Total Maximum Daily Load (TMDL)

Pinchot Lake
(Beaver Creek Watershed)

York County, Pennsylvania
State Water Plan 07F

Pennsylvania Department of Environmental Protection
Southcentral Regional Office
Water Management Program

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Executive Summary

Pinchot Lake is a 340-acre impoundment on Beaver Creek, located in Warrington Township, York County, PA. The lake has been the focal point of Gifford Pinchot State Park since the early 1960s. The entire watershed, including Beaver Creek and Pinchot Lake, is currently designated Warm Water Fishes (WWF). Current land use in the Pinchot Lake watershed is dominated by forest (71%) and agriculture (24%), with limited residential development (< 1%). Since land use in York County is a primarily agricultural and developed, the largely forested character of this watershed contributes a unique and valuable asset to the residents of York and surrounding Counties.

Pinchot Lake was identified on Pennsylvania's 1996 and 1998 303(d) list as being impaired by organic enrichment/low dissolved oxygen. The organic enrichment of the lake was primarily caused by nutrients from sewage system overflows and agricultural activities. Pennsylvania does not currently have numeric water quality standards for organic enrichment or nutrients; therefore the overall goal of this Total Maximum Daily Load (TMDL) is to improve the trophic status of Pinchot Lake from hyper-eutrophic to near mesotrophic. Based on this goal, the water quality target to address the stated impairments has been set at approximately 10 µg/L of chlorophyll-a.

A combined watershed/lake water modeling approach was used to estimate current nutrient loads to the lake, as well as to estimate the total phosphorus load reductions needed to achieve the chlorophyll-a target. Based on this modeling, it was estimated that the current annual phosphorus load of 1,974 kg/yr. would have to be reduced to 651 kg/yr., in order to achieve the chlorophyll-a target of approximately 10 µg/L . With an additional 10% margin of safety (MOS) factor, this target phosphorus load is further reduced to 586 kg/yr. All the components of the total phosphorus TMDL for Pinchot Lake are summarized below:

Component	**Total Phosphorus (kg/yr.)**
TMDL (Total Maximum Daily Load)	650.96
WLA (Wasteload Allocation)	-
MOS (Margin of Safety)	65.10
LA (Load Allocation)	585.86
LNR (Loads Not Reduced)	25.31
ALA (Adjusted Load Allocation)	560.55

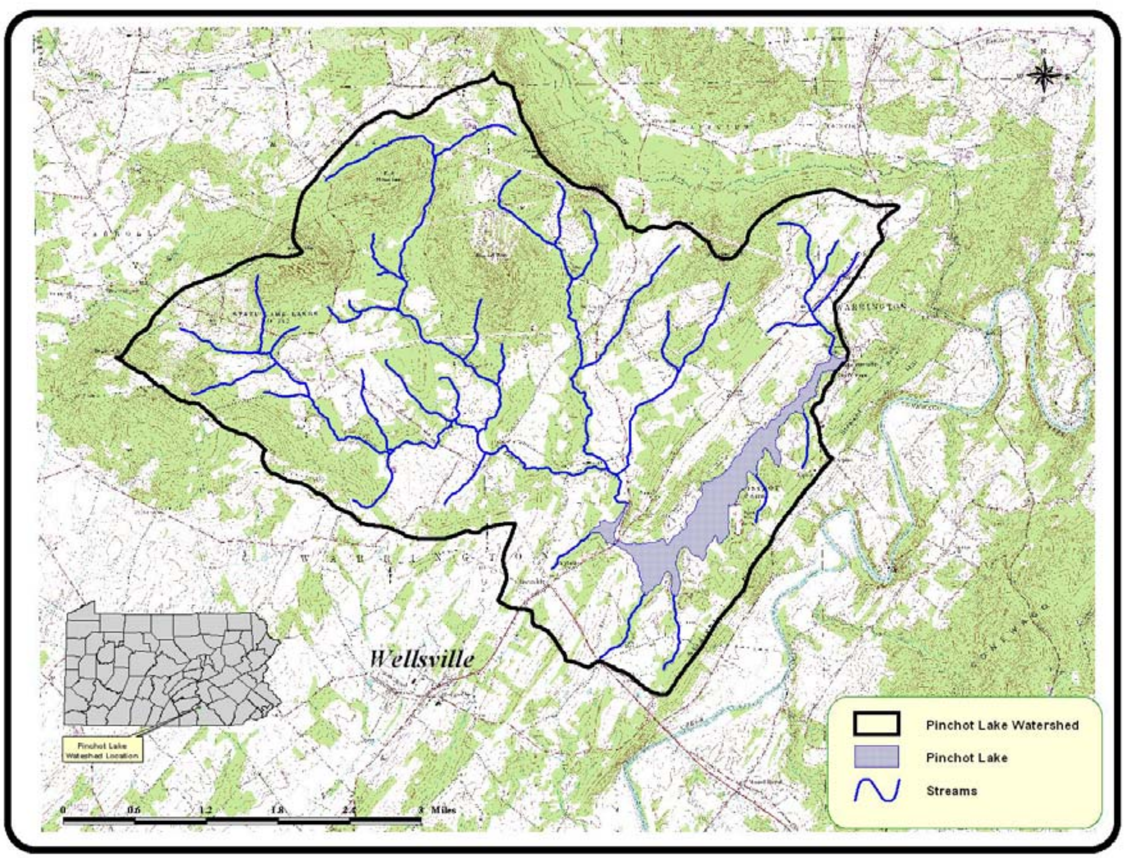
I. Introduction

A. Watershed Description

Pinchot Lake is a 340-acre impoundment on Beaver Creek, located in Warrington Township, York County, PA (Figure 1), approximately 17 miles south of Harrisburg and 14 miles northwest of York. Pinchot Lake was constructed during the period of May 1958 to November 1959 for the purpose of providing a recreational lake in York County. The lake has been the focal point of Gifford Pinchot State Park since the lake stage reached the conservation pool spillway on February 18, 1960. Access to the lake is available by traveling south on PA Route 177 from the Lewisberry Exit (35) off of Interstate 83. A total of 34.7 miles of streams, including Beaver and Little Beaver Creek, drain the 17.6mi^2 lake watershed. Portions of the watershed are located in Warrington, Monaghan, and Carroll Townships. Protected uses of Beaver Creek and Pinchot Lake include aquatic life, water supply, and recreation. The entire watershed is currently designated Warm Water Fishes (WWF) under §93.9o in Title 25 of the Pa. Code (Commonwealth of Pennsylvania, 2001).

Current land use in the Pinchot Lake watershed is roughly 71% forested, 24% agricultural, and 4% waterbodies and wetlands. Nearly 69% of the agricultural land in the watershed is currently croplands, consisting primarily of row crops (e.g. corn). The remaining agricultural lands are dominated by horse and cow pastures. Development activities in the watershed are fairly low, accounting for less than 1% of the total surface area. Historical estimates of agricultural land use in the watershed have been as high as 58% (1973). York County as a whole is primarily agricultural and developed. The existing largely forested character of this watershed contributes a unique and valuable asset to the residents of York and surrounding Counties.

Figure 1 – Pinchot Lake Watershed



B. Surface Water Quality

Pinchot Lake has been the subject of numerous water quality surveys, including a USGS survey conducted for the Department of Environmental Resources (1965 to 1968), a Clean Lakes Phase I study (final report in 1996), additional Clean Lake sampling (1996 –2001), Pennsylvania Department of Environmental Protection (DEP) Water Quality Network (WQN) sampling (1996-1999), and non-WQN lake sampling (2000-2002). Data collected during these studies have documented Pinchot Lake as a hyper-eutrophic lake with elevated nutrient concentrations, high biological productivity, and dissolved oxygen depletion in lower lake depths during summer stratification. Water quality problems have been documented in the lake, since the 1960's (Figures 2 and 3). Algal and aquatic weed problems occurred as early as 1961, less than 2 years after the impoundment filled with water. Reduced depth at the lake's inlet area, turbidity, cyanobacteria (blue-green algae) blooms and abundant macrophyte growth, have interfered with some water-based recreational uses of the lake. By 1996 (approximately 36 years) the lake had lost 13% of its original storage capacity due to sedimentation. Although sedimentation is a typical trend for impoundments of this age, it would be sensible to reduce the sediment loading to the lake during storm events.

Figure 2 – Historical Example (1965) of Algae Bloom in Pinchot Lake

Figure 3 – Historical Example (1966) of Abundant Macrophyte Growth in Pinchot Lake

C. 303(d) Listings

Pinchot Lake first appeared on Pennsylvania's 303d list in 1996 due to impairments from unnamed sources causing organic enrichment and/or low dissolved oxygen levels in the lake (Table 1). The 1998 303(d) list identified the source of impairment as agriculture and urban runoff/storm sewers.

Table 1 – 1996 & 1998 303(d) and Draft 2002 303(d) Listings for Pinchot Lake

Listing Year	Source	Cause	Acres
1996	Not yet done	Organic Enrichment/DO	340
1998	Agriculture Urban Runoff/Storm Sewers	Organic Enrichment/Low DO	340

All current pollutant contributions to Pinchot Lake are from non-point sources, primarily agricultural land uses. However, point source related discharges have influenced historical sampling results for nutrients. In 1993 overflow pipes from three sewage lift stations were reported to be running into Pinchot Lake. The lift stations were originally installed in the park in 1962 and there was clearly a potential for discharges of raw sewage into Pinchot Lake. One of the lift station overflow pipes was inundated at normal pool levels. The Department inspected the lift stations and overflow pipes on November 22, 1993. During the inspection, the Pinchot Park sewage treatment plant operator indicated that another lift station, which accepts sewage from the Wellsville area, sometimes overflowed during rain events, and that sewage got into the lake via overland flow into a drainage swale leading to the lake.

During a follow-up inspection on July 7, 1994 it was noted that the overflow pipes from the sewage lift stations had been capped. Due to problems with the lift stations and the age of the raw sewage lines, a major project was undertaken in late 1996 to update the sewage treatment plant, lift stations, and sewage lines. A December 22, 1997 inspection report indicated that three new pumping stations had been built and that the raw sewage lines had been replaced. It is impossible to know exactly how much sewage was getting into the lake from 1962 to 1997. It is known, that sewage was periodically getting into the lake from at least one of the lift stations, if not all of them. Part of the eutrophication of Pinchot Lake is certainly due to these confirmed and unconfirmed discharges, which have subsequently been eliminated. There are no urban areas located within the Pinchot Lake basin and developed areas account for less than 1% of the total watershed area. Therefore, the 303d listing of urban runoff/storm sewers as a source of impairment is no longer valid.

II. Approach to TMDL Development

Establishing the relationship between the in-stream/in-lake water quality targets and source loadings is a critical component of Total Maximum Daily Load (TMDL) development. It allows for evaluation of management options that will achieve the desired source load reductions. The link can be established through a range of techniques, from qualitative assumptions based on sound scientific principles, to sophisticated modeling techniques. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain waterbody responses to flow and loading conditions. The objective of this section is to present the approach taken to develop the linkage between sources and in-lake response, during development of the Pinchot Lake TMDL.

A. TMDL Endpoint

Pinchot Lake is hyper-eutrophic, suffering from high nutrient concentrations, frequent algal blooms, low transparency levels, and anoxic conditions in the hypolimnion during summer. In the absence of any significant documentation that there are dissolved oxygen criteria violations in the upper water levels of Pinchot Lake, the decision was made to concentrate on the organic enrichment portion of the 303d listing for organic enrichment/low D.O. In an effort to address organic enrichment as the cause of use impairment, a TMDL was developed for total phosphorus. The decision to use phosphorus load reductions to address 303d-listed impairments was based on an understanding of the relationship between nutrients and organic enrichment in lake systems, lake eutrophication and limiting nutrients.

i. Lake Eutrophication

Lake eutrophication is both a natural and culturally based phenomenon. Natural eutrophication is a slow, largely irreversible process associated with the gradual accumulation of organic matter and sediments in lake basins. Cultural eutrophication is an often rapid, possibly reversible process of nutrient enrichment and high biomass production stimulated by cultural activities causing nutrient transport to lakes. Lakes are considered to undergo a process of "aging" which can be characterized by the trophic status as oligotrophic, mesotrophic, or eutrophic. Oligotrophic lakes are normally associated with deep lakes which have relatively high levels of dissolved oxygen throughout the year, bottom sediments typically contain small amounts of organic matter, chemical water quality is good, and aquatic populations are both productive and diverse. Intermediate levels of biological productivity and diversity, along with slightly reduced dissolved oxygen levels and generally adequate water quality to support designated uses characterize mesotrophic lakes. However, there is recognition that these lakes are naturally or culturally moving towards a eutrophic state. Lakes that are classified as eutrophic typically exhibit high levels of organic matter, both suspended in the water column and in the upper portions of sediments. Biological productivity is high, often indicated by seasonal algae blooms and excessive plant growth. Dissolved oxygen concentrations are low, and may reach extreme levels during critical periods. In addition, water quality is often poor resulting in violations of the designated uses. Table 2 identifies typical water quality parameters associated with the various trophic state designations.

Table 2 - Trophic-State Classifications and Typical Lake Conditions*

Variable	Trophic-state		
	Oligotrophic	Mesotrophic	Eutrophic
Total Phosphorus (µg/L)	<10	10-20	>20
Chlorophyll-a (µg/L)	<4	4-10	>10
Secchi-disk depth (m)	>4	2-4	<2
Hypolimnion oxygen (% saturation)	>80	10-80	<10

*Principles of Surface Water Quality Modeling and Control, 1987, Thomann, R.V., and Mueller, J.A.

The secchi-disk depth listed in Table 2 is an assessment of water clarity. A Secchi disk is a circular plate divided into alternately painted black and white quarters. The disk is attached to a rope or chain and lowered into the water until it is no longer visible. Higher secchi-disk readings mean more rope/chain was let out before the disk disappeared from sight and indicates clearer water. Lower readings indicate turbid or colored water. Clear water lets light penetrate more deeply into the lake than does murky water. A general rule of thumb is that light can penetrate to a depth of about 2 - 3 times the secchi-disk depth. Although algae, soil particles, and other materials suspended in the water affect clarity, secchi-disk depth is primarily used as an indicator of algal abundance and general lake productivity.

In order to understand the term hypolimnion used in Table 2, one must first understand the concept of thermal stratification. Thermal stratification is where mixing in a water body is incomplete, allowing two or more distinct temperature layers to develop during at least part of the year. The two distinct temperature layers found in a vertically stratified waterbody are the epilimnion (top) and a hypolimnion (bottom). Therefore, the term "hypolimnion oxygen" refers to oxygen levels in the lower portion of a thermally stratified lake.

ii. Nutrient Limitation

Elevated nutrient loads (nitrogen and phosphorus in particular) can lead to increased productivity of plants and other organisms. In aquatic ecosystems the quantities of trace elements are typically plentiful; however, nitrogen and phosphorus may be in short supply. The nutrient that is in the shortest supply is called the limiting nutrient because its relative quantity affects the rate of production (growth) of aquatic biomass. If the limiting nutrient load to a water body can be reduced, the available pool of nutrients that can be utilized by plants and other organisms will be reduced and, in general, the total biomass can subsequently be decreased as well. In most efforts to control the eutrophication processes in water bodies, emphasis is placed on the limiting nutrient.

In most freshwater systems, phosphorus is the limiting nutrient for aquatic growth. In some cases, however, the determination of which nutrient is the most limiting is difficult. For this reason, the ratio of the amount of N to the amount of P has traditionally been used by DEP to make this determination. If the N/P ratio is less than 10, nitrogen is limiting. If the N/P ratio is greater than 10, phosphorus is the limiting nutrient. Based on samples collected by DEP (1996 to 2002) and Aqua-Link, Inc. (1999 & 2000), the N/P ratio for Pinchot Lake is estimated to be greater than 10 (Table 3), pointing to phosphorus as the limiting nutrient. Controlling the phosphorus loading to Pinchot Lake will limit plant growth, thereby helping to eliminate use impairments currently being caused by organic enrichment.

Table 3 - Total Nitrogen to Total Phosphorus Ratios in Pinchot Lake

Sampling Event	Sampling Period	Average TN/TP ratio	Minimum TN/TP ratio	Maximum TN/TP ratio
PA DEP WQN Sampling	1996-2000	22.8	13.1	32.8
PADEP Non-WQN Sampling	2000-2002	17.2	12.5	25.6
Aqua-Link, Inc Sampling	1999-2000	36.5	8.8	106.5

B. Water Quality Standards

Water Quality Standards consist of three components: designated and existing uses; narrative and/or numerical water quality criteria necessary to support those uses; and an anti-degradation statement. Water quality standards serve the dual purposes of establishing the water quality goals for a specific waterbody and serve as the regulatory basis for the establishment of water quality-based treatment controls and strategies beyond the technology-based levels of treatment required by section 301(b) and 306 of the Act. According to Pennsylvania Code, Title 25, Chapter 93, Water Quality Standards, Section 93.4, all surface waters in the state (including Pinchot Lake) shall be protected for the following uses: warm water fishes, potable water supply, industrial water supply, livestock water supply, wildlife water supply, irrigation, boating, fishing, water contact sports, and aesthetics.

Pennsylvania does not currently have specific numeric water quality criteria for organic enrichment or nutrients to support designated uses. However, Pennsylvania does have general water quality criteria (Section 93.6), which state:

a) Water may not contain substances attributable to point or nonpoint source discharges in concentration or amounts sufficient to be inimical or harmful to the water uses to be protected or to human, animal, plant or aquatic life;
b) In addition to other substances listed within or addressed by this chapter, specific substances to be controlled include, but are not limited to, floating materials, oil, grease, scum and substances which produce color, tastes, orders, turbidity or settle to form deposits.

C. Numeric Water Quality Target

In order to develop the TMDL, a water quality indicator and numeric water quality target must be specified. As mentioned, PA does not currently have numeric water quality standards for organic enrichment or nutrients. The overall goal of this TMDL is to improve the trophic status of Pinchot Lake from hyper-eutrophic to near mesotrophic. There are 4 parameters typically used to relate water quality with trophic state (Table 2). For the development of the Pinchot Lake TMDL, chlorophyll-a was used as the numeric water quality target. Chlorophyll-a is easy to measure, is a valuable surrogate for algal biomass, and is desirable as a water quality target because alga are either the direct (nuisance algal blooms) or indirect (high/low dissolved oxygen, pH, and high turbidity) cause of many problems related to organic enrichment and excessive nutrients. Based on the goal of improving the trophic status of Pinchot Lake from hyper-eutrophic to near mesotrophic, the water quality target to address existing organic enrichment impairments was set at approximately 10 μg/L chlorophyll-a.

The 10 µg/L chlorophyll-a target is consistently referenced in literature as a cutoff for mesotrophic status in a lake (Novotny and Olem, 1994; Wetzel, 2001; Carlson, 1977) and as an acceptable water quality condition. US EPA's Trophic State Delineation (EPA-NES, 1974) set the range of chlorophyll-a concentrations for mesotrophic lakes at 7-12 µg/L, further suggesting that the 10 µg/L used in this TMDL is fully protective of the lake's beneficial uses.

D. Dominant Processes

The approach taken in developing a TMDL must also consider the dominant processes regarding pollutant loadings and in-lake fate. The primary source contributing to organic enrichment impairments in Pinchot Lake is an array of nonpoint or diffuse sources. Loading processes for nonpoint sources, or land-based activities, are typically rainfall-driven and thus relate to surface runoff and subsurface discharge to a waterbody. Key in-lake factors that must be considered include routing of flow, dilution, transport of nutrients, and nutrient cycling.

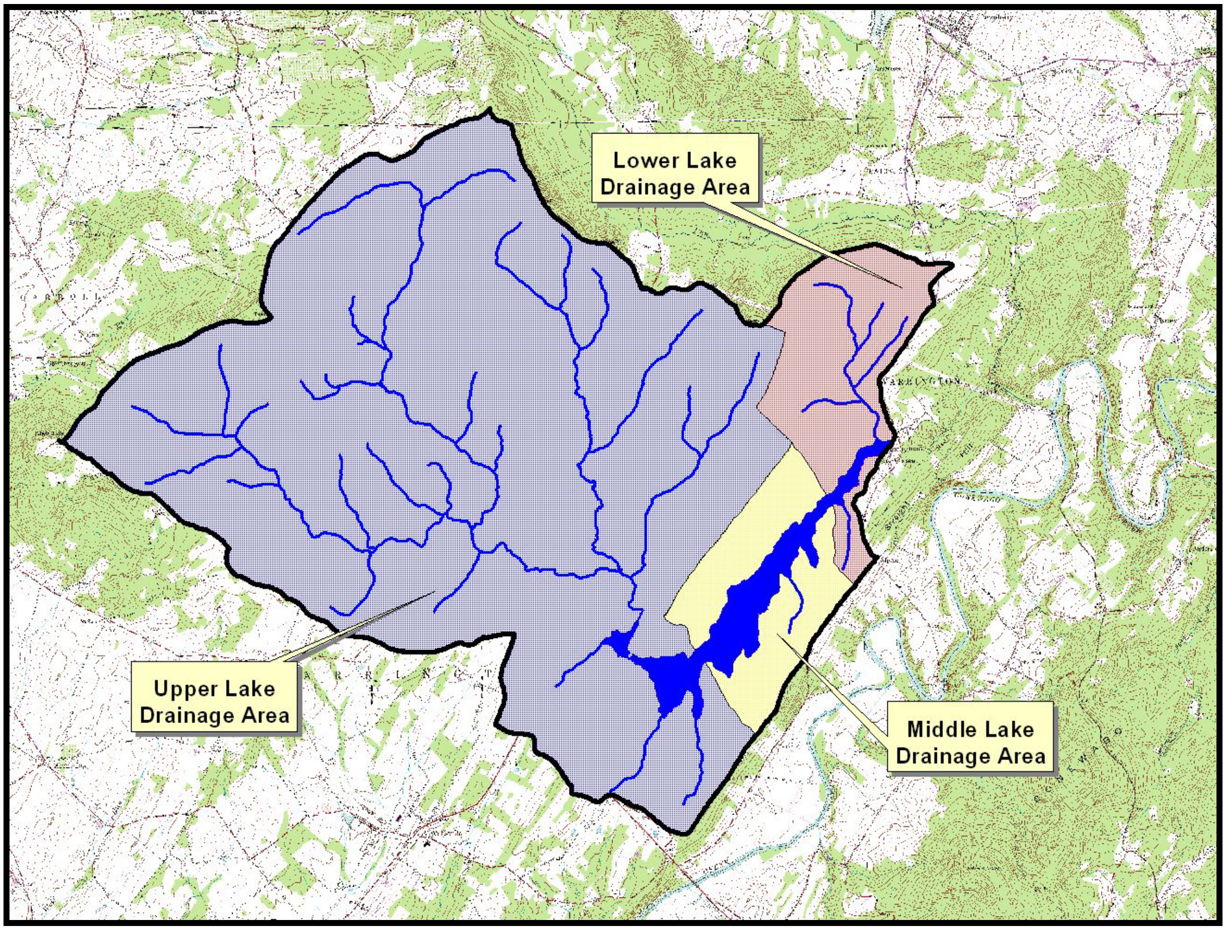
E. Technical Approach for Pinchot Lake TMDL

The technical approach used to develop the Pinchot Lake TMDL includes a combination of watershed and lake water quality modeling. This approach provides a hydrologic and nutrient loading budget from the watershed, which can be linked to an in-lake water quality model to assess the nutrient and algal condition of the lake. The Generalized Watershed Loading Functions (GWLF) model was chosen as the watershed model for this study. GWLF modeling was accomplished using an ArcView Version of GWLF (AVGWLF), developed by the Environmental Resources Research Institute of the Pennsylvania State University in ArcView (GIS software). The AVGWLF 4.0.3 GIS software (ArcView) interface facilitates the development of model input data and provides additional functionality. One of the benefits of using AVGWLF is that the model was customized to include Pennsylvania-specific data. The lake model used for TMDL development is BATHTUB, which performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network that accounts for advective and diffusive transport, and nutrient sedimentation. BATHTUB is used to simulate the fate and transport of nutrients and water quality conditions and responses to the nutrients load into the lake. BATHTUB has been cited as an effective tool for lake and reservoir water quality assessment and management, particularly where data are limited.

III. Pinchot Lake Watershed Modeling

The Pinchot Lake watershed was divided into three distinct subwatersheds (upper lake, middle lake, and lower lake drainage areas) in order to represent nutrient loadings to the lake (Figure 4). The upper lake drainage area included Beaver Creek, Little Beaver Creek, and 3 unnamed tributaries draining directly into the lake. The middle and lower lake drainage area included one and two unnamed tributaries, respectively.

Figure 4 – Pinchot Lake Subwatershed Delineations



Watershed modeling for the Pinchot Lake watershed was developed using the ArcView Generalized Watershed Loading Function model (AVGWLF) as described in Appendix B. All modeling outputs for the upper, middle and lower lake basins have been included in Appendix C, Appendix D, and Appendix E, respectively. The AVGWLF model provides the ability to simulate surface water runoff, as well as sediment and nutrient loads, from a watershed, based on landscape conditions such as topography, land use/cover, and soil type. In essence, the model is used to estimate surface runoff and nonpoint source loads from different areas in the watershed.

A. Critical Conditions and Seasonal Environmental Variation

The use of meteorological data by AVGWLF ensures that the TMDL methodology is consistent with the technical and regulatory requirements of 40 CFR Section 130. These regulations require TMDLs to consider critical environmental conditions and seasonal environmental variations. The requirements are designed to simultaneously ensure that water quality is protected during times when it is most vulnerable and take into account changes in stream flow and loading characteristics as a result of hydrological or climatological variations. These conditions are important because they describe the factors that combine to cause violations of water quality standards and can help identify necessary remedial actions. Critical conditions in Pinchot Lake include periods of increased nutrient loading to the lake, typically from October through March during higher seasonal stream flows and precipitation. Another critical condition occurs when the lake experiences higher temperatures and increased algal growth, typically from April through September. Nutrient loads may not be significant during this period due to reduced stream flows and precipitation; however, the concentration of nutrients in the lake may be elevated causing impairments. The AVGWLF model was executed from 1988 through 1998 and appropriately considers both critical environmental conditions and seasonal environmental variation.

There are no USGS stream gages located in the Pinchot Lake watershed. There is a gage station operated by the USGS located downstream of the lake, on Conewago Creek, near Manchester, PA. USGS Gage 0157400 is located at river mile index 3.3 of Conewago Creek and is located approximately 14.9 miles downstream from the outlet of Pinchot Lake (Figure 5). Flow data exist for this gage station from 1929 to the present (Table 4). Likewise, there are no weather stations situated in the Pinchot Lake watershed. The closest weather station is the Harrisburg WSO, located approximately 9.5 miles northeast of the watershed (Figure 5). The most recent update to the AVGWLF model includes data from 1975 to 1998 for the Harrisburg weather station (Table 4). Statistics on precipitation and stream flows for the years utilized by the AVGWLF in modeling of the Pinchot Lake watershed help support the conclusion that critical conditions and seasonal environmental variations are appropriately addressed (Table 5). Over the 10- year simulation period (April 1988 to March 1998) a range of precipitation and stream flow conditions were represented. In terms of precipitation, during 2 years the total precipitation was below the 20% occurrence probability. There were three years where precipitation was above the 80% occurrence probability. The remaining five years were close to average precipitation based on data from 1975 through 1998. In terms of stream flow, there were two years where stream flow was below the 20% occurrence probability. There were 3 years where stream flow was above the 80% occurrence probability. The remaining five years were close to average stream flow conditions based on historical data from 1929 through 2000.

Figure 5 – Location of USGS Gage Station 01574000 (West Conewago Creek near Manchester) and the Harrisburg Weather Service Station

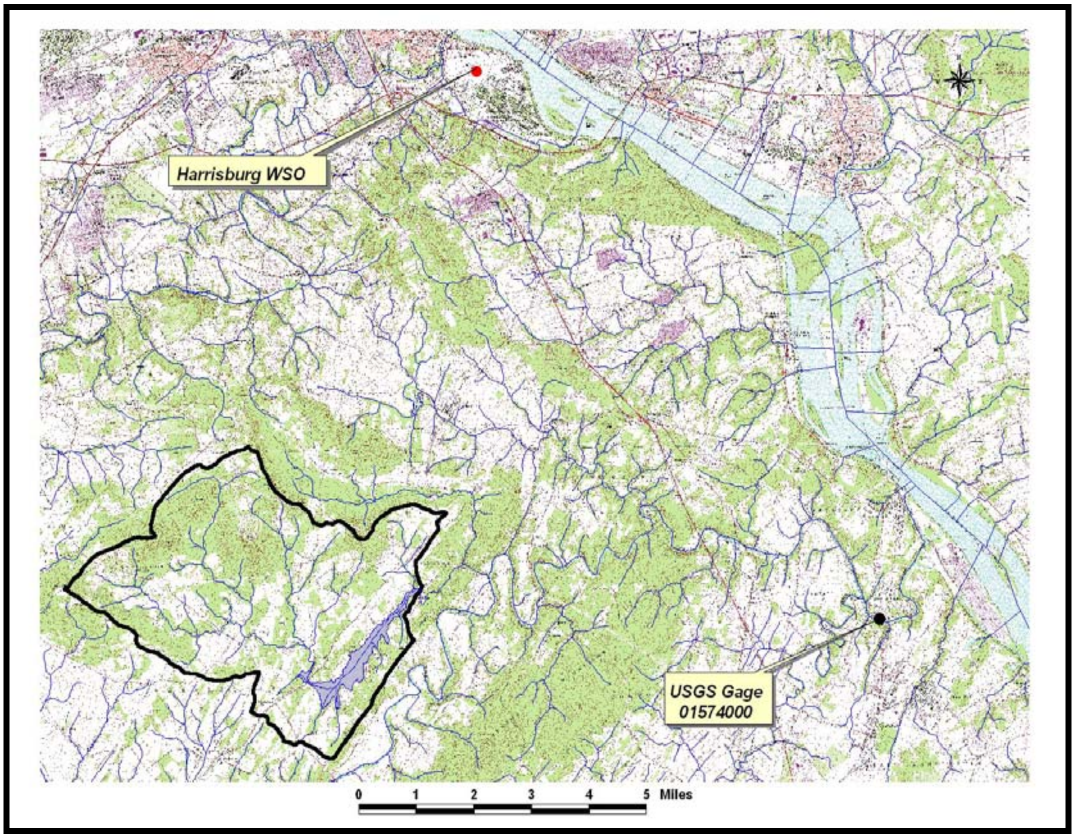


Table 4 – Historical Statistics for Harrisburg WSO and USGS Gage 01574000

Statistic	Harrisburg WSO Annual Precipitation (cm/year)	USGS Gage 01574000 Annual Stream Flow (ft^3/sec)
Average (1975 to 1998 for precip. & 1929 – 2000 for flow)	105.0	603.3
Average (1988-1998)	106.8	709.2
Minimum (1975 to 1998 for precip. & 1929 – 2000 for flow)	65.1	153
Maximum (1975 to 1998 for precip. & 1929 – 2000 for flow)	142.0	1,364
Percentile of selected values - 20%	91.02	419.0
Percentile of selected values - 40%	100.58	516.4
Percentile of selected values - 60%	106.82	641.2
Percentile of selected values - 80%	118.66	769.6

Table 5 - Descriptive Statistics for Precipitation and Stream Flow During AVGWLF Modeling Years

Modeling Year	Begin Month	Ending Month	Total Annual Precipitation (cm/year)	Mean Annual Stream Flow (ft^3/sec)
1	April 1988	March 1989	80.2	318.4
2	April 1989	March 1990	100.5	793.8
3	April 1990	March 1991	106.2	767.8
4	April 1991	March 1992	65.1	362.9
5	April 1992	March 1993	106.9	740.0
6	April 1993	March 1994	131.6	1,128.0
7	April 1994	March 1995	96.0	548.7
8	April 1995	March 1996	128.5	759.0
9	April 1996	March 1997	142.0	1,107.0
10	April 1997	March 1998	111.1	732.9

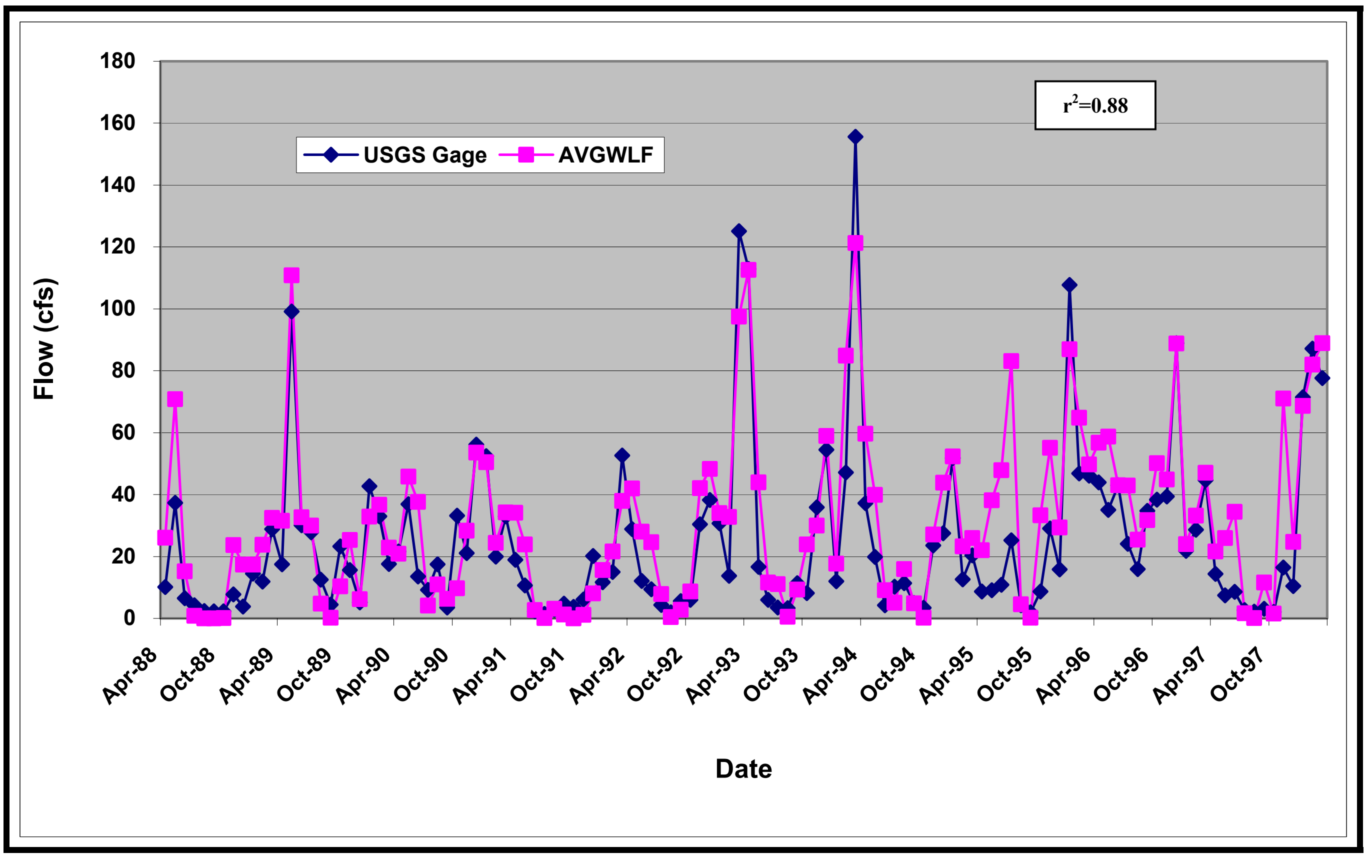
B. Background Pollutant Contributions

Federal regulations at 40 CFR Section 130 require TMDLs to consider the impact of background pollutant contributions. The AVGWLF model adequately considers background pollutants by including nutrient contributions from groundwater. The groundwater component includes both interflow and base flow contributions. Nutrient contributions from septic systems, background nutrient concentrations in soil, and nutrients from manure application are also considered by AVGWLF.

C. Hydrology Calibration and Validation

The model hydrology calibration and validation processes involved comparing the observed and simulated flow data. However, as described above, there are no USGS gages in the Pinchot Lake watershed. Therefore, historical stream flow data from USGS Gage 01574000 was used to estimate stream flow at the Pinchot Lake outlet, based on drainage areas for the lake and gage. Using input files created from the AVGWLF interface, GWLF predicted overall water balances for the watershed drained by the Pinchot Lake outfall. The predicted water balances (i.e. stream flow) were compared to observed water balance based on data from the USGS gage station. Average monthly observed and simulated stream flows were then compared over the 10-year GWLF model simulation period (Figure 6). There was a strong, positive correlation between the two data sets and no need for adjustments or calibration of the hydrologic parameters utilized by the GWLF mode.

Figure 6 – Comparison Plot for Flows at the Pinchot Lake Outlet



D. Watershed Modeling Results

The AVGWLF model was used to establish existing nutrient loading conditions for all three subwatersheds (upper, middle, and lower) in the Pinchot Lake watershed. Model simulations were conducted for a 10-year period from April 1988 through March 1998. All of the AVGWLF modeling outputs have been attached to this report as Appendices C, D, and E. DEP staff visited the Pinchot Lake watershed April 2002 to get a better understanding of existing conditions that might influence the

AVGWLF model. No adjustments were made to specific parameters used in the AVGWLF model based on observations made while touring the watershed.

The AVGWLF model produced information on total phosphorus loading (Table 6). The total phosphorus loads presented represent an annual average over the 10-year period simulated by the model (1988 to 1998). The load estimates also include contributions from the point source overflows, which have since been corrected.

Table 6 – Average Annual Total Phosphorus Loading for the Pinchot Lake Watershed

Source of Total Phosphorus	Estimated Annual Loading (kg/yr.)			
	Upper Watershed	Middle Watershed	Lower Watershed	Total Watershed
Hay/Pasture	11.70	0.33	3.97	16.01
Cropland	128.93	2.82	31.26	163.00
Conif Forest	0.09	0.05	0.04	0.19
Mixed Forest	0.14	0.02	0.02	0.19
Decid Forest	14.22	0.36	0.71	15.30
Unpaved Road	1.11	0.00		1.11
Low Intensity Development	0.00	0.00		0.01
Hi Intensity Development	0.01	0.00		0.01
Stream Bank	7.83	0.30	0.32	8.45
Groundwater/Internal Loading	500.36	31.01	59.52	590.88
Point Source Overflows	1,170.00			1,170.00
Septic Systems	6.81	0.85	0.85	8.52
Total	**1,841.21**	**35.74**	**96.70**	**1,973.65**

IV. Pinchot Lake Water Quality Modeling

BATHTUB applies a series of empirical eutrophication models to morphologically complex lakes and reservoirs. The program performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network that accounts for advective and diffusive transport, and nutrient sedimentation. Application of BATHTUB is limited to steady-state evaluation of relationships between nutrient-loading, transparency and hydrology, and eutrophication responses. Eutrophication-related water quality conditions (total phosphorus, total nitrogen, and chlorophyll a) are predicted using empirical relationships derived from assessment of reservoir data.

A. BATHTUB Model Setup

In an effort to more accurately represent the physical characteristics of Pinchot Lake (e.g., bathymetry, volume, and reservoir shape), the lake was divided into three segments (Figure 7). Utilizing varying characteristics for surface area, length, mean depth, mixed layer depth, and hypolimnetic depth in the upper, middle and lower portions of the lake (Table 7) provided the ability to more accurately predict chlorophyll-a concentrations with greater spatial resolution.

Figure 7 – Segmentation of Pinchot Lake for BATHTUB Modeling

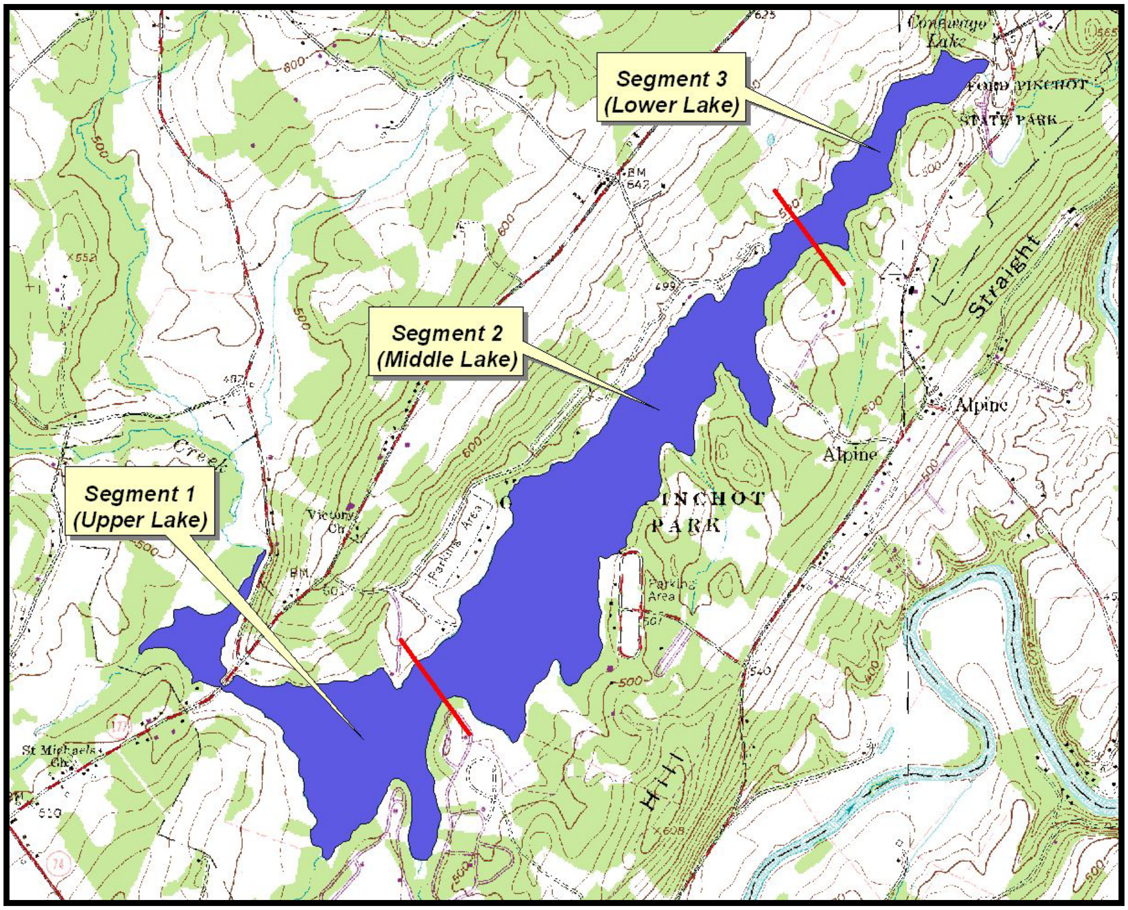


Table 7 - Characteristics of Pinchot Lake Segments for BATHTUB Modeling

	Model Segment		
Characteristics	**1 (Upper Lake)**	**2 (Middle Lake)**	**3 (Lower Lake)**
Surface Area (km^2)	0.45	0.86	0.14
Length (km)	0.95	1.5	0.64
Mean Depth (m)	2.2	3.8	8.0
Mixed Layer Depth (m)	2.2	3.8	5.0
Hypolimnetic Depth (m)	0	0	3.0
Ave. Observed Total P (ppb)	-	63.00	35.0
Ave. Observed Chlorophyll-a (ppb)	-	32.60	29.01
Ave. Observed Secchi Depth (m)	-	0.85	1.04

Flow and total phosphorus loads estimated by the AVGWLF watershed model where utilized as input data for the BATHTUB lake model, to determine chlorophyll-a concentrations in Pinchot Lake. Each of the lake model segments received inflows from the "tributary" subwatersheds that delivered water and nutrients to that segment, as depicted in Figure 4. AVGWLF based input data for the BATHTUB model are summarized in Table 8.

Table 8 – Summary of BATHTUB Model Input Data from AVGWLF

Parameter	Subwatershed Drainage Area		
	Upper Lake	Middle Lake	Lower Lake
BATHTUB Model Tributary	1	2	3
Drainage Area (km^2)	36.58	2.93	4.05
Ave. Flow (Hm^3/yr)	23.8	1.8	2.6
Ave. Total Phosphorus Conc. (ppb)	77.35	19.75	37.18
Ave. Ortho Phosphorus Conc. (ppb)	51.05	13.04	24.53

B. Critical Conditions and Seasonal Environmental Variation

As previously described, critical conditions and seasonal environmental variations are adequately accounted for in the AVGWLF model. For the BATHTUB modeling of Pinchot Lake, critical conditions include periods of increased sunlight, temperature, and algal growth that typically occur from April through September (i.e., the growing season). The BATHTUB model considers critical conditions through specification of model options that incorporate conditions like sunlight availability and chlorophyll-a flushing rates. Furthermore, the model can be executed over an entire year or limited to the growing season. The Lake Nockamixon BATHTUB model was executed over a one-year period to adequately consider critical conditions and seasonal environmental variations.

C. Background Pollutant Contributions

The Pinchot Lake BATHTUB model adequately considers background pollutant contributions by using observed nutrient concentrations from water quality monitoring data to set up initial concentrations in the lake. Data collected by PA DEP and Aqua Link, Inc. was used to characterize background nutrient concentrations in Pinchot Lake.

D. BATHTUB Lake Modeling Results

All BATHTUB modeling results for the development of the Pinchot Lake total phosphorus TMDL are included in Appendix F. Table 9 summarizes the results from the final BATHTUB model run for existing conditions in Pinchot Lake, based on the AVGWLF watershed modeling. A comparison of the model outputs to observed in lake values from sampling by DEP, CES and ALI, indicate that the model was capable of simulating conditions well enough to allow an estimation of the total phosphorus load reductions necessary to meet the TMDL based chlorophyll-a target of approximately 10 µg/L .

Table 9 – Comparison of BATHTUB Lake Model Simulation Results and Observed Sampling Data

Lake Segment		Total P (µg/L)	Chlorophyll-a (µg/L)	Secchi depth (m)
Segment 1 (Upper Lake)				
	Model Estimate	58.4	33.8	1.2
Segment 2 (Middle Lake)				
	Sampling Data	63.0	32.6	0.9
	Model Estimate	54.2	30.3	1.3
	Est./Observed Ratio	1.16	1.08	0.67
Segment 3 (Lower Lake)				
	Sampling Data	35.0	29.0	1.0
	Model Estimate	52.7	29.1	1.0
	Est./Observed Ratio	0.66	1.00	1.00
Area Wtd Mean (Entire Lake)				
	Sampling Data	59.1	32.1	0.9
	Model Estimate	55.4	31.3	1.2
	Est./Observed Ratio	1.07	1.03	0.72

V. Total Phosphorus TMDL

The target total phosphorus TMDL was used as the basis for load allocations and reductions in the Pinchot Lake watershed, using the following two equations:

1. TMDL = WLA + LA + MOS
2. LA = ALA - LNR

where:

TMDL = Total Maximum Daily Load
WLA = Waste Load Allocation (point sources)
LA = Load Allocation (nonpoint sources)
ALA = Adjusted Load Allocation
LNR = Loads not Reduced

A. TMDL Target

The BATHTUB model developed for Pinchot Lake was used to quantify the maximum total phosphorus loading to the lake that would achieve the water quality objective for chlorophyll-a levels of approximately 10 µg/L . Specifically, various nonpoint sources of phosphorus were iteratively decreased until the model simulated chlorophyll-a concentrations of approximately 10.0 µg/L throughout the lake. Based on these modeling runs, in order to maintain chlorophyll-a concentrations near 10.0 µg/L , the mean annual total phosphorus loading for the entire Pinchot Lake watershed needs to be reduced to 651 kg/yr. (Table 10).

Table 10 – Attainment of TMDL Based Chlorophyll-a Concentrations in Pinchot Lake

Parameter	BATHTUB Lake Model Segment			
	1 (Upper Lake)	2 (Middle Lake)	3 (Lower Lake)	Entire Lake
Annual TP Loading (kg/yr.)	543.68	28.95	78.33	650.96
TP Conc. (µg/L)	25.9	25.2	25.2	25.5
Chlorophyll-a Conc. (µg/L)	10.3	9.9	9.9	10.1
Secchi Depth (m)	3.9	4.0	4.0	4.0

B. Wasteload Allocation

The waste load allocation (WLA) portion of the TMDL equation is the total loading of a pollutant that is assigned to point sources. The watershed and lake modeling used in the development of this TMDL included point source overflows in the estimation of total phosphorus reaching Pinchot Lake. However, these sources have since been corrected. Reviewing the Department's permitting files indicates there are no current point source discharges in the Pinchot Lake watershed; therefore the phosphorus WLA was set at zero.

C. Margin of Safety

The margin of safety (MOS) is that portion of the pollutant loading that is reserved to account for any uncertainty in the data and computational methodology used for the analysis. For this analysis, the MOS is explicit. Ten percent of the targeted TMDL for total phosphorus was reserved as the MOS. Using 10% of the TMDL load is based on professional judgment and will provide an additional level of protection to the designated uses of Pinchot Lake. The MOS for the total phosphorus TMDL was at 65.1 kg/yr.

MOS = 650.96 kg/yr. (TMDL) x 0.1 = 65.10 kg/yr.

D. Load Allocation

The load allocation (LA) is that portion of the TMDL that is assigned to nonpoint sources. Since there are no point sources present in the Pinchot Lake watershed, the total phosphorus load allocation was computed by subtracting the MOS value from the targeted TMDL value. The load allocations for total phosphorus was set at 585 kg./yr

LA = 650.96 kg/yr. (TMDL) - 65.10 kg/yr. (MOS) = 585.86 kg/yr.

E. Adjusted Load Allocation

The adjusted load allocation (ALA) is the actual portion of the LA distributed among those nonpoint sources receiving reductions. It is computed by subtracting those non-point source loads that are not being considered for reductions (loads not reduced or LNR) from the LA. Reductions were applied to HAY/PASTURE, CROPLAND, Stream Bank, and Groundwater/Internal Loading sources of total phosphorus. Those land uses/sources for which existing loads were not reduced (CONIF_FOR, MIXED_FOR, DECID_FOR, UNPAVED_RD, LO_INT_DEV, HI_INT_DEV, and Septic Systems) were carried through at their existing loading values (Table 11). The ALA for total phosphorus was 560.55 kg/yr.

Table 11 - Load Allocations, Loads Not Reduced, and Adjusted Load Allocations for Pinchot Lake TMDL

TMDL Component	Total P (kg/yr.)
Load Allocation	**585.86**
Loads Not Reduced	**25.31**
CONIF_FOR	0.19
MIXED_FOR	0.19
DECID_FOR	15.30
UNPAVED_RD	1.11
LO_INT_DEV	0.01
HI_INT_DEV	0.01
Septic Systems	8.52
Adjusted Load Allocation	**560.55**

F. TMDL

The total phosphorus TMDL established for the Pinchot Lake watershed consists of a Load Allocation (LA) and a Margin of Safety (MOS). No TMDL was established for nitrogen because the lake is phosphorus limited. The individual components of the TMDLs are summarized in Table 12.

Table 12 - TMDL, WLA, MOS, LA, LNR, and ALA for Total Phosphorus in the Pinchot Lake Watershed

Component	Total Phosphorus (kg/yr.)
TMDL (Total Maximum Daily Load)	650.96
WLA (Wasteload Allocation)	-
MOS (Margin of Safety)	65.10
LA (Load Allocation)	585.86
LNR (Loads Not Reduced)	25.31
ALA (Adjusted Load Allocation)	560.55

VI. Calculation of Nutrient Load Reductions

The load allocation established in the previous section (585.86 kg/yr.) represents the total phosphorus load available for allocation between contributing sources in the Pinchot Lake watershed. The ALA for total phosphorus was allocated between agricultural land uses, stream bank erosion and groundwater/internal loading. Load allocation and reduction procedures were applied to the entire Pinchot Creek watershed using the Equal Marginal Percent Reduction (EMPR) allocation method (Appendix G). The load allocation and EMPR procedures were performed using MS Excel and results are also presented in Appendix G. The annual loading specified by the total phosphorus TMDL can be achieved through a 25% reduction in current loading from hay/pasture, cropland, and stream bank erosion, along with a 29% reduction for groundwater/internal loading (Table 13).

Table 13 - Phosphorus Load Allocations & Reductions for Pinchot Lake Watershed

Source	Current Load (kg/yr.)	Final LA (kg/yr.)	% Reduction
Hay/Past.	16.01	12.00	25%
Cropland	163.00	122.15	25%
Stream Bank	8.45	6.33	25%
Groundwater/Internal Loading	590.88	420.07	29%
Total	**778.34**	**560.55**	**28%**

VII. Recommendations for Implementation

TMDLs represent an attempt to quantify the pollutant load that may be present in a waterbody and still ensure attainment and maintenance of water quality standards. The TMDL developed for Pinchot Lake identifies the necessary overall load reduction for total phosphorus and distributes the reduction goal to the appropriate nonpoint sources. Reaching the reduction goal established by the TMDL will only occur through changes in current land use practices, including the incorporation of additional "best management practices" (BMPs) on agricultural and developing lands. BMPs that might be helpful in lowering the amount of nutrients reaching Pinchot Lake include riparian buffer strips, strip cropping, contour plowing, and conservation crop rotation among many others.

Determining the most appropriate nonpoint source BMPs, where they should be installed, and actually putting them into practice, will require the development and implementation of a comprehensive watershed restoration plan. Fortunately, there is already a fairly active Pinchot Lake watershed association in existence. Representatives from DEP, DCNR, York County Conservation District, local townships, and private citizens have already been instrumental in the implementation of BMPs under the 319-grant program.

By developing this TMDL for Pinchot Lake, the Department has set the stage for local citizens to continue designing and implementing restoration plans to correct current use impairments. The Department will continue to support local efforts to develop and implement watershed restoration plans based on the reduction goals specified in this TMDLs. Interested parties should contact the appropriate Watershed Manager in the Department's Southcentral Regional Office (717-705-4700) for information regarding technical and financial assistance currently available. Local governments, individuals and/or local watershed groups are strongly encouraged to avail themselves of funding sources available through DEP and other state and federal agencies (e.g., Growing Greener, 319 Program, and Storm Water Management Program grants).

The load reductions specified by this TMDL represent what is necessary to allow Pinchot Lake to eventually meet water quality standards. Even if the specified watershed-based load reductions were to be implemented all at once, there would not be an immediate impact on water quality in the lake. It is important to note that many of the historical use impairments in Pinchot Lake resulted from excessive organic enrichment due to overflowing sewage systems. These overflow sources have been eliminated, however it will take some time for the nutrients to naturally cycle through Pinchot Lake. The physical characteristics of Pinchot Lake combined with its fairly long hydraulic residence time (61 days), suggest that it will take a number of years before in lake nutrient levels begin to decline as a result of reductions in loadings from surrounding land uses. At certain times of the year, a significant portion of the in lake phosphorus is tied up aquatic macrophytes. Large scale harvesting of aquatic vegetation, with appropriate consideration for its usefulness as habitat for various forms of aquatic life, could help accelerate the elimination of excess nutrients. In order for such an effort to be successful, harvesting of aquatic vegetation from the lake must be done in such a way as to prevent the nutrients from returning to the lake. The best way to insure this would be total removal of the vegetation from the watershed. If harvested vegetation must be disposed of within the watershed, proper safe guards will need to be put in place to insure that the nutrients will not return to the lake through overland runoff or ground water infiltration.

VIII. Public Participation

A notice of availability for comments on the draft Pinchot Lake TMDL was published in the PA Bulletin on December 14, 2002 and on the Department's web page shortly thereafter. A 60-day period (ending on February 17, 2003) was provided for the submittal of written comments. In addition, a public meeting was held on January 23, 2003 at the Warrington Township Building in Rossville, PA to address any outstanding concerns regarding the draft TMDL. A total of 21 people attended the meeting and changes were made to the final report based on concerns and issues raised. Written comments received during the official 60-day comment period were taken into consideration in the development of the final TMDL document submitted to the U.S. Environmental Protection Agency (USEPA) for approval. Comments received and the Departments responses are summarized in Appendix H.

Notice of final TMDL approvals will be posted on the Department's website.

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Appendix A – Information Sheet for Pinchot Lake TMDL

What is being proposed?

A Total Maximum Daily Load (TMDL) plan has been developed to improve water quality in Pinchot Lake in York County, Pennsylvania.

Who is proposing the plan? Why?

The Pennsylvania Department of Environmental Protection (PADEP) is proposing to submit the plans to the U.S. Environmental Protection Agency (U.S. EPA) for review and approval as required by federal regulation. In 1995, U.S. EPA was sued for not developing TMDLs when Pennsylvania failed to do so. PADEP has entered into an agreement with U.S. EPA to develop TMDLs for certain specified waters over the next several years. This TMDL was developed in compliance with the state/U.S. EPA agreement.

What is a TMDL?

A TMDL sets a ceiling on the pollutant load that can enter a waterbody so that it will meet water quality standards. The Clean Water Act requires states to list all waters that do not meet their water quality standards even after pollution controls required by law are in place. For these waters, the state must calculate how much of a substance can be put in the water without violating the standard, and then distribute that quantity to all sources of the pollutant on that water body. A TMDL plan includes waste load allocations for point sources, load allocations for nonpoint sources, and a margin of safety. The Clean Water Act requires states to submit their TMDLs to U.S. EPA for approval. Also, if a state does not develop the TMDL, the Clean Water Act states that U.S. EPA must do so.

What is a water quality standard?

In order to meet state and national clean water goals states must adopt water quality standards. Water quality standards are state regulations that have two components. The first component is a designated use, such as "warm water fishes" or "recreation." States must assign a use, or several uses to each of their waters. The second component relates to the instream conditions necessary to protect the designated use(s). These conditions or "criteria" are physical, chemical, or biological characteristics such as temperature and minimum levels of dissolved oxygen, and maximum concentrations of toxic pollutants. It is the combination of the "designated use" and the "criteria" to support that use that make up a water quality standard. If any criteria are being exceeded, then the use is not being meet and the water is said to be in violation of water quality standards.

What is the purpose of the plan?

Pinchot Lake is impaired by organic enrichment/low dissolved oxygen. This TMDL plan includes a calculation of the total phosphorus loading that will allow Pinchot Lake to meet water quality objectives.

Why was Pinchot Lake selected for TMDL development?

In 1996 and 1998, Pa. DEP listed Pinchot Lake under Section 303(d) of the federal Clean Water Act as impaired due to organic enrichment/low dissolved oxygen.

What pollutant does this TMDL address?

The proposed plan provides a calculation of Pinchot Lake's capacity to accept total phosphorus. Based on an evaluation of the concentrations of nutrients in Pinchot Lake, phosphorus is the primary cause of the organic enrichment/low dissolved oxygen impairment in the lake.

Where do the pollutants come from?

The organic enrichment/low dissolved oxygen impairments in Pinchot Lake come from nonpoint sources (NPS) of pollution, primarily overland runoff from agricultural land uses, stream bank erosion, and groundwater/internal loading.

How was the TMDL developed?

PADEP used a combination of watershed and lake modeling to estimate the necessary loading reduction of total phosphorus that would be needed to restore a healthy aquatic community. The watershed modeling was used to estimate pollutant loads to the lake, using precipitation and land use characteristic data. For this analysis, PADEP used the AVGWLF model (the Environmental Resources Research Institute of the Pennsylvania State University's Arcview based version of the Generalized Watershed Loading Function model developed by Cornell University). The watershed modeling outputs were then utilized in the US Army Corps of Engineer's BATHTUB lake model to predict the effect of various pollutant load reductions on Pinchot

Lake water quality. The combination of watershed and lake modeling was used to set the allowable total phosphorus loading rates in the Pinchot Lake watershed because neither Pennsylvanian nor U.S. EPA has water quality criteria for phosphorus.

How much pollution is too much?

The allowable amount of pollution in a water body varies depending on several conditions. TMDLs are set to meet water quality standards at the critical flow condition. For this TMDL, the allowable total phosphorus loading is expressed as an annual loading. This accounts for pollution contributions over all flow conditions. Reducing the current total phosphorus loading in the Pinchot Lake watershed will result in meeting the water quality objectives.

How will the loading limits be met?

Best Management Practices (BMPs) will be encouraged throughout the watershed to achieve the necessary load reductions.

How can I get more information on the TMDL?

To request a copy of the full report, contact Lee McDonnell at 717-783-2938 during the business hours of 8:00 a.m. to 4:00 p.m., Monday through Friday. One may also contact Mr. McDonnell by mail at the Division of Water Quality Assessment and Standards, Pennsylvania Department of Environmental Protection, 400 Market Street, Harrisburg, PA 17105 or by e-mail at lmcdonnel@state.pa.us

How can I comment on the proposal?

You may provide e-mail or written comments postmarked no later than February 17, 2003 to the above addresses.

Appendix B - AVGWLF Model Overview & GIS-Based Derivation of Input Data

The Pinchot Lake TMDL was developed using the Generalized Watershed Loading Function or GWLF model. The GWLF model provides the ability to simulate runoff, sediment, and nutrient (N and P) loadings from watershed given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data. It is a continuous simulation model, which uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on the daily water balance accumulated to monthly values.

GWLF is a combined distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple land use/cover scenarios. Each area is assumed to be homogenous in regard to various attributes considered by the model. Additionally, the model does not spatially distribute the source areas, but aggregates the loads from each area into a watershed total. In other words, there is no spatial routing. For sub-surface loading, the model acts as a lumped parameter model using a water balance approach. No distinctly separate areas are considered for sub-surface flow contributions. Daily water balances are computed for an unsaturated zone as well as a saturated sub-surface zone, where infiltration is computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration.

GWLF models surface runoff using the Soil Conservation Service Curve Number (SCS-CN) approach with daily weather (temperature and precipitation) inputs. Erosion and sediment yield are estimated using monthly erosion calculations based on the Universal Soil Loss Equation (USLE) algorithm (with monthly rainfall-runoff coefficients) and a monthly composite of KLSCP values for each source area (e.g., land cover/soil type combination). The KLSCP factors are variables used in the calculations to depict changes in soil loss erosion (K), the length slope factor (LS) the vegetation cover factor (C) and conservation practices factor (P). A sediment delivery ratio based on watershed size and transport capacities based on average daily runoff are applied to the calculated erosion to determine sediment yield for each source area. Surface nutrient losses are determined by applying dissolved N and P coefficients to surface runoff and a sediment coefficient to the yield portion for each agricultural source area. Point source discharges can also contribute to dissolved losses to the stream and are specified in terms of kilograms per month. Manured areas, as well as septic systems, can also be considered. Urban nutrient inputs are all assumed to be solid-phase, and the model uses an exponential accumulation and wash off function for these loadings. Sub-surface losses are calculated using dissolved N and P coefficients for shallow groundwater contributions to stream nutrient loads, and the sub-surface sub-model only considers a single, lumped-parameter contributing area. Evapotranspiration is determined using daily weather data and a cover factor dependent upon land use/cover type. Finally, a water balance is performed daily using supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage, and evapotranspiration values. All of the equations used by the model can be viewed in GWLF Users Manuel.

For execution, the model requires three separate input files containing transport-, nutrient-, and weather-related data. The transport (TRANSPRT.DAT) file defines the necessary parameters for each source area to be considered (e.g., area size, curve number, etc.) as well as global parameters (e.g., initial storage, sediment delivery ratio, etc.) that apply to all source areas. The nutrient (NUTRIENT.DAT) file specifies the various loading parameters for the different source areas identified (e.g., number of septic systems, urban source area accumulation rates, manure concentrations, etc.). The weather (WEATHER.DAT) file contains daily average temperature and total precipitation values for each year simulated.

The primary sources of data for this analysis were geographic information system (GIS) formatted databases. A specially designed interface was prepared by the Environmental Resources Research Institute of the Pennsylvania State University in ArcView (GIS software) to generate the data needed to run the GWLF model, which was developed by Cornell University. The new version of this model has been named AVGWLF (ArcView Version of the Generalized Watershed Loading Function).

In using this interface, the user is prompted to identify required GIS files and to provide other information related to "non-spatial" model parameters (e.g., beginning and end of the growing season, the months during which manure is spread on agricultural land and the names of nearby weather stations). This information is subsequently used to automatically derive values for required model input parameters, which are then written to the TRANSPRT.DAT, NUTRIENT.DAT and WEATHER.DAT input files needed to execute the GWLF model. For use in Pennsylvania, AVGWLF has been linked with statewide GIS data layers such as land use/cover, soils, topography, and physiography; and includes location-specific default information such as background N and P concentrations and cropping practices. Complete GWLF-formatted weather files are also included for eighty weather stations around the state.

The following table lists the statewide GIS data sets and provides an explanation of how they were used for development of the input files for the GWLF model.

GIS Data Sets	
DATASET	DESCRIPTION
Censustr	Coverage of Census data including information on individual homes septic systems. The attribute *usew_sept* includes data on conventional systems, and *sew_other* provides data on short-circuiting and other systems.
County	The County boundaries coverage lists data on conservation practices, which provides C and P values in the Universal Soil Loss Equation (USLE).
Gwnback	A grid of background concentrations of N in groundwater derived from water well sampling.
Landuse5	Grid of the MRLC that has been reclassified into five categories. This is used primarily as a background.
Majored	Coverage of major roads. Used for reconnaissance of a watershed.
MCD	Minor civil divisions (boroughs, townships and cities).
Npdespts	A coverage of permitted point discharges. Provides background information and cross check for the point source coverage.
Padem	100-meter digital elevation model. This used to calculate landslope and slope length.
Palumrlc	A satellite image derived land cover grid that is classified into 15 different landcover categories. This dataset provides land cover loading rate for the different categories in the model.
Pasingle	The 1:24,000 scale single line stream coverage of Pennsylvania. Provides a complete network of streams with coded stream segments.
Physprov	A shapefile of physiographic provinces. Attributes *rain_cool* and *rain_warm* are used to set recession coefficient
Pointsrc	Major point source discharges with permitted N and P loads.
Refwater	Shapefile of reference watersheds for which nutrient and sediment loads have been calculated.
Soilphos	A grid of soil phosphorous loads, which has been generated from soil sample data. Used to help set phosphorus and sediment values.
Smallsheds	A coverage of watersheds derived at 1:24,000 scale. This coverage is used with the stream network to delineate the desired level watershed.
Statsgo	A shapefile of generalized soil boundaries. The attribute *mu_k* sets the k factor in the USLE. The attribute *mu_awc* is the unsaturated available capacity., and the *muhsg_dom* is used with landuse cover to derive curve numbers.
Strm305	A coverage of stream water quality as reported in the Pennsylvania's 305(b) report. Current status of assessed streams.
Surfgeol	A shapefile of the surface geology used to compare watersheds of similar qualities.
T9sheds	Data derived from a DEP study conducted at PSU with N and P loads.
Zipcode	A coverage of animal densities. Attribute *aeu_acre* helps estimate N & P concentrations in runoff in agricultural lands and over manured areas.
Weather Files	Historical weather files for stations around Pennsylvania to simulate flow.

Appendix C - AVGWL Model Outputs for Upper Pinchot Lake Watershed

GWLF Transport Summary for Pinchot_Seg1
Period of analysis: 10 years, 1989 to 1998

Month	Precip	Evapotrans	Gr. Wat. Flow	Runoff	Streamflow
	Units in Centemeters				
APR	6.8	0.5	7.7	0.0	7.7
MAY	11.7	2.7	8.5	0.1	8.6
JUN	7.5	6.7	4.4	0.1	4.4
JUL	12.1	9.9	3.2	0.1	3.3
AUG	9.0	9.2	1.1	0.0	1.2
SEP	9.3	6.1	1.1	0.0	1.2
OCT	7.0	2.8	2.3	0.1	2.4
NOV	9.6	1.5	5.7	0.3	6.0
DEC	7.3	0.7	6.5	0.2	6.7
JAN	8.7	0.4	6.4	0.6	7.0
FEB	6.4	0.5	6.5	0.3	6.8
MAR	11.5	1.1	9.4	0.5	9.8
Total	106.8	42.0	62.8	2.3	65.1

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GWLF Nutrient Summary for Pinchot_Seg1
Period of analysis: 10 years, 1989 to 1998

Month	MG (1000 Kg)		Nutrient Loads (Kg)			
	Erosion	Sediment	Dis. Nitr.	Tot. Nitr.	Dis. Phos.	Tot. Phos
APR	93.1	14.2	2603.9	2609.5	160.5	161.6
MAY	138.0	21.1	3056.6	3091.7	170.7	177.6
JUN	58.8	9.0	1564.6	1570.9	135.7	136.9
JUL	226.9	34.7	1239.5	1252.8	128.3	130.9
AUG	100.8	15.4	394.5	409.8	107.8	110.9
SEP	43.4	6.6	387.3	389.6	107.8	108.2
OCT	45.4	6.9	801.5	865.9	119.0	131.7
NOV	74.6	11.4	1992.3	2018.0	148.8	153.9
DEC	36.9	5.6	2464.2	2530.5	157.6	170.7
JAN	32.9	5.0	2956.0	3071.7	169.4	192.3
FEB	23.3	3.6	2644.1	2678.1	161.8	168.6
MAR	57.8	8.8	3295.5	3378.9	181.3	197.8
Total	931.8	142.6	23400.0	23867.3	1748.7	1841.2

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GWLF Total Loads for Pinchot_Seg1

Period of analysis: 10 years, 1989 to 1998

Source	(Ha) Area	(cm) Runoff	Mg (1000 Kg) Erosion	Mg (1000 Kg) Sediment	Total Loads (Kg) Dis. Nitr.	Total Loads (Kg) Tot. Nitr.	Total Loads (Kg) Dis. Phos.	Total Loads (Kg) Tot. Phos.
HAY/PAST	279	1.97	31.58	4.83	311.89	326.38	8.83	11.7
CROPLAND	631	5.99	759.44	116.19	2089.51	2438.09	59.91	128.93
CONIF_FOR	73	1.43	0.31	0.05	1.99	2.13	0.06	0.09
MIXED_FOR	107	1.43	0.58	0.09	2.91	3.18	0.09	0.14
DECID_FOR	2542	1.43	132.44	20.26	69.24	130.03	2.19	14.22
UNPAVED_RD	2	10.98	7.42	1.14	6.37	9.78	0.44	1.11
LO_INT_DEV	18	9.22	0.01	0.0	0.0	0.03	0.0	0.0
HI_INT_DEV	6	23.23	0.0	0.0	0.0	0.05	0.0	0.01
Stream Bank				26.4		39.5		7.8
Groundwater					18638.27	18638.27	500.36	500.36
Point Sources					0	0	1170	1170
Septic Syst.					2279.82	2279.82	6.81	6.81
Totals	3658	2.3	931.8	169.0	23400.0	23867.29	1748.7	1841.21

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Appendix D - AVGWL Model Outputs for Middle Pinchot Lake Watershed

GWLF Transport Summary for Pinchot_Seg2

Period of analysis: 10 years, 1989 to 1998

	Units in Centemeters				
Month	Precip	Evapotrans	Gr. Wat. Flow	Runoff	Streamflow
APR	6.8	1.4	7.0	0.0	7.1
MAY	11.7	3.5	7.7	0.1	7.8
JUN	7.5	7.0	3.9	0.0	4.0
JUL	12.1	9.9	3.0	0.1	3.0
AUG	9.0	8.9	1.1	0.0	1.1
SEP	9.3	6.0	1.3	0.0	1.3
OCT	7.0	3.1	2.3	0.1	2.4
NOV	9.6	1.8	5.4	0.2	5.6
DEC	7.3	0.8	6.3	0.2	6.5
JAN	8.7	0.6	6.3	0.5	6.8
FEB	6.4	0.7	6.4	0.2	6.6
MAR	11.5	1.7	9.1	0.4	9.4
Total	106.8	45.5	59.8	1.9	61.8

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GWLF Nutrient Summary for Pinchot_Seg2

Period of analysis: 10 years, 1989 to 1998

	MG (1000 Kg)		Nutrient Loads (Kg)			
Month	Erosion	Sediment	Dis. Nitr.	Tot. Nitr.	Dis. Phos.	Tot. Phos
APR	1.7	0.3	62.6	62.9	3.8	3.8
MAY	2.5	0.5	73.4	74.3	4.2	4.3
JUN	1.1	0.2	35.7	35.9	2.2	2.2
JUL	4.1	0.8	28.2	28.5	1.7	1.8
AUG	1.8	0.4	10.2	10.6	0.7	0.7
SEP	0.8	0.2	10.9	11.0	0.8	0.8
OCT	0.8	0.2	19.9	21.5	1.4	1.6
NOV	1.4	0.3	48.3	49.0	3.1	3.2
DEC	0.7	0.1	61.3	63.0	3.6	3.8
JAN	0.6	0.1	77.8	80.6	3.9	4.4
FEB	0.4	0.1	67.4	68.2	3.7	3.8
MAR	1.0	0.2	83.4	85.5	5.0	5.4
Total	16.9	3.3	579.3	591.0	33.9	35.7

Go Back | Loads by Source | Print | Export to Jpeg | Close

GWLF Total Loads for **Pinchot_Seg2**

Period of analysis: **10 years, 1989 to 1998**

Source	(Ha) Area	(cm) Runoff	Mg (1000 Kg) Erosion	Mg (1000 Kg) Sediment	Total Loads (Kg) Dis. Nitr.	Total Loads (Kg) Tot. Nitr.	Total Loads (Kg) Dis. Phos.	Total Loads (Kg) Tot. Phos.
HAY/PAST	9	1.97	0.49	0.09	10.06	10.35	0.29	0.33
CROPLAND	16	5.99	14.2	2.74	52.98	61.2	1.52	2.82
CONIF_FOR	40	1.43	0.19	0.04	1.09	1.2	0.03	0.05
MIXED_FOR	13	1.43	0.05	0.01	0.35	0.39	0.01	0.02
DECID_FOR	209	1.43	1.96	0.38	5.69	6.83	0.18	0.36
LO_INT_DEV	5	9.22	0.01	0.0	0.0	0.01	0.0	0.0
HI_INT_DEV	1	23.23	0.0	0.0	0.0	0.0	0.0	0.0
Stream Bank				1.3		1.9		0.3
Groundwater					277.38	277.38	31.01	31.01
Point Sources					0	0	0	0
Septic Syst.					231.71	231.71	0.85	0.85
Totals	293	1.9	16.9	4.6	579.26	590.96	33.89	35.74

Go Back | Print | Export to Jpeg | Close

Appendix E - AVGWL Model Outputs for Lower Pinchot Lake Watershed

GWLF Transport Summary for Pinchot_Seg3

Period of analysis: 10 years, 1989 to 1998

	Units in Centemeters				
Month	**Precip**	**Evapotrans**	**Gr. Wat. Flow**	**Runoff**	**Streamflow**
APR	6.8	1.1	7.3	0.1	7.3
MAY	11.7	3.2	8.0	0.1	8.1
JUN	7.5	6.6	4.1	0.1	4.2
JUL	12.1	9.6	3.2	0.1	3.3
AUG	9.0	8.6	1.3	0.0	1.3
SEP	9.3	5.9	1.5	0.0	1.6
OCT	7.0	3.0	2.5	0.1	2.7
NOV	9.6	1.7	5.7	0.3	6.0
DEC	7.3	0.8	6.4	0.2	6.6
JAN	8.7	0.5	6.3	0.6	6.9
FEB	6.4	0.6	6.3	0.3	6.7
MAR	11.5	1.5	9.1	0.5	9.6
Total	106.8	43.0	61.7	2.5	64.2

Go Back | Loads by Month | Print

Export to Jpeg | Close

GWLF Nutrient Summary for Pinchot_Seg3

Period of analysis: 10 years, 1989 to 1998

	MG (1000 Kg)		Nutrient Loads (Kg)			
Month	**Erosion**	**Sediment**	**Dis. Nitr.**	**Tot. Nitr.**	**Dis. Phos.**	**Tot. Phos**
APR	20.0	3.8	369.5	369.9	7.3	7.4
MAY	30.4	5.8	428.8	437.0	8.4	10.2
JUN	12.7	2.4	221.3	222.3	4.4	4.6
JUL	50.1	9.6	184.2	187.4	3.8	4.5
AUG	23.4	4.5	68.1	72.4	1.4	2.4
SEP	10.6	2.0	77.9	78.3	1.6	1.7
OCT	10.0	1.9	132.3	149.7	2.9	6.6
NOV	17.0	3.3	298.2	304.6	6.3	7.7
DEC	8.0	1.5	363.2	381.2	7.4	11.2
JAN	6.9	1.3	435.0	465.9	9.1	15.8
FEB	5.0	1.0	387.5	396.0	8.0	9.8
MAR	12.9	2.5	478.1	500.1	10.1	14.8
Total	207.0	39.7	3444.0	3564.7	70.8	96.7

Go Back | Loads by Source | Print

Export to Jpeg | Close

GWLF Total Loads for Pinchot_Seg3

Period of analysis: 10 years, 1989 to 1998

Source	(Ha) Area	(cm) Runoff	Mg (1000 Kg) Erosion	Sediment	Total Loads (Kg) Dis. Nitr.	Tot. Nitr.	Dis. Phos.	Tot. Phos.
HAY/PAST	60	1.97	16.75	3.22	67.07	76.72	1.9	3.97
CROPLAND	87	5.99	185.7	35.65	288.09	395.06	8.26	31.26
CONIF_FOR	29	1.43	0.15	0.03	0.79	0.88	0.02	0.04
MIXED_FOR	18	1.43	0.07	0.01	0.49	0.53	0.02	0.02
DECID_FOR	211	1.43	4.3	0.83	5.75	8.22	0.18	0.71
Stream Bank				1.0		1.5		0.3
Groundwater					2829.43	2829.43	59.52	59.52
Point Sources					0	0	0	0
Septic Syst.					252.39	252.39	0.85	0.85
Totals	405	2.5	207.0	40.7	3444.01	3564.72	70.75	96.7

Go Back | Print | Export to Jpeg | Close

Appendix F – BATHTUB Model Outputs for Pinchot Lake

```
BATHTUB.EXE
                         ═BATHTUB - VERSION 5.4═
  Case      Run       List      Plot     Utilities      Help      Quit
  Edit       Models       Read       Save        New        List       Morpho

          Define Case - Read, Enter, Edit, or List Input Values

   MOVE CURSOR & HIT <Enter> OR <First Letter> TO RUN ROUTINE, <F1,F7> HELP
CASE = Pinchot w/STP overflows            FILE = pinchot3.bin
SEGMENTS =  3,  TRIBUTARIES =  3,  CHANNELS =  0

MODEL OPTION ----->                  SELECTION ----->
CONSERVATIVE SUBSTANCE               0 NOT COMPUTED
PHOSPHORUS BALANCE                   1 2ND ORDER, AVAIL P
NITROGEN BALANCE                     0 NOT COMPUTED
CHLOROPHYLL-A                        5 P, JONES & BACHMAN
SECCHI DEPTH                         1 VS. CHLA & TURBIDITY
DISPERSION                           1 FISCHER-NUMERIC
PHOSPHORUS CALIBRATION               2 CONCENTRATIONS
NITROGEN CALIBRATION                 1 DECAY RATES
AVAILABILITY FACTORS                 1 USE FOR MODEL 1 ONLY
MASS-BALANCE TABLES                  1 USE ESTIMATED CONCS

OUTPUT TO: SCREEN                                          MODEL EXECUTED
```

```
CASE: Pinchot w/STP overflows

SEGMENT = 1 Upper Lake
CONSERVATIVE SUB=      .0   TOTAL P     MG/M3=    58.4   TOTAL N     MG/M3=      .0
CHL-A       MG/M3=   33.8   SECCHI          M=     1.2   ORGANIC N   MG/M3=   928.2
TP-ORTHO-P MG/M3=    56.1   HOD-V   MG/M3-DAY=      .0   MOD-V   MG/M3-DAY=      .0
C.NUTRIENT MG/M3=      .0   ANTILOG PC-1     =   720.9   ANTILOG PC-2     =    16.6
(N - 150) / P    =     .0   ZMIX * TURBIDITY=       .0   ZMIX / SECCHI    =     1.9
CHL-A * SECCHI   =   40.0   CHL-A / TOTAL P =       .6   TURBIDITY     1/M=      .0
INORGANIC N / P  =     .0   FREQ(CHL-a>10) %=     95.1   FREQ(CHL-a>20) %=    70.5
FREQ(CHL-a>30) %=    45.4   FREQ(CHL-a>40) %=     28.1   FREQ(CHL-a>50) %=    17.3
FREQ(CHL-a>60) %=    10.8   CARLSON TSI-P    =    62.8   CARLSON TSI-CHLA=    65.1
CARLSON TSI-SEC  =   57.6

SEGMENT = 2 Middle Lake
CONSERVATIVE SUB=      .0   TOTAL P     MG/M3=    54.2   TOTAL N     MG/M3=   945.0
CHL-A       MG/M3=   30.3   SECCHI          M=     1.3   ORGANIC N   MG/M3=   850.3
TP-ORTHO-P MG/M3=    50.7   HOD-V   MG/M3-DAY=      .0   MOD-V   MG/M3-DAY=      .0
C.NUTRIENT MG/M3=    41.9   ANTILOG PC-1     =   589.5   ANTILOG PC-2     =    17.0
(N - 150) / P    =   14.7   ZMIX * TURBIDITY=       .1   ZMIX / SECCHI    =     3.0
CHL-A * SECCHI   =   38.2   CHL-A / TOTAL P =       .6   TURBIDITY     1/M=      .0
INORGANIC N / P  =   26.8   FREQ(CHL-a>10) %=     93.0   FREQ(CHL-a>20) %=    64.1
FREQ(CHL-a>30) %=    38.4   FREQ(CHL-a>40) %=     22.4   FREQ(CHL-a>50) %=    13.2
FREQ(CHL-a>60) %=     7.9   CARLSON TSI-P    =    61.7   CARLSON TSI-CHLA=    64.1
CARLSON TSI-SEC  =   56.6

SEGMENT = 3 Lower Lake
CONSERVATIVE SUB=      .0   TOTAL P     MG/M3=    52.7   TOTAL N     MG/M3=   807.3
CHL-A       MG/M3=   29.1   SECCHI          M=     1.0   ORGANIC N   MG/M3=   838.2
TP-ORTHO-P MG/M3=    53.3   HOD-V   MG/M3-DAY=   447.4   MOD-V   MG/M3-DAY=   271.7
C.NUTRIENT MG/M3=    38.0   ANTILOG PC-1     =   593.8   ANTILOG PC-2     =    14.8
(N - 150) / P    =   12.5   ZMIX * TURBIDITY=      1.2   ZMIX / SECCHI    =     4.8
CHL-A * SECCHI   =   30.2   CHL-A / TOTAL P =       .6   TURBIDITY     1/M=      .2
INORGANIC N / P  =    1.0   FREQ(CHL-a>10) %=     92.1   FREQ(CHL-a>20) %=    61.6
FREQ(CHL-a>30) %=    36.0   FREQ(CHL-a>40) %=     20.5   FREQ(CHL-a>50) %=    11.8
FREQ(CHL-a>60) %=     7.0   CARLSON TSI-P    =    61.3   CARLSON TSI-CHLA=    63.7
CARLSON TSI-SEC  =   59.5
```

```
CASE: Pinchot w/STP overflows

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
 1 = OBSERVED WATER QUALITY ERROR ONLY
 2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
 3 = OBSERVED AND PREDICTED ERROR

SEGMENT:  1 Upper Lake
                       OBSERVED     ESTIMATED                T STATISTICS
VARIABLE               MEAN    CV   MEAN    CV    RATIO      1       2       3
----------------------------------------------------------------------------
TOTAL P    MG/M3         .0   .00   58.4   .00      .00    .00     .00     .00
CHL-A      MG/M3         .0   .00   33.8   .00      .00    .00     .00     .00
----------------------------------------------------------------------------

SEGMENT:  2 Middle Lake
                       OBSERVED     ESTIMATED                T STATISTICS
VARIABLE               MEAN    CV   MEAN    CV    RATIO      1       2       3
----------------------------------------------------------------------------
TOTAL P    MG/M3       63.0   .00   54.2   .00     1.16    .00     .56     .00
CHL-A      MG/M3       32.6   .00   30.3   .00     1.08    .00     .21     .00
----------------------------------------------------------------------------

SEGMENT:  3 Lower Lake
                       OBSERVED     ESTIMATED                T STATISTICS
VARIABLE               MEAN    CV   MEAN    CV    RATIO      1       2       3
----------------------------------------------------------------------------
TOTAL P    MG/M3       35.0   .00   52.7   .00      .66    .00   -1.52     .00
CHL-A      MG/M3       29.0   .00   29.1   .00     1.00    .00    -.01     .00
----------------------------------------------------------------------------

SEGMENT:  4 AREA-WTD MEAN
                       OBSERVED     ESTIMATED                T STATISTICS
VARIABLE               MEAN    CV   MEAN    CV    RATIO      1       2       3
----------------------------------------------------------------------------
TOTAL P    MG/M3       59.1   .00   55.4   .00     1.07    .00     .24     .00
CHL-A      MG/M3       32.1   .00   31.3   .00     1.03    .00     .08     .00
----------------------------------------------------------------------------
```

```
BATHTUB.EXE
                    BATHTUB - VERSION 5.4
 Case      Run       List      Plot     Utilities     Help     Quit
 Edit        Models      Read      Save      New        List      Morpho

       Define Case - Read, Enter, Edit, or List Input Values

  MOVE CURSOR & HIT <Enter> OR <First Letter> TO RUN ROUTINE, <F1,F7> HELP
CASE = Pinchot Lake w/ TMDL TP Reduct     FILE = pinchot4.bin
SEGMENTS  =   3,  TRIBUTARIES  =   3,  CHANNELS  =  0

MODEL OPTION ------>                  SELECTION ------>
CONSERVATIVE SUBSTANCE                0 NOT COMPUTED
PHOSPHORUS BALANCE                    1 2ND ORDER, AVAIL P
NITROGEN BALANCE                      0 NOT COMPUTED
CHLOROPHYLL-A                         5 P, JONES & BACHMAN
SECCHI DEPTH                          1 VS. CHLA & TURBIDITY
DISPERSION                            1 FISCHER-NUMERIC
PHOSPHORUS CALIBRATION                2 CONCENTRATIONS
NITROGEN CALIBRATION                  1 DECAY RATES
AVAILABILITY FACTORS                  1 USE FOR MODEL 1 ONLY
MASS-BALANCE TABLES                   1 USE ESTIMATED CONCS

OUTPUT TO: SCREEN
```

```
CASE: Pinchot Lake w/ TMDL TP Reduct

SEGMENT = 1 Upper Lake
CONSERVATIVE SUB=       .0  TOTAL P     MG/M3=     25.9  TOTAL N     MG/M3=       .0
CHL-A        MG/M3=   10.3  SECCHI          M=      3.9  ORGANIC N  MG/M3=     392.5
TP-ORTHO-P MG/M3=     14.3  HOD-V  MG/M3-DAY=        .0  MOD-V  MG/M3-DAY=        .0
C.NUTRIENT MG/M3=       .0  ANTILOG PC-1     =     77.6  ANTILOG PC-2     =     18.7
(N - 150) / P    =      .0  ZMIX * TURBIDITY=        .0  ZMIX / SECCHI    =       .6
CHL-A * SECCHI   =    39.8  CHL-A / TOTAL P =        .4  TURBIDITY     1/M=       .0
INORGANIC N / P =       .0  FREQ(CHL-a>10) %=     39.8  FREQ(CHL-a>20) %=      8.4
FREQ(CHL-a>30) %=      2.1  FREQ(CHL-a>40) %=        .6  FREQ(CHL-a>50) %=       .2
FREQ(CHL-a>60) %=       .1  CARLSON TSI-P    =     51.1  CARLSON TSI-CHLA=      53.5
CARLSON TSI-SEC =     40.5

SEGMENT = 2 Middle Lake
CONSERVATIVE SUB=       .0  TOTAL P     MG/M3=     25.2  TOTAL N     MG/M3=       .0
CHL-A        MG/M3=    9.9  SECCHI          M=      4.0  ORGANIC N  MG/M3=     383.6
TP-ORTHO-P MG/M3=     13.6  HOD-V  MG/M3-DAY=        .0  MOD-V  MG/M3-DAY=        .0
C.NUTRIENT MG/M3=       .0  ANTILOG PC-1     =     72.1  ANTILOG PC-2     =     18.8
(N - 150) / P    =      .0  ZMIX * TURBIDITY=        .0  ZMIX / SECCHI    =       .9
CHL-A * SECCHI   =    39.8  CHL-A / TOTAL P =        .4  TURBIDITY     1/M=       .0
INORGANIC N / P =       .0  FREQ(CHL-a>10) %=     37.4  FREQ(CHL-a>20) %=      7.5
FREQ(CHL-a>30) %=      1.8  FREQ(CHL-a>40) %=        .5  FREQ(CHL-a>50) %=       .2
FREQ(CHL-a>60) %=       .1  CARLSON TSI-P    =     50.7  CARLSON TSI-CHLA=      53.1
CARLSON TSI-SEC =     40.0

SEGMENT = 3 Lower Lake
CONSERVATIVE SUB=       .0  TOTAL P     MG/M3=     25.2  TOTAL N     MG/M3=       .0
CHL-A        MG/M3=    9.9  SECCHI          M=      4.0  ORGANIC N  MG/M3=     382.9
TP-ORTHO-P MG/M3=     13.6  HOD-V  MG/M3-DAY=     253.6  MOD-V  MG/M3-DAY=     154.0
C.NUTRIENT MG/M3=       .0  ANTILOG PC-1     =     71.7  ANTILOG PC-2     =     18.8
(N - 150) / P    =      .0  ZMIX * TURBIDITY=        .0  ZMIX / SECCHI    =      1.2
CHL-A * SECCHI   =    39.8  CHL-A / TOTAL P =        .4  TURBIDITY     1/M=       .0
INORGANIC N / P =       .0  FREQ(CHL-a>10) %=     37.2  FREQ(CHL-a>20) %=      7.4
FREQ(CHL-a>30) %=      1.8  FREQ(CHL-a>40) %=        .5  FREQ(CHL-a>50) %=       .2
FREQ(CHL-a>60) %=       .1  CARLSON TSI-P    =     50.7  CARLSON TSI-CHLA=      53.1
CARLSON TSI-SEC =     39.9
```

Appendix G - Equal Marginal Percent Reduction Method

The Equal Marginal Percent Reduction (EMPR) allocation method was used to distribute Adjusted Load Allocations (ALAs) between the appropriate contributing nonpoint sources. The load allocation and EMPR procedures were performed using MS Excel and results are presented below. The 5 major steps identified in the spreadsheet are summarized below:

Step 1: Calculation of the TMDL based on impaired watershed size and unit area loading rate of reference watershed.

Step 2: Calculation of Adjusted Load Allocation based on TMDL, Margin of Safety, and existing loads not reduced.

Step 3: Actual EMPR Process.

a. Each land use/source load is compared with the total ALA to determine if any contributor would exceed the ALA by itself. The evaluation is carried out as if each source is the only contributor to the pollutant load of the receiving waterbody. If the contributor exceeds the ALA, that contributor would be reduced to the ALA. If a contributor is less than the ALA, it is set at the existing load. This is the baseline portion of EMPR.

b. After any necessary reductions have been made in the baseline, the multiple analyses are run. The multiple analyses will sum all of the baseline loads and compare them to the ALA. If the ALA is exceeded, an equal percent reduction will be made to all contributors' baseline values. After any necessary reductions in the multiple analyses, the final reduction percentage for each contributor can be computed.

Step 4: Calculation of total loading rate of all sources receiving reductions.

Step 5: Summary of existing loads, final load allocations, and % reduction for each pollutant source.

Microsoft Excel - Pinchot_Seg-sum.xls

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Total Phosphorus**		**(kg/yr)**										
2	**Existing Load**		1,973.65										
3	**Point Source Overflows**		1,170.00										
4			803.65										
5	**Targeted TMDL**		650.96										
6													
7	**Step 1:**	**TMDL**				**Step 2:**	**Adjusted LA = (TMDL- MOS) - loads not reduced**						
8		**650.96**					**560.55**						
9											**MOS =**	65.10	
10											**LA =**	585.86	
11											**LNR=**	25.31	
12													
13	**Step 3:**		**Annual Average Load (kg)**	**Load Sum**	**Check**	**Initial Adjust**	**Recheck**	**% reduction allocation**	**Load Reduction**	**Initial LA**	**Area (ha)**	**Allowable Loading Rate (kg/ha)**	**% Reduction**
14		**Hay/Past.**	16.01	778.34	good	16.01	ADJUST	0.02	4.01	12.00	348.00	0.034	25%
15		**Cropland**	163.00		good	163.00	187.46	0.22	40.85	122.15	734.00	0.166	25%
16		**Stream Bank**	8.45		good	8.45		0.01	2.12	6.33	-	-	25%
17		**Groundwater**	590.88		bad	560.55		0.75	140.48	420.07			29%
18						748.01		1.00		560.55			
19													
20	**Step 4:**	**All Ag.**	**0.12**										
21													
22													
23	**Step 5:**		**Area (ha)**	**Allowable (Target) Loading Rate (kg/ha)**	**Final LA**	**Current Loading Rates**	**Current Load**	**% Red.**					
24		**Hay/Past.**	**348.00**	**0.034**	**12.00**	**0.05**	**16.01**	**25%**					
25		**Cropland**	**734.00**	**0.166**	**122.15**	**0.22**	**163.00**	**25%**					
26		**Stream Bank**	-	-	**6.33**	-	**8.45**	**25%**					
27		**Groundwater**	-	-	**420.07**		**590.88**	**29%**					
28													
29		**Total**	**1,082.00**		**560.55**		**778.34**	**28%**					

Appendix H – Comment & Response Document

The Department received one set of comments on the draft Pinchot Lake TMDL report during the official comment period. The comments were submitted by:

Thomas Henry, Acting Chief
PA/DE Branch
Office of Watersheds
Region 3
US Environmental Protection Agency

EPA's comments and DEP's responses are summarized below:

Comment: 1. "Section 1A, Paragraph 2. Please provide a short description of the types of agriculture in the lake basin."
Response: The final version of the report contains additional information on the agriculture activities present in the basin.

Comment: 2. "Section 2A, Table2. It is recommended that the terms 'Secchi disc' and 'Hypolimnion oxygen' within this section be explained."
Response: The terms "secchi-disk" and "hypolimnion oxygen" are explained/defined in Section 2A of the final version of the report.

Comment: 3. "Section 2A, Table 3. Please keep tables together on one page."
Response: Table 3 appears on one page in the final version of the report.

Comment: 4. "Section 2B, Paragraph 2. Please italicize "b)"."
Response: The requested change was made to the final version of the report.

Comment: 5. "Section 2C. Please expand the discussion explaining 1) the relationship between chlorophyll-a and algal biomass, and 2) why the 10 µg/L water quality target for Pinchot Lake is appropriate."
Response: Additional language explaining the relationship between chlorophyll-a, algal biomass, and the numerical water quality target was added to Section 2C in the final version of the report.

Comment: 6. "The report very briefly discusses D.O. levels and WWF criteria. Covering these issues in Section 2A is recommended since they are applicable to the lake' nutrient issues and water classification status."
Response: Additional language was added to Section 2A in the final version of the report. This will hopefully help explain why the Department decided to concentrate on the organic enrichment portion of the 1996 and 1998 303d listings for organic enrichment/low D.O.

Comment: 7. "All acronyms should be spelled out when initially used and all titles for acronyms should be consistent throughout the text, i..e. AWGWLF and BATHTUB."
Response: An attempt was made in the final version of the report to spell out all acronyms when initially used. An attempt was also made to be consistent with acronyms throughout the document. To the best of DEP's knowledge, "BATHTUB" is not an acronym per se, but rather a "catchy" name given to the lake model by the U.S. Army Corps of Engineers (ACOE).