A TOTAL MAXIMUM DAILY LOAD ANALYSIS FOR KENOSIA LAKE IN DANBURY, CONNECTICUT

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This document has been established pursuant to the requirements of Section 303(d) of the Federal Clean Water Act

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INTRODUCTION

The Federal Clean Water Act (CWA) provides regulations for the protection of streams, lakes, and estuaries within the United States. Section 303(d) of the CWA requires individual states to identify waters not meeting state water quality standards due to pollutant discharges and to develop Total Maximum Daily Loads (TMDLs) for these waters. A TMDL sets the maximum amount of a substance that a waterbody can receive without exceeding current state water quality standards, with the intent of supporting designated uses. Waterbodies for which Connecticut is required to develop TMDLs are included on the 2002 *List of Connecticut Waterbodies Not Meeting Water Quality Standards* [(1)] *(*2002 *List)*. Such waterbodies are identified on the 2002 *List* as Tiers 2 and 3. Kenosia Lake is included on the 2002 *List* as a Tier 2 waterbody due to impairment of recreational use caused by excessive nutrient loading and concentration. As such, TMDLs for nutrients (nitrogen and phosphorus) have been prepared for Kenosia Lake and are presented herein.

The purpose of the Kenosia Lake TMDL is to establish nutrient (nitrogen and phosphorus) loading targets that, if achieved, will result in consistency with the *State of Connecticut Water Quality Standards* [(2)] (WQS). Water quality that is consistent with WQS is expected to protect designated uses, and implies that conditions will be similar to those expected under natural conditions without undue human influence. This TMDL analysis was prepared following the Environmental Protection Agency's (EPA) protocol for developing nutrient TMDLs [(3)]. The main objectives of this TMDL analysis report include the following:

- describe existing conditions and applicable standards and guidelines;
- estimate the loading capacity of Kenosia Lake;
- assign loading capacities for existing and future sources;
- establish a margin of safety;
- account for seasonal variation;
- develop a monitoring plan;
- develop an implementation plan;
- provide reasonable assurances that the plans will be acted upon; and
- describe public participation in the TMDL process.

Determining the maximum daily nutrient load that a lake waterbody can assimilate without exceeding water quality standards is challenging and complex. First, many lakes receive a high portion of their nutrient loading from non-point sources, which are highly variable and are difficult to quantify. Secondly, lakes manifest nutrient loading on a seasonal scale, not on a daily basis. Loading during the winter months may have little effect on summer algal densities. Additionally, the nutrient loading capacity of lakes is typically determined through water quality modeling, which is usually expressed on an annual basis. Therefore, it is most appropriate to quantify a lake TMDL as an annual load and evaluate the results of that annual load on mid-summer conditions that are most critical to supporting recreational uses. Finally, variability in loading may be very high in response to weather patterns, and the forms in which nutrients enter lakes may cause increased variability in response. Consequently, while a single value may be chosen as the TMDL for each nutrient, it represents a range of loads with a probability distribution for associated water quality problems (such as algal blooms). Uncertainty is likely to be very high, and the TMDL should be viewed as a nutrient-loading goal that helps set the direction and magnitude of management, not as a rigid standard that must be achieved to protect against eutrophication.

DESCRIPTION OF WATERBODY

Much of the waterbody information presented in this section was obtained from a Diagnostic/Feasibility Study (D/F) of Kenosia Lake [(4)] completed for the City of Danbury in July 2000 and a follow-up stormwater investigation completed in 2001 [(5)].

Kenosia Lake is a 65-acre fresh water lake located in Danbury, Connecticut (northwest Fairfield County). Recreational uses are encouraged by the presence of a town beach and state boat launch. Kenosia Lake also serves as a back-up water supply to augment other sources with up to 9 millions gallons per day withdrawn on an intermittent basis. The lake and its 3,264-acre watershed lie within the Housatonic River basin and form the headwaters of the Still River. The maximum and mean water depths are 18.0 and 11.6 feet, respectively. The watershed is mostly comprised of forested (57%) and developed urban (30%) areas [(6)]. The remaining thirteen percent (13%) of the watershed consists of agriculture and open land. The majority of the developed areas surround the lake and extend north and west. Base flow from the watershed accounts for 49% of the total inflow to Kenosia Lake. Storm flow provides another 44%. As a result of high stormwater inputs, the detention time of Kenosia Lake varies mainly in response to precipitation (from one week to four months).

Limited stormwater controls exist throughout the watershed, lowering nutrient and solids loading to the lake only slightly. The lake experiences non-algal turbidity in response to inclement weather (runoff with soil erosion), algal blooms under low-flow conditions (high fertility with low flushing), and excessive rooted plant density, specifically Eurasian watermilfoil (*Myriophyllum spicatum*) and coontail (*Ceratophyllum demersum*). Nitrogen and phosphorus from anthropogenic sources are the root cause of eutrophication in Kenosia Lake and are therefore the subject of this TMDL. However, it should be noted that while past watershed inputs are to some extent responsible for current rooted plant growths, reduced nutrient loading is not expected to control those growths now that a nutrient-rich sediment base has accumulated.

Separate management actions will be required to address the impairment caused by rooted plants, and are not included in this TMDL.

PRIORITY RANKING AND POLLUTANTS OF CONCERN

Kenosia Lake is included on the 2002 *List* due to impairment of recreational use caused by excessive anthropogenic nutrient (nitrogen and phosphorus) loading. Excess nutrient loading to Kenosia Lake has resulted in increased algae growth, chlorophyll *a*, and to some extent increased growth of noxious and exotic plants, which impair recreational uses. Kenosia Lake is ranked a "T" priority on the 2002 *List*, which indicates that the waterbody is currently under study and may lead to development of a TMDL within the next two years if warranted. The State DEP has determined that establishing a TMDL is an appropriate pollution control strategy based on the results of a Diagnostic/Feasibility (D/F) study conducted in 2000 [(4)] and a follow-up stormwater investigation conducted in 2001 [(5)].

POLLUTANT SOURCES

Identification of Sources:

Sources of nitrogen and phosphorus include stormwater runoff, construction activities, use of fertilizers, illicit connections, failed or improperly functioning septic systems, and wildlife. The routes of entry for nitrogen and phosphorus to Kenosia Lake as identified in the D/F study include the following:

- surface water base flow (dry weather tributary flows, including groundwater infiltration);
- stormwater flow (runoff added to tributaries or directly to the lake);
- atmospheric deposition (direct precipitation to the lake);
- waterfowl (direct inputs to the lake from birds); and
- internal recycling (release from the sediment, either by chemical interaction with overlying waters, resuspension by wind, or “pumping” by macrophytes).

There are no permitted point source discharges of nutrients in Kenosia Lake's basin, with the exception of some stormwater discharges that are regulated as point sources under the federal NPDES regulations.

Analysis of Current and Background Loading:

Current nitrogen and phosphorus loading to Kenosia Lake was assessed using the following four methods:

1. Existing data (water budget and nutrient concentrations) from the D/F study. Direct assessment is the most traditional method of evaluating loading, but requires substantial data to be reliable. As all individual sources are not directly assessed in field studies, extrapolation and estimation are still necessary. However, direct measurement provides real data upon which to base loading estimates, and acts as a valuable reality check on modeling approaches.
2. Existing data (adjusted water budget and nutrient concentrations) from the 2001 drainage study. Additional data helped to refine the analysis provided through the D/F study, especially as it relates to stormwater inputs that exhibit high variability in water quality.
3. The average of empirical models [6-12] (Bachman [6], Kirchner-Dillion [7], Vollenwieder [8], Vollenweider [9], Reckhow [10], Larsen-Mercier [11], and Jones-Bachmann [12]). Empirical models generate estimates of the load necessary to achieve observed in-lake conditions, based on system features such as depth and detention time. They are based on relationships derived from many other lakes. As such, they may not apply accurately to any one lake, but provide an approximation of current loading and a reasonable estimate of the direction and magnitude of changes that might be expected if loading is altered.
4. Calibrated land use export coefficient model developed by ENSR [13] under contract to the DEP. Export coefficient models depend on empirical or assumed yields of water and nutrients from the watershed as a function of land use. Yields are assigned to each defined parcel in each defined sub-watershed of the lake. These yields can be modified as they move toward the lake through attenuation factors, based on distance to the lake, soils and any Best Management Practices (BMPs) in place. The export coefficient model employed here was developed by Kenneth Wagner, Ph.D. of ENSR for use in southern New England, and allows the user to select yield coefficients and attenuation factors from a range appropriate to this area. Values encompass those applied in the Long Island Sound Study [14] and work by Frink and Norvell [15] at the Connecticut Agricultural Station over many years. The generated load to the lake is processed through the empirical models noted above to derive estimates of in-lake concentrations and effects on algal productivity and water clarity. This model is most effective when calibrated with water quality data for the target system. While it is a spreadsheet model with inherent limitations on applied algorithms and resultant reliability of predictions, it provides a rational means to link actual water quality data and empirical models in an approach that addresses the whole watershed and lake.

This combination of approaches yielded a range of probable loads and provides a reasonable approximation of actual conditions over the longer term. From the four methods, total nitrogen loading ranged from 6,666 to 8,161 kg/yr and total phosphorus loading ranged from 365 to 735 kg/yr. Results of each method are provided in Table 1.

Table 1. Annual Nitrogen and Phosphorus Loading (Adapted from ENSR 2000[4]).

Method	Method ID Number	Nitrogen (kg/yr)	Phosphorus (kg/yr)
Existing Data D/F Study	1	6666	403
Existing Data Drainage Study*	2	6712	735
Empirical Model Average	3	7304	365
Land Use Export Coefficient Model	4	8161	396
Mean of All Methods		**7211**	**475**

*Only 3 basins evaluated in the 2001 drainage study; D/F study data was used to complete the budget

Nitrogen loading estimates from the four approaches are generally similar. The inter-annual range of nitrogen loads could be expected to exhibit such a range. The phosphorus loading estimates are similar for three of four approaches. The much higher estimate, derived from the drainage study, is a function of high phosphorus concentrations in early storm samples that represent overestimates of actual inputs. First flush effects have a greater influence on phosphorus loading estimates than on nitrogen loading estimates because a greater percentage of the total phosphorus concentration is in particulate form. Proportionally more of the total storm phosphorus loading is therefore contributed during the "first flush" when runoff velocities are highest and particulate material is resuspended and transported. In order to minimize the effects of stormwater first flush on total phosphorus loading estimates, 50% of the measured value was used to derive total storm inputs. This approach, although an improvement, continued to result in an overestimate of actual inputs. Regardless, the loading estimates for the land use export coefficient model are similar enough to the other three methods to justify further use of the model for computation of the nitrogen and phosphorus target loads.

The Kenosia Lake watershed was divided into six sub-basins (Figure 1) in order to consider nutrient loading among drainage areas. It is important to note that loadings from sub-basins 1-3 are included in sub-basin 4 since these basins pass through sub-basin 4 prior to entering Kenosia Lake. There is attenuation within each sub-basin that acts to reduce the cumulative load contribution from each. For example, attenuation of nutrients within sub-basins 1-3 results in the total loading from sub-basin 4 being less than the sum of loadings for sub-basins 1-3. Attenuation of total nitrogen in base flow and storm flow averages approximately 20-30% while attenuation of total phosphorus is substantially higher; approximately 48%-75% for base flow and stormwater flow, respectively. The higher attenuation rate for total phosphorus (in comparison to total nitrogen) results from the higher proportion of total phosphorus in particulate form.

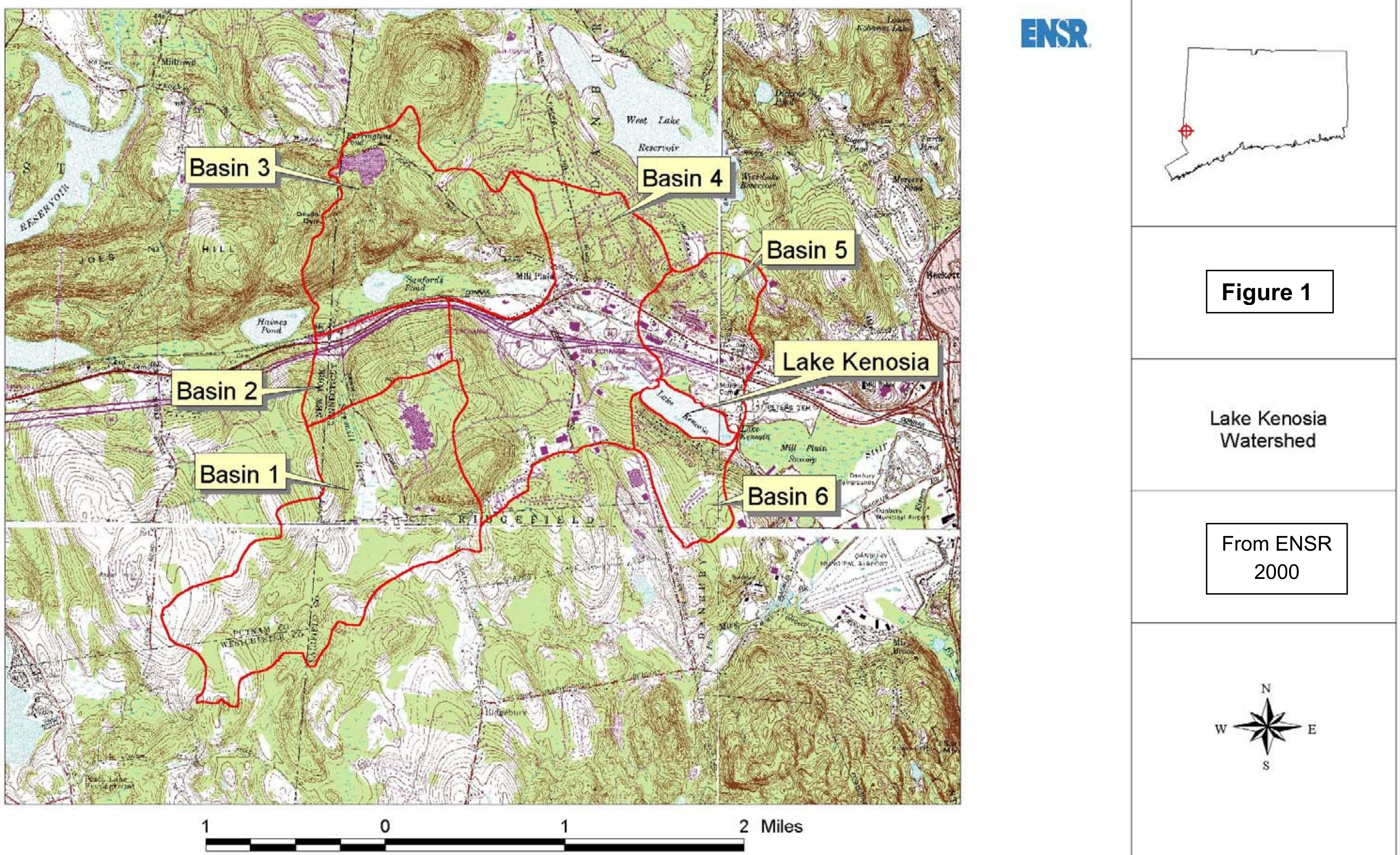

Figure 1

Lake Kenosia Watershed

From ENSR 2000

Background conditions were estimated using the land use export coefficient model calibrated to reflect current conditions at Kenosia Lake. Land use within the model was then changed to reflect pre-development background conditions (i.e. forested and wetland conditions) and the internal load was reduced by 50% (an estimate of more natural internal loading level). Background nitrogen and phosphorus loads under this scenario were 3,005 kg/yr and 181 kg/yr, respectively (2,703 kg/yr and 148 kg/yr from the watershed alone). Background in-lake nitrogen and phosphorus concentrations predicted from empirical models were 334 ug/L and 19 ug/L, respectively. A reduction of 55-63% from the current total nitrogen loading and 50-75% reduction from the current total phosphorus load would be necessary to return the watershed to expected "background" loading conditions.

Assumptions and Calculations Regarding Nitrogen and Phosphorus Sources:

Estimation of nutrient loading involves assumptions and can be derived in multiple ways. To facilitate understanding of the approaches applied here, the following listing of assumptions and calculation methods is offered:

Hydrologic Inputs

Direct precipitation

- Average annual precipitation for southwestern New England (16) was multiplied by the lake area.

Surface Water Base & Storm Flow

- Average annual precipitation was multiplied by runoff and base flow coefficients (17) based on land use obtained from UCONN (18).

Ground Water

- An estimate of permeable benthic area was multiplied by a seepage rate typical of areas with similar topography and soils (19).

Water Supply Withdrawal

- Withdrawal of up to 9 MGD on an intermittent basis is not significant to overall hydrology of Kenosia Lake (20).

Nutrient Inputs

Existing Data *(data collected in the field by ENSR personnel)*

- Nutrient concentrations for base and storm flow were multiplied by corresponding hydrologic inputs to obtain an estimated load.
- High variability in stormwater phosphorus concentrations resulted in a wide range of phosphorus loading.

- Total phosphorus concentrations were halved in an attempt to account for overestimation due to first flush sampling.

Empirical Model

- Hydrologic lake features and known in-lake concentrations were used to back-calculate the nutrient load required to obtain observed in-lake concentrations.
- A single three-part model was used for nitrogen (Bachman [(6)]) and an average of five phosphorus models was used (Kirchner-Dillion [(7)], Vollenweider [(8)], Vollenweider [(9)], Reckhow [(10)], Larsen-Mercier [(11)], and Jones-Bachmann [(12)]).

Export Coefficient Model

- Nutrient export coefficients from the literature for different land use types were used to calculate potential nutrient loads.
- Loads were reduced based on estimated natural attenuation and any existing water quality control devices, and adjusted based on comparison of results with existing data.
- Once calibrated for the specific watershed, this model is also used to predict impacts of watershed management actions.

Relationships

- It was assumed that water transparency and chlorophyll *a* concentrations in Kenosia Lake are mathematically related to total phosphorus concentrations as described by Carlson [(21)] and Frink and Norvell [(15)]. Interference by non-algal turbidity, toxicity, or other possible factors is assumed to be minimal.

Summary:

Kenosia Lake is a relatively shallow, 65-acre fresh water lake with a 3,264-acre watershed. The watershed exhibits substantial urbanization, primarily of the land surrounding the lake. In-lake water quality is dependent on the quality of surface water entering the lake from the watershed, and especially on stormwater runoff quality. Inadequate stormwater controls have lead to a decline in water quality and high variability of in-lake water quality. Excessive anthropogenic nitrogen and phosphorus loading over time has led to increased frequency and duration of algal blooms. Nutrient-rich sediment deposits support excessive rooted plant density. Multiple approaches provide estimates of the loads of nitrogen and phosphorus to Kenosia Lake that can be compared to desirable loading levels, based on water quality standards relating to use attainment goals. The current loading range of nitrogen is 6,666 to 8,161 kg/yr and phosphorus is 365 to 735 kg/yr. However, it is suspected that current phosphorus loading is closer to the low end of this range (365 kg/yr), as the highest estimate is based on early storm data (albeit adjusted downward by 50%) that likely still represents an overestimate total storm inputs. Background nitrogen and phosphorus loads were estimated to be 3,005 kg/yr and 181 kg/yr, respectively. As

such, a 55-63% reduction in current total nitrogen loading and 50-75% reduction in current total phosphorus load would be necessary to return the watershed to expected "background" loading conditions.

APPLICABLE WATER QUALITY STANDARDS

Kenosia Lake has been assigned a surface water classification of AA by the State of Connecticut. Surface water classifications are not a measure of water quality but rather they establish designated uses for a waterbody. Designated uses for Class AA waters include existing or proposed drinking water supply, habitat for fish and other aquatic life and wildlife; recreation; and water supply for industry and agriculture. Existing uses for Kenosia Lake include habitat for fish, other aquatic life, and wildlife; and recreation. Kenosia Lake is also used as a source of drinking water suitable for human consumption following treatment.

The applicable water quality standards for Kenosia Lake include two categories: Surface Water Standards and Lake Trophic Categories. The surface water standards criteria for nitrogen and phosphorus, for which Kenosia Lake TMDLs have been derived, are narrative. Standard numbers 8, 10, 11, 12, 13, 17, and 19 of the WQS [2] aid in the interpretation of such criteria. Specifically, standard 8 specifies that only those nutrients that remain following application of Best Management Practices (BMPs) can be considered to be of natural origin. Achieving consistency with this standard requires that 1) BMPs be used to minimize nutrient releases resulting from human activity and, 2) the nutrient loading that remains following implementation of BMPs does not result in adverse impact to existing or designated uses. As noted in the previous section, current practices to manage stormwater runoff are inadequate and much of the present nutrient loading to the lake cannot be considered "natural" due to the absence of effective BMPs. In order for the nutrient loading to be considered "natural" and consistent with standard 8, additional BMPs must be implemented in the watershed. Further, the post-BMP implementation loading must not adversely impact an existing or designated use in order to be considered "natural". This determination is made based on an examination of the impact of the projected post-BMP loading on recreational uses. Recreational uses in lakes are primarily determined by the lake's trophic category. Nutrient loading from human activities that results in the degradation of a lakes trophic category represents an adverse impact to designated recreational uses.

The lake trophic categories include numerical expected ranges for total phosphorus, total nitrogen, chlorophyll *a*, and secchi disk transparency. The values of these parameters vary depending on the trophic category. Designated recreational uses will be considered fully supported and maintained for lakes that do not exceed the numerical values for their expected trophic category. Such trophic categories are determined through assessments of lakes, absent of significant cultural impacts. Based on the surface area and depth, watershed size relative to lake area and volume, and natural features of the watershed, the expected trophic state of Kenosia Lake is mesotrophic to slightly eutrophic. As such, in the absence of any human influence or alteration of the natural nutrient load to the lake, Kenosia Lake would be in a mesotrophic condition, and might be slightly eutrophic. Connecticut WQS establish the following concentration ranges for nutrients, chlorophyll *a* and transparency as a guideline for evaluating attainment of mesotrophic conditions:

Total Phosphorus	10 - 30 ug/L spring and summer
Total Nitrogen	200 - 600 ug/L spring and summer
Chlorophyll *a*	2 - 15 ug/L mid-summer
Secchi Disk Transparency	2 - 6 meters mid-summer

However, Kenosia Lake currently has elevated nutrient concentrations and limitations on some forms of recreation that are an apparent consequence of human-derived inputs. The current trophic category for Kenosia Lake is eutrophic while the trophic condition that would exist in the absence of significant cultural impact is mesotrophic. To achieve consistency with Connecticut WQS and fully support designated recreational uses, nutrient loading to Kenosia Lake must be reduced.

Mesotrophic lakes generally provide substantial opportunities for water contact recreation. A significant percentage of the mesotrophic lakes in Connecticut have designated swimming areas and other "primary" contact activities such as water skiing and tubing. Boating and other “secondary” contact uses are considered recreational uses in mesotrophic lakes as well. There may be brief times during the year or limited areas of a mesotrophic lake where aesthetic considerations (i.e. macrophyte growth or short duration algal blooms) cause some reduction in the level of recreational activity. These limitations are not considered to be “impairments” since they reflect the normal and expected conditions in a mesotrophic lake.

TOTAL MAXIMUM DAILY LOAD

Kenosia Lake is listed on the 2002 *List* for impairment to recreational uses caused by excessive nutrient concentrations. Although nitrogen and phosphorus are naturally occurring elements, the amount of nitrogen and phosphorus entering Kenosia Lake has increased due to anthropogenic activities (i.e., development, fertilizer use, illicit connections, improperly functioning or failed septic systems, direct stormwater piping to the lake, and inadequate stormwater controls). Increased nutrient loading has led to increased phytoplankton densities, reduced water clarity, poor aesthetic quality, and low dissolved oxygen near the lake bottom, as well as altered natural color, taste and odor. Excessive rooted plant density also alters aesthetic characteristics and can impair designated uses such as recreation, navigation and potentially fish and wildlife habitat. While excessive rooted plant densities are more a function of accumulated nutrient-rich sediment than water column nutrient concentrations, these sediments are ultimately derived from watershed loading.

In order to achieve conditions consistent with Connecticut WQS, the TMDL must be based on reducing current loads to a level that can be considered "natural" in accordance with standard 8. This equates to the loading that will be achieved following implementation of BMPs to control nutrients throughout the watershed, provided that the target loading does not adversely impact any existing or designated uses.

The TMDL for Kenosia Lake is expressed as an annual load with the critical time being spring and early summer (See the "Seasonal Variation" section for a discussion of the critical time and seasonal loading component of the TMDL.). As required, the TMDL accounts for waste load allocations (WLA) for all point sources, including stormwater discharges regulated under the NPDES program; load allocations (LA) for all nonpoint sources, including background loading; and a margin of safety (MOS). The MOS accounts for any uncertainty regarding the relationship between waste load and load allocations, and water quality. The equation for the TMDL analysis is as follows:

$$TMDL = LA + WLA + MOS$$

The following section describes how the target loading was estimated. Based on the target loading, the expected resulting conditions for Kenosia Lake were modeled and evaluated with respect to achieving compliance with the WQS (Appendix A).

Target Loading:

Target loads for nitrogen and phosphorus to Kenosia Lake were determined using the land use export coefficient model (method 4). This approach was selected because it provides loading estimates based on land use categories and allows for reductions to be applied toward urban land use where it is generally anticipated that BMPs will be applied. In addition, this method calculates stormwater flow, which is needed in order to separate allocations for regulated and non-regulated stormwater as requested in the EPA's 2002 Guidance Memorandum [22].

As previously mentioned, a 55-63% reduction in current total nitrogen loading and 50-75% reduction in current total phosphorus loading would be necessary to return the watershed to expected "background" loading conditions. Realistically, an aggressive reduction of nitrogen and phosphorus loading attained by using BMPs applied to manageable sources is expected to result in loading reductions on the order of 60%. Greater reductions are possible without consideration of costs, space requirements, or legal ramifications (e.g., land acquisitions), but most techniques applied in a practical manner do not yield greater than 60% reductions in nitrogen or phosphorus loads [23]. The form of nitrogen or phosphorus will have a substantial impact on achievable loading reduction and choice of BMPs, with particulate forms easier to reduce than dissolved forms. Dissolved forms of nitrogen, especially nitrate, are particularly hard to remove except with anaerobic wetland treatments. Aerated soil will remove particulate phosphorus by filtration and adsorption, but substantial detention time is needed to remove dissolved forms. The assumption of a 60% reduction in nitrogen and phosphorus is ambitious but possible for the Kenosia Lake watershed.

A 60% reduction of total nitrogen loading from urban land uses would result in a total annual nitrogen load of 4,790 kg/yr (Table 2). A 60% reduction of total phosphorus loading from urban land uses combined with a 50% reduction in internal loading of phosphorus within Kenosia Lake would result in a total annual phosphorus load of 248 kg/yr (Table 2). Based on empirical models [6-12], the corresponding in-lake concentrations of nitrogen and phosphorus would be 478 ug/L and 25 ug/L, respectively. Upon the implementation of BMPs within urban land use areas, the remaining nutrient loading could be considered "natural" provided it does not result in adverse impacts to designated uses.

Table 2. Summary of Total Nitrogen and Total Phosphorus Current Load, Post-BMP Implementation Load and Predicted In-lake Concentrations.

	Current Conditions			Post – BMP Implementation			
	Watershed Load (kg/yr)	Other Load (kg/yr)	Total Load (kg/yr)	Watershed Load (kg/yr)	Other Load (kg/yr)	Total Load (kg/yr)	In-lake Concentration (ug/L)
TOTAL NITROGEN							
Export Coefficient Model	7438	723	8161	4067	723	4790	478
TOTAL PHOSPHORUS							
Export Coefficient Model	334	62	396	194	54	248	25

Stormwater Allocation

Recently issued EPA policy guidance [22] suggests that TMDL analyses provide separate allocations for “regulated” and “non-regulated” stormwater. Regulated stormwater is defined by EPA as stormwater that is discharged through a point source (discrete outfall) and requires a permit under federal NPDES regulations. This includes stormwater discharged from industrial facilities and construction sites covered under the “Phase I Rule" [24], and municipal small separate storm sewer (MS4) discharges covered under the “Phase II Rule" [25]. MS4 communities have been determined by the Census Bureau based on the 2000 population information. As such, the City of Danbury is considered an MS4 community and therefore, all stormwater loading to Kenosia Lake has been considered regulated (Table 3).

Table 3. Allocation of Current Regulated and Non-regulated Stormwater Loading.

Stormwater Allocation	Total Nitrogen (kg/yr)	Total Phosphorus (kg/yr)
Current Conditions		
Surface Water Base Load	4130	5
Stormwater Load	3308	329
Total Watershed Load	7438	334
Regulated Stormwater Load	**3308**	**329**
Non-regulated Stormwater Load	**0**	**0**

Based on methods 1, 2, and 4, stormwater inputs accounted for approximately 40-58% of the annual total nitrogen load, while base flow accounted for 30-51%. Stormwater inputs accounted for 58-83% of the annual total phosphorus load, while base flow accounted for 1-31%. Internal recycling of phosphorus from lake sediment accounted for approximately 2-3% of the total load. Direct precipitation, waterfowl, and internal sediment recycling combined to provide only relatively small portions of the total nitrogen and phosphorus loads and are therefore not considered significant controllable sources. Successful management must therefore focus on base flow and storm flow contributions, although the seasonal nature of internal loading may necessitate some action relating to this source as well.

Load Allocation

The non-point source load allocation for Kenosia Lake includes allocations to surface water base flow (including groundwater infiltration), internal sediment loading, atmospheric deposition, and waterfowl loading (Table 4).

The phosphorus load allocation for internal sediment recycling (i.e., release from sediment) is half the estimated current load, or about 8 kg/yr, and is most likely to be achieved by phosphorus inactivation with an aluminum compound. Reduced loading from the watershed may eventually lead to reduced internal loading, but it is not expected that this will happen shortly after BMP implementation. While the phosphorus load from internal sources is small relative to watershed inputs, the timing of this load in the summer season and the potentially high availability of the associated phosphorus make it a logical target for load reduction. A major but temporary reduction in phosphorus concentration in Kenosia Lake may be realized as a consequence of inactivation of internal phosphorus reserves, so the reduced load allocation for internal loading may have disproportionately larger benefits to water quality. No internal load reduction is proposed for nitrogen.

Load allocations for the atmospheric deposition and waterfowl are set at average current levels (643 kg/y for N and 46 kg/yr for P). No reduction is assumed, although management of geese could provide a small decrease in total loading. Overall, however, sources other than surface water and internal recycling do not account for enough of the total load for corresponding reductions to significantly affect in-lake conditions.

Table 4. Summary of Load Allocation to Kenosia Lake.

Non-point Source	Total Nitrogen (kg/yr)	Total Phosphorus (kg/yr)
Surface water base flow	1829	3
Internal Sediment Loading	81	8
Other (waterfowl, atmospheric deposition)	643	46
Total Load Allocation	**2553**	**57**

Waste Load Allocation

There are no known continuous point source discharges of nutrients in the Kenosia Lake watershed at this time. The Publicly Owned Treatment Facility where wastewater is treated discharges downstream of Kenosia Lake into Limekiln Brook. Stormwater discharges potentially regulated as point source discharges were separated from the overall non-point source load (Table 5). The City of Danbury's master plan [26] calls for 10% growth. However, no additional waste load allocations have been made to accommodate future growth in this TMDL. Any discharge permits that may be granted in the future (such as stormwater permits) will require BMPs as necessary to insure that stormwater loadings of nutrients to Kenosia Lake established in this TMDL are not exceeded.

Table 5. Summary of Waste Load Allocation to Kenosia Lake.

Point Source	Total Nitrogen (kg/yr)	Total Phosphorus (kg/yr)
Regulated Stormwater	2237	191
Other Point Source / Future growth	0	0
Total Waste Load Allocation	**2237**	**191**

MARGIN OF SAFETY

Federal regulations require that all TMDL analyses include a margin of safety (MOS) to account for uncertainties regarding the relationship between load and wasteload allocations, and water quality. The MOS may be either explicit or implicit in the analysis, or both.

The margin of safety applied in this TMDL is implicit in the analysis. The entire loading analysis employed in developing this TMDL is based on total phosphorus and total nitrogen loads, while the impact of those loads will be a function of nutrient availability. Dissolved phosphorus levels from the 51 stormwater samples collected in 2000-2001 averaged only 25% of the total phosphorus level (with only 5 values >50%), while dissolved nitrogen concentrations averaged 38% of total nitrogen concentrations (with 17 values >50%). Although some portion of the particulate fraction of total phosphorus and total nitrogen is likely to become available within a short time, much of the particulate fraction will be incorporated into the lake sediment and any later release is already accounted for as internal load. This suggests an implicit MOS of up to 75% for phosphorus and 62% for nitrogen.

Most guidance for developing TMDLs discourages the use of arbitrary MOS values in favor of a MOS implicit in the TMDL by virtue of a calculation method or an explicit MOS derived from statistical analysis of uncertainty (EPA [(27)], Walker [(28)]). Uncertainty in stormwater dominated systems is very high, as temporal variability in loading is large. Even with substantial sampling, characterization of this uncertainty is difficult and likely to lead to a MOS of more than 25%, perhaps even 50%. As the proposed loading targets are to be achieved mainly by addressing stormwater inputs (the primary source of the variability), and represent the greatest practical reduction in current loads, there is little benefit to be gained by incorporating a large explicit margin of safety in addition to the implicit MOS which exists as described above.

Finally, the target loads contain enough uncertainty that the TMDL should be viewed as reflecting the best judgment based on current information as to what will be needed to meet the WQS. The TMDL is not an absolute number that is guaranteed to be the endpoint of all management. Based on temporal loading variation, conditions could be much worse or much better at any instant in time than predicted by models into which average loads are inserted. Setting and achieving TMDLs for a stormwater dominated system such as Kenosia Lake should be an iterative process, with realistic goals over a reasonable timeframe and adjustment as warranted by ongoing monitoring. The selected targets represent a major improvement over current loading and will require substantial time and financial commitment to be attained. Adding a MOS at this time has little meaning within the greater context of meeting use attainment goals at Kenosia Lake, and so no numerical MOS is proposed at this time.

TMDL SUMMARY

TMDLs for total nitrogen and total phosphorus were established as the annual loads predicted to remain after a 60% reduction in the current watershed loading of total nitrogen and total phosphorus from urban land uses, achieved through BMP implementation, and a 50% reduction in the current internal total phosphorus load, achieved through phosphorus inactivation. The target loads represent what can be achieved through aggressive watershed management. Any future land use change that potentially increases loading will be expected to incorporate BMPs that limit that load appropriately. If the entire load allocation for the watershed is already used up (as it is today), multiple areas will have to be managed to achieve no net increase in loading. This is the approach currently applied in Maine with regard to watershed development, and while starting conditions may indeed be better in many Maine lakes, the process of "load re-allocation" to maintain a stable load has merit here. Post-BMP Implementation loads, expressed as annual values constituting the TMDL are summarized in Table 6.

Table 6. Summary of Estimated Current Nitrogen and Phosphorus Loading, and Total Maximum Daily Load Analysis for Kenosia Lake.

	Current Total Nitrogen (kg/yr)	Target Total Nitrogen (kg/yr)	Current Total Phosphorus (kg/yr)	Target Total Phosphorus (kg/yr)
LOAD ALLOCATION				
Surface Water Base Flow	4130	1829	5	3
Non-regulated Stormwater Runoff	0	0	0	0
Internal Sediment Loading	81	81	16	8
Atm. Deposition & Waterfowl	643	643	46	46
TOTAL LOAD ALLOCATION	**4854**	**2553**	**67**	**57**
WASTE LOAD ALLOCATION				
Regulated Stormwater	3308	2237	329	191
Other Point Sources / Future Growth	0	0	0	0
TOTAL WASTE LOAD ALLOCATION	**3308**	**2237**	**329**	**191**
MARGIN OF SAFETY		**Implicit**		**Implicit**
TOTAL MAXIMUM DAILY LOAD (expressed as an annual average load)	**8161**	**4790**	**396**	**248**

Once the TMDLs are achieved, the resultant trophic classification for Kenosia Lake according to the system adopted by the State of Connecticut will be mesotrophic to slightly eutrophic, which is the expected trophic category for Kenosia Lake. Post-TMDL implementation in-lake conditions were predicted using the calibrated land use export coefficient model [13] and are summarized in Table 7. It is estimated that in-lake concentrations of nitrogen and phosphorus will be 478 ug/L and 25 ug/L, respectively. Predicted mean chlorophyll *a* and secchi disk transparency (SDT) values under those conditions are 10.3 ug/L and 1.9 meters, typical mesotrophic values. Predicted maximum chlorophyll *a* is 34.8 ug/L, while predicted maximum SDT is 3.9 meters. Extreme values may fall outside the mesotrophic range for a brief period, but this is not expected to happen on a regular or sustained basis.

Based on this analysis, there is a high probability that the lake will be restored to a mesotrophic condition and recreational uses associated with mesotrophic lakes in Connecticut will be fully supported. It should be noted, however, that attainment of the target nutrient loads does not guarantee immediate full support for all uses designated for Kenosia Lake. For example, additional in-lake techniques for control of rooted aquatic vegetation may be required to enhance recreational opportunities in the near term.

Table 7. Predicted Post-TMDL Implementation Conditions in Kenosia Lake.

	Post-TMDL Conditions	Mesotrophic Category Conditions
Average In-Lake Total Phosphorus	25 ug/l	10-30 ug/l spring and summer
Average In-lake Total Nitrogen	478 ug/l	200-600 ug/l spring and summer
Average In-lake Chlorophyll *a*	10.3 ug/l	2-15 ug/l mid-summer
Average In-lake Secchi Disk Transparency	1.9 meters	2-6 meters mid-summer

The TMDLs are not too far above predicted background (undeveloped) levels, and are consistent with expectations based on documented BMP performance [29]. Compliance with current narrative water quality standards and criteria for use attainment appears achievable with nitrogen and phosphorus total annual loads of 4790 kg/yr and 248 kg/yr, respectively.

SEASONAL VARIATION

The TMDL, expressed as an annual target load, should be protective for all seasons since inputs are driven mainly by precipitation, which is distributed roughly evenly over the year on a long-term basis. However, the precipitation pattern in any given year can vary dramatically from the long-term trend on a weekly to seasonal basis. Also, runoff is the actual vehicle for most nutrient transport, and runoff generation depends on factors additional to precipitation. Spring inputs are potentially the largest component of watershed loads and may be more influential than other seasonal loads as they coincide with the start of the growing season in Connecticut.

Kenosia Lake flushes approximately eight times per year, a moderate flushing rate, but as with precipitation patterns, variability can be substantial. The most critical time appears to be late spring and early summer, as loads up to this time may be larger than average and flushing rate tends to decline during this period. In addition to the spring load from the watershed, the onset of summer stratification and accelerated decomposition processes signal the initiation of higher internal loading of phosphorus via sediment release. Intense summer storms followed by extended periods of dryness may also represent critical sequences, as nutrients may enter the lake in large quantity in a short burst without sufficient water to flush the system.

Ideally, the loads associated with key units of time would be as follows:

- Seasonally: No more than 1/4 of the annual load should occur in each of the spring and summer seasons (TN ≤ 1197 kg/season, TP ≤ 62 kg/season). Larger loads in spring or summer could cause a failure to meet use attainment goals, even if the annual target is not exceeded. High loading during spring or summer can not be offset by lower fall or winter loading, given the timing of the growing season and the flushing characteristics of Kenosia Lake.
- Monthly: No more than 1/3 of the seasonal load should occur in any given spring or summer month (TN ≤ 399 kg/month, TP ≤ 21 kg/month). Larger loads in any one-month may be offset by lower loads in a subsequent month, but as changes in loading generally equate with changes in flushing in the Kenosia Lake system, the impact of elevated loads over a late spring or summer month may be disproportionately large. That is, if storm-induced loads of nutrient-rich runoff flush cleaner water out of the lake in late spring or summer and then remain without further significant dilution for an extended period, use attainment may be compromised.
- Weekly or Daily: Loading over periods shorter than monthly is not especially meaningful in this system. Kenosia Lake flushes once every 43 days on average, and the nature of mixing and flushing in lake systems like this one is such that the impact of inputs is expressed over a period of time roughly equal to at least three flushings (130 days or 4 months).

MONITORING PLAN

The monitoring plan outlined in the D/F study [4] is appropriate for assessing the effectiveness of BMPs and applicability of target loads generated in this TMDL. Therefore, the monitoring plan is taken directly out of the D/F study and presented below.

> It is recommended that paired dry weather – wet weather samples be collected three times each summer, between May 15 and October 1, at the Mill Brook inlet and at any stormwater discharge pipe directly entering the lake that is targeted for management. Parameters should include total phosphorus, dissolved phosphorus, TKN, ammonium and nitrate nitrogen, E. coli (indicator bacteria) and turbidity.

In-lake conditions should be assessed through monthly measures of total phosphorus, dissolved phosphorus, TKN, ammonium and nitrate nitrogen, temperature, dissolved oxygen, and water clarity from June through September at the top and bottom of the water column. If funds allow, phytoplankton and zooplankton counts are also desirable.

IMPLEMENTATION PLAN

The D/F study outlined specific ways to reduce nitrogen and phosphorus loading in this system. A summary of the techniques is provided in the Feasibility section of the D/F study and is incorporated below. Table 8, modified from the D/F study, outlines the suggested management techniques discussed and Table 9 provides a possible action schedule. The reader is referred to the D/F study for specifics on each management technique.

Enhancing environmental quality of Kenosia Lake will involve reducing the loading of phosphorus and nitrogen, as well as other pollutants in stormwater discharged to the lake or its main tributary, Mill Brook. In-lake management should include reduced internal recycling of phosphorus, increased oxygen concentrations in deep water, enhanced grazing of zooplankton on algae, and control of rooted plant species.

A wide range of management options was evaluated for applicability and feasibility for meeting water quality and lake condition objectives. Watershed management options included source reduction techniques and pollutant transport mitigation methods, while in-lake management options included mainly methods for reducing algae and rooted plant abundance and for increasing deep water dissolved oxygen concentrations. The resultant plan includes multiple techniques with some overlap and flexibility of application. The plan is intended to evolve as it is implemented, with decisions based on both funding opportunities and the success of program implementation.

Stormwater management involves source controls through education, pre-treatment with street sweeping, catch basin cleaning, and oil/grit chambers, and infiltration or detention of stormwater. A concurrent effort to minimize future impacts from development of the watershed includes land use planning and implementation of current environmental regulations to minimize stormwater pollution. The estimated cost of major structural improvements in watershed stormwater management is on the order of $3,000,000 over an implementation period of a decade. The anticipated reduction in phosphorus loading will move the lake close to the level below which productivity problems are infrequent to rare. Additional reductions in pollutant loading are expected from non-structural methods such as education and planning at an estimated cost of $45,000. Enforcement of existing regulations at no additional cost to present programs would further aid water quality improvement. Benefits to habitat and human use for both recreation and water supply are expected to meet perceived goals for the Kenosia Lake system.

While watershed management is viewed as the most desirable approach to water resource management, desired in-lake conditions may be achievable for about 10% of the watershed management cost with a combined destratification and phosphorus inactivation system. Such an in-lake system would treat the lake water during the summer months, reducing nutrient levels and enhancing oxygen content on an as-needed basis. Long-term improvement would not be achieved by this approach, but it would be expected to meet water quality and use goals at a fraction of the cost of the desirable watershed controls. This may be a desirable interim approach to lake management while watershed controls are being established.

The 2001 drainage study [5] prioritized a large number of individually sampled stormwater drainage systems and suggested specific actions to be taken in most cases. In a surprising number of cases stormwater management devices (e.g., detention basins, filter berms) already existed, but were either inadequately sized or insufficiently maintained. Other areas without notable controls require retrofitting, which is often difficult in developed areas, but some key locations for detention facilities were identified. Improvement of the quality of stormwater runoff entering Kenosia Lake will not be a rapid or inexpensive process, but is achievable with persistent effort and adequate funding. The City of Danbury was consulted during development of the TMDLs for Kenosia Lake and has expressed its commitment to the effort. Sustained adequate funding will be the primary determinant of success in meeting this TMDL through stormwater management. In addition to stormwater management, the town and state have developed a plan to install sanitary sewers within Kenosia Lake's basin. This will be instrumental in reducing nutrient loading to the lake and subsequently help in meeting the TMDL goals.

The alternative of repetitive in-lake alum treatments most likely coupled with an aeration system would provide temporary improvement but will not address the root cause of the problem, which is loading from the watershed. However, it is preferable to repetitive algaecide applications, which address only the symptoms and provide no lasting relief. The use of phosphorus inactivation as an interim measure represents an intermediate approach that focuses on controlling the key nutrient, but falls short of controlling it at or near its sources. Given the expected length of time to properly implement a watershed management program, implementation of an in-lake phosphorus inactivation program does offer the means to achieve the target range for at least phosphorus in a shorter time and should allow regular use attainment through the summer season.

Table 8. Management Options Outlined in D/F Study [4]

Watershed Management	
Source Reduction	
Behavioral Modifications	Brochure and video production costs
Waste Water Management	Sewering of Jenson Park
Zoning and Land Use Planning	Consult with outside agency
Bank and Slope Stabilization	Enforcement action
Transport Mitigation	
Street Sweeping	2 sweepings per year
Catch Basin Cleaning	500 basins/yr
Catch Basins with Sumps and Hoods	Modification of 100 basins
Oil/Grit Chambers	20 chambers
Infiltration Systems	20 systems
Detention Systems	20 systems
Buffer Strips	Enforcement action
Coffer Dams	2 dams (enhance existing wetland treatment)
In-Lake Management – Algal Control and Dissolved Oxygen Enhancement	
Phosphorus Inactivation	Alum treatment
Destratification	Compressed air injection
Enhanced Grazing	Fish stocking and assessment costs
In-Lake Management – Rooted Aquatic Plant Control	
Benthic Barriers	100,000 square ft of installation
Fluridone Treatment	Three treatments over 10 years
Monitoring	
In-lake and watershed monitoring as described in the "Monitoring Plan" section.	

Table 9. Proposed Schedule for Completion of Management Options

	YR 1	YR2	YR3	YR4	YR5	YR6	YR7	YR8	YR9	YR10
Watershed Management										
Source Reduction										
Behavioral Modifications	X	X	X	X	X	X	X	X	X	X
Waste Water Management		X			X	X				
Zoning and Land Use Planning		X	X			X			X	
Bank and Slope Stabilization	X	X	X	X	X	X	X	X	X	X
Transport Mitigation										
Street Sweeping/Catch Basin Cleaning	X	X	X	X	X	X	X	X	X	X
Catch Basins with Sumps and Hoods			X	X						
Oil/Grit Chambers			X	X	X	X	X	X		
Infiltration Systems			X	X	X	X	X	X		
Detention Systems			X	X	X	X	X	X		
Buffer Strips		X	X	X	X	X	X	X	X	X
Coffer Dams		X	X							
In-Lake Management – Algal Control and Dissolved Oxygen Enhancement										
Phosphorus Inactivation		X	X	X	X	X	X	X	X	X
Destratification		X	X	X	X	X	X	X	X	X
Enhanced Grazing			X	X	X	X	X	X	X	X
In-Lake Management – Rooted Aquatic Plant Control										
Benthic Barriers		X	X	X	X	X	X	X	X	X
Fluridone Treatment		X			X			X		
Monitoring	X	X	X	X	X	X	X	X	X	X

REASONABLE ASSURANCES

Although not required for TMDL approval where only non-point sources are involved, reasonable assurance that the TMDL will be implemented is relevant in this case. The City of Danbury has already made a substantial commitment to achieving major nutrient load reductions for Kenosia Lake. A thorough D/F study was conducted as well as a detailed drainage investigation of most sub-basins that drain to Kenosia Lake. Enforcement actions have been taken to maintain the effectiveness of existing stormwater management systems operated under permits. An education program is underway, mainly through a brochure and direct contact with watershed residents and commercial operations. It is expected that the City will continue to take steps toward improving Kenosia Lake and the D/F study has provided the framework for management program implementation. The primary impediment to successful achievement of the TMDL for nutrient loading is funding. It may not be reasonable to assume that funding will be sustained at necessary levels without assistance at the State and Federal level. This may slow progress in what is already perceived as a ten-year program.

PROVISIONS FOR REVISING THE TMDL

The Department reserves the authority to modify the TMDL as needed to account for new information made available during the implementation of the TMDL. Modification of the TMDL will only be made following an opportunity for public participation and will be subject to the review and approval of the EPA. New information may include monitoring data, as well as new or revised State or Federal regulations adopted pursuant to Section 303(d) of the Clean Water Act, or the publication by EPA of national or regional guidance relevant to the implementation of the TMDL program. The Department will propose modifications to the TMDL analysis only in the event that a review of the available data indicates such a modification is warranted and is consistent with the anti-degradation provisions in Connecticut Water Quality Standards.

PUBLIC PARTICIPATION

The City of Danbury has held at least three public meetings concerning the assessment and improvement of water quality in Kenosia Lake. There is an active lake committee comprised of watershed residents that work with City staff in planning improvements. It is expected that open forums will continue as implementation of the management plan continues.

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Appendix A

Impact of Post-BMP Implementation Nutrient Loadings on Designated Uses

A series of models were used to evaluate anticipated in-lake conditions following implementation of BMPs to achieve the necessary reductions previously discussed. This section provides an evaluation of the model in regards to the WQS for mesotrophic conditions. As explained in the "Applicable Water Quality Standards" section, the trophic state for Kenosia Lake (absent of cultural impacts) is expected to be mesotrophic to slightly eutrophic. It can be assumed that if water quality in Kenosia Lake falls within the ranges of nutrients, chlorophyll a, and transparency specified for its mesotrophic conditions in Connecticut's WQS then all designated uses will be supported. Table A-1 provides the required annual loading in order to bring Kenosia Lake into the range of trophic classification values for mesotrophic systems.

Table A-1. State of Connecticut Trophic Classification Range for Mesotrophic Waterbodies and Corresponding Annual Load to Kenosia Lake.

Parameter	Connecticut WQS Concentration (ug/L)	Required Annual Load (kg/yr)
Total Nitrogen	200 – 600	1803 – 5399
Total Phosphorus	10 – 30	94 – 282
Chlorophyll *a*	2 – 15	TP Load = 71 – 323
SDT*	2 – 6	TP Load = 55 –235

* SDT = Secchi Disk Transparency

Empirical Equations

Mean and maximum chlorophyll *a* and Secchi Disk Transparency (SDT) levels were predicted using several empirical equations derived from substantial databases for northern temperate lakes [12,30,31,32,33]. Relationships observed for groups of lakes are not precisely applicable to any one lake in the data set, or to any other lake from the region. However, they do provide a conceptual basis for predicting the direction and magnitude of change expected in targeted lake features when nutrient loads are altered. Table A-2 lists the predicted chlorophyll *a* and SDT values using additional literature relationships. The predicted in-lake values match well with the Connecticut trophic classification range for mesotrophic waterbodies. In addition, the mesotrophic range matches well with predicted natural values (absence of human influence and/or practical reduction in anthropogenic loading achievable through BMPs).

Table A-2. Predicted Mean and Maximum Chlorophyll *a* and SDT Values with 60% Reduction of Surface Water Total Phosphorus Load and a 50% Reduction of Internal Total Phosphorus - Four Methods.

Source	Predicted In-Lake TP (ug/L)	Predicted Mean Chl (ug/L)[A]	Predicted Max Chl (ug/L)[B]	Predicted Mean SDT (m)[C]	Predicted Max SDT (m)[C]
Existing Data	19	7.1	24.3	2.4	4.3
Existing Data	33	14.3	47.5	1.6	3.7
Empirical Models	18	6.7	23.0	2.5	4.3
Export Coefficient Model	25	10.3	34.8	1.9	3.9

[A] From average of Dillon and Rigler 1974 [(30)], Jones and Bachmann 1976 [(12)], Oglesby and Schaffner 1978 [(31)], and Modified Vollenweider 1982 [(32)].
[B] From average of Modified Vollenweider (TP) 1982 [(32)], Vollenweider (CHL) 1982 [(32)], and Modified Jones, Rast and Lee 1979 [(33)].
[C] From Oglesby and Schaffner 1978 [(31)] (Avg) and Modified Vollenweider 1982 [(32)] (Max).

Trophic State Index

Lake use impairment was correlated to the Trophic State Index (TSI) developed by Carlson [(21)] and presented in the National Nutrient Guidance Manual for Lakes and Reservoirs [(34)]. When developed by Carlson, the TSI was used to simplify water quality assessment of lakes. It is currently used by many states for trophic classification. The National Nutrient Guidance Manual for Lakes and Reservoirs describes changes in trophic states of lakes with use-related problems. TSI values for use criteria are presented in Table A-3. As such, if these values are attained, then designated uses can be considered supporting. It is important to note that industrial and agricultural supplies were not addressed in the National Nutrient Guidance Manual, and complications introduced by macrophyte problems were not covered by Carlson's TSI. In addition, when applying this approach, it is important to remember that this TMDL has been prepared to guide management for recreational uses, not water supply management. Water quality criteria for drinking water supply use can be met through treatment, although attainment of a recreation-focused TMDL will also improve the quality of raw water that may be used for supply purposes.

Table A-3. Designated Uses and Associated TSI (Adapted from EPA [34]).

Lake Use	TSI*
Potable Water	≤ 40
Recreation	
Swimming/Primary contact recreation	≤ 60
Boating and Secondary contact recreation	≤ 70
Fish	
Salmonid fishery	<40-50
Percid fishery	50-60
Centrarchid fishery	60-80
Cyprinid fishery	>70-80
Wildlife (Aquatic Life)	No TSI Criteria.

* = TSI values based on calculations using the average summer values of Secchi Disk Transparency (SDT), chlorophyll *a*, phosphorus, and nitrogen.

Carlson [21] and Frink and Norvell [15] also established mathematical relationships between in-lake phosphorus concentrations and SDT and chlorophyll *a* concentrations. Carlson's relationships were based on lakes throughout North America, whereas Frink and Norvell's relationships were based on lakes in the State of Connecticut.

Equations used by Carlson and Frink and Norvell are:

<u>Carlson [21]</u>

SDT = 48/TP　　Chl *a* = 1.449*ln TP-2.442　　SDT = 2.04-0.68*ln Chl *a*

<u>Frink and Norvell [15]</u>

No equation for SDT　　Chl *a* = 0.374+0.431*TP　　SDT = 1/(0.0277*Chl a + 0.1235)

Applying these equations to the predicted total phosphorus in-lake concentration after a 60% reduction in watershed total phosphorus load and a 50% reduction in internal load yields a range of SDT values of 0.5 to 3.9 meters (Table A-4). These equations assume that water transparency is linked to total phosphorus. Non-algal turbidity will weaken the strength of this relationship, and is an issue associated with storm events in Kenosia Lake. Mean chlorophyll *a* concentrations are predicted to range from 4.8 to 14.6 ug/L using both Chl *a* equations. Mean and maximum chlorophyll *a* and SDT values using empirical models are presented in Table A-4.

Table A-4. Predicted Chlorophyll *a* and SDT with a 60% Reduction of Surface Water Load and a 50% Reduction of Internal Total Phosphorus.

Source	Ref	TP Load Post Reduction (kg/yr)	Predicted In-Lake TP (ug/L)	Predicted Mean Chl (ug/L)[A]	Predicted Mean SDT (m)[A]
Existing Data	1	181	19	5.2 – 8.6	1.4 – 3.7
Existing Data	2	314	33	11.6 – 14.6	0.5 –2.2
Empirical Models	3	170	18	4.8 – 8.1	1.6 – 3.9
Export Coefficient Model	4	248	25	7.9 – 12.5	1.9 – 3.9

[A] = Range from Carlson 1977 (21) and Frink and Norvell (15)

Using the predicted SDT, chlorophyll *a*, and total phosphorus derived from equations assuming a 60% reduction in surface water inputs and 50% reduction in internal phosphorus load, Kenosia Lake would have estimated TSI values as follows:

TSI of transparency = 39 - 70
TSI of chlorophyll = 46 - 68
TSI of phosphorus = 46 - 55

A 60% reduction in surface water total phosphorus loading and a 50% reduction in internal total phosphorus loading would result in achieving consistency with use-based (TSI-scored) criteria for recreation (Table A-3). Potable water use designations according to the TSI system would not be achievable on average. However, it is important to note that the suitability of a surface water as a source of drinking water in Connecticut is determined by the State Department of Health. Kenosia Lake is currently fully supporting as a drinking water supply and would presumably continue to support that use if nutrient loadings were reduced.

The implementation of BMPs in the watershed (TMDL based on best practical reduction) will put Kenosia Lake in the mesotrophic range, or slightly above the range under extreme circumstances, based on the Connecticut trophic classification range. It should be noted, however, that attainment of the target nutrient loads does not guarantee immediate full support for all uses designated for Kenosia Lake. For example, additional in-lake techniques for control of rooted aquatic vegetation may be required to enhance recreational opportunities in the near term.