# TMDL Development for Burches Run Lake, Marshall County, West Virginia

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## EXECUTIVE SUMMARY

The objective of this study was to identify the background information, analysis, and resulting load reduction which comprise a Total Maximum Daily Load (TMDL) for siltation and nutrients. The West Virginia Division of Environmental Protection (WVDEP) has identified Burches Run Lake (designated code O(L)-83-C-(1)) as being impacted by these pollutants, as reported in the 1998 303(d) list of water-quality-limited waters (WVDEP 1998). WVDEP has determined that the aquatic life use designation has been impaired by nutrients and siltation.

Nutrients and siltation have no specific numeric water quality criteria; however, elevated inputs of nutrients and sediment have been demonstrated to cause impairment of the support of aquatic life and recreational uses of the lake. In the case where no numeric criteria are available, an evaluation is made of alternative numeric targets that can be used for development of an acceptable loading. For nutrients a numeric value was selected based on the trophic state. The measure selected for trophic state was a chlorophyll *a* concentration of less than 15 ug/L (based on summer mean values). For the development of a TMDL for siltation for Burches Run Lake, the endpoint selected was based on the evaluation of the accumulation in a representative depositional cell.

To evaluate the relationship between the sources, their loading characteristics, and the resulting conditions in the lake, a combination of analysis tools were used. Assessments of the nonpoint source loading into the lake were developed for Burches Run Lake watershed using the Hydrologic Simulation Program—FORTRAN Version 11 (Bicknell et al., 1996). The watershed was divided into six land use categories and six subwatersheds. The lake was evaluated using a water quality simulation model. The Environmental Fluid Dynamics Code (EFDC) was used to simulate the lake as a two-dimensional system (Hamrick 1996; Hamrick and Wu 1996). The lake was segmented into two cells and two layers to better represent the system. The lake model was used to evaluate iron, nutrients and chlorophyll *a*, and siltation. The results of the watershed and reservoir models were compared with literature values, previous studies, and reservoir conditions to evaluate their performance.

TMDLs are composed of the sum of individual waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and natural background levels. The representative hydrologic simulation year used for testing and development of the TMDL was 1990. The resulting allocation for the two listed pollutants included a 30% reduction of nutrients (expressed as total phosphorus) and a 20% reduction of sediment load. The loads are described as average annual load reductions, which is typically appropriate for reservoirs and impoundments. The margin of safety was addressed through a series of conservative assumptions in the development of the TMDL analysis. The load reductions can be achieved through a combination of land use and restoration practices such as agricultural best management practices, erosion and sediment control practices, nutrient management programs, and forest management and stream restoration.

## ACKNOWLEDGMENTS

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# 1.0 INTRODUCTION

## 1.1 Background

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting designated uses under technology-based controls. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water-quality-based controls to reduce pollution from both point and nonpoint sources and restore and maintain the quality of their water resources (USEPA 1991).

Burches Run Lake is located in Marshall County, West Virginia, approximately 6 miles to the southeast of Wheeling, West Virginia. The lake's watershed is located within the Upper Ohio-Wheeling hydrologic cataloging unit (05030106) (Figure 1.1). The land area of the watershed is approximately 3,301 acres. Runoff from the watershed flows into Burches Run Lake from Burch Run. Burch Run is fed by two main streams—Big Run and an unnamed stream. Water discharged from the lake continues in Burch Run to Wheeling Creek and ultimately to the Ohio River. The impoundment structure for Burches Run Lake was completed in 1962. The impoundment has a normal storage capacity of approximately 175 acre-feet and a maximum storage capacity of approximately 380 acre-feet. The lake is used for recreational activities such as fishing and boating. The lake's watershed is primarily rural since the main land uses are forest and hay/pasture.

## 1.2 Purpose of the Study

The objective of this study was to identify the background information and framework needed for developing TMDLs for siltation and nutrients. The West Virginia Division of Environmental Protection (WVDEP) has identified Burches Run Lake (designated code O(L)-83-C-(1)) as being impacted by these contaminants, as reported in the 1998 303(d) list of water-quality-limited waters (WVDEP 1998). WVDEP has determined that the aquatic life use designation has been impaired by nutrients and siltation.

## 1.3 Selection of TMDL Endpoints

One of the major components of a TMDL is the establishment of in-lake endpoints, which are used to evaluate the attainment of acceptable water quality. In-lake endpoints, therefore, represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. The endpoints allow for a comparison between predicted in-lake conditions and conditions that are expected to restore beneficial uses; the endpoints are usually based on either the narrative or numeric criteria available in state water quality standards. When no established narrative or numeric criteria exist, other

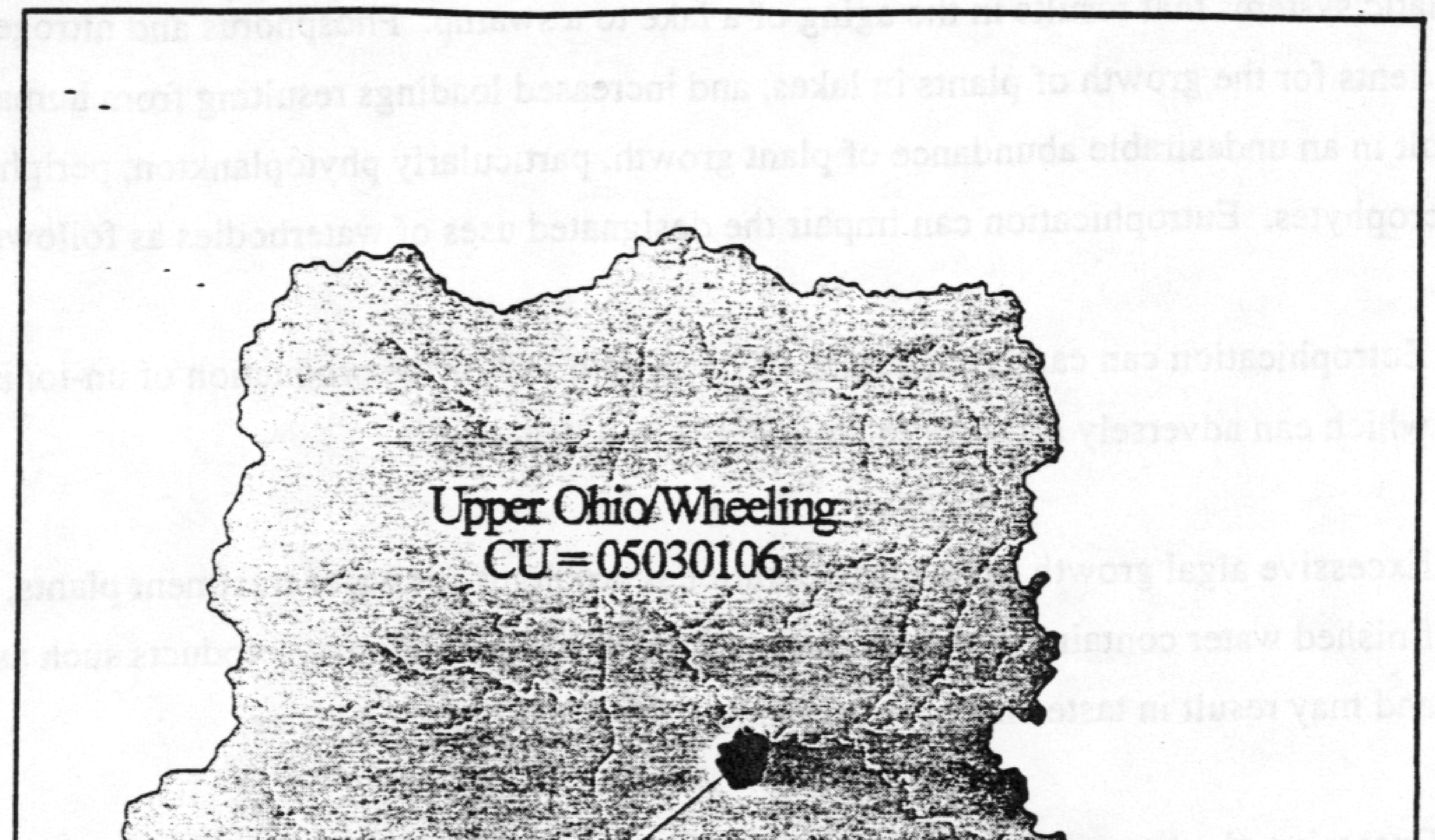

Figure 1.1. Location of Burches Run Lake watershed.

criteria must be used. Endpoints for each of the listed pollutants for Burches Run Lake are discussed below.

### 1.3.1 Nutrients

With regard to nutrients, nitrogen and phosphorus (in the forms of total nitrogen [TN] and total phosphorus [TP]) were selected as the nutrient endpoints. An increase in loading of these nutrients into a lake can detrimentally affect designated uses. Loadings of nutrients (primarily phosphorus for lakes) can cause impairments due to their role in accelerating the eutrophication process, the nutrient enrichment of aquatic systems that results in the aging of a lake to a swamp. Phosphorus and nitrogen are essential nutrients for the growth of plants in lakes, and increased loadings resulting from human influences can result in an undesirable abundance of plant growth, particularly phytoplankton, periphyton, and macrophytes. Eutrophication can impair the designated uses of waterbodies as follows:

- Eutrophication can cause the depletion of oxygen and/or the production of un-ionized ammonia, which can adversely affect both aquatic life and fisheries.

- Excessive algal growth can cause operational problems for water treatment plants, can result in finished water containing potentially carcinogenic disinfection by-products such as trihalomethanes, and may result in taste and odor problems in finished drinking water.

- Excessive plant growth can cause disruption to recreational activities such as swimming, boating, and fishing. Additionally, excessive plant growth can also negatively affect the aesthetic appeal of a waterbody.

Elevated nutrient concentrations can also represent other concerns not specifically associated with eutrophication. For example, drinking water supplies can be impaired by nitrogen when nitrate concentrations exceed 10 mg/L and cause methemoglobinemia in infants (USEPA 1998a).

Chlorophyll *a*, the major photosynthetic pigment in plants (both algae and macrophytes), is often used as an estimator of algal biomass (Carlson 1980; Chapra 1997; Watson et al. 1992) and is a good surrogate measure for nutrients because algae are either the direct or indirect cause of most problems related to excessive nutrient enrichment (USEPA 1998a). Because the relationship between chlorophyll *a* concentrations and nutrients (primarily phosphorus) is well established, chlorophyll *a* concentrations (i.e., seasonal mean and instantaneous measure) can be used to predict nutrient levels resulting in impaired or nonimpaired conditions. Several states, such as Oregon and North Carolina, have adopted chlorophyll *a* concentrations as a criterion for lake quality (USEPA 1998a). In general, published desirable endpoints for chlorophyll *a* for lakes range from approximately 10 ug/L to 25 ug/L (USEPA 1998a; NALMS 1992). WVDEP has not established specific narrative or numeric water quality criteria for nutrient-related impairments. In the absence of a numeric criterion, a surrogate endpoint of 15.0 ug/L chlorophyll *a* was chosen for development of the nutrient TMDL for Burches Run Lake. This value is consistent with published criteria for chlorophyll *a* and represents a relatively conservative value. The chlorophyll *a* endpoint will be used to define the acceptable nutrient load that can be introduced into the lake. Based on previous evaluation of Burches Run Lake data, and typical characteristics of lakes in the West Virginia area, it is likely phosphorus is the limiting nutrient. The TMDL was, therefore, expressed as a phosphorus load allocation.

### 1.3.2 Siltation

Excessive inputs of sediment to a lake can significantly impair the lake's designated uses. For example, sediment deposition on a lake bottom can deplete fish food sources. The fish habitat is also impaired due to the need for dredging and the lack of deepwater habitat for winter ice-over. Additionally, high concentrations of suspended sediment can cause physical harm to aquatic organisms and can alter feeding patterns. Excessive sediments can alter taste and odor of drinking water supplies and cause physical complications and increased processing costs for water treatment plants. Increased sedimentation of a drinking water reservoir can significantly reduce the planned lifespan of the reservoir. High levels of sediment can impair recreational activities such as swimming and boating by altering shorelines and reducing visibility in the water column. If fish habitat and physical conditions amenable to fish populations are impaired, recreational fishing can suffer from a decline in fish populations or from a change in the makeup of fish species in the lake.

For the development of a TMDL for siltation for Burches Run Lake, the following factors are considered: the evaluation of the average accumulation rate of sediment on the reservoir bottom, the accumulation in selected portions of the discharge points of the tributaries, and the concentrations of total suspended sediment. The selected endpoint was the accumulation rate in a representative depositional cell that would result in 70% of cell capacity loss over a 40-year period. Reductions in sediment load are expected to also result in beneficial reductions in the in-lake turbidity and suspended sediment concentrations.

## 2.0 SOURCE ASSESSMENT

This section presents an overview of the in-lake and in-stream water quality monitoring data available for Burches Run Lake and its inflows and then discusses the type, magnitude, and location of potential point and nonpoint sources of pollutant loading. No detailed information is apparently available regarding Burches Run Lake and its watershed. Based on the watershed's land use distribution, there is very little development present, and impairments are likely being caused by streambank erosion, storm water runoff from roads and drainage ditches, and potentially agricultural runoff.

### 2.1 Water Quality Monitoring Data

Limited water quality monitoring activities have been conducted for Burches Run Lake and its inflows. Water quality data reviewed as part of this report were collected as indicated below:

- WVDEP seasonal sampling of Burches Run Lake and its inflow (Burch Run) from spring 1993 through summer 1996 (a total of nine sampling events) and sampling conducted on April 29, 1998, in two tributaries to the lake and on May 7, 1998, at two in-lake locations. WVDEP sampling results are included as an appendix.

### 2.2 Assessment of Point Sources

A review of the Permit Compliance System (PCS) database indicates no point source dischargers in the watershed.

### 2.3 Assessment of Nonpoint Sources

Nonpoint sources of pollutants within the watershed can generally be associated with the different types of land uses that exist in the watershed. For example, sediment and nutrient loadings can originate from agricultural land uses (i.e., row crops, pasture, and animal operations), and expansion of residential and commercial/industrial areas can cause an increase in storm water flows from impervious areas and an increase in sediment loads through the wash-off and erosion of sediment from construction sites. High rates of sediment loading can potentially also mean increased phosphorus loads because phosphorus can readily be adsorbed onto soil particles. Septic systems are potential sources of nutrients.

To characterize flows and pollutant loadings from different parts of the Burches Run Lake watershed using the Hydrologic Simulation Program - FORTRAN (HSPF) Version 11.0, the Burches Run Lake watershed was divided into six subwatersheds (Figure 2.1). Subwatershed delineations were completed to isolate individual stream reaches in the watershed and were based on topographical analysis. The subwatersheds and their associated areas are provided in Table 2.1.

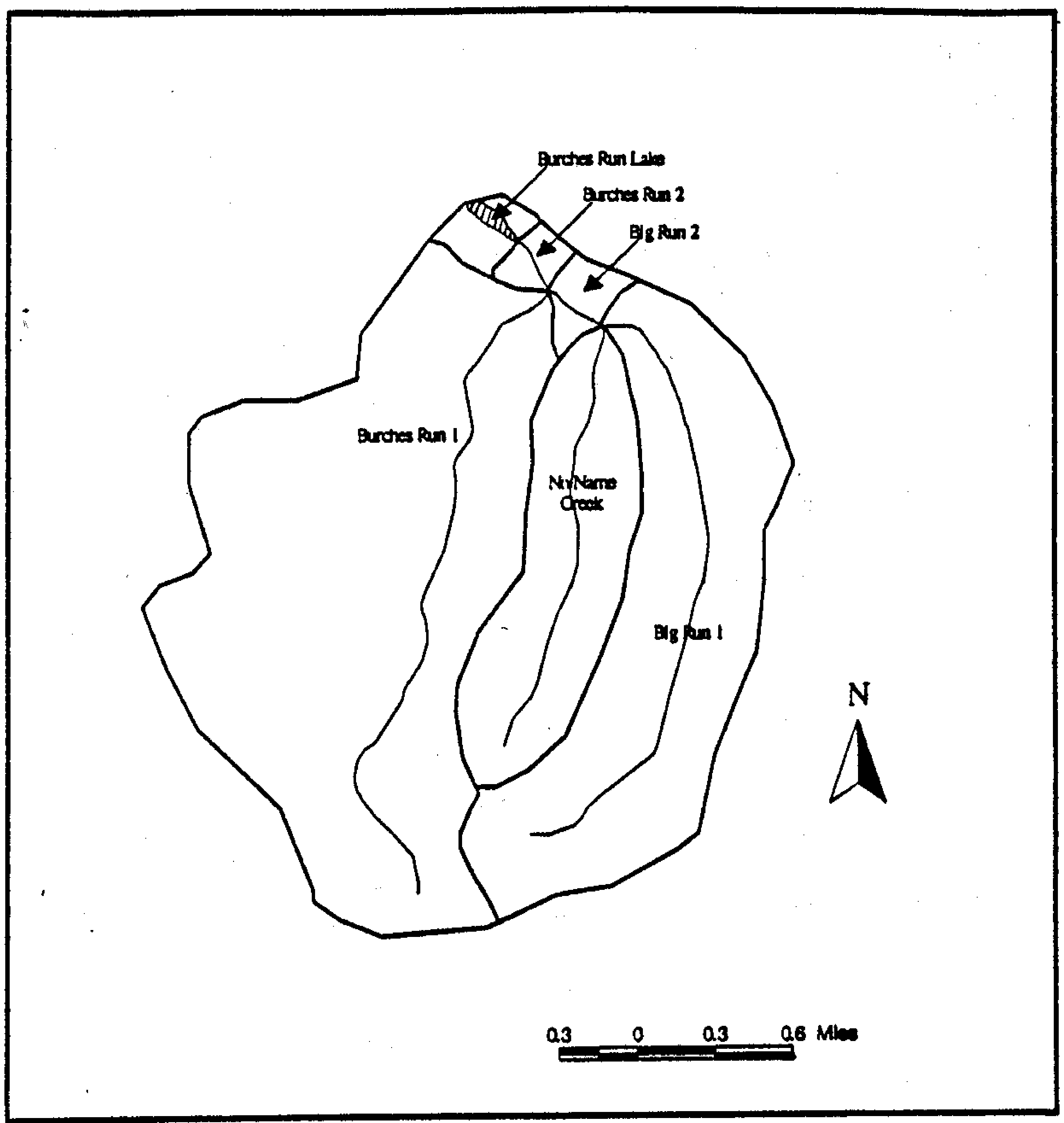

**Figure 2.1.** Burches Run Lake watershed and subwatersheds

**Table 2.1.** Summary of WVDEP sampling observations of selected pollutants, Burches Run Lake, 1993-96, 1998.

| Pollutant Type | Pollutant | Units | Criteria | Sample Type[a] | Total Obs | Minimum | Maximum | Mean |
|---|---|---|---|---|---|---|---|---|
| Metal | Iron | mg/L | 1.5 | Surface | 9 | 0.04 | 0.58 | 0.39 |
| | | mg/L | 1.5 | Bottom | 9 | ND[c] | 1.35 | 0.54 |
| Nutrient | TKN | mg/L | | Surface | 10 | ND[c] | 3.87 | 0.73 |
| | | mg/L | | Bottom | 9 | ND[c] | 0.74 | 0.38 |
| | $NO_2$-$NO_3$-N | mg/L | 10 | Surface | 11 | ND[c] | 0.820 | 0.206 |
| | | mg/L | 10 | Bottom | 10 | ND[c] | 0.720 | 0.203 |
| | TP | mg/L | 0.02[b] | Surface | 11 | 0.030 | 0.232 | 0.071 |
| | | mg/L | 0.02[b] | Bottom | 10 | 0.0290 | 0.0840 | 0.0510 |
| | | mg/kg | | Sediment | 1 | 438.0 | 438.0 | 438.0 |
| | Chlorophyll *a* | ug/L | 15[b] | Surface | 11 | 10.20 | 121.00 | 49.97 |
| | | ug/L | 15[b] | Surface, Summer | 4 | 26.32 | 79.90 | 52.04 |
| Siltation | Suspended Solids | mg/L | | Surface | 9 | 4 | 26 | 13 |
| | | mg/L | | Bottom | 9 | 4 | 31 | 13 |
| | Turbidity | NTU | | Surface | 2 | 43.0 | 52.9 | 48.0 |
| | | NTU | | Bottom | 1 | 112.0 | 112.0 | 112.0 |

[a] Water sample from 1993-96 and 1998 unless noted otherwise.

[b] Eutrophic condition threshold

[c] non-detect, assigned a value of zero for purposes of calculating the mean value of observations

Land use for the Burches Run Lake subwatershed was identified using the Federal Region III Land Cover Data Set (USGS 1998). This land cover data set was developed from MRLC Landsat thematic mapper data sets acquired in 1991, 1992, and 1993. The pixel size of the TM data is 30 X 30 meters. The MRLC data set contains 15 separate land use classes. The analysis of land use classification for the Burches Run Lake watershed identified the presence of 10 of the MRLC land use classes, not including the water class. For purposes of modeling runoff and pollutant loading from each land use in the subwatersheds, certain land use classes were aggregated to consolidate the process. Table 2.2 shows how the MRLC land uses were consolidated and also indicates the breakdown of certain land use classes into pervious and impervious components. A breakdown of land uses by subwatershed is provided in Table 2.3.

**Table 2.2.** Areas of Burches Run Lake subwatersheds.

| Subwatershed Number[a] | Reach Name | Total Area (acres) |
|---|---|---|
| 39 | Burches Run Lake | 41.81 |
| 40 | Burch Run 2 | 35.91 |
| 41 | Burch Run 1 | 1,804.41 |
| 42 | Big Run 2 | 74.49 |
| 43 | No Name Creek | 454.78 |
| 44 | Big Run 1 | 890.68 |
| Total | - | 3,302.13 |

[a] Subwatershed numbers are arbitrary; assigned during model setup.

**Table 2.3.** Burches Run Lake watershed land use class groupings.

| TMDL Land Use Classes | Pervious/Impervious (Percentage) | MRLC Land Use Class (Class No.) |
|---|---|---|
| Residential | Pervious (50%)<br>Impervious (50%) | Low Intensity Developed (21) |
| Commercial and Industrial | Pervious (30%)<br>Impervious (70%) | High Intensity Commercial/Industrial (23) |
| Forest | Pervious (100%) | Deciduous Forest (41)<br>Evergreen Forest (42)<br>Mixed Forest (43) |
| Cropland | Pervious (100%) | Row Crop (82) |
| Pasture | Pervious (100%) | Hay and Pasture (81) |
| Barren | Pervious (100%) | Quarries/Strip Mines/Gravel Pits (32) |
| Other (Assigned as Forest) | Pervious (100%) | Woody Wetland (91) |

**Table 2.4.** Land use distribution by subwatershed (acres).

| | Burches Run Lake | Burch Run 2 | Burch Run 1 | Big Run 2 | No Name Creek | Big Run 1 | Totals |
|---|---|---|---|---|---|---|---|
| Residential | 0 | 0 | 0.44 | 0 | 0 | 3.11 | **3.55** |
| Commercial/ Industrial | 0 | 0 | 0 | 0 | 0 | 0.44 | **0.44** |
| Forest | 30.46 | 20.91 | 1,149.31 | 60.71 | 3,34.91 | 559.11 | **2,155.41** |
| Cropland | 0.67 | 3.78 | 0.44 | 6.67 | 0.89 | 14.23 | **26.68** |
| Pasture | 4.45 | 4.34 | 654.27 | 7.11 | 118.98 | 288 | **1,077.15** |
| Barren | 0 | 0 | 0 | 0 | 0 | 25.57 | **25.57** |
| Other | 0 | 1.77 | 0 | 0 | 0 | 0 | **1.77** |
| Water | 6.23 | 5.11 | 0 | 0 | 0 | 0.22 | **11.56** |
| **Totals** | **41.81** | **35.91** | **1,804.46** | **74.49** | **454.78** | **890.68** | **3,302.13** |

The potential contribution of nutrients from failing septic systems was assessed for the Burches Run Lake watershed. No local information was readily available on the specific locations of septic systems, septic tank densities, or failure rates. Data associated with the number of reported septic systems present in Marshall County were obtained from 1990 U.S. Census data available from the Internet. A failure rate of 2.5% was assumed (NSFC 1993), resulting in an estimate of 1.4 failing septic systems in the watershed. The assumed septic system waste flow rate was based on a typical value of 70 gallons per capita per day (Horsley & Whitten 1996), with an assumed 2.5 persons per household served, based on the 1990 census data. All residences were assumed to be full-time (year-round) occupancy.

## 2.4 Critical Conditions

To develop a TMDL, it is necessary to consider a range of flow conditions to represent the pollutant loading phenomenon occurring within the watershed. During storm events, runoff from urban and agricultural land uses cause loadings of nutrients and sediment to be delivered to the lake. During dry periods, little or no land-based runoff occurs, and continued nutrient inputs (i.e., dissolved nitrogen and phosphorus) might be due to groundwater (baseflow inflows). During dry periods in-lake processes might also result in releases of phosphorus from bottom sediments.

The following rationale was applied to the development of appropriate critical conditions for Burches Run Lake:

*Nutrients.* Nutrients are contributing factors to the eutrophic conditions observed in the reservoir. The eutrophication processes (and the resulting chlorophyll *a* concentrations) are a function of the persistent nutrient loading to the reservoir. Critical conditions for eutrophic conditions (measured as chlorophyll *a*) occur during the spring and summer period when warm weather promotes algal growth. However, critical loading conditions are associated with average annual loading. Phosphorus inputs and subsequent load reductions should be reduced on an average annual basis for the purposes of TMDL allocation.

*Siltation.* Sediment inputs result in long-term accumulation of sediment. Sediment inputs are also related to increased turbidity in the reservoir. Relevant critical conditions are the long-term average loading characteristics. Modeling of the linkage between sediment loading and in-lake processes of sediment deposition and discharge will evaluate the implications for the reservoir siltation process.

A continuous simulation model is necessary to capture the buildup and washoff of pollutants due to nonpoint sources and to evaluate the linkage between episodic (wet-weather) loadings and the in-lake conditions. The loading model is linked to a continuous-simulation reservoir model. The reservoir model allows for the examination of the nutrient and eutrophication processes (expressed as seasonal average chlorophyll *a*), and long-term sediment accumulation rates.

# 3.0 MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between the in-stream water quality target and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired source load reductions. The link can be established through a range of techniques, from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain waterbody responses to flow and loading conditions.

## 3.1 Modeling Framework Selection

The development of a TMDL requires that the linkage between the waterbody-specific impairment and the source loading be described. Model selection will depend on the waterbody types, the pollutant of concern, the relevant pollutant processes, and the source loading characteristics. The selection of the modeling needs and capabilities includes examination of reservoir and watershed loading model components.

### 3.1.1 Reservoir Model Selection.

Burches Run Lake is characterized by variable nonpoint source inflows. The lake is listed for nutrients (related to eutrophication processes) and siltation. Lake impacts due to those pollutants are manifested under both short-term and long-term loadings.

Based on a review of the data, identification of the critical conditions, and the requirements for the development of a TMDL for the listed pollutants, the following modeling capabilities were identified for the reservoir model:

- Representation of the lake with two cells and two layers (two-dimensional modeling)
- Simulation of lake sediment deposition
- Simulation of lake eutrophication processes including flux from bottom sediments

Based on a review of the available public domain models (USEPA 1997), the Environmental Fluid Dynamics Code (EFDC) model was selected (Hamrick 1996; Hamrick and Wu 1996). The EFDC is a general-purpose modeling package for simulating one-, two- or three-dimensional flow, transport, and biogeochemical processes in surface water systems, including rivers, lakes, estuaries, reservoirs, and wetlands. The EFDC model was originally developed at the Virginia Institute of Marine Science and is considered public domain software. In addition to hydrodynamic and temperature transport simulation capabilities, EFDC is capable of simulating sediment behavior, eutrophication processes, and the transport and fate of toxic contaminants in the water and sediment phases. The EFDC code has been extensively tested and documented and used for more than 20 modeling studies. The code is currently used by university, governmental, and engineering and environmental consulting organizations. A new interface system for EFDC is under development by USEPA. EFDC is projected for inclusion in future versions of the EPA Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) modeling system (USEPA 1998b).

The EFDC has the capability to be applied at various levels of detail as deemed appropriate for specific modeling applications. For the Burches Run Lake application, the model was applied in two dimensions (longitudinal and depth). Simulation processes included

- Hydrodynamics
- Sediment deposition
- Eutrophication cycle

### 3.1.2 Watershed Loading Model

For Burches Run Lake the inputs to the lake are exclusively derived from nonpoint sources. Delivery of the nutrients to the system occurs under both baseflow and runoff conditions. Delivery of sediment occurs primarily during runoff events. The frequency and timing of loadings to the reservoir are important factors in the eutrophication indicator (i.e., chlorophyll *a*) concentrations manifested in the reservoir. For siltation, both the long-term loading and the trap efficiency for individual storm events are factors in the evaluation of the accumulation of sediment in the reservoir.

Based on a review of the data, identification of the critical conditions, and the requirements for the development of a TMDL for the listed pollutants, the following modeling capabilities were identified for the watershed loading model:

- Simulation of baseflow and runoff-related inputs from nonpoint sources using continuous simulation (output expressed as daily inputs to reservoir).

- Simulation of loadings of sediment and nutrients (TN and TP) from nonpoint sources.

Based on a review of the available public domain models (USEPA 1997), the Hydrologic Simulation Program—FORTRAN (HSPF) Version 11.0 was selected (Bicknell et al. 1996). HSPF has the capability to simulate a wide range of nonpoint source and point source loadings within a watershed or multiple subwatersheds. HSPF is an EPA-supported model. A major portion of the HSPF model is included within the Nonpoint Source Model (NPSM) of the EPA BASINS 2.0 modeling system.

HSPF has the capability to be used at various levels of detail depending on the requirements of the modeling application. For this application the following components of HSPF were employed:

- Runoff and erosion from nonpoint source land use classes (landscape modules IMPLND and PERLND).
- In-stream transport and delivery (RCHRES).

## 3.2 Model Setup

### 3.2.1 Burches Run Lake

Very limited information was available on the lake bathymetry. The lake was divided into two cells in a horizontal direction to provide some limited characterization of the transport processes. The widths of both cells was 180 meters. Two layers were used in the vertical. One major tributary provides inflow, suspended sediment loads, and nutrients (expressed as TN and TP).

EFDC was used to simulate advection and diffusion processes. Two sediment classes were used to simulate suspended sediment—one to represent silt and clay, and one to represent fine and medium sand. The EFDC model is capable of simulating up to 21 state variables. For this application only one algae class was simulated. Instead of using refractory particulate and labile particulate, only one particulate organic matter was used to simulate particulate phosphorus and nitrogen. Other state variables included dissolved nitrogen, $NH_4$, $NO_3$, and dissolved phosphorus and total phosphate. Partition methods were used to distribute TP and TN into loads of the relevant nitrogen and phosphorus state variables. The temperature and solar radiation were calculated using a SINE function with specified maximum and minimum solar radiation, and time at which maximum solar radiation has occurred since January 1. A similar technique was used to simulate temperature values.

Detailed information on lake morphometry was not available. Sources of information used to estimate lake characteristics included WVDEP lake sampling records, BASINS data layers, and USGS 1:24,000 scale topographical maps.

### 3.2.2 Watershed

To obtain a spatial variation of the concentration and loadings of nutrients and sediment entering Burches Run Lake, the watershed was subdivided into six subwatersheds. This approach allowed analysts to address the relative contribution of sources within each subwatershed to the different tributaries and inflow points to the lake. The watershed subdivision was based primarily on topographic data analysis in order to isolate each individual reach of the main tributaries.

## 3.3 Stream Characteristics

The channel geometry for reaches in the watershed was determined using WVDEP channel measurements for selected stream segments. Channel geometry for remaining reaches was extrapolated from observation data, topographic maps, and evaluation of contributing areas.

## 3.4 Source Representation

Due to the absence of point source dischargers in the watershed, only nonpoint sources were represented. Nonpoint sources were represented by the seven land use categories established for the watershed. Septic system discharges were quantified based on the following information: the population distribution within each of the six subwatersheds based on 1990 U.S. Census data, an assumed average daily discharge of 70 gallons per person per day (Horsley & Whitten 1996), assumed septic effluent concentrations of 56 mg/L TN and 20 mg/L TP, and a 2.5% failure rate (NSFC 1993). Additionally, these septic system discharges are assumed to be constant throughout the year.

The initial default values for the pollutant loading parameters needed for each land use were based on general literature values (USEPA 1988). Parameters were adjusted to reflect typical values observed in Burches Run Lake and its tributaries obtained from WVDEP sampling. The limited number of tributary samples and lack of continuous flow gaging data precluded development of formal calibration and validation analyses.

## 3.5 Model Development and Testing Process

### 3.5.1 Burches Run Lake

Inflows to the reservoir were based on predicted values supplied by the HSPF model application. The hydrodynamic simulation was examined over time to verify that the lake volume and condition corresponded to observed conditions. The calibration parameters for suspended solids are settling velocity and resuspension rates for both classes of sediment. For the present model simulation, bottom flux of $NH_4$, $NO_3$, Orthophosphorus and dissolved oxygen (DO) are also specified.

Nutrient inflows were provided by the HSPF simulation. Monitoring data were used to characterize initial conditions in the reservoir system. Literature values were used to set initial rates in the model for settling velocities and algal growth. Model results were compared with observed values for 1993-95. Parameters were adjusted to provide the best fit with observed data.

### 3.5.2 Watershed

To develop a representative linkage between the sources and the in-lake water quality response in Burches Run Lake, model parameters were adjusted to the extent possible for both hydrology and sediment loading in the tributaries and in-lake processes. Adjustment of the hydrologic parameters for the watershed portion of the model required comparison of the modeled overall water balance and stream flows. A hydrologic simulation was performed for a characteristic West Virginia watershed since no gage, was available within or downstream of the watershed. The gage selected was Poplar Fork at Teays (USGS gage #03201410). The drainage area is 8.71-mi$^2$ at the gage which is slightly larger than the 5.15-mi$^2$ drainage area of the Burches Run Lake watershed. The historical record available for Poplar Fork includes January 26, 1967, to October 11, 1978.

For hydrologic model setup the period from January 26, 1967, to October 11, 1978, was used with the matching precipitation records available for Griffithsville, West Virginia (Station No. 3749). A variety of parameters relating to surface water runoff, water balance, and groundwater flows were adjusted within their reasonable range of values until the predicted flows adequately matched observed values. Some of these parameters represented groundwater storage, evapotranspiration, infiltration capacity of the soil, interflow inflow, and length of assumed overland flow. These setup values were then employed in testing the model on the Burches Run Lake watershed.

Parameters related to nutrients (TP and TN) and sediment loading were adjusted by comparing average annual loading estimates to literature values. The modeled in-stream concentrations were also compared to available observed data from tributary sampling performed in 1993-96 and 1998. This process was limited by the absence of data for high flow and storm flow conditions. Parameter values were changed within a range of acceptable values, in a manner that retained consistency between relative contributions from the different land use groups.

## 3.6 Existing Loadings

### 3.6.1 Watershed Loadings

The model was run for the representative hydrologic period 1989-92. The modeling run represents the existing condition of sediment and TP and TN loadings to the lake, which are shown on Figures 3.1, 3.2, and 3.3. For the existing conditions, the overall sediment loadings by land use category are shown in Table 3.1.

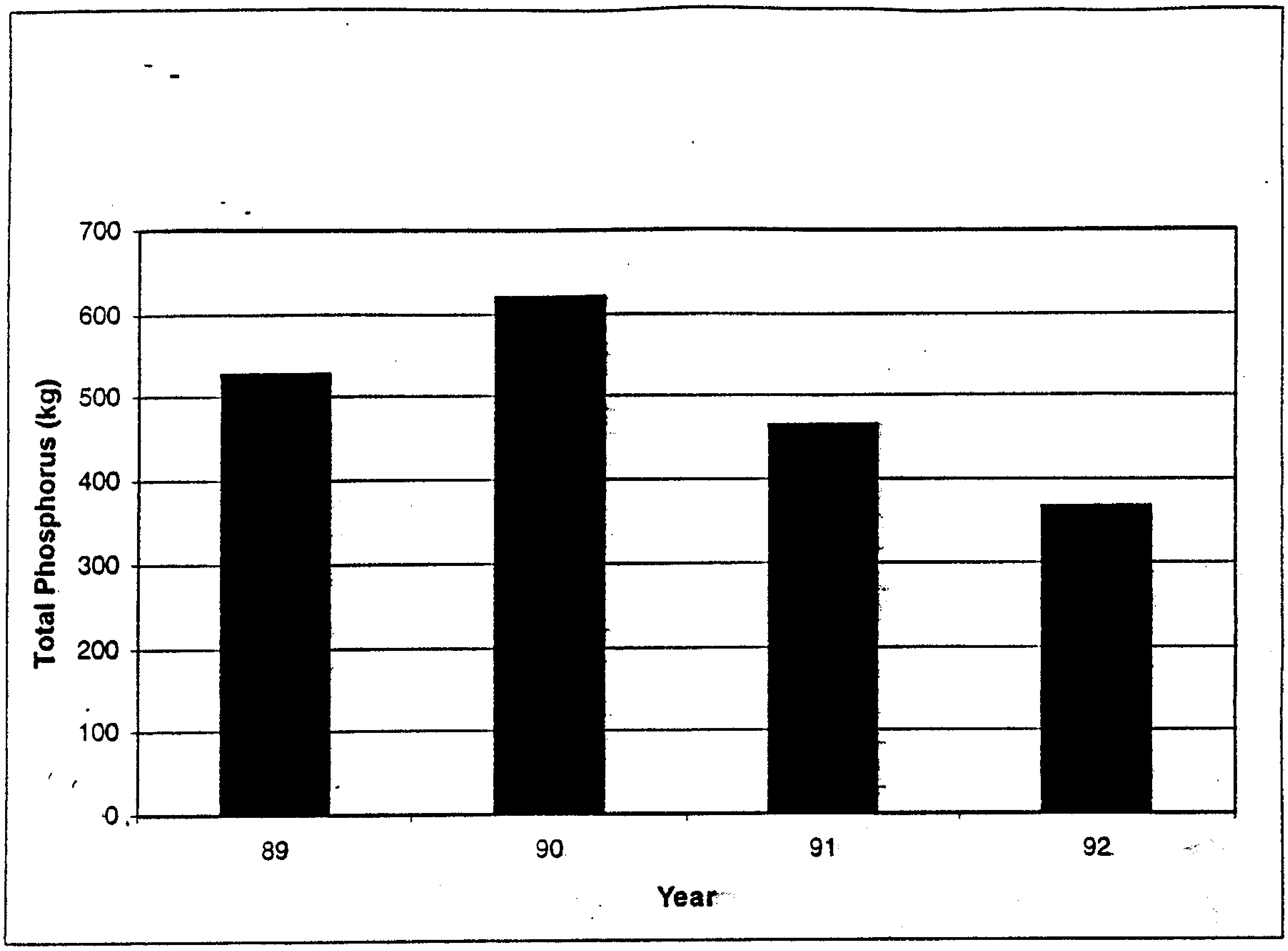

**Figure 3.1.** Average annual predicted total phosphorus load.

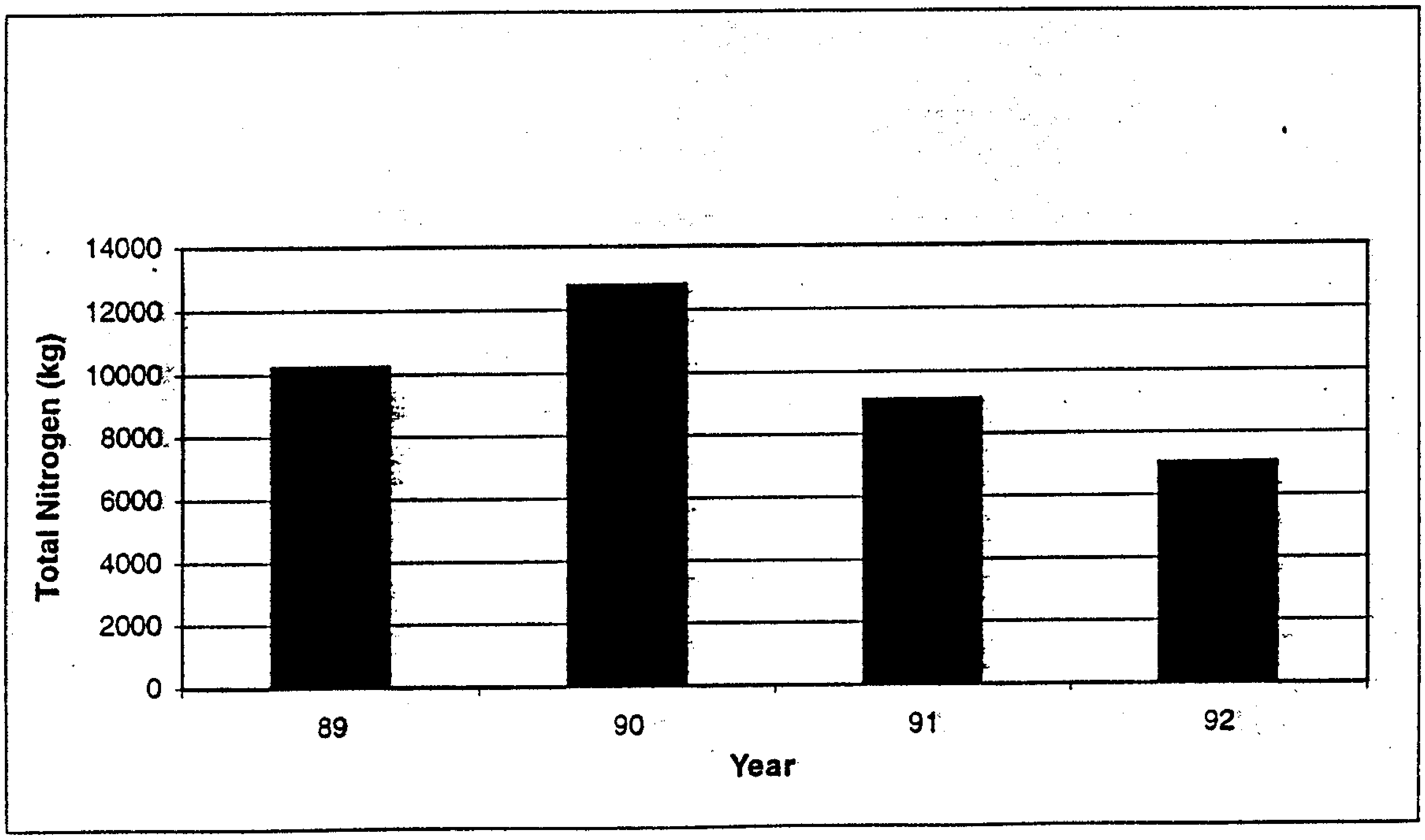

**Figure 3.2.** Average annual predicted total nitrogen load.

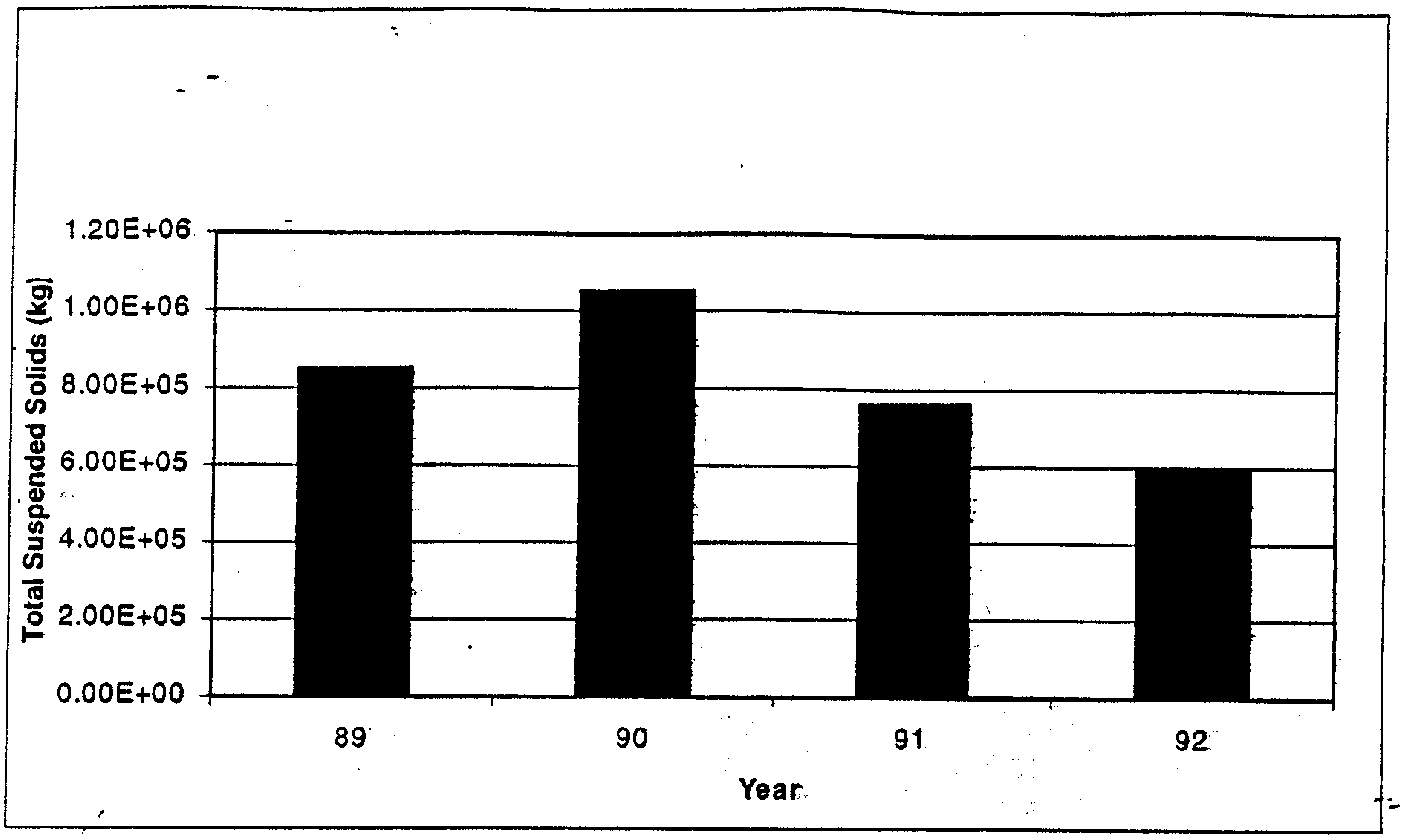

**Figure 3.3.** Average annual predicted total sediment load.

**Table 3.1.** Annual nonpoint source sediment and nutrient loadings (kg) to Burches Run Lake.

| Land Use Category | Sediment | TP | TN |
|---|---|---|---|
| Residential | 2547.99 | 1.46 | 11.06 |
| Commercial and Industrial | 789.52 | 0.24 | 1.40 |
| Forest | 413514.83 | 163.07 | 2634.51 |
| Cropland | 223906.19 | 66.63 | 537.46 |
| Pasture | 168065.09 | 259.36 | 6574.79 |
| Barren | 9176.37 | 5.23 | 39.79 |
| Total | 818000.00 | 496.00 | 9799.00 |

### 3.6.2 Evaluation of Reservoir Conditions

Model simulations were found to adequately characterize in-lake conditions within the constraints of the data available. Figures 3.4, 3.5, and 3.6 show predictions for chlorophyll *a*, sediment accumulations, and suspended sediment concentrations, respectively.

**Nutrients.** The selected endpoint for nutrients is the chlorophyll *a* concentration. The simulation showed periodic chlorophyll *a* concentrations between 5 and 50 ug/L, with a summer mean above 17 ug/L based on examination of the two cells.

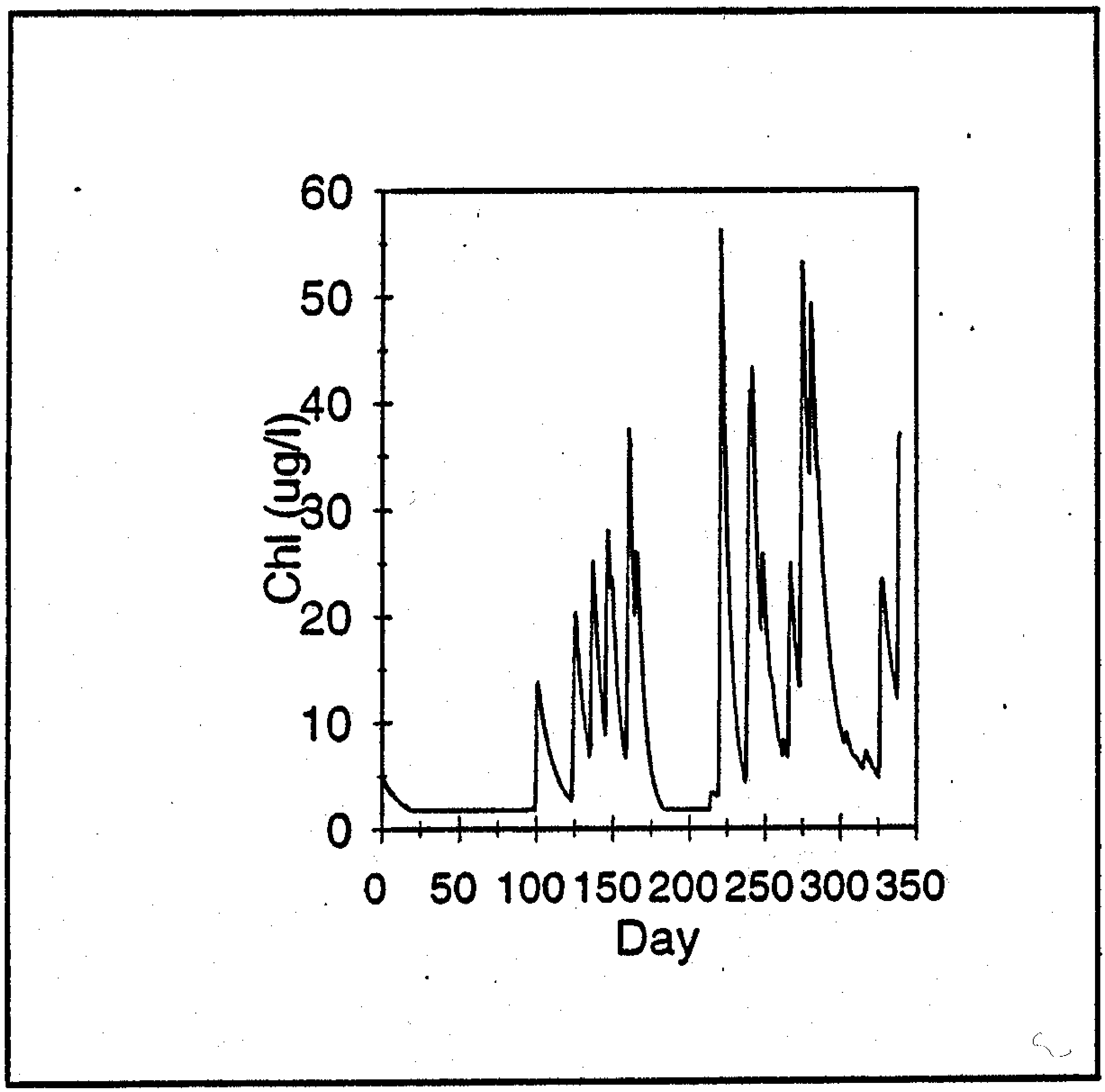

**Figure 3.4.** Simulated chlorophyll *a* for representative year (1990).

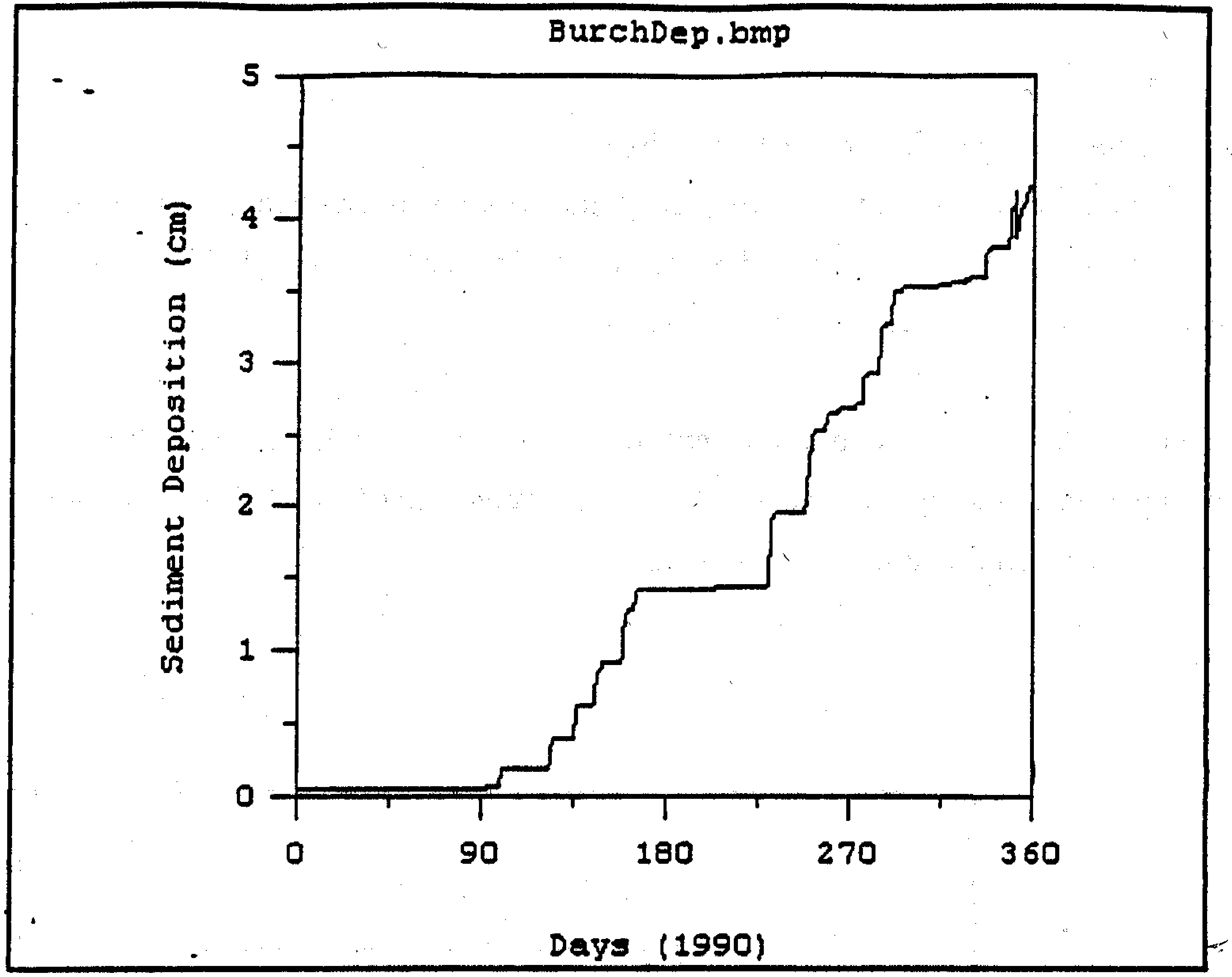

Figure 3.5. Accumulation of sediment in representative cell for 1990 simulation year.

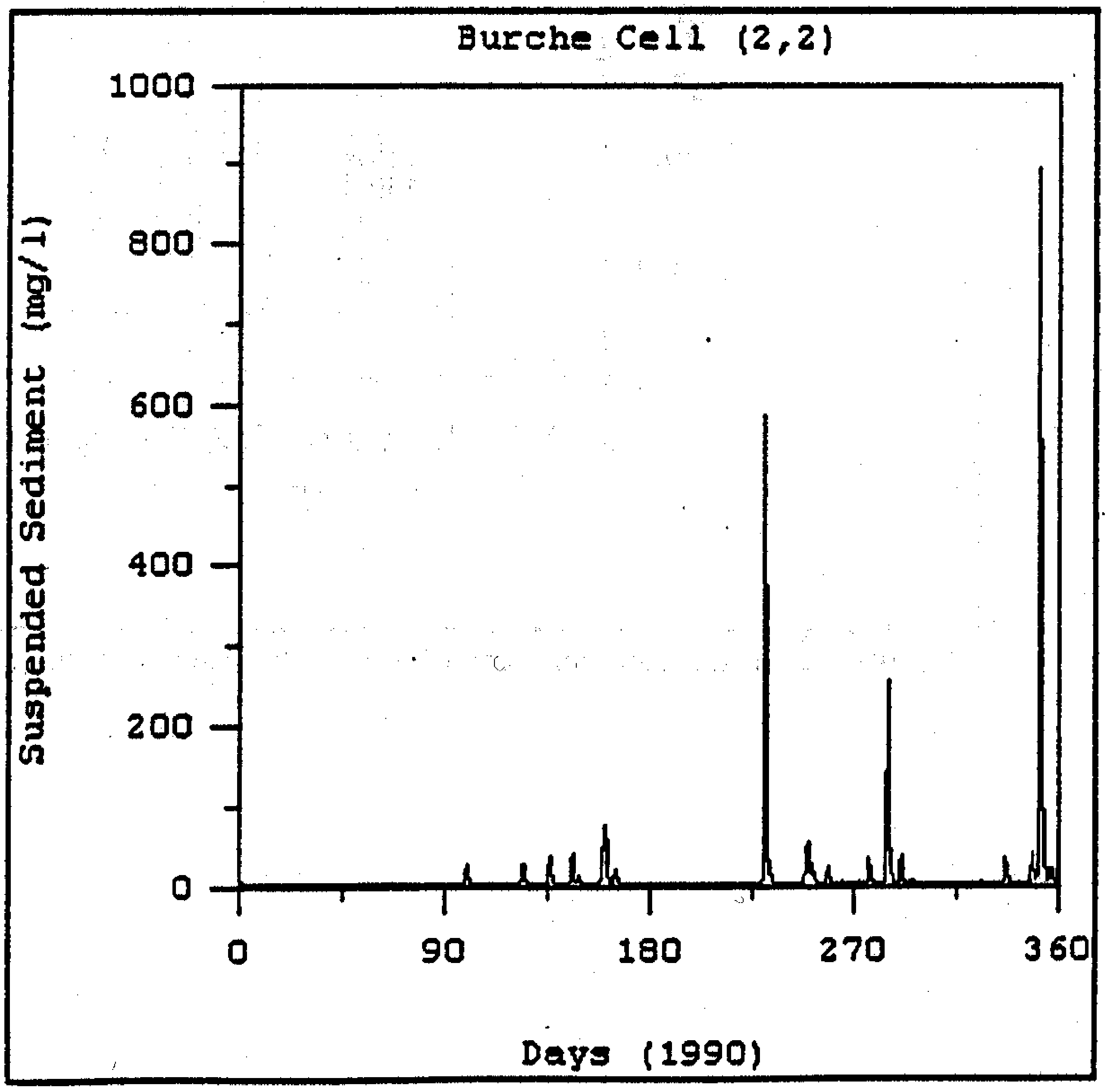

Figure 3.6. Suspended sediment concentration in representative cell for 1990 simulation year.

**Siltation Analysis.** Siltation of lakes and reservoirs can be quantified by the fraction of inflowing sediment retained in the waterbody. This fraction is commonly referred to as the trap efficiency. For a constant annual sediment inflow load, trap efficiency increases with waterbody volume, while for a fixed waterbody volume, trap efficiency decreases with increasing sediment load. The trap efficiency is also influenced by the types of sediments entering the waterbody, with the trap efficiency for bed load and suspended sands being higher than that for silts and clays.

Trap efficiency can be estimated by three different approaches. The first approach requires measurement of both sediment load and deposit over an interval of time. Direct measurements of sediment loads over long intervals require extensive field sampling, while measurement of sediment retention requires multiple bathymetric surveys to quantify deposition. The second approach is the use of empirical relationships between waterbody volume, annual volumetric inflow, and trap efficiency measurements for similar waterbodies. The Brune method (Brune 1953) exemplifies this approach using a graphical relationship between trap efficiency and the ratio of waterbody volume to annual volumetric inflow based on field measurement for a variety of lakes and reservoirs. Using a volume of 260,000 cubic meters and an annual inflow volume of 5.3 million cubic meters, the Brune parameter is approximately 0.05, corresponding to a trap efficiency in the range of 66% to 86% (Table 3.2).

The third approach for determining trap efficiency is direct simulation. For Burches Run Lake, a year-long simulation for hydrodynamic and sediment transport was conducted using 1990 inflows and sediment loading derived from a watershed model. The annual inflow to the lake was 5.3 million cubic meters, and the annual sediment load was 10.5 million kg. Using the mass of sediment deposited during the simulation, the trap efficiency was calculated to be 42%. The average annual siltation rate was estimated to be 0.7 cm per year.

The trap efficiency for Burches Run Lake was calculated at 66%-86%. This represents a long-term estimation. For 1990, the simulation model estimated the siltation of the lake due to the suspended load at 42%. The simulation model does not take into account the bed sediment load, which could significantly fill up the entrance/inflow points of the lake. The suspended load simulation for the 1990 hydrologic conditions alone resulted in a trapped load of about 420,000 kg. Although this trapped load corresponded to a predicted 0.7 cm/yr average accumulation (uniformly distributed over the lake), the accumulation of sediment in individual cells (preferential deposition areas) predicts accumulation in excess of 4 cm/year. The cells located near the inflow points are also exposed to deposition of the bed load, making siltation of the cells even higher.

**Table 3.2.** Calculated trap efficiencies for Burches Run Lake.

| Estimated Trap Efficiency Range (Brune 1953) | Simulated Trap Efficiency |
|---|---|
| 66 - 86 % | 42 % |

As the cells located downstream from the inflow points are rapidly silted, the usable lake area is reduced. Three ways in which the lake is impacted are reduction of surface area, reduction of access (e.g., public boat use), and reduction of habitat quality. A siltation rate in excess of 4 cm at the entrance cells can reduce the remaining life of the sensitive portion of the lake.

# 4.0 ALLOCATION

Total Maximum Daily Loads (TMDLs) are composed of the sum of individual waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relation between pollutant loads and the quality of the receiving water body. Conceptually, this definition is denoted by the equation:

$$\text{TMDL} = \Sigma\ \text{WLAs} + \Sigma\ \text{LAs} + \text{MOS}$$

The TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality standards. For some pollutants, TMDLs are expressed on a mass loading basis (e.g., pounds per day).

## 4.1 Incorporating a Margin of Safety

The MOS is part of the TMDL development process. There are two basic methods for incorporating the MOS (USEPA 1991):

- Implicitly incorporate the MOS using conservative model assumptions to develop allocations.
- Explicitly specify a portion of the total TMDL as the MOS; use the remainder for allocations.

The MOS is incorporated implicitly into the modeling process by conservative assumptions in the calculation the daily loadings of nutrients (phosphorus and nitrogen) and sediment. Other margins of safety used for this TMDL analysis include the following:

- Implementation of best management practices (BMPs) is not explicitly accounted for in the models since the BMPs' impact on loading rates is not known due to lack of "before and after" monitoring. Because the models do not reflect certain BMPs, which might be reducing nonpoint source loads, the overall load allocation reductions computed in this analysis might be overestimated and can be considered as part of the MOS.

## 4.2 Assessing Alternatives

For the allocation runs, the model was run for the 1990 representative hydrologic period. The reservoir model was used to evaluate the amount of load reduction required to meet the identified target values. Chlorophyll *a* concentration was reduced to an average summer value of less than 15 ug/L through a load reduction of 30% in total phosphorus loadings.

For siltation, three issues were considered—maintenance of adequate reservoir volume, preservation of reservoir surface area as measured through deposition in entrance points to the reservoir, and reservoir clarity (due to sediment loadings) measured as total suspended sediment. The final appropriate sediment loading was determined by evaluation of these issues through the following factors:

- The annual reservoir siltation accumulation rate (in centimeters per year) and 70% of the average reservoir depth.
- The annual siltation accumulation rate for a depositional cell and associated cell depth.
- The predicted total suspended sediment in the water column.

The recommended reduction in accumulation rate was assumed to be correlated to a corresponding sediment loading rate. The response to sediment loading reduction was tested by the repeated application of the reservoir model under various loading scenarios. In determining the required load reduction, all three factors were taken into consideration.

### 4.3 Recommended Allocations

For Burches Run Lake the average annual reservoir accumulation rate was 0.7 cm/yr with mean water depth approximated at 3.95 meters. The actual depth, especially at the tributary discharge points to the reservoir, might be less. A bathymetric survey is needed to better define the current condition of the lake and create a baseline condition for future monitoring. The simplified two cell model representation did not include a detailed evaluation of a depositional reach. The first cell had an estimated accumulation rate of 4 cm per year. For derivation of the load reduction a depositional cell with a depth of 1.8 meters was assumed. Seventy percent of the cell capacity would be removed due to sediment accumulation (4 cm/year) over a 32-year period. Reduction of the sedimentation rate by 20% would increase the time period for 70% by 8 years to 40 years. Evaluation of the endpoint for Burches Run Lake is based on consideration of the depositional cell.

The allocation reductions identified were 20% for sediment and 30% for the nutrient loadings expressed as total phosphorus. The overall nonpoint source sediment load reductions are summarized by percent for each land use category for the Burches Run Lake watershed in Tables 4.1 and 4.2. No point source load reductions were identified. These nonpoint source load allocations reduce the loadings of sediment and nutrients such that the in-lake conditions meet the identified target values.

**Table 4.1.** Nonpoint source total phosphorus allocations for the Burches Run Lake watershed for representative hydrologic year (1990).

| **Land Use** | **Percent Reduction** |
|---|---|
| Agriculture and Pasture | 40 % |
| Urban | 35 % |
| Forest | 10 % |
| **Overall Watershed** | **30 %** |

**Table 4.2.** Nonpoint source sediment allocations for the Burches Run Lake watershed for representative hydrologic year (1990).

| **Land Use** | **Percent Reduction** |
|---|---|
| Agriculture and Pasture | 30 % |
| Urban | 30 % |
| Forest | 10 % |
| **Overall Watershed** | **20 %** |

# 5.0 SUMMARY

Burches Run Lake watershed was divided into six subwatersheds, and the HSPF (Version 11.0) and EFDC models were selected as the modeling framework for performing TMDL allocations.

## 5.1 Findings

Output from the HSPF and EFDC models confirmed impaired conditions due to excess nutrient and sediment loading as measured by chlorophyll *a* and sediment accumulation rates. After applying the load allocations, the EFDC model indicated that the reservoir was meeting the established water quality goals. The model analysis indicates that water quality standards/goals will be achieved if loadings are reduced by 20% for sediment and 30% for nutrients.

## 5.2 Recommendations

This TMDL analysis was performed with very limited water quality data for characterizing point and nonpoint sources, as well as for characterizing in-stream water quality conditions. Because of the lack of high-frequency, long-term data sets, the water quality calibration of the HSPF watershed model and the EFDC reservoir model should be considered to be a "qualitative" calibration only. As additional data become available, they can be incorporated into the model and/or used to determine whether implemented controls are having the intended effect on improving water quality.

### 5.2.1 Hydrologic Flow Data

There were no stream USGS gages available in or directly downstream of the Burches Run Lake watershed. Daily flow values obtained from a USGS gage located in a characteristic West Virginia watershed were used to calibrate the hydrologic flow in the NPSM. Establishment of a gage within the watershed would likely improve the hydrologic calibration process and improve confidence in the computed stream flows in the model.

### 5.2.2 Water Quality Monitoring

In general, water quality conditions in Burches Run Lake and its inflows are monitored infrequently. Because sediment runoff problems in the study area are believed to generally coincide with storm runoff events, sampling at intervals of less than once per day will almost certainly miss the highest concentrations because storms tend to be short-term events. The ideal pollutant data set would consist of weekly samples collected during dry-weather periods and daily (or more frequent) samples during storm events. The cost of such an ambitious monitoring program might be prohibitive.

In 1998, WVDEP began a sampling program for selected water quality variables at locations in Burches Run Lake and its main inflows to support this TMDL development effort. It is recommended that the sampling program be continued on at least a monthly basis during the spring-to-autumn seasons to develop the database that will be necessary to (1) provide additional data for future modeling efforts and (2) determine the "before-and-after" impacts of BMPs implemented in the study watershed.

### 5.2.3 Point Sources

No point sources were identified as being located in the watershed. If point sources are established in the watershed in the future, the impact of their inputs should be evaluated to determine the effect on sediment and nutrient loadings related to this or any future TMDL analysis.

### 5.2.4 Septic System Information

The assumed failure rate of 2.5% for septic systems, as well as the estimated number of septic systems present in the watershed, is a source of some uncertainty. A septic survey of the watershed would be useful to determine more precisely the number of septic systems in use and whether the assumed failure rate is valid. Failing septic systems that are in close proximity to surface waters have the potential to contribute nutrient loadings.

### 5.2.5 Agricultural Data

The land use analysis indicates that agricultural land uses (i.e., row crops and hay/pasture) represent a significant percentage of the total watershed land area. No specific agricultural data (e.g., number of feedlots, livestock counts, fertilizer application rates) were evaluated as part of this analysis. Agricultural land uses potentially could be contributing to pollutant loading concerns (most specifically nutrient loadings), and incorporating more detailed agricultural data into the watershed model would likely improve the TMDL analysis. A more detailed land use and practice characterization should be compiled as part of the implementation process for the TMDL.

### 5.2.6 Wildlife Information

The contribution to pollutant loads (most specifically nutrient loads) from wildlife populations (e.g., duck, geese, and deer) was not evaluated during this study. If local data on wildlife populations are collected, an evaluation of potential impact could possibly be conducted for a future TMDL analysis.

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# Appendix

## 1993-1996 WVDEP Water Quality Sampling of Burches Run Lake

| | Sp 93 | Sum 93 | Sp 94 | Sum 94 | Fall 94 | Sp 95 | Sum 95 | Sp 96 | Sum 96 |
|---|---|---|---|---|---|---|---|---|---|
| Sample Date | 4-21 | 9-21 | 6-02 | 7-21 | 12-07 | 5-09 | 9-19 | 6-11 | 8-29 |
| Temperature, °C | | | | | | | | | |
| surface | 12.6 | 20.4 | 21.0 | 28.2 | 10.4 | 15.9 | 22.3 | 24.8 | 24.6 |
| bottom | 11.2 | 20.0 | 14.0 | 24.2 | ++ | 11.9 | 19.7 | 18.9 | 22.5 |
| inflow | 9.5 | 16.4 | 15.6 | 22.1 | 10.5 | 12.4 | 15.4 | 19.1 | 17.4 |
| PH, Standard Units | | | | | | | | | |
| surface | 7.2 | 7.6 | 8.4 | 8.0 | 8.4 | 8.8 | 7.4 | 8.6 | 7.8 |
| bottom | 7.5 | 7.4 | 7.5 | 7.6 | 7.7# | 7.8 | 7.4 | 7.6 | 7.2 |
| inflow | 7.1 | 7.7 | 8.1 | 7.4 | 7.8 | 8.3 | 8.0 | 8.1 | 7.8 |
| Conductivity, umhos/cm | | | | | | | | | |
| surface | 390 | 429 | 312 | 387 | 347 | 384 | 460 | 327 | 407 |
| bottom | 390 | 317 | 266 | 401 | 355# | 394 | 468 | 346 | 421 |
| inflow | 410 | 245 | 397 | 555 | 369 | 409 | 825 | 370 | 639 |
| Dissolved Oxygen, mg/L | | | | | | | | | |
| surface | 10.4 | 5.8 | 9.1 | 9.0 | 13.1 | 13.2 | 7.3 | 12.6 | 5.9 |
| bottom | 8.6 | 2.8* | 0.6* | 0.8* | ++ | 7.8 | 7.4 | 6.2 | 0.1* |
| inflow | 11.0 | 7.8 | 9.3 | 6.5 | 10.5 | 10.5 | 9.5 | 9.1 | 7.0 |
| Total Acidity, mg/L | | | | | | | | | |
| surface | 2 | 6 | 1 | 5 | 2 | 1 | <1 | <1 | <1 |
| bottom | 2 | 7 | 3 | 5 | 2 | 1 | <1 | <1 | <1 |
| inflow | --- | 8 | 1 | 8 | 2 | 1 | <1 | <1 | <1 |
| Total Alkalinity, mg/L | | | | | | | | | |
| surface | 117 | 148 | 148 | 10 | 110 | 128 | 151 | 130 | 144 |
| bottom | 130 | 150 | 138 | 154 | 138 | 130 | 153 | 120 | 143 |
| inflow | --- | 121 | 200 | 313 | 110 | 140 | 301 | 140 | 220 |
| Suspended Solids, mg/L | | | | | | | | | |
| surface | 4 | 11 | 16 | 17 | 26 | 11 | 12 | 12 | 6 |
| bottom | 6 | 31 | 8 | 31 | 4 | 8 | 12 | 12 | 8 |
| inflow | 2 | 64 | 2 | 1 | 1 | 10 | <1 | 11 | <1 |
| Total Phosphorus, mg/L | | | | | | | | | |
| surface | .030 | .070 | .072 | .057 | .232 | .052 | .060 | .040 | .050 |
| bottom | .031 | .082 | .030 | .084 | .029 | .032 | .070 | .040 | .050 |
| inflow | .026 | .226 | .033 | .050 | .034 | .026 | .100 | .040 | .050 |
| Orthophosphorus, mg/L | | | | | | | | | |
| surface | <.01 | .013 | .013 | <.010 | <.01 | | | | |
| bottom | <.01 | <.01 | .011 | .012 | <.01 | | | | |
| inflow | --- | .080 | .031 | .047 | <.01 | | | | |

**1993-1996 WVDEP Water Quality Sampling of Burches Run Lake (Continued)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Total Kjeldahl Nitrogen, mg/L | | | | | | | | | |
| surface | .37 | .72 | .60 | .64 | 3.87 | NR | .94 | <.50 | .19 |
| bottom | .39 | .57 | .31 | .65 | .47 | NR | .74 | <.50 | .28 |
| inflow | .15 | .79 | <.10 | <.10 | .17 | NR | .10 | <.50 | .16 |
| Ammonia Nitrogen, mg/L | | | | | | | | | |
| surface | <.01 | <.01 | <.01 | .10 | .17 | <.03 | .11 | <.50 | <.06 |
| bottom | <.01 | .07 | .02 | .26 | .15 | <.03 | .26 | <.50 | .09 |
| inflow | <.01 | .08 | .02 | .08 | .12 | <.03 | .06 | <.50 | <.06 |
| Nitrate-Nitrite Nitrogen, mg/L | | | | | | | | | |
| surface | .05 | .03 | <.01 | .03 | .82 | .55 | .06 | .11 | <.05 |
| bottom | .09 | .03 | .01 | .03 | .72 | .64 | .10 | <.05 | <.05 |
| inflow | .24 | .22 | .37 | .24 | 1.12 | .58 | .13 | .22 | .14 |
| Total Iron, mg/L | | | | | | | | | |
| surface | .035 | .380 | .435 | .250 | .580 | .510 | .330 | .490 | .540 |
| bottom | <.015 | 1.346 | .605 | 1.000 | .225 | .465 | .620 | .360 | .220 |
| inflow | --- | 2.094* | .130 | .175 | .140 | .310 | .090 | .420 | .240 |
| Total Mangenese, mg/L | | | | | | | | | |
| surface | .005 | .095 | .200 | .100 | .105 | .045 | .120 | .062 | .090 |
| bottom | <.005 | .129 | .470 | .595 | .095 | .060 | .150 | .057 | .870 |
| inflow | --- | .120 | .015 | .020 | .005 | .015 | .060 | .083 | .020 |
| Total Aluminum, mg/L | | | | | | | | | |
| surface | .190 | .313 | .300 | .100 | .340 | .280 | .190 | .520* | .200* |
| bottom | .340 | 1.112 | .185 | .705 | .060 | .210 | .520 | .410* | .500* |
| inflow | --- | 1.883 | <.050 | .115 | .080 | .505 | .420 | .380* | .140* |
| Chlorophyll *a*, mg/m3 | | | | | | | | | |
| surface | 10.20 | 53.02 | 28.68 | 26.32 | 60.85 | 15.19 | 48.93 | 14.0 | 79.90 |
| Secchi Depth, ft | 4.00 | 2.50 | 2.50 | 3.00 | 1.00 | 3.00 | 2.00 | 2.8 | 2.80 |

* = Violation of state water quality criteria
# = Laboratory value
++ = No result - field meter malfunction.
NR = No result, samples not analyzed.

## 1998 WVDEP Water Quality Sampling - Burches Run Lake and Tributaries

| | | Lake | | | | Burch Run | Big Run |
|---|---|---|---|---|---|---|---|
| | | 5/7/98 Near Dam Surface water | 5/7/98 Near Dam Bottom water | 5/7/98 Near Dam sediment | 5/7/98 Shallow End Surface water | 4/29/98 | 4/29/98 |
| Tot. Acidity | mg/L | ND | 1.8 | | 1.1 | ND | ND |
| Alkalinity | mg/L | 109 | 105 | | 115 | 153 | 120 |
| Tubidity (field) | NTU | 43 | 112 | | 52.9 | | |
| TSS | mg/L | 17 | 24 | | 20 | ND | 5 |
| TP | mg/L | 0.0312 | 0.0627 | | 0.0873 | 0.0222 | 0.0402 |
| Ortho P | mg/L | ND | ND | | ND | ND | ND |
| TKN | mg/L | ND | ND | | ND | ND | ND |
| Ammonia-N | mg/L | ND | ND | | ND | ND | ND |
| NO2-NO3-N | mg/L | 0.286 | 0.405 | | 0.325 | 0.298 | 0.3 |
| Al | ug/L | 118 | 789 | | 227 | 63.4 | 74.5 |
| Chlor a | mg/m3 | 121 | | | 91.6 | | |
| TP | mg/kg | | | 438 | | | |
| Al | mg/kg | | | 4849 | | | |
| Bulk Density | g/cc | | | 1.26 | | | |