TMDL Development for Tomlinson Run Lake, Hancock County, West Virginia

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Region 3
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EXECUTIVE SUMMARY

The objective of this study was to identify the background information and framework needed for developing a Total Maximum Daily Load (TMDL) for siltation for Tomlinson Run Lake. The West Virginia Division of Environmental Protection (WVDEP) has identified Tomlinson Run Lake (designated code O(L)-102-(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 of the lake. Elevated inputs of sediment have been demonstrated to have caused impairment of the recreational uses of the lake (Coastal Environmental Services 1994).

Siltation has no specific numeric water quality criterion. 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 Tomlinson Run Lake, the endpoint chosen is based on the evaluation of the average accumulation rate of sediment on the reservoir bottom. This target is chosen to protect the beneficial use of the reservoir for recreation and aquatic life by preserving reservoir capacity.

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 Tomlinson Run Lake watershed using the Hydrologic Simulation Program-FORTRAN (Version 11) (Bicknell et al. 1996). The watershed was divided into seven 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 model simulations were compared with literature values, previous studies, and lake conditions to evaluate the models 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 TMDL 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. It was assumed that the lake would be dredged, in keeping with previous recommendations of the Tomlinson Run Lake Clean Lakes study (Coastal Environmental 1994). The loads are described as average annual load reductions, which are 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, forest management techniques, and stream restoration activities.

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).

Tomlinson Run Lake is located in Hancock County, West Virginia, approximately 6 miles south of East Liverpool, Ohio. The lake's watershed is located in the extreme northern section of West Virginia's northern panhandle and extends into Beaver County, Pennsylvania. The watershed is located within the Upper Ohio hydrologic cataloging unit (05030101) (Figure 1.1). The lake and part of its watershed fall within Tomlinson Run Lake State Park. The land area of the watershed is approximately 13,812 acres. Runoff from the watershed flows into Tomlinson Run Lake from two main tributaries— the North Fork and the South Fork of Tomlinson Run. Discharge from the lake continues in Tomlinson Run via a concrete spillway, and Tomlinson Run eventually discharges to the Ohio River. The watershed is predominantly rural since the main land uses found within the watershed include forest and hay/pasture. Built-up (residential and commercial) areas and row crop agriculture represent relatively small portions of the watershed.

Tomlinson Run Lake was originally impounded in the early 1940s, a few years after the development of Tomlinson Run State Park (Coastal Environmental Services 1994). The lake is used primarily for fishing (the lake has been stocked with bass, catfish, and trout) and recreational boating. The park and areas around the lake are used for hiking, camping, and picnicking. According to a "Clean Lakes" report prepared as an evaluation of the lake and its watershed (Coastal Environmental Services 1994), the lake reportedly experienced significant siltation soon after its impoundment and has been dredged twice in the past. The buildup of sediment has adversely affected use of the lake for fishing (by impairing fish spawning habitat) and for boating.

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 Tomlinson Run Lake. The West Virginia Division of Environmental Protection (WVDEP) has identified Tomlinson Run Lake (designated code O(L)-102-(1)) as being impacted by this pollutant, as reported in the 1998 303(d) list of water-quality-limited waters

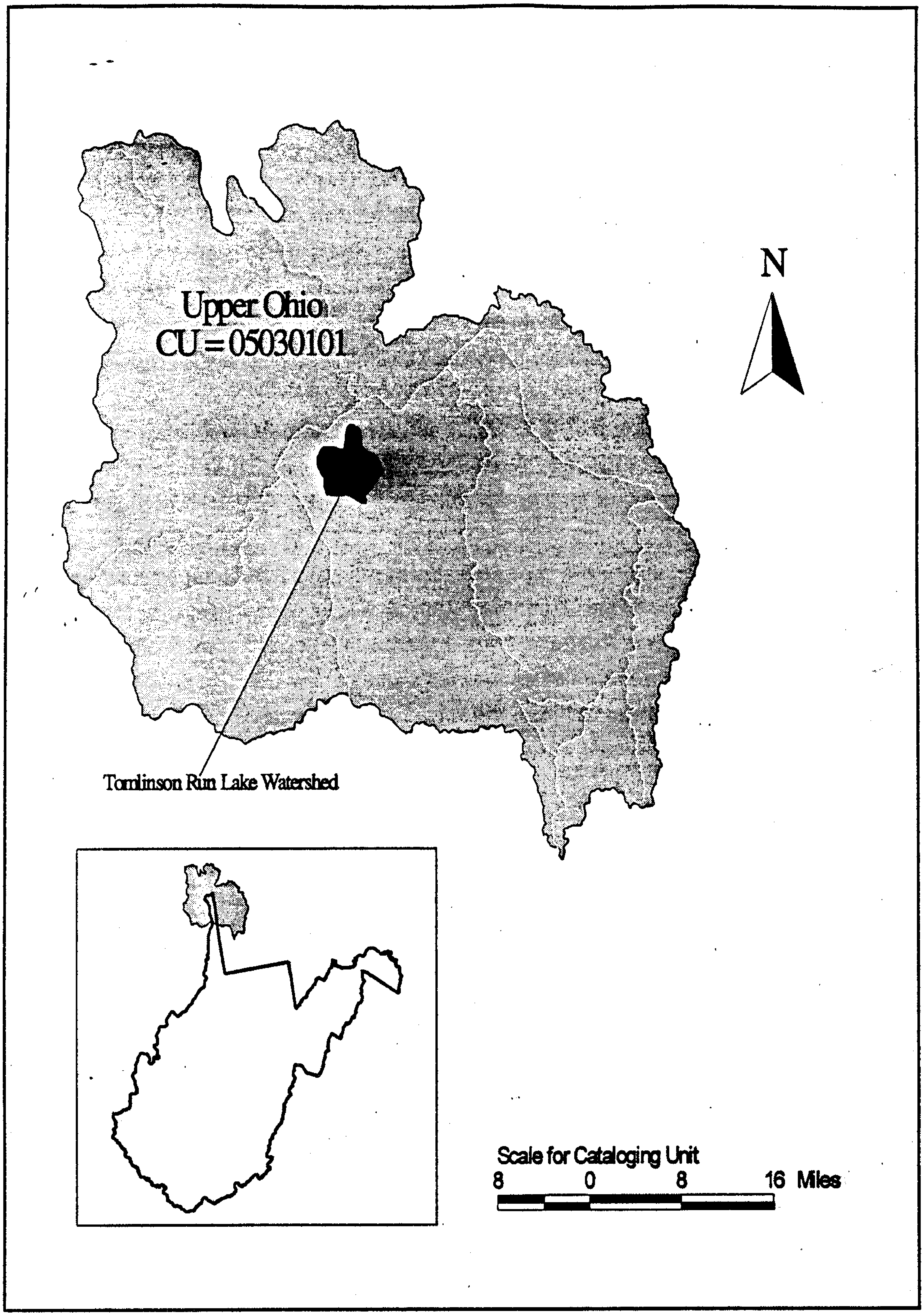

Figure 1.1. Location of Tomlinson Run Lake watershed.

(WVDEP 1998). WVDEP has determined that siltation is affecting the aquatic life designated use of the lake.

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 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 is 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 and can impair deepwater habitat needed by fish during 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 changes in the makeup of fish species in the lake.

For the development of a TMDL for siltation for Tomlinson Run Lake, the endpoint chosen to protect the designated use of the reservoir was based on evaluation of several factors including average rate of accumulation and average depth, inlet (depositional) cells and maximum accumulation rates, and total suspended solids (TSS) concentration in the water column. The endpoint selected was the accumulation rate, which will not exceed 70% of the reservoir storage capacity within a 40-year period. In the case of Tomlinson Run Lake, the implementation of dredging, as previously recommended by Coastal Environmental Services (1994), is essential to the long-term restoration of the lake.

2.0 SOURCE ASSESSMENT

This section presents an overview of the in-lake and in-stream water quality monitoring data available for Tomlinson Run 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 Tomlinson Run 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 roadside drainage ditches.

2.1 Water Quality Monitoring Data

Limited water quality monitoring activities have been conducted for Tomlinson Run Lake and its inflows. The following are water quality data reviewed and collected for this study:

- Sampling conducted during the course of the Clean Lakes study—monthly sampling from October 1993 through April 1994 and during September 1994, and biweekly sampling from May through August 1994. Lake samples were collected at three locations within the lake and at one location each within the North and South Forks of Tomlinson Run.

- WVDEP sampling at one location within Tomlinson Run Lake and at one location each in the North Fork and the South Fork of Tomlinson Run Lake on four dates (three for the North Fork) between May 1995 and August 1996. WVDEP also collected samples in the North Fork and South Fork of Tomlinson Run on April 29, 1998, and May 7, 1998. WVDEP sampling results are provided in the appendix.

- Sampling conducted by a West Virginia state agency on May 22, 1996, and found in STORET. The sampling station is identified as O-102-B in STORET.

A summary of the WVDEP lake water quality sampling results is provided in Table 2.1, and a summary of TSS results obtained during the Clean Lakes study is provided in Table 2.2. The Clean Lakes report evaluated morphometric and water quality monitoring data and concluded the following:

- Sedimentation has resulted in a loss of 75% of the original lake volume.
- Sediment thickness of more than 6 feet was encountered.
- Storm events produced high TSS concentrations from inflows compared to normal conditions.
- The significant amount of particulate matter in the water column prevents excessive algal productivity.

Table 2.1. Summary of WVDEP sampling observations of selected pollutants, Tomlinson Lake, 1995-96.

Pollutant Type	Pollutant	Units	Criteria	Sample Type[a]	Total Obs	Minimum	Maximum	Mean
Metal	Iron	mg/L	1.5	Surface	4	0.50	1.10	0.85
		mg/L	1.5	Bottom	4	0.60	1.50	0.93
Nutrient	TKN	mg/L		Surface	4	ND[c]	0.65	0.42
		mg/L		Bottom	4	ND[c]	1.46	0.72
	NO2-NO3-N	mg/L	10	Surface	4	0.12	0.81	0.46
		mg/L	10	Bottom	4	0.056	0.96	0.50
	TP	mg/L	0.02[b]	Surface	4	0.0480	0.0700	0.0545
		mg/L	0.02[b]	Bottom	4	0.0280	0.0800	0.0645
		mg/kg		Sediment				
	Chlorophyll *a*	ug/L	15[b]	Surface	4	ND[c]	164.00	51.80
		ug/L	15[b]	Surface, Summer	2	36.06	164.00	100.03
Siltation	Suspended Solids	mg/L		Surface	4	10	20	14
		mg/L		Bottom	4	7	22	16
	Turbidity	NTU						

[a] Water sample from 1995-96 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

No permitted point source dischargers were identified from the Permit Compliance System (PCS) database. However, according to the Clean Lakes report, four small package treatment plants existed in the watershed at the time of the Clean Lakes study. These are the Tomlinson Run State Park treatment plant located on the lake, Oak Glen High School, the Red Barn Trailer Court, and Roma's Pizza. Oak Glen High School, the Red Barn Trailer Court, and Roma's Pizza all were evaluated as having limited potential for contributing to the lake's pollutant load since all three have low permitted flows (2,500 to 14,000 gallons per day [gpd]) and none were reported to discharge directly to the lake or to major tributaries. Considering their low potential contribution of sediment to the lake, these three point sources are not considered significant and were not included in the analysis. The Tomlinson Run State Park treatment plant reportedly discharges to the lake. Its permitted flow is reported in the Clean Lakes report as 12,660 gpd with the following TSS limitations: 30 mg/L (average monthly), 60 mg/L (maximum daily), and 75 mg/L (instantaneous maximum). The one reported concentration measurement was 8.14 mg/L. This discharger was explicitly included in the analysis.

Table 2.2. TSS Concentrations Measured in Tomlinson Run Lake and Inflows 1993-1994 (mg/L).

Date	North Fork	South Fork	Lake North	Lake South	Lake Near Dam
10/25/93	1	1	6	8	4
11/15/93	49	21	24	27	21
12/13/93	4	3	1	1	1
1/27/94	89	30	22	94	19
1/28/94 storm	333	871			
2/15/94	3	5	0	1	0
3/27/94	41	60	16	34	13
4/12/94	26	21	28	25	24
5/17/94	16	44	30	15	27
5/28/94			24	28	23
6/13/94	4	1	1	19	1
6/21/94	182	196	13	31	75
7/12/94	1		9	9	2
7/25/94	5	16	18	24	13
8/8/94	1	1	12	29	10
8/18/94	14	6	14	9	13
9/6/94	3	5	9	13	9

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 loads can originate from agricultural land uses (i.e., row crops, pasture, and animal operations). Excessive sediment loading is also associated with expansion of residential and commercial/industrial areas due to the increase in storm water flows, the changes in stream hydrology, and the wash-off and erosion of sediment from construction sites.

To characterize flows and pollutant loadings from different parts of the Tomlinson Run Lake watershed, the watershed was divided into nine subwatersheds (Figure 2.1). 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.

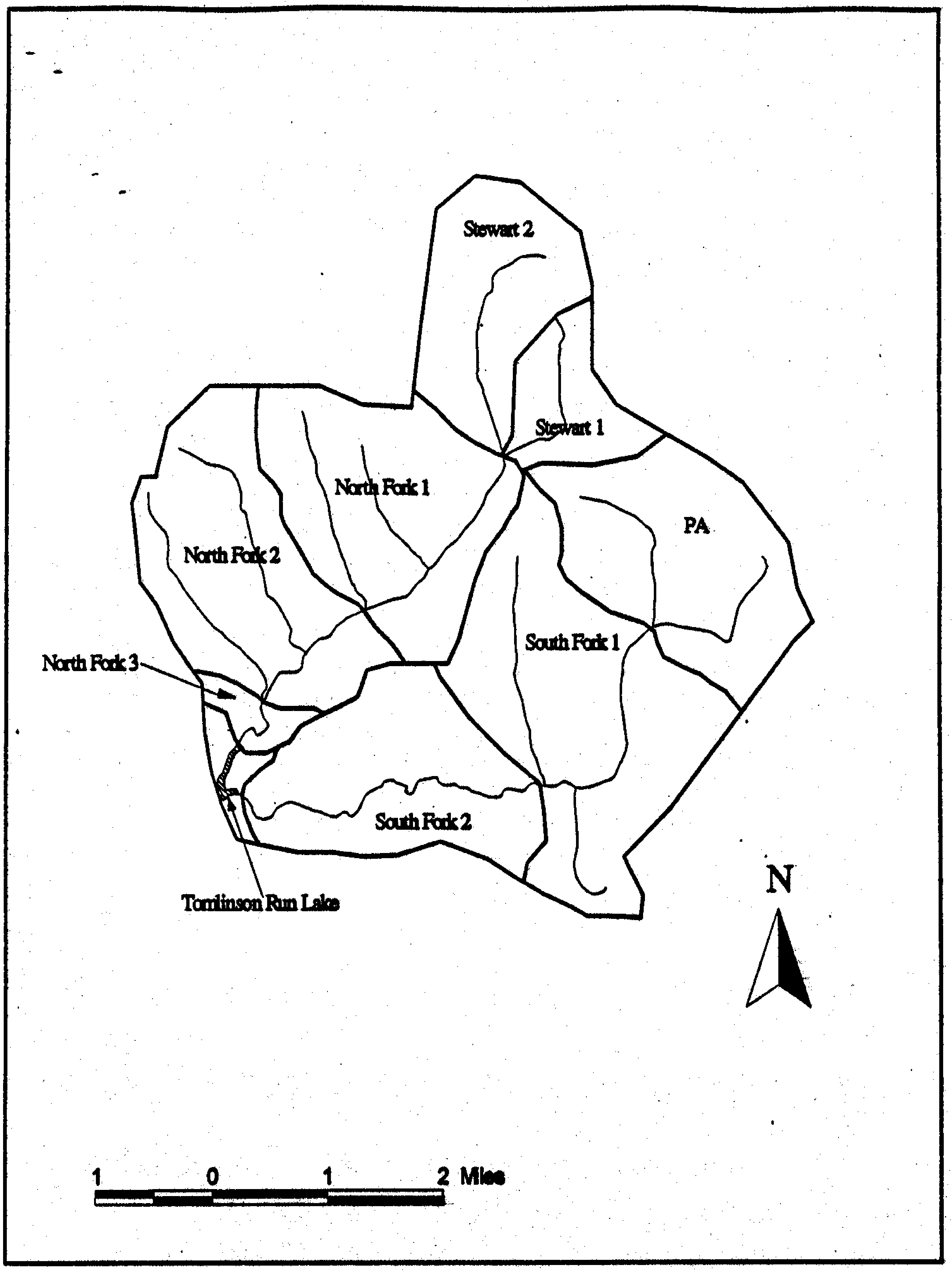

Figure 2.1. Tomlinson Run Lake watershed and subwatershed.

Table 2.3. Tomlinson Run Lake subwatersheds and associated areas.

Subwatershed Number	Reach Name	Total Area (acres)
25	Tomlinson Run Lake	113.18
26	South Fork Tomlinson Run 2	2,476.27
27	South Fork Tomlinson Run 1	3,105.66
28	PA	1,719.93
29	North Fork Tomlinson Run 3	295.33
30	North Fork Tomlinson Run 2	2,044.87
31	North Fork Tomlinson Run 1	2,178.76
32	Stewart 2	933.81
33	Stewart 1	944.26
Total		13,811.71

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

Land use for the Tomlinson Run 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 Characterization (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 Tomlinson Run Lake watershed identified the presence of 11 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, MRLC land use classes were aggregated into classes designated for this TMDL. 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 the watershed is almost exclusively forest (55%) and pasture (42%). Built-up areas make up only approximately 2% of the area of the watershed.

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

Table 2.4. Tomlinson Run Lake watershed 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) High-Intensity Residential (22)
Commercial and Industrial	Pervious (30%) Impervious (70%)	High-Intensity Commercial/Industrial (23)
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%)	Quarries/Strip Mines/Gravel Pits (32)
Other	Pervious (100%)	Woody Wetland (91) Emergent Herbaceous Wetland (92)

Table 2.5. Tomlinson Run Lake land use distribution by subwatershed acres.

	25	26	27	28	29	30	31	32	33	Totals
Residential	4.89	103.63	22.68	9.79	0.22	30.69	70.28	35.8	8.23	**286.21**
Commercial/ Industrial	0	1.33	1.33	1.11	0	0	2.45	3.11	0.22	**9.55**
Forest	83.17	1514.7	1396.38	915.36	189.26	1276.08	1162.43	399.19	615.12	**7,551.69**
Pasture	7.56	840.41	1648.13	770.14	103.41	718.32	932.26	479.92	313.13	**5,813.28**
Cropland	0	4.45	25.13	13.57	1.78	16.23	10.23	12.68	4.45	**88.52**
Barren	0	0	0	0	0	0.22	0	0.22	0.67	**1.11**
Other	2.00	1.78	7.34	9.56	0.44	2.89	1.11	0	0.44	**25.56**
Water	15.56	9.79	4.67	0.22	0.22	0.44	0	2.89	2.00	**35.79**
Totals	**113.18**	**2,476.27**	**3,105.66**	**1,719.93**	**295.33**	**2,044.87**	**2,178.76**	**933.81**	**944.26**	**13,811.71**

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 sediment loadings to be delivered to the lake. During dry periods, little or no land-based runoff will occur. For sediment loading the majority of the loading will be contributed during high-flow periods, especially large storm events. There can be significant year-to-year variability in sediment loading.

In general, critical conditions will vary depending on the pollutant type and the designated use impacted. 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 Tomlinson Run Lake:

> **Siltation** - Sediment inputs result in long-term accumulation of sediment. Sediment inputs also relate to increased turbidity in the reservoir. The relevant critical condition is the long-term accumulation of sediment. 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, trap efficiency, and sediment depostion in the reservoir. The loading model is linked to a continuous simulation reservoir model. The reservoir model allows for the examination of the long-term sediment accumulation rates under various loading conditions.

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

Tomlinson Run Lake is characterized by shallow depth, short residence time, and variable (nonpoint source) inflows. The lake is listed for siltation, and impacts 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 16 cells and two layers (two-dimensional modeling)
- Simulation of lake sediment deposition

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

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

3.1.2 Watershed Loading Model

For Tomlinson Run Lake the inputs to the lake are primarily derived from nonpoint sources. Several minor dischargers contribute the tributary inflows. The single point source input in the watershed is direct to the lake and is considered in the setup of the lake model. Delivery of sediment to the lake occurs 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 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 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 Tomlinson Run Lake

Sixteen cells were used for the model in a horizontal direction (Figure 3.1). The maximum width of the cells was 96 m and the minimum width was 46 m. The cells of the lake model were parameterized based on the lake bathymetry data developed for the Clean Lakes study (Coastal Environmental Services, 1994). Because the lake is very shallow, two layers were used in the vertical.

Two major tributaries provide inflow and suspended sediment loads. The tributary inflows were modeled directly into cells corresponding to the North Fork and the South Fork of Tomlinson Run. 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 Tomlinson Run Lake were obtained from the Clean Lakes report. A summary of lake characteristic information is provided in Table 3.1.

3.2.2 Watershed

To obtain a spatial variation of the concentration and loadings of sediment entering Tomlinson Run 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.

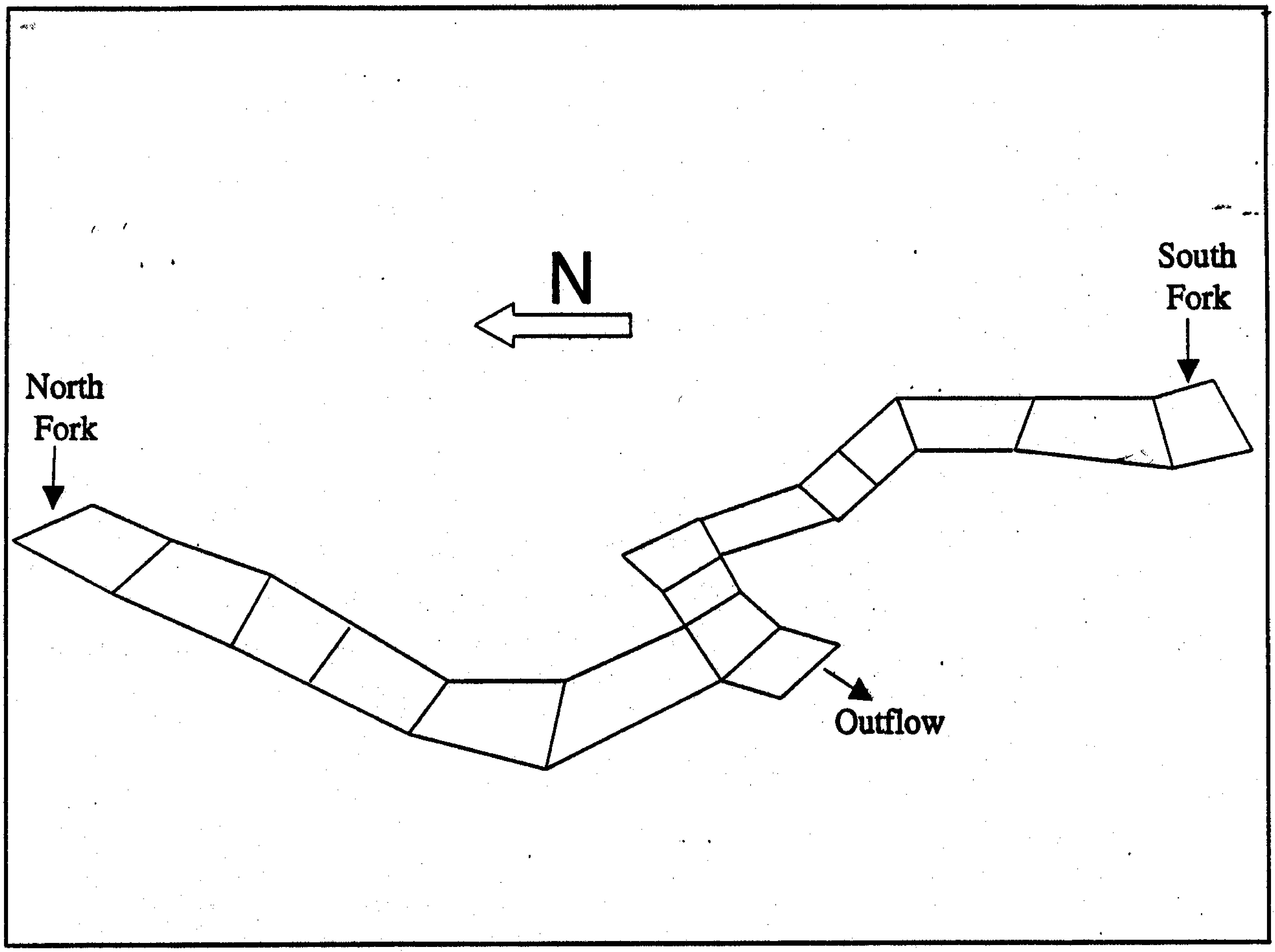

Figure 3.1. Model segmentation for Tomlinson Run Lake.

Table 3.1. Tomlinson Run Lake Characteristics.

Area	30 acres
Volume	58.0 acre feet / 71,500 cubic meters
Mean Depth	1.9 feet
Maximum Depth	15.7 feet
Mean Discharge	16.4 cubic feet per second
Hydraulic Residence Time	1.8 days

Data taken from Coastal Environmental Services, *1994*.

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

One point source discharger is present in the watershed and it discharges directly to the lake. The point source discharger was accounted for within the lake model. 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 Tomlinson Run Lake tributaries and average annual loading estimates developed for the Clean Lakes study (Coastal Environmental Services 1994). 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 Tomlinson Run 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 (Coastal Environmental Services 1994). The hydrodynamic simulation was examined over time to verify that the lake volume and condition corresponded to observed conditions. Year 1995 was selected for calibration purposes since in-lake monitoring observations are available for that time period. The calibration parameters for suspended solids 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 Tomlinson 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 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 selected was Poplar Fork at Teays (USGS gage #03201410). The historical record available for Poplar Fork extends from January 1, 1967, to October 11, 1978.

For 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 Tomlinson Run Lake watershed. Simulation results were then compared to the previously derived estimates of the water balance for the period 1993-94. Based on this evaluation the parameter values were deemed reasonable and it was assumed that the model was adequately representing the hydrologic inflow to Tomlinson Run 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 1995-96 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 Loading

The model was run for the representative hydrologic period 1988-95. The modeling run represents the existing condition of sediment loadings to Tomlinson Run Lake. The loading results by year are shown in Figure 3.2. For the existing conditions, the overall sediment loadings by land use category for Tomlinson Run Lake watershed are given in Table 3.2.

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 3.2 and 3.3 show the predicted sediment accumulation and suspended sediment loading, respectively.

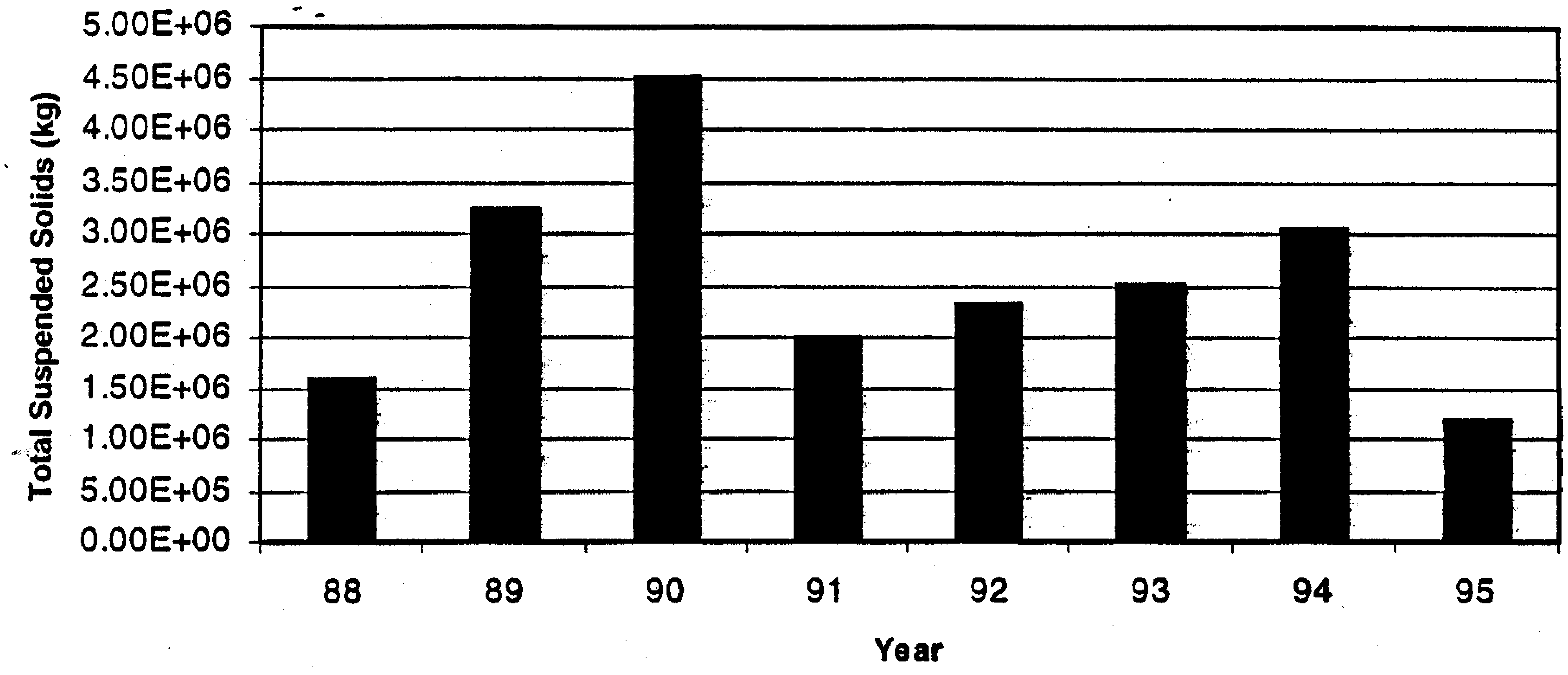

Figure 3.2. Estimated annual TSS loading toTomlinson Run Lake, 1988-95.

Table 3.2. Annual Nonpoint Source Sediment Loadings by Land Use Category for Tomlinson Run Lake Watershed (1993).

Land Use Category	Annual Sediment Loading (kg)
Residential	157,526.69
Commercial and Industrial	13,140.59
Forest	1,113,821.16
Cropland and Pasture	1,265,206.09
Barren	305.47
Total	2,550,000.00

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 type of sediments entering the waterbody, with the trap efficiency for bed load and suspended sands being higher than that for silts and clays.

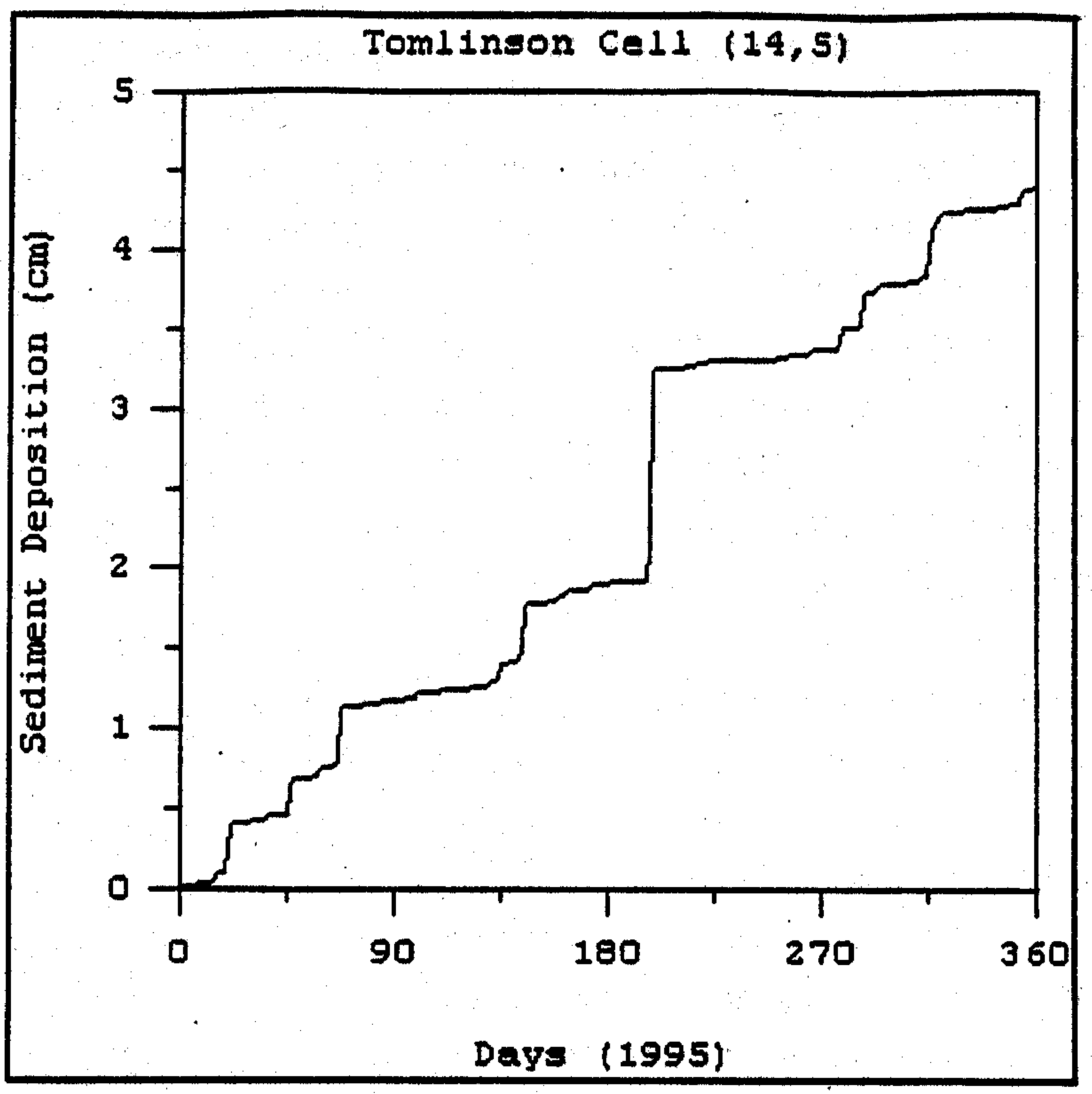

Figure 3.3. Accumulation of sediment in representative cell for 1995 simulation year.

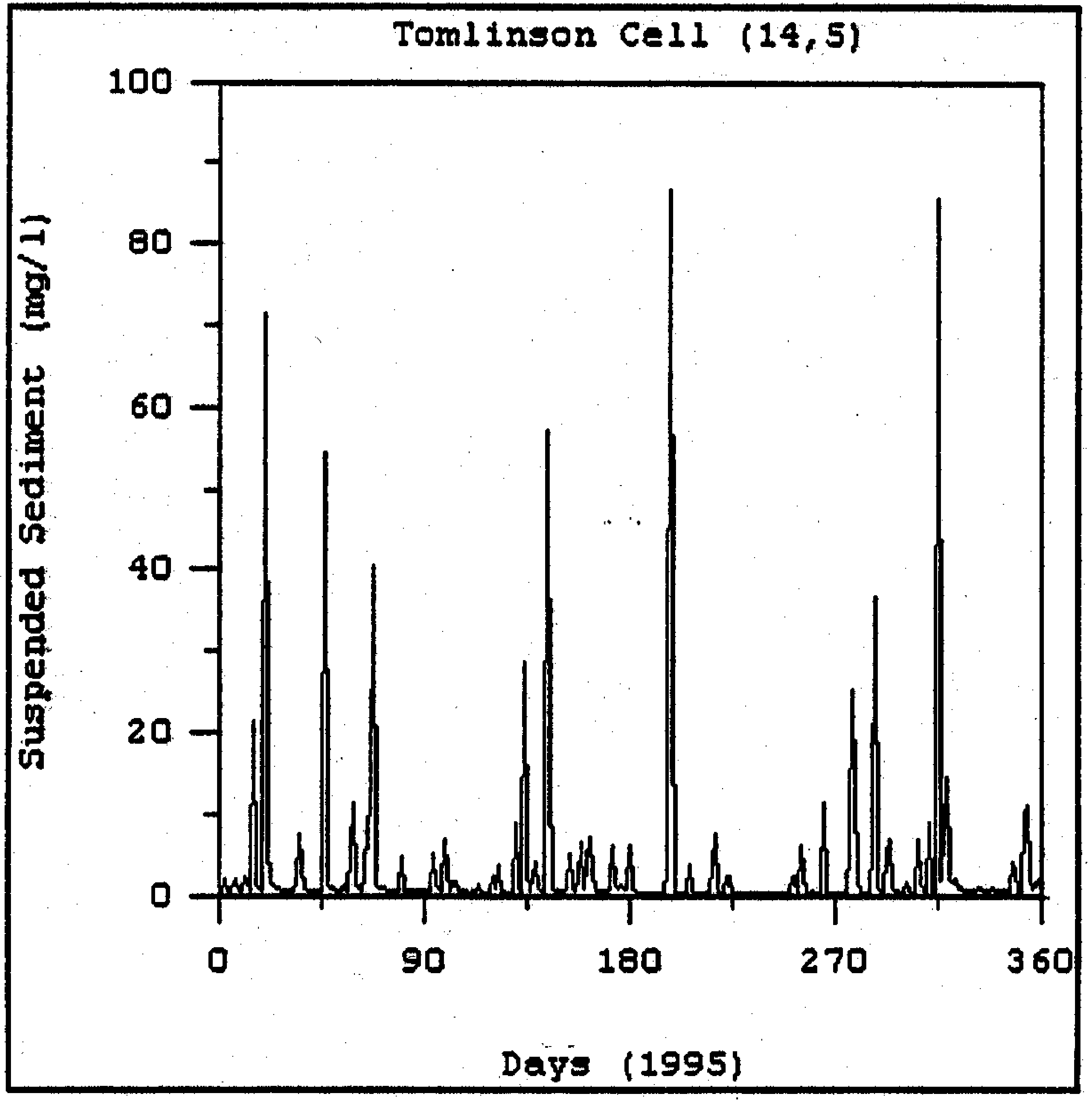

Figure 3.4. Suspended sediment in representative cell for 1995 simulation year.

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 water bodies. 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 70,000 cubic meters and an annual inflow volume of 14.6 million cubic meters, the Brune parameter is approximately 0.005, corresponding to a trap efficiency in the range of 12% to 42%.

The third approach for determining trap efficiency is direct simulation. For Tomlinson Run Lake a year-long simulation for hydrodynamic and sediment transport was conducted using 1995 inflows and sediment loading derived from a watershed model. The annual inflow to the lake was 4.2 million cubic meters and the annual sediment load was 1.24 million kg. Using the mass of sediment deposited during the simulation, the trap efficiency was calculated to be 12%. The average annual siltation rate was estimated to be 0.2 cm per year, ranging from 0 to 4 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.

Table 3.3. Calculated trap efficiencies for Tomlinson Run Lake.

Estimated Trap Efficiency Range (Brune 1953)	**Simulated Trap Efficiency**
12% - 42%	12%

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 or kilograms per day). In some cases a TMDL is expressed as another appropriate measure that is the relevant expression for the reduction of loadings of the specific pollutant to meet water quality standards or goals.

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.

For Tomilinson Run Lake the MOS is incorporated implicitly into the modeling process by running a dynamic simulation to calculate the daily loadings of sediment. Other margins of safety used for this TMDL analysis include the following:

- It is important to understand that any best managment 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 used in the development of the model and subsequent analysis of the load reductions. The loadings calculated for the watershed were relatively high and were consistent with the previously derived estimates from the Clean Lakes study (Coastal Environmental Services 1994). Evaluation of the accumulation rates was performed based on the higher typical accumulation rates derived from the modeling study.

4.2 Assessing Alternatives

For the allocation runs, the model was run for the same representative hydrologic year (1995) as used for the existing conditions calibration run. The depth of the lake varies from a minimum of 1.64 feet (0.49 m) to 9.843 feet (2.99 m). The mean depth of 1.9 feet (0.59 m) is based on the bathymetric survey performed in 1994. The Clean Lakes report clearly stated that dredging of the lake was essential to the long-term preservation of the reservoir (Coastal Environmental Services 1994). The simulation of the sediment processes indicated that the trap efficiency under current conditions is relatively low due to the short hydraulic residence time (1.8 days). Sedimentation rates were predicted by the model application to range between 0.2 cm and 4 cm per year. Even with the decreased trap efficiency, areas in the proximity of the inlets are likely to accumulate sediment quickly, further reducing the effective surface area of the lake.

Assuming that the reservoir is dredged to reinstitute a more acceptable habitat and restore recreational uses, a new representative cell depth can be defined. The cell depth is based on dredging recommendations provided in the Clean Lakes report (Coastal Environmental Services, 1994). Reduction of the sediment load by 30% would result in a 3-cm accumulation rate for the representative cell. Assuming a 3-cm per year accumulation rate, the 40-year/70% capacity loss target would be met for the representative 1.77 m (5.6 feet) cell depth. Reduction of sediment load is essential to maintaining adequate reservoir capacity subsequent to dredging. Figures 4.1 and 4.2 show the resulting sediment accumulation rate and TSS concentrations under the 30% reduction scenario.

4.3 Allocation

The overall load reduction identified is 30% for the Tomlinson Run Lake watershed. Based on examination of the land use distributions and source loading characteristics, a reduction of 30% applied to barren, residential, forest, and agricultural (cropland/pasture) areas is recommended. 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 activities. More specific sediment control recommendation are included in the Clean Lakes report (Coastal Environmental Services 1994).

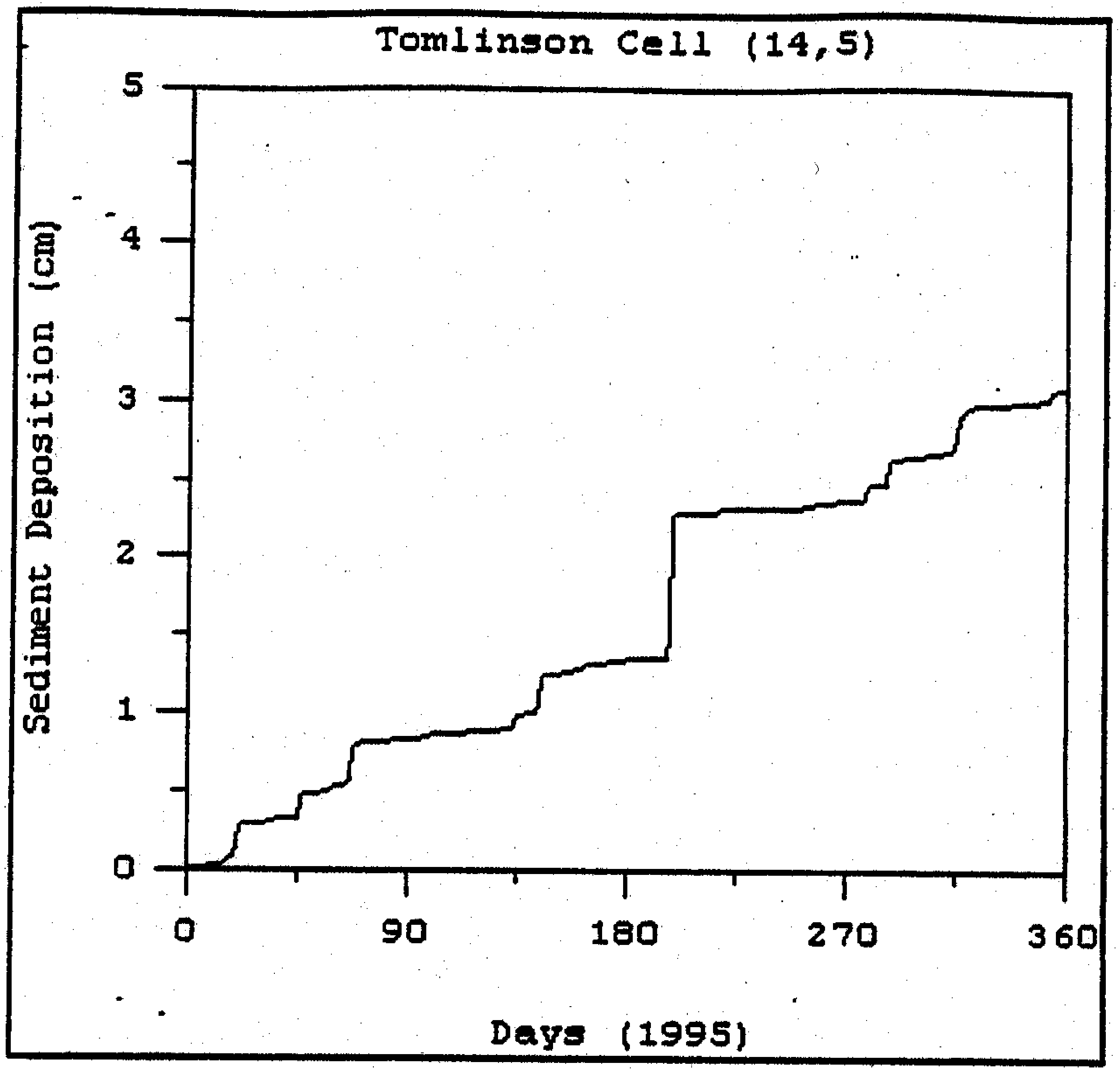

Figure 4.1. Sediment deposition for a representative reach with a 30% reduction in loading.

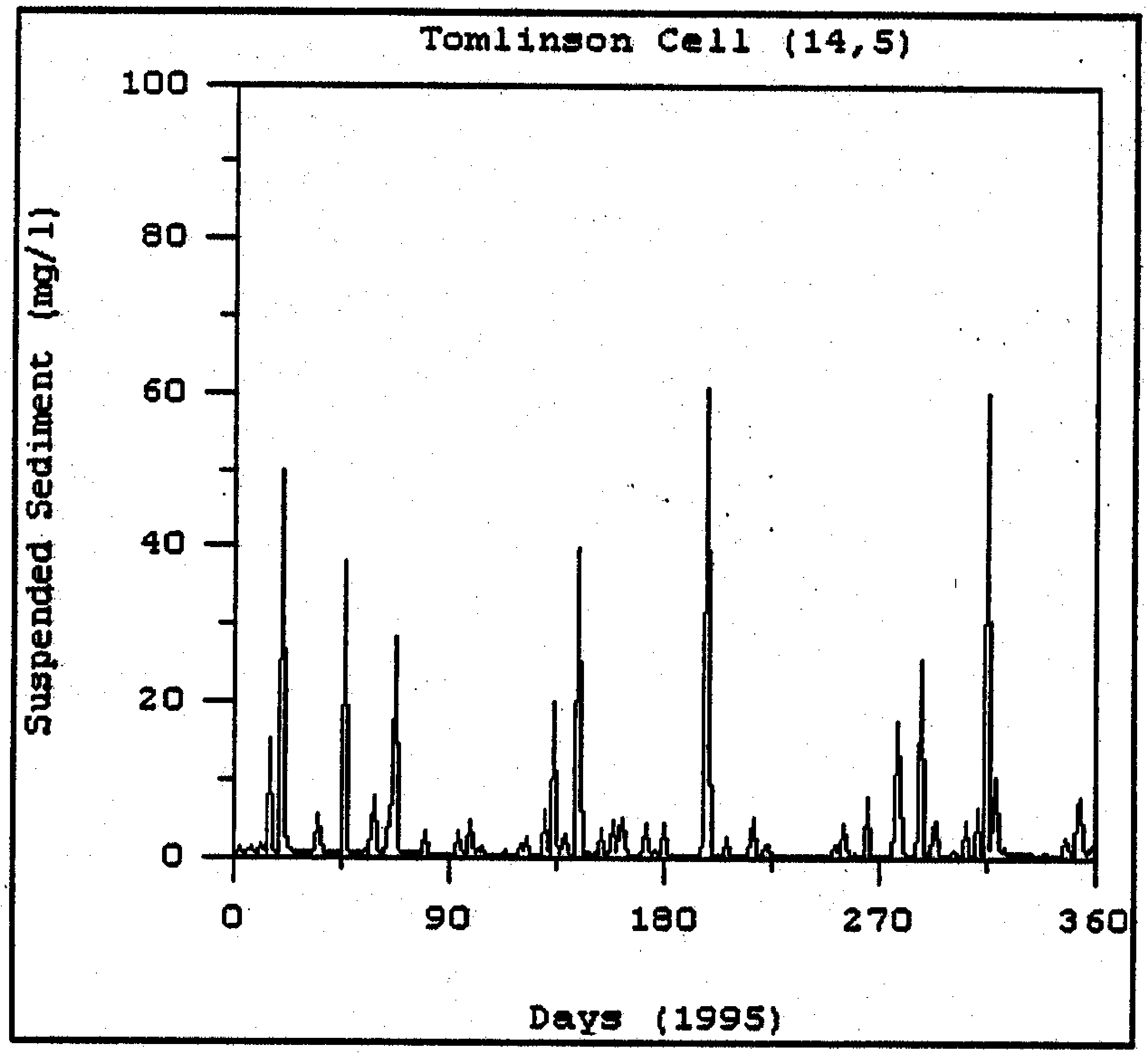

Figure 4.2. Suspended sediment concentration for a representative reach with a 30% reduction in loading.

5.0 SUMMARY

Tomlinson Run Lake watershed was divided into nine subwatersheds, and the BASINS Nonpoint Source Model (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 loadings as measured by sediment accumulation rate. 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 goals will be achieved if loadings are reduced by 30% for sediment.

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 NPSM 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. Additionally, a more detailed land use and practice characterization should be compiled as part of the implementation process for the TMDL.

5.2.1 Hydrologic Flow Data

There were no stream USGS gages available in or directly downstream of the Tomlinson 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 Tomlinson Run Lake and its inflows are monitored infrequently. The only long-term monitoring study in the watershed was the Clean Lakes study conducted during 1993-94 which collected data approximately once per month at one location 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 likely 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 Tomlinson 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 long-term 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

Flows from the Tomlinson Run 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 contributions 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 1995 water year. The hourly rainfall database available for this project covered the period 1970-95. A rain gage situated at the Pittsburgh, Pennsylvania airport was used for the watershed runoff modeling for the Tomlinson Run Lake watershed. Although this gage is relatively close to the watershed (approximately 20 miles to the east-southeast), further evaluation of the precipitation data set should be undertaken to account for some dates that lack associated data entries.

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Appendix

1995 - 1996 WVDEP Water Quality Sampling of Tomlinson Run Lake and Tributaries

Sampling Date	Spring 95 5-10	Summ 95 9-18	Spring 96 5-22	Summ 96 8-28
Temperature, °C				
surface	13.4	19.3	16.0	23.6
bottom	7.3	17.4	11.0	20.2
inflow	+	+	+	+
PH, Standard Units				
surface	8.0	8.0	7.6	8.4
bottom	6.9	7.4	7.3	7.2
inflow	+	+	+	+
Conductivity, umhos/cm				
surface	293	396	240	384
bottom	296	448	217	393
inflow	+	+	+	+
Dissolved Oxygen, mg/L				
surface	9.5	8.5	8.3	10.6
bottom	1.2*	0.3*	7.6	0.2*
inflow	+	+	+	+
Total Acidity, mg/L				
surface	3	<1	<1	<1
bottom	4	<1	<1	<1
inflow	+	+	+	+
Total Alkalinity, mg/L				
surface	68	99	46	104
bottom	65	103	38	109
inflow	+	+	+	+
Suspended Solids, mg/L				
surface	10	14	20	10
bottom	7	18	22	17
inflow	+	+	+	+
Total Phosphorus, mg/L				
surface	.048	.050	.070	.050
bottom	.028	.080	.070	.080
inflow	+	+	+	+
Total Kjeldahl Nitrogen, mg/L				
surface	.50	.51	<.50	.65
bottom	.66	.76	<.50	1.46
inflow	+	+	+	+
Ammonia Nitrogen, mg/L				
surface	<.03	.23	<.50	.09
bottom	.28	.40	<.50	.84
inflow	+	+	+	+
Nitrate-Nitrite Nitrogen, mg/L				
surface	.80	.13	.81	.116
bottom	.84	.16	.96	.056
inflow	+	+	+	+
Total Iron, mg/L				
surface	1.100	.500	1.100	.680
bottom	.600	.760	1.500	.840
inflow	+	+	+	+
Total Mangenese, mg/L				
surface	.345	.220	.390	.250
bottom	.860	.910	.280	2.620*
inflow	+	+	+	+
Total Aluminum, mg/L				
surface	.375	.380	1.200*	.520*
bottom	.190	.390	2.000*	.480*
inflow	+	+	+	+
Chlorophyll *a*, mg/m3				
surface	7.27	36.06	<6.00	164.0
Secchi Depth, ft	2.00	2.00	1.00	2.00

Tomlinson Run Lake Data Qualifiers
* = Violation of state WQ criteria
\+ = WQ data for inflows in Appendix D-4(b)

	South Fork Tomlinson Run				North Fork Tomlinson Run		
	Spring 95	Summ 95	Spring 96	Summ 96	Spring 95	Summ 95	Summ 96
Sampling Date	5-10	9-18	5-22	8-28	5-10	9-18	8-28
Temperature, °C	12.6	14.8	13.0	17.6	12.8	15.0	17.6
PH, Standard Units	8.1	8.0	8.1	8.1	8.3	8.2	7.7
Conductivity, umhos/cm	286	464	245	494	298	474	432
Dissolved Oxygen, mg/L	10.6	9.1	8.7	8.9	11.2	9.3	8.2
Total Acidity, mg/L	4	<1	<1	<1	4	<1	<1
Total Alkalinity, mg/L	67	110	48	121	65	108	114
Suspended Solids, mg/L	11	1	8	4	10	1	<1
Total Phosphorus, mg/L	.034	.03	.050	.04	.026	.01	.03
Total Kjeldahl Nitrogen, mg/L	.40	.11	<.50	.12	.36	<.10	.12
Ammonia Nitrogen, mg/L	<.03	.11	<.50	.06	<.03	.09	<.06
Nitrate-Nitrite Nitrogen, mg/L	1.17	.79	.76	.941	1.21	.07	.087
Total Iron, mg/L	.535	.13	.430	.25	.755	.12	.16
Total Manganese, mg/L	.095	.03	.063	.06	.145	.02	.04
Total Aluminum, mg/L	.180	.18	.560*	.62*	.190	.15	.22*

Tomlinson Run Lake Inflows Data Qualifiers

* = Violation of State WQ criteria

1998 WVDEP Water Quality Sampling - Tributaries of Tomlinson Run Lake

		NorthFork		SouthFork	
		4/29/98	5/7/98	4/29/98	5/7/98
Sample Type		water	water	water	water
Tot. Acidity	mg/L	ND		ND	ND
Alkalinity	mg/L	40.7		38.4	42
TSS	mg/L	14		11	15
TP	mg/L	0.0447	0.04	0.0537	ND
Ortho P	mg/L	ND	0.02	ND	ND
TKN	mg/L	ND	ND	ND	ND
Ammonia-N	mg/L	ND	ND	ND	ND
NO_2-NO_3-N	mg/L	0.849	0.69	0.705	0.73