TMDL Development for Mountwood Park Lake, Wood County, West Virginia

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EXECUTIVE SUMMARY

The objective of this study was to identify the background information and framework needed for developing a TMDL for siltation for Mountwood Park Lake. The West Virginia Division of Environmental Protection (WVDEP) has identified Mountwood Park Lake (designated code LK(L)-10-(1)) as being impacted by this pollutant, as reported in the 1998 303(d) list of water-quality-limited waters (WVDEP 1998). WVDEP has determined that siltation has impaired the aquatic life designated use.

Siltation has no specific numeric water quality criteria; however; elevated inputs of sediment have been demonstrated to cause impairment of the 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 the development of a TMDL for siltation for Mountwood Park Lake, the endpoint chosen is based on the evaluation of the average accumulation rate of sediment on the reservoir bottom.

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 the Mountwood Park Lake watershed using the Hydrologic Simulation Program—FORTRAN Version 11 (Bicknell et al. 1996). The watershed was divided into five land use categories and nine 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 multiple cells and two layers to better represent the system, and the lake model was used to evaluate siltation. The results of the watershed and reservoir models were compared with literature values, previous studies, and reservoir conditions to evaluate the models' performance.

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. The analysis was used to identify the appropriate load allocation to meet the in-lake numeric target identified. The representative hydrologic simulation year used for testing and development of the TMDL was 1995. The resulting load allocation from nonpoint sources was determined to be a 30% reduction of sediment load. 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, and forest management and stream restoration.

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).

Mountwood Park Lake is located in Wood County, West Virginia, approximately 14 miles to the east of Parkersburg. The lake's watershed is located within the Little Kanawha hydrologic cataloging unit (05030203) (Figure 1.1). The land area of the watershed is approximately 3,611 acres. Runoff from the watershed flows into Moutwood Park Lake from four main tributaries—Mudlick Run, East Fork Walker Creek, West Fork Walker Creek, and Eaton Tunnel Run. The East and West Forks of Walker Creek flow into Mountwood Park Lake on the northern part of the lake, Mudlick Run flows into the lake on the lake's eastern side, and Eaton Tunnel Run flows into the lake's southwestern portion. Discharge from the lake continues in Walker Creek, which flows to the Little Kanawha River and on to the Ohio River.

Mountwood Park Lake was originally impounded for recreational uses in 1979 as part of the Mountwood Park complex. The lake is used primarily for fishing (it has been stocked with bass, catfish, and trout) and recreational boating. The park and areas around the lake are used for hiking and family recreation. According to a "Clean Lakes" report prepared for the lake and its watershed, the swimming beach has been closed for a number of years due to excessive siltation and plant growth (F.X. Browne Associates 1992) The lake reportedly experienced significant siltation soon after its impoundment and a subsequent decrease in the number of users (visitors to the park) as the siltation problem continued.

The Mountwood Park Lake watershed is predominantly wooded with relatively small areas of pasture, row crops, and development. According to the Clean Lakes report, land use in the watershed had not changed significantly between 1973 and 1990, and it is not suspected that the watershed has undergone any significant changes in land use during the 1990s.

1.2 Purpose of the Study

The objective of this study was to identify the background information and framework needed for developing a TMDL for siltation for Mountwood Park Lake. The West Virginia Division of Environmental Protection (WVDEP) has identified Mountwood Park Lake (designated code LK(L)-10-(1)) as being impacted by this pollutant, as reported in the 1998 303(d) list of water-quality-limited waters (WVDEP 1998). WVDEP has determined that siltation is affecting the aquatic life designated use of the lake.

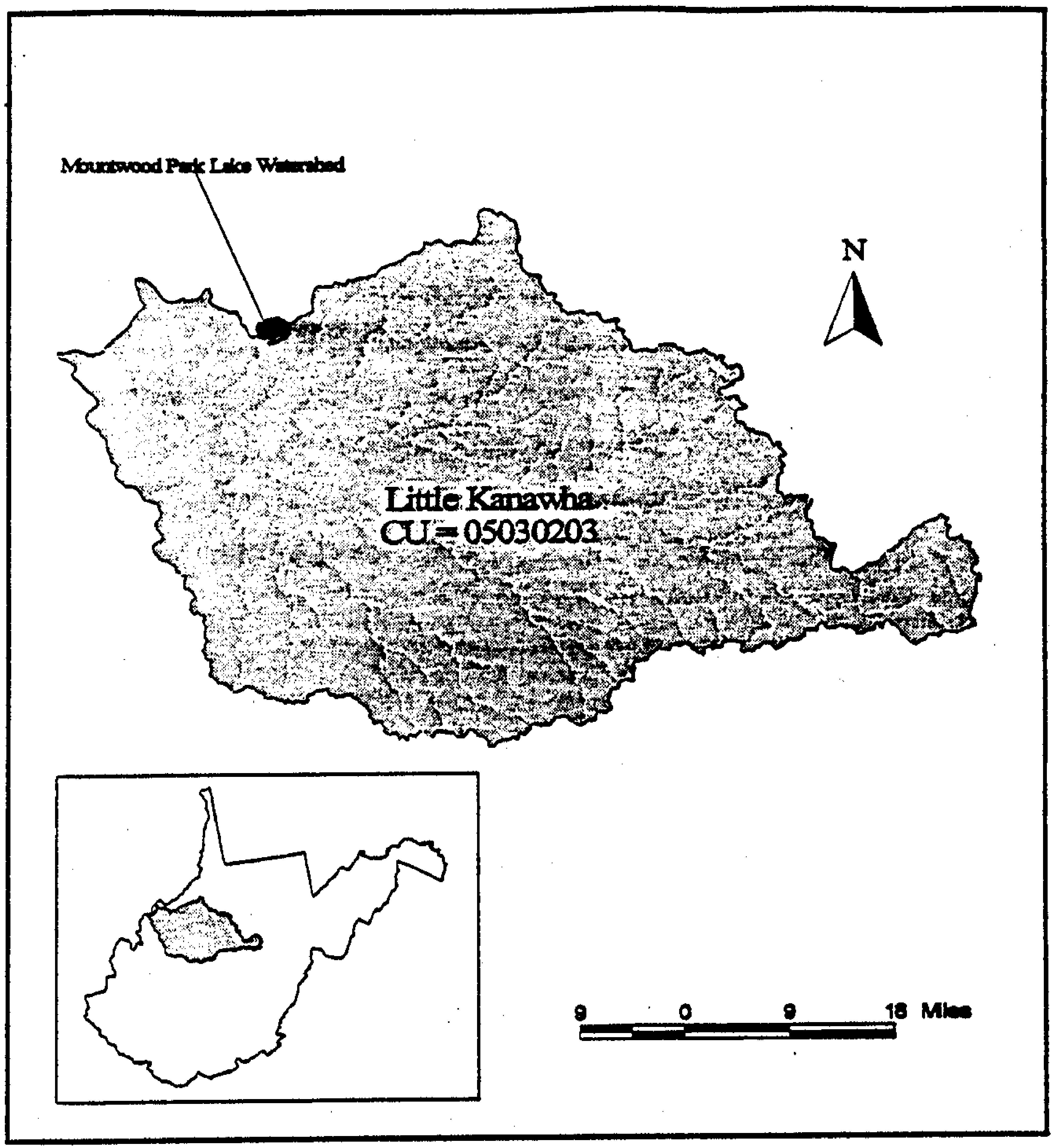

Figure 1.1. Location of Mountwood Park Lake watershed.

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 criteria must be used. The endpoint for siltation discussed below.

Excessive inputs of sediment to a lake can significantly impair its 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. Additionally, high concentrations of suspended sediment can cause physical harm to aquatic organisms and can alter feeding patterns. Increased sedimentation of a recreational use 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 a change in the makeup of fish species in the lake.

For the development of the TMDL for Mountwood Park 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 (TSS). Reductions in sediment load are expected to also result in beneficial reductions in the in-lake turbidity and suspended sediment concentrations. Changes in sediment loading and turbidity could result in changes in algal growth patterns and species composition.

2.0 SOURCE ASSESSMENT

This section presents an overview of the in-lake and in-stream water quality monitoring data available for Mountwood Park Lake and its inflows and then discusses the type, magnitude, and location of potential point and nonpoint sources of pollutant loading. The Clean Lakes study prepared for Mountwood Park Lake and its watershed provides an assessment of the water quality problems associated with the lake and the potential sources within the lake's watershed that are causing impairment of the lake's water quality. According to the Clean Lakes study, the major impact on the lake is caused by excessive sedimentation entering the lake from its inflows. Sediment loads were reported to likely be originating primarily from areas of streambank erosion and from forested areas.

2.1 Water Quality Monitoring Data

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

- Sampling conducted during the course of the Clean Lakes study in 1990—monthly sampling from January through April and September through December, and biweekly sampling from May through August. Lake samples were collected at two locations within the lake and at one location each within the East and West Forks of Walker Creek and Mudlick Creek. A summary of the TSS sample results for the lake's main inflows is shown in Table 2.1. The results clearly show that significant loading of sediment occurs during storm events.

- WVDEP sampling conducted at three locations in Mountwood Park Lake on May 13, 1998, and at one location each within the East and West Forks of Walker Creek, and Mudlick Run on April 29, 1998; May 6, 1998; and May 14, 1998. A summary of selected sample results is shown in Table 2.2, and the WVDEP sample results for 1998 sampling are provided in the appendix.

The Clean Lakes Study evaluated morphometric and monitoring data collected during the study and concluded the following:

- The average sediment thickness is 3.6 feet with a maximum of 12.1 feet.
- Sediment loading occurs primarily through the lake's inflows, and loading was estimated at 20,960 cubic yards per year.
- Low measured Secchi depths were attributed to sedimentation, not algal biomass.
- Chlorophyll *a* levels were relatively low year-round.

Table 2.1. Mountwood Park Lake tributary sampling TSS (mg/L).

Date	Mudlick	E. Fork	W. Fork
1/22/90	1	2.4	4
2/12/90	10	34	8.4
3/12/90	3.8	5.6	8.5
4/17/90	8.6	7	33
5/7/90	9.6	4.6	5.4
5/13/90 storm	410	280	1400
5/22/90	18	2	8
6/4/90	1.8	3.1	3.9
6/18/90	3.9	14	250
6/18/90 storm	290	450	250
7/9/90	8	6.4	15.2
7/23/90	8.8	18	16
8/20/90	9.2	20	14
8/27/90	8.7	8	0.2
9/10/90	26	3	5
10/15/90	14	2	6
11/11/90	3.6	7	12.4
12/17/90	3.6	1.8	1
4/29/98	ND	ND	ND
5/6/98	10	17	12
5/14/98	6	6	6

Table 2.2 Summary of WVDEP sampling observations of selected pollutants, Mountwood Park Lake, 1998.

Pollutant Type	Pollutant	Units	Criteria	Sample Type[a]	Total Obs	Minimum	Maximum	Mean
Metal	Iron	mg/L	1.5	Surface	2	0.53	0.55	0.54
		mg/L	1.5	Bottom	1	0.63	0.63	0.63
Nutrient	TKN	mg/L		Surface	2	ND[c]	ND[c]	ND[c]
		mg/L		Bottom	1	ND[c]	ND[c]	ND[c]
	NO2-NO3-N	mg/L	10	Surface	2	0.070	0.095	0.082
		mg/L	10	Bottom	1	0.241	0.241	0.241
	TP	mg/L	0.02[b]	Surface	2	ND[c]	0.0290	0.015
		mg/L	0.02[b]	Bottom	1	ND[c]	ND[c]	ND[c]
Sediment/ Solids	Turbidity	NTU		Surface	2	18.7	20.4	19.6
		NTU		Bottom	1	16.3	16.3	16.3

[a] Water sample in 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.

2.2 Assessment of Point Sources

A review of the Permit Compliance System (PCS) database indicates the presence of one permitted point source discharger in the watershed—the Mountwood Park sewage treatment plant, located near the lake. According to the Clean Lakes report, however, the sewage treatment plant discharges to Walker Creek below the impoundment structure; therefore, it was considered to contribute no pollutant loads to the lake or its inflows.

2.3 Assessment of Nonpoint Sources

Nonpoint sources of pollutants within the watershed can generally be associated with the different types of land uses in the watershed. For example, sediment loads can originate from agricultural land uses (i.e., row crops, pasture, animal operations). Moreover, expansion of residential and commercial/industrial areas can cause an increase in storm water flows due to the increase in impervious areas and an increase in sediment loads as a result of higher flows and the wash-off and erosion of sediment from construction sites.

To characterize flows and pollutant loadings from different parts of the Mountwood Park Lake watershed using the Hydrologic Simulation Program— FORTRAN (HSPF Version 11.0), the Mountwood Park Lake watershed was divided into nine subwatersheds (Figure 2.2). The watershed was divided into the nine subwatersheds to isolate reaches while maintaining practicality in the model setup. The nine subwatersheds and their associated areas are listed in Table 2.3.

Land use for the Mountwood Park Lake watershed was identified using the Federal Region III Land Cover Data Set (USGS 1998). This land cover data set was developed from multiresolution landscape classification (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 classes for the Mountwood Park Lake watershed identified the presence of seven 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, the MRLC land use classes were aggregated into classes designated for this TMDL study. Table 2.4 shows how the MRLC land uses were consolidated and also indicates the breakdown of the designated TMDL land use classes into pervious and impervious components.

A breakdown of land uses by subwatershed is provided in Table 2.5. A review of the land use information shows that forest land covers a vast majority (89%) of the area in the watershed. The next highest percentage of land is occupied by cropland (3%). Built-up areas make up only 0.55% of the watershed land area.

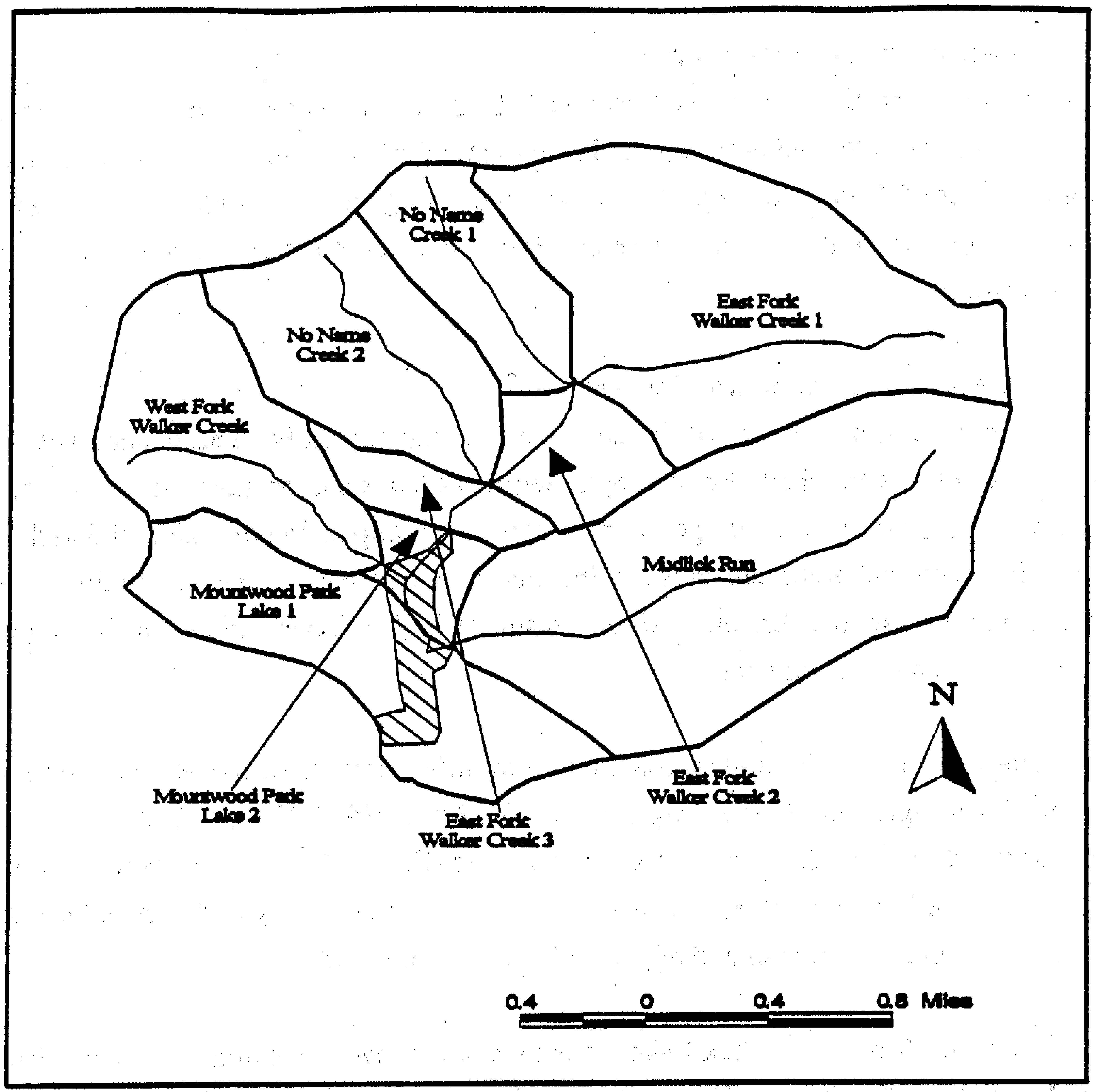

Figure 2.1. Mountwood Park Lake watershed and subwatershed.

Table 2.3. Mountwood Park Lake subwatersheds and associated areas.

Subwatershed Number[a]	Reach Name	Total Area(acres)
74	Mountwood Park Lake 1	385.84
75	Mudlick Run	900.67
76	Mountwood Park Lake 2	55.14
77	West Fork Walker Creek	527.73
78	East Fork Walker Creek 3	189.91
79	No Name Creek 2	277.77
80	East Fork Walker Creek 2	150.77
81	No Name Creek 1	264.20
82	East Fork Walker Creek 3	858.87
Total		3,610.9

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

Table 2.4. Land use class groupings.

TMDL Land Use Classes	Pervious/Impervious (Percentage)	MRLC Land Use Class (Class No.)
Residential	Pervious (50%) Impervious (50%)	Low Intensity Developed (21)
Forest	Pervious (100%)	Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43)
Cropland	Pervious (100%)	Row Crop (82)
Pasture	Pervious (100%)	Hay and Pasture (81)
Barren	Pervious (100%)	Transitional Barren (33)

Table 2.5. Land use distribution by subwatershed (acres).

Land use	Subwatershed									
	74	75	76	77	78	79	80	81	82	Totals
Residential	0.89	3.11	0.67	2.00	4.45	0	3.34	0	5.56	**20.02**
Forest	341.36	845.08	44.25	441.22	163.89	237.07	130.98	214.83	797.27	**3,215.95**
Pasture	7.78	7.56	1.11	65.61	5.34	34.25	0.44	46.48	10.45	**179.02**
Cropland	3.56	34.47	0.44	15.79	12.68	6.45	12.45	2.45	30.69	**1,18.98**
Barren	3.56	6.89	0.22	3.11	1.33	0	3.56	0	14.9	**33.57**
Water	28.69	3.56	8.45	0	2.22	0	0	0.44	0	**43.36**
Totals	**385.84**	**900.67**	**55.14**	**527.73**	**189.91**	**277.77**	**150.77**	**264.20**	**858.87**	**3,610.9**

Area values are in acres

The potential contribution of nutrients from failing septic systems was not assessed for the Mountwood Park Lake watershed because discharges from failing septic systems are not considered a significant contributor of sediment loads to the lake.

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 will cause loadings of sediment to be delivered to the lake. During dry periods, little or no land-based runoff will occur.

In general, the critical conditions will vary depending on the pollutant type and the designated use impact under evaluation. In most cases there are insufficient observed data available to evaluate the relationship between inflow and in-lake conditions. The following rationale was applied to the development of appropriate critical conditions for Mountwood Park Lake:

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

A continuous simulation model is necessary to capture the buildup and washoff of sediment due to nonpoint sources and to compare episodic (wet-weather) loadings to the in-lake conditions. The loading model is linked to a continuous simulation reservoir model. The reservoir model allows for the examination of the various critical conditions of long-term sediment accumulation rates.

3.0 MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between the in-lake 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 depends on the waterbody types, the pollutant of concern, the relevant pollutant processes, and the source loading characteristics. The selection of modeling needs and capabilities includes examination of reservoir and watershed loading model components.

3.1.1 Reservoir Model Selection

Mountwood Park Lake is characterized by shallow depth, short residence time, and variable (nonpoint source) inflows. The lake is listed for siltation, and impacts due to this pollutant 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 siltation, the following modeling capabilities were identified for the reservoir model:

- Representation of the lake with 31 cells and two layers (two-dimensional modeling).
- Simulation of lake sediment deposition.
- Simulation of lake eutrophication processes including flux from bottom sediments.
- Simulation of metals (e.g., iron) in the water column, deposition of sediment-associated metals, and adsorption/desorption processes.

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 currently under development by USEPA. EFDC is projected for inclusion in future versions of the EPA Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) 2.0 (USEPA 1998) modeling system.

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

- Hydrodynamics
- Sediment deposition
- Eutrophication cycle
- Iron adsorption/desorption (suspended and deposited sediment)

3.1.2 Watershed Loading Model

For Mountwood Park Lake the inputs to the lake are exclusively derived from nonpoint sources. Delivery of sediment is primarily during runoff events. 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 pollutant, 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 from nonpoint sources.

Based on a review of the available public domain models (USEPA 1997), Bicknell et.al. 1996 the Hydrologic Simulation Program—FORTRAN (HSPF) Version 11.0 (Bicknell et al. 1996) was selected. 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 can 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 Mountwood Park Lake

Thirty-one cells were used for the model in a horizontal direction (Figure 3.1). The maximum width of the cells was 155 m and the minimum was 31 m. The cells of the lake model were parameterized based on the lake bathymetry data developed for the Clean Lakes Study (F.X. Browne Associates 1992). Because the lake experiences very weak stratification and is relatively shallow, two layers were used in the vertical.

Three major tributaries provide inflow and suspended sediment loads. Outflow through the spillway is implemented through the use of flow control, one of the built-in functions of the model.

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.

Characteristics of Mountwood Park Lake were obtained from the Clean Lakes report. A summary of lake characteristic information is provided in Table 3.1.

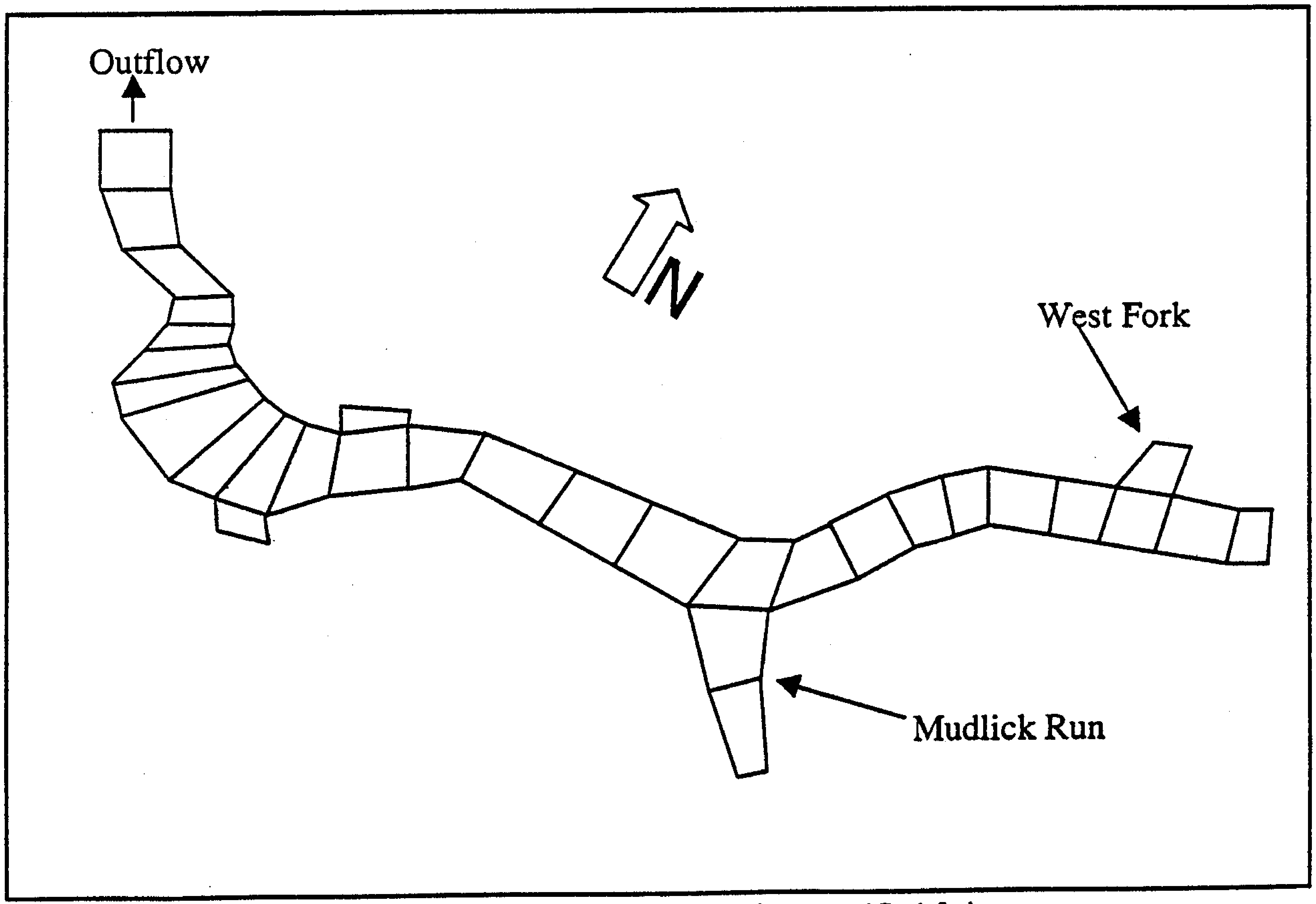

Figure 3.1. Model segmentation for Mountwood Park Lake.

Table 3.1. Mountwood Park Lake characteristics.

Area	41.3 acres
Volume	185.3 million gallons
Average Depth	14.4 feet
Maximum Depth	30.8 feet
Hydraulic Residue Time	39 days
Average Discharge	7.4 ft^3/sec

Source: F.X. Browne Associates, Inc. 1992

3.2.2 Watershed

To obtain a spatial variation of the concentration and loadings of sediment entering Mountwood Park Lake, the watershed was subdivided into nine 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.

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 the Mountwood Park Lake tributaries and average annual loading estimates developed for the Clean Lakes study (F.X. Browne Associates 1992). 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 Mountwood Park Lake

Inflows to the reservoir were based on predicted values supplied by the HSPF model application. Discharge from the reservoir was estimated from the water budget analysis provided in the Clean Lakes study (F.X. Browne Associates 1992). The hydrodynamic simulation was examined over time to verify that the lake volume and condition corresponded to observed conditions. The years 1989-1995 were selected for testing purposes since in-lake monitoring observations are available for that time period. The calibration parameters for suspended solids are settling velocity and resuspension rates for both classes of sediments.

3.5.2 Watershed

To develop a representative linkage between the sources and the in-lake water quality response in Mountwood Park 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 a comparison of the modeled overall water balance and stream flows. Two types of comparisons were performed. A hydrologic simulation was performed for a representative West Virginia watershed since no gage was available within or downstream of the watershed. The gage used was Poplar Fork at Teays (USGS gage #03201410), which has an available historical record of January 26, 1967 to October 11, 1978. The drainage area is 8.71-mi^2 at the gage, which is slightly larger than the 5.8-mi^2 drainage area of the Mountwood Park Lake watershed. It was assumed that the hydrologic characteristics of the Mountwood Park watershed were similar to those of the gage watershed.

For the hydrologic calibration, the period from January 1, 1970 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 Mountwood Park Lake watershed. Simulation results were then compared to the previously derived estimates of the water balance for 1990. Based on this evaluation, the parameter values were deemed reasonable and it was assumed that the model was adequately represented the hydrologic inflow to Mountwood Park Lake.

Parameters related to sediment loading were adjusted by comparing average annual loading estimates to previously derived estimates and literature values. The modeled in-stream concentrations were also compared to available observed data from tributary sampling performed in 1990 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

The model was run for the hydrologic period 1989-95. The modeling run represents the existing condition of total sediment loadings to the lake. For the existing conditions, the overall sediment loadings by land use category are shown in Table 3.2 and the overall annual loading is shown in Figure 3.2.

Table 3.2. Annual nonpoint source pollutant loading factors (kg).

Land Use Category	Annual Pollutant Loading - Sediment
Residential	6,825.96
Forest	292,848.82
Cropland and Pasture	487,602.25
Barren	5,722.96
Total	792,999.99

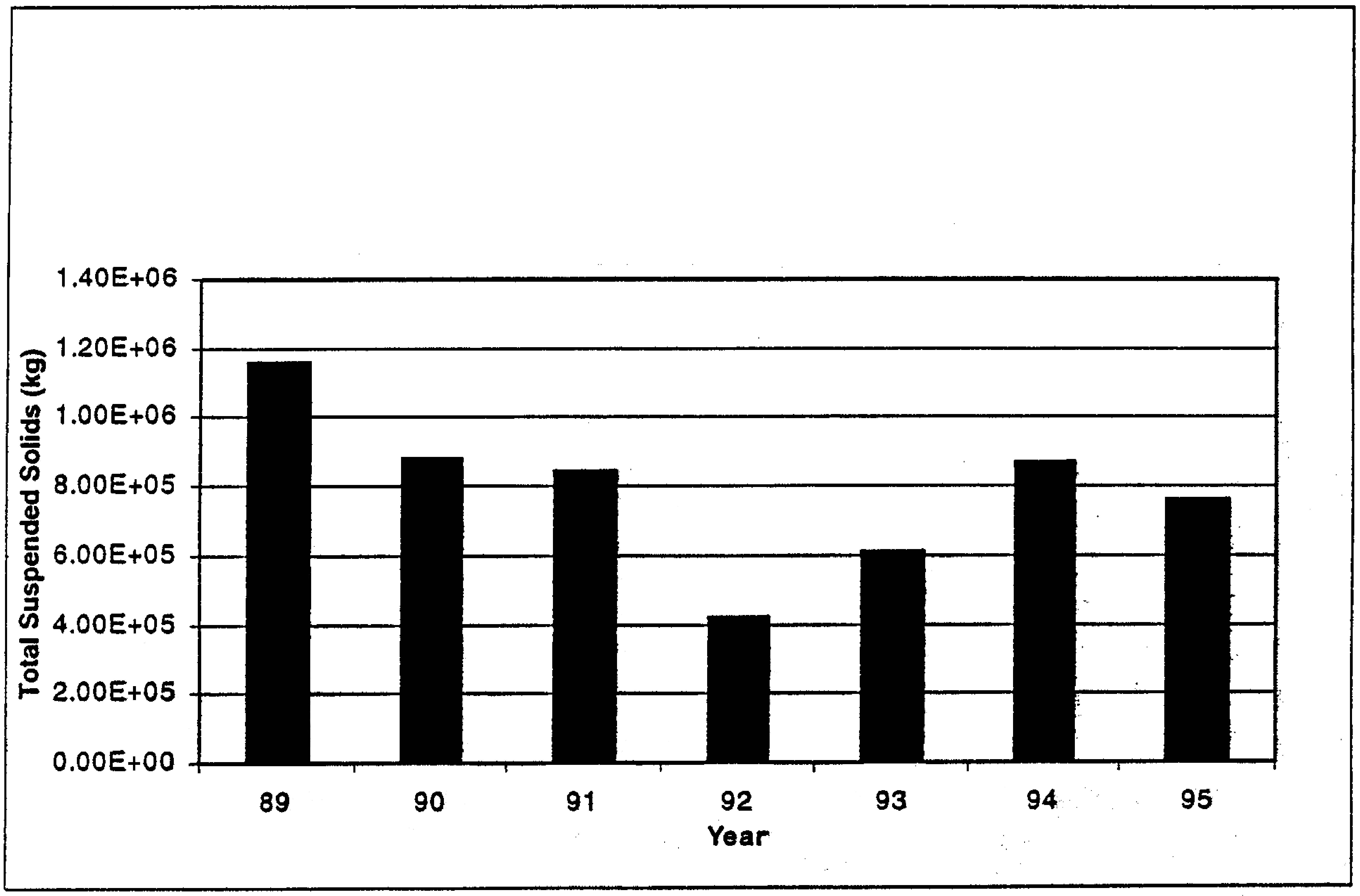

Figure 3.2. Annual TSS loading for 1989-95.

Model simulations were found to adequately characterize in-lake conditions within the constraints of the data available. Figures 3.3 shows the predicted sediment accumulations and Figure 3.4 shows the predicted sediment concentrations.

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 water body 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 701,000 cubic meters and an annual

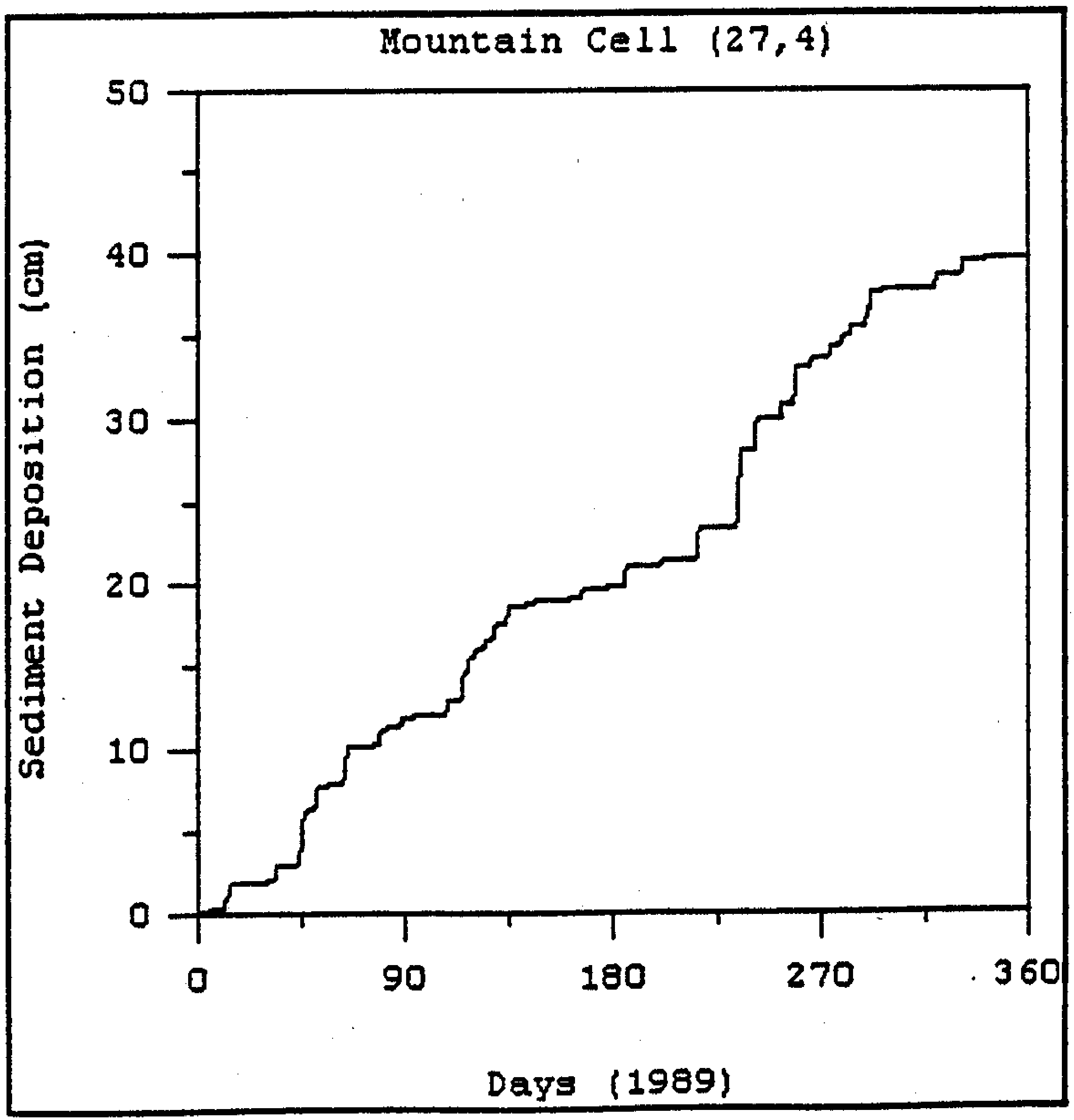

Figure 3.3. Sediment accumulation in representative cell for simulation period.

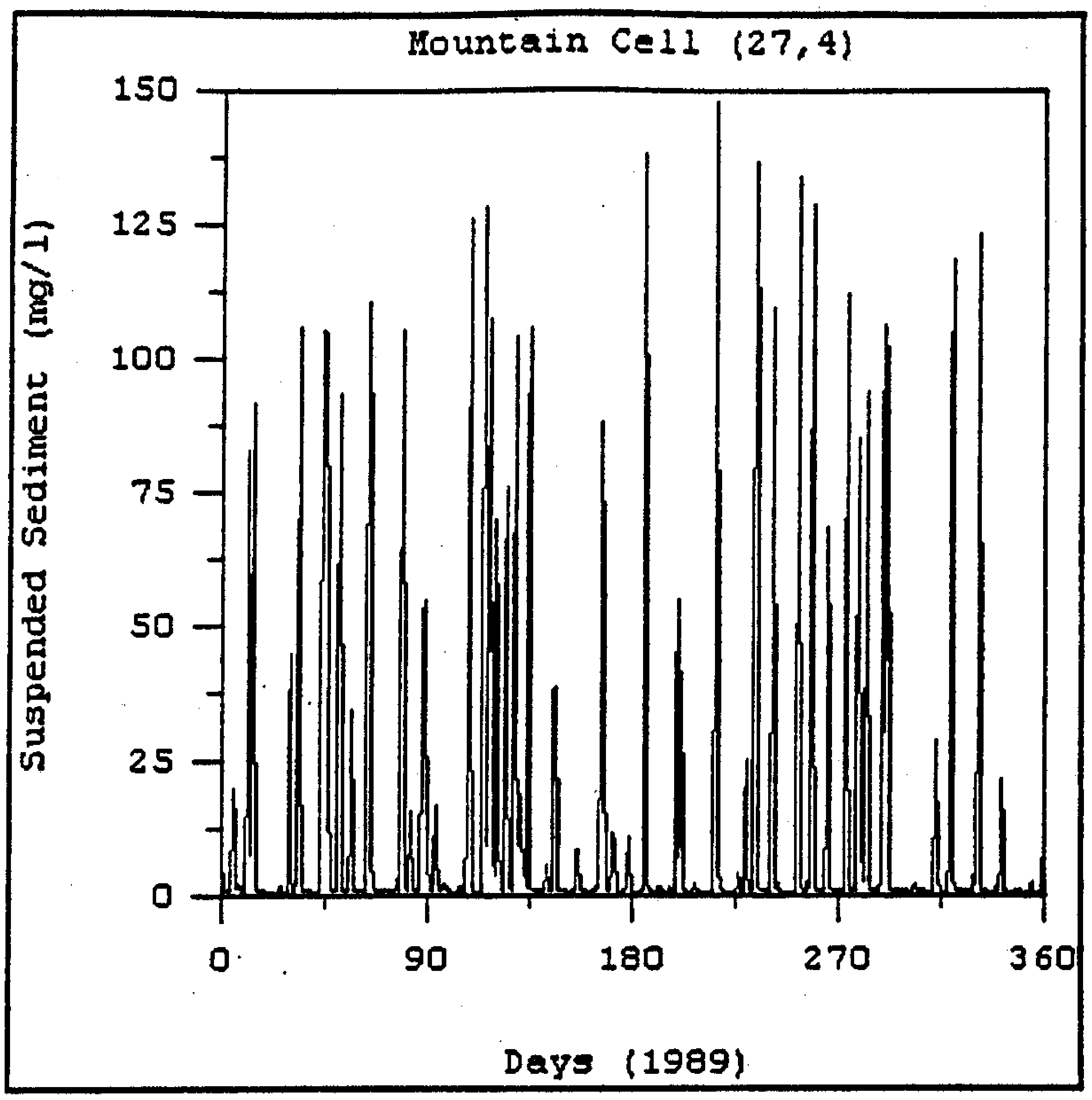

Figure 3.4. Suspended sediment concentration in representative cell for 1995 simulation period.

Table 3.3. Calculated trap efficiencies for Mountwood Park Lake.

Estimated Trap Efficiency Range (Brune 1953)	**Simulated Trap Efficiency**
78-94 %	52 %

inflow volume of 6.6 million cubic meters, the Brune parameter is approximately 0.11, corresponding to a trap efficiency in the range of 78% to 94 %.

The third approach for determining trap efficiency is direct simulation. For Mountwood Park Lake, a year-long simulation for hydrodynamic and sediment transport was conducted using 1989 inflows and sediment loading derived from a watershed model. The annual inflow to the lake was 10.1 million cubic meters and the annual sediment load was 11.7 million kg. Using the mass of sediment deposited during the simulation, the trap efficiency was calculated to be 52%. The average annual siltation rate was estimated to be 0.2 cm per year, ranging from 0 to 40 cm in the various cells of the model. The highest sediment accumulation rates were in the inlet cells along the north and south branches of the reservoir. The average annual accumulation rate predicted by the Clean Lakes report was 10.16 cm/hr (F.X. Browne Associates, 1992).

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 waterbody. 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.

Margins of safety used for this TMDL analysis include the following:

- Best management practices (BMPs) implemented are not explicitly accounted for in the models since their impact on loading rates is not known due to lack of "before and after" monitoring. Since the models do not reflect certain BMPs that 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.

- Conservative assumptions were sued in the development of the model and subsequent analysis of the load reductions. The loadings calculated for the watershed were relatively high, although consistent with the previously derived estimates from the Clean Lakes study (F.X. Browne Associates 1992). Evaluation of the accumulation rates was performed based on the higher typical accumulation rates derived from the previous Clean Lakes study (F.X. Browne Associates 1992).

4.2 Assessing Alternatives

The depth of the reservoir varies from a minimum of 5 feet (1.52 m) to 25 feet (7.6 m). The mean depth of 14.4 feet (4.4 m) is based on the bathymetric survey performed in 1990. The simulation of the sediment processes indicated that the trap efficiency under current conditions is relatively high based on predictions by both the Brune trap efficiency methods and model simulations. Sedimentation rates were predicted by the model application to exceed 0.4 cm/yr in many cells, with maximum accumulations of 40 cm in selected cells. The Clean Lakes report estimated an areawide accumulation rate of 4 inches (10.16 cm) per year based on review of the bathymetry. Areas in the proximity of the inlet are likely to accumulate quickly, further reducing the effective surface area of the lake. TSS concentrations at the inlet points are periodically high, in keeping with the high TSS observed during the tributary sampling in 1990.

The analysis of the accumulation rate was performed using an average cell depth of 14.4 ft (4.38 m). As a conservative assumption, the accumulation rate selected was that derived from the Clean Lakes report (10.18 cm per year). Assuming a cell depth of 4.38 m, a 70% capacity will be preserved for 40 years with a reduction of accumulation rate from 10.18 cm/yr to 7.75 cm/yr.

For the allocation runs, the model was run for the same representative hydrologic period (1989) as used for the existing conditions calibration run. The overall nonpoint source sediment load reductions by land use category for Mountwood Park Lake watershed are given in Table 4.1. Figure 4.1 illustrates the existing and allocated TSS loadings. Figures 4.2 and 4.3 show the expected sediment deposition and suspended sediment concentration after the 30 percent reduction in loading. These nonpoint source load allocations reduce the in-stream concentrations of sediment sufficiently for the representative year so that the in-lake conditions meet the identified target accumulation rate of 7.75 cm/yr.

4.3 Allocation

The overall reduction identified is 30% for the Mountwood Park Lake watershed. Based on examination of the land use distribution and source loading characteristics, it is recommended that reductions of 20%, 30%, 31% and 5% be applied to residential, agricultural (cropland/pasture), forest, and barren lands, respectively. These load reductions are expected to be achieved through a combination of erosion and sediment control practices, best management practices, forestry management, and stream restoration. More specific sediment control recommendations are included in the Clean Lakes report (F.X. Browne Associates 1992).

Table 4.1. Nonpoint source sediment allocations for Mountwood Park watershed for representative hydrologicyear (1989).

Land Use	**Percent Reduction**
Residential	20%
Cropland and Pasture	30%
Forest	31%
Barren	5%
Overall Watershed	**30%**

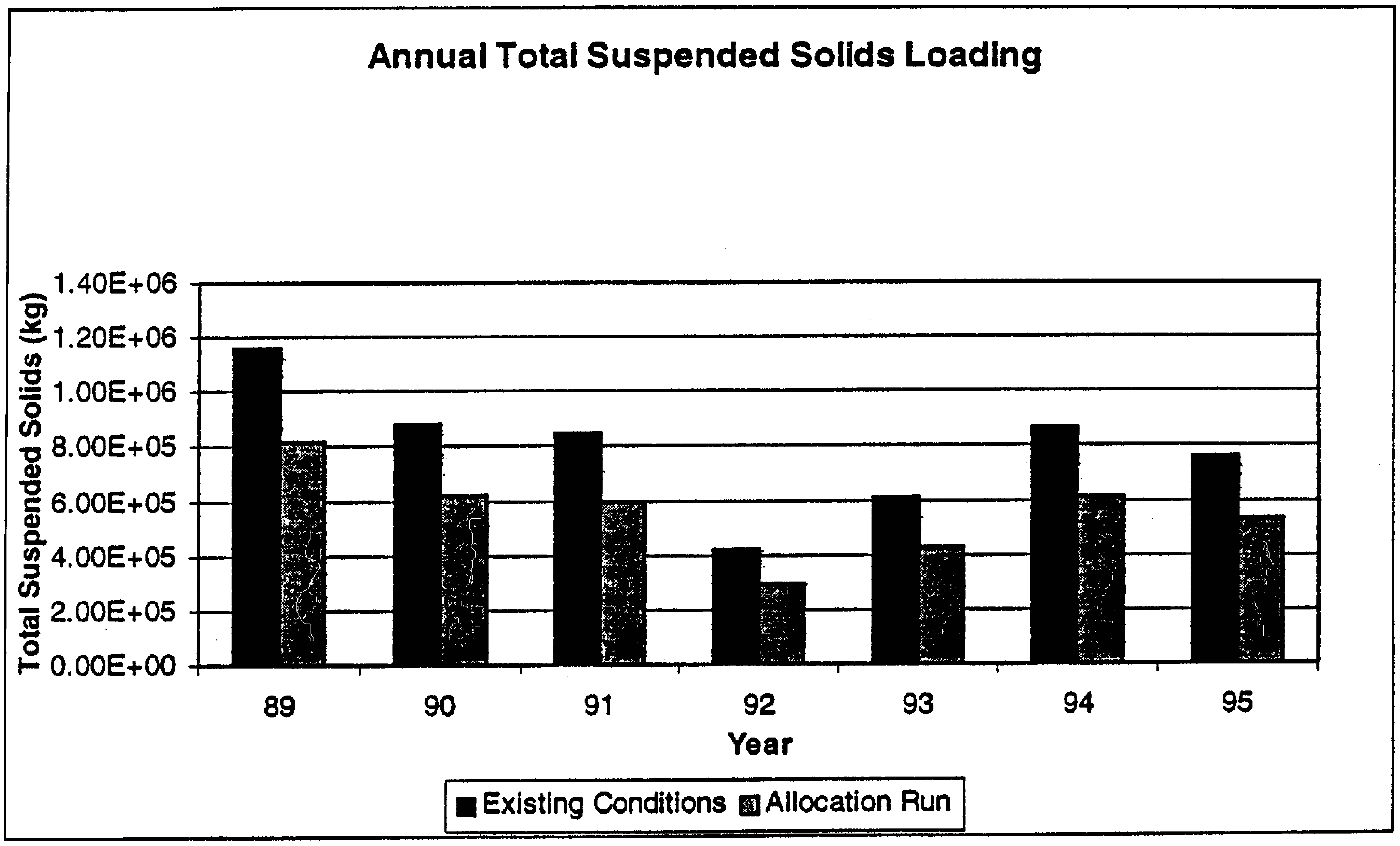

Figure 4.1. Existing and allocated TSS loadings for Mountwood Park Lake.

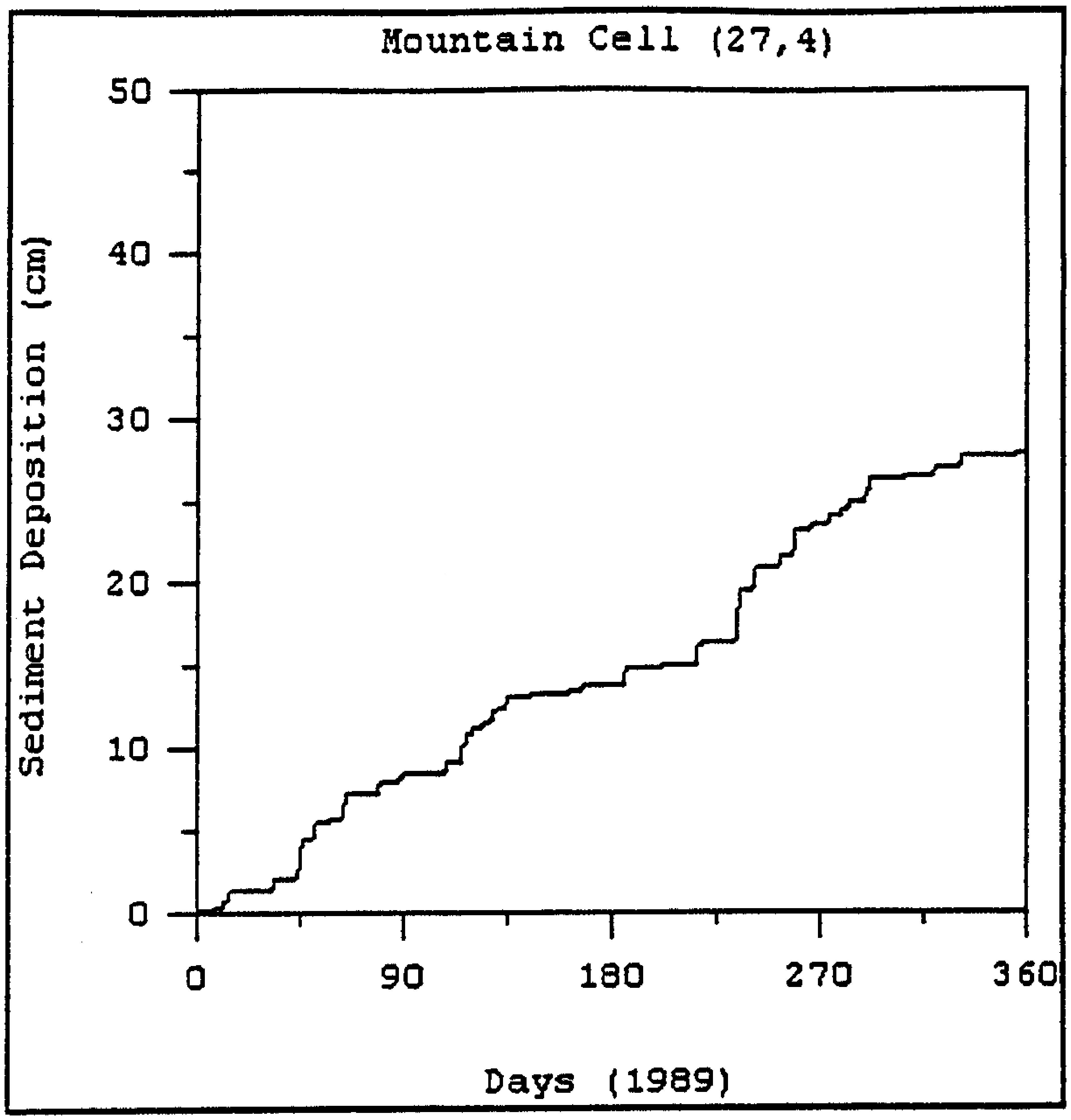

Figure 4.2. Sediment deposition for representative reach with 30% reduction in loading.

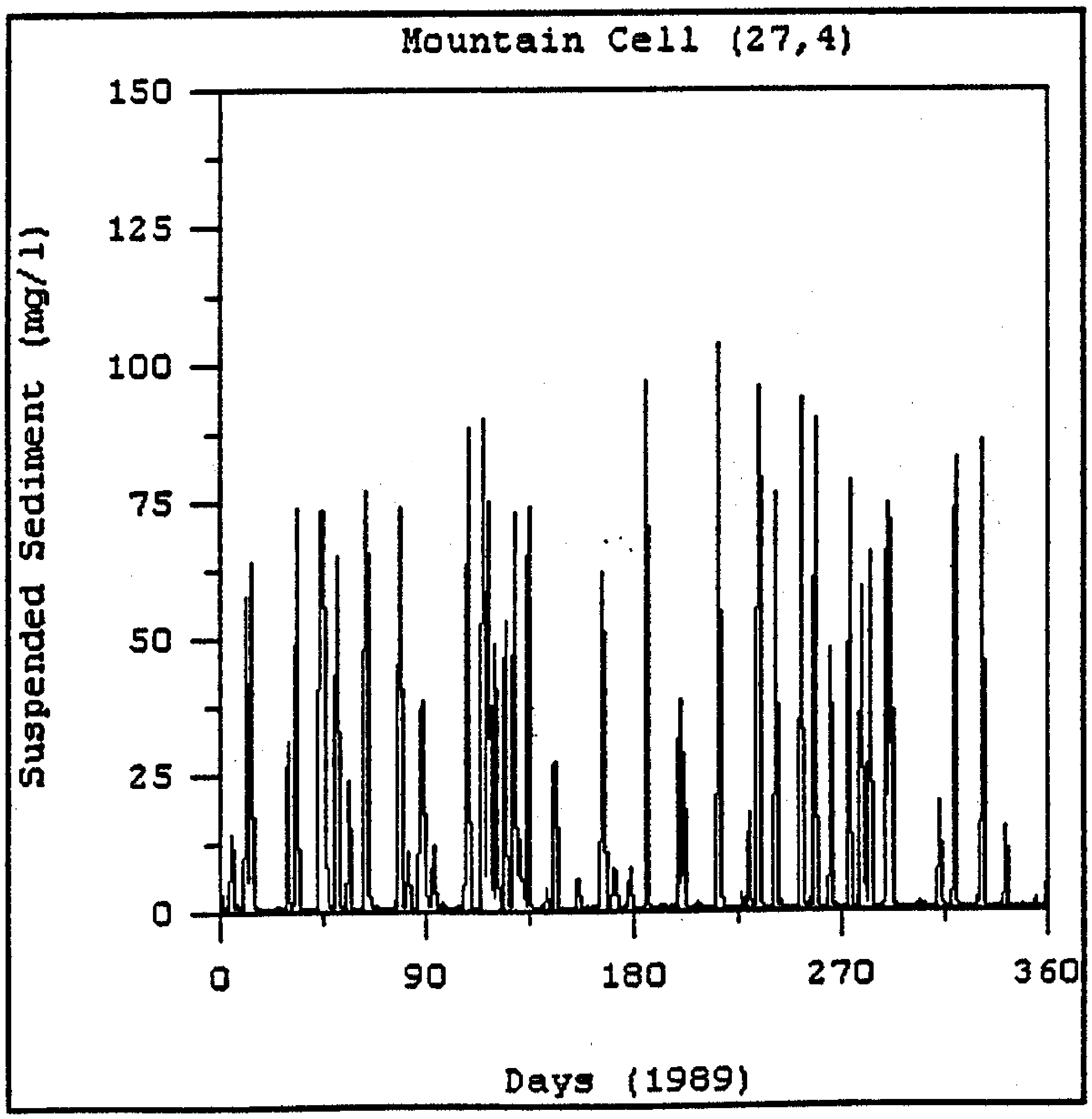

Figure 4.3. Suspended sediment concentration for representative reach based on 30% reduction in loading.

5.0 SUMMARY

The Mountwood Park Lake watershed was divided into nine subwatersheds, and BASINS, HSPF (Version 11.0), and EFDC were selected as the modeling framework for performing the TMDL allocations.

5.1 Findings

Output from the HSPF and EFDC models confirmed impaired conditions due to excess sediment loading as measured by 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 sediment loadings are reduced by 30%.

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-lake water quality conditions. Because of the lack of high-frequency, long-term data sets, the water quality calibration of the HSPF watershed 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.

The remainder of this section is a discussion that includes the key areas of data uncertainty as well as recommendations for filling the data gaps for future TMDL analyses.

5.2.1 Hydrologic Flow Data

There were no stream USGS gages available in or directly downstream of the Mountwood Park 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 HSPF model. 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 Mountwood Park Lake and its inflows are monitored infrequently. The only long-term monitoring study in the watershed was the Clean Lakes study conducted during 1990, which collected data approximately once per month at two locations in the lake and at one location in two of the main inflows. Because sediment runoff problems in the study area generally coincide with storm runoff events, sampling at intervals of less than once per day will almost certainly miss the highest concentrations since 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 Mountwood Park 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 long-term data base 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

Flows from the Mountwood Park treatment plant contribute relatively little sediment load to the lake and are not considered a significant contributor to sediment problems. If other point sources are established in the watershed in the future, the impact of their inputs should be evaluated to determine the effect on sediment loadings related to this or any future TMDL analysis.

5.2.4 Rainfall Data and Representative Hydrologic Year

The representative hydrologic year used for this TMDL was the 1989 water year. Hourly rainfall data from the Smithville station available in BASINS for this project covered the period 1970-97. Future modeling should use the most recent rainfall records corresponding to a representative hydrologic year that includes the best available concurrent water quality data set (i.e., 1994-97). This will help to improve certainty in the model water quality calibration.

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APPENDIX

		Lake			Mudlick Run			West Fork Walker Creek			East Fork Walker Creek		
		5/13/98	5/13/98	5/13/98	4/29/98	5/6/98	5/14/98	4/29/98	5/6/98	5/14/98	4/29/98	5/6/98	5/14/98
		Head of Lake	Near Spillway	Near Spillway				Above lake					
		Surface	Surface	Bottom									
		water	water	water	water	water	water	water	water	water	water	water	water
Tot. Acidity	mg/l	2.8	2	6.7	1.5	1.9	1.8	1.1	1.3	1.5	1.3	1.3	1.6
Alkalinity	mg/l	37.1	34	51.3	45.9	30.5	63	55.1	36.6	72.3	53.4	35.3	69.9
Tubidity	NTU	18.7	20.4	16.3	4.71	9.01	3.14	9.71	22.3	4.91	4.55	12.8	3.28
BOD5	mg/l	ND	ND	ND	3.3	ND	ND	ND	17	ND	ND	ND	ND
TSS	mg/l	15	14	18	ND	10	6	ND	17	6	ND	12	6
TP	mg/l	ND	0.029	ND	0.0245	ND	ND	ND	0.0469	ND	ND	ND	ND
Ortho P	mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TKN	mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.9
Ammonia-N	mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
NO2-NO3-N	mg/l	0.0947	0.0696	0.241	0.0673	0.112	0.0837	0.0529	0.106	0.127	ND	0.0708	0.0876
Al	ug/l	378	368	279	88.3	190	73.4	137	994	160	77.8	329	ND
Fe	ug/l	551	525	633	119	272	164	204	1080	243	108	474	97.9
Chlor a	mg/m3	2.84		20.8									