TOTAL MAXIMUM DAILY LOADS
FOR
BEAR LAKE, WEST VIRGINIA

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 Bear Lake for aquatic life has been impaired by nutrients, dissolved oxygen, and siltation. 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 Bear Lake for the uses designated by West Virginia.

This report (including the attached technical 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. The TMDLs are designed to implement applicable water quality standards.
2. The TMDLs include a total allowable load as well as individual waste load allocations and load allocations.
3. The TMDLs consider the impacts of background pollutant contributions.
4. The TMDLs consider critical environmental conditions.
5. The TMDLs consider seasonal environmental variations.
6. The TMDLs include a margin of safety.
7. The TMDLs has been subject to public participation.
8. There is reasonable assurance that the TMDLs can be met.

II. Background

The Bear Lake watershed is located within the Upper Ohio River hydrologic cataloging unit (05030106), as shown in Figure 2.1of the attached report. The land area of the watershed is approximately 185.8 hectares (457 acres) contained solely within Ohio County. Runoff from the watershed flows into Bear Lake from Todd Run. Water discharged from the lake continues in Todd Run to Middle Wheeling Creek and then to the Ohio River. The lake is used for recreational activities such as fishing and picnicking. Boating and electric motors only are permitted on the lake. The lake's watershed is primarily rural, and the main land uses are forest and hay/pasture.

WVDEP listed Bear 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 O(L)-88-D-2-F-1) was listed for nutrients, low dissolved oxygen, and siltation (WVDEP, 1998).

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 Bear 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 two cells to 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. The period from 1978 to 1997 was used to evaluate the source loading under a range of climatic conditions. The resulting allocation for the listed pollutants includes a 50 percent reduction of nutrients (expressed as total phosphorus) to address the dissolved oxygen and nutrient listing and a 30 percent reduction of sediment load to address siltation problems. The reduction of nutrient load is expected to improve the trophic condition resulting in less severe stratification and increased surface oxygen levels.

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 an explicit portion of the TMDL load. 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.

III. Discussion of Regulatory Conditions

EPA developed these TMDLs consistent with statutory and regulatory requirements and EPA policy and guidance. The Castleman Run Lake TMDLs address the following eight regulatory requirements.

1) The TMDLs are designed to implement applicable water quality standards.

These TMDLs ensure that Castleman Run Lake will meet applicable water quality criteria for nutrients and sediment, thus ensuring that the water supports its designated use. West Virginia has only narrative criteria related to nutrients and sediment.

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 Castleman 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 Castleman Run Lake.

1.1 Nutrients

No numeric criteria are available in the West Virginia water quality standards relevant to the 303(d) listing of this waterbody for nutrient impairment. 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 1.1 to 1.3.

$$TSI(SD) = 60 - 14.41 \ln (SD) \tag{1.1}$$

$$TSI(CHL) = 9.81 \ln (CHL) + 30.6 \tag{1.2}$$

$$TSI (TP) = 14.42 \ln (TP) + 4.15 \tag{1.3}$$

The trophic state can be related to the trophic state index and lakes conditions as shown in Table 3.

Table 3 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 (15 samples), observed chlorophyll *a*, an indicator of algae, is periodically elevated during the growing season, ranging from <3.8 ug/l to 226 ug/l, with a mean of 52.8 ug/l (see section 5.2 of the attached report). For Bear 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 76.4 and the chlorophyll *a* TSI is 69.5. 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). Based on Evaluation of the lake monitoring and modeling analysis and evaluation of the nitrogen-phosphorus ratio (see section 5.2 of the attached report). 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.

This lake is characterized by a shallow depth and a high watershed to surface area ratio. These characteristics make the lake highly sensitive to nutrient loading even under managed conditions. On the basis of the site specific characteristics of the lake, a target is selected which is consistent with the best water quality that this lake can be expected to achieve. The values used to designate the acceptable limit in Bear Lake are a total phosphorus TSI of 63.2 and a chlorophyll *a* TSI of 64.1.

1.2 Sediment

Bear 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 Bear 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 Bear 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 barrier to recreational uses. For small impoundments such as Bear 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 barriers for recreational uses. Specifically for Bear Lake, characterized by a small area (3.2 hectares) and a shallow depth (1.8 meters mean depth), the high siltation locations are assumed to correspond to 9,600 cubic meters.

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 0.3 cm was calculated and established as the numeric criteria for this siltation TMDL.

1.3 Dissolved Oxygen

Bear Lake is listed as impaired due to low dissolved oxygen on the 303(d) list. As obtained from the West Virginia Requirements Governing Water Quality Standards (Title 46), the relevant numeric criteria for low dissolved oxygen is 5.0 mg/l. West Virginia has specific procedures to determine if lakes should be listed for dissolved oxygen impairments (WVDEP 1998).

> Lakes were considered impaired by dissolved oxygen if: 1) a decrease of >10 mg/l occurred between the surface and six-foot depth (indicating severe stratification) or 2) the D.O. concentration was less than 5.0 mg/l for any reading taken between the surface and four-foot depth.

Low dissolved oxygen is typically a result of eutrophication of lakes. High nutrient concentrations during the growing season can cause increased algae and vegetation growth. The settling of detritus from these activities consumes oxygen which lowers dissolved oxygen concentrations near lake bottoms. As the trophic state index increases from eutrophic to hyper-eutrophic, the stratification of the reservoir becomes more pronounced and the occurrence of low DO in the surface layers of the lake increases (Carlson and Simpson, 1996).

Management of the DO impairment is achieved by improvement of the trophic state of the reservoir. In order to change the trophic state reduction of nutrient loads is required. Lowering the nutrient inputs (i.e. phosphorus) is expected to achieve TSI of <65. Reducing the TSI results in moving the trophic state from a hypereutrophic to eutrophic state and consequently will result in following:

- Increased oxygen in the surface portion of the lake
- Reduction of the severe stratification
- Reduced frequency of algal blooms and associated oxygen depletion
- Improved habitat for the warm water fishery.

The DO TMDL will therefore be addressed by meeting the trophic state index and reducing nutrient loads as defined under the nutrient TMDL.

2. **The TMDLs include a total allowable load as well as individual waste load allocations and load allocations.**

A) Wasteload Allocation

No point sources were identified within the drainage area of the listed water after review of several databases from WVDEP and EPA . Therefore the wasteload allocation is set to zero.

B) Load Allocation

2.1 Nutrients

The loading capacity was calculated as an average annual value, based on BATHTUB analysis of the chlorophyll *a* 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 of a trophic state index (TSI) of less than 65.

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.

Table 4. Bear Lake nutrient TMDL (in kilograms per year)

Source	Existing Loading Total Phosphorus (kg)	Estimated Percent Reduction	Load Allocation (kg)	Comments
Forest	17.7	10	15.9	
Agriculture	75.7	70	22.7	
Urban	2.2	0	2.2	
Construction	3.1	50	1.55	
Groundwater	9.5	0	9.5	
Septic Systems	1.8	80	0.36	
Total Load	**110**	**3 Load Allocation**	**52.1**	
Loading Reduction = 54.9 (50%)		**Waste Load Allocation**	**0**	**No point sources**
		Margin of Safety	**2.8**	**5% of Loading Capacity[a]**
		TMDL = Loading Capacity = 55.1		

2.2 Sediment

The sediment allocation was based on the long-term average siltation rate as an endpoint and a numeric limit of 0.3 cm per year. Table 5 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 0.3 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 6 summarizes the sediment load allocation scheme corresponding to an overall reduction of 30%, which will extend the timespan of the lake from 28 to 40 years.

Table 5. Siltation of Bear Lake

	Existing Conditions	Predevelopment Conditions	Loading Scenario
Mean Annual Load (kg)	137,934	64,861	96,554
Siltation Rate (cm)	0.43	0.20	0.30
Fill Time (years)[a]	28	59	40
Loading scenario for 40 year time span corresponds to a 30% load reduction (see Table 8.4 of report).			

[a]based on a critical siltation volume of 9,621 m^3

Table 6. Bear Lake sediment TMDL (in metric tons per year)

Source	Existing Loading Sediment (metric tons)	Percent Reduction	Load Allocation (metric tons)	Comments
Forest	37.3	20	29.8	
Agriculture	93.1	35	60.5	
Soil Disturbance due to construction	6.1	60	2.4	
Urban	1.4	0	1.4	
Total Load	**137.9**	**3 Load Allocation**	**94.1**	
Load Reduction = 41.4 (30%)		**Waste Load Allocation**	**0**	**No point sources**
		Margin of Safety	**2.4**	**2.5% of Load Allocation**
TMDL = Loading Capacity = 96.53				

2.3 Dissolved Oxygen

Low dissolved oxygen in the hypolimnium is associated with eutrophication processes including increased algal growth and severe stratification. Reduction of the phosphorus inputs has been identified as the treatment option for improving the trophic state and reducing the symptoms of eutrophication. By reducing the phosphorus inputs to the identified levels the required load reduction (i.e., TMDL) for dissolved oxygen control will be achieved as well. Control of dissolved oxygen will be achieved by meeting the allocation for phosphorus presented in Table 4.

3. The TMDLs consider the impacts of background pollutant contributions.

Background Conditions for nutrients

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.

Background Conditions for sediment

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.

4. The TMDLs consider critical environmental conditions.

Critical Conditions for nutrients

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).

Critical Conditions for sediment

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.

5. The TMDLs consider seasonal environmental variations.

Seasonality for nutrients

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.

Seasonality for sediment

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.

6. The TMDLs include a margin of safety.

Margin of Safety for nutrients

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

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

The 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:

- 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.

- 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.

Margin of Safety for sediment

The margin of safety for this TMDL was expressed as an explicit number, calculated as a percentage of the total loading capacity. A 2.5 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:

- 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 high loads and slightly larger required load reductions.

7. The TMDLs has been subject to public participation.

EPA published and requested comments on the proposed TMDLs on July 1, 1999 in the Charleston Gazette , which has statewide distribution. In addition, a press release was sent to most of the newspapers in West Virginia. The public comment period closed on August 16, 1999, and EPA did not receive comments from any individual or organization for the Castleman Run Lake TMDL.

8. There is reasonable assurance that the TMDLs can be met.

Management Practices

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:

Current regulations of the WV Dept of Health require correction of all straight pipes and failed septic systems, and it is recommended in the TMDL allocation that all such sources be brought into compliance. Because it is difficult to obtain accurate numbers for these sources during development of a TMDL, ground proofing may be needed as part of the implementation.

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

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. WV DEP, through the Nonpoint Management Program hs been successful in initiating land use controls of BMP's for controlling NPS pollution and protecting the designated uses of the states waterbodies.