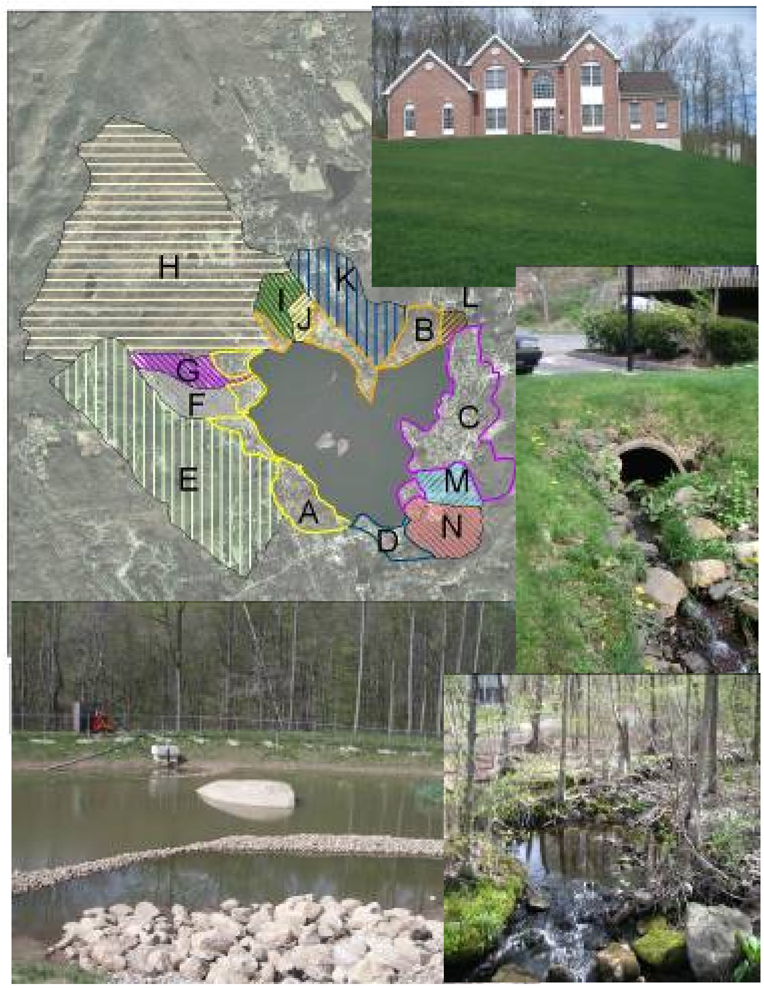
USE OF THE LAKE LOADING RESPONSE MODEL (LLRM) IN TMDL DEVELOPMENT FOR LAKE POCOTOPAUG, EAST HAMPTON, CT

Prepared for:
Town of East Hampton
and the Connecticut Department
of Environmental Protection



Prepared By:
AECOM
11 Phelps Way, PO 506
Willington, CT 06279

SUBMITTED ON BEHALF OF THE TOWN OF EAST HAMPTON, CT
PROJECT NUMBER 12095-005
AUGUST 2009

Use of the Lake Loading Response Model (LLRM) in TMDL Development for Lake Pocotopaug, East Hampton, CT

DATE: AUGUST 2009 FIRST REVISION **AECOM PROJECT NUMBER: 12095-005**

TABLE OF CONTENTS

TABLES

FIGURES

1.0 INTRODUCTION: PROBLEM STATEMENT AND BACKGROUND

Lake Pocotopaug, in East Hampton, Connecticut, is impacted by elevated levels of nutrients, resulting in algal blooms that impair designated uses of the lake. The watershed (Figure 1-1) covers 932.7 ha, and includes mostly residential and forested land uses. The lake itself covers 207.2 ha with an average depth of 3.4 m. Local interest is focused on swimming, boating and fishing. Elevated nutrient levels lead to elevated chlorophyll levels, relating to algal blooms, which then reduce water clarity to unsafe and ecologically deleterious levels. Lake Pocotopaug is on the Connecticut 303(d) list of impaired waters, although the exact causes for in-lake problems have not been listed, and is subject to development of a Total Maximum Daily Load that will support designated uses. The impairment is related to recreational uses and is due to high algal biomass, but the TMDL will focus on nutrients, especially phosphorus (P), as the controlling factor for algae. The Lake Loading Response Model (LLRM) used in this effort supports that effort.

Historically, Lake Pocotopaug had cottages along some of its shoreline and relatively little development farther out in its watershed until the 1980s. Building since then has been substantial, with multiple large subdivisions and many cottages being converted into year round housing, although much of the distant portion of the watershed remains minimally developed. Expansiveness and density of developed uses has increased markedly. Monitoring data collected by multiple groups over the years tracks the apparent result for the lake in terms of water clarity (Figure 1-2). As a rough guideline, average Secchi disk transparency (SDT) values <2.0 m (6.7 ft) are indicative of low clarity and potential impairment of human and ecological uses, while values in excess of 6.0 m (20 ft) are very high for Connecticut; values in excess of 3.0 m (10 ft) are generally considered acceptable for all uses.

To improve the condition of Lake Pocotopaug, we must understand the magnitude and sources of nutrient loading to the lake and gain some predictive capability to project the results of plausible management methods. Considerable sampling has been accomplished over nearly two decades, supporting a modeling effort that should support that understanding and needed predictive capacity. Project objectives can therefore be summarized as follows:

- Develop a model application that may be utilized to better understand lake response to nutrient loading.
- Determine the location of sources (subwatersheds of origin) of phosphorus and nitrogen responsible for eutrophication.
- Determine the relative contributions from sources in order to select and prioritize best management practices (BMP).
- Determine the load that will result in water quality compliance.
- Predict the results of BMP application and determine the level of effort necessary to achieve water quality compliance.

This process will facilitate implementation of corrective actions where the greatest positive impact will be realized.

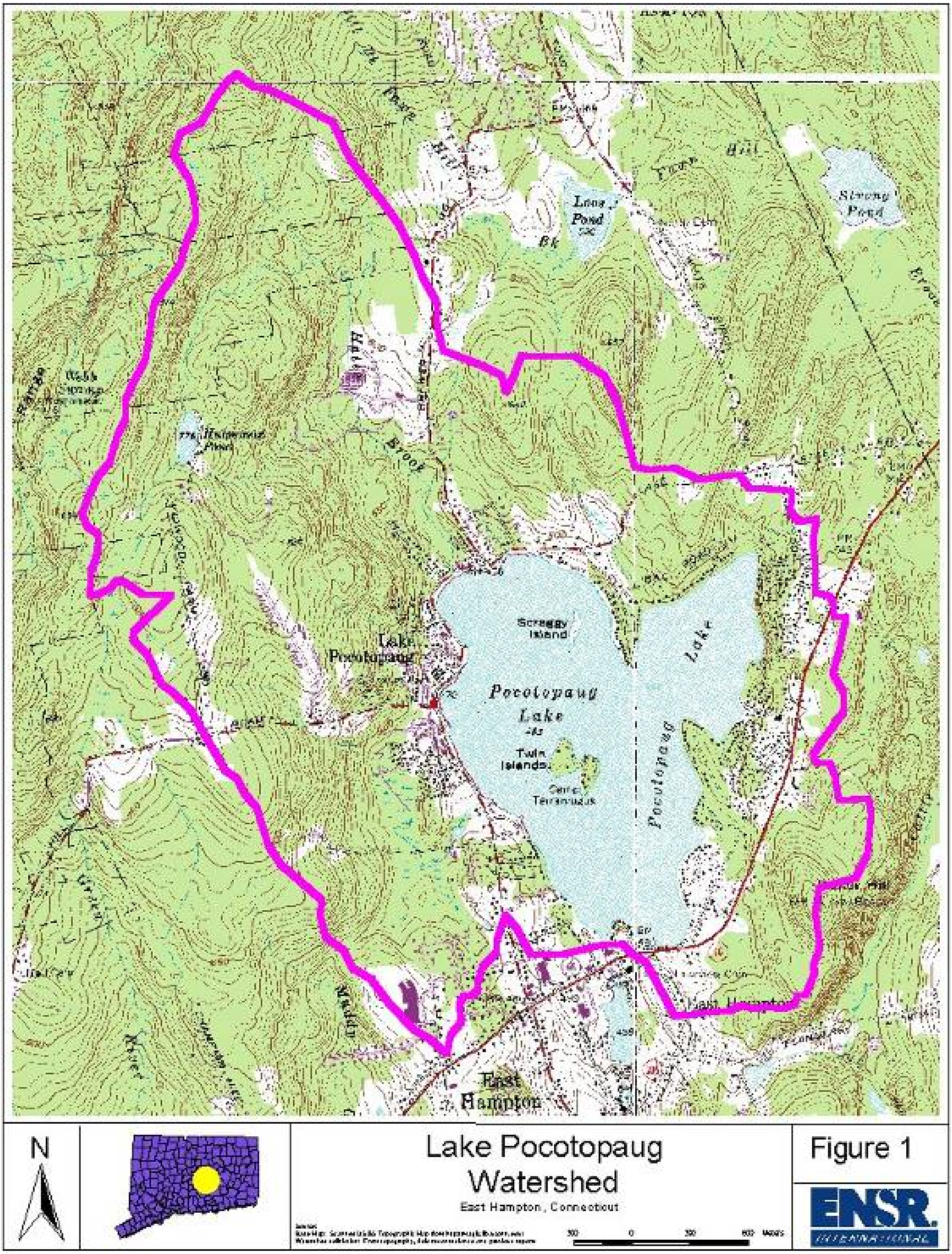


Figure 1-1. Lake Pocotopaug Watershed.

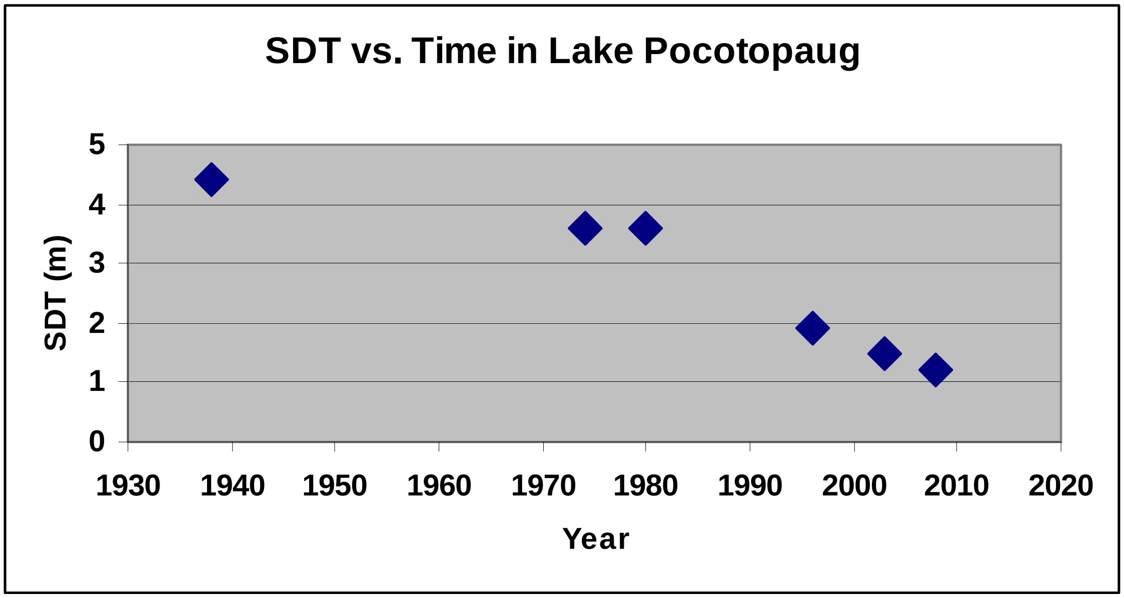


Figure 1-2. Water clarity as Secchi disk transparency in Lake Pocotopaug over time.

2.0 METHODOLOGICAL APPROACH

The companion Quality Assurance Project Plan and Lake Loading Response Model User's Guide provide discussions of how data are collected and assessed for quality in the development of the model, and how the model is calibrated, verified, and used in scenario evaluation. The model is only as good as the data used to set it up, so considerable time is spent accessing data sources and determining the validity of available data. For Lake Pocotopaug, historic studies and ongoing monitoring facilitate a fairly robust modeling process. LLRM provides an adaptive management tool that can provide preliminary direction and be adjusted as actions proceed.

2.1 Data Collection

Generation of data to run the LLRM is not specifically part of this project, but data are acquired from multiple sources to run LLRM. The quality of those data is important to model reliability. Therefore, attention is paid to the forms of data, means of acquisition, and evaluation of data quality. Necessary data and information will include lake morphometric data, information on precipitation and flows, watershed and subwatershed areas and land uses from GIS databases and other available sources, and water quality data for P, N, CHL, and SDT, plus ancillary water quality data that help interpret primary variable validity and meaning. The types of data used and sources of those data for this study are summarized in Table 2-1.

2.2 Model Set Up, Calibration and Verification

Values for independent variables are entered into the corresponding cells in the model spreadsheet. The only inputs necessary beyond the data described in Table 2-1 are export coefficients and attenuation factors. Export coefficients represent the yield of P or N from an areal unit (hectare) of land of any given use (e.g., dense residential, row crops, upland forest), and are set by land use for the entire watershed; an export coefficient therefore applies to all land of a given use throughout the watershed. Attenuation factors represent the portion of the generated P and N load that passes out of each subwatershed. These values are set based on knowledge of the subwatershed (e.g., soil permeability, size of buffer zones, existing detention), and can be different for P and N and each subwatershed. The Reference Variable worksheet in the model spreadsheet provides guidance on how to set these values.

The model then generates values for TP and TN at the output point of each subwatershed and for TP, TN, CHL and SDT within the lake as long-term averages that can be compared to actual data. If the predicted and actual values vary substantially, and the actual data are considered reliable, the model is adjusted to calibrate it to existing conditions. Export coefficients and/or attenuation factors are usually adjusted to achieve closer agreement, but no adjustment was needed for Lake Pocotopaug; predicted and actual data were in acceptable agreement. Once calibrated, independent variables can be changed to represent a period of time when corresponding values were different and for which water quality data exist to facilitate comparison. Most often, land use is changed; for Lake Pocotopaug, land use data were available from the 1970s and 1990s as well as for current conditions (2002-2004 and 2007-2008, with nominal land use changes in between), and some water

Table 2-1. Types and sources of data used for model set up.

Feature	Purpose in Model	Source for this Study
Lake bathymetry and hypsograph	Determination of volume at any depth or water level	Past studies, particularly SBFG 1959, CT DEP 1982. Frink and Norvell 1984, as updated by the Lake Study Group by 1992 (unpublished); results in area of 207 ha and mean depth of 3.44 m, with volume of 7,132,000 cubic m; ranges noted for each.
Watershed and subwatershed delineation	Defines areas to which loading functions and water quality comparisons will be applied in the model	USGS quad maps and ground truthing; compared to 1995 maps by Lake Advisory Committee (unpublished). Some variation in area noted, AECOM total area = 932.7 ha.
Subwatershed land uses and corresponding areas	determines range of possible loading to be used in the model	GIS maps, ground truthing. GIS data adjusted for recent development.
Precipitation	Used to calculate flows from land use and precipitation data	NOAA records for Bradley Airport; long-term mean of 1.21 m (48 inches)/yr.
Flow data	Used as a check on calculations from other data	None available for streams in the watershed.
Area water yield	Used with watershed area as a check on flow values derived from land use and precipitation	USGS data for Gauge 01192500, Hockanum River near East Hartford used to get areal yield, which is 1.6 cfsm.
Point source P and N monitoring data	Provides load from regulated sources	No permitted point source discharges to lake or tributaries.
On-site disposal (septic) system locations within direct drainage to the lake	Allows estimation of septic inputs by calculation using data for distance from lake, population served, and frequency of use	Area around lake sewered; only a few septic systems remain on island; septic systems farther from lake not accounted for separately.
Wildlife P and N inputs	Allows estimation of inputs from wildlife, mainly waterfowl	Estimates of waterfowl population very limited; assumed 20 bird-years for model (estimates as high as 100-200 found, but not for whole year), with median literature estimates applied for inputs by birds.
Atmospheric P and N loading	Provides estimate of loading from this source	Literature values for concentration combined with precipitation data; model assumes 16.5 ug P/L and 496 ug N/L, median values from unpublished studies in southern New England.
Internal P and N loading	Provides estimate of loading from this source	Past studies and some direct measurement, corroborated with literature values; has varied over the years; current internal load estimated at 1.0 mg P/m2/d and 5.0 mg N/m2/d for 100 days in summer over 71.6 ha; alum treatment in 2000-2001; see text for details.
Stream P and N concentrations	Used to check model results	Past studies and ongoing monitoring provide direct measurement; see table of results.
In-lake water quality (P, N, CHL, SDT)	Use to check model results	Past studies and ongoing monitoring provide direct measurement; see table of results.

quality data were available to facilitate comparison with predicted values. Additionally, limited water clarity data from the 1930s could be tentatively compared with the "natural background" scenario, in which all developed land is reset as forest.

2.3 Scenario Evaluation

To meet the objectives of this investigation, the model assumptions were changed to facilitate prediction of in-lake conditions under potential past or future conditions. The natural background scenario, mentioned above, set a lower bound on expected nutrient levels in the lake, based on the predicted inputs to the lake in the absence of human influence. This involves setting all developed uses (including residential, commercial, industrial and agricultural uses) as forest or wetland, and increasing attenuation by an additional 10% for each subwatershed (decreasing attenuation factors in the corresponding model cells, as less nutrients are exported with more undeveloped land to absorb them).

At the other extreme, a maximum build-out scenario will provide an upper bound on conditions that might be expected if development is not better managed. Not all land in the watershed can be developed, and it was assumed that land within direct drainages and certain well developed small subwatersheds would not be developed further. Half the remaining forest land in subwatersheds E, F, G, H and K was converted to low density residential area for this scenario, which may not represent the full possible build-out, but is believed to be a reasonable representation. Additionally, the internal load was doubled, consistent with pre-treatment data in the 1990s and expectations from other lakes with high nutrient loads and anoxic hypolimnia.

A best management scenario was also evaluated, in which the maximum reduction of nutrient inputs through feasible (although by no means inexpensive) application of best management practices (BMP) was applied. Attenuation factors for P were reduced by 10 – 40% over existing factor values, depending upon watershed features and anticipated "reasonable" success. Attenuation factors for N were reduced by 10 – 30% in the same manner, with best professional judgment applied. Internal load was reduced by 75% in this scenario, simulating the expectation for another aluminum treatment. A second version of this scenario was also run, with load reductions calculated from specific actions targeting loads in specific subwatersheds as part of a comprehensive plan. In this scenario, changes were not made to attenuation factors, but rather the summed load resulting from the management plan evaluation of each subwatershed was entered at the end of the calculations worksheet, in place of the current value.

3.0 DOCUMENTATION OF MODEL INPUTS

3.1 Physical Lake Features

For Lake Pocotopaug, information from several studies is available and depth checks have been made within the last three years. The outlet has some water level management capacity, but the water level is relatively stable during most of the year. Older studies agree with more current ones on a lake area of 202 - 209 ha (500 - 518 ac). Volume estimates vary somewhat, with a range of about 7 million to 7.4 million cubic meters. This modeling exercise applies a value of 7,132,000 cubic meters in an area of 207.2 ha, yielding a mean depth of 3.44 m. A bathymetric map of Lake Pocotopaug, seeming to date to 1959, is presented in Figure 3-1. This map appears to still be fairly accurate, however, based on spot depth checks.

3.2 Watershed Delineation

Delineation of the overall watershed and subwatersheds for Lake Pocotopaug was accomplished with a combination of topographic maps, past representations, and ground truthing. Multiple maps of the overall watershed have been generated in the past, and are generally similar. The map of subwatersheds developed for this effort from existing files, topographic maps, and field investigation (Figure 3-1) is new. Fourteen subwatersheds were delineated, four representing direct drainage areas north, south, east and west of the lake and including piped drainage and overland runoff without any tributary streams. Subwatershed F, Clark Hill, also has only piped and overland drainage, but was separated for possible management purposes, as the focus of many past discussions of problems spots around the lake. The remaining nine subwatersheds all have streams that deliver baseflow and stormwater runoff to the lake. Stream size and flow are generally proportional to drainage area size, with subwatershed H (Hales Brook) and E (Christopher Brook) as the largest. All subwatersheds contribute directly to the lake, simplifying the model; no subwatersheds pass through another subwatershed prior to discharging to the lake.

3.3 Land Use Determination

Land use was obtained from geographic information system (GIS) data files available from UCONN on behalf of the State of Connecticut, aerial photography, and from field investigation. As there is continuing development in the watershed, multiple adjustments to the GIS data had to be made, but an accurate listing of land uses for each subwatershed was obtained. The most recent online land use map is supplied in Figure 3-3, while the current listing of land uses by subwatershed is provided in Table 3-1.

Additional past watershed land use delineations were also reviewed to determine if it would be possible to verify the calibrated model with land use and water quality data from another time period. Useful data from the mid-1970s was provided by Norvell and Frink (1984), and the CT DEP (1992) provided data from the early 1990s. Current data indicates approximately 32% of the watershed to be in developed uses, while the early 1990s data suggested 24.5% development and the mid-1970s data suggested 19.3% developed uses. As the 1970s and 1990s data are not broken down by subwatershed, we reduced development in all subwatersheds equally to generate land use tables for model runs. A few adjustments were made in the 1990s table from direct knowledge of land use changes, improving that representation of land use.

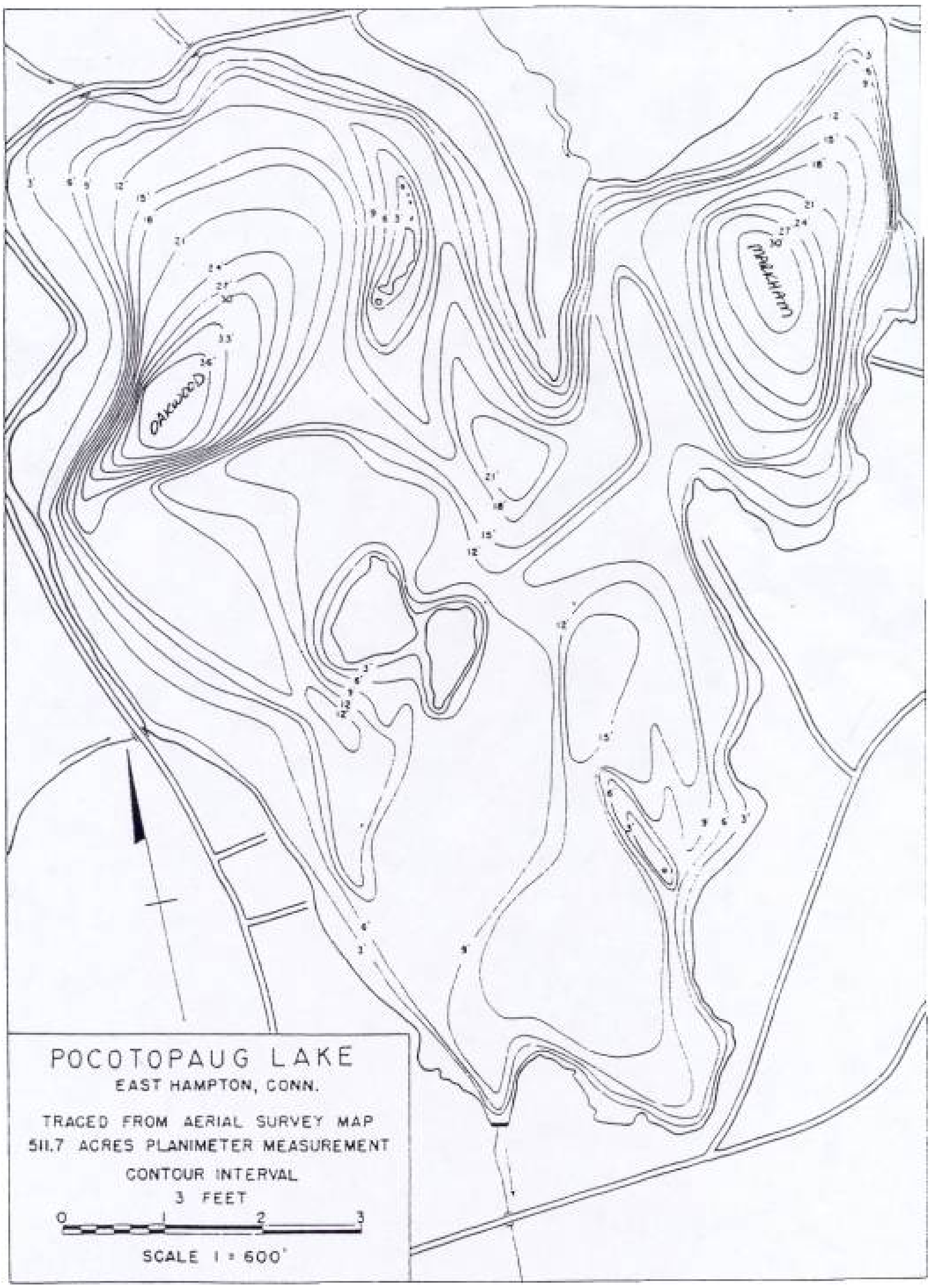


Figure 3-1. Lake Pocotopaug Bathymetry (Frink and Norvell 1984).

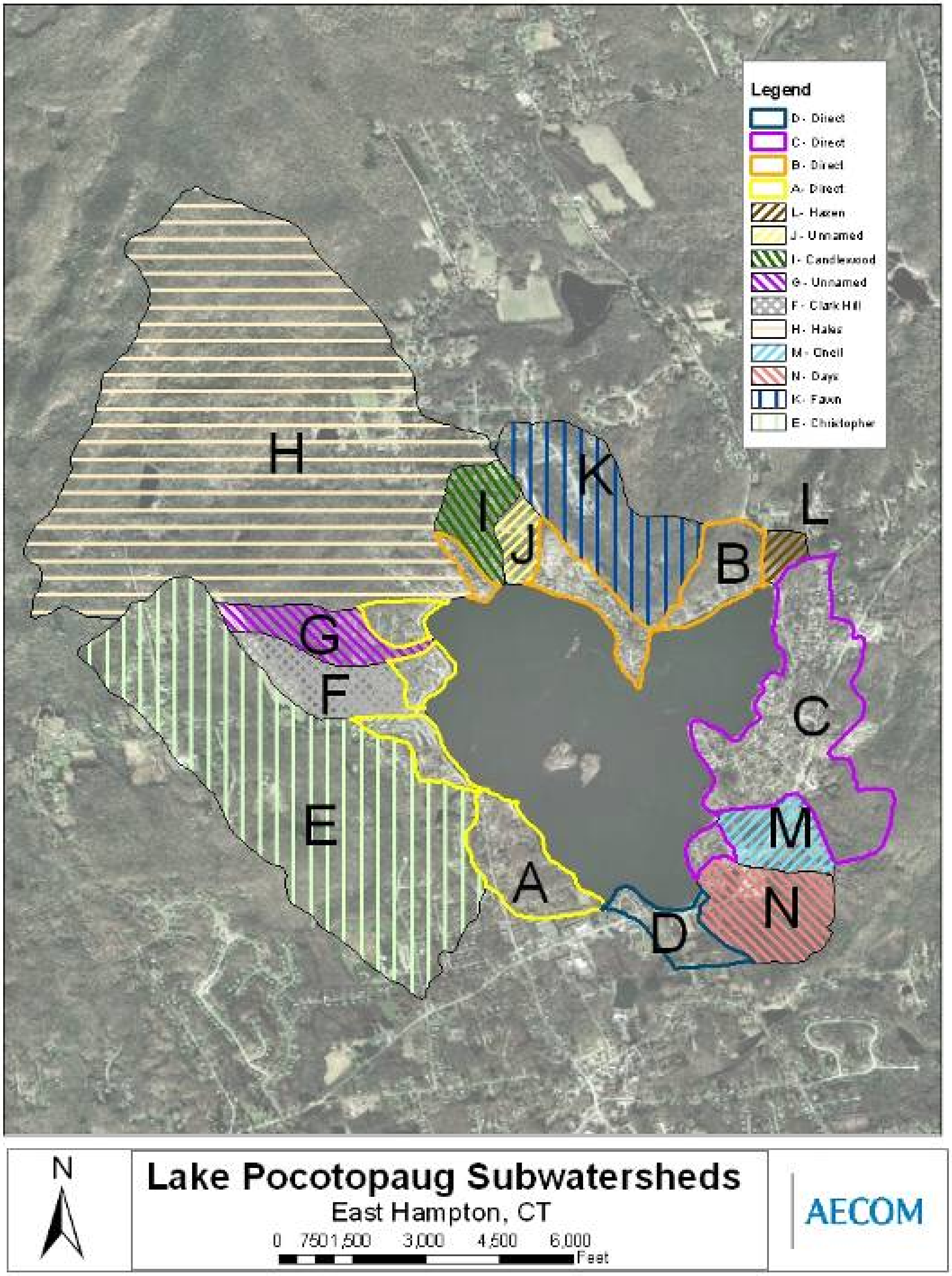


Figure 3-2. Subwatersheds draining into Lake Pocotopaug.

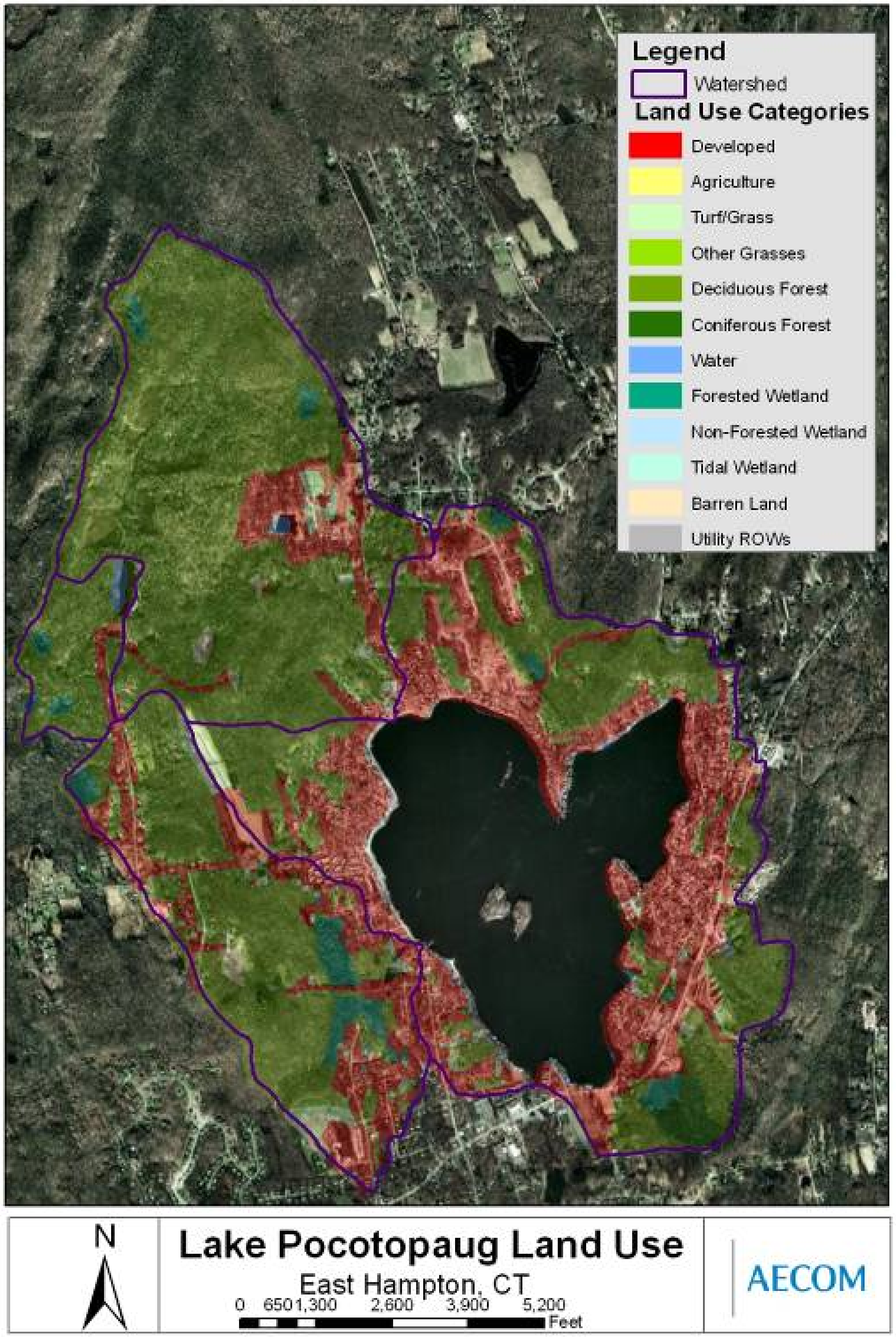


Figure 3-3. Watershed and general land uses for Lake Pocotopaug.

Table 3-1. Land use in the subwatersheds of Lake Pocotopaug.

LAND USE	A-Direct AREA (HA)	B-Direct AREA (HA)	C-Direct AREA (HA)	D-direct AREA (HA)	E-Christ AREA (HA)	F-Clark AREA (HA)	G-Unnamed AREA (HA)	H-Hales AREA (HA)	I-Candle AREA (HA)	J-Unnamed AREA (HA)	K-Fawn AREA (HA)	L-Hazen AREA (HA)	M-Oneil AREA (HA)	N-Days AREA (HA)	TOTAL AREA (HA)
Urban 1 (LDR)	29.8	19.9	43.7	6.7	47.4	10.9	2.2	31.8	6.7	4.5	18.1	0.4	8.7	6.7	237.5
Urban 2 (MDR/Hwy)	3.7	2.5	5.5	0.8	5.9	1.4	0.3	4.0	0.8	0.6	2.3	0.0	1.1	0.8	29.7
Urban 3 (HDR/Com)	3.7	2.5	5.5	0.8	5.9	1.4	0.3	4.0	0.8	0.6	2.3	0.0	1.1	0.8	29.7
Urban 4 (Ind)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Urban 5 (P/I/R/C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 1 (Cvr Crop)	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Agric 2 (Row Crop)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 3 (Grazing)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 4 (Feedlot)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest 1 (Upland)	7.7	11.1	27.5	3.1	113.8	8.9	15.4	302.2	9.2	3.1	33.6	4.3	5.8	21.2	566.9
Forest 2 (Wetland)	0.0	0.0	0.2	0.0	14.5	0.0	0.0	6.1	0.0	0.0	1.9	0.0	0.2	2.7	25.7
Open 1 (Wetland/Lake)	2.5	1.5	0.6	0.6	0.1	0.0	0.0	3.1	0.0	0.1	0.0	0.0	0.2	0.1	8.7
Open 2 (Meadow)	2.0	0.5	1.3	1.8	10.2	2.1	1.9	7.0	0.1	0.0	0.2	0.7	1.4	0.3	29.5
Open 3 (Excavation)	0.1	0.0	0.1	0.1	2.3	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	4.4
Other 1															0.0
Other 2															0.0
Other 3															0.0
TOTAL	49.5	38.0	84.3	13.9	200.9	24.6	20.1	360.0	17.6	8.8	58.3	5.4	18.6	32.8	932.7

Table 3-2. Export coefficients for water and nutrients in the Lake Pocotopaug watershed.

RUNOFF EXPORT COEFF.			BASEFLOW EXPORT COEFF.		
Precip Runoff Coefficient (Fraction)	P Export Coefficient (kg/ha/yr)	N Export Coefficient (kg/ha/yr)	Precip Baseflow Coefficient (Fraction)	P Export Coefficient (kg/ha/yr)	N Export Coefficient (kg/ha/yr)
0.30	0.65	6.50	0.15	0.010	7.50
0.40	0.75	6.50	0.10	0.010	7.50
0.60	0.80	6.50	0.05	0.010	7.50
0.50	0.70	5.50	0.05	0.010	7.50
0.10	0.80	8.00	0.05	0.010	7.50
0.15	0.80	6.08	0.30	0.010	2.50
0.30	1.00	9.00	0.30	0.010	2.50
0.30	0.40	5.19	0.30	0.010	5.00
0.45	224.00	2923.20	0.30	0.010	25.00
0.10	0.20	2.86	0.40	0.005	1.00
0.05	0.10	2.86	0.40	0.005	1.00
0.05	0.10	2.46	0.40	0.005	0.50
0.05	0.10	2.46	0.30	0.005	0.50
0.40	0.80	5.19	0.20	0.005	0.50
0.10	0.20	2.46	0.40	0.050	0.50
0.35	1.10	5.50	0.25	0.050	5.00
0.60	2.20	9.00	0.05	0.050	20.00

3.4 Acquire Precipitation Data

Precipitation data were obtained from the Bradley Airport (BDL) NOAA station near Hartford, CT. Long-term average precipitation was 1.21 m (48 inches). Variability across this portion of Connecticut, based on a survey of other measurement sites, is on the order of 46 to 52 inches of precipitation per year.

3.5 Acquire Flow Data

Flow data are not available from any of the streams discharging to Lake Pocotopaug. A surrogate mean flow can be calculated from the areal water yield, calculated from nearby gauged streams as the long-term mean flow divided by the watershed area at the point of measurement. Areal water yield based on flow and drainage area data for the Hockanum River (USGS Gauge 01192500) near East Hartford is 1.6 cubic feet per second per square mile of drainage area (actually 1.55 cfsm). Areal yield for the Connecticut River near Hartford is 1.65 cfsm. A value of 1.6 cfsm was applied in this effort. The areal water yield is multiplied by the drainage area to get an expected mean flow for that area. This value is used as a check on the flow calculated from division of precipitation into baseflow and runoff in the model.

The model generates independent estimates of flow by partitioning precipitation into baseflow and runoff fractions. That is, the product of annual precipitation and subwatershed area is subdivided into runoff and baseflow fractions, with an additional fraction allowed for water lost to either evapotranspiration in the watershed or deep groundwater that does not re-enter surface water within the watershed or lake. Consequently, the applied fractions for baseflow and runoff do not add up to 1.0 in the model. Fractions vary among land uses, and are set from a combination of guidance from Dunne and Leopold (1978) and best professional judgment. For Lake Pocotopaug, the breakdown of baseflow and runoff fractions is provided in Table 3-2.

3.6 Acquire Point Source Data

Point source data are normally acquired from Discharge Monitoring Reports filed under NPDES regulations. However, there are no permitted point sources in the Lake Pocotopaug watershed.

3.7 Determine Septic System Distribution and Use

For the Lake Pocotopaug watershed, virtually all land within the direct drainage watershed of Lake Pocotopaug is sewered. Only a few septic systems exist on an island, and these were not considered substantial enough to warrant special calculation.

3.8 Estimate Wildlife Inputs

Aquatic birds and mammals appear limited at Lake Pocotopaug, but there are no quantitative data upon which to base an estimate. Some reports have suggested 100 and 200 birds being present on the lake on specific days, but not for an entire year. No estimates of muskrats, beaver, or other water dependent mammals are available, but multiple sampling trips to the lake suggest that bird and mammal use is not high. A value of 20 bird-years was assigned based on observations by volunteers and consultants over multiple years, but is a rough estimate. A value of up to 100 bird-years will be used in sensitivity testing.

3.9 Estimate Atmospheric Inputs

The average concentration for nutrients in rainfall observed in unpublished studies for southern New England was applied to Lake Pocotopaug. Values of 16.5 ug/L for P and 496 ug/L for nitrogen were applied. Multiplied by the rainfall directly landing on the lake, loads of nutrients can be calculated. For sensitivity testing, values of 10 to 30 ug/L for P and 300 to 750 ug/L for N will be applied.

3.10 Estimate Internal Loading

Comparison of deep water P and N concentrations over time during summer stratification was applied at Lake Pocotopaug to estimate internal loading, with conversion to an areal load on an annual basis. Data for 2007 and 2008 were available, and suggest releases of 183 to 209 kg P during the period from May into September, and 3272 to 5328 kg N for the same time period. However, much of this load remains in the hypolimnion (deeper waters) and is inactivated when oxygen is present during fall turnover (mixing), and does not play a major role in algal blooms. In our experience, it is rare to have more than 40% of this internally generated P or N reach the surface waters during summer, by diffusion and mixing. Assumption of an active internal load equal to 40% of the average 2007-2008 load suggests values of 78 kg/yr for P and 1720 kg/yr for N.

Values for the Oakwood Basin in 2002 and 2003 to those for 2007 and 2008 (74 and 137 kg vs. 119 and 146 kg for P and 774 and 1010 vs. 1544 and 2885 kg for N) may be indicative of the effects of the aluminum treatment in 2000 and 2001, which temporarily decreased internal loading of at least phosphorus, but may have affecte nitrogen as well. Considering the recent data, the range for internal P load is suggested as 50 to 100 kg/yr, while that for N is about 1400 to 2000 kg/yr, for sensitivity testing purposes.

Table 3-3. Calculation of internal P and N load to Lake Pocotopaug

Station/Calculation	Date	Bottom P (ug/L)	Bottom N (mg/L)	Date	Bottom P (ug/L)	Bottom N (mg/L)	P diff (ug/L)	N diff (mg/L)	# of days	Hypolimnion Volume (m3)	Mass P increase (kg)	Mass N increase (kg)
LP-1 Markham	6/2/2007	21	1.48	9/4/2007	129	4.38	108	2.90	94	596,000	64	1728
LP-1 Markham	5/15/2008	43	1.86	9/11/2008	149	5.96	106	4.10	118	596,000	63	2444
LP-2 Oakwood	6/2/2007	45	1.86	9/4/2007	291	5.05	246	3.19	94	484,000	119	1544
LP-2 Oakwood	5/15/2008	59	1.87	9/11/2008	360	7.83	301	5.96	118	484,000	146	2885
2007 total	Oakwood Basin 2007 release X area + Markham Basin 2007 release X all remaining area >15 ft deep										183	3272
2008 total	Oakwood Basin 2008 release X area + Markham Basin 2008 release X all remaining area >15 ft deep										209	5328
Average	From 2007 and 2008 data										196	4300
40% of Avg	Rarely get more than 40% of internal load becoming active in epilimnion										78	1720
LP-2 Oakwood	6/17/2002	44	1.00	9/10/2002	196	2.60	152	1.60	85	484,000	74	774
LP-2 Oakwood	5/30/2003	41	0.52	8/27/2003	325	2.61	284	2.09	89	484,000	137	1012
Expected Low Values	Based on consideration of data range, converted to very round numbers										50	1400
Expected High Values	Based on consideration of data range, converted to very round numbers										100	2000

3.11 Determine N and P Concentrations in Streams

It is desirable to collect a series of grab samples to characterize water quality during storms at all major inlet points, and sometimes farther from the lake in the watershed to characterize more distant sub-watersheds with distinct inputs that might need to be addressed. The collection of these samples provides data for calibrating LLRM, but is covered under separate monitoring arrangements not specifically related to model set up. For Lake Pocotopaug, sampling by an active volunteer monitoring program and contracted consultants has occurred for many years (Table 3-4, Figure 3-4), with a focus on watershed inputs in recent years.

Table 3-4. Sampling stations in the Lake Pocotopaug watershed.

		Lake Pocotopaug Watershed Sampling Stations
Station	Type	Location
1	Stream	18 Wells Ave, 20' from Lake
2	Stream	Christopher Brook upstream of N Main
3	Drain	Christopher Brook, drain pipe at N Main
4	Stream	Christopher Brook, upstream of Christopher Road
5	Stream	Christopher Brook, South of Christopher Road
6	Road runoff	Christopher Brook, road runoff at N Main
7	Stream	Christopher Brook, North of Clark Hill Rd
8	Drain	Christopher Brook, storm drain at Clark Hill Rd
9	Drain	Drain at foot of Clark Hill Road
10	Drain	Drain at foot of Bobby's Road
11	Stream	Hales Brook at Lake Drive (above pool)
12	Road runoff	Hales Brook, road runoff at Lake Drive
13	Stream	Hales Brook, above Nelson's Campground
14	Stream	Hales Brook, unnamed tributary above Mott Hill Rd
15	Stream	Brook at Candlewood Dr., at Lake Dr.
16	Stream	Brook at Candlewood Dr, above Candlewood Dr
17	Road runoff	Brook at Candlewood, road runoff at Candlewood
18	Stream	Brook Near Spellman's Pt., at Bay Rd
19	Stream	Brook near Spellman's Pt., above Lake Dr.
20	Drain	Brook at Spellman's Pt., drain at Lake Dr.
21	Stream	Hazen's Brook
22	Drain	Drain at foot of Mohigan Trail
23	Stream	O'Neill's Brook at Old Marlborogh Rd
24	Drain	O'Neill's Brook, at Route 66
25	Stream	O'Neill's Brook, unnamed tributary above Rt 66
26	Stream	Day's Brook at Old Marlborogh Rd
27	Stream	Day's Brook, above Route 66
28	Stream	Pipe at Ola Ave. & N. Main
29	Stream	Unnamed Brook crossing Pine Trail
30	Road runoff	Ola Ave at N Main, road runoff
31	Stream	Hales Brook, downstream of Nelson's Campground
32	Stream	Stream at rear of 11 Ola Avenue
33	Stream	Stream East of Raymond Rd, Upstream of Lake Drive
34	Drain	South Wangonk, Drain on Beach
35	Drain	26 Hawthorne, Pipes on beach
36	Stream	Christopher Brook, South of Clark Hill Rd
37	Stream	Hales Brook, upstream of Midwood Farm Road

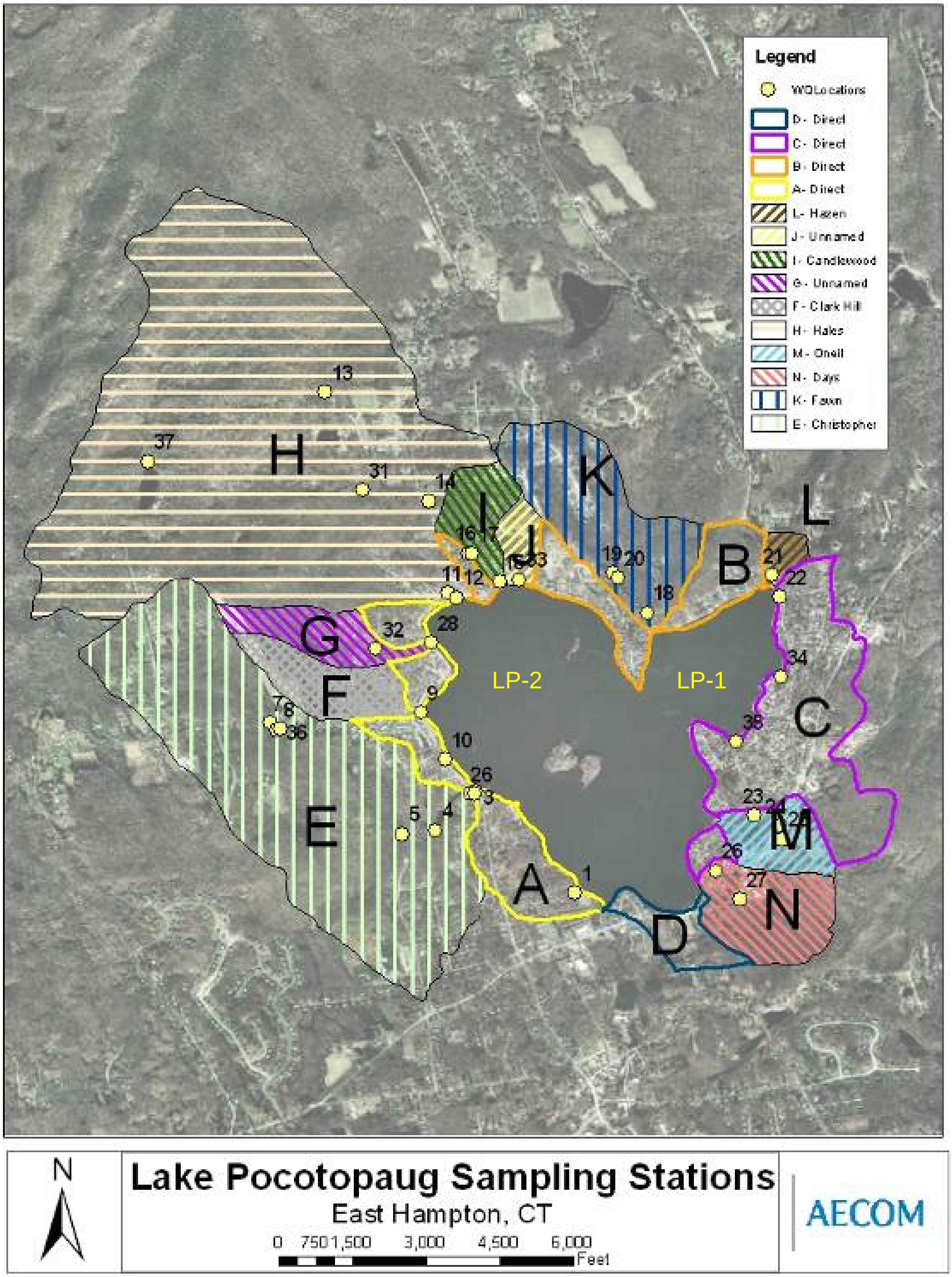


Figure 3-4. Location of sampling stations in Lake Pocotopaug and its watershed.

Sampling has been conducted over three different weather conditions (dry, first flush and post-peak storm conditions) enough times to characterize variability and get representative values for comparison with model predictions for many of the defined subwatersheds. Dry weather values are reported separately from first flush and post-peak sampling results, with the latter two categories combined to better represent the range of storm conditions. The complete data set used to characterize surface water inlets is provided in Appendix A. The summary (Table 3-5) demonstrates the range and overall magnitude of nutrient levels in surface water entering Lake Pocotopaug, with the wet weather P concentrations most strikingly high. Comparing total P to dissolved P, however, it is apparent that much of the entering P is in particulate form; this will add to the internal load more than to the immediately available P level in the lake.

Table 3-5. Summary of P and N for samples representing subwatersheds draining to Lake Pocotopaug

Drainage	Dry Weather TP (mg/L)				
Area	Maximum	Mean	Median	Minimum	Samples
A	0.198	0.198	0.198	0.198	1
B					
C	0.234	0.102	0.060	0.013	3
D					
E	1.027	0.162	0.021	0.008	7
F					
G	0.858	0.439	0.439	0.020	2
H	0.433	0.056	0.008	0.003	9
I	0.479	0.198	0.021	0.017	5
J	0.009	0.009	0.009	0.009	1
K	0.080	0.044	0.036	0.015	3
L	0.243	0.078	0.028	0.012	4
M	0.260	0.114	0.058	0.026	5
N	0.584	0.122	0.031	0.010	6

Drainage	Wet Weather TP (mg/L)				
Area	Maximum	Mean	Median	Minimum	Samples
A	1.775	0.556	0.149	0.112	9
B					
C	1.990	0.465	0.141	0.034	14
D					
E	4.438	0.512	0.065	0.022	16
F	3.760	0.531	0.196	0.087	11
G	5.096	1.033	0.090	0.037	7
H	3.090	0.329	0.042	0.011	17
I	1.863	0.386	0.114	0.053	10
J	0.320	0.174	0.163	0.029	5
K	0.335	0.176	0.174	0.022	4
L	1.660	0.367	0.169	0.013	8
M	3.260	0.921	0.706	0.070	15
N	0.940	0.277	0.178	0.031	15

Drainage	Dry Weather DP (mg/L)				
Area	Maximum	Mean	Median	Minimum	Samples
A	0.111	0.111	0.111	0.111	1
B					
C	0.185	0.072	0.030	0.001	3
D					
E	0.192	0.035	0.005	0.004	7
F					
G	0.230	0.118	0.118	0.005	2
H	0.041	0.009	0.005	0.001	9
I	0.123	0.029	0.005	0.005	5
J	0.002	0.002	0.002	0.002	1
K	0.020	0.012	0.010	0.006	3
L	0.020	0.010	0.010	0.001	4
M	0.033	0.018	0.016	0.005	5
N	0.039	0.018	0.012	0.005	6

Drainage	Wet Weather DP (mg/L)				
Area	Maximum	Mean	Median	Minimum	Samples
A	0.194	0.076	0.062	0.033	9
B					
C	0.228	0.065	0.043	0.011	14
D					
E	0.212	0.029	0.011	0.004	16
F	0.230	0.080	0.070	0.010	11
G	1.490	0.246	0.030	0.009	7
H	0.539	0.048	0.006	0.001	17
I	0.080	0.041	0.039	0.013	10
J	0.111	0.040	0.017	0.002	5
K	0.060	0.032	0.025	0.020	4
L	0.479	0.086	0.020	0.004	8
M	2.370	0.232	0.033	0.005	15
N	0.214	0.061	0.050	0.015	15

Drainage	Dry Weather TN (mg/L)				
Area	Maximum	Mean	Median	Minimum	Samples
A	0.000			0.000	0
B					
C	2.930	2.240	2.200	1.590	3
D					
E	0.750	0.586	0.595	0.425	7
F					
G	3.300	3.300	3.300	3.300	1
H	0.440	0.345	0.330	0.267	6
I	0.444	0.352	0.348	0.269	4
J	1.590	1.590	1.590	1.590	1
K	0.473	0.358	0.400	0.200	3
L	0.600	0.367	0.285	0.216	3
M	0.845	0.694	0.766	0.400	4
N	0.800	0.505	0.565	0.150	3

Drainage	Wet Weather TN (mg/L)				
Area	Maximum	Mean	Median	Minimum	Samples
A	3.419	1.366	1.085	0.682	7
B					
C	9.090	2.612	1.742	0.610	12
D					
E	16.580	2.864	0.931	0.400	10
F	4.380	2.002	1.926	0.840	8
G	1.937	1.051	0.826	0.718	5
H	25.280	3.417	0.894	0.200	11
I	4.864	1.546	1.007	0.500	8
J	3.344	1.066	0.745	0.029	10
K	3.055	0.631	0.310	0.022	8
L	1.926	0.763	0.558	0.013	14
M	8.680	1.825	1.220	0.450	11
N	3.060	0.731	0.454	0.740	9

The values in Table 3-5 can be used to calibrate model outputs from the corresponding subwatersheds, although in some cases no data are available or there are too few samples to provide a reliable estimate of expected concentrations.

3.12 Set Export Coefficients for P and N from Land Uses

The mass of P or N generated from a unit of area of a given land use must be entered into the model to initiate loading estimation. The likely range of values, with means and medians, is provided in the Reference Variables worksheet of the model spreadsheet. The median value is usually used as a default setting, but with data like those available for Lake Pocotopaug subwatersheds, it is possible to directly estimate export coefficients for more common land uses. The process is not simple, as we have dry and wet weather data samples, different numbers of each for a variety of stations, no direct measurement of flow, and mixed land uses in all basins, but it is still a useful exercise to estimate loads this way from the real data to guide the modeling process.

Appendix B contains the calculation sheets with derived loads for each basin and estimated TP and TN export coefficients for developed land in those basins with data, based on an assumed natural land loading export coefficient. The natural areal load tends to fall into a narrower range and is more readily estimated from literature and experience (Dillon et al. 1991, Clark et al. 2000, Schloss and Connor 2000, Rohm et al. 2002). Based on the values from subwatershed considered to provide more reliable results, mainly as a function of having been sampled more times, the values in Table 3-2 (accompanying the partitioning of precipitation into baseflow and runoff) have been assigned for use as export coefficients in LLRM.

3.13 Determine N, P, CHL and SDT Values for Lake

As with input sampling, in-lake sampling is essential to model calibration, but has been conducted as part of a monitoring program not specifically related to LLRM application. A volunteer monitoring program has been in place for almost 20 years at Lake Pocotopaug, so this lake has substantial in-lake water quality data. AECOM has participated in data collection in the lake over the last 8 years, but the local volunteer monitoring group has primary responsibility for sampling of the lake. In recent years, samples have been collected monthly from about April into October, sometimes semi-monthly. Total and dissolved P, nitrate, ammonium and Kjeldahl N are assessed, plus temperature and oxygen profiles, conductivity, pH and Secchi Disk Transparency (SDT). Chlorophyll was assessed in the 1990s, but not recently. Data acquired from monitoring of two stations within the lake (Figure 3-4) over the last two decades and determined to be of suitable quality were applied in the model. Markham Bay is LP-1, while Oakwood Basin is LP-2, these representing the two deep holes in the lake (Figure 3-1). All data used in this modeling effort are included in Appendix A, while a summary of relevant in-lake data is provided in Table 3-5.

Table 3-6. In-lake data for Lake Pocotopaug, 1991-2008.

	SDT	Ammonia	Nitrate/Nitrite	TKN	TN	Total P	Dissolved P	Chlorophyll a
1991-2001 Epilimnetic Values	(m)	as N (mg/l)	as N (mg/l)	as N (mg/l)	as N (mg/l)	as P (mg/l)	as P (mg/l)	(ug/L)
Mean	1.93				0.492	0.016		7.83
Median	1.88				0.467	0.015		7.21
Minimum	0.45				0.305	0.002		0.31
Maximum	4.09				0.930	0.057		24.00
Number of samples	275				14	209		52

	SDT	Ammonia	Nitrate/Nitrite	TKN	TN	Total P	Dissolved P
2002-2004 Epilimnetic Values	(m)	as N (mg/l)	as N (mg/l)	as N (mg/l)	as N (mg/l)	as P (mg/l)	as P (mg/l)
Mean	1.5	0.027	0.024	0.540	0.565	0.023	0.013
Median	0.9	0.020	0.005	0.550	0.555	0.025	0.014
Minimum	0.8	0.005	0.005	0.200	0.220	0.005	0.005
Maximum	2.9	0.090	0.120	0.900	0.905	0.034	0.022
Number of samples	3	12	11	10	10	13	12

	SDT	Ammonia	Nitrate/Nitrite	TKN	TN	Total P	Dissolved P
2007-2008 Epilimnetic Values	(m)	as N (mg/l)	as N (mg/l)	as N (mg/l)	as N (mg/l)	as P (mg/l)	as P (mg/l)
Mean	1.21	0.093	0.009	0.916	0.925	0.023	0.004
Median	1.15	0.047	0.010	0.745	0.755	0.021	0.003
Minimum	0.60	0.005	0.005	0.300	0.305	0.011	0.002
Maximum	2.40	0.395	0.026	2.040	2.066	0.041	0.014
Number of samples	39	25	25	25	25	28	23

4.0 MODEL CALIBRATION AND VERIFICATION

4.1 Calibration of LLRM

Detailed instructions for setting up LLRM are provided in Appendix A, the LLRM User's Guide. The model template was populated with site-specific data, or values selected from the range provided in the Reference Variables worksheet, based on knowledge that allowed adjustment for Lake Pocotopaug. Once all required fields were filled in the Calculations worksheet, the model automatically generated concentrations at defined nodes in the established network (points of exit from each subwatershed), and these concentrations were compared with the data collected for corresponding points in the actual watershed (Table 4-1). Likewise, in-lake P and N concentrations were predicted and compared with actual data (Table 4-2). The period of LLRM calibration was 2007-2008.

Comparison of predicted water outputs from subwatersheds by either partitioning of precipitation for each land use or by simple geographic water yield times each subwatershed area yielded very similar results with no adjustment of attenuation for subwatersheds from the small losses initially expected as a function of evaporation and transpiration; corresponding values matched within 6%. It is true that all predictions from precipitation partitioning were less than those from areal yield, but the differences were so small (4%) that no adjustment was warranted.

For predicted P concentrations leaving subwatersheds, 9 of 11 possible comparisons yielded predicted values between the corresponding dry and wet median values. The two predicted values that did not fall in between actual data for dry and wet periods had very limited and seemingly aberrant dry weather data. All predicted values were consistent with expectations for the corresponding subwatersheds, based on sampling and knowledge of land use and related pollutant controls. Wet weather values were higher than dry weather values except in two subwatersheds with very limited dry weather data (but very high values for those dry weather samples).

For predicted N concentrations leaving subwatersheds, only about half fell within the dry-wet range for actual data, but the range was narrow and most values were close; the average deviation from the corresponding wet weather median was 0.23 mg/L or 20.6%, but after removal of subwatershed A, which had only 7 wet weather data points for comparison, the difference averaged 0.16 mg/L and 14.3%. Wet weather values were not consistently higher than dry weather values, suggesting potentially different sources in different subwatersheds (e.g., fertilizers vs. septic systems).

For in-lake concentrations, predicted P was a very close match for actual mean P (0.023 mg/L each) and just slightly higher than actual median P (0.021 mg/L). Predicted N was slightly lower than actual measured N for 2007-2008, at 0.666 mg/L vs. 0.925 mg/L, respectively, which seems unusual since many predicted N values for subwatershed outputs were slightly higher than the range of dry-wet sample values. Although the difference is 28%, we did not consider this sufficient to alter the model at this point.

Table 4-1. Calibration check for LLRM for Lake Pocotopaug.

Measurement/Calculation	A-Direct	B-Direct	C-Direct	D-direct	E-Christ	F-Clark	G-Unnamed	H-Hales	I-Candle	J-Unnamed	K-Fawn	L-Hazen	M-Oneil	N-Days	TOTAL
Water Output (m3/yr)	269,079	209,582	466,361	74,508	1,055,083	133,831	105,659	1,934,806	98,565	48,818	309,667	29,656	100,817	183,992	5,020,424
Reality Check for Indiv. Basin	276,811	212,575	471,519	78,006	1,123,393	137,493	112,533	2,013,102	98,335	49,100	325,766	30,091	103,797	183,528	5,216,049
Calculated/Reality Check	0.97	0.99	0.99	0.96	0.94	0.97	0.94	0.96	1.00	0.99	0.95	0.99	0.97	1.00	
P Output (kg/yr)	24.9	17.6	39.0	6.0	48.3	10.2	4.7	64.7	6.8	4.0	20.3	1.1	8.0	9.4	265
P Output (mg/L)	0.092	0.084	0.084	0.081	0.046	0.076	0.045	0.033	0.069	0.083	0.066	0.038	0.079	0.051	0.053
P Reality Check: Dry Median (mg/L) from data	0.198		0.060		0.021		0.439	0.008	0.021	0.009	0.036	0.028	0.058	0.031	
P Reality Check: Wet Median (mg/L) from data	0.149		0.141		0.065	0.196	0.090	0.042	0.114	0.163	0.174	0.169	0.706	0.178	
P Basin Export Coefficient (kg/ha/yr)	0.50	0.46	0.46	0.43	0.24	0.42	0.24	0.18	0.39	0.46	0.35	0.21	0.43	0.29	0.28
N Output (kg/yr)	564.5	397.3	878.3	136.3	962.3	231.1	104.4	1608.6	106.6	63.5	317.5	17.3	126.7	148.0	5662
N Output (mg/L)	2.098	1.895	1.883	1.830	0.912	1.727	0.988	0.831	1.081	1.300	1.025	0.582	1.257	0.804	1.128
N Reality Check: Dry Median (mg/L) from data			2.200		0.595		3.300	0.330	0.348	1.590	0.400	0.285	0.766	0.565	
N Reality Check: Wet Median (mg/L) from data	1.085		1.742		0.931	1.926	0.826	0.894	1.007	0.745	0.310	0.558	1.220	0.454	
N Basin Export Coefficient (kg/ha/yr)	11.40	10.45	10.42	9.77	4.79	9.40	5.19	4.47	6.06	7.23	5.45	3.21	6.83	4.51	6.07

Table 4-2. Comparison of LLRM in-lake predictions under calibration, verification and several scenarios for Lake Pocotopaug and its watershed.

Time Period	**2007-2008**		**2002-2004**		**1991-2001**		**1973-1974**		**Older Conditions**		**Projected Build-Out**	**All Feasible Mgmt**	**Target Mgmt**
Source of Values	**Model Value**	**Actual Data**	**Model Value**	**Actual Data**	**Model Value**	**Actual Data**	**Model Value**	**Actual Data (1974)**	**Bkgrd Model Value**	**Actual Data (1937-38)**	**Model Value**	**Model Value**	**Model Value**
Lake Feature													
Phosphorus (ppb)	23	23	23	23	18	16	15	17	11		33	14	14
Nitrogen (ppb)	666	925	591	565	494	492	470	386	355		820	503	502
Mean Chlorophyll (ug/L)	9.0		8.8		6.5	7.8	5.2	6.8	3.4		14	4.6	4.9
Peak Chlorophyll (ug/L)	30.8		30.2		22.5	24.0	18.4	15.5	12.5		46.6	16.5	17.2
Mean Secchi	2.1	1.5	2.1	1.2	2.5	1.9	2.9	3.6	3.6	4.4	1.6	3.1	3.0
Peak Secchi	4.1	2.9	4.1	2.4	4.4	4.1	4.6	4.5	5.0	6.2	3.7	4.7	4.6
Bloom Probability													
Probability of Chl >10 ug/L	32.4%		31.0%		13.1%		6.1%		0.8%		66.1%	3.7%	4.5%
Probability of Chl >15 ug/L	10.3%		9.6%		2.7%		0.9%		0.1%		34.6%	0.5%	0.6%
Probability of Chl >20 ug/L	3.3%		3.0%		0.6%		0.2%		0.0%		16.6%	0.1%	0.1%
Probability of Chl >30 ug/L	0.4%		0.4%		0.0%		0.0%		0.0%		3.7%	0.0%	0.0%
Probability of Chl >40 ug/L	0.1%		0.1%		0.0%		0.0%		0.0%		0.9%	0.0%	0.0%

CHL concentrations were not available for this time period, but SDT is influenced mainly by CHL in Lake Pocotopaug and was slightly lower than expected based on P concentrations. This is consistent with past evaluations, and is almost certainly a function of the formation of cyanobacterial (blue-green algae) surface scums that lower clarity at lower CHL levels than would be necessary for other non-scum-forming algae. Knowing this about the lake, we opted not to alter the model at this time to adjust SDT.

4.2 Validation of LLRM

Validation involves comparing predicted and actual values for a different set of conditions for which data are available (Table 4-2). For Lake Pocotopaug, data are available for the period 2002-2004, which is not substantially different than 2007-2008, providing a “duplicate” calibration period. Data are also available for the mid-1990s facilitating model verification for the period 1991-2001. Land use is also known from the 1970s, and there are some water quality data for 1973-1974 that allow a separate verification effort. Additionally, while pre-development data are not available, there are some data for 1937-1938 that can be compared to the pre-development predictions for Lake Pocotopaug.

Duplicate calibration for 2002-2004 results in identical predictions for P and SDT as for the 2007-2008 calibration, but a lower N value for the lake (0.591 mg/L). Actual data for in-lake P match the prediction, and the in-lake N level (0.565 mg/L) is much closer to the predicted value than for the 2007-2008 model run. The primary difference is related to the internal load, which was reduced by a treatment in 1999-2000. SDT values are even lower than for 2007-2008, indicating issues with surface blue-green scums that were indeed observed during 2002-2004. Agreement between the two calibration runs was considered sufficient to move to further validation

Applying land use data from the 1990s (Table 4-3, generated from CT DEP data in ENSR 2002) and adjusting attenuation where additional undeveloped land would have been present, the P concentration in the lake declines to 0.018 mg/L, while the actual data from that period averaged 0.016 mg/L (Table 4-2). Predicted and actual in-lake N matched much more closely, at 0.494 vs. 0.492 mg/L, respectively. There are CHL data from this period, and the predicted average CHL level of 6.5 ug/L was slightly less than the measured mean of 7.8 ug/L. The predicted peak and actual CHL values were a close match. Predicted SDT continues to be higher than the actual value, although the values are closer (2.5 vs 1.9 m for the average, 4.4 vs. 4.1 m for the peak).

Applying land use data from the 1970s (Table 4-4, generated from data in Frink and Norvell 1984), LLRM predicts a P concentration of 0.015 mg/L while actual data suggest a value of 0.017 mg/L. While these values are close, the sanitary sewer system was installed later in the 1970s, and there may be inputs not being accounted for in the model as a result; no change was made to increase the septic system inputs in the direct drainage areas. However, predicted N was noticeably higher than measured N (0.470 vs. 0.386 mg/L), and one might expect that without the sewers the N level would be higher. Predicted mean CHL is still somewhat lower than actual mean CHL, and the peak levels are comparable. Unlike other model runs, predicted mean SDT is lower than the actual mean value, at 2.9 m vs. 3.6 m, suggesting that the blue-green scums were less prevalent in the 1970s. Predicted and actual peak SDT was nearly identical.

The setting of all land uses to natural forms, mainly forest and wetland, results in an estimation of the load the lake might experience in the absence of human influence. Predicted P in the lake is 0.011 mg/L and predicted

Table 4-3. Land use data applied to LLRM to represent the 1990s. Data from CT DEP as reported in ENSR 2002 for the whole watershed were partitioned among subwatersheds in accordance with knowledge of where development had occurred in that period.

LAND USE	A-Direct AREA (HA)	B-Direct AREA (HA)	C-Direct AREA (HA)	D-direct AREA (HA)	E-Christ AREA (HA)	F-Clark AREA (HA)	G-Unnamed AREA (HA)	H-Hales AREA (HA)	I-Candle AREA (HA)	J-Unnamed AREA (HA)	K-Fawn AREA (HA)	L-Hazen AREA (HA)	M-Oneil AREA (HA)	N-Days AREA (HA)	TOTAL AREA (HA)
Urban 1 (LDR)	24.8	18.9	41.7	4.7	42.4	8.9	1.8	26.8	4.7	3.5	3.1	0.4	4.7	5.7	192.1
Urban 2 (MDR/Hwy)	1.9	1.3	2.8	0.4	3.0	0.7	0.2	2.0	0.4	0.3	1.2	0.0	0.6	0.4	15.2
Urban 3 (HDR/Com)	1.9	1.3	2.8	0.4	3.0	0.7	0.2	2.0	0.4	0.3	1.2	0.0	0.6	0.4	15.2
Urban 4 (Ind)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Urban 5 (P/I/R/C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 1 (Cvr Crop)	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Agric 2 (Row Crop)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 3 (Grazing)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 4 (Feedlot)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest 1 (Upland)	16.3	14.5	34.9	5.9	124.6	12.3	16.0	311.2	12.0	4.7	50.8	4.3	10.8	23.0	641.3
Forest 2 (Wetland)	0.0	0.0	0.2	0.0	14.5	0.0	0.0	6.1	0.0	0.0	1.9	0.0	0.2	2.7	25.7
Open 1 (Wetland/Lake)	2.5	1.5	0.6	0.6	0.1	0.0	0.0	3.1	0.0	0.1	0.0	0.0	0.2	0.1	8.7
Open 2 (Meadow)	2.0	0.5	1.3	1.8	10.2	2.1	1.9	7.0	0.1	0.0	0.2	0.7	1.4	0.3	29.5
Open 3 (Excavation)	0.1	0.0	0.1	0.1	2.3	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	4.4
TOTAL	49.5	38.0	84.4	13.9	200.8	24.7	20.1	360.0	17.6	8.9	58.4	5.4	18.6	32.7	932.8

Table 4-4. Land use data applied to LLRM to represent the 1970s. Data from Norvell and Frink 1984 for the whole watershed were partitioned among subwatersheds equally.

LAND USE	A-Direct AREA (HA)	B-Direct AREA (HA)	C-Direct AREA (HA)	D-direct AREA (HA)	E-Christ AREA (HA)	F-Clark AREA (HA)	G-Unnamed AREA (HA)	H-Hales AREA (HA)	I-Candle AREA (HA)	J-Unnamed AREA (HA)	K-Fawn AREA (HA)	L-Hazen AREA (HA)	M-Oneil AREA (HA)	N-Days AREA (HA)	TOTAL AREA (HA)
Urban 1 (LDR)	20.0	15.2	33.6	3.8	34.1	7.2	1.4	21.6	3.8	2.8	2.5	0.3	3.8	4.6	154.6
Urban 2 (MDR/Hwy)	1.5	1.0	2.3	0.3	2.4	0.6	0.2	1.6	0.3	0.2	1.0	0.0	0.5	0.3	12.3
Urban 3 (HDR/Com)	1.5	1.0	2.3	0.3	2.4	0.6	0.2	1.6	0.3	0.2	1.0	0.0	0.5	0.3	12.3
Urban 4 (Ind)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Urban 5 (P/I/R/C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 1 (Cvr Crop)	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Agric 2 (Row Crop)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 3 (Grazing)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 4 (Feedlot)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest 1 (Upland)	21.9	18.7	44.1	7.0	134.2	14.3	16.4	317.2	13.1	5.5	51.9	4.3	12.0	24.3	684.8
Forest 2 (Wetland)	0.0	0.0	0.2	0.0	14.5	0.0	0.0	6.1	0.0	0.0	1.9	0.0	0.2	2.7	25.7
Open 1 (Wetland/Lake)	2.5	1.5	0.6	0.6	0.1	0.0	0.0	3.1	0.0	0.1	0.0	0.0	0.2	0.1	8.7
Open 2 (Meadow)	2.0	0.5	1.3	1.8	10.2	2.1	1.9	7.0	0.1	0.0	0.2	0.7	1.4	0.3	29.5
Open 3 (Excavation)	0.1	0.0	0.1	0.1	2.3	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	4.4
TOTAL	49.5	38.0	84.4	13.9	200.8	24.7	20.1	360.0	17.6	8.9	58.4	5.4	18.6	32.7	932.8

N is 0.355 mg/L. Mean and peak CHL are predicted at 3.4 and 12.5 ug/L, respectively. SDT is predicted at a mean of 3.6 m and a peak of 5.0 m. The limited data from 1937-1938 do not include reliable data for P, N or CHL, but a mean SDT of 4.4 m and a peak value of 6.2 m are somewhat higher than the predicted values for an undeveloped watershed. The pattern is consistent with expectations however, and the model appears to represent the system well enough to use it to investigate possible future conditions under possible scenarios.

4.3 Sensitivity Testing

Based on the expected potential range for input data, LLRM was run multiple times and the results were compared with the original, calibrated run with 2007-08 data (Table 4-5). Most resultant changes (71%) were <5% different from the calibrated model. A few (23%) had changes between 5 and 10% of the original run, and just three (6%) had changes between 10 and 15%, the highest % change being 14.4%. The model will be sensitive to major changes, mainly relating to land use or management of attenuation, but is not overly sensitive to minor changes within the range of possible data input error. Changes in land use or attenuation that are comparable to the range of possible input value variation will lead to minor changes that cannot be expected to be detectable within the variance of the model, but major shifts associated with most scenarios of interest will exceed the confidence interval associated with model error and should be readily apparent.

Table 4-5. Comparison of LLRM runs with stated changes in variable values with the calibrated 2007-08 model run for TP, TN, CHL and SDT.

	Predicted In-lake Values							
Condition	**Mean TP**		**Mean TN**		**Mean CHL**		**Mean SDT**	
	(ug/L)	**% change**	**(ug/L)**	**% change**	**(ug/L)**	**% change**	**(ug/L)**	**% change**
Calibrated model, current conditions	23	0	666	0	9.0	0	2.1	0
Precipitation lowered from 48 to 46 inches	24	4.3%	677	1.7%	9.2	2.2%	2.0	-4.8%
Precipitation raised from 48 to 52 inches	22	-4.3%	625	-6.2%	8.3	-7.8%	2.2	4.8%
Water export coefficients for runoff raised 10%	23	0.0%	656	-1.5%	8.8	-2.2%	2.1	0.0%
Water export coefficients for runoff lowered 10%	24	4.3%	677	1.7%	9.2	2.2%	2.0	-4.8%
TP and TN runoff export coefficients raised 10%	25	8.7%	686	3.0%	9.9	10.0%	2.0	-4.8%
TP and TN runoff export coefficients lowered 10%	21	-8.7%	646	-3.0%	8.2	-8.9%	2.2	4.8%
Wildlife inputs doubled	23	0.0%	667	0.2%	9.2	2.2%	2.1	0.0%
Wildlife inputs increased tenfold	26	13.0%	677	1.7%	10.3	14.4%	1.9	-9.5%
Atmospheric TP and TN concentrations increased 20%	24	4.3%	682	2.4%	9.3	3.3%	2.0	-4.8%
Atmospheric TP and TN concentrations lowered 20%	23	0.0%	663	-0.5%	8.7	-3.3%	2.1	0.0%
Internal loading increased from 71.6 to 100 kg/yr	25	8.7%	710	6.6%	10.0	11.1%	2.0	-4.8%
Internal loading decreased from 71.6 to 50 kg/yr	22	-4.3%	632	-5.1%	8.3	-7.8%	2.2	4.8%

5.0 QA/QC REVIEW OF DATA INPUTS AND MODEL OUTPUTS

5.1 Quality Control and Quality Assurance for Data Inputs

Data acquired from all sources described in Section 3 were subjected to QA/QC assessment to the extent feasible. Data from programs with strong QA/QC programs (USGS, NOAA) were accepted as is if from a published report. Data for land use were compared to old maps and knowledge of more recent developments, conferring with local officials and residents as necessary to ascertain the time period of various watershed activities. The ENSR 2001 investigation report (ENSR 2002) has a useful chronology up to that point, and AECOM staff have been involved in work in East Hampton since that time. Literature sources for atmospheric and bird inputs are credible, but their application to this site is done with only best professional judgment applied. Most critical, perhaps, are the water quality data used to estimate a number of loading sources, export coefficients, and actual values for comparison with model predictions. These were subjected to careful review.

There have not been any major QA/QC samples collected from the lake or its tributaries in recent years. Past efforts have involved such samples, and the results from one such effort in 2001 are presented in Tables 5-1 and 5-2. While maximum error is sometimes substantial, the average Relative Percent Difference (RPD) is generally acceptable in accordance with the goals established in the QAPP for this project. Blanks did not result in values above the detection limit. No spikes were run as part of this effort, but the internal lab QA/QC program has resulted in recertification of Columbia Labs each year, indicating satisfactory compliance. There have been no QA/QC samples sent to Berkshire Envirolabs for Lake Pocotopaug, but past assessments have yielded similar results as for Columbia Labs. In general, data quality is acceptable, but occasional “bad” values do occur, so all data must be reviewed for possible outliers and related problems or inconsistencies.

To this end, the in-lake data from 1937-38, 1973-73, 1991-2001, 2002-2004, and 2007-2008 were reviewed in the most original form obtainable: spreadsheets for data from 1991 and more recently, and published reports for the older data. Methods could not be ascertained for nutrient analyses for the 1937-38 samples, and the values seemed high; elevated detection limits are suspected, so these data were not applied. Data from 1973-74 included elevated nutrient values vertically throughout the lake on one date (September 1974). It is possible that mixing of high nutrient concentrations near the bottom of the lake into the upper waters from a late summer storm was responsible, or that there was lab error; either way, these results were not considered representative and were deleted. Five seemingly outlier values from the 1991-2001 database were eliminated; these looked to be transcription errors (e.g., ug/L recorded as mg/L) and represented <1% of the data. There were no suspect values encountered in the 2002-04 or 2007-08 data sets. CHL data were available only for the 1970s and 1990s data sets, but no suspect values were detected. SDT values from all time periods appeared sound, although some were recorded in feet and were converted to m for this analysis. The data applied in this effort are provided in Appendix A.

Tributary data are from 2001 through 2008, and are all from samples collected by or under the direction of current AECOM staff. All lab data were generated by Columbia Laboratory. Some stormwater values are quite high, but variability for such samples is usually high, and no values were eliminated from the database. Applied values are also provided in Appendix A.

Table 5-1. QA/QC results for water quality data from Lake Pocotopaug and its inputs.
QA/QC is expressed as RPD (relative percent difference), a measure of precision.

Tributaries and storm drains

Parameter (units)		n	range of values min	- max	RPD min	RPD average	RPD max	std. dev.
pH	SU	5	5.9	6.8	0.0	0.7	1.7	0.1
Turbidity	NTU	6	2.6	93	0.0	16.8	56.3	16.5
Spec. Cond	us/cm	5	52	140	1.5	21.2	81.0	33.7
Alkalinity	mg/L	7	4	26	0.0	27.6	85.7	2.2
Suspended Solids	mg/L	7	3.7	252	7.8	33.4	90.9	30.9
Chloride	mg/L	1	10	11	9.5	9.5	9.5	
Total Phosphorus	mg/L	7	0.012	0.229	4.4	26.1	59.5	0.0
Dissolved Phosphorus	mg/L	7	0.008	0.05	0.0	28.3	63.4	0.0
Ammonium-N	mg/L	7	0.01	0.17	0.0	61.5	133.8	0.0
Nitrate-N	mg/L	7	0.01	0.81	0.0	19.4	56.3	0.1
TKN	mg/L	7	0.36	1.989	1.8	8.7	18.2	0.1

In-lake

Parameter (units)		n	range of values min	- max	RPD min	RPD average	RPD max	std. dev.
pH	SU	4	7	8.5	0.0	1.3	4.2	0.1
Turbidity	NTU	4	2.1	5.2	1.9	10.7	21.3	0.3
Spec. Cond	us/cm	4	91	111	0.0	1.2	2.2	1.0
Alkalinity	mg/L	4	4	10	0.0	2.9	11.8	0.5
Total Phosphorus	mg/L	6	0.008	0.02	0.0	10.6	19.4	0.0
Dissolved Phosphorus	mg/L	6	0.001	0.004	0.0	22.2	66.7	0.0
Dissolved Iron	mg/L	1	0.01	0.01	0.0	0.0	0.0	

Table 5-2. Laboratory percent error during the 2001 Lake Pocotopaug investigation.

Columbia Environmental Laboratory QA/QC

Parameter (units)		n	% Error min	% Error average	% Error max	Max difference True – Obs.
Total Phosphorus	mg/L	12	0	3.5	8.7	0.004
Dissolved Phosphorus	mg/L	8	0	3.5	18.2	0.002
Ammonium-N	mg/L	3	0	6.8	13.1	0.014
Nitrate-N	mg/L	2	3.8	6.8	9.7	0.006
Dissolved Aluminum	mg/L	1	12.5	12.5	12.5	0.050

The quantitative objective for comparison of actual data to predictions is at least 10 values available for any station to construct a mean or median, and both wet and dry weather should be represented. One out of 18 in-lake data sets had <10 values, while 3 out of 14 tributary sample sets had <10 values (Tables 3-4 and 3-5). The potential limitations imposed by these data were considered in the analysis, but the values are still useful for evaluating model results. We separated wet and dry weather values for Lake Pocotopaug tributaries. Values represent April through November of multiple years, and represent a range of precipitation conditions.

5.2 Quality Control and Quality Assurance for Model Outputs

Model outputs generally conform to QA/QC objectives as laid out in the QAPP (Table 5-3). Some differences are slightly in excess of the targets, but there are valid explanations for the differences. Nutrient concentration deviations are generally a function of limited measurements and high variability in stormwater, but even then the level of agreement is reasonably close. The in-lake TP prediction is nearly identical to the actual median value and only 9% off of the mean value for both the 2007-08 and 2002-04 calibration runs. Actual SDT values tend to be lower than predicted, as Lake Pocotopaug is subject to buoyant cyanobacterial blooms in mid-summer to early fall, resulting in surface scums and lower clarity than if the algae were mixed in the water column (as assumed in the model). Going back in time, as the nutrient values decline and the SDT increases, the predicted value is eventually lower than the actual value, consistent with changes in algal dominance and distribution.

The key comparison from the perspective of using the model for further scenario evaluation is the in-lake TP, actual vs. predicted. These values match very closely for both the 2007-08 and 2002-04 calibration runs, which are essentially duplicates (separate actual data, very similar land use and watershed features). CHL and SDT follow from the TP concentration, with expected greater variability. There are no CHL data after 2001, and the overprediction of SDT is expected in light of the surface cyanobacterial blooms that are common during summer. As most SDT measures are made in the summer, the surface scums skew the SDT value away from the model prediction, which does not account for those scums.

Table 5-3. Difference between predicted and observed values.

Comparison	Maximum Difference Accepted	Observed Difference
Calculated annual discharge vs. annualized measured flow	10%	No measured flow data
Calculated annual discharge vs. estimation by standard water yield	10%	4% overall (0-6% by basin)
Predicted stream concentration of P at basin outflow vs. actual average or median value	20%	Difference between predicted value and simulated mean (mix of wet and dry in proportion) is 25%, but this is not necessarily representative of the true value.
Predicted stream concentration of N at basin outflow vs. actual average or median value	20%	Average difference between actual wet and predicted values is 14% for comparisons with adequate data.
Predicted stream concentration of P at basin outflow vs. actual range from wet and dry weather samples	Inside of range, closer to dry weather value	9 of 10 basins with adequate data have TP concentration between wet and dry medians; remaining basin has suspect dry weather value.
Predicted stream concentration of N at basin outflow vs. actual range from wet and dry weather samples	Inside of range, closer to dry weather value	5 of 10 basins with adequate data have TN concentration between wet and dry medians; all but one other pair of basin values is close.
Predicted in-lake P or N concentration vs. mean or median of actual data	10%	P match is very close (<1% for median, 9% for mean); N match off for 2007-08 data (28%), but very close for 2002-04 data (5%).
Predicted in-lake CHLA concentration vs. mean or median of actual data	20%	No actual CHL data
Predicted in-lake SDT vs. mean or median of actual data	20%	Predicted SDT is 29% higher than actual for 2007-08, but algal surface scums are responsible; predicted values is appropriate. Difference is even larger for 2002-04, but SDT measurements are limited.

6.0 CURRENT LOADING TO LAKE POCOTOPAUG

Loading to Lake Pocotopaug has been evaluated in several past efforts (Fugro East 1993, Lake Advisory Committee 1995, ENSR 2002, ENSR 2007b). This modeling effort adds to those estimates (Table 6-1), which provides a rather wide range of suggested loads. Part of the discrepancy comes from different periods of time, which are represented by different databases, different watershed features, and different management situations. Some estimates are not really believeable (e.g., 207 kg P/yr from atmospheric sources in LAC 1995), but most estimates are distinctly possible as a function of variable loading processes; the range really could be as wide as shown over a series of years.

Table 6-1. Comparison of loading estimates for Lake Pocotopaug.

<table>
<tr><th></th><th colspan="6">TP Load (kg/yr)</th><th colspan="2">TN Load (kg/yr)</th></tr>
<tr><th>Source</th><th>Fugro 1993</th><th>LAC 1995</th><th>ENSR 2002</th><th>ENSR 2007</th><th>AECOM 2009 Model</th><th>AECOM 2009 Expected Range</th><th>AECOM 2009 Model</th><th>AECOM 2009 Expected Range</th></tr>
<tr><td>Atmospheric</td><td rowspan="4">574</td><td>207</td><td>25 to 50</td><td>75</td><td>41</td><td>33 to 49</td><td>1242</td><td>1201 to 1283</td></tr>
<tr><td>Wildlife</td><td>20</td><td>20 to 40</td><td>20</td><td>4</td><td>4 to 40</td><td>19</td><td>19 to 190</td></tr>
<tr><td>Direct Groundwater</td><td></td><td>5 to 18</td><td>12</td><td rowspan="2">265</td><td rowspan="2">242 to 408</td><td rowspan="2">5662</td><td rowspan="2">4701 to 6013</td></tr>
<tr><td>Watershed</td><td>360</td><td>280 to 720</td><td>318 to 364</td></tr>
<tr><td>Internal</td><td>500</td><td>?</td><td>62</td><td>16</td><td>72</td><td>50 to 100</td><td>1790</td><td>1400 to 2000</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total</td><td>1074</td><td>587+ internal</td><td>392 to 890</td><td>441 to 487</td><td>382</td><td>329 to 597</td><td>8713</td><td>7321 to 9486</td></tr>
</table>

The P load extrapolated from the LLRM as applied here is the lowest total load to the lake. This is a consequence of the model predicting the load to which the lake appears to be responding, not necessarily the actual total load received. Larger particulate forms will settle quickly in the lake and do not become part of the short-term “effective” load, the load that correlates with the predicted P concentration in the lake and directly produces algae, as represented by CHL, and lowers water clarity, as represented by SDT. Part of this particulate load, however, can eventually be liberated through biological and chemical processes in the lake and forms the basis of the internal load. That the lake experienced a substantial internal load just a few years after the 2000-2001 aluminum treatments to inactivate sediment P suggests that the watershed contribution to that internal load is significant; it took no more than three years to replace the sediment P that was inactivated by the treatments.

The best estimate of the portion of the current watershed load that contributes to the internal load comes from the effort to estimate export coefficients from available data for subwatersheds (Appendix B). This exercise suggests empirically that about 91 kg P/yr enters the lake during dry weather, while 317 kg P/yr enters with stormwater runoff. Assuming that the dry weather inputs are largely dissolved (and therefore available), and given a total effective load from the watershed of 265 kg P/yr, about 174 kg P/yr of the stormwater load is readily available, leaving 143 kg P/yr to be incorporated into the sediment. Typical ratios of dissolve to particulate P in stormwater range from 0.33 to 0.75, with 0.5 often applied in the absence of real data. The load from stormwater to Lake Pocotopaug appears to be about 55% available, consistent with expectations.

Much of the load that is unavailable upon entry to the lake will remain unavailable, but it would not be surprising if 25 to 33% of this load did become available, or a net increase of 36 to 47 kg P/yr. At that rate, with some flushing and natural inactivation, it would take only about two to three years to replace the entire internal P load if inactivated, as with the 2000-2001 aluminum treatment. In fact, the lake returned to its former condition between two and three years after that treatment.

Most past studies have not addressed N loading to any great detail, although N was measured in the lake in some cases. This investigation suggests that total N loading averages about 8713 kg/yr (Table 6-1). The ratio of N to P loads is fairly high (22:1), suggesting P limitation in Lake Pocotopaug, but much of the N is in unavailable forms when it reaches the lake, and despite substantial internal recycling, soluble forms of N (i.e., ammonium and nitrate) are in short supply much of the summer. Lake Pocotopaug therefore undergoes an oscillation from P to N limitation over the course of the year, and low summer available N levels favor the cyanobacteria that bloom in the lake at that time. These blue-green algae can utilize dissolved N gas, unlike most other algae, and therefore are less limited by the short supply of available N.

The expected range of N loading, 7321 to 9486 kg/yr, has major components from the watershed, atmosphere and internal sources. The internal load appears to be very high, especially since it is all dissolved, available N. Watershed and atmospheric sources will contain much more particulate N, which will not be nearly as available for plant and algae uptake. Much of the internal load is trapped in the bottom layer of water during summer stratification, however, and may not become available. Yet the estimates provided here (1400 to 2000 kg/yr) assume that only 40% of the generated internal load ever becomes part of the effective lake load; internal regeneration of available N may be an important source in Lake Pocotopaug.

Even though N may limit productivity at times in Lake Pocotopaug, control of P can minimize algal blooms if it is made to be limiting. For most lakes with desirable aesthetic conditions, P is the limiting nutrient, and the focus of management in Lake Pocotopaug and its watershed should be on P management. Many techniques for lowering P inputs to the lake will also lower N inputs, and N should not be ignored, but supporting designated use goals for Lake Pocotopaug will depend on P control in the lake and watershed.

7.0 EVALUATION OF SCENARIOS

7.1 Scenarios to be Evaluated

Once the model is adjusted to the point where it provides the best possible representation of reality, scenarios relating to possible changes in land use or watershed and lake management can be evaluated. Where setting P or N concentration or load targets is desired, as with a Total Maximum Daily Load, it is often helpful to set all land uses to undeveloped conditions (forest or wetland) to determine the minimum load and concentration that might be expected under pre-development conditions. Note that attenuation may change with land uses changes, and internal loading is likely to be lower. The resultant values will set lower bounds on historic loading to the lake and conditions in it. The reverse scenario is also of interest, where the maximum expected build out is explored by setting all land uses that might be changed to developed uses and reducing attenuation in the watershed as buffering natural lands are lost. Additionally, one or more scenarios involving feasible management approaches can be tested, allowing some prediction of the results of management options under consideration.

7.2 Natural Conditions

The “natural” scenario was run as part of the validation effort for LLRM as applied to Lake Pocotopaug, with the results as shown in Table 4-2. The expected conditions in the absence of human influence include in-lake TP at 0.011 mg/L, TN and 0.355 mg/L, CHL at an average of 3.4 ug/L, and an average SDT of 3.6 m. These values are all consistent with support of all designated uses of Lake Pocotopaug. There are no data from a time when there was no human influence, but the SDT data from the 1930s suggests that conditions may be even better than suggested by the model under a natural land use scenario (average SDT = 4.4 m, but data are few). Actual data from the 1970s, prior to the building boom of the 1980s and beyond, suggest an average SDT of 3.6 m. The natural scenario is considered to represent a reasonable boundary to the improvement in Lake Pocotopaug that might be achieved, and is probably beyond what will actually be achievable.

7.3 Complete Build Out

An alternative scenario of potential use is total build out, under which all land that can be converted to developed uses is set to those uses. Knowledge of zoning, wetlands regulations, public vs. private ownership, and related influences is important to a proper build out analysis. Attenuation values are likely to change in this scenario as well. The resultant values will set and upper bound on probable loading to the lake and concentrations in it. Land use was altered only in subwatersheds E, F, G, H and K (Table 7-1), as other subwatersheds are either nearly built out now or have protected lands in them that, at least theoretically, will not be developed. This may underrepresent the full build out scenario, but was considered a reasonable representation of what might happen at Lake Pocotopaug without greater management effort.

The results of the build out scenario are shown in Table 4-2, and indicate an equilibrium TP concentration of 0.033 mg/L, TN of 0.82 mg/L, CHL averaging 14 ug/L and a mean SDT of 1.6 m. This represents a definite deterioration from present conditions, although it is not clear that the summer algal blooms will get worse. Rather, such blooms are likely to occur more often, and at other times of the year as well, although an increase

Table 7-1. Land use changes representing full build out in the Lake Pocotopaug watershed.

LAND USE	A-Direct AREA (HA)	B-Direct AREA (HA)	C-Direct AREA (HA)	D-direct AREA (HA)	E-Christ AREA (HA)	F-Clark AREA (HA)	G-Unnamed AREA (HA)	H-Hales AREA (HA)	I-Candle AREA (HA)	J-Unnamed AREA (HA)	K-Fawn AREA (HA)	L-Hazen AREA (HA)	M-Oneil AREA (HA)	N-Days AREA (HA)	TOTAL AREA (HA)
Urban 1 (LDR)	29.8	19.9	43.7	6.7	104.301343	15.3408837	9.93791655	182.935384	6.7	4.5	34.8384295	0.4	8.7	6.7	474.4
Urban 2 (MDR/Hwy)	3.7	2.5	5.5	0.8	5.9	1.4	0.3	4.0	0.8	0.6	2.3	0.0	1.1	0.8	29.7
Urban 3 (HDR/Com)	3.7	2.5	5.5	0.8	5.9	1.4	0.3	4.0	0.8	0.6	2.3	0.0	1.1	0.8	29.7
Urban 4 (Ind)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Urban 5 (P/I/R/C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 1 (Cvr Crop)	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Agric 2 (Row Crop)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 3 (Grazing)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 4 (Feedlot)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest 1 (Upland)	7.7	11.1	27.5	3.1	56.9029121	4.44982686	7.69569195	151.098331	9.2	3.1	16.7770445	4.3	5.8	21.2	330.0
Forest 2 (Wetland)	0.0	0.0	0.2	0.0	14.5	0.0	0.0	6.1	0.0	0.0	1.9	0.0	0.2	2.7	25.7
Open 1 (Wetland/Lake)	2.5	1.5	0.6	0.6	0.1	0.0	0.0	3.1	0.0	0.1	0.0	0.0	0.2	0.1	8.7
Open 2 (Meadow)	2.0	0.5	1.3	1.8	10.2	2.1	1.9	7.0	0.1	0.0	0.2	0.7	1.4	0.3	29.5
Open 3 (Excavation)	0.1	0.0	0.1	0.1	2.3	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	4.4
Other 1															0.0
Other 2															0.0
Other 3															0.0
TOTAL	49.5	38.0	84.3	13.9	200.9	24.6	20.1	360.0	17.6	8.8	58.3	5.4	18.6	32.8	932.7

Table 7-2. Changes in subwatershed export as a result of feasible BMP application.

PHOSPHORUS	A-Direct	B-Direct	C-Direct	D-direct	E-Christ	F-Clark	G-Unname	H-Hales	I-Candle	J-Unname	K-Fawn	L-Hazen	M-Oneil	N-Days	Total
CUMULATIVE TOTAL	21.7	15.6	34.6	5.4	59.5	9.2	4.8	86.0	6.3	3.6	19.0	1.2	7.1	9.1	
OLD BASIN ATTENUATION	0.90	0.90	0.90	0.90	0.70	0.90	0.90	0.70	0.90	0.90	0.90	0.90	0.90	0.90	
NEW BASIN ATTENUATION	0.80	0.70	0.50	0.70	0.50	0.70	0.60	0.60	0.60	0.60	0.50	0.70	0.60	0.60	
REDUCTION IN TRANSPORT	0.1	0.2	0.4	0.2	0.2	0.2	0.3	0.1	0.3	0.3	0.4	0.2	0.3	0.3	
OLD OUTPUT LOAD	24.9	17.6	39.0	6.0	48.3	10.2	4.7	64.7	6.8	4.0	20.3	1.1	8.0	9.4	265.1
NEW OUTPUT LOAD	17.3	10.9	17.3	3.8	29.7	6.4	2.9	51.6	3.8	2.2	9.5	0.8	4.3	5.5	165.9
NITROGEN	A-Direct	B-Direct	C-Direct	D-direct	E-Christ	F-Clark	G-Unname	H-Hales	I-Candle	J-Unname	K-Fawn	L-Hazen	M-Oneil	N-Days	TOTAL
CUMULATIVE TOTAL	564.5	397.3	878.3	136.3	1374.6	231.1	104.4	1787.3	152.3	90.7	453.6	24.7	181.0	211.4	
OLD BASIN ATTENUATION	1.00	1.00	1.00	1.00	0.70	1.00	1.00	0.90	0.70	0.70	0.70	0.70	0.70	0.70	
NEW BASIN ATTENUATION	0.90	0.80	0.70	0.80	0.60	0.80	0.70	0.80	0.60	0.60	0.60	0.60	0.60	0.60	
REDUCTION IN TRANSPORT	0.1	0.2	0.3	0.2	0.1	0.2	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
OLD OUTPUT LOAD	564.5	397.3	878.3	136.3	962.3	231.1	104.4	1608.6	106.6	63.5	317.5	17.3	126.7	148.0	5662.2
NEW OUTPUT LOAD	508.0	317.8	614.8	109.1	824.8	184.9	73.1	1429.8	91.4	54.4	272.2	14.8	108.6	126.9	4730.4

in the peak CHL level would be expected (46.6 ug/L vs. the current 30.8 ug/L). Perhaps most striking is the distribution of CHL values over the problem range (>10 ug/L being the low end of concern, and >40 ug/L representing “pea soup” conditions); the amount of time CHL will be greater than 10 ug/L roughly doubles, while values >15 ug/L can be expected more than a third of the time, compared to about 10% of the time now. While it may be hard for some to believe, conditions could get worse at Lake Pocotopaug; action is necessary just to slow the decline, and considerable action will be needed to reverse it.

7.4 Application of Feasible BMP

For Lake Pocotopaug, perhaps the scenario of greatest interest relates to how low in-lake P and N concentrations might be with the application of all feasible BMP. As achieving reductions will be an iterative process, use of the model to assign priorities to different subwatersheds for management is also of great interest. For this scenario, P export coefficients for residential and commercial land uses were cut by 25% to simulate source reductions, most notably phosphate fertilizer avoidance, which has been shown to reduce P inputs from urban lands by on the order of 25% (Heiskary pers. comm.., Lehman pers. comm.). N was not reduced in this fashion, however. The internal load was cut in half, simulating an aluminum treatment and reduced watershed inputs to replace the inactivated P. Attenuation factors were altered (Table 7-2) to reflect structural measures in each subwatershed, with the degree of alteration dependent on the distance of the subwatershed from the lake, available land for installation, height of the groundwater table, soils conditions, slope and related watershed factors.

The result is a predicted in-lake average TP of 0.014 mg/L, with a TN value of 0.503 mg/L, a CHL of 4.6 ug/L and a SDT of 3.1 m. While not back to natural conditions, these values represent a major improvement over current conditions and would support all designated uses of Lake Pocotopaug. CHL levels in excess of 10 ug/L would be expected <4% of the time, compared to 32% now. This is probably the best set of conditions that could be achieved without extreme effort, will still cost on the order of several million dollars, would take years to implement, and does not allow for additional development without major offsets to reduce overall loading to the lake, but this scenario is technically achievable.

An additional BMP scenario was run after considering basin by basin actions that were most appropriate (see Section 9), and those results are recorded in Table 4-2 with the other scenarios, for convenient comparison. This scenario is similar to the Feasible BMP scenario, but rather than changing export and attenuation values in the model, the feasible reduction in each subwatershed was estimated by best professional judgment after considering exactly which actions would be most appropriate in each subwatershed. The likely percent reduction was applied to the predicted current load output from each subwatershed and the new total was summed. The internal load was also reduced by 75%, a more aggressive treatment program than in the Feasible BMP scenario, and the new total load was substituted in the Calculations worksheet of LLRM.

The result of this Target Management scenario is much like that of the Feasible BMP scenario, with virtually identical TP and TN values (to the decimal places reported here) but a minimally higher CHL and lower SDT. CHL >10 ug/L would occur <5% of the time. More explanation of the associated management actions is included in Section 9.

8.0 RECOMMENDED TARGET PHOSPHORUS CONCENTRATION AND LOAD

Using July and August data from 1991-2001, 2002-2004, and 2007-2008, the trophic state of Lake Pocotopaug, as determined from the State of Connecticut Water Quality Standards, is mesotrophic (intermediate nutrient levels), although the trend toward higher nutrient levels and lower water clarity is evident (Table 8-1). It is probably unreasonable to assume that Lake Pocotopaug can be made oligotrophic, and it may never have been oligotrophic, based on model projections. However, the mesotrophic range is fairly broad, and support for designated uses such as contact recreation is best provided toward the low end of the mesotrophic scale for nutrients and the upper end of the corresponding scale for water clarity.

Table 8-1. Range of means for the surface of Lake Pocotopaug for July and August data vs. water quality categories for mesotrophic lakes in Connecticut.

	Mesotrophic Category Values	1991-2001	2002-2004	2007-2008
TP	10-30 ug/L spring and summer	11-23	10-23	18-23
TN	200-600 ug/L spring and summer	440	560-700	558-1016
CHL	2-15 ug/L mid-summer	5.5-7.4	NA	NA
SDT	2-6 meters mid-summer	0.7-3.5	0.8-2.9	0.9-1.5

Considering use goals for Lake Pocotopaug and the results of various scenario runs, an average SDT of about 3.0 m (10 ft) would be appropriate. This equates to a CHL concentration of just under 5.0 ug/L. To achieve both of these values with a P limitation, the average P concentration would need to be 0.0145 mg/L, or 14.5 ug/L. Based on the Feasible BMP and Target Management scenarios, this is an achievable value.

Natural background P for Lake Pocotopaug, based on LLRM, is about 11 ug/L, although data from the 1930s for SDT suggest that an average value as low as 9 ug/L might be possible with no human influence. However, eliminating human influence is not a realistic goal, and the Connecticut standards for nutrients are written to allow anthropogenic sources as long as reasonable BMP are applied. The two management scenarios represent reasonable BMP application.

To achieve a target P concentration of 14 to 15 ug/L, the effective P load must be reduced to 238 kg/yr. This is almost exactly the projected load under the Target Management scenario, explained in further detail in Section 9.

9.0 RECOMMENDED ACTIONS TO ACHIEVE TARGETS

Achieving an effective P load of 238 kg/yr to Lake Pocotopaug equates to a 35-40% reduction in current P loading, and is considered an appropriate target for Lake Pocotopaug and its watershed. This will require action over much of the watershed, as no one subwatershed represents that much of the load. Yet while activities intended to reduce the generation of P in the watershed and its transport to the lake are desirable in all basins, there are subwatersheds that appear to have a higher priority for action, by virtue of the combination of actual load, yield per unit area, and P control implementation feasibility. While source reduction approaches are applicable to most if now all subwatersheds (e.g., fertilizer management), pollution trapping techniques that will provide significant loading reductions vary by subwatershed as a function of natural and human-derived features.

It is helpful to establish a general priority order for subwatershed attention, but it should be recognized that it is not essential to address subwatersheds in exact priority order; in fact, most subwatersheds will require some attention, and the Town should take advantage of opportunities to reduce P generation and transport whenever possible. For example, if a roadway is to be torn up for utility work, this presents an opportunity to alter the stormwater drainage system as may be warranted at less cost than would otherwise be necessary. Where development can be avoided by property purchase, opportunities to do so should be actively sought. Where a stormwater management facility is to be built to serve one area, an adjacent area without needed structural controls might be included with proper planning. Focus with flexibility will be an important feature of a successful program. We have therefore established priority groupings rather than a precise order.

9.1 Relative Importance of Subwatersheds

Relative importance can be determined based on multiple features, including absolute magnitude of loading, the load per unit area, and feasibility of implementation (itself a mix of technical applicability, opportunity, and cost). The total P load, the represented percent of the total load to the lake, the areal export rate, and a brief assessment of load reduction feasibility is presented for each subwatershed in Table 9-1. There could be legitimate debate over the precise numbers and level of feasibility, but priority groups are readily apparent based on magnitude of load and potential for reduction through available techniques.

The Priority 1 group includes subwatersheds C (direct drainage on the east side), E (Christopher Brook) and K (Fawn Brook, draining Seven Hills development). These subwatersheds represent significant loading fractions with a high potential for reduction through readily available techniques. Infiltration is highly applicable to subwatershed C, while detention is most applicable in subwatersheds E and K. For subwatershed C, installation of leaching basins at key points along stormwater drainage systems in this area should reduce storm-induced loading of P and N, and also alleviate some flooding problems in this subwatershed. Detention in subwatershed E would involve dredging Christopher Pond and potentially adding gabion weirs at key points in the associated wetland, slowing the delivery of stormwater to the lake. The Seven Hills development covers much of subwatershed K, and already has extensive detention facilities. However, inspection during storms

Table 9-1. Prioritization of subwatersheds for management action and resulting loads.

Source	P Load (kg/yr)	% of Total Load	P Export (kg/ha/yr)	Feasibility Assessment	Priority Group	Target Reduction (%)	Load Reduction (kg/yr)	Load After Reduction (kg/yr)
Subwatershed								
A-Direct	24.9	6.5%	0.50	Difficult - short distance to lake, shallow depth to groundwater, limited space; LID techniques and education most appropriate.	2	33	8.2	16.7
B-Direct	17.6	4.6%	0.46	Difficult - short distance to lake, shallow depth to groundwater, limited space; LID techniques and education most appropriate.	2	33	5.8	11.8
C-Direct	39.0	10.2%	0.46	Near lake, moderate to dense development, but with substantial depth to groundwater, sandy soils; high potential for infiltration.	1	60	23.4	15.6
D-direct	6.0	1.6%	0.43	Densely developed, commercial, but with some controls in place; LID, education and monitoring of existing systems needed.	4	20	1.2	4.8
E-Christ	48.3	12.6%	0.24	Large area, mostly peripheral development, wetlands and pond with high detention potential; detention enhancement needed, dredging/gabions.	1	33	15.9	32.3
F-Clark	10.2	2.7%	0.42	Difficult - steep road, moderate development, more occurring at upper end, limited area for detention, some potential for infiltration, stormceptor near lake, but will need many more to handle load; LID appropriate.	3	20	2.0	8.2
G-Unnamed	4.7	1.2%	0.24	Mix of wooded and developed area, more occurring at upper end, some space available for possible detention/infiltration.	4	50	2.4	2.4
H-Hales	64.7	16.9%	0.18	Largest area, but least developed and lowest areal load; seasonal campground on east side, development near lake end; has small detention pond at downstream end, recently dredged; LID and land protection most suitable.	4	20	12.9	51.7
I-Candle	6.8	1.8%	0.39	Difficult - mostly developled, close to lake, limited space, shallow depth to groundwater; education and LID most suitable, need to check Seven Hills influence.	3	33	2.3	4.6
J-Unnamed	4.0	1.1%	0.46	Difficult - mostly developled, close to lake, limited space, shallow depth to groundwater; education and LID most suitable, need to check Seven Hills influence.	3	33	1.3	2.7
K-Fawn	20.3	5.3%	0.35	Primarily newer development; problems documented during development, detention facilities do not appear to be controling WQ; structural enhancements and education warranted.	1	50	10.2	10.2
L-Hazen	1.1	0.3%	0.21	Small area with some development; maintain stream buffer and pursue education.	4	10	0.1	1.0
M-Oneil	8.0	2.1%	0.43	Developed are with condos and commercial areas, includes runoff from nursery/landscaping store; has detention pond, but may need enhancement; limit exposure of fertilizers to precipitation.	2	33	2.6	5.3
N-Days	9.4	2.5%	0.29	Mix of wetland and commercial area with some residences; possible issues from auto maintenance operation; LID and education most appropriate.	2	33	3.1	6.3
Watershed P Load	265.1	69.4%	0.28				91.5	173.6
Other Sources								
Atmospheric	41.4	10.8%	0.20	Minimal control possible		0	0	41.4
Internal	71.6	18.7%	0.35	Reduced by aluminum treatment in 2000-2001; regained importance over ensuing years; may require additional treatment, but not until watershed inputs better controlled.		75	53.7	17.9
Wildlife	4.0	1.0%	0.02	Limited inputs, limited control potential.		0	0.0	4.0
Septic systems	0.0	0.0%	0.00	Direct drainage area sewered; only a few systems on island; not addressed this effort. Inputs from non-direct drainage appear limited for P, but may be a substantial source of N; standard maintenance in non-direct drainage areas warranted.		0	0.0	0.0
Total P Load	382.1	1.000					145.2	236.9

indicates that they are holding minimal water; some adjustment is needed, either to the collection system to make better use of these detention areas or to the outlets of detention basins to hold water longer. A range of 33 – 60% reduction for P loading seems achievable for this group.

The Priority 2 group includes subwatersheds A and B (both direct drainage areas, to the west and north of the lake, respectively) and M and N (both on the southeastern side of the lake). These areas represent almost 16% of the load and three of the four subwatersheds have P export levels in excess of 0.4 kg/ha/yr. Subwatersheds A and B are highly developed residential home areas, while subwatersheds M and N have largely commercial or condo uses. All have space limitations on structural controls, but all could benefit for Low Impact Development (LID) techniques and education. Some existing facilities in subwatersheds M and N might need enhancement. A P loading reduction of 33% seems achievable for this group.

The Priority 3 group includes subwatersheds F (Clark Hill), I and J (two small developed areas just north of the lake). These are all difficult areas, with space limitations on structural controls, relatively high P export rates, but fortunately relatively small actual P loads. Some careful consideration of options is needed for these, including education, LID techniques, and possibly buried structural controls (e.g., more stormceptors, leaching galleries). In the case of subwatersheds I and J, they may have influence from the Seven Hills development that could be reduced through better stormwater management as suggested for subwatershed K.

The Priority 4 group includes subwatersheds D (a small direct drainage to the south of the lake), G (a mixed wooded and residential area west of the lake), H (the large Hales Brook drainage) and L (the small Hazen Brook drainage). Only Hales Brook has a substantial P load to the lake, but the P export value is close to the expectation for undeveloped land. Preventive actions are most important in this subwatershed, with LID and education warranted for the campground and housing areas closer to the lake. The small pond near the inlet to Lake Pocotopaug was recently dredged, and some additional upstream detention would be desirable.

Subwatershed D has mostly road and commercial land drainage. Recently installed structural controls associated with development (the new bank/pharmacy complex) should be monitored for effectiveness. Additional controls should be considered, but the load is not large enough to warrant major, special expense. Subwatershed L has a few homes and a small stream, yielding a small P load; maintaining the buffer zone around the stream, which has been encroached upon in recent years, is recommended. Subwatershed G is a mixed woodland and residential drainage area with some possible locations for detention and/or infiltration facilities. Monitoring of impacts from the Skyline Estates development on the upper portion of this watershed is warranted.

If appropriate actions were taken in each subwatershed, and the internal load was reduced by 75% through another aluminum treatment, the total load to Lake Pocotopaug would be reduced from an estimated average of 382.1 kg/yr to 236.9 kg/yr. Plugging the new load into the LLRM, an average in-lake P concentration of 14.4 ug/L would result, with an average SDT of 3.0 m (10 ft). This is very close to the results of LLRM when run with what were feasible implementation efforts applied to each subwatershed, the Feasible BMP scenario. This is not surprising, as the reductions in Table 9-1 are considered to be achievable by feasible BMP, but the reduction was derived independently of the model, and it is gratifying that the results match.

This Target Management model scenario, described previously in Section 7, appears to be a reasonable starting place for TMDL development.

9.2 Recommended Initial Actions

While no opportunity to address any problem in any subwatershed should be ignored, dealing with loading from subwatersheds C, E and K should be actively pursued first, at least where structural controls are planned. Subwatershed C consists of a series of residential streets with mostly small lots and limited street drains, but nearly all streets do have drains, and these outlet to the lake. The homes are mostly on flat to gently sloping land, but the slope to the lake is fairly steep near the lake. At a point well up the slope, but low enough to catch most stormwater, installation of leaching chambers would be feasible and desirable. This approach was used at Lake Lorraine in Springfield, MA with success in the 1990s (ENSR 1997). In its simplest form, leaching basins are put in line with the stormwater pipe prior to the lake, such that all water passing through the pipe enters the leaching chamber. The outlet pipe is set near the top of the chamber, such that excessive flows can still overflow to the lake. Much of the stormwater is infiltrated into the surrounding soils if the sand content is high enough, and moves to the lake as groundwater. These units can be installed under existing roads, limiting intrusion on private property and facilitating access for maintenance. Cost varies with site condition and desired capacity.

For subwatershed C, the eastern direct drainage area to Lake Pocotopaug, the soils are indeed sandy enough for infiltration to work (Figure 9-1), and Wangonk Trail runs along the hillside well above the lake in the northern portion of subwatershed C, parallel to its shoreline; all stormwater pipes cross it, providing a logical point for leaching basin installation in each case. Locations on Pine Trail and Hawthorne Road in the southern portion of subwatershed C also appear amendable to leaching facility installation. Potential locations are shown in Figure 9-2. Further engineering is needed, but the process is relatively simple. Many of the target locations show signs of stormwater damage now (Figure 9-3), so detention and leaching facilities will help alleviate flood damage as well as improve water quality entering the lake. A typical design for a leaching basin is shown in Figure 9-4. Installed costs for units in subwatershed C are estimated at $50,000 per location.

For subwatershed E, Christopher Brook, detention increases could enhance P and N removal in the associated pond and wetland. The pond should be dredged, but a separate survey is needed to determine the best approach and quantity of sediment to be removed, along with the quality of that sediment, which will affect disposal options. Additionally, there appear to be several locations in the stream within broader wetlands where gabion weirs could be intalled. These weirs would back up water during storms, allowing it to pass through gradually, thus increasing detention time and pollutant removal in the wetland. A more detailed topographic survey is needed before precise locations can be recommended, as it will be important not to cause any flooding of non-wetland areas. Properly setting the location, height, and low flow passage size for gabion weirs will result in better water quality and can support healthier wetlands as well.

Work in subwatershed K is harder to specify. The detention systems there now appear adequate, but none has been observed to hold any appreciable water after any storm observed to date. Either runoff is not being directed into these basins or the outlets are passing the water out too quickly. Both factors may be issues. The drainage plan for this relatively new development should be reviewed and some further observation is warranted before recommending a course of action.

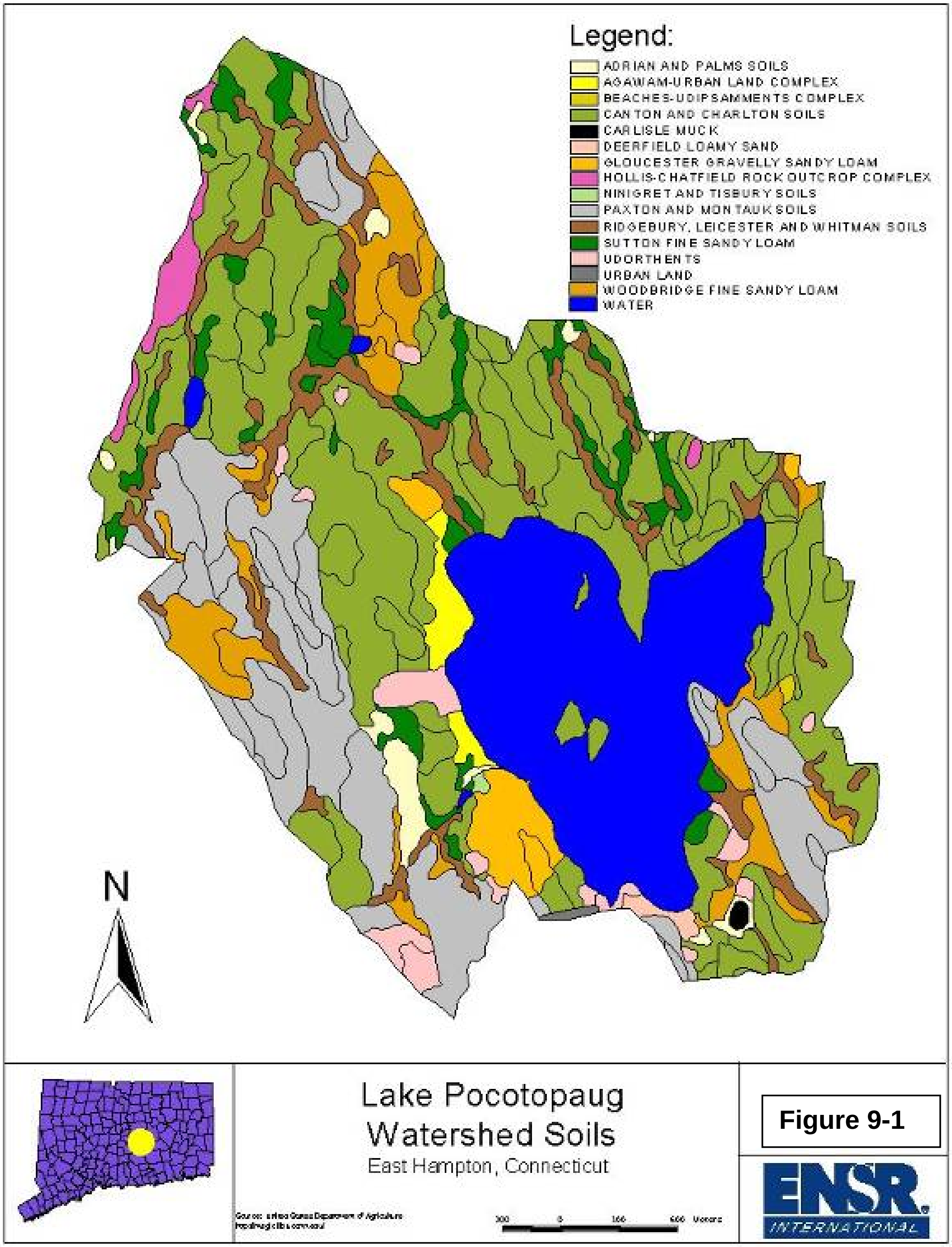


Figure 9-1. Soils of the Lake Pocotopaug watershed.

Figure 9-2. Potential locations of leaching basins in association with stormwater drainage systems in subwatershed C at Lake Pocotopaug.

Red dots indicate target locations.

A. Undercut road at Wangonk and Mohigan Trails in subwatershed C

B. Erosion of beach downstream of Clearwater Condos in subwatershed C

Figure 9-3. Current problems caused by excessive stormwater flows.

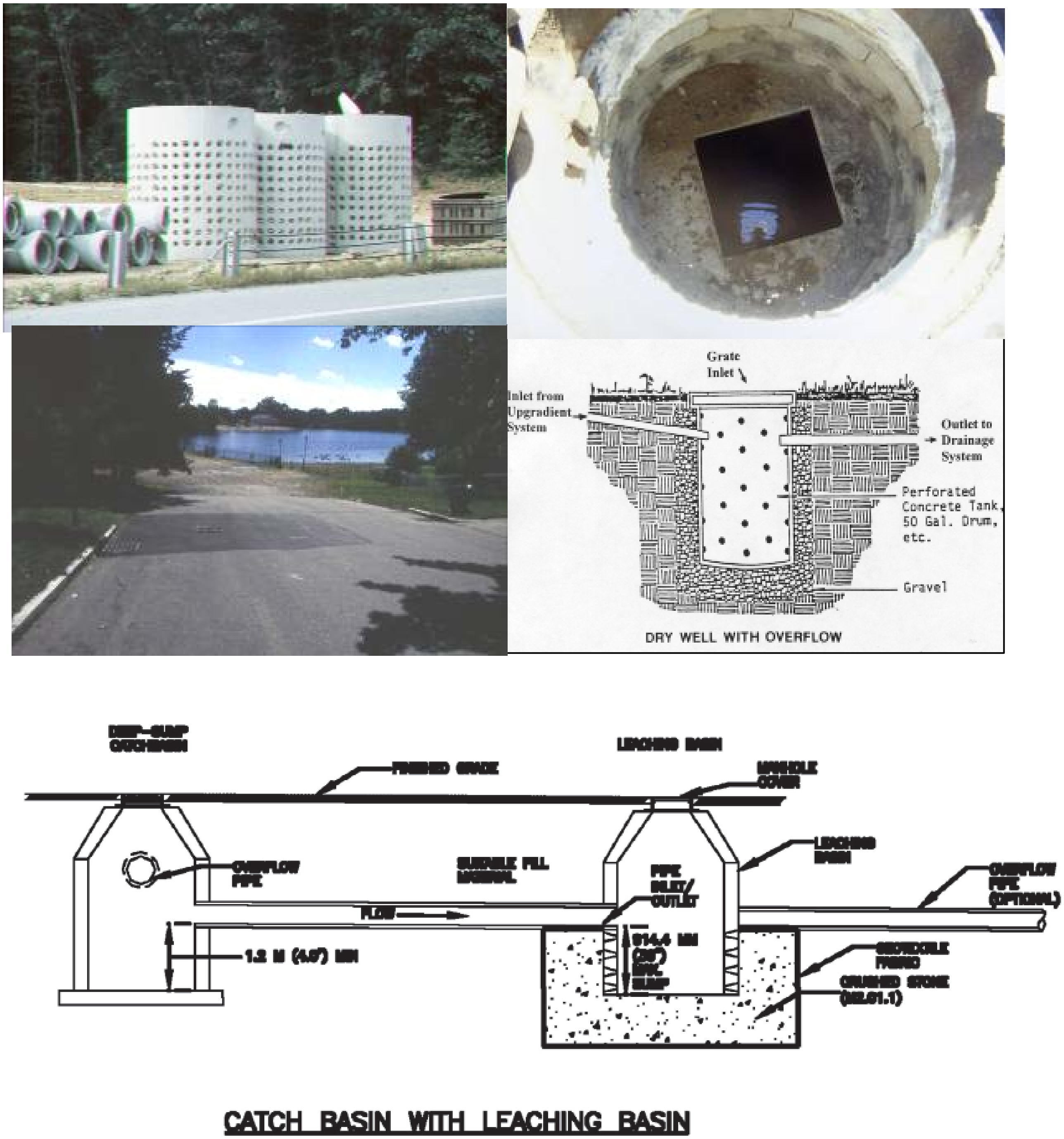


Figure 9-4. Example leaching basin elements.

Beyond the intial work specified for subwatersheds C, E and K, it is essential to implement watershed-wide controls on nutrient load and runoff generation. It is unrealistic to expect housing and related developmental features to disappear, but more recently advanced approaches to controlling runoff quantity and quality are highly applicable. The entire range of options known as Low Impact Development, or LID, is appropriate for the Lake Pocotopaug watershed. Rain gardens, bioretention areas, reduced impervious surface, porous pavement, limited fertilizer use, and a host of related techniques can be applied on individual properties to limit the amount of runoff generated and to improve the quality of unavoidable runoff. As a recently developed field of study, much of the LID work is web-based; see http://www.lowimpactdevelopment.org/ for considerably more information and guidance on resources.

To support LID efforts, two ordinances are needed:

1) Post-development runoff is not to exceed pre-development runoff – this goes beyond standard engineering practice of limiting peak runoff to capturing and infiltrating as much runoff after development as would have entered the ground before development. With increased impervious surface during development, this requires thought and creative design, but is entirely practical in most areas, even as a retrofit. It is most difficult in sloped areas with less permeable soils, but these produce more runoff under natural conditions anyway. For the Lake Pocotopaug watershed, the areas close to the lake, some with shallow depth to groundwater, may prove most difficult in this regard. This type of bylaw is not typically applied to existing development, but should be applied to all new development and could be applied to existing sites when they are sold.
2) Phosphorus is to be eliminated from fertilizers applied to any land except bare soil for the purpose of enhancing cover growth – this has been considered previously in East Hampton, but is necessary if the impacts of landscape fertilizing are to be ameliorated. Studies in Minnesota and Michigan have already documented P reductions in receiving waters on the order of 25%, and many states are now considering bans on P in fertilizers. This is the single greatest reduction in P loading that can be achieved in the Lake Pocotopaug watershed at essentially no cost.

With regard to other management options within the watershed, the following specific target actions are suggested:

Subwatershed	**Site or Location**	**Activity**
A	Lake Blvd	Install leaching sumps in catch basins
A	Edgemere Condominums	Install some form of detention/infiltration system
A	Ola Drive and nearby streets	Install infiltration facilities
B	Entire direct drainage area	Difficult for structural measures; push education and LID
D	New bank/pharmacy site	Monitor output thoroughly; new system needs to work
E	Part of Skyline Estates	Monitor construction carefully, push for LID
F	Mountainview	Install infiltration swale
G	Part of Skyline Estates	Monitor construction carefully, push for LID
G	Lower portion	Look for place to install infiltration facility
H	Downstream of campground	Establish greater detention capacity in wetland
H	Upstream portion	Purchase/protect as much land as possible
I/J	Flat portion	Difficult for structural measures; push education and LID
L	Homes near lake	Encourage expansion of stream buffer zone

M	Paul and Sandy's	Nursery/landscaping business has detention area, but potential for nutrient releases is high; work to minimize risks
M	Lake Vista Condominiums	Has detention facility; monitor for effectiveness, enhance as necessary
N	Commercial area on Rt 66	Investigate runoff and implement stormwater controls on developed area

Aside from essential watershed management activities, it will be necessary to control the internal load as well. This was done in 2000-2001 with an aluminum treatment, the results of which were evident for about two years. The replacement of the inactivated P in the lake sediments by additional watershed inputs, is entirely consistent with expectations based on current knowledge and the model, so addressing the watershed load has the higher priority. However, the internal load has more immediate impact, and will continue to fuel algal blooms if not addressed, even after watershed inputs have been suitably lowered.

A second aluminum treatment would be appropriate, and is a very valid approach to inactivating past loading. However, the town should be aware that there are options, the most appropriate of which would be an aeration system. Such a system would oxygenate the deep waters of the lake, focusing on the Oakwood and Markham basins. There are many such systems, but one that uses compressed air to both oxygenate and mix the lake waters thoroughly would be recommended in this case. Such a system will carry a capital cost on the order of $250,000 and will require an annual operation and maintenance budget, probably on the order of $25,000 to $35,000. As an oxygenation/mixing system will both depress internal loading and disrupt the life cycle of some of the problem algae in the lake, installation of such a system could be considered prior to completion of the watershed program, and should provide some immediate relief. Application of aluminum compounds would carry a similar cost and have only short-lived benefits. While aluminum treatments usually provide a greater reduction in available P, they give less longevity of benefits than an aeration/mixing system when external loading remains high. Neither the aluminum nor aeration/mixing is a substitute for watershed management, but the aeration/mixing system has greater potential to provide lasting relief while watershed management is being implemented.

While action-oriented programs are now needed, there must be a feasibility step before implementation that provides proper engineering evaluation and design for structural elements of the program. This investigation provides some guidance on what type of BMP to apply where, but not at the level of detail necessary for full implementation. Additionally, monitoring still plays a very important role in the management of Lake Pocotopaug. The volunteer monitoring group has done an excellent job transitioning into investigative work and more of this effort is needed. There are adequate data now to establish baseline conditions for most subwatersheds, and the focus can now shift toward identifying specific issues and tracking management success. With regard to the above recommended actions, monitoring efforts should have the following priorities:

1) Continued monitoring of the lake as performed for many years. It is sufficient to sample monthly at one station, LP-2 in the Oakwood Basin, from May through September, assessing total and dissolved P, ammonium N, nitrate N, Kjeldahl N, pH, temperature and dissolved oxygen at the top and bottom,

with a SDT measurement from the surface. More monitoring is welcome, but where time and budgets are limiting, this is the basic program level.

2) Assessment of targeted parcels that are suspected as important sources:
   a. Directly sampled runoff in subwatersheds A and B, from as many source areas as possible
   b. Detention facility outlets in the Seven Hills development, affecting subwatersheds I, J and K
   c. The discharge from the new bank/pharmacy complex in subwatershed D
   d. Drainage from the developing Skyline Estates, affecting subwatersheds E, F, G and H
   e. The outlet of the detention facility for Lake Vista Condominiums in subwatershed M
   f. Upstream and downstream of Paul and Sandy's in subwatershed M
   g. Upstream and downstream of the Rt 66 commercial property in subwatershed N

   Note that targeting specific parcels will be a locally sensitive activity; work with concerned parties, not against them, and promote a cooperative effort to enhance stormwater management for the benefit of all. How this is handled can result in greater community appreciation or a public relations disaster; make heroes out of cooperating parties, not scapegoats.
3) Sample upstream and downstream of any structural control installed to improve runoff quality; some systems may prove difficult to assess, especially leaching facilities, so careful consideration of sampling details is warranted.

10.0 REFERENCES

Clark, G.M., D.K. Mueller and M.A. Mast. 2000. Nutrient concentrations and yields in undeveloped stream basins of the United States. JAWRA 36:849-860.

CT DEP. 1982. The Trophic Classification of Seventy Connecticut Lakes. DEP Bulletin #3, Hartford, CT.

Dillon, P.J., L.A. Molot and W.A. Schneider. 1991. Phosphorus and nitrogen export from forested stream catchments in central Ontario. J. Environ. Quality 20:857-864.

East Hampton Ad Hoc Lake Advisory Committee. 1995. Lake Pocotopaug Management Recommendations. East Hampton, CT.

ENSR. 1997. Storm Water Infiltration Program for Lakes Lorraine and Fivemile Pond. ENSR, Northborough, MA.

ENSR. 2001. Analysis of Phosphorus Inactivation Issues at Lake Pocotopaug, East Hampton, CT. Willington, CT.

ENSR. 2002. Lake Pocotopaug Lake and Watershed Restoration Evaluation. Willington, CT.

ENSR. 2004. Lake Pocotopaug 2003 In-Lake Water Sampling Results. Willington, CT.

ENSR. 2004. Lake Pocotopaug 2004 Monitoring Results and Management Implications. Willington, CT.

ENSR. 2006. Results of 2005 Sampling of Inputs to Lake Pocotopaug. Willington, CT.

ENSR. 2007a. Results of 2006 Sampling of Inputs to Lake Pocotopaug and the Lake Itself. Willington, CT.

ENSR. 2007b. Loading to Lake Pocotopaug: Memorandum to the East Hampton Inland Wetlands Commission. Willington, CT.

ENSR. 2009a. Results of 2007-2008 Sampling Lake Pocotopaug and Watershed Inputs. Willington, CT.

ENSR. 2009b. Lake Loading Response Model User's Guide. Willington, CT.

ENSR. 2009c. Quality Assurance Project Plan for the Use of the Lake Loading Response Model (LLRM) in TMDL Development for Lake Pocotopaug, East Hampton, CT. Willington, CT.

Frink, C and W. Norvell. 1984. Chemical and Physical Properties of Connecticut Lakes. Ct Agricultural Experiment Station Bulletin 817. New Haven, CT.

Fugro East. 1993. Diagnostic and Management Assessment of Lake Pocotopaug. Sandwich, MA.

Rohm, C.M., J.A. Omernik, A.J. Woods, and J.L. Stoddard. 2002. Regional characteristics of nutrient concentrations in streams and their application to nutrient criteria development. JAWRA 38:213-239.

Schloss, J.A. and J. Conner. 2000. Development of Statewide Nutrient Loading Coefficients through Geographic Information System Aided Analysis. University of New Hampshire, Water Resources Research Center, project summary.

State Board of Fisheries and Game. 1959. A Fishery Survey of the Lakes and Ponds of Connecticut. Report #1, Hartford, CT.

WMC Consulting Engineers. 1995. Stormwater Renovation and Management Plan for the Lake Pocotopaug Watershed. W. Hartford, CT.

APPENDIX A

Water Quality Data

Data for tributaries and stormwater drainage systems in the Lake Pocotopaug watershed.

Capital letter indicates terminal sampling point (last before lake). Others are upstream samples.

All values in mg/L

Model Drainage Area	Town Station	AECOM Station	Date	Type	Amm-N mg/L Dry	Nitrate-N mg/L Dry	TKN mg/L Dry	TN mg/L Dry	TP mg/L Dry	DP mg/L Dry
A	1	LP-1	Jul-06	Dry					0.20	0.11
A	1	LP-1	Apr-08	Post-Wet	0.005	0.080	0.970	1.050	0.150	0.062
A	1	LP-1	Sep-08	Post-Wet	0.056	0.03	1.09	1.12	0.140	0.099
A	1	LP-1	Nov-05	Wet	0.45	0.23			1.61	0.19
A	1	LP-1	Jul-06	Wet					1.78	0.03
A	1	LP-1	Apr-08	Wet	0.005	0.005	1.080	1.085	0.124	0.052
A	1	LP-1	Sep-08	Wet	0.062	0.12	0.86	0.98	0.112	0.074
E	4	LP-3	Mar-01	Dry	0.050	0.50	0.10	0.60	0.010	0.005
E	4	LP-3	May-01	Dry	0.042	0.34	0.22	0.56	0.008	0.004
E	4	LP-3	Jun-01	Dry	0.023	0.15	0.45	0.60	0.010	0.004
E	4	LP-3	Aug-01	Dry	0.050	0.13	0.30	0.43	0.021	0.014
E	4	LP-3	Sep-03	Dry	0.06	0.25	0.5	0.75	0.027	0.022
E	4	LP-3	Oct-04	Dry	0.01	0.33			0.03	0.005
E	4	LP-3	Jul-06	Dry					1.03	0.19
E	4	LP-3	Sep-03	Post-Wet	0.03	0.18	0.7	0.88	0.031	0.022
E	4	LP-3	Aug-04	Post-Wet	0.03	0.17			0.03	0.03
E	4	LP-3	Oct-04	Post-Wet	0.005	0.18			0.022	0.005
E	4	LP-3	Apr-08	Post-Wet	0.144	0.064	0.595	0.659	0.023	0.004
E	4	LP-3	Sep-08	Post-Wet	0.014	0.05	0.93	0.98	0.038	0.007
E	4	LP-3	Mar-01	Wet	0.050	0.30	0.10	0.40	0.030	0.005
E	4	LP-3	May-01	Wet	0.010	0.11	2.29	2.40	0.196	0.007
E	4	LP-3	Aug-01	Wet	0.102	0.13	0.38	0.51	0.027	0.012
E	4	LP-3	Sep-01	Wet	0.010	0.26	1.16	1.42	0.108	0.012
E	4	LP-3	Sep-03	Wet	0.04	0.18	16.4	16.58	2.1	0.042
E	4	LP-3	Aug-04	Wet	0.03	0.27			0.104	0.036
E	4	LP-3	Oct-04	Wet	0.005	0.19			0.03	0.005
E	4	LP-3	Nov-05	Wet	0.31	0.22			0.70	0.21
E	4	LP-3	Jul-06	Wet					4.44	0.05
E	4	LP-3	Apr-08	Wet	0.005	0.104	0.690	0.794	0.091	0.005
E	4	LP-3	Sep-08	Wet	0.013	0.01	4.00	4.01	0.215	0.009
e	7	LP-3B	Jul-06	Dry					0.33	0.04
e	7	LP-3B	Nov-05	Wet	3.27	0.31			2.11	1.99
e	7	LP-3B	Jul-06	Wet					0.34	0.10
F	9	LP-4	Oct-04	Post-Wet	0.05	0.08			0.197	0.106
F	9	LP-4	Apr-08	Post-Wet	0.005	0.096	0.800	0.896	0.087	0.047
F	9	LP-4	Sep-08	Post-Wet	0.011	0.01	2.00	2.01	0.184	0.047
F	9	LP-4	Mar-01	Wet	0.050	2.00	0.20	2.20	0.100	0.070
F	9	LP-4	Aug-01	Wet	0.093	0.33	1.38	1.71	0.210	0.104
F	9	LP-4	Sep-01	Wet	0.098	0.01	0.83	0.84	0.196	0.022
F	9	LP-4	Sep-03	Wet	0.05	0.38	4	4.38	3.76	0.23
F	9	LP-4	Aug-04	Wet	0.005	0.55			0.634	0.096
F	9	LP-4	Oct-04	Wet	0.005	0.11			0.216	0.104
F	9	LP-4	Apr-08	Wet	0.600	0.435	1.700	2.135	0.163	0.010
F	9	LP-4	Sep-08	Wet	0.375	0.09	1.75	1.84	0.099	0.044
A	10	LP-10	Apr-08	Post-Wet	0.017	0.089	3.330	3.419	0.815	0.055
A	10	LP-10	Sep-08	Post-Wet	0.005	0.03	0.66	0.68	0.125	0.077
A	10	LP-10	Apr-08	Wet	0.005	0.005	1.220	1.225	0.149	0.041
H	11	LP-5	Mar-01	Dry	0.050	0.20	0.10	0.30	0.005	0.005
H	11	LP-5	May-01	Dry	0.005	0.15	0.12	0.27	0.008	0.003
H	11	LP-5	Jun-01	Dry	0.025	0.07	0.20	0.28	0.009	0.004
H	11	LP-5	Aug-01	Dry	0.010	0.22	0.21	0.43	0.008	0.001
H	11	LP-5	Sep-01	Dry	0.014	0.26	0.18	0.44	0.003	0.002
H	11	LP-5	Sep-03	Dry	0.005	0.16	0.2	0.36	0.005	0.005
H	11	LP-5	Aug-04	Dry	0.005	0.25			0.017	0.005
H	11	LP-5	Oct-04	Dry	0.005	0.17			0.019	0.016
H	11	LP-5	Jul-06	Dry					0.43	0.04

Model Drainage Area	Town Station	AECOM Station	Date	Type	Amm-N mg/L Dry	Nitrate-N mg/L Dry	TKN mg/L Dry	TN mg/L Dry	TP mg/L Dry	DP mg/L Dry
H	11	LP-5	Sep-03	Post-Wet	0.005	0.08	0.3	0.38	0.02	0.017
H	11	LP-5	Aug-04	Post-Wet	0.005	0.11			0.022	0.019
H	11	LP-5	Oct-04	Post-Wet	0.005	0.07			0.033	0.005
H	11	LP-5	Apr-08	Post-Wet	0.005	0.005	0.615	0.620	0.039	0.005
H	11	LP-5	Sep-08	Post-Wet	0.005	0.01	1.36	1.37	0.043	0.002
H	11	LP-5	Mar-01	Wet	0.050	0.10	0.10	0.20	0.300	0.070
H	11	LP-5	May-01	Wet	0.023	0.05	0.89	0.94	0.084	0.006
H	11	LP-5	Jun-01	Wet	0.005	0.01	0.88	0.89	0.098	0.006
H	11	LP-5	Aug-01	Wet	0.013	0.29	0.25	0.53	0.011	0.001
H	11	LP-5	Sep-01	Wet	0.045	0.24	0.36	0.60	0.019	0.011
H	11	LP-5	Sep-03	Wet	0.02	0.08	25.2	25.28	3.09	0.031
H	11	LP-5	Aug-04	Wet	0.005	0.3			0.036	0.025
H	11	LP-5	Oct-04	Wet	0.005	0.08			0.016	0.005
H	11	LP-5	Nov-05	Wet	0.64	0.22			0.61	0.54
H	11	LP-5	Jul-06	Wet					0.97	0.07
H	11	LP-5	Apr-08	Wet	0.005	0.055	1.110	1.165	0.042	0.002
H	11	LP-5	Sep-08	Wet	0.018	0.10	5.50	5.60	0.168	0.004
h	13	LP-13	Jun-01	Dry	0.035	0.33	0.38	0.71	0.007	0.006
h	13	LP-13	Jul-06	Dry					0.57	0.01
h	13	LP-13	Oct-08	Dry	0.005	0.01	0.61	0.62	0.012	0.002
h	13	LP-13	Apr-08	Post-Wet	0.086	0.076	0.320	0.396	0.007	0.001
h	13	LP-13	Sep-08	Post-Wet	0.005	0.01	0.84	0.85	0.029	0.015
h	13	LP-13	May-01	Wet	0.113	0.01	22.95	22.96	3.010	0.012
h	13	LP-13	Aug-01	Wet	0.032	0.12	1.74	1.86	0.124	0.014
h	13	LP-13	Nov-05	Wet	1.14	0.24			1.17	1.16
h	13	LP-13	Jul-06	Wet					0.30	0.02
h	13	LP-13	Apr-08	Wet	0.005	0.005	0.390	0.395	0.024	0.001
h	13	LP-13	Sep-08	Wet	0.018	0.01	1.30	1.31	0.050	0.011
h	13	LP-13	Oct-08	Wet	0.005	0.01	0.26	0.27	0.007	0.003
h	14	LP-5A	Jul-06	Dry					0.08	0.01
h	14	LP-5A	Oct-08	Dry	0.005	0.03	0.39	0.42	0.005	0.001
h	14	LP-5A	Sep-08	Post-Wet	0.005	0.22	0.65	0.87	0.023	0.014
h	14	LP-5A	Nov-05	Wet	2.76	0.23			2.03	1.96
h	14	LP-5A	Jul-06	Wet					4.16	0.08
h	14	LP-5A	Sep-08	Wet	0.005	0.01	1.12	1.13	0.083	0.053
h	14	LP-5A	Oct-08	Wet	0.005	0.01	4.86	4.87	0.450	0.125
I	15	LP-6	Mar-01	Dry	0.050	0.30	0.10	0.40	0.450	0.005
I	15	LP-6	May-01	Dry	0.030	0.05	0.25	0.30	0.021	0.009
I	15	LP-6	Jun-01	Dry	0.010	0.08	0.36	0.44	0.021	0.005
I	15	LP-6	Sep-01	Dry	0.013	0.07	0.20	0.27	0.017	0.005
I	15	LP-6	Jul-06	Dry					0.48	0.12
I	15	LP-6	Apr-08	Post-Wet	0.005	0.265	0.635	0.900	0.054	0.016
I	15	LP-6	Sep-08	Post-Wet	0.039	0.16	1.22	1.38	0.070	0.034
I	15	LP-6	Mar-01	Wet	0.050	0.30	0.20	0.50	0.100	0.080
I	15	LP-6	May-01	Wet	0.023	0.07	4.80	4.86	0.590	0.013
I	15	LP-6	Jun-01	Wet	0.010	0.23	0.88	1.11	0.255	0.019
I	15	LP-6	Sep-01	Wet	0.045	0.24	0.54	0.78	0.053	0.050
I	15	LP-6	Nov-05	Wet	0.05	0.22			0.66	0.06
I	15	LP-6	Jul-06	Wet					1.86	0.08
I	15	LP-6	Apr-08	Wet	0.005	0.120	0.640	0.760	0.127	0.017
I	15	LP-6	Sep-08	Wet	0.040	0.15	1.93	2.08	0.087	0.043
K	18	LP-7	Mar-01	Dry	0.050	0.10	0.10	0.20	0.080	0.020
K	18	LP-7	May-01	Dry	0.060	0.03	0.44	0.47	0.036	0.010
K	18	LP-7	Sep-01	Dry	0.033	0.01	0.39	0.40	0.015	0.006
K	18	LP-7	Sep-03	Post-Wet	0.01	0.02	0.3	0.32	0.022	0.022
K	18	LP-7	Mar-01	Wet	0.050	0.05	0.10	0.15	0.300	0.060
K	18	LP-7	May-01	Wet	0.010	0.01	3.05	3.06	0.335	0.027
K	18	LP-7	Sep-01	Wet	0.170	0.23	0.59	0.82	0.047	0.020
k	19	LP-19	Jul-06	Dry					0.28	0.04
k	19	LP-19	Apr-08	Post-Wet	0.005	0.005	0.455	0.460	0.019	0.005

Model Drainage Area	Town Station	AECOM Station	Date	Type	Amm-N mg/L Dry	Nitrate-N mg/L Dry	TKN mg/L Dry	TN mg/L Dry	TP mg/L Dry	DP mg/L Dry
k	19	LP-19	Nov-05	Wet	0.64	0.22			0.53	0.52
k	19	LP-19	Jul-06	Wet					1.17	0.07
k	19	LP-19	Apr-08	Wet	0.005	0.046	0.565	0.611	0.050	0.006
L	21	LP-8	Mar-01	Dry	0.050	0.50	0.10	0.60	0.030	0.020
L	21	LP-8	May-01	Dry	0.015	0.01	0.21	0.22	0.026	0.002
L	21	LP-8	Jun-01	Dry	0.010	0.01	0.28	0.29	0.012	0.001
L	21	LP-8	Jul-06	Dry					0.24	0.02
L	21	LP-8	Apr-08	Post-Wet	0.005	0.005	0.545	0.550	0.013	0.004
L	21	LP-8	Sep-08	Post-Wet	0.005	0.20	1.15	1.35	0.042	0.012
L	21	LP-8	Mar-01	Wet	0.050	0.50	0.10	0.60	0.200	0.070
L	21	LP-8	May-01	Wet	0.010	0.16	1.77	1.93	0.137	0.007
L	21	LP-8	Jun-01	Wet	0.011	0.10	1.77	1.87	0.203	0.012
L	21	LP-8	Sep-01	Wet	0.026	0.63	0.84	1.47	0.112	0.027
L	21	LP-8	Nov-05	Wet	0.07	0.01			0.57	0.48
L	21	LP-8	Jul-06	Wet					1.66	0.08
C	22	LP-12	Mar-01	Dry	0.050	2.10	0.10	2.20	0.060	0.030
C	22	LP-12	Jun-01	Dry	0.049	1.27	0.32	1.59	0.013	0.001
C	22	NA	Apr-08	Post-Wet	0.005	0.073	1.040	1.113	0.090	0.044
C	22	NA	Sep-08	Post-Wet	0.005	0.05	0.61	0.66	0.066	0.040
C	22	LP-12	Mar-01	Wet	0.050	1.90	0.40	2.30	0.080	0.050
C	22	LP-12	May-01	Wet	0.113	0.01	9.08	9.09	0.925	0.031
C	22	LP-12	Aug-01	Wet	0.132	0.51	1.30	1.81	0.162	0.095
C	22	LP-12	Sep-01	Wet	0.072	0.01	0.87	0.88	0.079	0.060
M	23	LP-10	Mar-01	Dry	0.050	0.30	0.10	0.40	0.260	0.005
M	23	LP-10	May-01	Dry	0.206	0.29	0.44	0.73	0.026	0.007
M	23	LP-10	Jun-01	Dry	0.117	0.15	0.70	0.85	0.058	0.016
M	23	LP-10	Sep-03	Dry	0.14	0.4	0.4	0.8	0.03	0.027
M	23	LP-23	Jul-06	Dry					0.20	0.03
M	23	LP-10	Sep-03	Post-Wet	0.08	0.43	0.8	1.23	0.156	0.045
M	23	LP-10	Apr-08	Post-Wet	0.005	0.250	1.050	1.300	0.094	0.013
M	23	LP-10	Sep-08	Post-Wet	0.050	0.05	1.20	1.25	0.118	0.040
M	23	LP-10	Mar-01	Wet	0.050	0.05	0.40	0.45	0.070	0.005
M	23	LP-10	May-01	Wet	0.034	0.20	7.80	8.00	1.210	0.014
M	23	LP-10	Jun-01	Wet	0.025	0.33	2.96	3.29	1.070	0.029
M	23	LP-10	Aug-01	Wet	0.143	0.96	3.66	4.62	0.706	0.024
M	23	LP-10	Sep-01	Wet	0.091	0.61	0.85	1.46	0.075	0.070
M	23	LP-10	Sep-03	Wet	0.05	0.48	8.2	8.68	2.5	0.042
M	23	LP-10	Nov-05	Wet	0.89	0.23			0.97	0.66
M	23	LP-23	Nov-05	Wet	4.15	0.23			2.40	2.37
M	23	LP-10	Jul-06	Wet					0.86	0.03
M	23	LP-23	Jul-06	Wet					3.26	0.09
M	23	LP-10	Apr-08	Wet	0.005	0.230	1.200	1.430	0.201	0.016
M	23	LP-10	Sep-08	Wet	0.094	0.22	1.70	1.92	0.126	0.027
m	25	LP-25	Jul-06	Dry					0.07	0.02
m	25	LP-25	Nov-05	Wet	0.57	0.29			1.90	0.28
m	25	LP-25	Jul-06	Wet					1.24	0.33
N	26	LP-11	Mar-01	Dry	0.050	0.05	0.10	0.15	0.010	0.005
N	26	LP-11	May-01	Dry	0.063	0.01	0.56	0.57	0.012	0.008
N	26	LP-11	Jun-01	Dry	0.049	0.01	0.79	0.80	0.022	0.008
N	26	LP-11	Aug-04	Dry	0.08	0.08			0.066	0.039
N	26	LP-11	Oct-04	Dry	0.04	0.02			0.04	0.03
N	26	LP-11	Jul-06	Dry					0.58	0.02
N	26	LP-11	Sep-03	Post-Wet	0.04	0.04	0.7	0.74	0.031	0.028
N	26	LP-11	Aug-04	Post-Wet	0.14	0.6			0.109	0.093
N	26	LP-11	Oct-04	Post-Wet	0.005	0.17			0.156	0.066
N	26	LP-11	Apr-08	Post-Wet	0.005	0.144	0.740	0.884	0.149	0.097
N	26	LP-11	Sep-08	Post-Wet	0.044	0.14	1.03	1.17	0.109	0.050
N	26	LP-11	Mar-01	Wet	0.050	1.30	0.50	1.80	0.040	0.030
N	26	LP-11	May-01	Wet	0.091	0.09	1.35	1.44	0.084	0.017
N	26	LP-11	Jun-01	Wet	0.011	0.01	1.70	1.71	0.196	0.015

Model Drainage Area	Town Station	AECOM Station	Date	Type	Amm-N mg/L Dry	Nitrate-N mg/L Dry	TKN mg/L Dry	TN mg/L Dry	TP mg/L Dry	DP mg/L Dry
N	26	LP-11	Sep-01	Wet	0.032	0.40	0.90	1.30	0.206	0.040
N	26	LP-11	Aug-04	Wet	0.15	0.24			0.683	0.038
N	26	LP-11	Oct-04	Wet	0.005	0.15			0.197	0.06
N	26	LP-11	Nov-05	Wet	0.09	0.24			0.86	0.08
N	26	LP-11	Jul-06	Wet					0.94	0.21
N	26	LP-11	Apr-08	Wet	0.005	0.305	0.990	1.295	0.178	0.062
N	26	LP-11	Sep-08	Wet	0.059	0.08	2.98	3.06	0.225	0.025
n	27	LP-11A	Jul-06	Dry					0.30	0.02
n	27	LP-11A	Nov-05	Wet	0.04	0.22			0.59	0.05
n	27	LP-11A	Jul-06	Wet					0.79	0.10
G	28	LP-31	Mar-01	Dry	0.050	3.20	0.10	3.30	0.020	0.005
G	28	LP-31	Jul-06	Dry					0.86	0.23
G	28	LP-31	Apr-08	Post-Wet	0.005	0.076	0.750	0.826	0.037	0.013
G	28	LP-31	Sep-08	Post-Wet	0.022	0.15	0.57	0.72	0.069	0.042
G	28	LP-31	Mar-01	Wet	0.050	0.40	0.60	1.00	0.090	0.030
G	28	LP-31	Nov-05	Wet	2.80	0.23			1.65	1.49
G	28	LP-31	Jul-06	Wet					5.10	0.12
G	28	LP-31	Apr-08	Wet	0.005	0.096	0.680	0.776	0.072	0.009
G	28	LP-31	Sep-08	Wet	0.032	0.06	1.88	1.94	0.218	0.023
h	31	LP-5B	Jul-06	Dry					0.11	0.01
h	31	LP-5B	Oct-08	Dry	0.075	0.03	0.34	0.37	0.005	0.001
h	31	LP-5B	Apr-08	Post-Wet	0.005	0.025	0.305	0.330	0.011	0.001
h	31	LP-5B	Sep-08	Post-Wet	0.005	0.07	1.19	1.26	0.068	0.016
h	31	LP-5B	Nov-05	Wet	0.89	0.23			1.14	0.78
h	31	LP-5B	Jul-06	Wet					0.09	0.06
h	31	LP-5B	Apr-08	Wet	0.005	0.005	0.635	0.640	0.017	0.001
h	31	LP-5B	Sep-08	Wet	0.005	0.04	1.35	1.39	0.117	0.004
h	31	LP-5B	Oct-08	Wet	0.005	0.01	1.64	1.65	0.035	0.004
g	32	LP-32	Jul-06	Dry					0.50	0.01
g	32	LP-32	Nov-05	Wet	12.40	0.02			4.75	4.62
g	32	LP-32	Jul-06	Wet					0.90	0.22
J	33	NA	Oct-08	Dry	0.005	0.01	1.58	1.59	0.009	0.002
J	33	NA	Apr-08	Post-Wet	0.005	0.005	1.230	1.235	0.075	0.017
J	33	NA	Sep-08	Post-Wet	0.075	0.05	1.60	1.65	0.163	0.111
J	33	NA	Apr-08	Wet	0.005	0.060	2.330	2.390	0.320	0.016
J	33	NA	Sep-08	Wet	0.048	0.06	3.28	3.34	0.285	0.055
J	33	NA	Oct-08	Wet	0.018	0.01	1.16	1.17	0.029	0.002
C	34	LP-14	Aug-01	Wet	0.110	0.40	1.73	2.13	0.198	0.041
C	34	LP-14	Sep-01	Wet	0.032	0.01	0.60	0.61	0.120	0.082
C	35	LP-9	May-01	Dry	0.021	2.75	0.18	2.93	0.234	0.185
C	35	LP-9	Mar-01	Wet	0.113	0.01	5.08	5.09	0.770	0.135
C	35	LP-9	May-01	Wet	0.034	0.26	4.76	5.02	1.245	0.028
C	35	LP-9	Jun-01	Wet	0.039	1.29	0.38	1.67	0.063	0.011
C	35	LP-9	Aug-01	Wet	0.026	0.76	0.22	0.97	0.034	0.030
C	35	LP-9	Nov-05	Wet	0.50	0.25			1.99	0.23
C	35	LP-9	Jul-06	Wet					0.69	0.04
e	36	NA	Apr-08	Post-Wet	0.005	0.210	0.450	0.660	0.027	0.002
e	36	NA	Sep-08	Post-Wet	0.005	0.12	1.18	1.30	0.086	0.017
e	36	NA	Apr-08	Wet	0.005	0.210	1.000	1.210	0.086	0.002
e	36	NA	Sep-08	Wet	0.029	0.07	1.15	1.21	0.087	0.016
e	NA	LP-3C	Jul-06	Dry					0.08	0.02
e	NA	LP-3C	Nov-05	Wet	0.07	0.01			0.61	0.49
e	NA	LP-3C	Jul-06	Wet					0.64	0.05
h	NA	LP-5C	Jul-06	Dry					0.07	0.01
h	NA	LP-5C	Oct-08	Dry	0.005	0.01	0.33	0.34	0.040	0.004
h	NA	LP-5C	Apr-08	Post-Wet	0.005	0.093	0.485	0.578	0.018	0.002
h	NA	LP-5C	Sep-08	Post-Wet	0.005	0.01	1.44	1.45	0.139	0.021
h	NA	LP-5C	Nov-05	Wet	1.18	0.23			1.65	0.78
h	NA	LP-5C	Jul-06	Wet					0.18	0.06
h	NA	LP-5C	Apr-08	Wet	0.059	0.005	0.880	0.885	0.015	0.001
h	NA	LP-5C	Sep-08	Wet	0.016	0.01	0.95	0.96	0.032	0.004
h	NA	LP-5C	Oct-08	Wet	0.005	0.01	0.83	0.84	0.024	0.003

Data Lake Pocotopaug.

Lake Pocotopaug (In-Lake Data Only)
LP-1S = Markham Bay Surface
LP-1M = Markham Bay Mid-Depth
LP-1B = Markham Bay Bottom

LP-2S = Oakwood Bay Surface
LP-2M = Oakwood Bay Mid-Depth
LP-2B = Oakwood Bay Bottom

LP-1I = Markham Bay Intergrated Sample (roughly upper 20')
LP-2I = Oakwood Bay Intergrated Sample (roughly upper 20')

* If value appears in this column, results were below the detection limit and 1/2 value was used for averaging.

AECOM Location	Date	TP (mg/L)	TP 1/2 detection limit (mg/L)*	Dissolved Phosphorus (mg/L)	1/2 Diss Phos (mg/L)*	Secchi (ft)	Chlorophyll a (ug/L)
LP-2S	4/7/1991	0.018				7.4	
LP-2M	4/7/1991	0.017					
LP-2B	4/7/1991	0.021					
LP-1S	4/7/1991	0.014				9	
LP-1M	4/7/1991	0.019					
LP-1B	4/7/1991	0.016					
LP-1B	5/12/1991	0.023					15.01
LP-2S	5/12/1991	0.015				6.2	7.41
LP-2M	5/12/1991	0.015					12.07
LP-2B	5/12/1991	0.031					15.08
LP-1S	5/12/1991	0.018				7.4	24
LP-1M	5/12/1991	0.018					12.03
LP-1B	6/30/1991	0.056					13.31
LP-2S	6/30/1991	0.018				8.2	7.48
LP-2M	6/30/1991	0.024					5.26
LP-2B	6/30/1991	0.037					11.57
LP-1S	6/30/1991	0.016				8.2	7.22
LP-1M	6/30/1991	0.024					7.53
LP-1M	8/11/1991	0.026					
LP-1B	8/11/1991	0.058					
LP-1S	8/11/1991	0.014				8.2	
LP-2B	8/11/1991	0.033					
LP-2M	8/11/1991	0.021					
LP-2S	8/11/1991	0.013				8.2	
LP-1B	9/8/1991	0.044					15.13
LP-2B	9/8/1991	0.033					14.13
LP-2S	9/8/1991	0.016				4.1	6.5
LP-1S	9/8/1991	0.019				4.1	5.4
LP-2M	9/8/1991	0.025					9.07
LP-1M	9/8/1991	0.019					1.94
LP-2B	10/27/1991	0.046					10.85
LP-2M	10/27/1991	0.032					7.42
LP-1B	10/27/1991	0.065					11.07
LP-1M	10/27/1991	0.04					7.51
LP-1S	10/27/1991	0.025				4.9	10.07
LP-2S	10/27/1991	0.027				4.9	5.78
LP-1M	5/17/1992	0.023					
LP-1B	5/17/1992	0.034					
LP-2M	5/17/1992	0.021					
LP-2B	5/17/1992	0.034					
LP-2S	5/17/1992	0.02				4.9	
LP-1S	5/17/1992	0.02				5.2	
LP-1S	5/24/1992					5.6	
LP-2S	5/24/1992					5.9	
LP-2S	6/21/1992	0.013				6.6	
LP-1M	6/21/1992	0.057					
LP-1B	6/21/1992	0.206					
LP-1S	6/21/1992	0.014				7.2	

AECOM Location	Date	TP (mg/L)	TP 1/2 detection limit (mg/L)*	Dissolved Phosphorus (mg/L)	1/2 Diss Phos (mg/L)*	Secchi (ft)	Chlorophyll a (ug/L)
LP-2B	6/21/1992	0.141					
LP-2M	6/21/1992	0.02					
LP-2S	7/12/1992					3.9	
LP-1S	7/12/1992					4.1	
LP-1B	7/26/1992	0.645					
LP-1S	7/26/1992	0.027				2.8	
LP-2S	7/26/1992	0.026				2.5	
LP-2M	7/26/1992	0.027					
LP-2B	7/26/1992	0.57					
LP-1M	7/26/1992	0.042					
LP-1S	8/15/1992					1.6	
LP-2S	8/15/1992					1.5	
LP-2S	8/30/1992	0.03				1.6	
LP-2M	8/30/1992	0.033					
LP-2B	8/30/1992	0.54					
LP-1S	8/30/1992	0.033				1.5	
LP-1M	8/30/1992	0.097					
LP-1B	8/30/1992	0.44					
LP-2S	9/13/1992					2	
LP-1S	9/13/1992					2	
LP-2B	9/27/1992	0.643					
LP-1S	9/27/1992	0.031					
LP-1B	9/27/1992	0.409					
LP-2M	9/27/1992	0.029				5.2	
LP-2S	9/27/1992	0.036					
LP-1M	9/27/1992	0.034				6.2	
LP-2S	10/18/1992					4.9	
LP-1S	10/18/1992					4.9	
LP-2S	11/1/1992	0.035				4.9	
LP-2M	11/1/1992	0.029					
LP-2B	11/1/1992	0.039					
LP-1S	11/1/1992	0.028				4.6	
LP-1B	11/1/1992	0.031					
LP-1M	11/1/1992	0.028					
LP-1B	12/1/1992	0.02					
LP-1S	12/1/1992	0.01	0.005			6.2	7.8
LP-2B	12/1/1992	0.01	0.005				
LP-2S	12/1/1992	0.01	0.005			5.6	7.2
LP-1B	4/15/1993	0.02					
LP-2S	4/15/1993	0.02				7.5	0.31
LP-1S	4/15/1993	0.01				8.5	0.41
LP-2B	4/15/1993	0.02					
LP-1B	5/18/1993	0.02					
LP-2M	5/18/1993	0.03					
LP-2B	5/18/1993	0.57					
LP-2S	5/18/1993	0.01				7.2	2.07
LP-1S	5/18/1993	0.01				6.2	2.33
LP-1M	5/18/1993	0.01					
LP-1S	6/23/1993	0.01				12.8	7
LP-2S	6/23/1993	0.01	0.005			12.8	6.4
LP-2M	6/23/1993	0.01	0.005				
LP-1B	6/23/1993	0.02					
LP-1M	6/23/1993	0.01	0.005				
LP-2B	6/23/1993	0.01					
LP-1M	7/21/1993	0.01	0.005				
LP-1S	7/21/1993	0.01	0.005			13.1	15
LP-2M	7/21/1993	0.02					
LP-2S	7/21/1993	0.02				11.5	10.5
LP-1B	7/21/1993	0.06					
LP-2B	7/21/1993	0.04					

AECOM Location	Date	TP (mg/L)	TP 1/2 detection limit (mg/L)*	Dissolved Phosphorus (mg/L)	1/2 Diss Phos (mg/L)*	Secchi (ft)	Chlorophyll a (ug/L)
LP-1B	8/17/1993	0.02					
LP-2M	8/17/1993	0.02					
LP-2B	8/17/1993	0.02					
LP-1S	8/17/1993	0.01				10.2	2.2
LP-2S	8/17/1993	0.02				10.5	2
LP-1M	8/17/1993	0.01					
LP-2B	9/22/1993	0.21					
LP-2M	9/22/1993	0.45					
LP-1S	9/22/1993	0.05				3.3	2.12
LP-1M	9/22/1993	0.03					
LP-1B	9/22/1993	0.02					
LP-2S	9/22/1993					3.3	2.18
LP-2B	2/19/1994	0.066					
LP-2S	2/19/1994	0.014					
LP-2B	4/9/1994	0.012					
LP-1S	4/9/1994	0.002	0.001			7.2	
LP-2S	4/9/1994	0.006				7.5	
LP-1B	4/9/1994	0.011					
LP-1B	4/23/1994	0.05					
LP-2S	4/23/1994	0.02				6.6	
LP-2B	4/23/1994	0.047					
LP-1S	4/23/1994	0.017				7.2	
LP-2M	5/7/1994	0.019					
LP-1S	5/7/1994	0.028				6.6	
LP-1M	5/7/1994	0.022					
LP-1B	5/7/1994	0.048					
LP-2B	5/7/1994	0.07					
LP-2S	5/7/1994	0.016				5.6	
LP-2S	5/21/1994					5.2	
LP-1S	5/21/1994					5.4	
LP-2S	5/29/1994					6.2	
LP-1S	5/29/1994					6.9	
LP-1S	6/7/1994	0.017				7.5	
LP-1M	6/7/1994	0.029					
LP-2B	6/7/1994	0.063					
LP-2M	6/7/1994	0.028					
LP-2S	6/7/1994	0.02				6.6	
LP-1B	6/7/1994	0.077					
LP-1S	6/20/1994					12.1	
LP-2S	6/20/1994					11.8	
LP-2B	7/5/1994	0.234					
LP-1S	7/5/1994	0.013				9.5	
LP-1M	7/5/1994	0.019					
LP-1B	7/5/1994	0.21					
LP-2M	7/5/1994	0.031					
LP-2S	7/5/1994	0.013				9.8	
LP-1S	7/14/1994					8.5	
LP-2S	7/14/1994					8.2	
LP-2B	7/22/1994	0.268					
LP-1B	7/22/1994	0.244					
LP-1S	7/22/1994	0.02				8.9	
LP-2M	7/22/1994	0.027					
LP-2S	7/22/1994	0.011				8.5	
LP-1M	7/22/1994	0.021					
LP-2S	8/5/1994					6.2	
LP-1S	8/7/1994	0.02				5.9	
LP-2M	8/7/1994	0.045					
LP-2B	8/7/1994	0.39					
LP-1M	8/7/1994	0.028					
LP-1B	8/7/1994	0.204					

AECOM Location	Date	TP (mg/L)	TP 1/2 detection limit (mg/L)*	Dissolved Phosphorus (mg/L)	1/2 Diss Phos (mg/L)*	Secchi (ft)	Chlorophyll a (ug/L)
LP-2S	8/7/1994	0.024				5.2	
LP-2S	8/19/1994	0.016				4.6	
LP-1S	8/19/1994	0.007				4.3	
LP-2S	9/3/1994	0.007				4.3	
LP-2M	9/3/1994	0.083					
LP-2B	9/3/1994	0.25					
LP-1S	9/3/1994	0.011				4.6	
LP-1M	9/3/1994	0.08					
LP-1B	9/3/1994	0.2					
LP-1S	9/19/1994					5.2	
LP-2S	9/19/1994					4.9	
LP-2B	10/6/1994	0.003					
LP-1S	10/6/1994	0.011					
LP-1B	10/6/1994	0.005					
LP-2S	10/6/1994	0.002	0.001				
LP-1M	4/2/1995	0.021					
LP-1B	4/2/1995	0.019					
LP-2B	4/2/1995	0.017					
LP-2S	4/2/1995	0.016				7.5	
LP-2M	4/2/1995	0.023					
LP-1S	4/2/1995	0.017				7.9	
LP-1S	4/24/1995					7.9	
LP-2S	4/24/1995					7.2	
LP-2S	5/9/1995	0.011				8.2	
LP-2M	5/9/1995	0.018					
LP-2B	5/9/1995	0.042					
LP-1S	5/9/1995	0.012				8.9	
LP-1M	5/9/1995	0.02					
LP-1B	5/9/1995	0.03					
LP-2S	5/22/1995					9.8	
LP-1S	5/22/1995					9.5	
LP-2B	6/6/1995	0.12					
LP-2M	6/6/1995	0.023					
LP-1S	6/6/1995	0.007				13.5	
LP-1M	6/6/1995	0.013					
LP-1B	6/6/1995	0.149					
LP-2S	6/6/1995	0.01				12.5	
LP-2S	6/17/1995					12.1	
LP-1S	6/17/1995					13.1	
LP-1B	7/6/1995	0.165					
LP-2S	7/6/1995	0.022				8.9	
LP-2M	7/6/1995	0.018					
LP-2B	7/6/1995	0.272					
LP-1M	7/6/1995	0.014					
LP-1S	7/6/1995	0.012				10.2	
LP-2S	7/20/1995					8.2	
LP-1S	7/20/1995					9.5	
LP-1S	8/2/1995	0.018				6.6	
LP-1M	8/2/1995	0.031					
LP-1B	8/2/1995	0.073					
LP-2S	8/2/1995	0.019				5.6	
LP-2B	8/2/1995	0.209					
LP-2M	8/2/1995	0.019					
LP-2S	8/4/1995	0.017					
LP-2B	8/4/1995	0.05					
LP-2M	8/4/1995	0.02					
LP-2S	8/21/1995					6.6	
LP-2B	8/21/1995						
LP-1S	8/21/1995					7.2	
LP-1B	8/21/1995						
LP-2M	8/21/1995						

AECOM Location	Date	TP (mg/L)	TP 1/2 detection limit (mg/L)*	Dissolved Phosphorus (mg/L)	1/2 Diss Phos (mg/L)*	Secchi (ft)	Chlorophyll a (ug/L)
LP-1M	8/21/1995						
LP-2S	8/23/1995						
LP-2B	8/23/1995						
LP-2M	8/23/1995						
LP-2M	9/4/1995	0.034					
LP-1B	9/4/1995	0.112					
LP-1M	9/4/1995	0.052					
LP-2B	9/4/1995	0.066					
LP-2S	9/4/1995	0.024				6.6	
LP-1S	9/4/1995	0.027				7.2	
LP-2B	9/15/1995	0.049					
LP-2M	9/15/1995	0.016					
LP-2S	9/15/1995	0.01					
LP-1B	9/15/1995	0.031					
LP-1M	9/15/1995	0.009					
LP-1S	9/15/1995	0.008					
LP-2S	9/19/1995					5.9	
LP-1S	9/19/1995					6.2	
LP-1B	9/30/1995	0.068					
LP-2S	9/30/1995	0.014				7.2	
LP-2M	9/30/1995	0.042					
LP-2B	9/30/1995	0.06					
LP-1S	9/30/1995	0.014				7.5	
LP-1B	9/30/1995	0.015					
LP-2M	9/30/1995	0.033					
LP-2B	9/30/1995	0.053					
LP-1S	9/30/1995	0.015					
LP-2S	9/30/1995	0.013					
LP-2S	3/29/1996	0.009				8.5	
LP-1B	3/29/1996	0.008					
LP-1M	3/29/1996	0.007					
LP-2B	3/29/1996	0.008					
LP-1S	3/29/1996	0.004				8.5	
LP-2M	3/29/1996	0.013					
LP-1S	3/31/1996	0.009				9.2	
LP-2S	3/31/1996	0.009				9.2	
LP-1M	3/31/1996	0.013					
LP-2B	3/31/1996	0.014					
LP-1B	3/31/1996	0.013					
LP-2M	3/31/1996	0.014					
LP-1B	4/13/1996	0.02					
LP-2S	4/13/1996	0.009				8.2	
LP-2M	4/13/1996	0.009					
LP-1M	4/13/1996	0.012					
LP-2B	4/13/1996	0.01					
LP-1S	4/13/1996	0.009				8.2	
LP-2M	4/26/1996	0.017					
LP-1S	4/26/1996	0.057				6.6	
LP-1M	4/26/1996	0.028					
LP-1B	4/26/1996	0.02					
LP-2S	4/26/1996	0.02				6.6	
LP-2B	4/26/1996	0.023					
LP-1S	5/3/1996	0.016				6.6	
LP-1M	5/3/1996	0.02					
LP-2M	5/3/1996	0.018					
LP-2S	5/3/1996	0.013				5.9	
LP-2B	5/3/1996	0.022					
LP-1B	5/3/1996	0.021					

AECOM Location	Date	TP (mg/L)	TP 1/2 detection limit (mg/L)*	Dissolved Phosphorus (mg/L)	1/2 Diss Phos (mg/L)*	Secchi (ft)	Chlorophyll a (ug/L)
LP-2S	5/20/1996					6.6	
LP-1S	5/20/1996					6.9	
LP-1M	5/24/1996	0.016					
LP-1B	5/24/1996	0.026					
LP-2B	5/24/1996	0.033					
LP-1S	5/24/1996	0.018				8.2	
LP-2S	5/24/1996	0.019				8.2	
LP-2M	5/24/1996	0.016					
LP-2S	6/4/1996	0.019				6.9	
LP-1B	6/4/1996	0.033					
LP-1M	6/4/1996	0.014					
LP-1S	6/4/1996	0.015				7.2	
LP-2B	6/4/1996	0.06					
LP-2M	6/4/1996	0.015					
LP-1S	6/18/1996					11.2	
LP-2S	6/18/1996					11.8	
LP-2M	6/20/1996	0.017					
LP-1S	6/20/1996	0.016				10.5	
LP-1M	6/20/1996	0.012					
LP-1B	6/20/1996	0.081					
LP-2B	6/20/1996	0.126					
LP-2S	6/20/1996	0.013				10.5	
LP-1B	7/2/1996	0.13					
LP-2M	7/2/1996	0.005					
LP-2B	7/2/1996	0.146					
LP-1M	7/2/1996	0.008					
LP-1S	7/2/1996	0.008				6.9	
LP-2S	7/2/1996	0.005				7.9	
LP-1M	7/16/1996	0.021					
LP-1B	7/16/1996	0.085					
LP-1S	7/16/1996	0.023				6.2	
LP-2B	7/16/1996	0.17					
LP-2M	7/16/1996	0.016					
LP-2S	7/16/1996	0.013				6.2	
LP-1S	7/20/1996					4.8	
LP-2S	7/20/1996					5.1	
LP-2S	7/24/1996	0.017				4.9	
LP-1M	7/24/1996	0.013					
LP-1B	7/24/1996	0.074					
LP-1S	7/24/1996	0.016				4.9	
LP-2B	7/24/1996	0.102					
LP-2M	7/24/1996	0.014					
LP-1M	8/16/1996	0.019					
LP-1S	8/16/1996	0.019				4.9	
LP-2B	8/16/1996	0.285					
LP-2S	8/16/1996	0.017				4.9	
LP-1B	8/16/1996	0.145					
LP-2M	8/16/1996	0.02					
LP-2S	8/19/1996					4.9	
LP-1S	8/19/1996					4.9	
LP-1S	8/22/1996	0.023				4.9	
LP-2B	8/22/1996	0.216					
LP-2M	8/22/1996	0.028					
LP-2S	8/22/1996	0.023				4.9	
LP-1M	8/22/1996	0.023					
LP-1B	8/22/1996	0.178					
LP-2B	8/26/1996	0.26					
LP-2M	8/26/1996	0.02					
LP-2S	8/26/1996	0.012				4.6	
LP-1M	8/29/1996	0.019					
LP-1B	8/29/1996	0.163					

AECOM Location	Date	TP (mg/L)	TP 1/2 detection limit (mg/L)*	Dissolved Phosphorus (mg/L)	1/2 Diss Phos (mg/L)*	Secchi (ft)	Chlorophyll a (ug/L)
LP-1S	8/29/1996	0.012				4.6	
LP-2S	9/4/1996						
LP-2M	9/4/1996						
LP-1S	9/15/1996					5.2	
LP-2S	9/15/1996					5.2	
LP-2B	9/26/1996	0.045					
LP-1S	9/26/1996	0.015				6.2	
LP-1M	9/26/1996	0.015					
LP-1B	9/26/1996	0.06					
LP-2M	9/26/1996	0.02					
LP-2S	9/26/1996	0.017				5.7	
LP-2B	10/5/1996	0.032					
LP-1B	10/5/1996	0.02					
LP-1S	10/5/1996	0.013				5.2	
LP-2M	10/5/1996	0.019					
LP-2S	10/5/1996	0.013				5.2	
LP-1M	10/5/1996	0.11					
LP-1B	3/29/1997	0.012					
LP-1B	3/29/1997	0.018					
LP-1S	3/29/1997	0.013				6.9	
LP-2B	3/29/1997	0.016					
LP-2M	3/29/1997	0.011					
LP-2S	3/29/1997	0.01				6.9	
LP-1B	4/3/1997	0.02					
LP-2S	4/3/1997	0.016				7.5	
LP-1M	4/3/1997	0.17					
LP-2B	4/3/1997	0.022					
LP-2M	4/3/1997	0.019					
LP-1S	4/3/1997	0.018				5.5	
LP-1S	4/21/1997	0.006				6.6	
LP-2B	4/21/1997	0.036					
LP-1B	4/21/1997	0.035					
LP-1M	4/21/1997	0.015					
LP-2M	4/21/1997	0.015					
LP-2S	4/21/1997	0.015				6.2	
LP-1S	5/5/1997	0.017				5.9	
LP-2B	5/5/1997	0.024					
LP-2M	5/5/1997	0.017					
LP-2S	5/5/1997	0.018				5.6	
LP-1B	5/5/1997	0.017					
LP-1M	5/5/1997	0.016					
LP-1S	5/18/1997					5.6	
LP-2S	5/18/1997					5.6	
LP-1B	5/27/1997	0.027					
LP-1S	5/27/1997	0.017				8.2	
LP-2B	5/27/1997	0.053					
LP-2M	5/27/1997	0.025					
LP-2S	5/27/1997	0.021				6.9	
LP-1M	5/27/1997	0.024					
LP-2S	6/5/1997	0.014				7.9	
LP-1B	6/5/1997	0.228					
LP-1S	6/5/1997	0.012				8.2	
LP-1M	6/5/1997	0.017					
LP-2M	6/5/1997	0.018					
LP-2B	6/5/1997	0.235					
LP-1S	6/19/1997					9.2	
LP-2S	6/19/1997					8.5	
LP-2M	6/30/1997	0.018					
LP-2B	6/30/1997	0.235					
LP-1S	6/30/1997	0.012				8.2	
LP-1M	6/30/1997	0.017					
LP-1B	6/30/1997	0.228					

AECOM Location	Date	TP (mg/L)	TP 1/2 detection limit (mg/L)*	Dissolved Phosphorus (mg/L)	1/2 Diss Phos (mg/L)*	Secchi (ft)	Chlorophyll a (ug/L)
LP-2S	6/30/1997	0.014				7.9	4.6
LP-2S	7/15/1997					9.2	
LP-1S	7/15/1997					9.5	
LP-2S	7/23/1997	0.014				4.9	
LP-2B	7/23/1997	0.035					
LP-2M	7/23/1997	0.05					
LP-1B	7/23/1997	0.112					
LP-1M	7/23/1997	0.026					
LP-1S	7/23/1997	0.015				4.9	
LP-1M	8/2/1997	0.015					
LP-2B	8/2/1997	0.06					
LP-2M	8/2/1997	0.009					
LP-1B	8/2/1997	0.172					
LP-1S	8/2/1997	0.011				3	
LP-2S	8/2/1997	0.01				3	
LP-1S	8/7/1997						23.1
LP-1S	8/17/1997					4.9	
LP-2S	8/17/1997					4.9	
LP-1S	8/22/1997	0.016				4.8	
LP-1M	8/22/1997	0.021					
LP-1B	8/22/1997	0.17					
LP-2M	8/22/1997	0.021					
LP-2B	8/22/1997	0.155					
LP-2S	8/22/1997	0.018				4.3	
LP-1B	9/1/1997	0.124					
LP-1M	9/1/1997	0.018					
LP-1S	9/1/1997	0.01				3.3	
LP-2B	9/1/1997	0.009					
LP-2M	9/1/1997	0.013					
LP-2S	9/1/1997	0.008				3.3	
LP-1S	9/16/1997					3.9	
LP-2S	9/16/1997					3.6	
LP-2S	10/2/1997	0.031				2.5	
LP-1B	10/2/1997	0.033					
LP-1M	10/2/1997	0.03					
LP-1S	10/2/1997	0.025				3.6	
LP-2M	10/2/1997	0.035					
LP-2B	10/2/1997	0.069					
LP-2S	10/6/1997	0.024				3.9	
LP-2M	10/6/1997	0.02					
LP-2B	10/6/1997	0.08					
LP-1S	10/6/1997	0.024				4.3	
LP-1M	10/6/1997	0.021					
LP-1B	10/6/1997	0.029					
LP-1B	3/30/1998	0.015					
LP-2S	3/30/1998	0.018				4.6	
LP-2M	3/30/1998	0.016					
LP-2B	3/30/1998	0.023					
LP-1M	3/30/1998	0.016					
LP-1S	3/30/1998	0.014				4.9	
LP-1M	4/24/1998	0.032					
LP-2S	4/24/1998	0.016				5.6	
LP-2M	4/24/1998	0.026					
LP-1B	4/24/1998	0.039					
LP-2B	4/24/1998	0.031					
LP-1S	4/24/1998	0.022				6.2	
LP-1S	5/14/1998	0.019				4.6	
LP-1M	5/14/1998	0.023					
LP-1B	5/14/1998	0.032					
LP-2S	5/14/1998	0.017				4.6	
LP-2M	5/14/1998	0.022					
LP-2B	5/14/1998	0.034					

AECOM Location	Date	TP (mg/L)	TP 1/2 detection limit (mg/L)*	Dissolved Phosphorus (mg/L)	1/2 Diss Phos (mg/L)*	Secchi (ft)	Chlorophyll a (ug/L)
LP-2S	5/20/1998	0.01				4.3	
LP-1S	5/20/1998	0.013				4.9	
LP-1B	5/29/1998	0.064					
LP-1M	5/29/1998	0.018					
LP-1S	5/29/1998	0.011				7.5	
LP-2B	5/29/1998	0.096					
LP-2M	5/29/1998	0.022					
LP-2S	5/29/1998	0.017				7.5	
LP-1B	5/31/1998	0.193					
LP-1M	5/31/1998	0.022					
LP-2S	5/31/1998	0.016				6.2	
LP-1S	5/31/1998	0.017				6.6	
LP-2M	5/31/1998	0.022					
LP-2B	5/31/1998	0.128					
LP-2S	6/18/1998					7.2	
LP-1S	6/18/1998					7.9	
LP-2M	6/24/1998	0.015					
LP-2B	6/24/1998	0.154					
LP-1S	6/24/1998	0.008				7.4	
LP-1M	6/24/1998	0.018					
LP-1B	6/24/1998	0.151					
LP-2S	6/24/1998	0.008				7.4	
LP-1S	7/6/1998	0.035				9.2	
LP-1B	7/6/1998	0.224					
LP-2S	7/6/1998	0.03				8.9	
LP-2B	7/6/1998	0.265					
LP-2M	7/6/1998	0.042					
LP-1M	7/6/1998	0.038					
LP-2S	7/26/1998	0.01				7.9	
LP-2M	7/26/1998	0.021					
LP-2B	7/26/1998	0.252					
LP-1S	7/26/1998	0.014				9.2	
LP-1M	7/26/1998	0.026					
LP-1B	7/26/1998	0.452					
LP-1M	8/30/1998	0.041					
LP-1S	8/30/1998	0.015				5.6	
LP-2S	8/30/1998	0.016				5.9	
LP-2M	8/30/1998	0.028					
LP-1B	8/30/1998	0.168					
LP-2B	8/30/1998	0.33					
LP-1B	9/4/1998	0.125					
LP-2S	9/4/1998	0.017				5.6	
LP-2M	9/4/1998	0.016					
LP-2B	9/4/1998	0.29					
LP-1S	9/4/1998	0.013				5.2	
LP-1M	9/4/1998	0.021					
LP-1S	9/24/1998					4.3	
LP-2S	9/24/1998					4.3	
LP-2S	10/4/1998	0.014				4.6	
LP-1M	10/4/1998	0.018					
LP-2M	10/4/1998	0.022					
LP-2B	10/4/1998	0.134					
LP-1S	10/4/1998	0.019				3.9	
LP-1B	10/4/1998	0.074					
LP-2S	4/6/1999	0.018				4.3	
LP-1S	4/6/1999	0.017				4.6	
LP-2S	5/1/1999	0.017				5.2	
LP-2M	5/1/1999	0.024					
LP-2B	5/1/1999	0.029					
LP-1S	5/1/1999	0.015				5.9	
LP-1M	5/1/1999	0.025					
LP-1B	5/1/1999	0.022					

AECOM Location	Date	TP (mg/L)	TP 1/2 detection limit (mg/L)*	Dissolved Phosphorus (mg/L)	1/2 Diss Phos (mg/L)*	Secchi (ft)	Chlorophyll a (ug/L)
LP-1S	5/15/1999					6.2	
LP-2S	5/15/1999					6.9	
LP-2M	6/6/1999	0.018					
LP-2B	6/6/1999	0.133					
LP-1S	6/6/1999	0.018				6.9	
LP-1M	6/6/1999	0.021					
LP-1B	6/6/1999	0.165					
LP-2S	6/6/1999	0.018				6.2	
LP-2S	6/19/1999					8.5	
LP-1S	6/19/1999					8.5	
LP-1S	7/3/1999	0.006				8.5	
LP-2S	7/3/1999	0.009				7.9	
LP-2B	7/3/1999	0.323					
LP-1M	7/3/1999	0.02					
LP-1B	7/3/1999	0.135					
LP-2M	7/3/1999	0.015					
LP-2S	7/18/1999					6.2	
LP-1S	7/18/1999					6.2	
LP-2S	8/1/1999	0.009				4.6	
LP-2M	8/1/1999	0.02					
LP-2B	8/1/1999	0.108					
LP-1S	8/1/1999	0.01				4.6	
LP-2M	8/1/1999	0.029					
LP-2B	8/1/1999	0.092					
LP-1S	8/16/1999					5.6	
LP-2S	8/16/1999					5.6	
LP-2M	9/3/1999	0.025					
LP-2B	9/3/1999	0.07					
LP-1S	9/3/1999	0.01				5.6	
LP-1M	9/3/1999	0.021					
LP-1B	9/3/1999	0.106					
LP-2S	9/3/1999	0.012				5.6	
LP-2S	10/1/1999	0.014				3.9	
LP-2B	10/1/1999	0.047					
LP-1S	10/1/1999	0.012				3.9	
LP-1B	10/1/1999	0.048					
LP-1M	4/1/2000	0.03					
LP-1B	4/1/2000	0.031					
LP-2M	4/1/2000	0.028					
LP-2S	4/1/2000	0.023				4.9	
LP-1S	4/1/2000	0.022				4.6	
LP-2B	4/1/2000	0.04					
LP-2B	4/16/2000	0.056					
LP-2M	4/16/2000	0.027					
LP-2S	4/16/2000	0.02				4.9	
LP-1S	4/16/2000	0.018				5.2	
LP-1M	4/16/2000	0.024					
LP-1B	4/16/2000	0.043					
LP-1S	5/3/2000	0.015				4.6	
LP-1M	5/3/2000	0.018					
LP-2M	5/3/2000	0.024					
LP-2B	5/3/2000	0.031					
LP-2S	5/3/2000	0.016				4.6	
LP-1B	5/3/2000	0.022					
LP-1B	5/31/2000	0.024					
LP-2S	5/31/2000	0.009				6.6	
LP-2M	5/31/2000	0.023					
LP-2B	5/31/2000	0.05					
LP-1S	5/31/2000	0.01				6.6	
LP-1M	5/31/2000	0.013					
LP-1S	6/17/2000					7.2	

AECOM Location	Date	TP (mg/L)	TP 1/2 detection limit (mg/L)*	Dissolved Phosphorus (mg/L)	1/2 Diss Phos (mg/L)*	Secchi (ft)	Chlorophyll a (ug/L)
LP-2S	6/17/2000					6.6	
LP-1M	7/3/2000	0.018					
LP-1B	7/3/2000	0.121					
LP-1S	7/3/2000	0.007				8.5	
LP-2B	7/3/2000	0.085					
LP-2S	7/3/2000	0.008				7.9	
LP-2M	7/3/2000	0.009					
LP-1S	7/17/2000					5.6	
LP-2S	7/17/2000					5.9	
LP-2S	7/30/2000	0.016				3.3	
LP-1B	7/30/2000	0.131					
LP-1M	7/30/2000	0.03					
LP-1S	7/30/2000	0.017				3.6	
LP-2B	7/30/2000	0.137					
LP-2M	7/30/2000	0.025					
LP-1S	8/21/2000					2	
LP-2S	8/21/2000					2.3	
LP-2S	9/4/2000	0.021				1.6	
LP-1M	9/4/2000	0.023					
LP-1S	9/4/2000	0.023				2	
LP-2M	9/4/2000	0.013					
LP-1B	9/4/2000	0.183					
LP-2B	9/4/2000	0.226					
LP-2S	9/17/2000					3.6	
LP-1S	9/17/2000					3.6	
LP-1S	10/3/2000	0.017				5.2	
LP-1M	10/3/2000	0.02					
LP-1B	10/3/2000	0.07					
LP-2M	10/3/2000	0.017					
LP-2B	10/3/2000	0.054					
LP-2S	10/3/2000	0.012				4.6	
LP-1S	4/26/2001	0.01		0.002	0.001	5.5	
LP-2I	4/26/2001						4.55
LP-1I	4/26/2001						2.24
LP-1B	4/26/2001	0.015		0.003			
LP-2S	4/26/2001	0.014		0.002	0.001	4.5	
LP-2B	4/26/2001	0.015		0.003			
LP-1S	5/17/2001	0.01		0.005		6	
LP-1I	5/17/2001						3.29
LP-1B	5/17/2001	0.021		0.004			
LP-2S	5/17/2001	0.01		0.005		6	
LP-2B	5/17/2001	0.02		0.008			
LP-2I	5/17/2001						2.55
LP-1M	6/13/2001	0.014		0.001	0.0005		
LP-2I	6/13/2001						6.34
LP-1I	6/13/2001						1.5
LP-2B	6/13/2001	0.023		0.001	0.0005		
LP-2M	6/13/2001	0.017		0.002			
LP-2S	6/13/2001	0.009		0.001	0.0005	7.5	
LP-1B	6/13/2001	0.019		0.004			
LP-1S	6/13/2001	0.009		0.001	0.0005	8.5	
LP-1M	6/19/2001	0.013					
LP-1B	6/19/2001	0.16					
LP-1S	6/19/2001	0.014				9.8	
LP-2B	6/19/2001	0.216					
LP-2S	6/19/2001	0.013				9.8	
LP-2M	6/19/2001	0.012					
LP-2I	7/23/2001						1.61
LP-1B	7/23/2001	0.019		0.004			
LP-2B	7/23/2001	0.03		0.003			
LP-2M	7/23/2001	0.014		0.006			
LP-2S	7/23/2001	0.008		0.003		7.1	

AECOM Location	Date	TP (mg/L)	TP 1/2 detection limit (mg/L)*	Dissolved Phosphorus (mg/L)	1/2 Diss Phos (mg/L)*	Secchi (ft)	Chlorophyll a (ug/L)
LP-1M	7/23/2001	0.012		0.003			
LP-1S	7/23/2001	0.008		0.003		8.5	
LP-1I	7/23/2001						3.11
LP-1I	8/23/2001						10.84
LP-2I	8/23/2001						6.52
LP-2M	8/23/2001	0.015		0.004			
LP-2S	8/23/2001	0.01		0.002	0.001	3.3	
LP-1B	8/23/2001	0.019		0.003			
LP-1M	8/23/2001	0.018		0.004			
LP-1S	8/23/2001	0.011		0.002	0.001	3.5	
LP-2B	8/23/2001	0.037		0.003			
LP-2B	9/20/2001	0.023		0.003			
LP-2M	9/20/2001	0.019		0.003			
LP-2S	9/20/2001	0.02		0.003		4.6	
LP-2I	9/20/2001						11.7
LP-1I	9/20/2001						14.78
LP-1M	9/20/2001	0.022		0.006			
LP-1S	9/20/2001	0.015		0.003		4.6	
LP-1B	9/20/2001	0.02		0.003			
LP-2S	10/31/2001	0.014		0.002		5	
LP-1S	10/31/2001	0.019		0.002		5	
LP-2M	10/31/2001	0.024		0.002			
LP-1M	10/31/2001	0.017		0.002			
LP-2S	11/27/2001	0.019		0.002		8.9	
LP-1M	11/27/2001	0.016		0.004			
LP-2M	11/27/2001	0.025		0.002			
LP-2S	11/27/2001	0.018		0.004		7.5	
LP-1S	12/28/2001	0.005		0.001	0.0005	8.5	
LP-1M	12/28/2001	0.009		0.003			
LP-2M	12/28/2001	0.009		0.001	0.0005		
LP-2S	12/28/2001	0.01		0.001	0.0005	7.5	

All Data							
Max		0.645	0.005	0.008	0.001	13.50	24.00
Min		0.002	0.001	0.001	0.001	1.50	0.31
Mean		0.049	0.004	0.003	0.001	6.38	7.83
Median		0.020	0.005	0.003	0.001	6.20	7.21
n		592	10	44	11	275	52

APPENDIX B

Export Coefficient Evaluation

P Export Coefficient Calculations for Lake Pocotopaug Watershed

Drainage Area	Dry Weather Median TP (mg/L)	Wet Weather Median TP (mg/L)	Wet Weather Flow (m3/yr)	Dry Weather Flow (m3/yr)	Dry weather load (kg/yr)	Wet weather load (kg/yr)	Total Load (kg)	Area (ha)	Areal Load (kg/ha/yr)	% Developed	% Natural	Export for Developed Assuming 0.15 kg/ha/yr for Undev.	Most Reliable
A	0.198	0.149	165663	117577.4	32.8	17.5	50	49.5	1.016591	0.75	0.25	1.31	
B			117049	103563.1				38.0					
C	0.060	0.141	259854	231052.1	15.6	32.6	48	84.3	0.571294	0.65	0.35	0.80	X
D			40049	38380.6				13.9					
E	0.021	0.065	408831	763483.2	8.6	49.2	58	200.9	0.287878	0.33	0.67	0.57	X
F		0.196	68030	72845.1		14.3	14	24.6	0.580715				
G	0.439	0.090	31321	86078.0	13.8	7.7	21	20.1	1.068278	0.14	0.86	6.71	
H	0.008	0.042	547914	1601870.0	4.4	67.3	72	360.0	0.199071	0.11	0.89	0.60	X
I	0.021	0.114	45421	58331.8	1.0	6.6	8	17.6	0.430756	0.50	0.50	0.71	X
J	0.009	0.163	26864	24522.9	0.2	4.0	4	8.8	0.4828	0.65	0.35	0.66	
K	0.036	0.174	134765	209309.7	4.9	36.3	41	58.3	0.706686	0.39	0.61	1.58	
L	0.028	0.169	7387	23830.7	0.2	4.0	4	5.4	0.784686	0.08	0.02	9.77	
M	0.058	0.706	53064	53059.5	3.1	37.5	41	18.6	2.184035	0.60	0.40	3.54	X
N	0.031	0.178	62184	131492.0	1.9	23.4	25	32.8	0.771924	0.25	0.75	2.64	X
Total					86.4	300.5	386.8	880.8					
Adjusted for missing watershed area					91.2	317.2	408.4	932.7					

N Export Coefficient Calculations for Lake Pocotopaug Watershed

Drainage Area	Dry Weather Median TN (mg/L)	Wet Weather Median TN (mg/L)	Wet Weather Flow (m3/yr)	Dry Weather Flow (m3/yr)	Dry weather load (kg/yr)	Wet weather load (kg/yr)	Total Load (kg)	Area (ha)	Areal Load (kg/ha/yr)	% Developed	% Natural	Export for Developed Assuming 2.7 kg/ha/yr for Undev.	Most Reliable
A		1.085	165663	117577.4	0.0	127.6	128	49.5	2.577247	0.75	0.25	2.54	
B			117049	103563.1				38.0					
C	2.200	1.742	259854	231052.1	571.7	402.5	974	84.3	11.55374	0.65	0.35	16.32	
D			40049	38380.6				13.9					
E	0.595	0.931	408831	763483.2	243.3	710.4	954	200.9	4.747387	0.33	0.67	8.90	X
F		1.926	68030	72845.1	0.0	140.3	140	24.6	5.704932				
G	3.300	0.826	31321	86078.0	103.4	71.1	174	20.1	8.669671	0.14	0.86	45.34	
H	0.330	0.894	547914	1601870.0	180.8	1432.1	1,613	360.0	4.480464	0.11	0.89	18.89	X
I	0.348	1.007	45421	58331.8	15.8	58.7	74	17.6	4.236454	0.50	0.50	5.77	X
J	1.590	0.745	26864	24522.9	42.7	18.3	61	8.8	6.9457	0.65	0.35	9.23	
K	0.400	0.310	134765	209309.7	53.9	64.9	119	58.3	2.039233	0.39	0.61	1.01	
L	0.285	0.558	7387	23830.7	2.1	13.3	15	5.4	2.862496	0.08	0.02	35.11	
M	0.766	1.220	53064	53059.5	40.6	64.7	105	18.6	5.676053	0.60	0.40	7.66	X
N	0.565	0.454	62184	131492.0	35.1	59.7	95	32.8	2.889576	0.25	0.75	3.46	
Total					1289.4	3163.5	4452.9	880.8					
Adjusted for missing watershed area					1361.2	3339.7	4700.9	932.7					