Final

TMDLs for Turkey Run Lake, Jackson County, West Virginia

U.S. Environmental Protection Agency
Region 3
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Philadelphia, PA 19103

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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 Turkey Run Lake (designated code WV_O(L)-37-1 for aquatic life and 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 were considered to be impacted by nutrients.

- 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 Turkey Run Lake is based on the evaluation of the total sediment load delivered to the lake, as indicated by the average accumulation rate of sediment on the reservoir bottom.

To evaluate the relationship between the sources, their loading characteristics, and the resulting conditions in the lake, a combination of analytical tools were used. Assessments of the nonpoint source loading into the lake were developed for Turkey Run 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 represent characteristics of 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 hydrologic period from 1978 to 1997 was used to derive the TMDL. The resulting allocation for the four listed pollutants includes a 20 percent reduction of nutrients (expressed as total phosphorus) and a 40 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. An explicit margin of safety has been identified for each pollutant. 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 Turkey Run 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 Turkey Run Lake for the uses designated by West Virginia.

This report presents the background information, analyses, and TMDLs that address the designated use impairments of Turkey Run 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 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, Turkey Run Lake, and the causes for its listing on the 303(d) list are presented in this section.

The Turkey Run Lake watershed is located within the Upper Ohio-Shade hydrologic cataloging unit (05030202), as shown in Figure 2.1. The land area of the watershed is approximately 869 hectares (2,147 acres) contained solely within Jackson County. Runoff from the watershed flows into Turkey Run Lake from Turkey Run. The lake is used for recreational activities such as fishing and picnicking. Only boats with electric motors are permitted on the on the lake. The lake's watershed is primarily rural, and the main land uses are forest and hay/pasture.

Turkey Run Lake is a 6.1-hectare (15-acre) impoundment located just north of Ravenswood in Jackson County, West Virginia (WVDNR, 1983). The impoundment structure for Turkey Run Lake was completed in 1964 and opened for fishing in 1966.

WVDEP listed Turkey Run 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_O(L)-37-1) 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 petroleum activities. Petroleum activities refer to access roads which are in poor conditions and contribute to sedimentation in the reservoir (Stutler, personal communication, June 1999).

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

- Nutrients: 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 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 Turkey Run Lake 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 Turkey Run Lake pursuant to section 303(d) of the Clean Water Act

Stream Name	Stream Code	Use Affected	Pollutant	Primary Source	Size Affected (acres)
Turkey Run Lake	O(L)-37-1	Aquatic Life	Nutrients, siltation, iron, aluminum	Petroleum activities	15
Turkey Run Lake	O(L)-37-1	Human Health	Iron	Petroleum activities	15

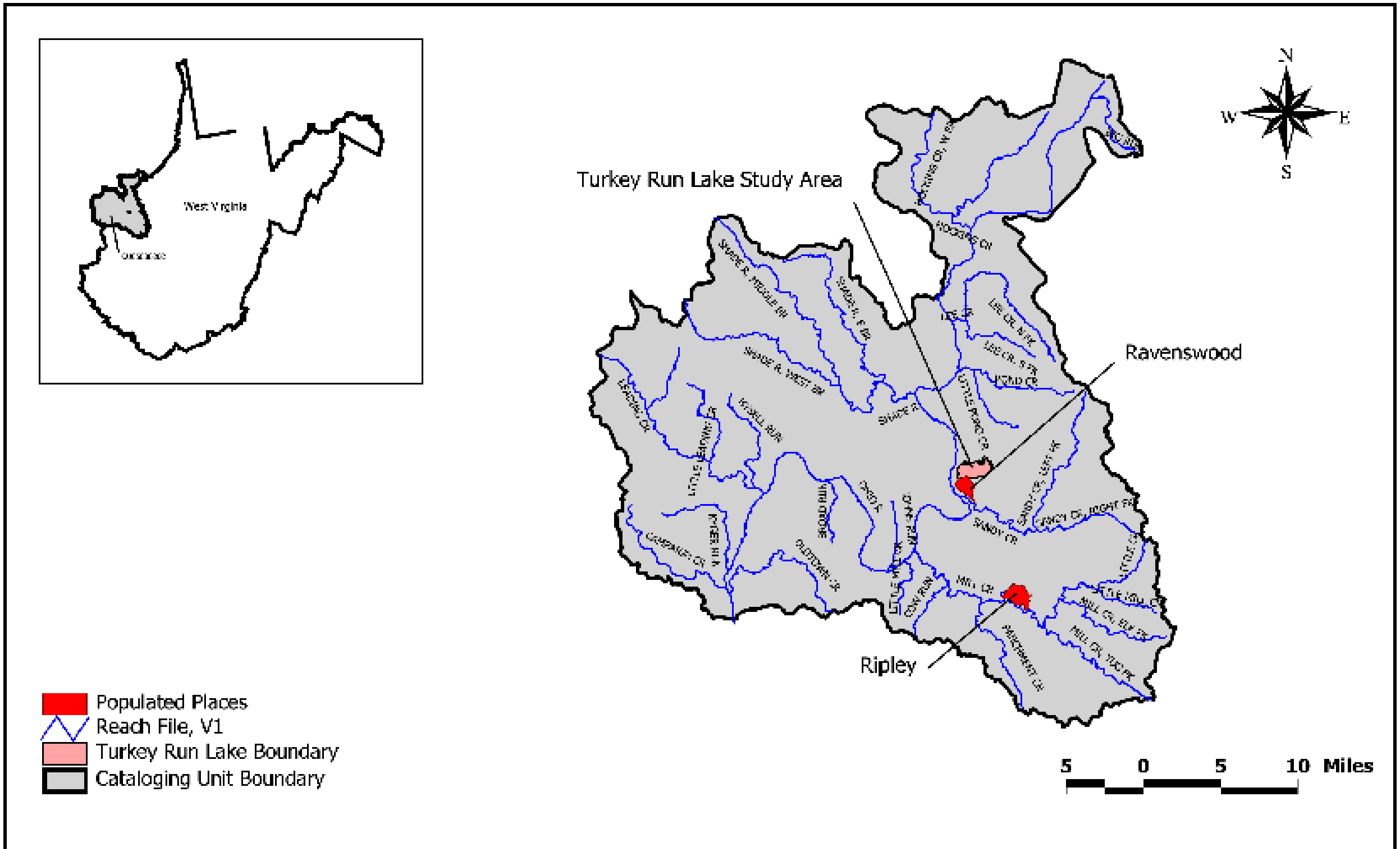


Figure 2.1. Site and Location Map
Turkey Run Lake Watershed, Jackson County, West Virginia

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 Turkey Run Lake include those of the lake itself, the watershed, and the atmosphere. 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 Turkey Run Lake was collected. The lake is a 6.1 hectare (15-acre) impoundment built in 1964. It was opened to fishing in 1966. 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, (Stutler, personal communication, May 1999). A highway, which is oriented parallel to the lake dam, crosses the lake about 150 meters (500 feet) upstream of the dam. A narrow breach in the roadway embankment acts as a constriction to flow from the upper segment of the lake.

The lake consists of the flooded Turkey Run stream valley shortly before it discharges to the Ohio River. The lake is subject to flooding from the Ohio River. The oldest records available are the WVDNR description and bathymetric survey (WVDNR, 1983). Based on the available bathymetric and physical characteristics data obtained from the 1980 survey (WVDNR, 1983), several physical characteristics of Turkey Run Lake have been derived and are presented in Table 3.1. The lake was shallow with a maximum depth of 2.7 meters (9 feet) and a mean depth of 1.2 meters (4 feet). The overall storage volume of the lake at normal pool was about 44,100 cubic meters (36 acre-feet) and drained a watershed area totaling 869 hectares (2,147 acres). Bathymetric data were collected in 1999 that can be compared with the 1980 contours (WVDNR,1983) to estimate the sediment thickness at various regions within the lake.

Table 3.1. Description of the physical characteristics of Turkey Run Lake

Characteristics	Original (1964)	1980[a]	Present (1999)[b]
Lake volume (cubic meters)	NA	72,780	NA
Surface area (hectares)	NA	6.1	NA
Drainage area (hectares)	NA	869	869
Mean depth (meters)	NA	1.2	NA
Maximum depth (meters)	NA	2.7	2.3
Length (meters)	NA	1.2×10^3	NA
Mean width (meters)	NA	62	NA

[a]WVDNR, 1983.
[b]WVDEP 1999 bathymetric survey.

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 0.4, 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. A review of bathymetric data collected in 1999 indicates that the north, west, and south shores have side slopes of up to a 30 percent grade with about a 5 percent grade being typical away from the dam and road embankments.

The ratio of the drainage area to lake surface area is about 142, 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 large in comparison to the impoundment area, making the lake very sensitive to increased loading, especially in the areas surrounding the lake.

The ratio of the length of Turkey Run Lake to its mean width (19) indicates that the length of the lake is the dominant process. Because of the size of the impounded area, combined with the lake's low longitudinal gradient, the lake appears to act as a wide river rather than a lake, especially during high flow and storm events.

The lake began in 1964 as an excavated streambed and floodplain. As is typical of reservoirs, its deepest point is at the downstream (western) shore adjacent to the dam. The shallowest area is located at the upstream (eastern) edge of the lake at the inflow from Turkey Run.

Table 3.2. Morphometric parameters of Turkey Run Lake

Characteristics	Original (1964)	1980[a]	Present[b]
Mean to max depth ratio	NA	0.44	NA
Drainage area to surface area ratio	NA	142	NA
Length to mean width ratio	NA	19	NA

[a]WVDNR, 1983.
[b]1999 Screening bathymetry.

The WVDNR (1983) report states that a maximum depth of 2.7 meters (9 feet) existed about 1980. A maximum depth of 2.3 meters (7.5 feet) was detected in 1999. However, the contours of the 1980 survey (which show only a 5-foot contour) do not noticeably differ from the 1999 survey. Analysis of the data shows a 0.8 meter (2.5 feet) accumulation in the narrow segment between the dam and road embankment. Whether the potential sediment accumulation source is from Turkey Run or Ohio River floods is unknown.

3.1.3 Hydrologic Characteristics of the Lake

Two key hydrologic parameters of Turkey Run 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 2.9 and 4.4 days, as shown in Table 3.3. This extremely short residence time is typical for lakes with a large drainage area-to-lake surface area ratio. In lakes with short residence times, a significant portion of the sediment and nutrient loads is transported farther into the impoundment beyond the transition to deeper water.

Table 3.3. Hydraulic residence time estimates for Turkey Run Lake

Annual Precipitation (cm)	Date of Occurrence	Magnitude	Annual Discharge (m^3/yr)	Hydraulic Residence Time (days)
110	1978 to 1996	Average	4.3×10^6	3.7
142	1978	Maximum	5.6×10^6	2.9
92	1987	Minimum	3.6×10^6	4.4

Rainfall data source: Charleston, West Virginia.

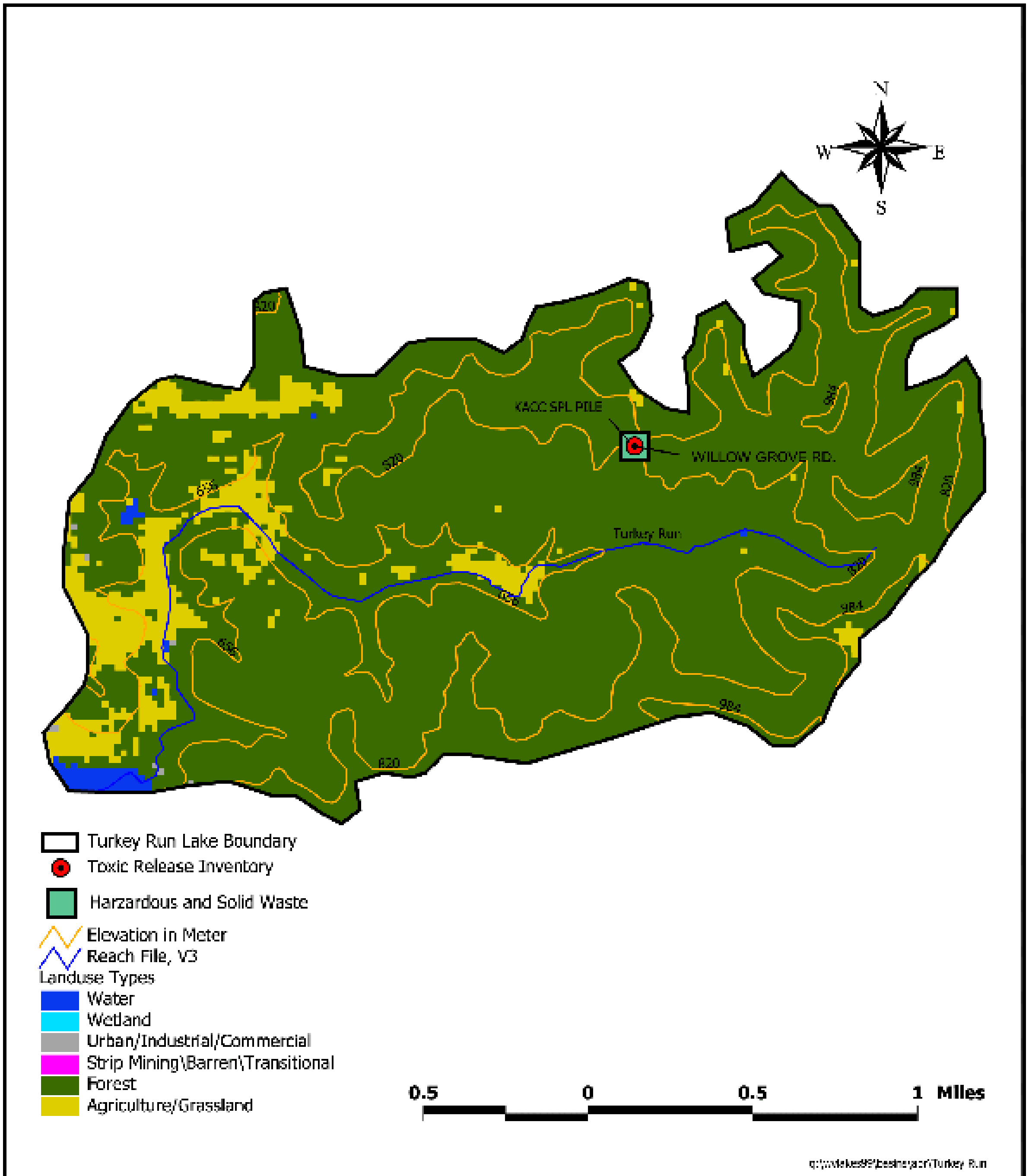
3.2 Watershed Characteristics

The Turkey Run Lake watershed is a small drainage basin of 869 hectares (2,147 acres). According to soil survey information, 34 percent of the watershed consists of hydrologic soil group D and 66 percent is hydrologic soil group B (USDA, 1993). The major soil series include Upshur, Gilpin, and Ashton. The watershed size yields an estimated sediment delivery rate of 0.23, that is 23 percent of the eroded soil reaches the lake based on long-term average annual loading analysis (Vanoni, 1977).

Multi-Resolution Land Classification (MRLC) coverage was used to develop the land use distributions within the Turkey Run Lake watershed (USGS, 1998), which are presented in Table 3.4. Forest land is the dominant land use with minor crop and pasture areas (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)	0.7
Forest	Pervious (100%)	Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43)	793.0
Cropland	Pervious (100%)	Row Crop (82)	3.7
Pasture	Pervious (100%)	Hay and Pasture (81)	65.5
Water	Impervious (100%)	Lakes and Streams	6.4
Total			**869.3**



Turkey Run Lake Watershed
Jackson County, West Virginia

Data Sources: West Virginia State

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 Turkey Run Lake include the following:

- Propagation and Maintenance of Fish and Other Aquatic Life (Category B-1)
- Water Contact Recreation (Category C)

No special exceptions or use designations are identified for Turkey Run 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 condition 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, 1999)

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).

The concept of trophic states was developed by Einar Naumann to characterize the condition of lakes (Naumann, 1919). The principle behind trophic states is that physical and chemical factors control the production of algae which in turn affects the biological structure of the lake. The amount of algal production plays an important role in lake conditions such as color, visible light penetration, dissolved oxygen concentrations, and odor. Common trophic state classifications include oligotrophic (low production, low nitrogen and phosphorus, oxygenated hypolimnion), mesotrophic (moderate production, moderate nitrogen and phosphorus), and eutrophic (high production, high nitrogen and phosphorus, anoxic hypolimnion).

The Carlson Trophic State Index (TSI) (Carlson, 1977) was developed to estimate the algal production and determine trophic state based upon chlorophyll pigments, secchi depth, and total phosphorus. The TSI is a logarithmic scale that ranges from approximately 0 to 100. The three index variables chlorophyll pigments (CHL), Secchi depth (SD), and total phosphorus (TP) use regression equations to estimate the index value and algal production. These three index variables are interrelated and should produce the same index value for a given combination of variables values. The regression equations used to calculate the TSI are shown in equations 4.1 to 4.3.

$$TSI(SD) = 60 - 14.41 \ln (SD) \tag{4.1}$$
$$TSI(CHL) = 9.81 \ln (CHL) + 30.6 \tag{4.2}$$
$$TSI\ (TP) = 14.42 \ln (TP) + 4.15 \tag{4.3}$$

The trophic state can be related to the trophic state index and lakes conditions as shown in Table 4.1.

Table 4.1. Trophic state, trophic state index and lakes conditions

TSI	Trophic State	Attributes	Aquatic Life
< 30	Oligotrophic	Clear water, low production, oxygenated hypolimnion.	Trout possible in deep lakes.
30-50	Mesotrophic	Moderately clear water, possible anoxia in summer.	Warm Water Fishery
50-70	Eutrophic	Low transparency, anoxic hypolimnion in summer.	Warm Water Fishery
>70	Hypereutrophic	Dense algae and macrophytes, noticeable odor, fish kills possible.	

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 (14 samples), observed chlorophyll *a*, an indicator of algae, is periodically elevated during the growing season, ranging from 11.52 ug/l to 102.2 ug/l, with a mean of 42.6 ug/l (see section 5.2). For Turkey Run Lake, the total phosphorus and chlorophyll *a* TSI were calculated from the available sampling information. Insufficient monitoring data was available to calculate the secchi depth TSI. The phosphorus TSI is 69.1 and the chlorophyll TSI is 67.4. Both TSI clearly exceed the West Virginia listing guideline of 65.

In the absence of a relevant numeric criterion, a numeric endpoint is selected consistent with the use description, the narrative condition, and West Virginia listing guidelines. The numeric endpoint is based on consideration of the trophic state index (TSI). Consistent with the West Virginia listing procedures, the TSI threshold of 65 (chlorophyll *a* and total phosphorus) was used as the upper limit for reservoir condition. The values used to designate the acceptable limit in Turkey Run Lake are a total phosphorus TSI of 61.4 and a chlorophyll *a* TSI of 63.8.

4.3 Sediment

Turkey Run 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 conditions specify 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 Turkey Run 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 Turkey Run Lake, is consistent with the causes of the Lake 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 a barrier to recreational uses. For small impoundments such as Turkey Run Lake draining a relatively large watershed 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 this lake, characterized by a small area (6.1 hectares) and a shallow depth (1.2 meters mean depth), the high siltation locations are assumed to correspond to 20,400 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 0.33 cm was calculated and established as the numeric criteria for this siltation TMDL.

4.4 Metals

Turkey Run 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 4.2.

Table 4.2. Metals Numeric criteria for Aquatic Life

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 Turkey Run 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 in the contributing watershed
- 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, greater than the 85th percentile of all streams in West Virginia, occur in stream sediments in the Upper Ohio-Shade cataloging unit (USGS, 1994). These enriched sediments occur naturally in areas with aluminous host rocks.

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 TMDL development for metals for Turkey Run Lake is to set the criteria to an annual loading value resulting from managed condition (assuming controls are implemented according to the sediment loading allocation identified in the sediment TMDL). This recommendations is in accordance with §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.

5 WATER QUALITY ASSESSMENT

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

5.1 Inventory of Available Water Quality Monitoring Data

Limited water quality monitoring activities have been conducted for Turkey Run Lake and its inflows. Water quality data reviewed as part of this report were collected as follows: WVDEP seasonal sampling of Turkey Run Lake and its inflow (Turkey Run) from spring to fall during 1993, 1994, 1995, and 1996 (a total of 29 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 for Turkey Run Lake

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 tributary, lake, 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.

- Suspended sediment concentrations are higher in the lake than in the tributary.

- The long-term mean chlorophyll *a* concentration is 42.63 ug/l, with a high reading of 102.16 ug/l.

- The trophic state index for total phosphorus is 69.1 and chlorophyll *a* is 67.4. These values both exceed the state nutrient listing trophic threshold of 65.

Table 5.1. Summary of WVDEP tributary sampling observations of selected pollutants, Turkey Run Lake, 1993-96, 1998a.

Pollutant Type	Pollutant	Units	Total Obs.	Minimum	Maximum	Total Average
Nutrient	TKN	mg/l	12	0.08	0.94	0.41
	NO2-NO3-N	mg/l	12	0.01	0.38	0.12
	TP	mg/l	12	0.02	0.08	0.04
	Ammonia	mg/l	12	0.01	0.50	0.30
Siltation	Suspended Solids	mg/l	12	1.00	104.00	18.58
	Turbidity	NTU	3	14.00	167.00	72.33
Metals	Aluminum	mg/l	11	50	4100	888
	Iron	mg/l	11	164	2320	792

Table 5.2. Summary of WVDEP lake sampling observations of selected pollutants, Turkey Run Lake, 1993-96, 1998a.

Pollutant Type	Pollutant	Units	Total Obs.	Minimum	Maximum	Total Average	Lake Bottom Average	Lake Surface Average
Nutrient	TKN	mg/l	26	0.45	1.50	0.79	0.70	0.80
	NO2-NO3-N	mg/l	26	0.01	0.53	0.09	0.10	0.09
	TN	mg/l	26	0.51	1.59	0.89	0.86	0.92
	TP	mg/l	26	0.03	0.70	0.10	0.13	0.07
	Ammonia	mg/l	25	0.01	0.50	0.29	0.26	0.29
	Chlorophyll *a*	ug/l	14	11.52	102.16	42.63	--	--
Siltation	Suspended Solids	mg/l	26	4.00	75.00	22.07	20.67	18.92
	Turbidity	NTU	4	92.00	136.00	113.25	--	--
Metals	Aluminum	mg/l	26	0.01	0.53	0.09	1.29	0.72
	Iron	mg/l	26	0.20	3.20	1.24	1.37	1.01

Table 5.3. Summary of WVDEP lake sediment sampling observations of selected pollutants, Turkey Run Lake, 1993-96, 1998a.

Pollutant Type	Pollutant	Units	Total Obs	Minimum	Maximum	Mean
Metals	Aluminum	mg/kg	3	3850	7,980	6,147
	Iron	mg/kg	3	9010	11,500	10,303
Nutrient	TP	mg/kg	3	127	440	252

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 Turkey Run Lake is about 9.

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.

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.

These classifications may be used to determine whether waterbodies are meeting their “fishable” and “swimmable” designated uses. The Trophic State indices for chlorophyll *a* and phosphorus for Turkey Run is shown in Table 5.5 (Carlson and Simpson, 1996).

Table 5.5. Trophic State Index

Pollutant	Observed Mean (ug/l)	TSI
Total Phosphorus	90	69.1
Chlorophyll *a*	42.6	67.4

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 USEPA Region 3 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

No active point sources were identified in 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 Turkey Run 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 agriculture, silvicultural, and road construction activities. 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.

The primary land uses within the Turkey Run Lake watershed is forest with minor components of agriculture and residential 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 West Virginia Forestry Service (Warren, personal communication, May 1999). It has been assumed that 4% percent of the forest land in the watershed is selectively logged every year with the minimum erosion/sediment control practices, (Sergent, personal communication, May 1999).

The inspector for WVDEP walked the watershed and found numerous gas well roads which are deeply rutted and not well maintained. Four-wheeler roads, along the creeks and through the creeks were also found. Sediment also appears to accumulate in some stream channels (Stutler, personal communication, June 1999).

The potential contribution of nutrients from failing septic systems was also assessed. No sanitary sewers are present within the watershed, so all residences were assumed to be within the watershed. Data associated with the number of reported septic systems present in Jackson County were obtained from 1990 U.S. Census data and the analysis of existing maps.

Wildlife, especially waterfowl, can contribute significant nutrient loadings directly to the lake. While waterfowl are expected to be present during the warmer months, no specific wildlife counts are available at this time. Contribution of wildlife is incorporated into loadings from forest areas.

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	0.7
Forest	793.0
Cropland	3.7
Pasture/Hay	65.5
Water[a]	6.4
Total	**869.3**

[a] Includes the lake area

Table 6.2. Additional potential nonpoint sources in the watershed

Potential Nonpoint Sources	Magnitude	Data Sources	Comments
Silvicultural activities (hectares/year)	31.7	WV Forestry Service	Selective tree logging methods assumed
Septic Releases (population)	49	USGS quads; US Census data	Assumes 0% population growth per year
Wildlife and waterfowl (counts)	NA[a]	–	Included in forest

[a] Not available.

6.3 Representation of Potential Sources in the Development of Loading Estimation

The representation of the nonpoint 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 three 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 forested land, include forest harvesting and wildlife and waterfowl
Agriculture	Cropland and pasture hayland
Urban	Residential areas
Groundwater	Nutrients from groundwater
Septic system	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/hayland
Urban	Residential and commercial/industrial 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. In-lake modeling is compared with numeric criteria (for metals), trophic state indices (for nutrients), and available depth (for sediment).

7.1 Nutrient Model Setup

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 D soils
- Simulation time period: 1978-97
- Meteorologic station: Charleston, West Virginia

The flow to Turkey Run 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). The average discharge to the lake was estimated as being approximately 45 percent of the total precipitation received by the watershed. This was within the range of the estimates from five USGS gaging stations for small watersheds (less than 5 square miles) in West Virginia (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 simulation model was used to estimate the nutrient loading for the sources described in table 7.2.

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

Land Use	Existing Area (hectares)	Percent of Watershed	Description
Forest	793	91.9%	Forest harvest, wildlife, background erosion losses
Agriculture	69.2	8.0%	Crop, pasture, and hay
Residential	0.7	0.1%	Single-family homes; all on septic
Ground water			Assume background concentrations of 0.31 mg/l total nitrogen and 0.015 mg/l total phosphorous
Septic System			Conventional septic systems with 32% nitrogen removal efficiency; 2.5% septic failure rate
Total	863.1[b]	100%	

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

[b] Excludes the lakes area but includes 0.3 hectares of other 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	204.8
Agriculture	27.5
Groundwater	55.6
Urban	0.0
Septic Systems	0.8
Total	288.7

The phosphorus loads converted to concentrations (mg/l) were compared to observed lake concentrations. 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 Lake Concentration [a]
Total Nitrogen (mg/L)	0.79	0.89
Total Phosphorus (mg/L)	0.066	0.10

[a]Based on 12 sampling events during the period from 1993-1998.

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
- Configuration: Lake segmentation represented in the BATHTUB model (Table 7.5)

Table 7.5. Turkey Run Lake morphology as represented in the BATHTUB model

Segment	pre-1980 Lake Volume	1999 Lake Volume
Segment 1	3,620	4,300
Segment 2	10,670	6,020
Segment 3	36,600	30,400
Segment 4	21,960	18,960

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 calibrated the model. The calibration 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)	37.6	42.6

[a] based on 14 samples collected during the period from 1993-1998.

The lake model was used to predict total phosphorus and chlorophyll *a* and associated TSI values for comparison with the endpoints identified in section 4.3.

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 from the land. 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 Turkey Run Lake.

Table 7.7. Sediment loading estimates by source

Source	Existing Sediment Loading (metric tons)
Forest	472.7
Agriculture	45.8
Urban	0.03
Total	518.5

7.2.2 Sediment Lake Analysis

The sediment accumulation to the 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 an approximate volume of 74,000 cubic meter and an estimated annual inflow rate of approximately 0.2 cubic meters per second, the Brune parameter is approximately 0.02, corresponding to a trap efficiency in the range of 35 percent to 62 percent (51 percent median value) (Table 7.8).

Table 7.8. Estimated sediment loadings to Turkey Run Lake

Mean Sediment Loading (metric tons/yr)	Siltation (metric tons/yr)	Mean Accumulation rate (cm/yr)
518.5	264.4	0.54

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. 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 Turkey Run 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 from Turkey Run Lake (7980 mg/kg aluminum and 11,500 mg/kg iron). The enrichment ratio is assumed to be 1.5 to recognize that metals inputs may be relatively higher than deposited sediment due to variations in particle size distribution. The annual load computed using this approach under existing conditions, is 6,208 kg/year for aluminum and the iron load is 8,946 kg/year.

8 TMDL

The nutrient, sediment and metals modeling and analysis techniques were used to derive the TMDLs for Turkey Run Lake. Presented in this section are the results of the TMDL analysis for each of the listed pollutants.

8.1 Nutrients

The loading capacity was calculated as an average annual value, based on BATHTUB analysis of the total phosphorus chlorophyll *a* TSI indicator. 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.

Table 8.1. Allocation of Scenarios for Turkey Run Lake

Scenario	**TP**	**TSI(TP)**	**Chlorophyll *a***	**TSI (CHL)**
Observed Value	90	69.1	42.6	67.4
Baseline	66	64.6	35.3	65.5
10% nutrient reduction	59	63.0	29.9	64.8
20% nutrient reduction	53	61.4	29.6	63.8
30% nutrient reduction	46	59.4	25.8	62.5
A 20% reduction to meet the TSI (TP) and TSI (CHL) 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. 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 represent 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. Turkey Run Lake nutrient TMDL

Source	Existing Loading Total Phosphorus (kg)	Estimated Percent Reduction	Load Allocation (kg)	Comments
Forest	204.8	27%	149.5	
Agriculture	27.5	35%	17.9	
Groundwater	55.6	0%	55.6	
Septic Systems	0.8	100%	0	
Total Load	**288.7**	**3 Load Allocation**	**223**	
Loading Reduction = 57.7 (20%)		**Waste Load Allocation**	**0**	**No point sources**
		Margin of Safety	**8**	**3.5% of Loading Capacity[a]**
TMDL = Loading Capacity = 231.0				

[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 endpoint for the reservoir is defined as a TSI less than 65. The selected load reduction is below 65 providing an additional margin of safety.

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 trophic state indices 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 derived based on the endpoint. The target value for sediment load was derived based on analysis of lake siltation. Access areas and selected shores are critical to recreational uses of the lake. Using a conservative assumption, sedimentation volume in these critical areas was estimated to be 20,353 cubic meters. In addition, these areas are assumed to experience high siltation rates compared to deep pools. Table 8.3 estimates the mean siltation rate of the lake and number of years for these critical areas to be filled with sediment. The table compares the life span of this critical volume under predevelopment conditions (natural forested watershed). The table also presents the loading scenario used in deriving the allocation.

Table 8.4 summarizes the sediment load allocation scheme corresponding to an overall reduction of 40% and extending the useful life of the lake from 25 to 41 years.

Table 8.3. Siltation Analysis of Turkey Run Lake

	Existing Conditions	Predevelopment Conditions	Loading Scenario
Mean annual load (kg)	518,593	202,914	311,155
Siltation rate (cm)	0.54	0.4	0.33
Fill time (years)[a]	25	63	41
Loading scenario for 41 year time span corresponds to a 40% load reduction (see Table 8.4)			

[a]based on a siltation critical volume of 20,353 cubic meters

Table 8.4. Turkey Run Lake sediment TMDL

Source	Existing Loading Sediment (metric tons)	Percent Reduction	Load Allocation (metric tons)	Comments
Forest	472.7	45	260.0	
Agriculture	45.8	45	25.2	
Urban	0.03	0	0.03	
Total Load	**518.5**	**3 Load Allocation**	**285.2**	
Load Reduction = 207.4 (40%)		**Waste Load Allocation**	**0**	**No point sources**
		Margin of Safety	**25.9**	**8% of Loading Capacity**
TMDL = Loading Capacity = 311.1				

Margin of Safety. An explicit margin of safety was calculated as a percentage of the loading capacity (8%). 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 8 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:

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

- 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

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.

Analysis of the Turkey Run watershed did not identify any point and nonpoint source discharges of metals. 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 Turkey Run 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. The sediment load allocation derived from the sediment TMDL was multiplied by an enrichment ratio to quantify the sediment- associated metals loadings (see section 7.3). Table 8.5 summarizes the computation of loading capacity and presents a loading reduction scenario. Aluminum and iron TMDL allocations are shown in Table 8.6 and 8.7.

Table 8.5. Loading allocation for metals in Turkey Run Lake

Metal	Sediment Concentration (mg/kg)	Existing Sediment Load (kg/yr)	Enrichment Ratio	Loading Capacity (kg/yr)	Load Allocation (kg/yr)
Aluminum	7,980	285,200	1.5	3,414	3,414
Iron	11,500	285,200	1.5	4,920	4,920

Table 8.6. Turkey Run Lake aluminum TMDL

Total Load	**3414**	**3 Load Allocation**	**3414**	**Comments**
		Waste Load Allocation	**0**	**No point sources**
		Margin of Safety	**0**	**0% of Loading Capacity**
TMDL = Loading Capacity = 3414				

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.

Table 8.7. Turkey Run Lake iron TMDL

Total Load	**4,920**	**3 Load Allocation**	**84,920**	
		Waste Load Allocation	**0**	**No point sources**
		Margin of Safety	**0**	**0% of Loading Capacity**
TMDL = Loading Capacity = 8,946				

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:

- Fine sediment particles have larger surface areas for adsorption 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).

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 results 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.

9 REASONABLE ASSURANCES 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, 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.

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 urban 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.

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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