Final

TMDLs for Ridenour Lake Kanawha County, West Virginia

U.S. Environmental Protection Agency
Region 3
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EXECUTIVE SUMMARY

The objective of this study was to summarize the background information, analyze load reductions, and document Total Maximum Daily Loads (TMDLs) for aluminum, iron, nutrients, and siltation. The West Virginia Division of Environmental Protection (WVDEP) has identified Ridenour Lake (designated code WV_K(L)-30-A(1) for aquatic life and WV_K(L)-30-A(1) for human health) as being impacted by these pollutants, as reported in the 1998 303(d) list of water-quality-limited waters (WVDEP 1998). WVDEP has determined that the aquatic life use designation (Class B1 for warm water fishery) has been impaired by aluminum, iron, nutrients, and siltation and the human health designated use (Class A drinking water standard and consumption of fish) has been impaired by iron.

- As obtained from the West Virginia Requirements Governing Water Quality Standards (Title 46), the water quality criterion for aluminum is 0.75 mg/l (acute) and the criterion for iron is 1.5 mg/l (chronic). However, soils within the watershed have naturally elevated concentrations of aluminum and iron.

- West Virginia uses a trophic state index when considering lakes for listing due to nutrient impairment. Lakes with a total phosphorus or chlorophyll *a* trophic state index greater than or equal to 65 or with summer algal bloom or excessive vegetation were considered to be impacted by nutrients. Since Ridenour Lake does not exceed the trophic state index a chlorophyll *a* target of 15 ug/l was selected.

- Siltation has no specific water quality criteria; however, elevated inputs of sediment has been demonstrated to cause impairment of the support of aquatic life and recreational uses of the lake. An endpoint for the development of a TMDL for siltation of Ridenour Lake is based on the evaluation of the total sediment load delivered to the lake, as indicated by the average accumulation rate of sediment in selected critical locations on the reservoir bottom.

To evaluate the relationship between the sources, their loading characteristics, and the resulting conditions in the lake, a combination of analytical tools were used. Assessments of the nonpoint source loading into the lake were developed for Ridenour Lake watershed using the Generalized Watershed Loading Function (GWLF) computer program. GWLF provided estimates of nutrients and sediments transported to the lake for individual land use categories. The lake was evaluated using the BATHTUB water quality simulation computer model to estimate the concentrations of nutrients and chlorophyll *a*. The lake was segmented into four cells to better represent the system. The results of the watershed and reservoir models were compared with observed water quality data, literature values, previous studies, and reservoir 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. A representative hydrologic simulation year was used for testing and development of the TMDL by averaging the hydrology from daily rainfall records for the period from 1978 to 1997. The resulting allocation for the four listed pollutants includes a 7 percent reduction of nutrients (expressed as total phosphorus) and a 35 percent reduction of sediment load. The aluminum and iron loads are believed to occur from their natural presence in clay sediments. The aluminum and iron TMDLs are set consistent with the sediment loading for the sediment TMDL.

The loads are described as average annual load reductions, which is typically appropriate for reservoirs and impoundments. The margin of safety has been 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 erosion and sediment control practices, forest management, and stream restoration.

1 INTRODUCTION

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 to restore and maintain the quality of their water resources (USEPA, 1991).

The West Virginia Division of Environmental Protection (WVDEP) has determined that the use designation of Ridenour Lake for aquatic life has been impaired by nutrients, siltation, aluminum, and iron and that the human health use designation has been impaired by iron. The United States Environmental Protection Agency (USEPA) conducted this study to analyze the loadings to the lake and to establish TMDLs that will restore and maintain the quality of Ridenour Lake for the uses designated by West Virginia.

This report presents the background information, analyses, and TMDLs that address the designated use impairments of Ridenour Lake. The report is organized as follows:

- Section 2 - A description of the waterbody and the impairments listed by West Virginia as required under Section 303(d) of the Clean Water Act
- Section 3 - A presentation of the essential information that characterizes the impaired waterbody and watershed
- Section 4 - A description of the applicable water quality standards and the selection of TMDL endpoints to achieve the standards and to meet the designated uses
- Section 5 - An assessment of the water quality data and information pertinent to developing TMDLs
- Section 6 - An assessment of the sources of pollutants pertinent to TMDL allocation
- Section 7 - A description of the modeling process used to develop TMDLs
- Section 8 - Allocation of the load reductions to sources
- Section 9 - A description of the process used to monitor the effectiveness of the proposed TMDLs and compliance

This report also provides a description of the waterbody and associated pollution sources, provides a summary of water quality monitoring data, and describes the analytical approach used to develop the TMDL. The report specifically addresses each of the elements of a TMDL, including the following:

1. Describe waterbody, pollutant of concern, pollutant sources, and priority ranking (Section 2)
2. Describe applicable water quality standards and numeric water quality targets (Section 4)
3. Loading capacity- linking water quality and pollutant sources (Section 8)
4. Load allocations (LAs) (Section 8)
5. Wasteload allocations (WLAs) (Section 8)
6. Margin of safety (MOS) (Section 8)
7. Seasonal variation (Section 8)
8. Reasonable assurance for implementation (Section 9)

2 PROBLEM STATEMENT

A general description of the impaired waterbody, Ridenour Lake, and the causes for its listing on the 303(d) list are presented in this section.

The Ridenour Lake watershed is located within the Lower Kanawha River hydrologic cataloging unit (05050008), as shown in Figure 2.1. The land area of the watershed is approximately 613 hectares (1,560 acres) contained solely within Kanawha County. Runoff from the watershed flows into Ridenour Lake from Blakes Creek. Water discharged from the lake continues in Blakes Creek to Armour Creek and then to the Kanawha River, (Please note, historically Armour Creek was also known as tributary of Blake Creek or as part of Blake Creek, but for the purpose of this report should be known as Armour Creek). The primary purpose of the impoundment is for flood control (WVDNR, 1983). The lake is also used for recreational activities such as fishing and picnicking. Private boats and boat motors are prohibited on the lake. The lake's watershed is primarily rural, and the main land uses are forest and hay/pasture.

Ridenour Lake is a 10.9-hectare (27-acre the lake area reported here is slightly different from that from the land use map, 10.4 ha) impoundment located in the city of Nitro's Ridenour Park in Kanawha County, West Virginia, 1 mile east of Nitro and 16 miles west of Charleston, West Virginia (WVDNR, 1983). The impoundment structure for Ridenour Lake is owned by the city of Nitro and was completed in 1970. The lake was filled in 1971 and opened for fishing in 1972.

WVDEP listed Ridenour Lake on the 1998 303(d) list for not meeting its designated uses. The waterbody is given a high priority for TMDL development. The lake (designated code WV_K(L)-30-A-(1)) was listed for nutrients, siltation, iron, and aluminum (WVDEP, 1998). The impairments, from the West Virginia Primary Waterbody List, are presented in Table 2.1.

The water quality uses that are impaired are aquatic life (impaired by nutrients, siltation, aluminum, and iron) and human health (impaired by iron). The primary source column provides the "general source descriptions, if confirmed" (WVDEP, 1998). WVDEP assumed that the lake impairments are due to a variety of sources including domestic sewage, construction activity, agriculture, and urban runoff.

West Virginia classifies a waterbody as impaired for the listed pollutants based on the following considerations:

- Nutrients: West Virginia typically uses a trophic state index when considering lakes for listing due to nutrient impairment. Lakes with a total phosphorus or chlorophyll *a* trophic state index greater than or equal to 65 or with summer algal blooms or excessive vegetation were considered to be impacted by nutrients (WVDEP, 1998).

- Siltation: West Virginia considers lakes to be impaired by siltation if sediments are visually observed to accumulate to a depth approaching the lake normal pool elevation.

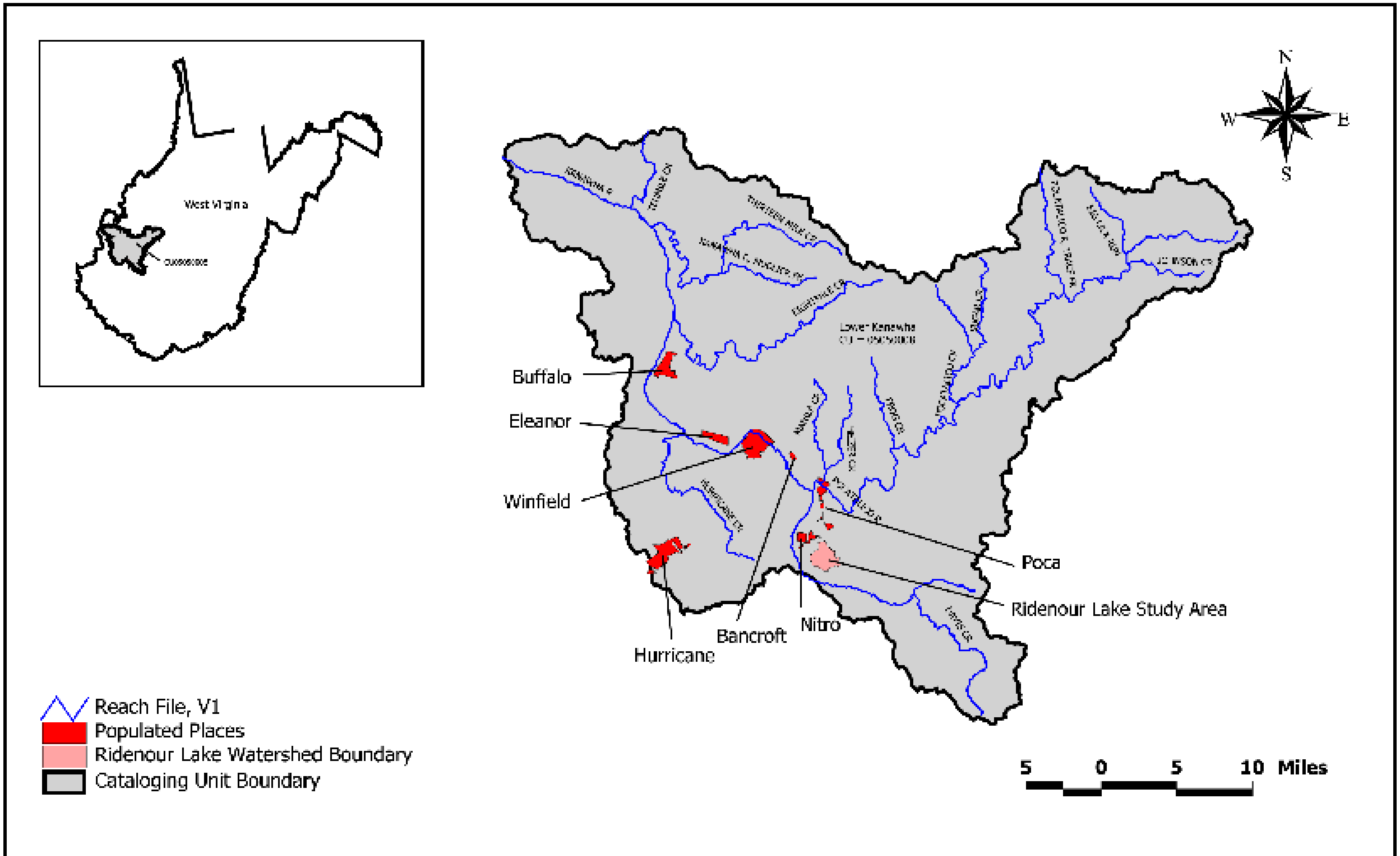
- Metals: Observed data violate specific aluminum and iron criteria at a frequency greater than 10%.

The development of TMDLs for Lake Ridenour includes a review of the potential causes of impairment and the establishment of the TMDL loading capacity, load allocation, wasteload allocation, and margin of safety.

Table 2.1. Water quality impairments of Ridenour Lake pursuant to section 303(d) of the Clean Water Act

Stream Name	Stream Code	Use Affected	Pollutant	Primary Source	Size Affected (acres)
Ridenour* Lake	K(L)-30-A-1	Aquatic Life	Nutrients, siltation, iron, aluminum	Domestic sewage, construction, agriculture, urban runoff	27
Ridenour* Lake	K(L)-30-A-1	Human Health	Iron	Construction, urban runoff	27

*Please note, on the 303(d) list Ridenour is spelled differently, due to a spelling error.



2.1. Site and Location Map
Ridenour Lake Watershed, Kanawha County, West Virginia

Map Projection: Albers Equal Area, GRS 80

Data Sources: USGS (RF1), ESRI 1995

3 ENVIRONMENTAL SETTINGS

The environmental settings that contribute to the impairment of Ridenour Lake include those of the lake itself, and the watershed. This section presents the environmental information that will be used in subsequent sections.

3.1 Lake Characteristics

3.1.1 Physical Characteristics

Based on discussion with WVDEP personnel, historical information regarding the Ridenour Lake was collected. The lake was formed by an earth dam in 1970. The impoundment was excavated and the underlying clay was used to construct the dam. The excavated topsoil was used to help landscape the shores of the lake, and the remaining topsoil was used to create a small island within the impoundment area (Stutler, personal communication, May 1999).

The lake consists of the flooded Blakes Creek stream valley shortly before it discharges to Armour Creek. The oldest records available are the WVDNR description and bathymetric survey (WVDNR, 1983), which show a shallow lake bed extending from the Blakes Creek outfall (at a depth of 0 meters) to slightly past the island (at a depth of less than1.5 meters) at a grade of 0.8 percent. This shallow bed accounted for approximately 10 percent of the total lake surface area and is expected to have collected the majority of the sediment load delivered by Blakes Creek. The grade steepens to approximately 1.3 percent as the lake bed drops to a depth of approximately 5.2 meters (17 feet).

The lake was dredged in the early 1980s, but no records of the volume of material removed are available (Sergent, personal communication, May 1999). The dredging occurred in response to siltation that resulted when two upstream sediment control check dams failed. The check dams had been constructed as part of the erosion and sediment control practices for the expansion of commercial facilities within the watershed.

Since 1980, erosion and subsequent sedimentation processes have continued to limit the storage capacity of the lake thus affecting the lake limnologic characteristics. Other than the dredging in the early 1980s, there are no known construction or dredging activities in the lake. A screening survey of lake bathymetry, conducted in 1999, allows some estimation of the changes that have occurred since 1980. The results are consistent with siltation in at least the upstream segment of the lake.

The current lake bed between the Blakes Creek inflow point and the island located within the upstream portion of the impoundment appears to be less than a meter (3 feet) higher than in 1980. Because of the past dredging, the actual depth of sediment accumulation since 1980 is unknown. The rise in the lake bed in the deeper water beyond the island appears to average about 0.5 meter (1.5 feet). Recent field observations indicate that the upstream segment of the lake, from the outfall of Blakes Creek to the island, has filled again with sediment to an elevation slightly below the lake water surface (Sergent, personal communication, May 1999).

Based on the available bathymetric and physical characteristics data obtained from the 1980 survey (WVDNR, 1983), several physical characteristics of Ridenour Lake have been derived and are presented in Table 3.1. The lake surface area extends over approximately 10.9 hectares (27 acres). The lake is shallow with a maximum depth of 5.2 meters (17 feet) and a mean depth of 2.4 meters (8 feet). The overall storage volume of the lake at normal pool is about 267,000 cubic meters (216 acre-feet) and drains a watershed area totaling 613 hectares (1,514 acres).

Table 3.1. Description of the physical characteristic of Lake Ridenour

Characteristics	Original (1970)	1980[a]
Lake volume (cubic meters)	NA	2.67×10^5
Surface area (hectares)	NA	10.9
Drainage area (hectares)	NA	613
Mean depth (meters)	NA	2.4
Maximum depth (meters)	NA	5.2
Length (meters)	NA	570
Mean width (meters)	NA	19
Shoreline (meters)	NA	1800

[a]WVDNR, 1983.

3.1.2 Morphometric Characteristics

The 1980 bathymetric analysis (summarized in Table 3.2) showed that the ratio of mean to maximum depth is close to 0.5, indicating moderately steep side slopes. As the lake continues to lose capacity to siltation, sediment deposits around the inflow points reduce the slopes at lake entrance areas. The bathymetric data collected in 1980 indicate that the east and west shores have side slopes with roughly a 2 percent grade.

The ratio of the drainage area to lake surface area is about 56, which indicates that the watershed loading, including both sediment and nutrient, could have a significant impact on the lake water quality. The drainage watershed is relatively large in comparison to the impoundment area, making the lake very sensitive to increased loading, especially from the areas surrounding the lake.

The ratio of the length of Ridenour Lake to its mean width (30) indicates that the longitudinal gradient of the lake is a dominant factor. Because of the size of the impounded area, the lake appears to act as a wide river rather than a lake, especially during high flow and storm events.

The lake began in 1970 as an excavated streambed and floodplain. As is typical of reservoirs, its deepest point is at the downstream (northern) shore adjacent to the dam. The shallowest area is located at the upstream (southern) edge of the lake at the inflow from Blakes Creek. Siltation from watershed contributions required dredging in the early 1980s, and has resulted predominately in sedimentation of the upper 10 percent of the lake, with less impact to the deeper end of the lake.

There is limited information on the existing conditions within the lake, as indicated in Table 3.2. Because of the observed siltation and known dredging of the 1980s, however, it can be assumed that the lake surface area and capacity are reducing with time. The greatest reduction in lake capacity occurs in the upstream portion of the lake. As this area fills, the deeper downstream end will become the primary recipient of sediment deposits. This reduction in lake volume and surface area will increase the ratio of drainage area to lake surface area, exacerbating the sediment and nutrient accumulation in the deeper portion of the lake.

Table 3.2. Morphometric parameters of Ridenour Lake

Characteristics	Original (1970)	1980[a]
Mean to max depth ratio	NA	0.46
Drainage area to surface area ratio	NA	56
Length to mean width ratio	NA	30

[a]WVDNR, 1983.

3.1.3 Hydrologic Characteristics of the Lake

Two key hydrologic parameters of Ridenour Lake were determined based on estimates of streamflow rates and volumetric characteristics of the impoundment. The lake residence time, calculated as lake volume over the annual flow rate, is estimated to range between 25 and 38 days, as shown in Table 3.3. This short residence time is typical for lakes with a large drainage area-to-lake surface area ratio.

Table 3.3. Hydraulic residence time estimates for Ridenour Lake

Annual Precipitation (cm)	Date of Occurrence	Magnitude	Annual Discharge (m^3/yr)	Hydraulic Residence Time (days)
110	1978 to 1996	Average	3.0×10^6	32
142	1978	Maximum	3.9×10^6	25
92	1987	Minimum	2.5×10^6	38

Rainfall data source: Charleston, West Virginia.

The flushing potential of Ridenour Lake was also evaluated based on daily flow rates associated with storm runoff. The flushing ratio was estimated to be close to 1 for storms that cause more than 1.7 centimeters of runoff. These flushing values show that the lake is most likely fully mixed following large rainfall events.

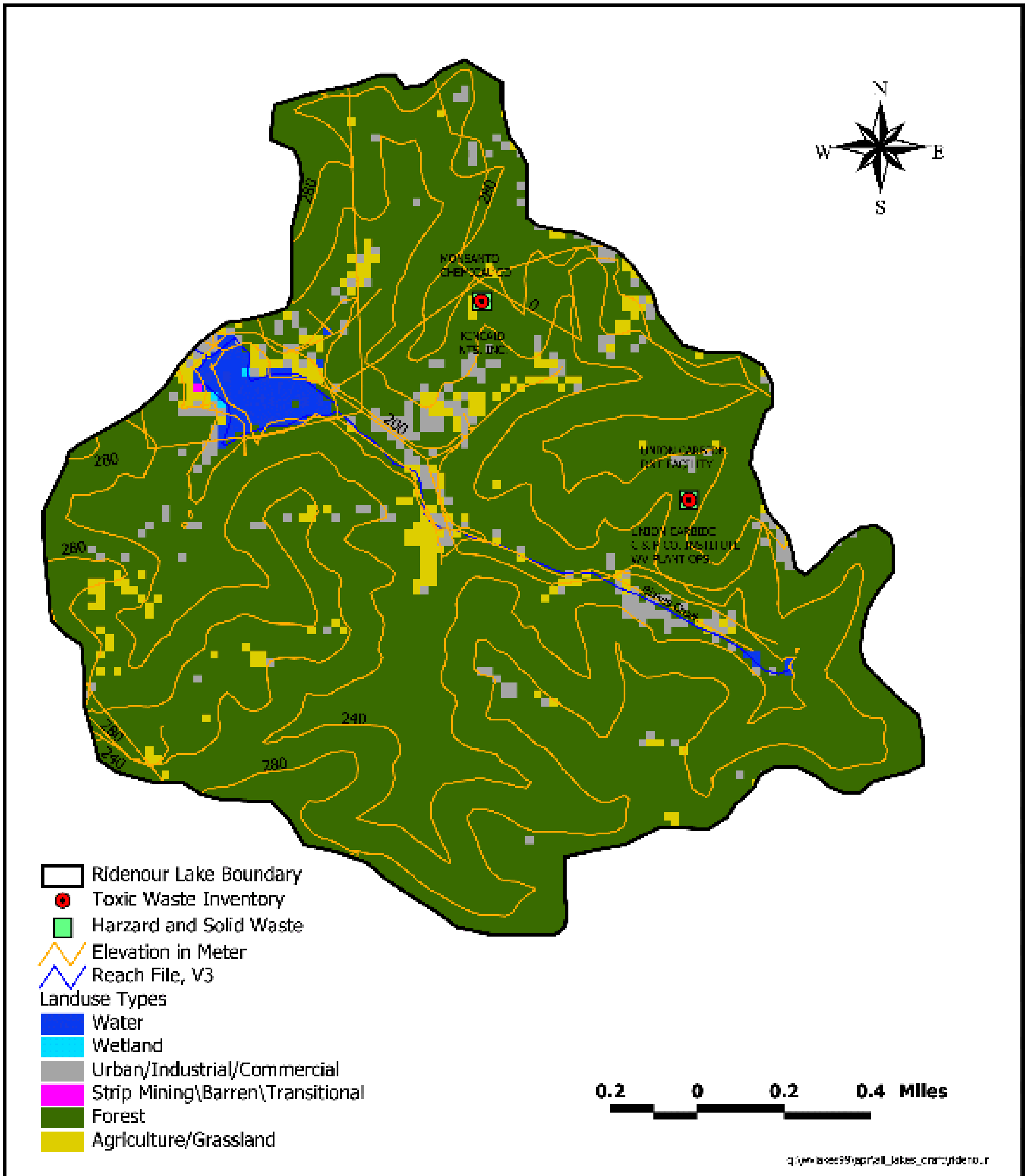
3.2 Watershed Characteristics

The Ridenour Lake watershed is a small drainage basin of 613 hectares (1,514 acres). More than 94 percent of the watershed consists of hydrologic soil group B, and 6 percent is hydrologic soil group C (USDA, 1993). The major soil series include Gilpin, Upshur, and Kanawha. The watershed size yields an estimated sediment delivery rate of 0.24, that is 24 percent of the eroded soil reaches the lake based on long-term average annual loading analysis (Vanoni, 1975).

Multi-Resolution Land Classification (MRLC) coverage was used to develop the land use distributions within the Ridenour Lake watershed (USGS, 1998), which are presented in Table 3.4. Forest land occupies most of the drainage area (Figure 3.1).

Table 3.4. Watershed land use distributions

TMDL Land Use Classes	Pervious/Impervious (Percent)	MRLC Land Use Class (Class No.)	Land Use Distribution in Watershed (hectares)
Residential	Pervious (50%) Impervious (50%)	Low-Intensity Developed (21)	22.8
Commercial and Industrial	Pervious (30%) Impervious (70%)	High-Intensity Commercial/Industrial (23)	0.5
Forest	Pervious (100%)	Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43)	558.0
Cropland	Pervious (100%)	Row Crop (82)	5.1
Pasture	Pervious (100%)	Hay and Pasture (81)	15.1
Barren (includes grading or construction)	Pervious (100%)	Quarries/Strip Mines/Gravel Pits (32)	0.6
Water	Impervious (100%)	Lakes and Streams	10.9
Wetland	Pervious (100%)	Woody Wetland (91) Emergent Herbaceous Wetland (92)	0.3
Total			**613.3**



Ridenour Lake Watershed
Putnam County, West Virginia

Data Sources: BASINS, MRLC

Map Projection: Albert Equal Area

4 WATER QUALITY STANDARDS AND TMDL ENDPOINT

4.1 Water Quality Standards

The state water quality standards include water use categories, antidegradation criteria, numeric criteria, and narrative descriptions of conditions in waters of the state.

The relevant water use categories for Ridenour Lake include the following:

- Propagation and Maintenance of Fish and Other Aquatic Life (Category B-1)
- Water Contact Recreation (Category C)
- Drinking water and consumption of fish (Class A)

No special exceptions or use designations are identified for Ridenour Lake.

4.2 Nutrients

No numeric criteria are available in the West Virginia water quality standards relevant to the 303(d) listing. The relevant narrative description of conditions includes the following:

> §46-1.3 Conditions Not Allowable in State Waters.
> 3.2 No sewage, industrial wastes or other wastes present in any of the water of the State shall cause therein or materially contribute to any of the following conditions thereof:
> a. Distinctly visible floating or settleable solids, suspended solids, scum, foam or oily slicks;
> b. Deposits or sludge banks on the bottom;
> ...
> i. Any other condition ... which adversely alters the integrity of the waters of the State including wetlands; no significant adverse impact to the chemical, physical, hydrologic, or biological components of aquatic ecosystems shall be allowed. (Title 46, Series 1, Requirements Governing Water Quality Standards)

WVDEP identifies lakes as impaired due to nutrients on the state's 303(d) list

> "if summer total phosphorus or chlorophyll *a* levels in surface waters resulted in a trophic state index value of $ 65 (highly eutrophic) or summer algal blooms or excessive aquatic vegetation were noted." (WVDEP, 1998).

Review of the available water quality monitoring information from 1993 to 1996 and 1998 indicates the likely source of impairment is periodic nuisance algal blooms. Based on monitoring (15 samples), observed chlorophyll *a*, an indicator of algae, is periodically elevated during the growing season, ranging from <1 ug/l to 57.3 ug/l, with a mean of 15.3 ug/l (Table 5.1). The observed trophic state indices are 60.6 for total phosphorus and 57.3 for chlorophyll *a*. Neither exceed the listing threshold of 65.

In the absence of a relevant numeric criterion, a numeric endpoint is selected consistent with the use description and the narrative condition. The trophic state index and the mean chlorophyll *a* concentration were considered as potential endpoints. The trophic state index threshold of 65 is currently not exceeded in Ridenour Lake. Chlorophyll *a* concentration is a measure of algal productivity and is directly correlated to the trophic state of the reservoir. Since Ridenour Lake is well below the trophic state index limit, a chlorophyll *a* threshold of 15 ug/l was selected. The selection of the limit for Ridenour Lake is consistent with the reservoir characteristics and the use designation.

4.3 Sediment

Ridenour Lake is listed as impaired due to siltation on the 303(d) list. Siltation is the excessive accumulation of sediment in the reservoir. The accumulation of sediment can impair the water uses of Fish and Other Aquatic Life and Recreation. The excessive accumulation of sediment can adversely affect aquatic life by creating thick mud deposits, filling habitat, and increasing turbidity. The excessive accumulation of sediment impairs recreational use by reducing access and degrading the aesthetic character of the lake.

The state has no numeric criteria related to the impairment of siltation in lakes. The relevant narrative description of conditions specifies the following:

> §46-1-3.3.2 No sewage, industrial wastes or other wastes present in any of the water of the State shall cause therein or materially contribute to any of the following conditions thereof:
> ...
> c. Deposits or sludge banks on the bottom.
> ...
> i. Any other condition ... which adversely alters the integrity of the waters of the State including wetlands; no significant adverse impact to the chemical, physical, hydrologic, or biological components of aquatic ecosystems shall be allowed. (Title 46, Series 1, Requirements Governing Water Quality Standards)

In the absence of numeric criteria for lake siltation in West Virginia, a numeric limit is selected for the development of Ridenour Lake siltation TMDL. This numeric limit is selected to be protective of the lake uses and serves as a target for identifying achievement of water quality standards associated with the lake listing. The selection of this numeric limit was based on several considerations:

- The selected endpoint, expressed as a long-term sedimentation rate for Ridenour Lake, is consistent with the causes of the Lake Ridenour listing. Excessive siltation is reported by the state as the main cause of the lake impairment.

- The long-term annual siltation rate should not be excessive and should allow for a reasonable life span of the lake before deposits become evident at normal pool elevations or create barrier to recreational uses. For small impoundments such as Ridenour Lake, and in the absence of the design specifications of the lake, a minimum 40-year life span is selected as a target and is used in derivation of siltation rate limit for this TMDL.

- Siltation does not occur uniformly over the entire lake bottom. Selected locations within the lake experience high siltation rates compared to other locations within the lake. The selected locations are the areas most likely to create barrier for recreational uses. Specifically for Ridenour Lake, characterized by a small area (10.9 hectares) and a shallow depth (2.4 meters mean depth), the high siltation locations are assumed to correspond to 26,000 cubic meters (less than 10% of the lake volume).

Based on the above considerations regarding the life span of the impoundment and the siltation volume (or critical volume), a long-term average annual siltation rate limit of 0.25 cm was calculated and established as the numeric criteria for this siltation TMDL.

4.4 Metals

Ridenour Lake is on the 303(d) list as impaired due to elevated iron and aluminum. The West Virginia water quality standards establish numeric criteria for chronic and acute levels of metals. The currently applicable numeric criteria for waters designated as category B-1 are presented in Table 4.1.

Table 4.1. Numeric criteria for metals

Averaging Period	Iron - measured as total (mg/l)	Aluminum - measured as total (ug/l)
Acute	--	750
Chronic	1.5	__[a]

[a] Chronic aluminum criteria may be reinstated as a result of EPA's review of the 1998 West Virginia Water Quality Standards Triennial Review. These TMDLs may need to be reviewed following these water quality standards revision to determine if water quality standards can still be met.

Review of the water quality data and discussion with WVDEP led to the conclusion that the soils in the Ridenour Lake watershed are naturally rich in metals. The increased metals concentration in the lake and tributary are related to the inputs of sediment and associated metals. The following information was reviewed:

- Existing water quality monitoring information
- Inventory of potential sources of aluminum and iron and watersheds
- Regional geology and soil aluminum and iron content

The review revealed that concentration was not significantly elevated in the lake or tributary when compared with other undeveloped watersheds.

The inventory of potential sources failed to identify any activities, current or historical, that are likely sources of elevated metals. No existing or past records of mining activities were identified. However, evaluation of USGS report *Isopleth Maps of Titanium, Aluminum, and Associated Elements in Stream Sediments of West Virginia* indicates that elevated metals concentrations occur in stream sediments in the Lower Kanawha River cataloging unit (USGS, 1994). These enriched sediments occur naturally in areas with aluminous host rocks. Analysis of the sediment-associated aluminum distribution in the vicinity of Ridenour Lake watershed show significantly higher concentrations than the median values.

Sediment is the dominant, and only apparent source, of the listed metals in the Turkey Run watershed. Control of the listed metals in the watershed can only be achieved by reducing the disturbance of sediment in the watershed and thereby reducing erosion and transport of sediment to the lake.

The recommendation for the 303(d) listing is to set the criteria to the loading under managed sediment loading conditions based on §46-1-7.7.2. which states

c. Exceptions: Numeric water quality standards shall not apply: ...
   D. Where lesser quality is due to natural conditions. In such cases the naturally occurring values shall be the applicable criteria.

The TMDL is derived using the managed sediment loading condition (defined under the sediment TMDL) as the relevant criteria.

5 WATER QUALITY ASSESSMENT

This section provides an inventory and analysis of the available water quality data for Ridenour Lake, its tributary (Blakes Creek), and the watershed.

5.1 Inventory of Available Water Quality Monitoring Data

Limited water quality monitoring activities have been conducted for Ridenour Lake and its inflows. Water quality data reviewed as part of this report were collected as follows: WVDEP seasonal sampling of Ridenour Lake and its inflow (Blakes Creek) from spring to fall during 1993, 1994, 1995, and 1996 (a total of 10 sampling events) and from spring to fall 1998 (a total of 3 sampling events). Data include the monitoring of nutrients, metals, temperature, suspended solids, and other water quality parameters.

5.2 Analysis of Water Quality Monitoring Data

Summaries of the minimum, maximum, and average values for the monitored water quality parameters are presented on Tables 5.1, 5.2, and 5.3 for the lake, tributary, and lake sediments, respectively. The summaries were derived using the following practices:

- Analytical results of less than the detection limit were assigned a value of one-half the detection limit when calculating the average value.
- Numerous samples collected on a single date were averaged and treated as one sample when calculating an average value.

The conclusions from the review of the data are as follows:

- Although a few parameters showed a range of nearly two orders of magnitude (for example, dissolved oxygen, total suspended solids, and ammonia), the wide range was generally due to an extreme value detected from a single sampling date.
- The pH values of the tributary flows and lake surface are typically 7.0 or greater. Acidity does not appear to be contributing to an elevated metals concentration in the tributary.
- Aluminum and iron concentrations are greater in the lake than in the tributary.
- The metals concentrations are higher near the bottom of the lake, where the sediment concentrations are higher and the pH lower. This might indicate a relationship between elevated sediment and metals concentrations.
- Nutrient and suspended sediment concentrations are lower in the lake than in the inflows from Blakes Creek.
- The long-term average chlorophyll *a* concentration (15.3 ug/l) is slightly above the TMDL endpoint of 15 ug/l, with a high reading nearly four times the endpoint.
- The trophic state index (TSI) for total phosphorus is 60.6 and chlorophyll *a* is 57.3.

Table 5.1. Summary of WVDEP lake sampling observations for selected pollutants: Ridenour Lake, 1993-96, 1998

Pollutant Type	Pollutant	Units	Criteria	Total Obs.	Minimum	Maximum	Mean		
							Total	Lake Bottom	Lake Surface
Metal	Aluminum	mg/l	0.75	27	0.07	12.	1.8	3.1	1.2
	Iron	mg/l	1.5	27	0.3	13.	2.2	3.5	1.5
Nutrient	TKN	mg/l		28	<0.38	2.45	0.74	1.0	0.6
	NO_2-NO_3-N	mg/l	10[a]	8	<0.01	0.51	0.19	0.19	0.20
	TP	mg/l		28	0.016	0.13	0.05	0.06	0.05
	Ammonia	mg//l		28	<0.5	1.7	0.4	0.63	0.26
	Chlorophyll *a*	ug/l	15[b]	15	<1	57.3	15.3	--	15.3
Siltation	Suspended Solids	mg/l		28	2	150	33	44	23
	Turbidity	NTU	__[c]	9	90	407	233	--	--

[a] Nitrate as nitrogen is not to exceed the 10 mg/l acute human health use designation.
[b] Surrogate eutrophication criteria established as part of this investigation.
[c] Turbidity cannot exceed 10 nephalometric turbidity units (NTU) when background is 50 NTU or less or have more than a 10 percent increase when background is 50 NTU or greater (plus 10 NTU minimum).

Nitrogen:Phosphorus Ratio

The levels of nitrogen and phosphorus in the water column control the growth of aquatic plants. It is important to determine which nutrient is limiting in order to accurately model the system. A general guide used to determine the limiting nutrient is the Nitrogen : Phosphorus ratio. Aquatic systems where the N:P ratio is greater than 7.2 are considered to be phosphorus limited (Chapra, 1997). The N:P ratio of Ridenour Lake, using the means of total nitrogen and total phosphorus from Table 5.1, is estimated at about 19.

Trophic State

Trophic state indices have been developed to help define the usability of a lake for fishing and recreational uses. These indices are frequently based upon factors such as nutrient levels, temperature, light, and lake geometry (Carlson and Simpson, 1996). A common classification based on these factors includes the trophic states; oligotrophic (low production), mesotrophic (medium production), eutrophic (high production), and hypereutrophic (very high production). A quantitative description of these trophic states is seen in Table 5.4.

The trophic state indices for Ridenour Lake are 60.6 for total phosphorus and 57.3 for chlorophyll *a*. Neither exceed the West Virginia listing threshold of 65.

Table 5.2. Summary of WVDEP tributary sampling observations of selected pollutants: Ridenour Lake, 1993-96, 1998

Pollutant Type	Pollutant	Units	Criteria	Total Obs	Minimum	Maximum	Mean
Metal	Aluminum	mg/L	0.75	15	<0.05	3.55	0.57
	Iron	mg/L	1.5	15	<0.05	5.84	0.77
Nutrient	TKN	mg/L		9	<0.19	1.5	0.39
	NO_2-NO_3-N	mg/L	10[a]	15	<0.05	1.37	0.50
	TP	mg/L		15	0.02	0.17	0.05
Siltation	Suspended Solids	mg/L		16	1.0	378.0	46.1
	Turbidity	NTU	__[b]	2	22	371	197

[a] Nitrate as nitrogen is not to exceed the 10 mg/l acute human health use designation.
[b] Turbidity cannot exceed 10 NTU when background is 50 NTU or less or have more than a 10 percent increase when background is 50 NTU or greater (plus 10 NTU minimum).

These classifications may be used to determine whether waterbodies are meeting their "fishable" and "swimmable" designated uses. The Ridenour Lake seems to be slightly eutrophic based on Table 5.4.

Table 5.3. Summary of WVDEP lake sediment sampling observations of selected pollutants: Ridenour Lake, 1993-96, 1998

Pollutant Type	Pollutant	Units	Total Obs	Minimum	Maximum	Mean
Metal	Aluminum	mg/kg	3	8,620	12,500	10,607
	Iron	mg/kg	3	14,400	20,300	16,533
Nutrient	TP	mg/kg	3	148	320	219

Table 5.4. Common trophic state characteristics [a]

Trophic State	Characteristics	Attributes
Oligotrophic	Low phosphorus (3.0 - 17.7 ug/L) Low nitrogen (307 - 1630 ug/L) Low Chlorophyll *a* (0.3 - 4.5 ug/L) High secchi depth (5.4 - 28.3 m)	Oxygenated hypolimnion, clear water, suitable for cold water aquatic life in deeper lakes.
Mesotrophic	Moderate phosphorus (10.9 - 95.6 ug/L) Moderate nitrogen (361 - 1387 ug/L) Moderate Chlorophyll *a* (3 - 11 ug/L) Moderate secchi depth (1.5 - 8.1 m)	Hypolimnetic anoxia possible, moderately clear water, suitable for warm water aquatic life.
Eutrophic	Moderate phosphorus (16 - 386 ug/L) Moderate nitrogen (393 - 6100 ug/L) Moderate Chlorophyll *a* (3 - 78 ug/L) Moderate secchi depth (0.8 - 7.0 m)	Decreased transparency, noticeable odor and color, possible macrophyte problems, suitable for warm water aquatic life.
Hypereutrophic	High phosphorus (750 -1200 ug/L) High nitrogen (Not available) High Chlorophyll *a* (1 - 150 ug/L) Low secchi depth (0.4 - 0.5 m)	Dense algae growth, nuisance weeds present, noticeable odor and color, low transparency, winter fish kills possible.

[a] Vollenweider and Kerekes, 1980.

6 SOURCE ASSESSMENT

6.1 Assessment of Point Sources

Several databases were reviewed to determine if permitted or regulated point source discharges were present within the watershed. The databases reviewed were obtained primarily from the USEPA mainframe system. In addition to review of available databases, local agencies, including WVDEP and the City Engineer for Nitro, West Virginia, were contacted by telephone. The following database systems were searched:

- Permit Compliance System for permitted industrial or municipal facilities
- Hazardous and solid waste facilities
- Abandoned mines
- Oil and gas wells
- Toxic release inventory

Investigation of the relevant databases and consultation with the City Engineer of Nitro (Sergent, personal communication, May 1999) indicated that no point sources were located within the watershed.

To further investigate potential historical discharges or disturbances, WVDEP reviewed a series of maps developed in the 1930s of existing and abandoned mines. No inactive or historical mining activities were identified in the Ridenour Lake watershed.

6.2 Assessment of Nonpoint Sources

Nonpoint sources of pollutants within the watershed can generally be associated with the different types of land uses and land activities within the watershed. For example, sediment loadings can originate from silvicultural activities and road construction. Expansion of residential and commercial/industrial areas can also cause an increase in storm water flows and sediment loads through soil erosion and sediment transport. In addition, the erosion rate can potentially increase phosphorus loads since phosphorus is readily adsorbed onto soil particles. For nutrient enrichment, animal waste handling, manure and fertilizer application, and septic systems are the key potential sources.

Forest is the primary land use within the Ridenour Lake watershed with minor components of agricultural and urban/industrial/commercial land uses. The land uses within the watershed are presented on Table 6.1.

The broad categories of land uses have been separated into more detailed classes based on information obtained from the Forestry Service (Warren, personal communication, May 1999). In particular, forest land, which accounts for 91 percent of the land use, is fully logged within approximately a 25-year period (West Virginia Department of Forestry, 1999). Therefore, it has been assumed that 4 percent of the forest land is selectively logged every year. In addition, under existing conditions forest harvesting activities are performed with minimum erosion/sediment control practices (Sergent, personal communication, May 1999).

The potential contribution of nutrients from failing septic systems was also assessed. A sanitary sewer line is being installed from the city of Nitro to the shopping mall currently under construction, though residents within the watershed are not required to connect to the sanitary sewer (Sergent, personal communication, May 1999). Data associated with the number of reported septic systems present in Kanawha County were obtained from 1990 U.S. Census data and the analysis of existing maps.

Urban development and associated construction activities were derived from analysis of population growth in Kanawha County. Construction activities for urban development was estimated at 0.5 hectare per year.

Wildlife, especially waterfowl, can contribute significant nutrient loadings directly to the lake. The City has an ordinance prohibiting the feeding of waterfowl at Ridenour. Geese are so prevalent at Ridenour Lake that the gazebo on the lake shore must be hosed off by the fire department before large gatherings (Sergent, personal communication, May 1999). No specific wildlife counts are available at this time.

Table 6.2 presents a summary of additional potential sources considered in this analysis.

Table 6.1. Land use categories

Land Use Classes	Area (hectares)
Residential	22.8
Commercial and Industrial	0.5
Forest	558.0
Cropland	5.1
Pasture	15.1
Barren (includes grading or construction)	0.6
Water	10.9
Wetland	0.3
Total (includes lake area)	**613.3**

Table 6.2. Considerations in source evaluations

Potential Nonpoint Sources	Magnitude	Data Sources	Comments
Silvicultural activities (hectares/year)	22.3	City Engineer, Nitro, WV; WV Forestry Service	Selective tree logging methods assumed - considered as part of forest loadings
Septic releases (population)	106	USGS quads; US Census data	Assumes 2.8% population growth per year - represents a separate source
Urban development (hectares/year)	0.5	US Census data; USGS quads	Represents construction areas
Wildlife and waterfowl (counts)	--	--	Incorporated into forest loadings

6.3. Representation of Potential Sources in the Development of Loading Estimation

The representation of the non-point sources in the loading model was determined based on the available data and considering the differences among the various categories of sources

Nutrients

The sources simulated in the model include four land use categories representing surface loading, the septic system as an independent source, and the contribution of nutrient from groundwater. Table 6.3 presents the nutrient sources simulated.

Table 6.3. The nutrient sources simulated in the loading model.

Sources Simulated	Characteristics
Forest	All the forest land, including forest harvesting, wildlife, and waterfowl.
Agriculture	Cropland and pasture/hayland
Urban	Residential and commercial/industrial areas
Construction	Barren and construction areas
Groundwater	Nutrients from groundwater
Septic systems	Septic release from human population

Sediment

The sediment sources represented in the model are shown in Table 6.4.

Table 6.4. The sediment sources simulated in the loading model

Sources Simulated	Characteristics
Forest	All the forested land, including forest harvesting
Agriculture	Cropland and pasture/hay land
Urban	Residential and commercial/industrial areas
Construction	Barren and construction areas.

7 MODELING AND ANALYSIS SUMMARY

Based on a review of the available data, listed pollutants and lake characteristics, the following approach was identified. The analysis is presented and described by pollutant—nutrients, sediment, and metals.

7.1 Nutrient Model

7.1.1 Nutrient Loading Model

The loading assessment requires evaluation of seasonal and annual loadings of nitrogen and phosphorus to the reservoir. The GWLF model was selected as consistent with the land use type, available information, and loading time scale. The GWLF model provides predictions of monthly total and dissolved nitrogen and phosphorus (Haith and Shoemaker, 1987; Haith, Mandel and Wu, 1992). The model requires standard inputs of soil and land cover information. Daily precipitation and temperature are used for the selected simulation period. The GWLF model was applied as follows:

- Land use classification: MRLC (USEPA, 1998)
- Hydrologic soil group: B and C soils
- Simulation time period: 1978-97
- Meteorologic station: Charleston, West Virginia

The flow to Ridenour Lake was estimated using the GWLF model. The flow consists of surface water runoff and groundwater contributions. The surface water runoff was simulated in GWLF using soil curve number information from Natural Resources Conservation Service (NRCS) Technical Release 55 (TR-55) (SCS, 1986). For comparative purposes, the average stream flow to the lake obtained from the model was estimated to be approximately 45 percent of the total precipitation. This value is within the range of estimates from five USGS gaging stations for small watersheds (less than 5 square miles) in West Virginia that have characteristics similar to those of the Ridenour Lake watershed (see Table 7.1). The precipitation records were obtained from Charleston, West Virginia, for the period of 1978 to 1997.

Table 7.1. Long-term average discharges reported by USGS gaging stations for small watersheds

USGS Station ID	Watershed Area (mi^2)	USGS Gaging Station Average Discharge (cfs)	Estimated Watershed Precipitation Rate (cfs)	Streamflow as a Percentage of Precipitation
03193776	0.91	1.20	2.95	40.6%
03193778	1.44	1.96	4.66	42.0%
03198020	2.73	2.72	8.84	30.8%
03181200	3.06	5.20	9.91	52.5%
03114650	4.19	5.61	13.57	41.3%
03113700	4.95	6.48	16.03	40.4%
Average	2.88	3.86	9.33	41.3%
Minimum	0.91	1.20	2.95	30.8%
Maximum	4.95	6.48	16.03	52.5%

The GWLF model was used to estimate nutrient loading for identified sources as described in Table 7.2.

Table 7.2. Information used to quantify source loadings [a]

Land Use	Existing Area (hectares)	Percent of Watershed	Consideration
Forest	558	92.6%	Forest harvesting, wildlife, background erosion losses
Agriculture	20.2	3.4%	Includes crops, pasture and hay
Urban	23.3	3.9%	Includes residential, commercial and industrial
Construction	0.6	0.1%	Includes estimated mean annual construction area
Ground water			Assume background concentrations of 0.31 mg/l total nitrogen and 0.015 mg/l total phosphorous
Septic System	From 106 people		Conventional septic systems with 32% nitrogen removal efficiency; 2.5% septic failure rate
Total	602.9[b]	100%	

[a] Based on MRLC land use coverage representative of 1986-94 conditions (USEPA, 1998).

[b] Excludes the lake area and includes 0.8 hectare of wetlands and water area.

A summary of phosphorus loading obtained from GWLF application is presented in Table 7.3.

Table 7.3. Nonpoint source loadings

Source	Phosphorus Loading (kg)
Forest	124.9
Agriculture	10.3
Urban	3.6
Construction	2.9
Groundwater	38.6
Septic Systems	2.6
Total	182.9

The phosphorus loads converted to concentrations (in mg/l) were compared to the observed concentrations in the lake. Comparisons between predicted and observed nutrient concentrations are presented in Table 7.4.

Table 7.4. Annual mean simulated and observed nutrients concentrations

Constituent	Simulation Results	Observed Concentration[a]
Total Nitrogen (mg/L)	0.81	0.93
Total Phosphorus (mg/L)	0.059	0.050

[a]Based on 13 sampling events during the 1993-1998 period.

7.1.2 Nutrient Lake Model

For in-lake assessment, the BATHTUB model (USACE, 1996) was selected to evaluate the chlorophyll *a* concentration resulting from nutrient inputs under existing and TMDL conditions. The BATHTUB model uses empirical relationships to evaluate lake conditions based on the physical characteristics of the lake, the nutrient inputs, and the meteorologic conditions. The BATHTUB model was set up as follows:

- Time period: Average annual loading
- Bathymetry: Existing conditions derived from 1980 bathymetry data and 1999 observations; allocation run assumes lake is at pre-1980 conditions
- Configuration: Lake segmentation represented in the BATHTUB model (Table 7.5)

Table 7.5. Ridenour Lake morphology as represented in the BATHTUB model

Segment	1980 Lake Volume (m^3)	1999 Lake Volume (m^3)
Segment 1	19,253	12,120
Segment 2	57,960	50,400
Segment 3	70,692	64,500
Segment 4	109,500	99,000

Results of the BATHTUB analysis, under existing conditions, were compared with the observed lake data for the 1993-98 sampling seasons. The observed chlorophyll *a* concentrations were used to calibrate the model. The concentration results are shown in Table 7.6.

Table 7.6. In-lake chlorophyll *a* concentrations

Constituent	In-lake Simulation Results	In-lake Observed Concentration[a]
chlorophyll *a* (ug/L)	15.7	15.3

[a] based on 13 sampling dates during the period from 1993-1998.

Predictions of chlorophyll *a* concentrations were used to evaluate the selected TMDL endpoint for nutrients

7.2 Sediment Model

7.2.1 Sediment Loading Model

The loading evaluation requires the simulation of annual loading of sediment to the reservoir. The GWLF model was used to estimate sediment loading. The model provides monthly and annual estimates of sediment yield to the reservoir, taking into consideration soil characteristics and land use information. Setup, analysis, and model testing were based on the same configuration as the nutrient loading model. Insufficient monitoring information is available to compare predictions to the observed tributary loadings. Table 7.7 presents the sediment loading estimates for Ridenour Lake.

Table 7.7. Sediment loading estimates by source

Source	Existing Sediment Loading (metric tons)
Forest	358.5
Agriculture	18.2
Soil Disturbance due to Construction	7.0
Urban	2.1
Total	385.8

7.2.2 Sediment Lake Analysis

The sediment accumulation in Ridenour Lake is assessed using trap efficiency calculations. Trap efficiency refers to the ability of lakes and reservoirs to retain a portion of the sediment loading. This efficiency is expressed as the percent of sediment retained compared to total incoming sediment. The key factors that affect the efficiency of lakes/reservoirs to trap sediment include sediment particle size distribution, the lake hydraulic residence time, and the design and operation of the reservoir outlets. Brune's method for estimating lakes and reservoirs trap efficiency was developed based on analysis of numerous reservoir siltation studies (Chow, 1953). The method establishes a graphical relationship between the sediment trap efficiency and the ratio of the reservoir available storage capacity to the total annual inflow. This relationship has been extensively used to estimate siltation rates, reservoir life span, and other engineering parameters used in economic feasibility studies of reservoirs.

Using a volume of 267,000 cubic meters and estimated annual inflows from the GWLF model, the trap efficiency of Ridenour Lake is estimated to vary between 74 percent to 90 percent (83 percent median value). Using a median value of 83 percent as the lake trap efficiency, the siltation rate was estimated at 0.38 cm/year (Table 7.8).

Table 7.8. Estimated sediment loadings to Ridenour Lake

Mean Sediment Loading (metric tons/yr)	Siltation (metric tons/yr)	Accumulation Rate (cm/yr)
386	320	0.38

7.3 Metals Analysis

Analysis of aluminum and iron concentrations was performed on water quality monitoring data (Section 5). This analysis confirms the high metal values in the lake water column samples. Analysis of metal content in lake bottom sediment also show relatively elevated values of aluminum and iron. The source identification and assessment concluded that there are no point or nonpoint sources of metals in the watershed. It assumes that the elevated concentrations are due to naturally occurring sources. The watershed area is believed to have a high metal content. This assumption was confirmed in USGS report *Isopleth Maps of Titanium, Aluminum, and Associated Elements in Stream Sediment of West Virginia* (USGS, 1994). The computation of aluminum and iron loading for Ridenour Lake watershed considers (1) sediment loading as the main surrogate for metals transport, (2) metal content in sediment, and (3) the ratio of metal content in watershed soils to that in lake sediment (the enrichment ratio). The computational approach is as follows:

$$L_{(Al)} = S_L * C_{sed} * E_R * K$$

where
$L_{(Al)}$ = Annual loading of metal (kg)
S_L = Annual sediment load (kg)
C_{sed} = Maximum metal content in sediment (mg/kg)
E_R = Enrichment ratio
K = Conversion Factor

The maximum metal content is derived from the metals content in three sediment samples available for Ridenour Lake (aluminum 12,500 mg/kg and iron 20,300 mg/kg Table 5.3). The enrichment ratio is assumed to be 1.5, recognizing that the metals inputs may be relatively higher than deposited sediment due to variation in particle size distribution.

The annual load computed using this approach under existing conditions is 7,235 kg/year for aluminum and the iron load is 11,750 kg/year.

8 TMDL

The load estimation model and the lake model were used to derive the TMDLs for Ridenour Lake. Presented in this section are the results of the TMDL analysis for each of the listed pollutants.

8.1 Nutrients

Nutrient loading capacity was evaluated based on simulated chlorophyll *a* and estimates of the Trophic State Index (TSI) for phosphorus and chlorophyll *a*. Several loading reduction scenarios were simulated and summarized in Table 8.1. Table 8.1 describes the derivation of the required load reduction for nutrients and presents the selected level of control that meets the TMDL endpoint of 15 ug/l chlorophyll *a*.

Table 8.1 Analysis of loading reduction scenarios for Ridenour Lake

Scenario	TP	TSI(TP)	Chlorophyll *a*	TSI(CHL)
Observed value	50	60.6	15.3	57.3
Baseline	59	59.0	15.7	57.6
5% nutrient reduction	56	62.2	15.2	57.3
10% nutrient reduction	53	61.4	14.6	56.9
15% nutrient reduction	50	60.6	14.0	56.5
20% nutrient reduction	47	59.7	13.4	56.0

A 7% reduction in nutrient loading meets the targeted endpoint of 15 ug/l chlorophyll *a* and also is significantly below a TSI of 65.

The 1999 bathymetry data was used to setup the lake model under existing conditions. The designated use of the lake was specified using the as-built volumetric conditions. The original bathymetric data was not available to determine the as-built conditions of the lake. The allocation scenarios were simulated using the 1980 bathymetry data to approximate the as-built conditions.

Based on the evaluation of the lake monitoring and modeling analysis and evaluation of the nitrogen-phosphorus ratio (see section 5.2), phosphorus is determined to be the limiting nutrient for the reservoir. Table 8.2 summarizes the existing loading, the loading capacity, the projected load reductions, and the load allocation for the nutrient TMDL.

Table 8.2. Ridenour Lake nutrient TMDL

Source	Existing Loading Total Phosphorus (kg)	Estimated Percent Reduction	Load Allocation (kg)	Comments
Forest	124.9	13.5%	108.0	
Agriculture	10.3	10.3%	9.0	
Urban	3.6	0%	3.6	
Construction	2.9	25%	2.2	
Groundwater	38.6	0%	38.6	
Septic Systems	2.6	100%	0.0	
Total Existing Load	**182.9**	**3 Load Allocation**	**161.4**	
Loading Reduction	**13 (7%)**	**Waste Load Allocation**	**0.0**	**No point sources**
		Margin of Safety	**8.5**	**5% of Loading Capacity[a]**
TMDL = Loading Capacity = 169.9				

[a]**Margin of Safety**. An explicit margin of safety was calculated as a percentage of the loading capacity (5%). The selected margin of safety is consistent with level of uncertainty identified in performance of the TMDL analysis.
Seasonality. The analysis considered seasonality in the loading through the simulation of monthly loadings. The evaluation of nutrient impacts in the reservoir was considered for the average annual conditions. The allocation is presented as an annual average loading consistent with the impairment of the reservoir and the expression of the load reduction required to achieve water quality standards.
Critical Condition. The critical conditions for the nutrient TMDL are selected to evaluate the impairments observed in the lake. The lake condition is evaluated based on chlorophyll *a* in response to long-term annual loading of nutrients (phosphorus).

Margin of Safety

The MOS one of the required elements of a TMDL. There are two basic methods for incorporating the MOS (USEPA 1991):

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

The margin of safety for this TMDL was expressed as an explicit number, calculated as a percentage of the total loading capacity. A 5 percent margin of safety was selected to reflect the uncertainty in the modeling analysis and the selection of the TMDL endpoint. Other implicit conservative assumptions provide an additional margin of safety. Specific conservative assumptions include:

C The loadings calculated by the nonpoint source model (GWLF) were derived using conservative assumptions in the selection of nutrient potency factors. The use of conservative assumptions in developing the loading model results in relatively highly loads and slightly larger required load reductions.

Seasonality

The nutrient analysis considered seasonality in the loading through the simulation of monthly watershed loadings based on historic precipitation records. The evaluation of nutrient impacts in the reservoir was considered for the average annual conditions representing the response to long term, cumulative nutrient loading. The TMDL and load allocation are presented as annual average loading consistent with the type of impairment (eutrophication) and waterbody type (reservoir). Reduction of the average annual load is expected to result in achievement of water quality standards.

Critical Condition.

The critical conditions for the nutrient TMDL are selected to evaluate the type of impairment (eutrophication) and the type of waterbody (reservoir). Protection of the lake condition requires the control of long term loadings and accumulation of phosphorus. The lake condition is evaluated based on chlorophyll *a* concentrations in response to long-term annual loading of nutrients (phosphorus).

Background Conditions

The TMDL load allocation should include, when possible as a separate allocation, the natural background loading of the pollutant. In this analysis natural background is included as an allocation to groundwater or baseflow loadings, and the forest loadings. Note that the forest category also includes some loads due to forestry activities, which are in addition to the naturally occurring runoff and erosion from forested areas. The monitoring data were insufficient to separate natural forest loadings from other forest sources.

8.2 Sediment

The sediment allocation was based on the long-term average siltation rate as an endpoint and a numeric limit of 0.25 cm per year. Table 8.3 provides the computed mean siltation rate of the lake for three different conditions: (1) existing condition; (2) predevelopment condition (assuming the watershed is totally forested); and (3) a loading scenario that meet the numeric limit of 0.25 cm per year as the long-term average siltation rate. The table also compares the life span of the lake under these 3 conditions.

Table 8.4 summarizes the sediment load allocation scheme corresponding to an overall reduction of 35% and extending the useful life of the lake from 26 to 40 years.

Table 8.3. Siltation Analysis of Ridenour Lake

	Existing Conditions	Predevelopment Conditions	Loading Scenario
Mean annual load (kg)	385,887	161,673	250,820
Siltation rate (cm)	0.38	0.16	0.25
Fill time (years)[a]	26	62	40
Loading scenario for 40 year time span corresponds to a 35% load reduction (see Table 8.4)			

[a]Based on a siltation volume of 26,000 m^3

Table 8.4. Ridenour Lake sediment TMDL

Source	Existing Loading Sediment (metric tons)	Percent Reduction	Load Allocation (metric tons)	Comments
Forest	358.5	38.2%	221.6	
Agriculture	18.2	10%	16.4	
Construction	7.0	50%	3.5	
Urban	2.1		2.1	
Groundwater	-			
Septic Systems	-			
Total Existing Load	**385.8**	**3 Load Allocation**	**243.6**	
Load Reduction	**134.4 (35%)**	**Waste Load Allocation**	**0**	**No point sources**
		Margin of Safety	**7.5**	**3% of Loading Capacity**
TMDL = Loading Capacity = 251.1				

Margin of Safety. An explicit margin of safety was calculated as a percentage of the loading capacity (3%). The selected margin of safety is consistent with level of uncertainty identified in performance of the TMDL analysis.
Seasonality. The analysis considered seasonality in the loading through the simulation of monthly loadings. The evaluation of sediment impacts in the reservoir was considered for the long-term average annual conditions. The allocation is presented as an annual average loading consistent with the impairment of the reservoir and the expression of the load reduction required to achieve water quality standards.
Critical Condition. The critical conditions for the sediment TMDL are selected to evaluate the long-term siltation impairments observed in the lake.

Margin of Safety

The margin of safety for this TMDL was expressed as an explicit number, calculated as a percentage of the total loading capacity. A 3 percent margin of safety was selected to reflect the uncertainty in the modeling analysis and the selection of the TMDL endpoint. Other implicit conservative assumptions provide an additional margin of safety. Specific conservative assumptions include:

C The endpoint for the reservoir is defined based on a 40 year lifespan for a selected volume of the lake.

C The loadings calculated by the nonpoint source model (GWLF) were derived using conservative assumptions in the selection of soil erosion factors. The use of conservative assumptions in developing the loading model results in relatively highly loads and slightly larger required load reductions.

Seasonality

The sediment analysis considered seasonality in the loading through the simulation of monthly watershed loadings based on historic precipitation records. The evaluation of sediment impacts in the reservoir was considered for the average annual conditions representing the response to long term, cumulative siltation. The TMDL and load allocation are presented as annual average loading consistent with the type of impairment (siltation) and waterbody type (reservoir). Reduction of the average annual load is expected to result in achievement of water quality standards.

Critical Condition.

The critical conditions for the sediment TMDL are selected to evaluate the type of impairment (siltation) and the type of waterbody (reservoir). Protection of the lake condition requires the control of long term loadings and accumulation of sediment. The lake condition is evaluated based on mean siltation rates, in selected locations, in response to long-term annual loading and trapping of sediments in the reservoir.

Background Conditions

The TMDL load allocation should include, when possible as a separate allocation, the natural background loading of the pollutant. For sediment natural background is included as an allocation to the forest loadings. Note that the forest category also includes some loads due to forestry activities, which are in addition to the naturally occurring runoff and erosion from forested areas. The monitoring data were insufficient to separate natural forest loadings from other forest sources.

8.3 Metals

Analysis of the Ridenour Lake watershed did not identify any point or nonpoint sources of metals. Evaluation of USGS report *Isopleth Maps of Titanium, Aluminum, and Associated Elements in Stream Sediments of West Virginia* indicates that elevated metal concentrations occur in stream sediments in Ridenour Lake watershed (USGS, 1994). Sediment is the dominant, and only apparent source, of the listed metals in the Turkey Run watershed. Control of the listed metals in the watershed can only be achieved by reducing the disturbance of sediment in the watershed and thereby reducing erosion and transport of sediment to the lake. Metal concentration in sediment collected from Lake Ridenour bottom deposits range from low values to 12.5 g/kg for aluminum and 20.3 g/kg for iron (Table 5.3). Assuming that sediment deposited on the lake bottom is less enriched than the soil of origin, an enrichment ratio of 1.5 was assumed as the ratio of metal content in soil to that in lake sediment (see section 7.3). Aluminum and iron TMDL allocations are shown in Table 8.6 and Table 8.7. Table 8.5 summarizes the computation of loading capacity and a load reduction scenario. An explicit 10% margin of safety is considered.

Table 8.5. Derivation of loading capacity for aluminum and iron assumed to be naturally occurring

Metal	Sediment Concentration (mg/kg)	Sediment Load Allocation (kg/yr)	Enrichment Ratio	Metal Loading Capacity (kg/yr)	Load Allocation (kg/yr)
Aluminum	12,500	243,600	1.5	4,568	4,568
Iron	20,300	243,600	1.5	7,418	7,418

Table 8.6. Ridenour Lake aluminum TMDL

Source	Existing Loading Total Aluminum	Percent Reduction	Load Allocation (kg)	Comments
Naturally Occurring (soil)	---	---	4,568	
Total Existing Load	**---**	**3 Load Allocation**	**4,568**	
Load Allocation	**---**	**Waste Load Allocation**	**0**	**No point sources**
		Explicit Margin of Safety	**0**	
TMDL = Loading Capacity = 4,568				
Margin of Safety. An implicit margin of safety was defined based on conservative assumption in the analysis . The selected margin of safety is consistent with level of uncertainty identified in performance of the TMDL analysis. **Seasonality.** The analysis considered seasonality in the metals loading through the simulation of monthly loadings. The allocation is presented as an annual average loading consistent with the impairment of the reservoir and the expression of the load reduction required to achieve water quality standards. **Critical Condition.** The critical conditions for the aluminum (acute) TMDL are expected to be addressed through reduction in long-term loading.				

Critical Condition

The critical conditions for the metals TMDL are selected consistent with the delivery mechanism of the metals and the type of waterbody (reservoir). The metals loads are expected to be delivered with fine grained, naturally occurring sediment. Variability in the fined grained sediment load is expected to occur due to natural fluctuations in the hydrology. Periodic elevated concentrations of iron and aluminum are expected to occur due to the high concentration of metals in local sediments. The TMDL sets a site specific criteria under the sediment loading conditions defined by the sediment TMDL. This will result in controlling long term loadings and accumulation of sediment and associated metals. The lake condition is evaluated based on annual metals loading associated with reduced sediment loading, under the sediment load allocation.

Background Conditions

The TMDL load allocation should include, when possible as a separate allocation, the natural background loading of the pollutant. Metals naturally occur in the existing sediments in the watershed and no other contributing sources were identified. All metals loadings defined in the TMDL are considered background under the TMDL. If additional sources are defined in the future, through reconnaissance and monitoring, a revision to the TMDL could establish separate LAs or WLAs as appropriate.

Table 8.7. Ridenour Lake iron TMDL

Source	Existing Loading Total Iron (kg)	Percent Reduction	Load Allocation (kg)	Comments
Naturally Occurring (soil)	---	---	7,418	
Total Existing Load	**---**	**3 Load Allocation**	**7,418**	
Load Reduction	**---**	**Waste Load Allocation**	**0**	**No point sources**
		Explicit Margin of Safety	**0**	
TMDL = Loading Capacity = 7,418				

Margin of Safety. An implicit margin of safety was defined based on conservative assumption in the analysis. The selected margin of safety is consistent with level of uncertainty identified in performance of the TMDL analysis.
Seasonality. The analysis considered seasonality in the metals loading through the simulation of monthly loadings. The allocation is presented as an annual average loading consistent with the impairment of the reservoir and the expression of the load reduction required to achieve water quality standards.
Critical Condition. The critical conditions for the iron (chronic) TMDL are expected to be addressed through reduction in long-term loading.

Margin of Safety

The margin of safety for this TMDL was expressed as an implicit conservative assumption in the analysis. The analysis of the metals' TMDL takes into account the sediment load allocation derived under the sediment TMDL. Therefore all specific conservative assumptions made in the development of the sediment TMDL apply to the metals TMDL as well. In addition, other conservative assumptions associated with the metals TMDL include:

C Fine sediment particles have larger surface areas for adsoption and contain higher levels of metals' coarser particles. The trap efficiency for fine sediment, with associated metals, is likely to be lower than the total sediment trap efficiency identified for the sediment TMDL. This results in relatively less accumulation of metals in the reservoir than identified under the selected TMDL.

Seasonality

The sediment analysis considered seasonality in the loading through the simulation of monthly watershed loadings based on historic precipitation records. The TMDL and load allocation are presented as annual average loading consistent with the available information, the transport mechanism (metals associated with sediment) and waterbody type (reservoir).

9 REASONABLE ASSURANCES FOR IMPLEMENTATION

Reasonable Assurance for Implementation:

There are number of best management practices that can be adopted to minimize the nutrient, sediment and metals loadings in accordance with the identified TMDLs and load reduction targets.

Nutrient

The nutrient TMDL identifies load allocations and reductions from forested land, agricultural operations, urban, transition/ barren areas, construction areas, and septic systems. Some of the management practices that can be used to achieve the identified load reductions include:

Forestry management: forestry practices including preharvest planning, streamside area management and buffers, road construction/reconstruction/management, timber harvest management, site preparation, erosion and sediment control, and forest regeneration. Wildlife and water fowl control can also be used to manage nutrient loads.

Agricultural management: Agricultural management practices can reduce sediment and associated nutrient loads. Typical practices include conservation tillage, terraces, crop rotations, and stream buffers. A nutrient management plan can be adopted for individual farms. The plan addresses the methods to utilize manure nutrient and to apply manure and fertilizers at agronomic rates. Fencing or alternative water supplies can assist in reducing the time where livestock are in or near streams.

Urban/Construction Areas: Sediment and associated nutrient loads can be reduced through management of new developments, site planning, pollution prevention, and stormwater management.

Maintenance and inspection of septic systems: By properly maintaining septic systems, the failure rate and associated nutrients loadings could be greatly reduced.

Sediment

The sediment TMDL identifies load allocations and reductions from forest land, agricultural operations, and construction areas. Some of the management practices that can be used to achieve the identified load reductions include:

Forestry management: forestry practices including preharvest planning, streamside area management and buffers, road construction/reconstruction/management, timber harvest management, site preparation, erosion and sediment control, and forest regeneration.

Agricultural management: Agricultural management practices can reduce erosion and sediment delivery. Typical practices include conservation tillage, terraces, crop rotations, and stream buffers. Fencing or alternative water supplies can assist in reducing the time when livestock are in or near streams. Trampling of stream corridors can increase erosion and turbidity.

Construction /Urban areas: Sediment loads can be reduced through management of new developments, erosion and sediment control practices, site planning, and stormwater management.

West Virginia Nonpoint Source Programs

The West Virginia Division of Environmental Protection-Office of Water Resources, as the lead agency for West Virginia's nonpoint source program, coordinates with other cooperating state agencies to address nonpoint source impacts, develop and implement best management practices reducing pollutant loads for agricultural, silvicultural, oil and gas, abandoned mines and construction activities. Activities in the various categories include education, technical assistance, financial assistance, research, regulatory and enforcement.

Silvicultural

The Division of Forestry administers several state and federally funded programs that relate to water quality protection and improvement. These include programs that provide technical and financial assistance, education and enforcement of state regulations. In coordination between the Office of Water Resources and the Division of Forestry, the Logging Sediment Control Act is enforced. Under the West Virginia Logging Sediment Control Act, all logging operations are required to be registered with the Division of Forestry and are to be in compliance with all regulations and laws of the state. Timber harvesting operators are required to protect the environment through the judicious use of silviculture best management practices adopted by the Division of Forestry to minimize soil erosion and sedimentation.

The West Virginia Division of Forestry may be reached at (304) 558-2788.

Agriculture

In cooperation with the West Virginia Soil Conservation Agency, agricultural nonpoint source problems are addressed through state and federal assistance programs to develop and apply best management practices. When water quality problems emanate from agricultural activity, the Division of Environmental Protection relies on the Soil Conservation Agency to contact and work with the landowner to correct problems. The two prominent areas of direct assistance provided to the agricultural community are technical and financial assistance that involves the following:

a. Nutrient Management/Pesticide Management planning with land users,
b. Agriculture erosion control conservation planning and BMP implementation with land users,
c. Manage NPS demonstration projects and coordinate with assisting agencies to carry out this management program.

For additional information on agricultural best management practices, you may contact the West Virginia Soil Conservation Agency at (304) 558-2204.

Oil and Gas Exploration

In West Virginia a well work permit from the Office of Oil and Gas of the West Virginia Division of Environmental Protection is required before any well work, including site preparation, can be performed. An erosion and sediment control plan must accompany each application for a well work permit, with the exception of permits to plug or replug a well. Each plan must contain methods of stabilization and drainage control that must meet the minimum requirements established in the Division of Environmental

Protections “Erosion and Sediment Control Technical Manual,” adopted by the Office of Oil and Gas. The erosion and sediment control plan becomes part of the terms and conditions of the well work permit which is issued. The erosion and sediment control plan also establishes the method of reclamation that will comply with the Oil and Gas regulations.

For additional information on oil and gas, you may contact the WVDEP - Office of Oil and Gas, (304) 759-0514

Construction

The West Virginia Nonpoint Source Program for construction activity involves coordination with the State Soil Conservation Agency and Office of Environmental Enforcement to provide education, technical assistance, compliance assistance and regulatory enforcement to minimize sediment and other pollutants impacts on surface and ground water resources.

For construction sites of less than 3 acres, voluntary Sediment Control Plans are prepared and submitted by the developer to one of the 14 Soil Conservation Districts in the State. They are reviewed by a Nonpoint Source Technician for adequacy to protect sediment runoff during the period of construction is ongoing. Construction sites of less than 3 acres are not subject to the Stormwater NPDES permitting process in West Virginia. Therefore, it is the responsibility of the developer to work with the local SCD to submit sediment and erosion control plans. Approved erosion and sediment control plans are forwarded to the Nonpoint Source Program at the Office of Water Resources, where upon agency approval, provides protection in the event a violation of the turbidity water standard should occur while the plan is being properly implemented.

For additional information on construction sites which are less than three acres contact the WVDEP - Office of Water Resources, at (304) 558-2108.

Construction activities involving greater than 3 acres require a Stormwater NPDES Permit from the Office of Water Resources. The Permit Section may be contacted for additional information at (304) 558-4086.

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