8	5
ROD-1	6/21/1996	24	7
ROD-1	6/21/1996	21.6	9
ROD-1	6/21/1996	20.5	11
ROD-1	6/21/1996	19.7	13
ROD-1	6/21/1996	19.1	15
ROD-1	6/21/1996	18.3	17
ROD-1	6/21/1996	16.6	19
ROD-1	6/21/1996	15.5	21
ROD-1	6/21/1996	14.6	23
ROD-1	6/21/1996	13.5	25
ROD-1	7/29/1996	26.2	0
ROD-1	7/29/1996	27	1
ROD-1	7/29/1996	27	3
ROD-1	7/29/1996	27	5
ROD-1	7/29/1996	27	7
ROD-1	7/29/1996	27	9
ROD-1	7/29/1996	25.9	11
ROD-1	7/29/1996	25.1	13
ROD-1	7/29/1996	24.2	15
ROD-1	7/29/1996	20.1	17
ROD-1	7/29/1996	17.3	19
ROD-1	7/29/1996	15.8	21
ROD-1	7/29/1996	14.6	23
ROD-1	7/29/1996	14	25
ROD-1	7/29/1996	13.5	27
ROD-1	8/23/1996	31.3	0
ROD-1	8/23/1996	30	1
ROD-1	8/23/1996	29.5	3
ROD-1	8/23/1996	29.1	5

ROD-1	8/23/1996	28.1	7
ROD-1	8/23/1996	27	9
ROD-1	8/23/1996	26.2	11
ROD-1	8/23/1996	25.9	13
ROD-1	8/23/1996	25.3	15
ROD-1	8/23/1996	23.7	17
ROD-1	8/23/1996	20	19
ROD-1	8/23/1996	17	21
ROD-1	8/23/1996	16	23
ROD-1	8/23/1996	15.1	25
ROD-1	8/23/1996	14.6	27
ROD-1	10/4/1996	18.2	0
ROD-1	10/4/1996	18	1
ROD-1	10/4/1996	18	3
ROD-1	10/4/1996	17.6	5
ROD-1	10/4/1996	16.7	7
ROD-1	10/4/1996	18.4	9
ROD-1	10/4/1996	18.4	11
ROD-1	10/4/1996	18.4	13
ROD-1	10/4/1996	18.3	15
ROD-1	10/4/1996	18.3	17
ROD-1	10/4/1996	18.2	19
ROD-1	10/4/1996	18.2	21
ROD-1	10/4/1996	18.2	23
ROD-1	10/4/1996	18.2	25
ROD-1	10/4/1996	18.2	27
ROD-1	5/12/1999	21.7	0
ROD-1	5/12/1999	21.1	1
ROD-1	5/12/1999	20	3
ROD-1	5/12/1999	19.6	5
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ROD-1	5/12/1999	19	11
ROD-1	5/12/1999	18.6	13
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ROD-1	5/12/1999	17.2	17
ROD-1	5/12/1999	16.2	19
ROD-1	5/12/1999	16.2	21
ROD-1	5/12/1999	15.4	23
ROD-1	5/12/1999	13.4	25
ROD-1	5/12/1999	12.2	27
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ROD-1	6/11/1999	21.7	13
ROD-1	6/11/1999	20.4	15
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ROD-1	6/11/1999	18.2	19
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ROD-1	6/11/1999	13.3	27
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ROD-3	6/11/1999	24.5	9
ROD-3	6/11/1999	22.7	11
ROD-3	6/11/1999	22.1	12
ROD-3	7/15/1999	27.9	0
ROD-3	7/15/1999	27.6	1
ROD-3	7/15/1999	27.4	3
ROD-3	7/15/1999	27.4	5
ROD-3	7/15/1999	27	7
ROD-3	7/15/1999	26.9	9
ROD-3	7/15/1999	26.2	11
ROD-3	7/15/1999	26	12
ROD-3	8/26/1999	26.6	0
ROD-3	8/26/1999	26.6	1
ROD-3	8/26/1999	26.3	3
ROD-3	8/26/1999	25.8	5
ROD-3	8/26/1999	25.1	7
ROD-3	8/26/1999	25	9
ROD-3	8/26/1999	25	11
ROD-3	8/26/1999	25	12
ROD-3	10/26/1999	14.8	0
ROD-3	10/26/1999	14.1	1
ROD-3	10/26/1999	13.2	3
ROD-3	10/26/1999	13	5

ROD-3	10/26/1999	12.8	7
ROD-3	10/26/1999	12.6	9
ROD-3	10/26/1999	12.6	11

ROD-1 7/1(	ROD-1 8/1(	ROD-1 10/	ROD-1 4/7	ROD-1 6/2	ROD-1 7/2(	ROD-1 8/2	ROD-1 10/	ROD-1 5/9
30.4	26.3	21	8.4	27.3	31.2	30	16	18.7
30.4	26.3	20.4	8.3	27.3	31	29.5	16	18.4
30.4	26.3	18.1	8.3	27.3	30.1	28.6	16	18.2
30.2	26.3	17.9	8.2	27.2	29.4	28.5	16	18.1
30.1	26.3	17.4	8.2	27.1	28.7	28.4	15.9	17.8
30.1	26.3	17.3	8.1	27.1	28	28.3	15.9	17.2
28.4	26.3	17.2	8.1	25.1	27.7	28.1	15.9	15.6
26.8	26.2	17.1	8.1	23.7	27.4	27.8	15.9	15.2
24.4	25.5	17.1	8.1	21.6	26.6	27.2	15.8	14.8
22.4	24.7	17.1	8.1	20.7	25.9	26.4	15.7	13.9
19.4	23.4	17.1	8.1	19.3	23.8	24.5	15.7	13.5
17.5	21.4	17.1	8.1	18.4	20.1	22.7	15.6	13.3
16.1	16.8	17	8.1	17.3	17.1	20	15.6	13.1
15	15.3	17	8.1	16.6	16	17.2	15.5	12.9
13.8	14.4	17	8.1	15.9	14.8	16.2	15.5	12.8
13.5		17					15.5	

ROD-2 7/1(	ROD-2 8/1(	ROD-2 10/	ROD-2 4/7	ROD-2 6/2	ROD-2 7/2(	ROD-2 8/2	ROD-2 10/	ROD-2 5/9
29.8	26.1	19.3	9	28	31.9	30.2	16	17.5
29.8	26.1	18.8	8.9	28	31.8	30.2	16	17.3
29.8	26.1	17.7	8.9	28	30.1	28.8	16	17.2
29.6	26	17.4	8.8	28	29.7	28.4	16	17.2
29.4	26	17.3	8.8	27.8	29.3	28.3	16	17.2
29.2	26	17.2	8.8	27.5	28.8	28.2	15.9	17.2
27	26	17	8.8	25.8	27.8	27.9	15.9	17
25.4	26	17	8.8	22.8	26.6	27.6	15.9	16
23.8	25.8	16.7	8.8	21.1	26	27.2	15.9	15
22.2	24.5	16.7	8.8	19.8	25.2	25.5	15.9	14.3
20.6	22.6	16.7	8.8	18.6	23.2	24	15.9	13.4
20	19.4	16.7	8.8	17.7	20.1	22.5	15.9	13.3
	17.1	16.7		17.2	18.5	21.3	15.9	
		16.7						

ROD-3 7/1(	ROD-3 8/1(	ROD-3 10/	ROD-3 4/7	ROD-3 6/2	ROD-3 7/2(	ROD-3 8/2	ROD-3 10/	ROD-3 5/9
29.9	25.8	20.9	10	27.8	31.4	30	16	17.6
29.5	25.8	20.6	10	27.8	31.3	30	16	17.5
28.3	25.8	17.4	10	27.8	31.1	28.1	16	17.4
27.9	25.7	16.9	9.9	27.8	29.5	27.8	15.9	16.7
27.6	25.7	16.6	9.9	27.3	29.3	27.8	15.9	16.2
27	25.7	16.5	9.9	26.2	28.9	27.6	15.9	15.2
25.8	25.6	16.5	9.8	25	28.4	27.5	15.9	14.8

23.2	25.6	16.5	9.3	22	27.2	27.2	15.9	14.8

ROD-1 6/2	ROD-1 7/2	ROD-1 8/2	ROD-1 10/	Depth	ROD-1 5/1	Depth	ROD-1 6/1	Depth
28.8	27	31.3	18.4	0	21.7	0	30.7	0
27.1	27	30	18.4	1	21.1	1	30.2	1
26.2	27	29.5	18.4	3	20	3	29.3	3
25.8	27	29.1	18.3	5	19.6	5	27.6	5
24	27	28.1	18.3	7	19.5	7	26.3	7
21.6	26.2	27	18.2	9	19.3	9	25.2	9
20.5	25.9	26.2	18.2	11	19	11	23.8	11
19.7	25.1	25.9	18.2	13	18.6	13	21.7	13
19.1	24.2	25.3	18.2	15	18	15	20.4	15
18.3	20.1	23.7	18.2	17	17.2	17	19.6	17
16.6	17.3	20	18.2	19	16.2	19	18.2	19
15.5	15.8	17	18	21	16.2	21	17.6	21
14.6	14.6	16	18	23	15.4	23	16.7	23
13.5	14	15.1	17.6	25	13.4	25	14.6	25
	13.5	14.6	16.7	27	12.2	27	13.3	27

ROD-2 6/2	ROD-2 7/2	ROD-2 8/2	ROD-2 10/	Depth	ROD-2 5/1	Depth	ROD-2 6/1	Depth
29	26.7	30.4	18.4	0	22.6	0	30.7	0
28.6	26.7	30.3	18.4	1	22.5	1	30.3	1
27.9	26.7	29.3	18.4	3	22	3	29	3
26.2	26.4	28.5	18.4	5	20.7	5	28.2	5
25.2	26.1	27.9	18.3	7	19.9	7	27.2	7
22.6	25.6	27.2	18.2	9	19.2	9	25.1	9
21.1	24.6	26.5	18.2	11	18.6	11	23.2	11
20.2	24.4	25.7	18.2	13	18	13	21.3	13
19.3	23.5	24.6	18.2	15	17.7	15	20.2	15
17.8	20.6	22.5	18.1	17	17.4	17	19.5	17
15.9	17.6	20.2	18	19	16.8	19	18.4	19
15.2	16.2	19.4		21	16.3	21	17.5	21
	15.6							

ROD-3 6/2	ROD-3 7/2	ROD-3 8/2	ROD-3 10/	Depth	ROD-3 5/1	Depth	ROD-3 6/1	Depth
29.6	23.4	30	18	0	21.1	0	30	0
27.2	26.8	29.7	18	1	22.8	1	29.8	1
26	26.8	28.9	18	3	21.7	3	28.7	3
25.9	26.5	28.5	18	5	20.7	5	28.1	5
24.7	26.2	28.1	17.8	7	19.8	7	26.5	7
22.7	25.8	27.1	17.7	9	19.1	9	24.5	9
20.8	25.2	26.4	17.5	11	18.6	11	22.7	11

20.3	25	26	12.5	18.1	12	22.1	12

ROD-1 7/1	Depth	ROD-1 8/2	Depth	ROD-1 10/26/99
27.9	0	26.5	0	15
27.9	1	26.5	1	14.5
27.9	3	26.5	3	14.1
27.7	5	26.3	5	13.9
26.8	7	26.1	7	13.8
26.3	9	25.6	9	13.8
26	11	25.4	11	13.8
25.4	13	25.2	13	13.8
23.8	15	24.9	15	13.8
20.6	17	24.8	17	13.7
19	19	23.6	19	13.7
17.7	21	18.9	21	13.7
16.3	23	16.8	23	13.6
14.9	25	15.5	25	13.6
14	26	15.2	26	13.6

ROD-2 7/1	Depth	ROD-2 8/2	Depth	ROD-2 10/26/99
28.3	0	26.6	0	16
28.2	1	26.5	1	15.5
28.2	3	25.6	3	14.1
27.9	5	25.4	5	13.8
27.8	7	25.3	7	13.8
26.9	9	25.2	9	13.7
26.2	11	25.2	11	13.6
25.4	13	25.1	13	13.5
23.5	15	24.8	15	13.4
21.3	17	24.6	17	13.4
18.9	19	22.2	19	13.2
17.4	21	20	20	13.2
	22	18.3		

ROD-3 7/1	Depth	ROD-3 8/2	Depth	ROD-3 10/26/99
27.9	0	26.6	0	14.8
27.6	1	26.6	1	14.1
27.4	3	26.3	3	13.2
27.4	5	25.8	5	13
27	7	25.1	7	12.8
26.9	9	25	9	12.6
26.2	11	25	11	12.6

26 12 25

Appendix G
Sensitivity Analysis – BATHTUB Output Files

G.1 BATHTUB Sensitivity

This appendix provides the BATHTUB output files for the soil phosphorus and dairy concentration sensitivity analysis. For each modeled year, the BATHTUB model was run with soil phosphorus values of 616 ppm and 792 ppm. The output concentrations from BATHTUB were not calibrated so that the raw model results could be compared.

BATHTUB Output for 1993 Sensitivity Analysis
Constant Sediment Phosphorus Concentration of 616 mg/kg

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CASE: Vandalia 1993 - No Calibration, Sed 616

 T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
 USING THE FOLLOWING ERROR TERMS:
  1 = OBSERVED WATER QUALITY ERROR ONLY
  2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
  3 = OBSERVED AND PREDICTED ERROR

 SEGMENT:  1 Upper Pool
                      OBSERVED     ESTIMATED                T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 ---------------------------------------------------------------------------
 TOTAL P    MG/M3    93.2   .43    93.0   .45    1.00    .00    .01    .00
 CHL-A      MG/M3    22.4   .31    35.7   .44     .63  -1.52  -1.35   -.86
 SECCHI         M      .5   .36      .4   .31    1.18    .45    .58    .34
 ORGANIC N  MG/M3      .0   .00  1072.0   .34     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    91.1   .33     .00    .00    .00    .00
 ---------------------------------------------------------------------------

 SEGMENT:  2 Mid Pool
                      OBSERVED     ESTIMATED                T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 ---------------------------------------------------------------------------
 TOTAL P    MG/M3    76.0   .59    59.4   .45    1.28    .42    .91    .33
 CHL-A      MG/M3    21.2   .47    12.7   .45    1.67   1.09   1.48    .79
 SECCHI         M      .6   .31      .7   .36     .86   -.47   -.53   -.31
 ORGANIC N  MG/M3      .0   .00   524.5   .25     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    42.8   .30     .00    .00    .00    .00
 ---------------------------------------------------------------------------

 SEGMENT:  3 Near Dam
                      OBSERVED     ESTIMATED                T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 ---------------------------------------------------------------------------
 TOTAL P    MG/M3   150.4   .94    51.2   .46    2.94   1.15   4.01   1.03
 CHL-A      MG/M3    20.4   .66    10.4   .48    1.96   1.02   1.94    .82
 SECCHI         M      .7   .31      .9   .42     .82   -.65   -.71   -.38
 ORGANIC N  MG/M3      .0   .00   459.5   .24     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    35.1   .33     .00    .00    .00    .00
 ---------------------------------------------------------------------------

 SEGMENT:  4 AREA-WTD MEAN
                      OBSERVED     ESTIMATED                T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 ---------------------------------------------------------------------------
 TOTAL P    MG/M3   103.7   .63    75.9   .45    1.37    .49   1.16    .40
 CHL-A      MG/M3    21.7   .42    24.8   .43     .87   -.32   -.39   -.23
 SECCHI         M      .6   .33      .6   .24     .97   -.08   -.10   -.06
 ORGANIC N  MG/M3      .0   .00   810.3   .31     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    67.5   .31     .00    .00    .00    .00
 ---------------------------------------------------------------------------
```

CASE: Vandalia 1993 - No Calibration, Sed 616

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	17.660	8.568	.000E+00	.000	.485
2	1	Subbasin 2	6.270	2.921	.000E+00	.000	.466
3	1	Subbasin 3	10.930	5.302	.000E+00	.000	.485
4	1	Subbasin 4	8.990	4.144	.000E+00	.000	.461
5	1	Subbasin 5	9.970	4.867	.000E+00	.000	.488
6	1	Subbasin 6	3.080	1.697	.000E+00	.000	.551
7	1	Subbasin 7	4.060	2.046	.000E+00	.000	.504
PRECIPITATION			2.671	3.739	.559E+00	.200	1.400
TRIBUTARY INFLOW			60.960	29.545	.000E+00	.000	.485
***TOTAL INFLOW			63.631	33.284	.559E+00	.022	.523
ADVECTIVE OUTFLOW			63.631	31.035	.101E+01	.032	.488
***TOTAL OUTFLOW			63.631	31.035	.101E+01	.032	.488
***EVAPORATION			.000	2.249	.455E+00	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	2400.3	29.0	.000E+00	.0	.000	280.1	135.9
2	1	Subbasin 2	1000.1	12.1	.000E+00	.0	.000	342.4	159.5
3	1	Subbasin 3	1800.4	21.7	.000E+00	.0	.000	339.6	164.7
4	1	Subbasin 4	1100.2	13.3	.000E+00	.0	.000	265.5	122.4
5	1	Subbasin 5	1400.3	16.9	.000E+00	.0	.000	287.7	140.4
6	1	Subbasin 6	200.0	2.4	.000E+00	.0	.000	117.8	64.9
7	1	Subbasin 7	300.0	3.6	.000E+00	.0	.000	146.6	73.9
PRECIPITATION			80.1	1.0	.161E+04	100.0	.500	21.4	30.0
TRIBUTARY INFLOW			8201.2	99.0	.000E+00	.0	.000	277.6	134.5
***TOTAL INFLOW			8281.3	100.0	.161E+04	100.0	.005	248.8	130.1
ADVECTIVE OUTFLOW			1589.1	19.2	.543E+06	33789.6	.464	51.2	25.0
***TOTAL OUTFLOW			1589.1	19.2	.543E+06	33789.6	.464	51.2	25.0
***RETENTION			6692.3	80.8	.544E+06	33859.7	.110	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
11.62	.5183	103.7	.2014	4.9658	.8081

1993 – *Constant Sediment Phosphorus Concentration of 792 mg/kg*

CASE: Vandalia 1994; Sed 792; No Calib

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	93.2	.43	97.5	.45	.96	-.11	-.17	-.07
CHL-A	MG/M3	22.4	.31	36.9	.44	.61	-1.63	-1.45	-.94
SECCHI	M	.5	.36	.4	.30	1.19	.49	.63	.37
ORGANIC N	MG/M3	.0	.00	1099.5	.34	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	93.3	.33	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	76.0	.59	62.3	.45	1.22	.34	.74	.27
CHL-A	MG/M3	21.2	.47	13.1	.45	1.62	1.03	1.40	.75
SECCHI	M	.6	.31	.7	.36	.87	-.45	-.50	-.29
ORGANIC N	MG/M3	.0	.00	532.6	.25	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	43.5	.30	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	150.4	.94	53.2	.46	2.83	1.11	3.86	1.00
CHL-A	MG/M3	20.4	.66	10.6	.48	1.91	.99	1.88	.80
SECCHI	M	.7	.31	.9	.42	.82	-.63	-.69	-.37
ORGANIC N	MG/M3	.0	.00	465.1	.24	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	35.5	.32	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	103.7	.63	79.5	.45	1.30	.42	.99	.34
CHL-A	MG/M3	21.7	.42	25.6	.42	.85	-.40	-.49	-.28
SECCHI	M	.6	.33	.6	.24	.98	-.05	-.06	-.04
ORGANIC N	MG/M3	.0	.00	828.5	.31	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	69.0	.31	.00	.00	.00	.00

CASE: Vandalia 1994; Sed 792; No Calib
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	17.660	8.568	.000E+00	.000	.485
2	1	Subbasin 2	6.270	2.921	.000E+00	.000	.466
3	1	Subbasin 3	10.930	5.302	.000E+00	.000	.485
4	1	Subbasin 4	8.990	4.144	.000E+00	.000	.461
5	1	Subbasin 5	9.970	4.867	.000E+00	.000	.488
6	1	Subbasin 6	3.080	1.697	.000E+00	.000	.551
7	1	Subbasin 7	4.060	2.046	.000E+00	.000	.504
PRECIPITATION			2.671	3.739	.559E+00	.200	1.400
TRIBUTARY INFLOW			60.960	29.545	.000E+00	.000	.485
***TOTAL INFLOW			63.631	33.284	.559E+00	.022	.523
ADVECTIVE OUTFLOW			63.631	31.035	.101E+01	.032	.488
***TOTAL OUTFLOW			63.631	31.035	.101E+01	.032	.488
***EVAPORATION			.000	2.249	.455E+00	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	2600.4	29.0	.000E+00	.0	.000	303.5	147.2
2	1	Subbasin 2	1000.2	11.1	.000E+00	.0	.000	342.4	159.5
3	1	Subbasin 3	1900.2	21.2	.000E+00	.0	.000	358.4	173.9
4	1	Subbasin 4	1300.4	14.5	.000E+00	.0	.000	313.8	144.6
5	1	Subbasin 5	1500.5	16.7	.000E+00	.0	.000	308.3	150.5
6	1	Subbasin 6	300.0	3.3	.000E+00	.0	.000	176.8	97.4
7	1	Subbasin 7	299.9	3.3	.000E+00	.0	.000	146.6	73.9
PRECIPITATION			80.1	.9	.161E+04	100.0	.500	21.4	30.0
TRIBUTARY INFLOW			8901.6	99.1	.000E+00	.0	.000	301.3	146.0
***TOTAL INFLOW			8981.8	100.0	.161E+04	100.0	.004	269.8	141.2
ADVECTIVE OUTFLOW			1651.1	18.4	.587E+06	36536.3	.464	53.2	25.9
***TOTAL OUTFLOW			1651.1	18.4	.587E+06	36536.3	.464	53.2	25.9
***RETENTION			7330.6	81.6	.588E+06	36606.6	.105	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
11.62	.5183	103.7	.1857	5.3858	.8162

BATHTUB Output for 1996 Sensitivity Analysis

Constant Sediment Phosphorus Concentration of 616 mg/kg

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CASE: Vandalia 1996 - No Calibration, Sed 616

 T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
 USING THE FOLLOWING ERROR TERMS:
  1 = OBSERVED WATER QUALITY ERROR ONLY
  2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
  3 = OBSERVED AND PREDICTED ERROR

 SEGMENT:  1 Upper Pool
                      OBSERVED     ESTIMATED                T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 ---------------------------------------------------------------------------
 TOTAL P    MG/M3   138.0   .75    92.5   .45    1.49    .53   1.49    .46
 CHL-A      MG/M3    23.3   .66    26.8   .48     .87   -.21   -.41   -.17
 SECCHI         M      .4   .46      .4   .41    1.03    .07    .12    .05
 ORGANIC N  MG/M3      .0   .00   920.2   .30     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    91.4   .31     .00    .00    .00    .00
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 SEGMENT:  2 Mid Pool
                      OBSERVED     ESTIMATED                T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 ---------------------------------------------------------------------------
 TOTAL P    MG/M3   120.2   .80    58.5   .45    2.05    .90   2.68    .79
 CHL-A      MG/M3    18.4   .66    13.5   .54    1.37    .47    .90    .37
 SECCHI         M      .5   .49      .5   .49     .94   -.12   -.21   -.08
 ORGANIC N  MG/M3      .0   .00   594.0   .25     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    60.7   .37     .00    .00    .00    .00
 ---------------------------------------------------------------------------

 SEGMENT:  3 Near Dam
                      OBSERVED     ESTIMATED                T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 ---------------------------------------------------------------------------
 TOTAL P    MG/M3   221.0   .87    49.9   .46    4.42   1.71   5.53   1.51
 CHL-A      MG/M3    26.6   .94    10.8   .62    2.47    .96   2.61    .80
 SECCHI         M      .5   .51      .6   .65     .82   -.39   -.71   -.24
 ORGANIC N  MG/M3      .0   .00   518.8   .24     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    51.5   .48     .00    .00    .00    .00
 ---------------------------------------------------------------------------

 SEGMENT:  4 AREA-WTD MEAN
                      OBSERVED     ESTIMATED                T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 ---------------------------------------------------------------------------
 TOTAL P    MG/M3   154.7   .80    75.2   .45    2.06    .90   2.68    .79
 CHL-A      MG/M3    23.1   .74    20.2   .46    1.15    .18    .39    .16
 SECCHI         M      .4   .48      .4   .31     .95   -.11   -.19   -.09
 ORGANIC N  MG/M3      .0   .00   755.4   .28     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    75.4   .28     .00    .00    .00    .00
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CASE: Vandalia 1996 - No Calibration, Sed 616

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	17.660	5.777	.000E+00	.000	.327
2	1	Subbasin 2	6.270	1.981	.000E+00	.000	.316
3	1	Subbasin 3	10.930	3.607	.000E+00	.000	.330
4	1	Subbasin 4	8.990	2.741	.000E+00	.000	.305
5	1	Subbasin 5	9.970	3.261	.000E+00	.000	.327
6	1	Subbasin 6	3.080	1.201	.000E+00	.000	.390
7	1	Subbasin 7	4.060	1.106	.000E+00	.000	.272
PRECIPITATION			2.671	2.751	.303E+00	.200	1.030
TRIBUTARY INFLOW			60.960	19.674	.000E+00	.000	.323
***TOTAL INFLOW			63.631	22.425	.303E+00	.025	.352
ADVECTIVE OUTFLOW			63.631	20.176	.758E+00	.043	.317
***TOTAL OUTFLOW			63.631	20.176	.758E+00	.043	.317
***EVAPORATION			.000	2.249	.455E+00	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	1800.3	30.1	.000E+00	.0	.000	311.6	101.9
2	1	Subbasin 2	600.1	10.0	.000E+00	.0	.000	302.9	95.7
3	1	Subbasin 3	1200.1	20.1	.000E+00	.0	.000	332.7	109.8
4	1	Subbasin 4	900.0	15.0	.000E+00	.0	.000	328.3	100.1
5	1	Subbasin 5	1000.1	16.7	.000E+00	.0	.000	306.7	100.3
6	1	Subbasin 6	200.0	3.3	.000E+00	.0	.000	166.5	64.9
7	1	Subbasin 7	200.1	3.3	.000E+00	.0	.000	180.9	49.3
PRECIPITATION			80.1	1.3	.161E+04	100.0	.500	29.1	30.0
TRIBUTARY INFLOW			5900.6	98.7	.000E+00	.0	.000	299.9	96.8
***TOTAL INFLOW			5980.7	100.0	.161E+04	100.0	.007	266.7	94.0
ADVECTIVE OUTFLOW			1007.8	16.9	.219E+06	13658.7	.465	49.9	15.8
***TOTAL OUTFLOW			1007.8	16.9	.219E+06	13658.7	.465	49.9	15.8
***RETENTION			4972.9	83.1	.220E+06	13731.2	.094	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.55	.7776	154.7	.4057	2.4649	.8315

1996 - *Constant Sediment Phosphorus Concentration of 792 mg/kg*

CASE: Vandalia 1996; Sed 792; No Calib

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	138.0	.75	96.6	.45	1.43	.47	1.33	.41
CHL-A	MG/M3	23.3	.66	27.6	.48	.84	-.26	-.49	-.21
SECCHI	M	.4	.46	.4	.41	1.04	.09	.14	.07
ORGANIC N	MG/M3	.0	.00	937.8	.30	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	92.8	.31	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	120.2	.80	60.9	.45	1.98	.85	2.53	.74
CHL-A	MG/M3	18.4	.66	13.9	.53	1.33	.43	.82	.33
SECCHI	M	.5	.49	.5	.49	.95	-.11	-.19	-.08
ORGANIC N	MG/M3	.0	.00	602.8	.25	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	61.4	.37	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	221.0	.87	52.4	.46	4.22	1.66	5.35	1.46
CHL-A	MG/M3	26.6	.94	11.2	.62	2.38	.92	2.51	.77
SECCHI	M	.5	.51	.6	.64	.82	-.38	-.69	-.23
ORGANIC N	MG/M3	.0	.00	527.6	.24	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	52.2	.47	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	154.7	.80	78.5	.45	1.97	.85	2.52	.74
CHL-A	MG/M3	23.1	.74	20.8	.45	1.11	.14	.31	.12
SECCHI	M	.4	.48	.4	.31	.95	-.10	-.17	-.08
ORGANIC N	MG/M3	.0	.00	769.0	.28	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	76.4	.28	.00	.00	.00	.00

CASE: Vandalia 1996; Sed 792; No Calib
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	17.660	5.777	.000E+00	.000	.327
2	1	Subbasin 2	6.270	1.981	.000E+00	.000	.316
3	1	Subbasin 3	10.930	3.607	.000E+00	.000	.330
4	1	Subbasin 4	8.990	2.741	.000E+00	.000	.305
5	1	Subbasin 5	9.970	3.261	.000E+00	.000	.327
6	1	Subbasin 6	3.080	1.201	.000E+00	.000	.390
7	1	Subbasin 7	4.060	1.106	.000E+00	.000	.272
PRECIPITATION			2.671	2.751	.303E+00	.200	1.030
TRIBUTARY INFLOW			60.960	19.674	.000E+00	.000	.323
***TOTAL INFLOW			63.631	22.425	.303E+00	.025	.352
ADVECTIVE OUTFLOW			63.631	20.176	.758E+00	.043	.317
***TOTAL OUTFLOW			63.631	20.176	.758E+00	.043	.317
***EVAPORATION			.000	2.249	.455E+00	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	1900.1	29.3	.000E+00	.0	.000	328.9	107.6
2	1	Subbasin 2	800.1	12.3	.000E+00	.0	.000	403.9	127.6
3	1	Subbasin 3	1200.0	18.5	.000E+00	.0	.000	332.7	109.8
4	1	Subbasin 4	999.9	15.4	.000E+00	.0	.000	364.8	111.2
5	1	Subbasin 5	1000.1	15.4	.000E+00	.0	.000	306.7	100.3
6	1	Subbasin 6	200.0	3.1	.000E+00	.0	.000	166.5	64.9
7	1	Subbasin 7	300.1	4.6	.000E+00	.0	.000	271.3	73.9
PRECIPITATION			80.1	1.2	.161E+04	100.0	.500	29.1	30.0
TRIBUTARY INFLOW			6400.3	98.8	.000E+00	.0	.000	325.3	105.0
***TOTAL INFLOW			6480.4	100.0	.161E+04	100.0	.006	289.0	101.8
ADVECTIVE OUTFLOW			1057.4	16.3	.240E+06	14973.4	.464	52.4	16.6
***TOTAL OUTFLOW			1057.4	16.3	.240E+06	14973.4	.464	52.4	16.6
***RETENTION			5423.1	83.7	.242E+06	15047.4	.091	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.55	.7776	154.7	.3744	2.6708	.8368

BATHTUB Output for 1999 Sensitivity Analysis
Constant Sediment Phosphorus Concentration of 616 mg/kg

CASE: Vandalia 1999 - No Calibration, Sed 616

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	66.4	.63	94.6	.45	.70	-.56	-1.31	-.45
CHL-A	MG/M3	45.3	.37	33.0	.46	1.37	.86	.91	.54
SECCHI	M	.4	.32	.5	.37	.87	-.43	-.49	-.28
ORGANIC N	MG/M3	.0	.00	1003.6	.34	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	84.0	.32	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	42.8	.59	58.8	.45	.73	-.54	-1.18	-.43
CHL-A	MG/M3	37.0	.38	14.2	.50	2.60	2.53	2.76	1.53
SECCHI	M	.5	.32	.8	.46	.70	-1.14	-1.29	-.65
ORGANIC N	MG/M3	.0	.00	552.9	.27	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	43.8	.33	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	173.0	2.10	49.8	.47	3.47	.59	4.63	.58
CHL-A	MG/M3	31.7	.51	11.7	.53	2.71	1.94	2.88	1.36
SECCHI	M	.6	.32	.8	.48	.72	-1.03	-1.18	-.57
ORGANIC N	MG/M3	.0	.00	498.3	.26	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	40.2	.36	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	87.6	1.34	76.3	.45	1.15	.10	.51	.10
CHL-A	MG/M3	40.3	.40	24.0	.43	1.68	1.30	1.50	.88
SECCHI	M	.5	.32	.6	.28	.78	-.78	-.89	-.59
ORGANIC N	MG/M3	.0	.00	787.9	.31	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	65.1	.31	.00	.00	.00	.00

CASE: Vandalia 1999 - No Calibration, Sed 616

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	17.660	5.459	.000E+00	.000	.309
2	1	Subbasin 2	6.270	1.868	.000E+00	.000	.298
3	1	Subbasin 3	10.930	3.389	.000E+00	.000	.310
4	1	Subbasin 4	8.990	2.616	.000E+00	.000	.291
5	1	Subbasin 5	9.970	3.082	.000E+00	.000	.309
6	1	Subbasin 6	3.080	1.167	.000E+00	.000	.379
7	1	Subbasin 7	4.060	1.425	.000E+00	.000	.351
PRECIPITATION			2.671	2.778	.309E+00	.200	1.040
TRIBUTARY INFLOW			60.960	19.006	.000E+00	.000	.312
***TOTAL INFLOW			63.631	21.784	.309E+00	.026	.342
ADVECTIVE OUTFLOW			63.631	19.535	.764E+00	.045	.307
***TOTAL OUTFLOW			63.631	19.535	.764E+00	.045	.307
***EVAPORATION			.000	2.249	.455E+00	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	1700.3	28.4	.000E+00	.0	.000	311.5	96.3
2	1	Subbasin 2	800.1	13.4	.000E+00	.0	.000	428.3	127.6
3	1	Subbasin 3	1200.3	20.1	.000E+00	.0	.000	354.2	109.8
4	1	Subbasin 4	900.2	15.1	.000E+00	.0	.000	344.1	100.1
5	1	Subbasin 5	900.2	15.1	.000E+00	.0	.000	292.1	90.3
6	1	Subbasin 6	199.9	3.3	.000E+00	.0	.000	171.3	64.9
7	1	Subbasin 7	200.0	3.3	.000E+00	.0	.000	140.3	49.3
PRECIPITATION			80.1	1.3	.161E+04	100.0	.500	28.8	30.0
TRIBUTARY INFLOW			5901.1	98.7	.000E+00	.0	.000	310.5	96.8
***TOTAL INFLOW			5981.2	100.0	.161E+04	100.0	.007	274.6	94.0
ADVECTIVE OUTFLOW			972.8	16.3	.205E+06	12788.4	.466	49.8	15.3
***TOTAL OUTFLOW			972.8	16.3	.205E+06	12788.4	.466	49.8	15.3
***RETENTION			5008.4	83.7	.206E+06	12861.8	.091	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.31	.8041	87.6	.2301	4.3451	.8374

1999 - *Constant Sediment Phosphorus Concentration of 792 mg/kg*

CASE: Vandalia 1999; Sed 792; No Calib

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	66.4	.63	101.7	.45	.65	-.67	-1.58	-.55
CHL-A	MG/M3	45.3	.37	34.6	.45	1.31	.73	.78	.46
SECCHI	M	.4	.32	.5	.36	.89	-.37	-.43	-.25
ORGANIC N	MG/M3	.0	.00	1039.2	.33	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	86.8	.32	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	42.8	.59	62.4	.45	.69	-.64	-1.40	-.51
CHL-A	MG/M3	37.0	.38	14.7	.49	2.51	2.43	2.66	1.48
SECCHI	M	.5	.32	.8	.45	.70	-1.11	-1.25	-.64
ORGANIC N	MG/M3	.0	.00	565.0	.27	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	44.7	.32	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	173.0	2.10	53.1	.46	3.26	.56	4.39	.55
CHL-A	MG/M3	31.7	.51	12.2	.52	2.60	1.86	2.76	1.31
SECCHI	M	.6	.32	.8	.48	.73	-1.00	-1.14	-.56
ORGANIC N	MG/M3	.0	.00	510.2	.26	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	41.1	.35	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	87.6	1.34	81.7	.45	1.07	.05	.26	.05
CHL-A	MG/M3	40.3	.40	25.1	.42	1.61	1.19	1.37	.81
SECCHI	M	.5	.32	.6	.27	.79	-.73	-.84	-.56
ORGANIC N	MG/M3	.0	.00	812.9	.31	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	67.0	.30	.00	.00	.00	.00

CASE: Vandalia 1999; Sed 792; No Calib
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	17.660	5.459	.000E+00	.000	.309
2	1	Subbasin 2	6.270	1.868	.000E+00	.000	.298
3	1	Subbasin 3	10.930	3.389	.000E+00	.000	.310
4	1	Subbasin 4	8.990	2.616	.000E+00	.000	.291
5	1	Subbasin 5	9.970	3.082	.000E+00	.000	.309
6	1	Subbasin 6	3.080	1.167	.000E+00	.000	.379
7	1	Subbasin 7	4.060	1.425	.000E+00	.000	.351
PRECIPITATION			2.671	2.778	.309E+00	.200	1.040
TRIBUTARY INFLOW			60.960	19.006	.000E+00	.000	.312
***TOTAL INFLOW			63.631	21.784	.309E+00	.026	.342
ADVECTIVE OUTFLOW			63.631	19.535	.764E+00	.045	.307
***TOTAL OUTFLOW			63.631	19.535	.764E+00	.045	.307
***EVAPORATION			.000	2.249	.455E+00	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	2000.2	29.5	.000E+00	.0	.000	366.4	113.3
2	1	Subbasin 2	900.2	13.3	.000E+00	.0	.000	481.9	143.6
3	1	Subbasin 3	1400.3	20.6	.000E+00	.0	.000	413.2	128.1
4	1	Subbasin 4	900.2	13.3	.000E+00	.0	.000	344.1	100.1
5	1	Subbasin 5	1000.4	14.8	.000E+00	.0	.000	324.6	100.3
6	1	Subbasin 6	199.9	2.9	.000E+00	.0	.000	171.3	64.9
7	1	Subbasin 7	300.0	4.4	.000E+00	.0	.000	210.5	73.9
PRECIPITATION			80.1	1.2	.161E+04	100.0	.500	28.8	30.0
TRIBUTARY INFLOW			6701.2	98.8	.000E+00	.0	.000	352.6	109.9
***TOTAL INFLOW			6781.3	100.0	.161E+04	100.0	.006	311.3	106.6
ADVECTIVE OUTFLOW			1036.8	15.3	.233E+06	14501.1	.465	53.1	16.3
***TOTAL OUTFLOW			1036.8	15.3	.233E+06	14501.1	.465	53.1	16.3
***RETENTION			5744.5	84.7	.234E+06	14576.0	.084	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.31	.8041	87.6	.2030	4.9263	.8471

Appendix H
Phosphorus Reduction Analysis – BATHTUB Output Files

BATHTUB Output for 1993 Reduction Analysis

CASE: Vandalia 1993 - Reduced

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	93.2	.43	49.7	.45	1.87	1.47	2.34	1.01
CHL-A	MG/M3	22.4	.31	14.7	.54	1.53	1.38	1.23	.68
SECCHI	M	.5	.36	.6	.40	.90	-.30	-.39	-.20
ORGANIC N	MG/M3	.0	.00	591.6	.31	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	53.6	.37	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	76.0	.59	36.0	.45	2.11	1.27	2.77	1.01
CHL-A	MG/M3	21.2	.47	12.4	.52	1.71	1.15	1.56	.77
SECCHI	M	.6	.31	.7	.37	.86	-.49	-.55	-.32
ORGANIC N	MG/M3	.0	.00	516.8	.28	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	42.2	.33	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	150.4	.94	53.0	.45	2.84	1.12	3.88	1.01
CHL-A	MG/M3	20.4	.66	13.8	.48	1.48	.59	1.13	.48
SECCHI	M	.7	.31	.8	.38	.88	-.42	-.45	-.26
ORGANIC N	MG/M3	.0	.00	537.0	.27	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	41.1	.30	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	103.7	.63	47.7	.45	2.17	1.23	2.88	1.00
CHL-A	MG/M3	21.7	.42	14.0	.48	1.55	1.04	1.27	.68
SECCHI	M	.6	.33	.7	.26	.88	-.37	-.44	-.29
ORGANIC N	MG/M3	.0	.00	563.0	.29	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	48.2	.32	.00	.00	.00	.00

CASE: Vandalia 1993 - Reduced
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	17.660	8.568	.000E+00	.000	.485
2	1	Subbasin 2	6.270	2.921	.000E+00	.000	.466
3	1	Subbasin 3	10.930	5.302	.000E+00	.000	.485
4	1	Subbasin 4	8.990	4.144	.000E+00	.000	.461
5	1	Subbasin 5	9.970	4.867	.000E+00	.000	.488
6	1	Subbasin 6	3.080	1.697	.000E+00	.000	.551
7	1	Subbasin 7	4.060	2.046	.000E+00	.000	.504
PRECIPITATION			2.671	3.739	.559E+00	.200	1.400
TRIBUTARY INFLOW			60.960	29.545	.000E+00	.000	.485
***TOTAL INFLOW			63.631	33.284	.559E+00	.022	.523
ADVECTIVE OUTFLOW			63.631	31.035	.101E+01	.032	.488
***TOTAL OUTFLOW			63.631	31.035	.101E+01	.032	.488
***EVAPORATION			.000	2.249	.455E+00	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	1200.4	21.0	.000E+00	.0	.000	140.1	68.0
2	1	Subbasin 2	500.1	8.8	.000E+00	.0	.000	171.2	79.8
3	1	Subbasin 3	900.3	15.8	.000E+00	.0	.000	169.8	82.4
4	1	Subbasin 4	549.9	9.6	.000E+00	.0	.000	132.7	61.2
5	1	Subbasin 5	700.4	12.3	.000E+00	.0	.000	143.9	70.2
6	1	Subbasin 6	200.0	3.5	.000E+00	.0	.000	117.8	64.9
7	1	Subbasin 7	30.1	.5	.000E+00	.0	.000	14.7	7.4
PRECIPITATION			80.1	1.4	.161E+04	100.0	.500	21.4	30.0
INTERNAL LOAD			1550.3	27.1	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW			4081.1	71.5	.000E+00	.0	.000	138.1	66.9
***TOTAL INFLOW			5711.5	100.0	.161E+04	100.0	.007	171.6	89.8
ADVECTIVE OUTFLOW			1644.0	28.8	.549E+06	34189.4	.451	53.0	25.8
***TOTAL OUTFLOW			1644.0	28.8	.549E+06	34189.4	.451	53.0	25.8
***RETENTION			4067.5	71.2	.550E+06	34255.3	.182	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
11.62	.5183	103.7	.2920	3.4248	.7122

BATHTUB Output for 1998 Reduction Analysis

CASE: Vandalia 1996 - Reduced

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	138.0	.75	42.3	.46	3.26	1.57	4.39	1.35
CHL-A	MG/M3	23.3	.66	11.1	.59	2.10	1.13	2.15	.84
SECCHI	M	.4	.46	.4	.51	.88	-.27	-.45	-.18
ORGANIC N	MG/M3	.0	.00	561.5	.27	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	63.4	.44	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	120.2	.80	49.8	.46	2.41	1.11	3.28	.96
CHL-A	MG/M3	18.4	.66	9.5	.56	1.93	.99	1.90	.76
SECCHI	M	.5	.49	.5	.53	.90	-.22	-.38	-.15
ORGANIC N	MG/M3	.0	.00	504.0	.23	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	53.7	.44	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	221.0	.87	62.8	.45	3.52	1.45	4.68	1.28
CHL-A	MG/M3	26.6	.94	16.4	.59	1.62	.51	1.39	.43
SECCHI	M	.5	.51	.5	.57	.88	-.24	-.44	-.16
ORGANIC N	MG/M3	.0	.00	647.4	.28	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	61.6	.37	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	154.7	.80	48.9	.45	3.17	1.44	4.28	1.26
CHL-A	MG/M3	23.1	.74	12.1	.51	1.91	.88	1.88	.72
SECCHI	M	.4	.48	.5	.34	.89	-.25	-.43	-.21
ORGANIC N	MG/M3	.0	.00	570.8	.26	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	61.0	.33	.00	.00	.00	.00

CASE: Vandalia 1996 - Reduced
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	17.660	5.777	.000E+00	.000	.327
2	1	Subbasin 2	6.270	1.981	.000E+00	.000	.316
3	1	Subbasin 3	10.930	3.607	.000E+00	.000	.330
4	1	Subbasin 4	8.990	2.741	.000E+00	.000	.305
5	1	Subbasin 5	9.970	3.261	.000E+00	.000	.327
6	1	Subbasin 6	3.080	1.201	.000E+00	.000	.390
7	1	Subbasin 7	4.060	1.106	.000E+00	.000	.272
PRECIPITATION			2.671	2.751	.303E+00	.200	1.030
TRIBUTARY INFLOW			60.960	19.674	.000E+00	.000	.323
***TOTAL INFLOW			63.631	22.425	.303E+00	.025	.352
ADVECTIVE OUTFLOW			63.631	20.176	.758E+00	.043	.317
***TOTAL OUTFLOW			63.631	20.176	.758E+00	.043	.317
***EVAPORATION			.000	2.249	.455E+00	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	414.2	10.6	.000E+00	.0	.000	71.7	23.5
2	1	Subbasin 2	138.1	3.5	.000E+00	.0	.000	69.7	22.0
3	1	Subbasin 3	275.9	7.1	.000E+00	.0	.000	76.5	25.2
4	1	Subbasin 4	206.9	5.3	.000E+00	.0	.000	75.5	23.0
5	1	Subbasin 5	229.9	5.9	.000E+00	.0	.000	70.5	23.1
6	1	Subbasin 6	40.0	1.0	.000E+00	.0	.000	33.3	13.0
7	1	Subbasin 7	20.0	.5	.000E+00	.0	.000	18.1	4.9
PRECIPITATION			80.1	2.0	.161E+04	100.0	.500	29.1	30.0
INTERNAL LOAD			2504.3	64.1	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW			1325.1	33.9	.000E+00	.0	.000	67.4	21.7
***TOTAL INFLOW			3909.5	100.0	.161E+04	100.0	.010	174.3	61.4
ADVECTIVE OUTFLOW			1267.6	32.4	.329E+06	20521.7	.453	62.8	19.9
***TOTAL OUTFLOW			1267.6	32.4	.329E+06	20521.7	.453	62.8	19.9
***RETENTION			2641.9	67.6	.331E+06	20592.0	.218	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.55	.7776	154.7	.6206	1.6113	.6758

BATHTUB Output for 1999 Reduction Analysis

CASE: Vandalia 1999 - Reduced

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	66.4	.63	48.8	.45	1.36	.49	1.15	.40
CHL-A	MG/M3	45.3	.37	36.7	.55	1.23	.57	.60	.31
SECCHI	M	.4	.32	.5	.38	.91	-.29	-.34	-.19
ORGANIC N	MG/M3	.0	.00	1088.0	.42	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	90.6	.40	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	42.8	.59	31.0	.45	1.38	.55	1.20	.44
CHL-A	MG/M3	37.0	.38	17.1	.59	2.16	2.03	2.22	1.10
SECCHI	M	.5	.32	.7	.43	.74	-.97	-1.10	-.57
ORGANIC N	MG/M3	.0	.00	619.2	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	49.0	.37	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	173.0	2.10	63.5	.45	2.72	.48	3.72	.47
CHL-A	MG/M3	31.7	.51	21.9	.49	1.45	.72	1.07	.52
SECCHI	M	.6	.32	.7	.37	.86	-.46	-.53	-.30
ORGANIC N	MG/M3	.0	.00	730.5	.32	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	58.3	.29	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	87.6	1.34	48.7	.45	1.80	.44	2.18	.42
CHL-A	MG/M3	40.3	.40	29.1	.51	1.38	.82	.94	.51
SECCHI	M	.5	.32	.6	.28	.85	-.50	-.58	-.38
ORGANIC N	MG/M3	.0	.00	904.7	.38	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	74.2	.36	.00	.00	.00	.00

CASE: Vandalia 1999 - Reduced
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	17.660	5.459	.000E+00	.000	.309
2	1	Subbasin 2	6.270	1.868	.000E+00	.000	.298
3	1	Subbasin 3	10.930	3.389	.000E+00	.000	.310
4	1	Subbasin 4	8.990	2.616	.000E+00	.000	.291
5	1	Subbasin 5	9.970	3.082	.000E+00	.000	.309
6	1	Subbasin 6	3.080	1.167	.000E+00	.000	.379
7	1	Subbasin 7	4.060	1.425	.000E+00	.000	.351
PRECIPITATION			2.671	2.778	.309E+00	.200	1.040
TRIBUTARY INFLOW			60.960	19.006	.000E+00	.000	.312
***TOTAL INFLOW			63.631	21.784	.309E+00	.026	.342
ADVECTIVE OUTFLOW			63.631	19.535	.764E+00	.045	.307
***TOTAL OUTFLOW			63.631	19.535	.764E+00	.045	.307
***EVAPORATION			.000	2.249	.455E+00	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	1275.2	21.3	.000E+00	.0	.000	233.6	72.2
2	1	Subbasin 2	600.0	10.0	.000E+00	.0	.000	321.2	95.7
3	1	Subbasin 3	900.1	15.0	.000E+00	.0	.000	265.6	82.4
4	1	Subbasin 4	675.2	11.3	.000E+00	.0	.000	258.1	75.1
5	1	Subbasin 5	675.3	11.3	.000E+00	.0	.000	219.1	67.7
6	1	Subbasin 6	199.9	3.3	.000E+00	.0	.000	171.3	64.9
7	1	Subbasin 7	150.1	2.5	.000E+00	.0	.000	105.3	37.0
PRECIPITATION			80.1	1.3	.161E+04	100.0	.500	28.8	30.0
INTERNAL LOAD			1431.0	23.9	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW			4475.8	74.8	.000E+00	.0	.000	235.5	73.4
***TOTAL INFLOW			5986.9	100.0	.161E+04	100.0	.007	274.8	94.1
ADVECTIVE OUTFLOW			1241.1	20.7	.314E+06	19542.9	.451	63.5	19.5
***TOTAL OUTFLOW			1241.1	20.7	.314E+06	19542.9	.451	63.5	19.5
***RETENTION			4745.9	79.3	.315E+06	19619.0	.118	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.31	.8041	87.6	.2299	4.3492	.7927

Appendix I
Responsiveness Summary

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Responsiveness Summary

This responsiveness summary responds to substantive questions and comments received during the public comment period from November 19, 2003 through January 20, 2004 postmarked, including those from the December 17, 2003 public meeting discussed below.

What is a TMDL?

A Total Maximum Daily Load (TMDL) is the sum of the allowable amount of a pollutant that a water body can receive from all contributing sources and still meet water quality standards or designated uses. The Vandalia Lake TMDL report contains a plan detailing the actions necessary to reduce pollutant loads to the impaired water bodies and ensure compliance with applicable water quality standards. The Illinois EPA implements the TMDL program in accordance with Section 303(d) of the federal Clean Water Act and regulations thereunder.

Background

The watershed targeted for TMDL development is Vandalia Lake (ILO08), which is located in Fayette County, Illinois. The watershed encompasses an area of approximately 25 square miles. Land use in the watershed is predominately agriculture followed by grassland and forestland. Vandalia Lake consists of 660 acres. The water body is listed on the Illinois EPA 2002 Section 303(d) List as being impaired for phosphorus, pH, nitrogen, excessive algal growth, and cholorophyll-a. The Clean Water Act and USEPA regulations require that states develop TMDLs for waters on the Section 303(d) List. Illinois EPA is currently developing TMDLs for pollutants that have numeric water quality standards. Therefore, TMDLs were only developed for phosphorus and pH. The Illinois EPA contracted with Camp Dresser & McKee (CDM) to prepare a TMDL report for the Vandalia Lake Watershed.

Public Meetings

Public meetings were held in the city of Springfield on June 5, 2001, and in the city of Vandalia on December 4, 2001 and December 17, 2003. The Illinois EPA provided public notice for the December 17, 2003 meeting by placing display ads in the "Vandalia Leader-Union" on November 19, 2003. This notice gave the date, time, location, and purpose of the meeting. The notice also provided references to obtain additional information about this specific site, the TMDL Program and other related issues. Approximately 36 individuals and organizations were also sent the public notice by first class mail. The draft TMDL Report was available for review at the Vandalia Junior High School offices and also on the Agency's web page at http://www.epa.state.il.us/water/tmdl .

The final public meeting started at 6:30 p.m. on Wednesday, December 17, 2003. It was attended by approximately 13 people and concluded at 7:50 p.m. with the meeting record remaining open until midnight, January 20, 2004.

Questions and Comments

1. Has new phosphorus data been taken from the lake since 1999?

Response: Yes, data were taken during 2002 and will be used in the next assessment for the 2004 305(b) Water Quality Report.

2. The City of Vandalia has been applying copper sulfate to the lake the last couple of years in an attempt to control algal growth, and has been successful in doing so. Could this be aiding the internal cycling of phosphorus in the lake?

Response: This should not aid in the increase of internal cycling. Addition of copper sulfate should not reduce oxygen levels near the sediments of the lake, which results in internal cycling of phosphorus.

3. As of now, all of the BMPs recommended in the Implementation Plan are strictly voluntary. Does the Agency foresee this policy changing?

Response: We do not foresee the practices recommended in the Implementation Plan for controlling nonpoint source runoff for this TMDL becoming mandatory.

4. Are all of the samples, taken during lake monitoring, grab samples?

Response: Yes. Lake samples are taken at the 3 monitoring sites approximately once a month, spring through fall.

5. NRCS currently uses RUSLE, whereas the GWLF model used USLE. Are there any plans to update the GWLF model to use RUSLE?

Response: RUSLE is best used to determine runoff on a field-by-field basis, whereas USLE is better suited to calculate runoff on a watershed basis, which was the focus of the TMDL study. The erosion rates calculated for the Vandalia Lake Watershed Implementation Plan Report (August 2002) were compared with the erosion rates generated from the GWLF model, and the results were very similar.

6. The TMDL Implementation Plan promotes the Wetland Restoration Program, but there are very few areas within this watershed which have the characteristics necessary to qualify for this program.

Response: Thank you for your comment. This information will be added to the final version of the report.

7. About 15 percent of the soils in this area are considered sodic, which could cause pH to rise. Was this considered during the study?

Response: Soil chemistry is not a component of the GWLF model, so we were not able to account for potential affects from the sodic soil. Although the sodic soils could have a small impact on pH, the strong relationship between chlorophyll-a and pH suggests that controlling algal growth will help control the pH level.

8. How will aeration remove phosphorus in the lake?

Response: Installing an aeration system in the lake will not remove phosphorus from the lake. Aerating the lake will prevent the release of phosphorus from the sediments and into the water column, thus making the phosphorus unavailable for algal growth. The only way to remove the phosphorus would be to dredge the lake, which is much more expensive than aeration.

9. Does the shallowness of the lake affect the amount of phosphorus in the lake?

Response: Yes. The internal cycling of phosphorus occurs more readily in shallower lakes.

10. The report states that the life span for the improvements of dredging can last up to 50 years, but the watershed will still supply phosphorus to the lake during subsequent storm events, and could thus cause future impairment.

Response: That is correct, which is why Best Management Practices need to be implemented in the watershed in order to prevent future loading of phosphorus to the lake.

11. What is the drinking water standard for phosphorus?

Response: The General Use standard in lakes for phosphorus is 0.05 mg/l. This same standard also applies to public water supply waters at the point of withdrawal.

12. The report states that total ammonia-nitrogen is also listed as a cause of impairment. Was this listed because the standard was violated?

Response: No. The listing of total ammonia-nitrogen was based on the assumption that the amount of total nitrogen in the lake potentially contributes to the excessive algal growth, even though the standard was not violated. The standard for total ammonia-nitrogen is determined by the pH and temperature for each waterbody.

13. Were nitrate standards violated in the lake?

Response: No, nitrates are not listed as a cause of impairment in Vandalia Lake. The nitrate-nitrogen drinking water standard does not apply to this lake since it is not used for a public water supply.

14. The City of Vandalia has taken water samples in the past that show spikes of ammonia, particularly during the fall season. What could be the sources of this?

Response: Ammonia data were not analyzed for this report. However, possible sources of ammonia include waterfowl, natural decomposition of organic compounds, and fertilizer applications, although anhydrous ammonia is not commonly applied in this area in the fall.

15. What are the matching fund requirements for the 319 Federal grant program?

Response: The Federal Clean Water Act requires a local match of 40 percent of the grant amount.

16. The TMDL Implementation Plan suggests landowners install filter strips through the Conservation Reserve Program. Due to rules for CRP eligibility, some of the land that may need filter strips or buffer strips don't qualify for enrollment into the program.

Response: Thank you for your comment. This information will be included in the final version of the report.

17. Could the Federal 319 Program offer incentive payments for the installation of filter strips, as well as yearly easement payments to the landowners, like the CRP program?

Response: Illinois EPA tries to avoid offering programs that would compete with other federal or state programs. The Agency would be more inclined to use the 319 program to fund a suite of BMPs that would result in improving the lake's water quality. 319 funds have not traditionally been used in Illinois as continuing incentive payments.

18. Will controlling nonpoint source runoff control the level of phosphorus so that it no longer exceeds the 0.05 mg/L standard?

Response: The TMDL report states that nonpoint sources account for approximately 15 percent of the phosphorus loading to the lake. In order for the standard to be met, the internal cycling of phosphorus, which accounts for 78% of the loading, must be controlled as well.

19. Has aeration been successfully used in other lakes throughout the state to control phosphorus?

Response: Most aeration systems are currently being used in lakes that are sources of drinking water in order to increase DO, and in some cases to decrease the re-suspension of phosphorus to curb algal growth. Such conditions, if not corrected, can cause taste and odor problems in finished drinking water.

20. Are there any safety hazards associated with using an aeration system?

Response: The agency is not aware of any safety concerns associated with aeration systems in lakes.

21. By installing an aeration system, will the 90% reduction in internal cycling be achieved?

Response: According to literature from past studies, it is possible.

22. The City of Vandalia uses an agitator that uses air to push warm water from the lake bottom to the lake surface in the wintertime to deice the lake. Is this similar to an aeration system.

Response: An agitator is similar, but an aeration system would provide more aeration than an agitator. The size and type of aeration system that would need to be installed for this particular lake would need to be investigated further once the decision to purchase one is made by local parties.

23. Does IEPA perform tests on lake sediment to determine levels of contaminants, such as phosphorus? It would be good to know what the level of phosphorus is in the parent material as well.

Response: Sediment data are usually taken once at two different monitoring sites at one time during the season when a lake is being sampled. The level of phosphorus in the sediment is available for Vandalia Lake. A core sample of the lake bottom could possibly be taken to determine the thickness of the sedimentation verses the parent material of the lake bottom, and subsequent phosphorus values. Sediment data from this lake can also be compared to other, non-impaired lakes of similar size and watershed characteristics.

24. Has the Illinois State Water Survey performed a sedimentation study on Vandalia Lake?

Response: No, a sedimentation study has not been performed for Vandalia Lake by the Illinois State Water Survey.

25. Does the state have plans to perform some of the follow-up measures recommended in the report?

Response: Illinois EPA will continue taking data through its lake monitoring program and assessing whether or not the lake is meeting its designated uses. We are also interested in working with local parties and potentially funding remediation efforts consistent with this TMDL and Implementation Plan.

26. What is the next step in the process?

Response: Once the report is finalized and approved by USEPA, it will be up to local groups to take action in implementing the measures outlined in the Implementation Plan. The Agency is available to work with such groups.

27. Could IEPA provide additional technical support to local groups in future monitoring and implementation efforts?

Response: The Agency is available to provide additional services if needed. The local NRCS and SWCD would also be a good source of technical information for implementing BMPs. Further study of the watershed may be required to locate "hotspots" where implementation of BMPs can best be used.

28. Is Vandalia Lake part of the Volunteer Lake Monitoring Program?

Response: Yes, Vandalia Lake has been part of the Volunteer Lake Monitoring Program for 17 years. Most of the data taken are Secchi disk readings, although some water chemistry samples have been taken.