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January 20, 2009

Mr. Martin Krauter
Town Manager
Town of Fryeburg
16 Lovewell Pond Rd.
Fryeburg, ME 04037

Re: Project Title "Continuation of Wards Brook/Lovewell Pond Study
Final Report

Dear Mr. Krauter,

Please find attached our report entitled "Lovewell Pond Watershed Phosphorus Loading Analysis", pursuant to the project referenced above.

It has been a pleasure working with the Town of Fryeburg over the past two years or so. If there are additional services that we can provide related to Wards Brook/Lovewell Pond or other issues, please don't hesitate to get in touch.

Sincerely
NORMANDEAU ASSOCIATES

A handwritten signature in blue ink that reads "Mark L. Hutchins".

Mark L. Hutchins
Senior Water Resources Engineer

Lovewell Pond Watershed Phosphorus Loading Analysis

Introduction

In January of 2008, Normandeau Associates was contracted by the Town of Fryeburg, Maine to develop a quantitative phosphorus budget for Lovewell Pond in an attempt to better evaluate the potential impact of groundwater withdrawals from the Wards Brook watershed on Lovewell Pond water quality. This effort was to use existing data in the form of watershed aerial photography to define current land uses, water quality data for Lovewell Pond and the Saco River from various sources and a nationally recognized watershed nutrient loading model that would provide a product that would form an acceptable basis for future watershed planning/modeling activities. This letter report provides the results of this effort.

Watershed Characterization

Watershed land use information and boundary delineation was derived from Maine Office of Geographic Information Systems database. Figure 1 presents the land use information for the watershed. Twenty one different land use categories were used to describe the watershed. These uses and the associated acreages are provided in Table 1. It should be noted that the watershed size determined by this method is substantially larger (by nearly 1,350 acres) than that reported by the Maine Voluntary Lake Monitoring Program data. Because of the precision of the mapping used to generate these new estimates, we believe that the new watershed acreage values are accurate.

Watershed Phosphorus Loading Model

Watershed phosphorus loading estimation was accomplished using the US Environmental Protection Agency's STEPL model. STEPL, short for **Spreadsheet Tool for Estimating Pollutant Load**, allows the user to calculate nutrient and sediment loads from different land uses and the load increases or reductions that would result from changes in land use or the implementation of various best management practices (BMPs). STEPL provides a user-friendly Visual Basic (VB) interface to create a customized, spreadsheet-based model in Microsoft (MS) Excel. It is capable of computing watershed surface runoff; nutrient loads, including nitrogen, phosphorus, and 5-day biological oxygen demand (BOD5); and sediment delivery based on various land uses and management practices. For each watershed, the annual nutrient loading is calculated based on the runoff volume and the pollutant concentrations in the runoff water as influenced by factors such as the land use distribution and management practices.

For the Lovewell Pond watershed, we used the STEPL model to evaluate total phosphorus loading only. Loading results were then used as input into the commonly-used Vollenweider

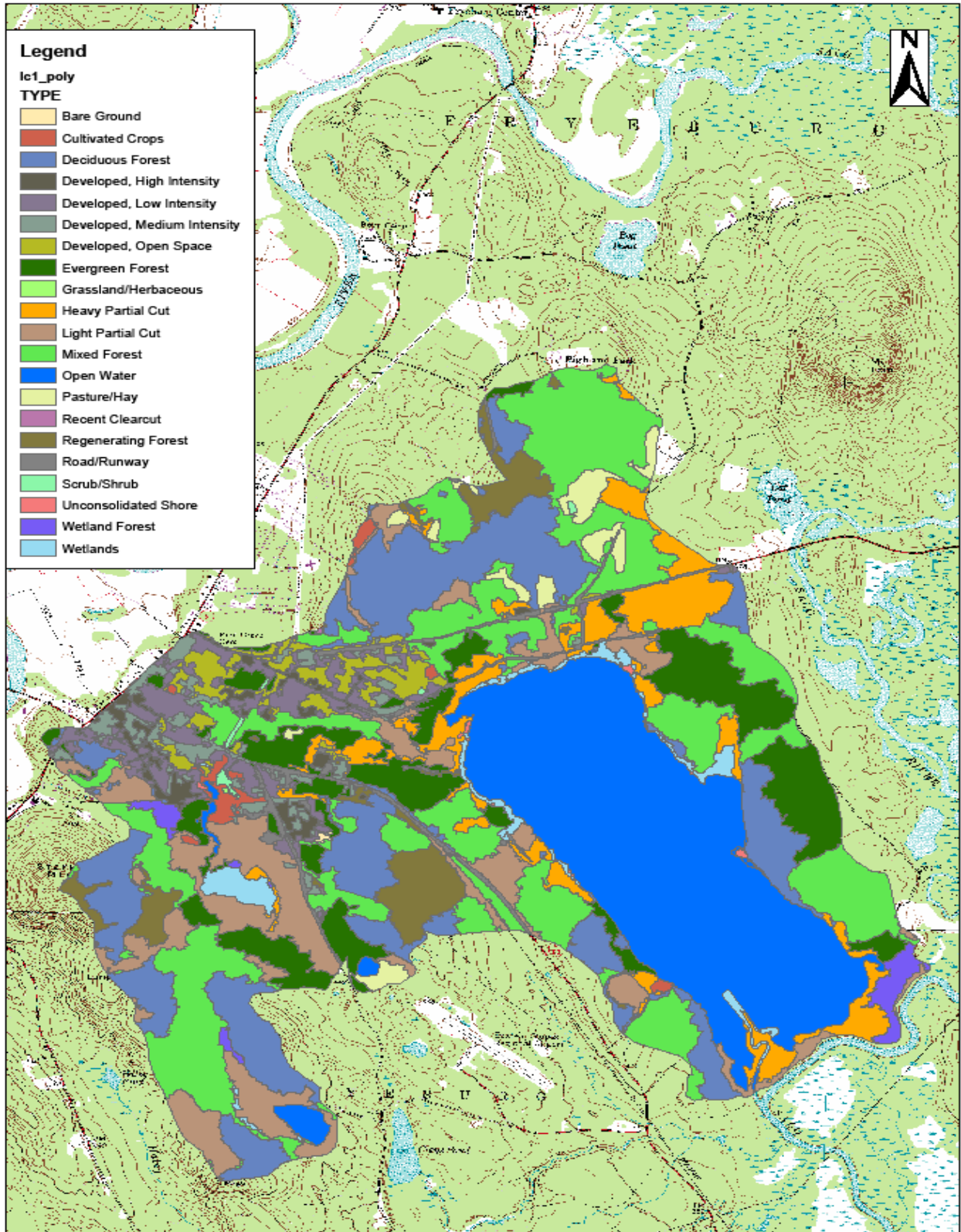


Figure 1 – Lovewell Pond Watershed Land Use Characterization

Table 1: Land Characterization of the Lovewell Pond Watershed

Land Use Type	Acreage (acres)
1. Bare Ground	1.7
2. Cultivated Crops	36.9
3. Deciduous Forest	836.1
4. Developed, High Intensity	72.1
5. Developed, Medium Intensity	107.6
6. Developed, Low Intensity	185.9
7. Developed, Open Space	128.2
8. Evergreen Forest	548.8
9. Grassland/Herbaceous	0.4
10. Heavy Partial Cut	340.8
11. Light Partial Cut	495.1
12. Mixed Forest	1,153.9
13. Open Water	1,136.7
14. Pasture/Hay	90.6
15. Recent Clearcut	0.5
16. Regenerating Forest	193.7
17. Road/Runway	86.0
18. Scrub/Shrub	8.2
19. Unconsolidated Shore	5.1
20. Wetland Forest	52.2
21. Wetlands	86.4
Total	5,566.9

phosphorus input-output model (Vollenweider 1976) to determine expected in-lake concentrations of total phosphorus. Using these methods, we were able to predict how groundwater withdrawal from the Wards Brook sand and gravel aquifer would be expected to impact water quality in Lovewell Pond and to compare groundwater withdrawal impacts to impacts expected from changes in land use within the watershed.

For modeling purposes, the various land uses presented in Table 1 were consolidated into 5 categories – Urban, Cropland, Pasture/Rangeland, Forest and Water. Table 2 provides a summary of the modeling categories. The urban category includes a distribution of land uses including such uses as Commercial, industrial, institutional transportation and several residential categories.

It should be noted that modeling of Lovewell Pond is complicated by the influence of the Saco River. Lovewell Pond is unusual in that it receives substantial “inflow” from its outlet during times that the Saco River floods, especially during the spring. Most lakes do not experience backflow through their outlets from “downstream” sources. This factor complicates the analysis substantially in that backflow introduces water and nutrient loading to Lovewell, both of which are integral factors in determining in-lake water quality. Furthermore, it is not clear from a limnological perspective whether intermittent loadings from the outlet have the same influence on water quality as do the more or less constant loadings from the “rest” of watershed. Even so, commonly-used lake water quality models do not differentiate between water or nutrient sources,

Land Use Type	Acreage (acres)
Urban (composed of Developed – High, Medium, Low Intensity and Open Space; Road/Runway; Bare Ground; Unconsolidated Shore)	586.6
Cropland (composed of Cultivated Crops)	36.9
Pasture/Rangeland (composed of Pasture/Hay)	90.6
Forest (composed of Deciduous, Evergreen, Mixed, Regenerating and Wetland Forest; Grassland/Herbaceous; Heavy and Light Partial Cut; Recent Clearcut; Scrub/shrub; Wetlands)	3,716.1
Water	1,136.7 (1,120 acres of which is Lovewell Pond)
Total	5,566.9

either spatially or temporally, which would suggest that the introduction of water and nutrients to a lake, irrespective of where they enter from or when, is the overriding factor.

For the purposes of this modeling effort, we have focused our quantitative analyses on the Lovewell Pond watershed. We have also attributed a portion of the in-lake total phosphorus concentration in the pond to inflow from the Saco River, but we have quantified the portion attributable to the Saco indirectly rather than by quantitative modeling. Since our focus is on the Lovewell Pond watershed proper and more specifically on the influence of groundwater withdrawals from the Wards Brook aquifer, this modeling approach is sufficient for these purposes. However, it is important to recognize that the Saco River plays a very significant role in determining water quality in Lovewell Pond and may be responsible for one-third or more of the phosphorus loading to the Pond.

Summary of Modeling Results

Details of the modeling approach and methods are provided in a Technical Appendix attached to this report. A summary of the results is provided here. Using the STEPL model, watershed land use delineation based on the Maine Geographical Information System database, phosphorus loading associated with various land uses and the Vollenweider Input/Output Phosphorus Model for lakes, we were able to determine the expected in-lake concentration of total phosphorus that results from current land uses in the watershed. We then were able to modify land use by assuming various changes in the amounts of urban/cropland/pasture/forest to determine how total phosphorus concentrations in Lovewell Pond would be expected to change with changing land use. Finally, we were able to determine the Lovewell Pond total phosphorus changes that would be expected from groundwater withdrawal from the Wards Brook aquifer and to compare the impact of groundwater withdrawal with land use changes.

Table 3 presents the modeling results. Under current conditions, it is estimated that phosphorus loading from existing land uses is ~1,237.2 lbs/year which would result in an in-lake total phosphorus concentration in Lovewell Pond of about 6.853 µg/l. Recent water quality sampling by the Maine Voluntary Lake Monitoring Program, Waite Environmental Management (2007) and the Saco River Corridor Commission has found that in-lake total phosphorus concentrations

Table 3: Selected STEPL and Vollenweider Model Results for Lovewell Pond, Fryeburg, ME (cont.)

Modeling Scenario	Phosphorus Loading (lbs/yr)	Lovewell Pond Total Phosphorus Concentration Resulting from Watershed Loading (µg/l)	Estimated Lovewell Pond Total Phosphorus Concentration Resulting from Saco River Loading (µg/l)¹	Net Lovewell Pond Total Phosphorus Concentration Resulting from both Watershed and Saco River Loading (µg/l)	Percent Change in Lovewell Pond Total Phosphorus Concentration from Existing Conditions (%)
Existing Conditions	1,237.2	6.853	3.147	10.000	N/A
Scenario 1 – Double phosphorus loading coefficients from all land uses	1,694.8	9.387	3.147	12.534	+25.3
Scenario 2 – Half phosphorus loading coefficients from all land uses	1,008.3	5.585	3.147	8.732	-12.9
Scenario 3 – Use Concord, NH precipitation data rather than Portland, ME	1,216.2	6.736	3.147	9.883	-1.2
Scenario 4 – Change % distribution of urban land uses	1,285.1	7.118	3.147	10.265	+2.6
Scenario 5a – Increase urban by 10% (58.7 acres), take from forest	1,297.5	7.186	3.147	10.333	+3.3
Scenario 5b – Increase urban by 50% (293.3 acres), take from forest	1,538.5	8.521	3.147	11.668	+16.7
Scenario 5c – Increase urban by 100% (586.6 acres), take from forest	1,839.9	10.744	3.147	13.891	+38.9
Scenario 6a – Increase cropland by 10% (3.7 acres), take from forest	1,242.7	6.883	3.147	10.03	+0.0
Scenario 6b – Increase cropland by 50% (18.5 acres), take from forest	1,264.7	7.005	3.147	10.152	+1.5
Scenario 6c – Increase cropland by 100% (36.9 acres), take from forest	1,292.0	7.156	3.147	10.303	+3.0

Table 3: Selected STEPL and Vollenweider Model Results for Lovewell Pond, Fryeburg, ME

Modeling Scenario	Phosphorus Loading (lbs/yr)	Lovewell Pond Total Phosphorus Concentration Resulting from Watershed Loading (µg/l)	Estimated Lovewell Pond Total Phosphorus Concentration Resulting from Saco River Loading (µg/l)¹	Net Lovewell Pond Total Phosphorus Concentration Resulting from both Watershed and Saco River Loading (µg/l)	Percent Change in Lovewell Pond Total Phosphorus Concentration from Existing Conditions (%)
Scenario 7a – Decrease forest by 10% (371.6 acres), add to urban	1,619.0	8.967	3.147	12.114	+21.1
Scenario 7b – Decrease forest by 25% (929.0 acres), add to urban	2,191.7	12.139	3.147	15.286	+52.9
Scenario 8a – Decrease forest by 10% (371.6 acres), add to cropland	1,789.8	9.913	3.147	13.060	+30.6
Scenario 8b – Decrease forest by 25% (929.0 acres), add to cropland	2,618.8	14.505	3.147	17.652	+76.5
Scenario 9a – Increase cropland by 100 acres, take from forest	1,385.9	7.676	3.147	10.823	+8.2
Scenario 9b – Increase cropland by 200 acres, take from forest	1,534.6	8.500	3.147	11.647	+16.5
Scenario 10a - Groundwater withdrawal from Wards Brook Aquifer (220 mgd @ 10 µg/l TP)	1,218.8	6.899	3.147	10.046	+0.5
Scenario 10b – Groundwater withdrawal from Wards Brook Aquifer (220 mgd @ 15 µg/l TP)	1,209.7	6.714	3.147	9.861	-1.4
Scenario 10c – Groundwater withdrawal from Wards Brook Aquifer (220 mgd @ 17 µg/l TP)	1,206.0	6.517	3.147	9.664	-3.4

¹Sampling from Maine Voluntary Lake Monitoring Program, Waite Environmental Management and Saco River Corridor Commission indicates that recent total phosphorus concentrations in Lovewell Pond are generally in the range of 6 - 9 µg/l. We have assumed a conservative 10 µg/l for our analyses.

are generally in the 6 – 9 µg/l range. To be conservative, we have assumed a concentration of 10 µg/l in our analyses. Thus, we attribute about 2/3 of the phosphorus in Lovewell Pond to watershed loading (6.853 µg/l) and about 1/3 to Saco River loading (~3.147 µg/l).

Modeling scenarios 1 – 4 were developed to explore the sensitivity of the modeling approach to various overarching input parameters in the model. It can be seen in Table 3 that doubling or halving the phosphorus loading coefficients for all land uses (Scenario 1 and 2, respectively) results in an increase or decrease in in-lake total phosphorus concentration of about 25 and 12%, respectively. Since it is unlikely that coefficient estimates would be in error by a factor of 2, we conclude that it is highly probable the phosphorus loading from the Lovewell Pond watershed results in an in-lake phosphorus concentration of somewhere between 9.5 and 11 µg/l.

In Scenario 3, we evaluate the influence of use Concord, NH rainfall data rather Portland, ME data, exploring whether rainfall in coastal Maine might not representative of inland conditions. We found that using an inland station (Concord, NH) made very little difference in results as compared to Portland. Therefore, the model is not particularly sensitive to reasonable estimates of rainfall.

In Scenario 4, we explored the impact of changing the mix of urban land uses, specifically by modifying the relative amounts of institutional, transportation and residential land use types (see Technical Appendix). Results indicate that modest changes in the mix of urban land uses produce only small changes in Lovewell Pond total phosphorus concentrations.

In Scenarios 5 – 9, we evaluated how changes in the mix of land uses within the watershed would be expected to influence in-lake total phosphorus concentrations. For example, in Scenario 5b, we increased urban lands by 50% (293.3 acres) while reducing forested lands by an equal amount. Similarly in Scenario 9a, we converted 200 acres of forest into cropland. The following general conclusions can be drawn from the various modeling scenarios:

- Large changes in land use, whether forest to urban or forest to cropland, would be expected to result in large increases in in-lake phosphorus levels in Lovewell Pond. These increases could be large enough to significantly reduce water quality, approaching eutrophic conditions in some extreme cases.
- Modest land use changes, comparable to those which could reasonably be expected to occur in the near foreseeable future, would be expected to produce similarly modest increases in in-lake phosphorus concentrations in Lovewell Pond. Increases on the order of 2-3% or 0.2 – 0.3 µg/l could be reasonably expected.

In the short-term, modest increases in total phosphorus concentrations of the magnitude presented here would be of no great concern, but in the longer term, continuing urbanization of the watershed could lead to very significant declines in Lovewell Pond water quality.

Scenarios 10a-c present the estimated impact of groundwater withdrawal from the Wards Brook aquifer on Lovewell Pond total phosphorus concentrations. Because phosphorus concentrations in Wards Brook and the Wards Brook aquifer were not known, we sampled Wards Brook in

February 2008 above and below the groundwater withdrawal well and from the well itself to determine what phosphorus concentrations might be during non-runoff, baseflow conditions. Laboratory analysis found levels of 18 µg/l total phosphorus immediately below Rte. 113, 14 µg/l at the downstream old mill site and 17 µg/l in the well water. All phosphorus levels were within expected ranges, although we would not have been surprised to find lower levels in the well sample. To be conservative, we evaluated a range of groundwater withdrawal concentrations (10 – 17 µg/l, in Scenarios 10a-c, respectively). Results provided in Table 3 indicate that in-lake total phosphorus concentrations are inversely proportional to the total phosphorus concentration in the withdrawn groundwater and that under most scenarios, groundwater withdrawal actually improves water quality in Lovewell Pond by reducing in-lake total phosphorus concentrations. This potentially counterintuitive result occurs for two reasons: groundwater withdrawal results in reduced loading of both water and phosphorus to Lovewell Pond. According to the Vollenweider model, reduced water loading always results in reduced in-lake phosphorus concentrations, in theory due to increased loss of phosphorus to the sediments and therefore less remaining in the water column. Reduced phosphorus loading usually results in reduced in-lake phosphorus, unless the concentration in the withdrawn water is considerably less than in the average inflowing water. In Scenarios b and c, removal of 220 million gallons per year of water with phosphorus concentrations of 15 and 17 µg/l, respectively both are predicted to result in small reductions in in-lake phosphorus concentration. However, in Scenario a, removal of the same amount of water but with a concentration of 10 µg/l would be expected to result in a slight increase in in-lake total phosphorus concentration. Regardless of whether the expected impact is negative or positive, both are slight under any reasonable scenario of likely phosphorus concentration in the withdrawn water.

Conclusions

We delineated the watershed of Lovewell Pond and determined the various land uses within the watershed. By using the EPA-supported STEPL model, combined with the Vollenweider Input/Output Lake Model, we determined the expected in-lake concentration of total phosphorus that results from current land uses. By modifying the mix of land uses (generally forest to urban or forest to cropland), we were able to predict how total phosphorus concentrations in Lovewell Pond would be expected to change with changing land use. It was concluded that the potential near-term land use changes were not likely to result in major increases in total phosphorus in Lovewell Pond, but that continuing urbanization of the watershed in the long-term could result in significant increases in in-lake phosphorus and consequently significant declines in water quality.

The impact of groundwater withdrawal from the Wards Brook aquifer, in the volumes currently permitted, on total phosphorus concentrations in Lovewell Pond is expected to slight and negative (i.e., reduced phosphorus), resulting in a slight improvement in water quality.

Literature Cited

Tetra Tech, Inc. 2006. User's Guide Spreadsheet Tool for the Estimation of Pollutant Load (STEPL) Version 4.0, developed for U.S. Environmental Protection Agency. November 2006.

Vollenweider, R. A. 1976. Advances in defining critical loading levels of phosphorus in lake eutrophication. *Mem. Ist. Ital. Idrobiol.* 33:53-83.

Waite Environmental Management, Inc. 2007. Final Report. Lovewell Pond Summer 2006 Water Quality & Vegetation Study, Fryeburg, Maine. 9 pp.

Technical Appendix

STEPL MODEL INPUT

Weather

Parameters	Values – Normal Scenario	Values – S.A. #3
Weather Station	ME Portland International Jetport	NH Concord Municipal Airport
Rainfall Assumption	45.51 inches (115.6 cm)	45.51 inches (115.6 cm)
Rain Days	133.2 days	133.2 days
AverageRain/Event	0.696	0.715
Rain Correction Factors	0.890 and 0.437	0.858 and 0.410

Land Use

Parameters	Values –Normal Scenario	Values – S.A. #5	Values – S.A. # 6
Urban	586.6 acres (2.4 km ²)	Increase by 10% = 645.3 acres (0.24 km ²)	586.6 acres (2.4 km ²)
Cropland (not modeled for irrigation or BMP use)	36.9 acres (0.15 km ²)	36.9 acres (0.15 km ²)	Increase by 10% = 94.3 acres (0.382 km ²)
Pasture/Rangeland	90.6 acres (0.37 km ²)	90.6 acres (0.37 km ²)	36.9 acres (0.15 km ²)
Forest	3,716.1 acres (15 km ²)	3,716.1 acres – 58.7 acres = 3,657.4 acres (14.8 km ²)	3,716.1 acres – 3.7 acres = 3,712.4 acres (15.0 km ²)
Water (model does not use this category)	1,136.7 acres (4.6 km ²) [1,120 acres (4.5 km ²) from Lovewell Pond and 16.7 acres (0.068 km ²) from other waterbodies]	1,136.7 acres (4.6 km ²) [1,120 acres (4.5 km ²) from Lovewell Pond and 16.7 acres (0.068 km ²) from other waterbodies]	1,136.7 acres (4.6 km ²) [1,120 acres (4.5 km ²) from Lovewell Pond and 16.7 acres (0.068 km ²) from other waterbodies]
Total Watershed Area	5,566.9 acres (22.5 km ²)	5,566.9 acres (22.5 km ²)	5,566.9 acres (22.5 km ²)

Agricultural Animals and Septic Systems

Parameter	Values
Animals	None
Number of Months Manure Applied	None
Number of Septic Systems	None
Population per Septic System	2.43
Septic System Failure Rate %	2

Universal Soil Loss Equation Parameters (Based on the model's retrieval of Oxford County data)

Land Use Type	R	K	LS	C	P
Cropland	99.972	0.199	1.006	0.200	1.000
Pastureland	99.972	0.199	1.006	0.040	1.000
Forest	99.972	0.199	1.006	0.003	1.000

Urban Reference Curve Numbers for Soil Hydrologic Group B

Parameters	Values
Commercial	92
Industrial	88
Institutional	88
Transportation	98
Multi - Family	85
Single - Family	72
Urban - Cultivation	78
Vacant - Developed	85
Open Space	69

Soil Hydrologic Group B

Parameters	Values
Group B – P Soil Concentration %	0.031
Group B – Runoff Curve # Urban	89
Group B – Runoff Curve # Cropland	78
Group B – Runoff Curve # Pastureland	69
Group B – Runoff Curve # Forest	60

Phosphorus Concentration in Runoff (mg/l)

Parameters	Values –Normal Scenario	Values – S.A. #1	Values – S.A. #2
L – Cropland (low livestock density <1,500 lb/acre live animal weight)	0.3	0.6	0.15
L – Cropland (low livestock density <1,500 lb/acre live animal weight) w/ manure	2	4	1
M – Cropland (medium livestock density >1,500 but <2,500 lb/acre live animal weight)	0.4	0.8	0.2
M– Cropland (medium livestock density >1,500 but <2,500 lb/acre live animal weight) w/ manure	3	6	1.5
H – Cropland (high livestock density >2,500 lb/acre live animal weight)	0.5	1	0.25
H – Cropland (high livestock density >2,500 lb/acre live animal weight) w/ manure	4	8	2
Pastureland	0.3	0.6	0.15
Forest	0.1	0.2	0.05

Urban Land Use Distribution (%) Total Acres = 586.6 (2.3 km²)

Parameters	Values –Normal Scenario	Values – S.A. #4
Commercial	15	15
Industrial	10	10
Institutional	10	5
Transportation	10	15
Multi - Family	10	5
Single - Family	30	25
Urban - Cultivation	5	10
Vacant - Developed	5	5
Open Space	5	10

Model Results for Phosphorus Loading in lbs/year - Including Sensitivity Analysis (S.A.)

Normal Scenario	S.A. #1: Double Phosphorus Concentration Runoff	S.A. #2: Half Phosphorus Concentration Runoff	S.A. #3: Use NH Weather Station	S.A. #4: Change Urban Land Use Distribution
1,237.2 lbs/year (561.2 kg/year) 6.853 µg/l	1,694.8 lbs/yr (768.8 kg/yr) 9.387 µg/l	1,008.3 lbs/yr (457.4 kg/yr) 5.585 µg/l	1,216.2 lb/year (551.7 kg/year) 6.736 µg/l	1,285.1 lb/year (582.9 kg/year) 7.118 µg/l

Normal Scenario	S.A. #5a: Increase Urban by 10% (58.7 acres) and Decrease Forest 58.7 acres	S.A. #5b: Increase Urban by 50 % (293.3 acres) and Decrease Forest by 293.3 acres	S.A. #5c: Increase Urban by 100 % (586.6 acres) and Decrease Forest by 586.6 acres
1,237.2 lbs/year (561.2 kg/year) 6.853 µg/l	1,297.5 lbs/year (588.5 kg/year) 7.186 µg/l	1,538.5 lbs/year (697.9 kg/year) 8.521 µg/l	1,939.9 lbs/year (834.5 kg/year) 10.744 µg/l

Normal Scenario	S.A. #6a: Increase Crop by 10% (3.7 acres) and Decrease Forest by 3.7 acres	S.A. #6b: Increase Crop by 50 % (18.5 acres) and Decrease Forest by 18.5 acres	S.A. #6c: Increase Crop by 100 % (36.9 acres) and Decrease Forest by 36.9 acres
1,237.2 lbs/year (561.2 kg/year) 6.853 µg/l	1,242.7 lbs/year (563.7 kg/year) 6.883 µg/l	1,264.7 lbs/year (573.7 kg/year) 7.005 µg/l	1,292.0 lbs/year ⁷ (586.0 kg/year) 7.156 µg/l

Normal Scenario	S.A. #7a: Decrease Forest by 10% (371.6 acres) and Increase Urban by 371.6 acres	S.A. #7b: Decrease Forest by 25% (929.0 acres) and Increase Urban by 929.0 acres
1,237.2 lbs/year (561.2 kg/year) 6.853 µg/l	1,619.0 lb/year (734.4 kg/year) 8.967 µg/l	2,191.7 lbs/year (994.1 kg/year) 12.139 µg/l

Normal Scenario	S.A. #8a: Decrease Forest by 10%(371.6 acres) and Increase Crop 371.6 acres	S.A. #8b: Decrease Forest by 25% (929.0 acres) and Increase Crop by 929.0 acres
1,237.2 lbs/year (561.2 kg/year) 6.853 µg/l	1,789.8 lbs/year (811.8 kg/year) 9.913 µg/l	2,618.8 lbs/year (1,187.9 kg/year) 14.505 µg/l

Normal Scenario	S.A. #9a: Increase Crop by 100 acres and Decrease Forest by 100 acres	S.A. #9b: Increase Crop by 200 acres and Decrease Forest by 200 acres
1,237.2 lbs/year (561.2 kg/year) 6.853 µg/l	1,385.9 lbs/year (628.6 kg/year) 7.676 µg/l	1,534.6 lbs/year (696.1 kg/year) 8.500 µg/l

MODEL SENSITIVITY ANALYSIS DETAILS

Sensitivity Analysis 1: The model was run using double the nutrient concentrations for runoff (mg/l) for phosphorus. The calculated phosphorus loading to Lovewell Pond was 1,694.8 lbs/yr (768.8 kg/yr).

This translates to an annual watershed loading (L_p) of 0.170 g/m²-yr.

The calculated in-lake phosphorus concentration was 9.387 µg/l.

Sensitivity Analysis 2: The model was run using half of the nutrient concentrations for runoff (mg/l) for phosphorus. The calculated phosphorus loading to Lovewell Pond was 1,008.3 lbs/yr (457.4 kg/yr).

This translates to an annual watershed loading (L_p) of 0.101 g/m²-yr.

The calculated in-lake phosphorus concentration was 5.585 µg/l.

Sensitivity Analysis 3: The model was run using NH Concord Municipal Airport weather station. The calculated phosphorus loading to Lovewell Pond was 1,216.2 lb/year (551.7 kg/year)

This translates to an annual watershed loading (L_p) of 0.122 g/m²-yr.

The calculated in-lake concentration was 6.736 µg/l.

Sensitivity Analysis 4: The model was run changing the distribution of the urban land use category by increasing transportation, urban, cultivated, and open space categories and decreasing multi-family, single-family and institutional categories. The calculated phosphorus loading to Lovewell Pond was 1,285.1 lb/year (582.9 kg/year).

This translates to an annual watershed loading (L_p) of 0.129 g/m²-yr.

The calculated in-lake phosphorus concentration was 7.118 µg/l.

Sensitivity Analysis 5a: The model was run increasing the values for urban by 10 % (58.7 acres or 0.24 km²) and subtracting that value from the forest category. The calculated phosphorus loading to Lovewell Pond was 1,297.5 lb/year (588.5 kg/year).

This translates to an annual watershed loading (L_p) of 0.130 g/m²-yr.

The calculated in-lake concentration was 7.186 µg/l.

Sensitivity Analysis 5b: The model was run increasing the values for urban by 50 % (293.3 acres or 1.19 km²) and subtracting that value from the forest category. The calculated phosphorus loading to Lovewell Pond was 1,538.5 lb/year (697.9 kg/year).

This translates to an annual watershed loading (L_p) of 0.154 g/m²-yr.

The calculated in-lake concentration 8.521 µg/l.

Sensitivity Analysis 5c: The model was run increasing the values for urban land use by 100 % (586.6 acres or 2.4 km²) and subtracting that value from the forest category. The calculated phosphorus loading to Lovewell Pond was 1,839.9 lb/year (834.6 kg/year).

This translates to an annual watershed loading (L_p) of 0.194 g/m²-yr.

The calculated in-lake concentration was calculated to be 10.744 µg/l.

Sensitivity Analysis 6a: The model was run increasing the values for crop by 10 % (3.7 acres or 0.015 km²) and subtracting that value from the forest category. The calculated phosphorus loading to Lovewell Pond was 1,242.7 lb/year (563.7 kg/year).

This translates to an annual watershed loading (L_p) of 0.124 g/m²-yr.

The calculated in-lake concentration was calculated to be 6.883 µg/l.

Sensitivity Analysis 6b: The model was run increasing the values for crop by 50 % (18.5 acres or 0.075 km²) and subtracting that value from the forest category. The calculated phosphorus loading to Lovewell Pond was 1,264.7 lb/year (573.7 kg/year).

This translates to an annual watershed loading (L_p) of 0.127 g/m²-yr.

The calculated in-lake concentration was calculated to be 7.005 µg/l.

Sensitivity Analysis 6c: The model was run increasing the values for crop by 100 % (36.9 acres or 0.15 km²) and subtracting that value from the forest category. The calculated phosphorus loading to Lovewell Pond was 1,292.0 lb/year (586.0 kg/year).

This translates to an annual watershed loading (L_p) of 0.129 g/m²-yr.

The calculated in-lake concentration was calculated to be 7.156 µg/l.

Sensitivity Analysis 7a: The model was run decreasing the values for forest by 10 % (371.6 acres or 1.5 km²) and adding that value to the urban category (63% change). The calculated phosphorus loading to Lovewell Pond was 1,619.0 lb/year (734.4 kg/year).

This translates to an annual watershed loading (L_p) of 0.162 g/m²-yr.

The calculated in-lake concentration was calculated to be 8.967 µg/l.

Sensitivity Analysis 7b: The model was run decreasing the values for forest by 25 % (929.0 acres or 3.8 km²) and adding that value to the urban category (158 % change). The calculated phosphorus loading to Lovewell Pond was 2,191.7 lb/year (994.1 kg/year).

This translates to an annual watershed loading (L_p) of 0.219 g/m²-yr.

The calculated in-lake concentration was calculated to be 12.139 µg/l.

Sensitivity Analysis 8a: The model was run decreasing the values for forest by 10 % (371.6 acres or 1.5 km²) and adding that value to the crop category. The calculated phosphorus loading to Lovewell Pond was 1,789.8 lb/year (811.8 kg/year).

This translates to an annual watershed loading (L_p) of 0.179 g/m²-yr.

The calculated in-lake concentration was calculated to be 9.913 µg/l.

Sensitivity Analysis 8b: The model was run decreasing the values for forest by 25 % (929.0 acres or 3.8 km²) and adding that value to the crop category. The calculated phosphorus loading to Lovewell Pond was 2,618.8 lb/year (1,187.9 kg/year).

This translates to an annual watershed loading (L_p) of 0.262 g/m²-yr.

The calculated in-lake concentration was calculated to be 14.505 µg/l.

Sensitivity Analysis 9a: The model was run increasing the values for the crop land use by 100 acres and subtracting that amount from the forest value. The calculated phosphorus loading to Lovewell Pond was 1,385.9 lb/year (628.6 kg/year).

This translates to an annual watershed loading (L_p) of 0.139 g/m²-yr.
The calculated in-lake concentration was calculated to be 7.676 µg/l.

Sensitivity Analysis 9b: The model was run increasing the values for the crop land use by 200 acres and subtracting that amount from the forest value. The calculated phosphorus loading to Lovewell Pond was 1,534.6 lb/year (696.1 kg/year).

This translates to an annual watershed loading (L_p) of 0.154 g/m²-yr.
The calculated in-lake concentration was calculated to be 8.500 µg/l.

Sensitivity Analysis 10a: The model was run for existing conditions but adding a groundwater withdrawal from the Ward Brook aquifer of 220 million gallons per year with a total phosphorus concentration of 10 µg/l. The calculated phosphorus loading to Lovewell Pond was 1,218.8 lb/year (552.8 kg/year).

This translates to an annual watershed loading (L_p) of 0.1220 g/m²-yr.
The calculated in-lake concentration was calculated to be 6.899 µg/l.

Sensitivity Analysis 10b: The model was run for existing conditions but adding a groundwater withdrawal from the Ward Brook aquifer of 220 million gallons per year with a total phosphorus concentration of 15 µg/l. The calculated phosphorus loading to Lovewell Pond was 1,209.7 lb/year (548.7 kg/year).

This translates to an annual watershed loading (L_p) of 0.1211 g/m²-yr.
The calculated in-lake concentration was calculated to be 6.714 µg/l.

Sensitivity Analysis 10c: The model was run for existing conditions but adding a groundwater withdrawal from the Ward Brook aquifer of 220 million gallons per year with a total phosphorus concentration of 17 µg/l. The calculated phosphorus loading to Lovewell Pond was 1,206.0 lb/year (547.0 kg/year).

This translates to an annual watershed loading (L_p) of 0.1207 g/m²-yr.
The calculated in-lake concentration was calculated to be 6.517 µg/l.