TECHNICAL | MEMORANDUM

TO: Pat Tarpey, Lake Winnipesaukee Association

FROM: Laura Diemer, FB Environmental Associates

SUBJECT: **LLRM Update – Moultonborough Bay Inlet Watershed**

DATE: May 10, 2016

CC: Forrest Bell, FB Environmental Associates; Don Kretchmer, DK Water Resource Consulting

The purpose of this memo is to provide final results from the Lake Loading Response Model (LLRM) developed for the Moultonborough Bay Inlet (MBI) watershed. The LLRM is an Excel-based model that uses environmental data to develop a water and phosphorus loading budget for lakes and their tributaries. Water and phosphorus loads (in the form of mass and concentration) are traced from various sources in the watershed through tributary basins and into the lake. The model requires detailed and accurate information about the waterbody, including the extent and number of sub-basins draining to the lake, the type and area of land uses within those sub-basins, water quality data for deep holes and tributary outlets, lake volumes, septic system loading estimates, etc.

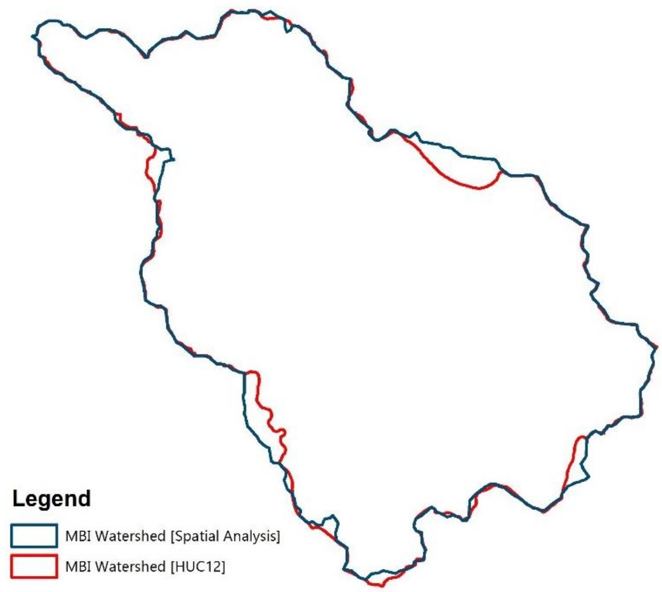
The following describes the process by which these critical inputs were determined and input to the LLRM using available resources and advanced GIS modeling, and also presents in-lake annual average predictions of chlorophyll-a, total phosphorus, and Secchi disk transparency. The final outcome of this model will be used to identify current and future pollution sources, estimate pollution limits and water quality goals, and guide watershed improvement projects.

Watershed and Sub-basin Delineations

Watershed and tributary drainage basin (sub-basin) boundaries are needed to calculate the amount of water flowing into the tributaries and lakes and determine what land uses contribute to nutrient loading. Revised watershed and sub-basin shapefiles for MBI were generated using advanced GIS modeling. The following sources were used to help create these files:

- Streams [nhd24kst_l_nh003.shp], Carroll County, GRANIT
- HUC12 Shannon Brook-Frontal Moultonborough Bay [wbdhu12_a_nh003.shp], Carroll County, GRANIT
- Digital Elevation Models (DEM) – Quads #98, 99, 85, 86, 87, GRANIT [Updated March 1999]
- LAS files, LiDAR from Town of Moultonborough Town Planner [Received Feb 2015]

The DEM images were combined into a single "mosaic" file, and the "seams" were averaged for consistency across the combined image edges. This new raster was input to a series of steps in GIS to generate a stream network (i.e., "flowacc") and sub-basins based on assigned "pour points." These pour points were selected and finalized by L. Diemer and D. Kretchmer on 2/20/2015 and are located at major tributary junctions, pond outlets, and at the outlet to the Moultonborough Bay Inlet. The sub-basins were dissolved into a single watershed shapefile. A comparison of the watershed boundary generated using GIS modeling (32,246 acres) and the watershed obtained from GRANIT's HUC12 (31,562 acres) is shown in Figure 1. The MBI watershed boundary generated from GIS modeling is larger than the HUC12 watershed boundary by 684 acres. The boundary analysis was re-run after gaining input from local stakeholders at a meeting in Moultonborough on 2/17/2015 and obtaining LiDAR data from the Town of Moultonborough. Unfortunately, the LiDAR data could not be used as direct input to the analysis, but was used to spot check areas, particularly the large wetland complex at the outlet to Halfway Brook.



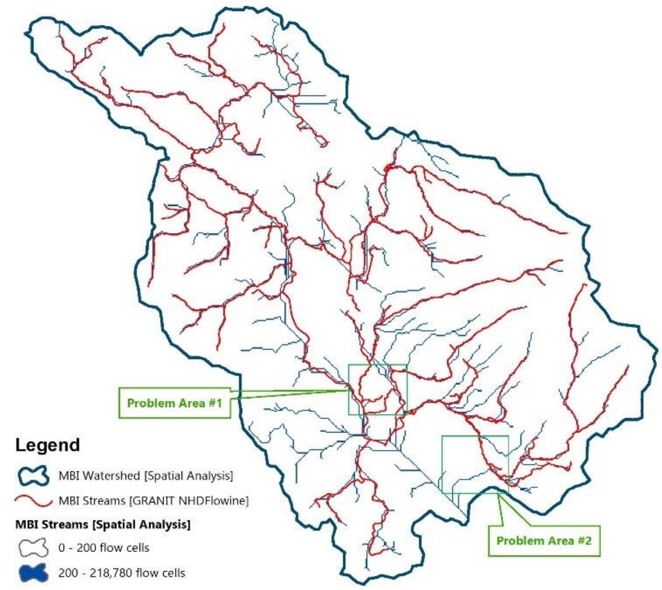


Figure 1. LEFT - Moultonborough Bay Inlet watershed boundary comparison between GRANIT's HUC12 watershed shapefile and the GIS modeling. The watershed boundary generated by GIS modeling is 32,246 acres and the watershed obtained from GRANIT's HUC 12 is 31,562 acres, a difference of 684 acres. **RIGHT** - Moultonborough Bay Inlet watershed stream network comparison between GRANIT and GIS modeling. Overall, the modeled stream network conformed well to the GRANIT NHDFlowline with two "problem area" exceptions that were corrected in the modeled sub-basin delineation output.

The stream network generated by GIS modeling also shows good conformity to the GRANIT NHDFlowline stream file with two "problem area" exceptions (Figure 1). GIS modeling rerouted water around a large wetland complex just south of the Red Hill Brook outlet to MBI. The sub-basins for Halfway Brook and part of Middle Brook were manually delineated to match GRANIT NHDFlowline and LiDAR elevation as best as possible. The second problem area concerned the Shannon Brook drainage. GIS modeling split the Shannon Brook drainage in two, rerouting Shannon Brook to outlet farther downstream along the MBI shoreline. The GRANIT NHDFlowline stream file shows Shannon Brook flowing north around a large residential development (Suissevale). The accuracy of GRANIT NHDFlowline was confirmed from local stakeholders, field observations, and a FEMA study delineating the entire length of Shannon Brook. However, the modeled downstream outlet to Shannon Brook exists and was confirmed in the field and by local residents to have continuous (though minor) flow all year round. As such, the main stem of Shannon Brook outlets upstream following the NHDFlowline, but a portion of the flow is diverted to this smaller tributary offshoot. The portion of this flow diversion from Shannon Brook is unknown at present and for purposes of the LLRM, the tributary was incorporated into the "Basin 3 Direct" sub-basin.

The sub-basin delineation is provided in Figure 2. After discussions with D. Kretchmer and review of available bathymetry data, it was determined that the best approach for modeling would be to split MBI into three distinct basins, with each upstream basin treated as a point source to the downstream modeled basin. For example, Basin 1 (Green's Basin) was modeled first and the resulting water and phosphorus loadings were input as a point source to Basin 2 (Blanchard's Island); similarly, the resulting water and phosphorus loadings from Basin 2 were input as a point source to Basin 3 (deep hole). Basin 3 was more complicated with multiple tributaries and ponds; a simplified schematic of water routing within Basin 3 is provided in Figure 3.

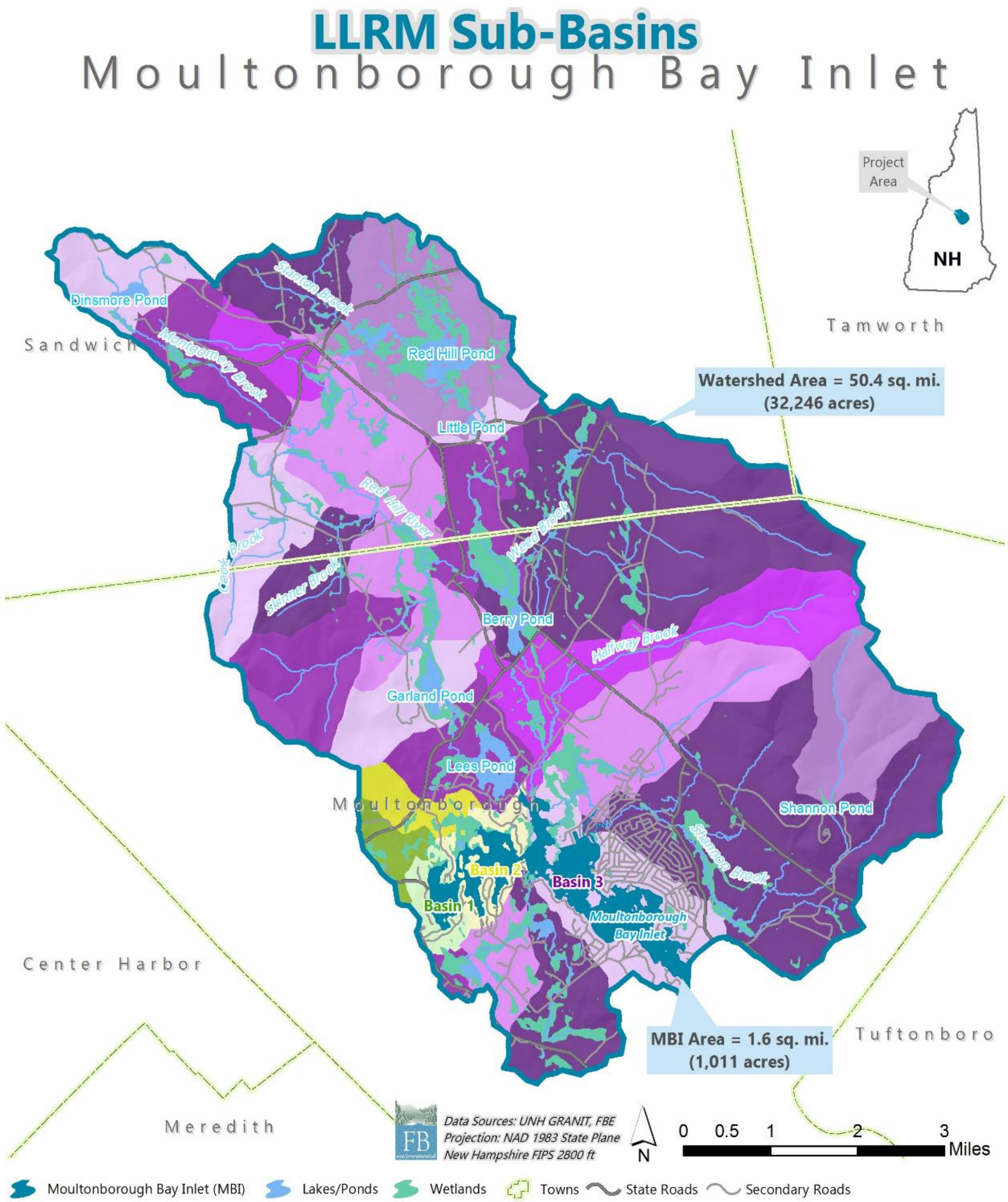


Figure 2. Moultonborough Bay Inlet watershed with all sub-basin delineations for major tributaries and pond outlets. Green indicates sub-basins draining to Basin 1; yellow indicates sub-basins draining to Basin 2; and purple indicates sub-basins draining to Basin 3.

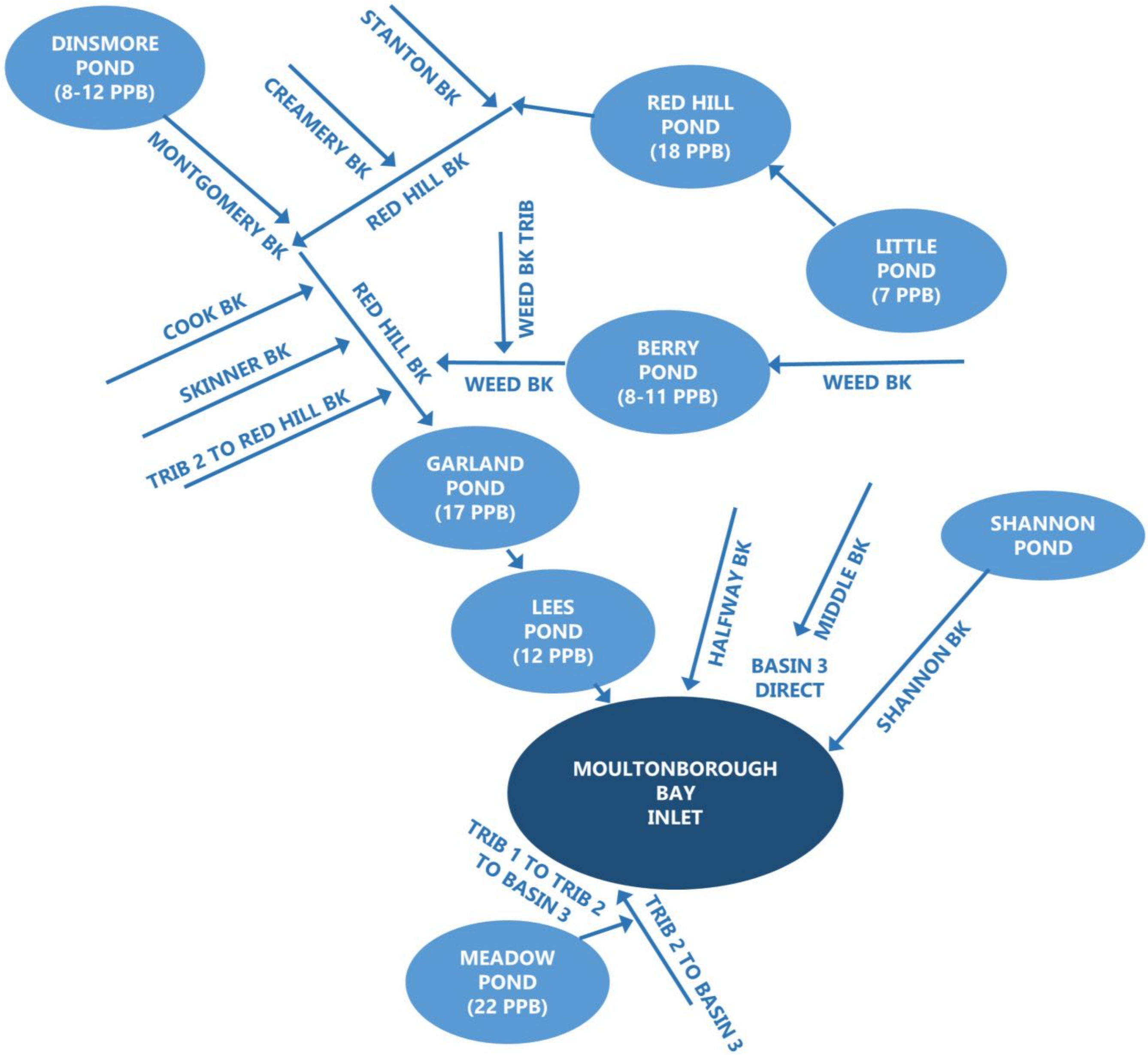


Figure 3. Schematic of water routing for Basin 3 sub-basins used to inform the LLRM. Total phosphorus concentrations for ponds are provided in parentheses, where available. (Note: There are few water quality data from many of the upstream ponds and some of these data are not current).

Land Use Update

Land use is the essential element in determining how much phosphorus is contributing to a lake via stormwater runoff. A significant amount of time went into reviewing and refining the land use data. UNH GRANIT's New Hampshire Land Cover Assessment 2001 [NHLC01] was used as a baseline for editing. First, the NHLC01 land use categories [grid codes] were plugged into similar LLRM land use categories (refer to Attachment 1). Next, rectangular grids (or quads) were made to break up the watershed into more manageable portions for review.

2009 NAIP aerials from GRANIT were uploaded and compared to 9/18/2013 Google Earth satellite images for major land use changes in each quad. If discrepancies between the aerials and the NHLC01 land use file were found, changes were made using the Topology tool for editing polygon vertices or the Editor tool for splitting polygons. Each new polygon was relabeled in the attribute table with the appropriate LLRM land use category. A few assumptions were made during this process:

- Any alterations to add in forested land cover was defaulted to "Forest 3: Mixed"
- Any agricultural fields that were clearly not pasture or row crops were defaulted to "Agric 4: Hayfield"; it was difficult to discern whether a field was hayfield or cover crop
- Any residential or commercial lawns, cemeteries, and athletic fields were labeled as "Urban 5: Mowed Fields"
- Any orchards, tree farms, or field crops were labeled as "Agric 2: Row Crop" first and then later refined into more specific categories: Other 2: Orchards and Other 3: Tree Farm
- Any shrubby areas that did not seem to be a result of a logging operation were labeled as "Open 2: Meadow"
- Any major bare soil areas that were not associated with new residential home construction were labeled as "Open 3: Excavation"
- Following stakeholder review, a new land cover category was generated for unpaved roads (Other 1) by overlaying the unpaved roads layer with the land use file; there were no conflicts with the Urban 3: Roads category as this only reflected paved roads in the watershed
- Urban 1 was updated using the existing buildings layer provided by K. Ryan for the buildout analysis, adding Urban 1 where buildings were concentrated, particularly along shorelines

The resulting updated land use file is a more accurate representation of current land use within the Moultonborough Bay Inlet watershed (refer to Figure 4 for zoomed-in examples of "before" and "after" modifications). The final land use is shown in Figures 5 and 6. The most significant changes to land use were the addition of grazing/pasture areas throughout the watershed and low density residential development around the inlet.

Agricultural land was checked carefully since modeling coefficients (i.e., phosphorus export) are generally higher for this land use type. Aerials were checked thoroughly for each major agricultural area to distinguish between hayfields, row crops, orchards, tree farms, and grazing/pasture areas. Refer to Attachment 2 for examples of how the agricultural categories were distinguished in this watershed.

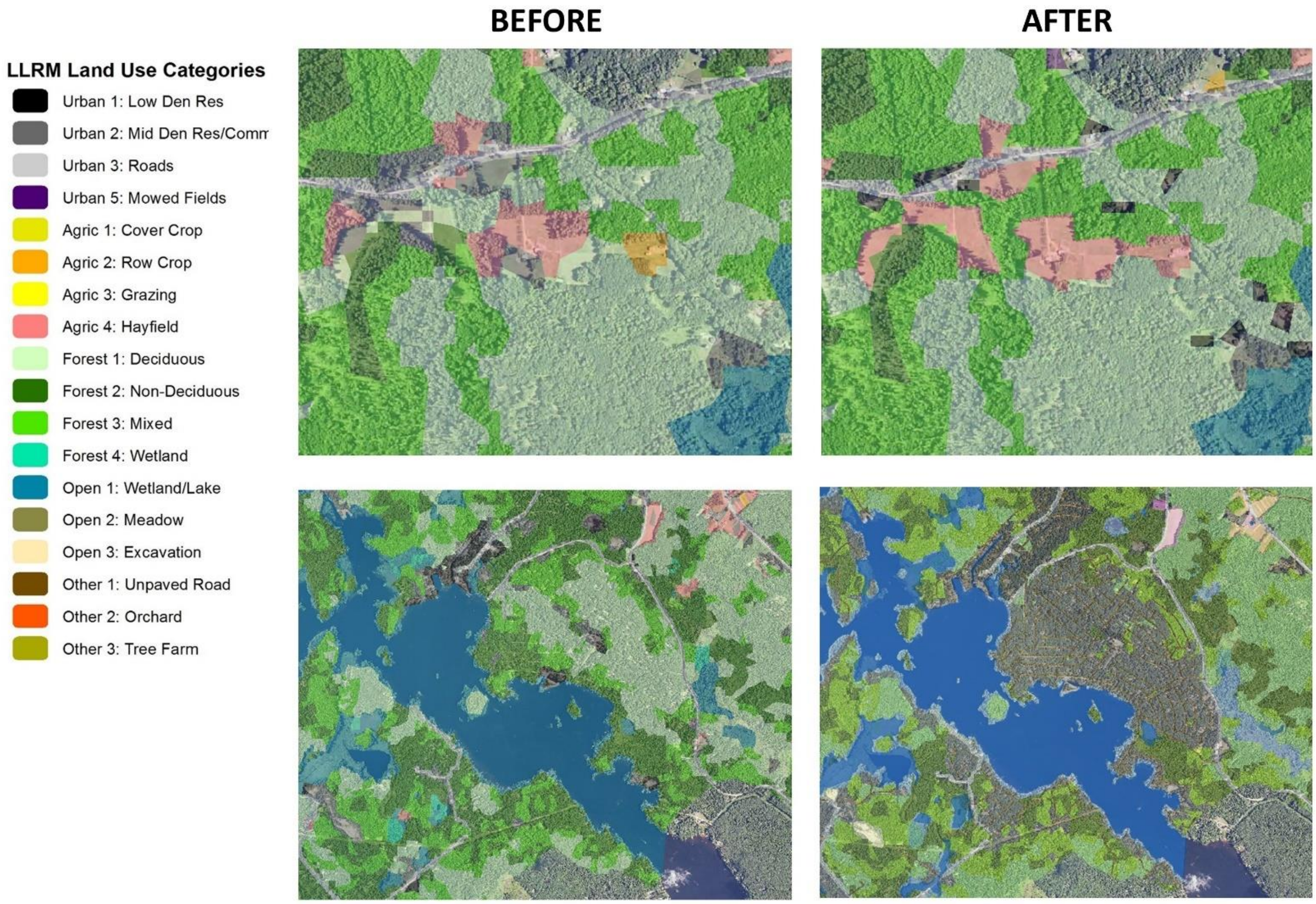


Figure 4. Examples of "before" and "after" land use file modifications for the Moultonborough Bay Inlet watershed for agricultural and residential areas.

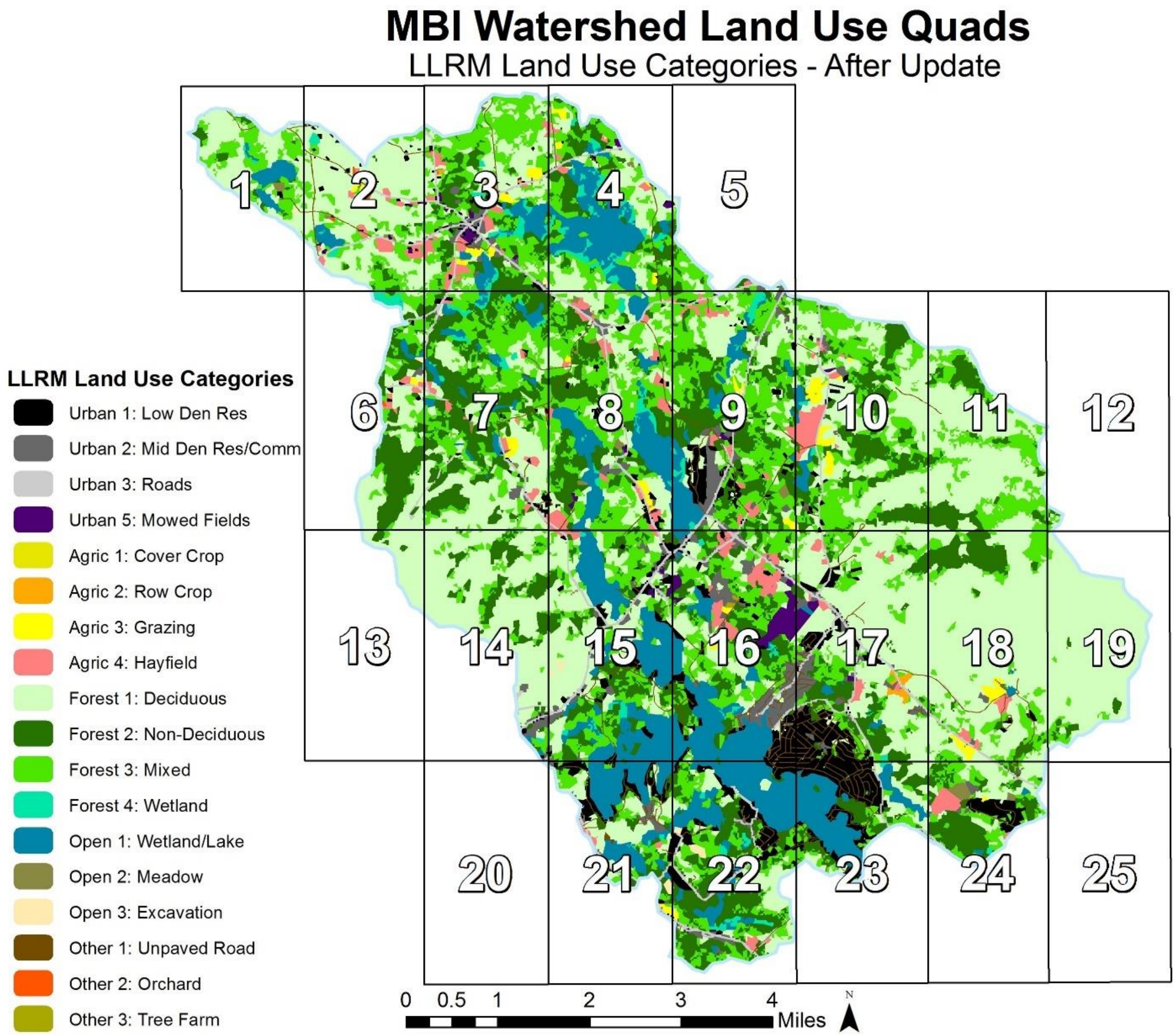


Figure 5. NH Land Cover Assessment 2001 (NHLC01) data with final LLRM land use categories. Notable differences include Urban 1 category additions around shorelines, overlay of a new Other 1: Unpaved Roads category, and refinement of Agric 2 category into Other 2: Orchard and Other 3: Tree Farm. Quads 1-25 split the watershed into manageable sections for review. Note: includes updated watershed boundary after stakeholder review and remodeling.

Within the LLRM, an export coefficient is assigned to each land use to represent typical concentrations of phosphorus in runoff from those land use types. Unmanaged forested land, for example, tends to deliver very little phosphorus downstream when it rains, while row crops and high density urban land export significantly more phosphorus due to fertilizer use, soil erosion, car and factory exhaust, pet waste, and many other sources. Smaller amounts of phosphorus are also exported to lakes and streams during dry weather under base flow conditions. Table 1 presents the export coefficients for each land use category used in the model, along with the total land use area by category for Basins 1, 2, and 3 as hectares (ha) and percentage of total. One hectare is equivalent to 2.5 acres. These coefficients were based on updated values from Lake Waukewan/Winona LLRM, which used data from P. Tarpey's 2013 thesis, among a number of other sources. Figure 7 shows a basic breakdown of land use by major category for the entire watershed as well as TP load by land use type.

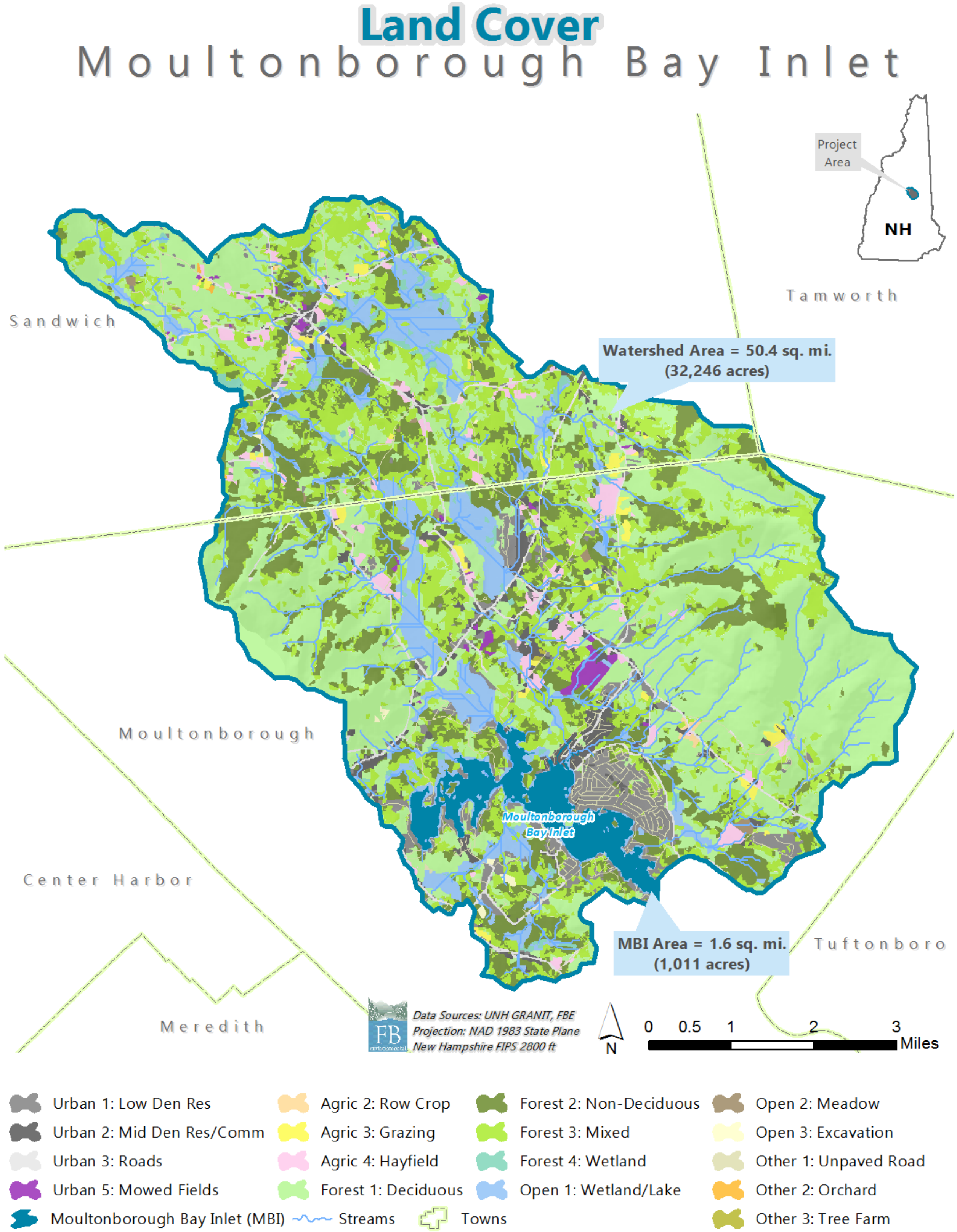


Figure 6. Land cover in the Moultonborough Bay Inlet watershed.

Table 1. Land use phosphorus export coefficients and land use areas for drainages to Basins 1, 2, and 3.

LAND USE	Runoff P export coefficient used	Baseflow P export coefficient used	Area (hectares)									
			BASIN 1		BASIN 2		BASIN 3					
			Basin 1 Direct	Trib to Basin 1	Basin 2 Direct	Trib to Basin 2	Basin 3 Direct	Cook Brook	Dinsmore Pond	Direct Red Hill Brook Drainage	Halfway Brook	Lees Pond
Urban 1 (Low Density Residential)	0.79	0.010	22.0	4.6	19.9	3.0	153.2	2.5	4.5	12.7	19.8	25.2
Urban 2 (Mid Density Residential/Commercial)	0.90	0.010	1.9	15.6	3.1	6.0	11.2	1.7	0.7	14.3	43.6	6.6
Urban 3 (Roads)	1.05	0.010	1.9	6.9		4.0	8.4	8.3		23.7	20.3	13.8
Urban 4 (Industrial)	1.10	0.010										
Urban 5 (Mowed Fields)	0.60	0.010								2.5	7.1	1.7
Agric 1 (Cvr Crop)	0.60	0.010										
Agric 2 (Row Crop)	1.23	0.010										
Agric 3 (Grazing)	0.80	0.010					1.0	2.5		13.7	5.3	
Agric 4 (Hayfield)	0.50	0.010	2.7	0.1				12.3		25.1	37.8	
Forest 1 (Deciduous)	0.03	0.004	30.1	34.1	19.9	78.8	51.1	112.0	161.5	196.9	308.3	117.2
Forest 2 (NonDeciduous)	0.03	0.004	9.1	15.4	22.3	28.6	72.9	191.7	15.9	235.8	121.8	29.4
Forest 3 (Mixed)	0.03	0.004	21.9	28.7	22.4	18.6	69.7	68.6	75.6	312.7	202.3	55.4
Forest 4 (Wetland)	0.03	0.004	0.7	2.9	0.0	4.8	1.5	1.3	4.5	21.8	1.1	
Open 1 (Wetland/Lake)	0.03	0.004	13.2	11.0	32.2	9.4	47.5	16.4	31.0	93.6	14.9	96.9
Open 2 (Meadow)	0.20	0.004							2.7	4.3		
Open 3 (Excavation)	0.80	0.010				2.9		0.9		1.8		0.5
Other 1: Unpaved Road	0.83	0.010	6.2	0.3	8.2	1.4	37.7		4.4	7.8	3.9	7.7
Other 2: Orchard	0.30	0.010						0.5				
Other 3: Tree Farm	0.14	0.004									2.1	
		TOTAL	**109.7**	**119.7**	**128.1**	**157.3**			**454.2**	**418.7**	**300.7**	**966.7**

Table 1 (CONTINUED). Land use phosphorus export coefficients and land use areas for drainages to Basins 1, 2, and 3.

LAND USE	Runoff P export coefficient used	Baseflow P export coefficient used	Area (hectares)									
			BASIN 3									
			Little Pond	Middle Brook	Montgomery Brook	Red Hill Pond	Shannon Brook	Shannon Pond	Skinner Brook	Stanton Brook	Creamery Brook	Trib 2 to Basin 3
Urban 1 (Low Density Residential)	0.79	0.010	1.0	30.4	4.2	3.8	92.1		1.7	5.0	5.9	11.0
Urban 2 (Mid Density Residential/Commercial)	0.90	0.010	1.0	30.0	0.5	5.8	47.7	0.7	0.0	4.6	5.6	9.1
Urban 3 (Roads)	1.05	0.010	4.5	18.2	8.4	11.4	38.7		5.4	9.1	12.6	18.4
Urban 4 (Industrial)	1.10	0.010										
Urban 5 (Mowed Fields)	0.60	0.010	0.0	41.0	2.3	4.4	1.0			1.6	4.8	
Agric 1 (Cvr Crop)	0.60	0.010										
Agric 2 (Row Crop)	1.23	0.010				0.4	9.2			0.8		
Agric 3 (Grazing)	0.80	0.010	1.0	1.7	3.8	14.0	17.1	1.6	0.1	0.9	3.4	0.5
Agric 4 (Hayfield)	0.50	0.010	2.4	19.8	16.5	19.1	33.4		1.6	8.3	23.3	4.6
Forest 1 (Deciduous)	0.03	0.004	12.4	274.2	193.2	207.7	970.6	419.1	88.1	136.7	75.2	66.1
Forest 2 (NonDeciduous)	0.03	0.004	10.7	114.8	17.6	117.0	211.4	18.7	102.1	44.3	14.7	148.9
Forest 3 (Mixed)	0.03	0.004	24.8	124.5	86.9	261.4	207.5	37.9	54.5	104.6	39.6	110.5
Forest 4 (Wetland)	0.03	0.004		2.9	12.7	61.7	4.1		0.4	3.4		13.4
Open 1 (Wetland/Lake)	0.03	0.004	9.3	12.3	12.7	191.7	29.5	2.0	11.1	1.7	2.9	53.5
Open 2 (Meadow)	0.20	0.004			0.9	2.2	10.0		1.0		1.0	
Open 3 (Excavation)	0.80	0.010			0.7	0.5						0.1
Other 1: Unpaved Road	0.83	0.010	0.9	9.5	6.1	5.6	33.2	0.3	1.2	4.2	0.6	4.8
Other 2: Orchard	0.30	0.010			2.0					0.2	0.9	
Other 3: Tree Farm	0.14	0.004										
		TOTAL	**67.8**	**679.3**	**368.5**	**906.6**	**1705.5**	**480.4**	**267.1**	**325.3**	**190.2**	**441.0**

Table 1 (CONTINUED). Land use phosphorus export coefficients and land use areas for drainages to Basins 1, 2, and 3.

LAND USE	Runoff P export coefficient used	Baseflow P export coefficient used	Area (hectares)					
			BASIN 3					
			Trib 2 to Red Hill Brook	Meadow Pond	Weed Brook/Berry Pond	Weed Brook/Trib	Garland Pond	Trib 1 to Trib 2 to Basin 3
Urban 1 (Low Density Residential)	0.79	0.010	5.4	1.4	51.6	8.9	4.9	19.9
Urban 2 (Mid Density Residential/Commercial)	0.90	0.010	4.7	0.6	54.7	6.8	0.6	6.7
Urban 3 (Roads)	1.05	0.010	4.3	4.6	39.1	13.8	6.3	8.6
Urban 4 (Industrial)	1.10	0.010						
Urban 5 (Mowed Fields)	0.60	0.010	0.6		2.7	0.7	0.0	
Agric 1 (Cvr Crop)	0.60	0.010						
Agric 2 (Row Crop)	1.23	0.010			0.2			
Agric 3 (Grazing)	0.80	0.010			31.1	0.1		3.5
Agric 4 (Hayfield)	0.50	0.010	8.3	0.6	57.4	13.6	3.3	1.1
Forest 1 (Deciduous)	0.03	0.004	345.7	13.1	610.8	83.4	156.5	36.4
Forest 2 (NonDeciduous)	0.03	0.004	68.7	4.9	387.2	58.0	56.1	41.4
Forest 3 (Mixed)	0.03	0.004	47.7	4.6	530.7	126.4	70.1	36.8
Forest 4 (Wetland)	0.03	0.004		0.2	15.0	11.9	0.7	1.6
Open 1 (Wetland/Lake)	0.03	0.004		16.9	99.8	69.0	54.9	33.7
Open 2 (Meadow)	0.20	0.004	0.1		3.1	2.4	0.4	
Open 3 (Excavation)	0.80	0.010			0.5	0.5		8.6
Other 1: Unpaved Road	0.83	0.010	0.7	1.6	14.9	3.2	0.7	3.8
Other 2: Orchard	0.30	0.010						
Other 3: Tree Farm	0.14	0.004						
		TOTAL	**486.1**	**48.5**	**1898.8**	**398.4**	**354.6**	**202.1**

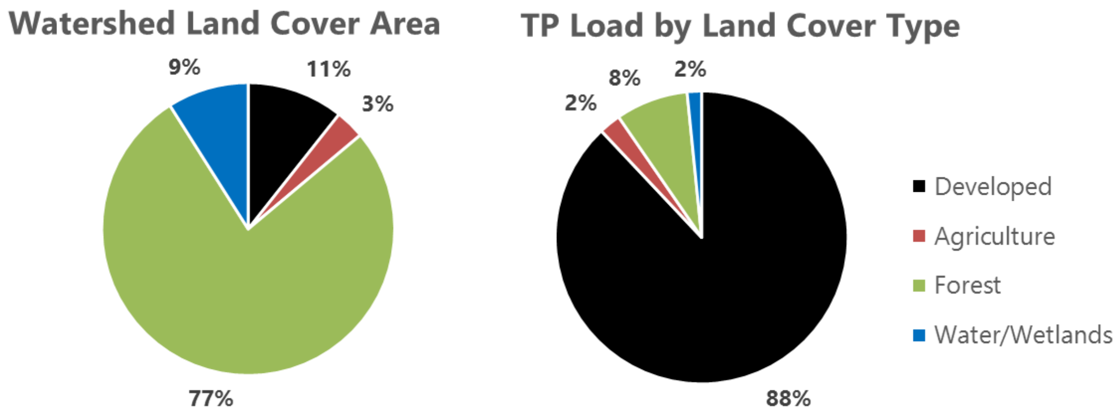


Figure 7. Watershed land cover area by general category (developed, agriculture, forest, and water/wetlands) and total phosphorus (TP) load by general land cover type. This shows that although developed areas cover only 11% of the watershed, these areas are contributing 88% of the TP load to Moultonborough Bay Inlet.

Other Major LLRM Inputs

The following presents a brief outline of other variable sources and assumptions input to the models:

- Annual precipitation data were obtained from NOAA National Climatic Data Center (NCDC) 30-year climate normals (1981-2010) for Meredith 3 NNE, NH, US. Recorded at 46.62 inches. A more local weather station for the Shannon Brook area did not have a long enough record for use in the model.
- Lake area was based on a clip from GRANIT NHDWaterbody shapefile and further delineated into three major basins (Basins 1, 2, and 3). Refer to Figure 2.
- Lake volume was based on GRANIT bathymetry shapefile, which was further modified based on 2001 NHDES Trophic Report for Moultonborough Bay (sent by Andy Chapman, NHDES, on 1/29/2015). The resulting shapefile is still very coarse; more accurate data should be obtained in the future to further inform the model.
- Septic system data were estimated using a variety of sources and assumptions, including P. Tarpey's 2013 thesis, 2010 US Census data for New Hampshire, MBI preliminary buildout analysis results, ArcGIS area calculations, and Lake Waukewan/Winona septic survey results. Model only takes into account septic systems within 250 feet of a waterbody (i.e., streams, ponds, lakes, wetlands).
- Water quality data were obtained from P. Tarpey (assimilative capacity analysis). Basin 1 model calibrated to WMO00GL data; Basin 2 model calibrated to WMO01BL data; and Basin 3 calibrated to the median of WMO10AL, WMO01LL, WMO0SSL, WMOLEML, and WMOSTLL data.
- Assumed roughly 0.3 waterfowl per hectare of lake area (Basin 1 = 15; Basin 2 = 30; Basin 3 = 90) are contributing to the phosphorus load to each basin for half the year. Waterfowl can be a direct source of nutrients to lakes, however, if they are eating from the lake, and their waste returns to the lake, the net change may be less than might otherwise be assumed; however, the phosphorus excreted may be in a form that can readily be used by algae.
- Limited dissolved oxygen and water temperature profiles were available for any stations within the Inlet. Therefore, we estimated internal loading based on a mass balance equation that accounts for the difference in phosphorus

concentration before and after fall turnover. The equation is as follows, with "Pre-Turnover Hypolimnion TP" being the unknown variable to solve for:

[Pre-turnover Hypolimnion TP] x [Hypolimnion + Metalimnion Lake Volume] + [Pre-turnover Epilimnion TP] x [Epilimnion Lake Volume] = [Post-turnover Epilimnion TP] x [Total Lake Volume]

These estimates could only be calculated for Basins 1 and 3, which had adequate data for input to the equation. More data are needed for Basin 2; for now, internal loading is assumed zero for Basin 2. Assumptions were made for lake volume; more accurate estimates can be derived with higher resolution bathymetry.

Calibration

Calibration is the process by which model results are brought into agreement with observed data, and is an essential part of environmental modeling. Usually, calibration focuses on the input data with the greatest uncertainty. Changes are made within a plausible range of values, and an effort is made to find a realistic explanation among environmental conditions for these changes. In the case of the MBI LLRM models, the in-stream and in-lake phosphorus concentrations were used as guideposts, and phosphorus attenuation factors both in the tributary drainages and in the overall model, were adjusted to better match the monitoring data. Future monitoring can be designed to reduce the uncertainty encountered in modeling, and help assess the changes made during calibration, if it is deemed worthwhile.

Land cover is a big consideration for modifying basin attenuation factors. For instance, the major wetland complex at the outlet to Halfway, Middle, and Shannon Brooks was considered in basin attenuation because the wetland will attenuate phosphorus. **Great uncertainty surrounds outputs for all subdrainages upstream of Lees Pond since limited data are available for those tributaries and ponds. As such, model outputs for the upper watershed should be interpreted with caution until better data are collected. The model was calibrated to Lees Pond, since a more robust dataset was available.** Lees Pond is the downstream catchment for many of the upstream ponds and streams (Figure 3), so while overall loading to the Inlet from the Lees Pond watershed is likely well simulated, allocation of that load among upstream ponds and streams may not be.

Limitations to the Model

- Minimal data are available for most tributaries and ponds entering the Inlet. More data are needed to effectively calibrate the model to known observations. Until then, we have to make large assumptions based on land use or other contributing factors. Model outputs for subdrainages in the upper watershed (that feed into Lees Pond) should be interpreted with caution until better data are collected.
- Assessment currently assumes no internal loading for Basin 2 and internal loading estimates for Basin 1 and 3 are based on limited data. Phosphorus that enters the inlet and settles to the bottom can be re-released from sediment under anoxic conditions, providing a food source for algae and other plants. Internal phosphorus loading can also result from physical disturbance of the sediment, such as dredging, dragging of anchors or fishing gear, or heavy boat traffic. Dissolved oxygen and water temperature profiles should be collected with greater frequency in each of the three basins, along with hypolimnion TP samples and epilimnion TP samples before and after fall turnover.
- Bathymetry based on coarse contour resolution. A more accurate estimation of lake volume for each basin may be needed in the future. Lake volume is an important modeling component, because it indicates the level of dilution of incoming phosphorus, which in turn helps calculate final in-lake phosphorus contributions. It also contributes to calculation of the lake's flushing rate and internal loading.
- Data associated with point sources was limited or non-existent. Two potential point sources were noted by stakeholders, including a septic lagoon near Lees Pond and a capped dump. Without data, these point sources

cannot be included in the model, but should be included in the future if they are determined to be significant sources of TP once data become available.

- Waterfowl counts are based on estimates. In the future, a more precise bird census would help improve the model.
- Basin 2 (Blanchard's Island) data minimal. Unable to calibrate the model without more observed data.
- No data are available for existing buildings in Sandwich. Existing and future buildings in the Town of Sandwich were estimated based on the percent of the town in the MBI watershed. Better estimates should be derived and a buildout analysis of the entire MBI watershed should be completed.

Table 2. Basin attenuation factors for Basins 1, 2, and 3 drainages, along with a brief account for the assigned factor.

Basin	Sub-drainage to Basin	Water Attenuation Factor	P Attenuation Factor	Reasoning
Basin 1	Basin 1 Direct	0.90	0.90	Standard factor: direct drainage so little attenuation.
	Trib to Basin 1	0.85	0.85	Standard factor: some attenuation from tributary drainage.
Basin 2	Basin 2 Direct	0.90	0.85	Standard factor: direct drainage so little attenuation.
	Trib to Basin 2	0.85	0.80	Standard factor: some attenuation from tributary drainage. Residential houses further back, more wetlands, basin not as deep, so assumed more TP attenuation compared to Basin 1.
Basin 3	Basin 3 Direct	0.90	0.75	Standard factor: direct drainage so little attenuation; particularly since much of the contributing land use is near the outlet to MBI (model assumes well-mixed basin with all direct drainage inputs mixing with entire basin, but this isn't true, so need to account for part of that). Phosphorus inputs near the downstream end of Basin 3 are still important for Lake Winnipesaukee as a whole, but somewhat less important for Basin 3.
	Cook Brook	0.90	0.85	Standard factor: some attenuation from tributary drainage.
	Dinsmore Pond	0.90	1.00	Standard factor: pond output so little attenuation.
	Direct Red Hill Brook Drainage	0.90	0.85	Standard factor: some attenuation from tributary drainage.
	Halfway Brook	0.90	0.60	Standard factor: attenuation from wetland complex.
	Lees Pond	1.00	1.00	Collects all loading from upper watershed; calibrated model to this; very short distance from this to the outlet.
	Little Pond	0.90	0.50	Standard factor: greater attenuation to match limited data (but roads may be factor to high TP). More data needed.
	Middle Brook	0.90	0.60	Standard factor: attenuation from wetland complex.
	Montgomery Brook	0.90	0.50	Standard factor: attenuation from wetland complex.
	Red Hill Pond	0.90	0.85	Standard factor: some attenuation from tributary drainage.
	Shannon Brook	0.90	0.60	Standard factor: attenuation from wetland complex.
	Shannon Pond	0.90	1.00	Standard factor: pond output so little attenuation.
	Skinner Brook	0.90	0.85	Standard factor: some attenuation from tributary drainage.
	Stanton Brook	0.90	0.50	Standard factor: greater attenuation to match limited data (but roads may be factor to high TP). More data needed.
	Creamery Brook	0.90	0.60	Standard factor: some attenuation from tributary drainage; agricultural fields/dairy production; adjusted attenuation so modeled TP is only twice that of reality check.
	Trib 2 to Basin 3	0.90	0.70	Standard factor: attenuation from wetland complex, low-lying area.
	Trib 2 to Red Hill Brook	0.90	1.00	Standard factor: pond output so little attenuation.
	Meadow Pond	0.90	0.70	Standard factor: attenuation from wetland complex, low-lying area.
	Weed Brook/Berry Pond	0.90	0.50	Standard factor: attenuation from wetland complex.
	Weed Brook/Trib	0.90	0.85	Standard factor: some attenuation from tributary drainage.
	Garland Pond	1.00	1.00	Short distance from outlet to Lees Pond.
	Trib 1 to Trib 2 to Basin 3	0.90	0.70	Standard factor: attenuation from wetland complex, low-lying area.

Results

Watershed loads are broken down by subdrainage for Basins 1, 2, and 3 in Table 3 and Figure 8. Tributaries with larger drainage areas will naturally have higher stream flow and will contribute more phosphorus than smaller tributaries. Therefore, it is best to review TP concentration for each subdrainage than the mass of exported phosphorus. Basin 3 Direct had the highest TP concentration exported to MBI at 0.05 mg/L. Basin 1 Direct and Basin 3 Direct had the highest TP loading per area (kg/ha/yr; Figure 8). This is expected given the development around the shorelines. Watershed runoff was the largest loading contribution for all three basins (Table 4; Figure 9). Septic systems account for less than 10%. Interestingly, the load from Basin 2 to Basin 3 accounts for only 3% of the total load. This suggests that the higher TP concentrations observed at Green's Basin, while important locally, may not have a large impact further downstream.

Table 3. Summary of total phosphorus (TP) loading by subdrainage for Basins 1, 2, and 3.

		Watershed Loads				
Basin	Sub-drainage to Basin	Land Area (ha)	Water Flow (m3/year)	P Concentration (mg/L)	P Mass (kg/year) Cumulative	P Mass (kg/year) Not Cumulative
Basin 1	Basin 1 Direct	110	666,450	0.04	27	27
	Trib to Basin 1	120	708,173	0.03	24	24
	TOTAL	**229**	**1,374,623**	**0.04**	**52**	
Basin 2	Basin 2 Direct	128	760,660	0.03	25	25
	Trib to Basin 2	157	938,114	0.02	16	16
	TOTAL	**285**	**1,698,773**	**0.02**	**41**	
Basin 3	Basin 3 Direct	454	2,765,095	0.05	137	137
	Cook Brook	419	2,626,955	0.01	30	30
	Dinsmore Pond	301	1,859,792	0.01	18	18
	Direct Red Hill Brook Drainage	967	36,014,254	0.01	419	95
	Halfway Brook	788	4,963,483	0.02	78	78
	Lees Pond	354	40,762,955	0.01	502	59
	Little Pond	68	416,363	0.01	6	6
	Middle Brook	679	4,287,256	0.02	80	80
	Montgomery Brook	369	3,963,320	0.01	31	22
	Red Hill Pond	907	5,729,461	0.01	72	67
	Shannon Brook	1705	13,527,746	0.01	195	168
	Shannon Pond	480	3,058,261	0.01	45	45
	Skinner Brook	267	1,683,773	0.01	15	15
	Stanton Brook	325	2,058,442	0.01	19	19
	Creamery Brook	190	1,177,122	0.02	28	28
	Trib 2 to Basin 3	441	4,068,517	0.02	67	40
	Trib 2 to Red Hill Brook	486	3,086,526	0.01	34	34
	Meadow Pond	48	283,462	0.02	7	7
	Weed Brook/Berry Pond	1899	11,856,425	0.01	129	129
	Weed Brook/Trib	398	13,068,505	0.01	153	43
	Garland Pond	355	38,421,900	0.01	444	25
	Trib 1 to Trib 2 to Basin 3	202	1,511,720	0.03	40	35
	TOTAL	**12,103**	**70,375,053**	**0.01**	**1,097**	

Basin 3 loads are not summed due to water routing through certain basins; refer to model

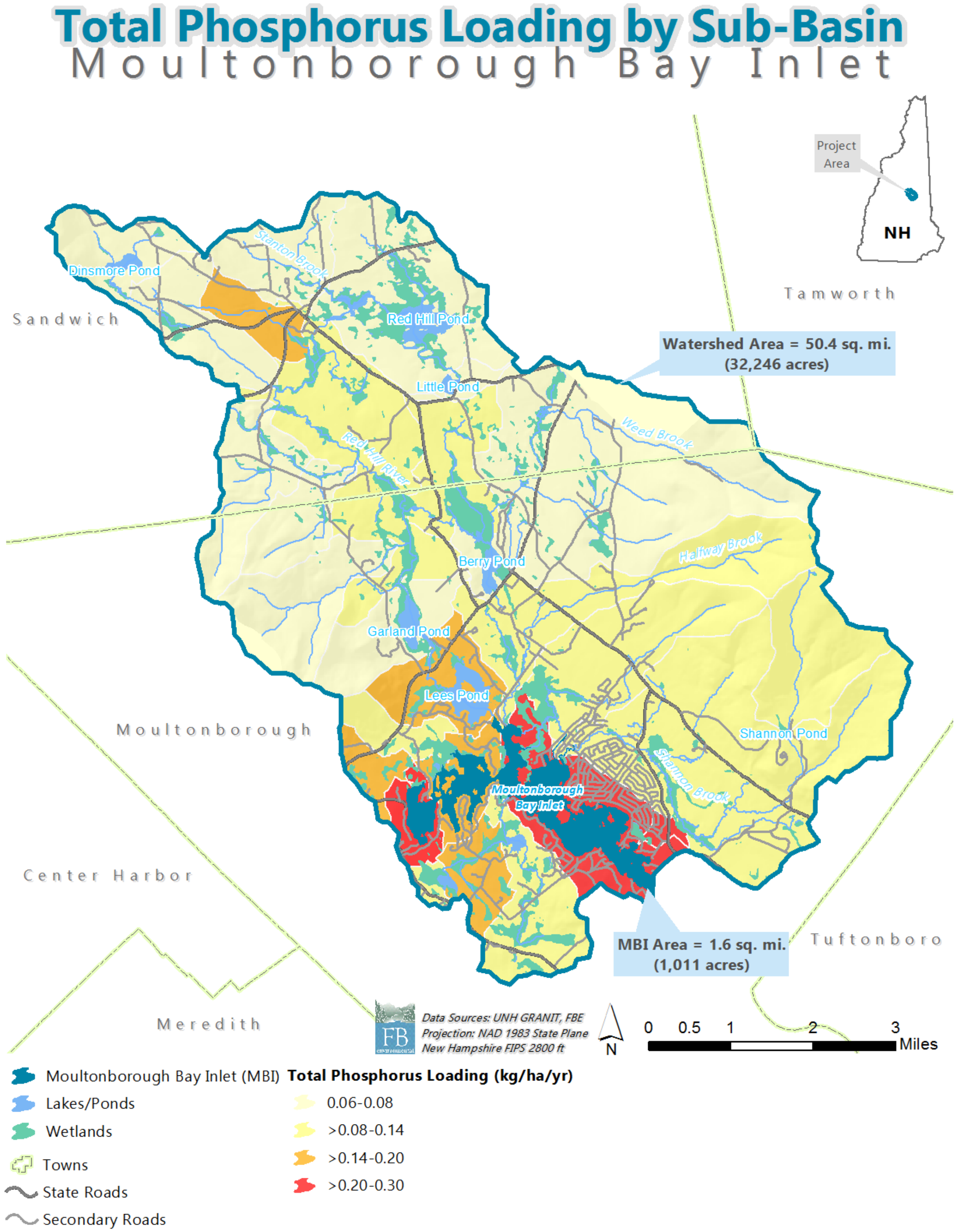


Figure 8. Total phosphorus loading by sub-basin in the Moultonborough Bay Inlet watershed.

Table 4. Moultonborough Bay Inlet total phosphorus (TP) and water loading summary.

INPUT CATEGORY	BASIN 1			BASIN 2			BASIN 3		
	P (KG/YR)	%	WATER (CU.M/YR)	P (KG/YR)	%	WATER (CU.M/YR)	P (KG/YR)	%	WATER (CU.M/YR)
ATMOSPHERIC	5	8%	295,995	9	11%	558,205	31	3%	1,868,572
INTERNAL	1	2%	0	0	0%	0	18	2%	0
WATERFOWL	2	2%	0	3	3%	0	9	1%	0
SEPTIC SYSTEM	3	5%	2,505	8	9%	6,545	47	4%	39,441
WATERSHED LOAD	52	83%	1,374,623	41	47%	1,698,773	1,060	88%	70,375,053
LOAD FROM BASIN 1				25	29%	1,673,123			
LOAD FROM BASIN 2							37	3%	3,936,647
TOTAL LOAD TO LAKE	**62**	**100%**	**1,673,123**	**86**	**100%**	**3,936,647**	**1,202**	**100%**	**76,219,714**

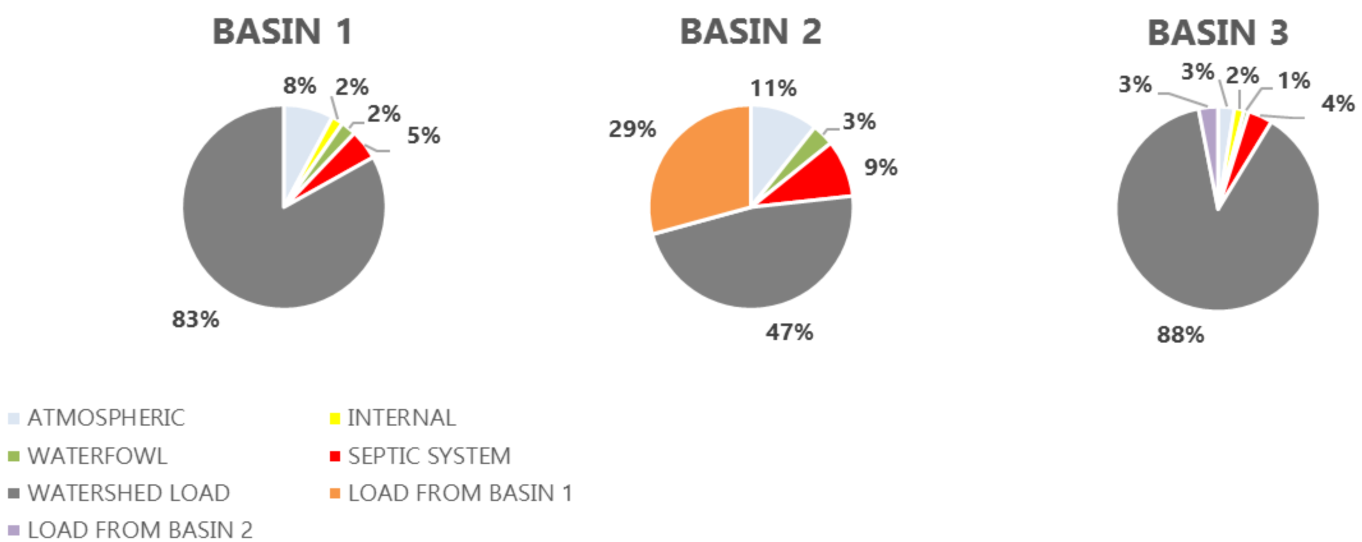


Figure 9. Percentage of total phosphorus loading (kg/yr) by source (atmospheric, internal loading, waterfowl, septic systems, watershed load, load from Basin 1, or load from Basin 2) for Basin 1, Basin 2, and Basin 3.

The model predicted within 3% difference of observed median TP for Basins 1 and 3 (Table 5). We left a 28% difference between modeled and observed in-lake TP concentrations for Basin 2 due to the lack of data (n=2) for the Blanchard's Island station. The median in-lake TP concentration of 12.5 ppb may not be representative of the basin. Without a more robust dataset, it is difficult to calibrate the model. Attenuation factors that were appropriate for other similar tributaries with data were used consistently and no further calibration was done for Basin 2. Interestingly, despite the model predicting variable (low or high) median TP concentrations compared to observation data, the model consistently predicted higher-than-observed Chl-a concentrations and lower-than-observed mean water clarity (Table 5). This suggests that other factors aside from phosphorus may be controlling observed water quality (i.e., the general empirical equations used in the LLRM do not fully account for all the biogeochemical processes occurring within the Inlet that contribute to the overall water quality condition).

Table 5. In-lake water quality predictions for Basins 1, 2, and 3. *Note: median TP concentrations represent 20% greater than actual median values to account for year-round variation. This is because most data are collected in the summer when TP concentrations are typically lower than the annual average concentrations.*

Basin	Median TP (ppb)	Predicted Median TP (ppb)	Mean Chl-a (ppb)	Predicted Mean Chl-a (ppb)	Mean SDT (m)	Predicted Mean SDT (m)
Basin 1	14.9	14.8	4.0	5.2	4.6	2.9
Basin 2	12.5	9.4	2.0	2.9	--	4.1
Basin 3	10.8	11.1	2.3	3.6	5.3	3.6

Past and Future Phosphorus Loads

Once the model is calibrated for current in-lake TP concentration, we can then manipulate land use and other factor loadings to estimate historical and future TP loading (e.g., what in-lake TP concentration was prior to human development and what in-lake TP concentration will be following full buildout of the watershed under current zoning restrictions). Refer to Attachment 3 for details on methodology. One major limiting factor for estimating future TP loading is that projected buildings could only be added for the Town of Moultonborough. A buildout analysis was not completed for the Town of Sandwich; therefore, Basin 3 future TP loading and in-lake TP concentration are likely underestimated. Detailed results by subdrainage and input category are presented in Tables 6 and 7. A comparison of historical, current, and future in-lake TP concentrations for the three basins is shown in Figure 10.

The historical TP load for pre-development conditions was significantly lower than current conditions. Historical (non-cumulative) TP loads ranged from 1-36 kg/yr compared to 6-168 kg/yr for the three basins under current conditions. Historical median in-lake TP concentration ranged from 2.9-4.9 ppb compared to 9.4-14.8 ppb for the three basins under current conditions. This represents an increase of 64-130% compared to current conditions. Basin 3 Direct and Shannon Brook subdrainages changed the most from historical to current conditions, likely a result of concentrated development in these drainages. The historic assessment is useful to provide an estimate of the best possible water quality for the Inlet.

The future TP load was estimated at full buildout when there would be a possible 2,184 additional buildings in the watershed. The model predicted an in-lake TP concentration of 22.5, 14.5, and 16.6 ppb in Basins 1, 2, and 3, respectively, at full buildout in 2056 (based on conservative 20-year average annual growth rate of 1.58%). This represents an increase of 40-43% compared to current conditions. Any new increases in phosphorus to a lake can disrupt the ecological balance in favor of increased algal growth, resulting in degraded water clarity. **Shannon Brook is most at risk for increases in TP loading as a result of increased development.** Septic system TP loading is estimated to double from 3-47 kg TP/yr to 5-94 kg TP/yr under full buildout. Future loading from septic systems can be greatly reduced by ensuring that all new systems are well separated from the lake, streams, and wetlands both horizontally and vertically (above seasonal high groundwater in suitable soil).

Table 6. Historical, current, and future phosphorus loading by subdrainage.

Basin	Sub-drainage to Basin	Land Area (ha)	Historical Watershed Loads		Current Watershed Loads		Future Watershed Loads	
			Water Flow (m3/year)	P mass (kg/year)	Water Flow (m3/year)	P mass (kg/year)	Water Flow (m3/year)	P mass (kg/year)
Basin 1	Basin 1 Direct	110	677,085	3	666,450	27	673,080	45
	Trib to Basin 1	120	699,267	3	708,173	24	709,958	37
	TOTAL	**229**	**1,376,352**	**7**	**1,374,623**	**52**	**1,383,037**	**83**
Basin 2	Basin 2 Direct	128	765,217	4	760,660	25	763,843	49
	Trib to Basin 2	157	925,357	4	938,114	16	939,035	23
	TOTAL	**285**	**1,690,574**	**8**	**1,698,773**	**41**	**1,702,879**	**72**
Basin 3	Basin 3 Direct	454	2,816,022	12	2,765,095	137	2,773,671	195
	Cook Brook	419	2,639,678	12	2,626,955	30	2,641,534	32
	Dinsmore Pond	301	1,859,436	11	1,859,792	18	1,859,792	18
	Direct Red Hill Brook Drainage	967	36,178,004	29	36,014,254	95	36,200,472	140
	Halfway Brook	788	4,998,230	16	4,963,483	78	5,029,395	98
	Lees Pond	354	40,927,618	12	40,762,955	59	40,963,235	97
	Little Pond	68	417,276	1	416,363	6	416,363	6
	Middle Brook	679	4,304,288	14	4,287,256	80	4,333,930	156
	Montgomery Brook	369	3,981,214	6	3,963,320	22	3,963,320	22
	Red Hill Pond	907	5,749,028	27	5,729,461	67	5,729,461	67
	Shannon Brook	1705	13,565,827	36	13,527,746	168	13,608,262	303
	Shannon Pond	480	3,057,714	16	3,058,261	45	3,058,878	51
	Skinner Brook	267	1,683,683	8	1,683,773	15	1,689,877	42
	Stanton Brook	325	2,064,759	6	2,058,442	19	2,058,442	19
	Creamery Brook	190	1,207,356	4	1,177,122	28	1,177,122	28
	Trib 2 to Basin 3	441	4,040,101	10	4,068,517	40	4,088,113	74
	Trib 2 to Red Hill Brook	486	3,097,468	17	3,086,526	34	3,104,553	73
	Meadow Pond	48	281,553	1	283,462	7	284,908	9
	Weed Brook/Berry Pond	1899	11,916,127	33	11,856,425	129	11,958,659	164
	Weed Brook/Trib	398	13,134,443	12	13,068,505	43	13,184,341	54
	Garland Pond	355	38,589,894	12	38,421,900	25	38,617,501	53
	Trib 1 to Trib 2 to Basin 3	202	1,484,945	5	1,511,720	35	1,519,101	61
	TOTAL	**12,103**	**74,573,212**		**70,375,053**		**70,796,605**	

Basin 3 loads are not summed due to water routing through certain basins; refer to model
Note: Water flow is cumulative routing through drainages; P mass is NOT cumulative routing through drainages

Table 7. Historical, current, and future phosphorus loading by input category for Basins 1, 2, and 3.

INPUT CATEGORY BASIN 1	HISTORICAL			CURRENT			FUTURE		
	P (KG/YR)	%	WATER (CU.M/YR)	P (KG/YR)	%	WATER (CU.M/YR)	P (KG/YR)	%	WATER (CU.M/YR)
ATMOSPHERIC	5	37%	295,995	5	8%	295,995	5	5%	295,995
INTERNAL	0	0%	0	1	2%	0	1	1%	0
WATERFOWL	2	11%	0	2	2%	0	2	2%	0
SEPTIC SYSTEM	0	0%	0	3	5%	2,505	5	5%	4,196
WATERSHED LOAD	7	52%	1,376,352	52	83%	1,374,623	83	87%	1,383,037
TOTAL LOAD TO LAKE	**13**	**100%**	**1,672,348**	**62**	**100%**	**1,673,123**	**95**	**100%**	**1,683,229**

INPUT CATEGORY BASIN 2	HISTORICAL			CURRENT			FUTURE		
	P (KG/YR)	%	WATER (CU.M/YR)	P (KG/YR)	%	WATER (CU.M/YR)	P (KG/YR)	%	WATER (CU.M/YR)
ATMOSPHERIC	9	21%	558,205	9	11%	558,205	9	7%	558,205
INTERNAL	0	0%	0	0	0%	0	0	0%	0
WATERFOWL	3	7%	0	3	3%	0	3	2%	0
SEPTIC SYSTEM	0	0%	0	8	9%	6,545	10	8%	8,735
WATERSHED LOAD	8	18%	1,690,574	41	47%	1,698,773	72	54%	1,702,879
LOAD FROM BASIN 1	25	55%	1,672,348	25	29%	1,673,123	38	29%	1,683,229
TOTAL LOAD TO LAKE	**45**	**100%**	**3,921,128**	**86**	**100%**	**3,936,647**	**133**	**100%**	**3,953,049**

INPUT CATEGORY BASIN 3	HISTORICAL			CURRENT			FUTURE		
	P (KG/YR)	%	WATER (CU.M/YR)	P (KG/YR)	%	WATER (CU.M/YR)	P (KG/YR)	%	WATER (CU.M/YR)
ATMOSPHERIC	31	10%	1,868,572	31	3%	1,868,572	31	2%	1,868,572
INTERNAL	0	0%	0	18	2%	0	18	1%	0
WATERFOWL	9	3%	0	9	1%	0	9	0%	0
SEPTIC SYSTEM	0	0%	0	47	4%	39,441	94	5%	79,062
WATERSHED LOAD	260	82%	70,652,084	1,060	88%	70,375,053	1,609	88%	70,796,605
LOAD FROM BASIN 2	19	6%	3,921,128	37	3%	3,936,647	57	3%	3,953,049
TOTAL LOAD TO LAKE	**319**	**100%**	**76,441,784**	**1,202**	**100%**	**76,219,714**	**1,819**	**100%**	**76,697,288**

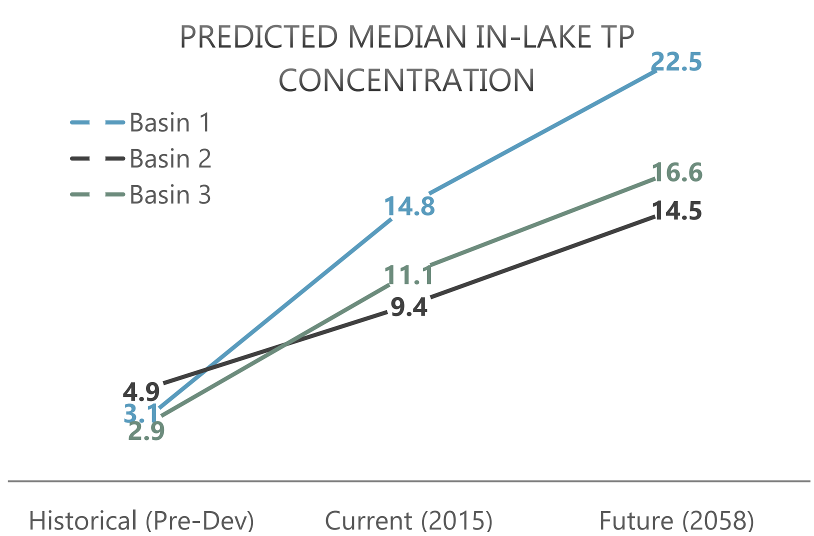


Figure 10. Historical, current, and future in-lake total phosphorus concentrations for Basins 1, 2, and 3.

Water Quality Goal Recommendations

The model results revealed changes in TP loading and in-lake TP concentrations over time from historical pre-development through future conditions. We can use these results to make informed management decisions and set an appropriate water quality goal for the Moultonborough Bay Inlet. Basin 1 (Green's Basin) has seen the greatest increase in in-lake TP concentration since pre-development and will continue on a more aggressive upward trajectory than Basins 2 and 3. Despite the model showing that Basin 1 has little impact on downstream water quality (Basin 3), TP concentrations are already high and significant reductions are needed to avoid adverse water quality impacts within that basin. Since there are minimal data available for Basin 2 to determine a reasonable water quality goal, we recommend collecting several years of data (epilimnion and hypolimnion TP, Chl-a, and SDT) for the deep spot in Basin 2 and revisiting a water quality goal in five years. Refer to the assimilative capacity analysis for more detail. The following is based on the assumption that oligotrophic thresholds be applied to all three basins.

If we set a water quality goal of 7.2 ppb for Basin 1 (equates to 8.6 ppb in the model – 20% increase to account for year-round variation and a 42% reduction in current condition), this would reduce median in-lake TP concentrations to 8.2 ppb (14%) for Basin 2 and 11.0 ppb (1%) for Basin 3. To get the median in-lake TP concentration in Basin 3 down to 7.2 ppb (or 8.6 ppb in the model), we would need a 20% reduction in in-lake TP concentration. This would require tremendous effort by the watershed community. Therefore, interim goals should be established and/or the water quality goals should reflect the true borderline nature (oligotrophic/mesotrophic) of the Inlet. This should be a topic of discussion at the next Steering Committee Meeting.

Attachment 1: Land Use File Update Workflow Record

```
LLRM Land Use Update Workflow
2/22/2015 L. Diemer
Project #188: MBI WMP

All data projected in NAD_1983_StatePlane_New_Hampshire_FIPS_2800_Feet

Data
            2009 NAIP Imagery (Quads 25,26,32,33)
                  http://www.granit.sr.unh.edu/data/search?dset=2009naip&#47;2009naip01

            NH Land Cover Assessment 2001
                  http://www.granit.sr.unh.edu/data/search?dset=nhlc01&#47;nh
                  Data Management Tools > Raster > Raster Processing > Clip
                        Extent clipped to "mbi_watershed_updated"
                        Set display transparency to 70%
                        file = "nhlc01_mbi"
                  Conversion Tools > From Raster > Raster to Polygon
                        file = "nhlc01_mbi_poly_before"

                        NHLC01 GRIDCODE/LABEL
                        110 Residential/Commercial/Industrial
                        140 Transportation
                        211 Row Crops
                        212 Hay/Pasture
                        221 Orchards
                        412 Beach/Oak
                        414 Paper Birch/Aspen
                        419 Other Hardwoods
                        421 White/Red Pine
                        422 Spruce/Fir
                        423 Hemlock
                        424 Pitch Pine
                        430 Mixed Forest
                        500 Open Water
                        610 Forested Wetland
                        620 Open Wetland
                        710 Disturbed Land
                        790 Other Cleared

                        LLRM CAT/NHLC01 GRIDCODE
                        Urban 1 (Low Den Res) / 110
                        Urban 2 (Mid Den Res/Comm) / 110,790
                        Urban 3 (Roads) / 140
                        Urban 4 (Industrial) / 110
                        Urban 5 (Mowed Fields) / 110
                        Agric 1 (Cover Crop) / NA
                        Agric 2 (Row Crop) / 211, 221
                        Agric 3 (Grazing) / 212
                        Agric 4 (Hayfield) / 212
                        Forest 1 (Deciduous) / 412,414,419
                        Forest 2 (NonDeciduous) / 421,422,423,424
                        Forest 3 (Mixed) / 430
                        Forest 4 (Wetland) / 610
                        Open 1 (Wetland/Lake) / 500,620
                        Open 2 (Meadow) / NA
                        Open 3 (Excavation) / 710
```

ArcCatalog > Copy "nhlc01_mbi_poly_before" > Rename "nhlc01_mbi_poly_after"

New Shapefile "Grids"
Created 1.3x2.5 mi grids; labeled quads #1-25

Land Use Analysis
Step 1: Zoom to Quad #X; compare 2009 NAIP aerials to 9/18/2013 Google Earth satellite images for major land use changes
Step 2: Compare 2009 NAIP aerials to "nhlc01_mbi" land use file
Step 3: If changes needed, used Topology tool to edit vertices or Editor tool to split polygons; relabel polygons in attribute table
Note: limited time per quad to 10 minutes each or less

Changes
Default: Mixed Forest, Agric 4: Hayfield
Urban 5: Mowed Fields = residential/commercial lawns, cemeteries, athletic fields
Agric 2: Row Crop = Orchards, Tree farms
Open 2: Meadow = shrubby areas
Open 3: Excavation = major bare soil areas

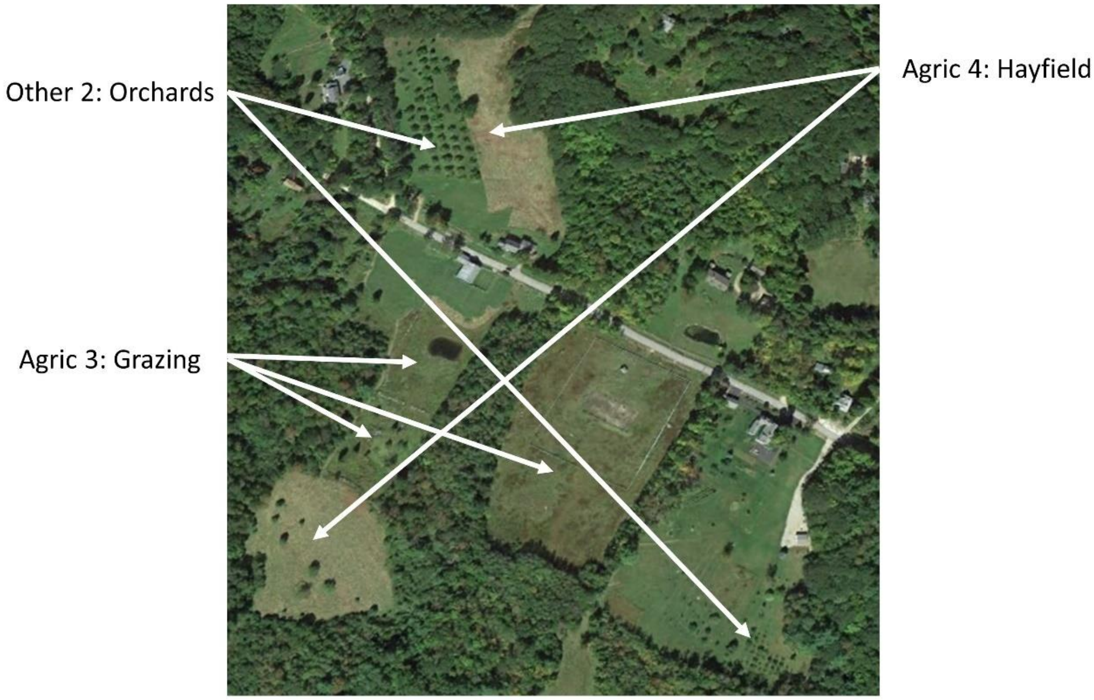
ADD UNPAVED ROADS LAND COVER TYPE
> Select "Unpaved" from "SURF_TYPE" attribute in "mbi_roads.shp" -> "unpaved_rds.shp"
> Geoprocessing > Buffer > Input "unpaved_rds.shp"; buffer = 25ft -> "unpaved_rds_buffer.shp"
> Geoprocessing > Union > Input "nhlc01_mbi_poly_after" and "unpaved_rds_buffer" -> "nhlc01_mbi_poly_after_rds"
> Rerelabeled added road polygons as "Other 1: Unpaved Roads" under "LLRM_CAT"
> Note: need to change LU coefficient in LLRM to account for additional gravel roads layer (current coeff. already accounts for roads)

ADD URBAN LAND COVER TYPE
> Overlay "Existing_Buildings3" from buildout analysis (K. Ryan)
> Cut polygons and relabeled areas with clustered building points as "Urban 1 or 2"; paid particular attention to pond shorelines

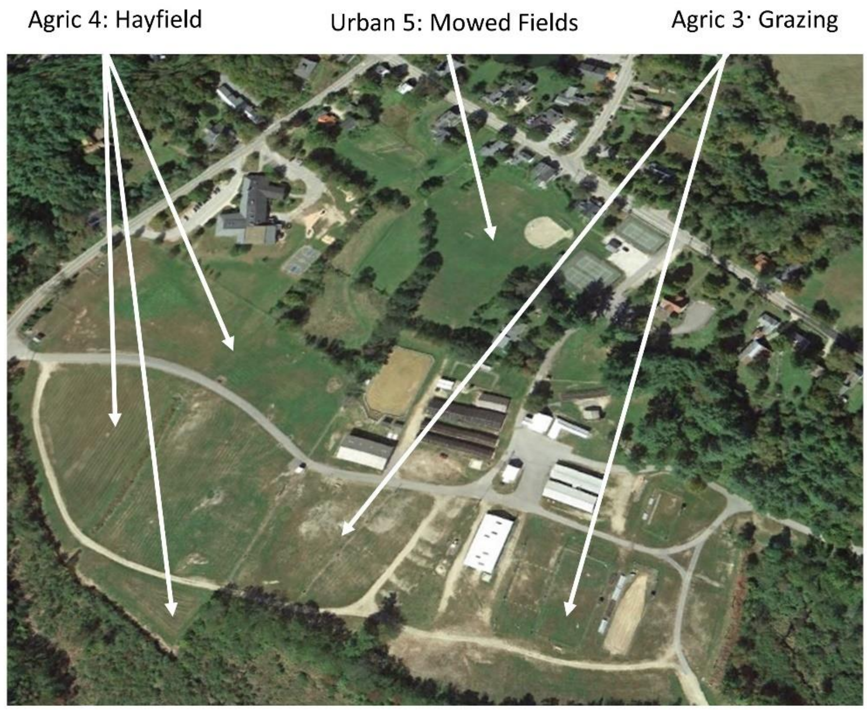
DISTINGUISH ORCHARDS AND TREE FARMS
> Changed "Agric 2: Row Crop" to "Other 2: Orchards" or "Other 3: Tree Farm", wherever applicable

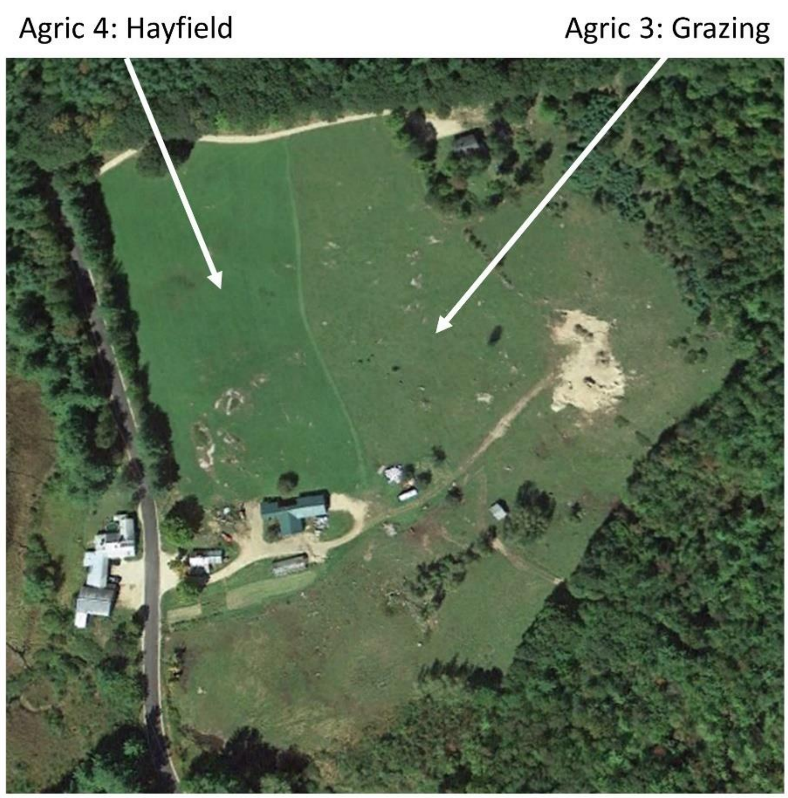
> "MBI_watershed_updated" = old watershed outline
> "mbi_watershed_final2" = new watershed outline
> "mbi_lu_updated4_clip" = editable and most recent land cover
> "mbi_lu_final_dissolve2" = final land cover
> "mbi_lu_subwat4_final2_cutout2" = final land cover by subdrainage

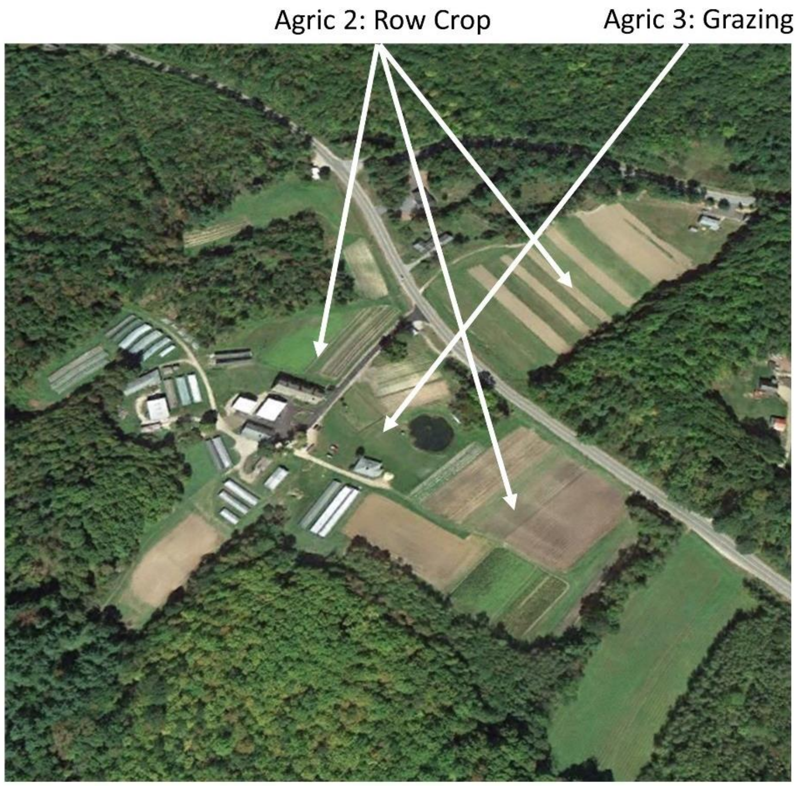
Attachment 2: Examples of Distinguishing Agricultural Land Uses from Aerials



Agric 4: Hayfield


Agric 4: Hayfield
Urban 5: Mowed Fields
Agric 3· Grazing


Agric 4: Hayfield
Agric 3: Grazing


Agric 2: Row Crop
Agric 3: Grazing

Attachment 3: Estimating Historical and Future TP Loads

HISTORICAL TP LOAD

1. Convert all human land use to mixed forest (Forest 3) for each subdrainage and update model.
2. Remove all septic inputs (set population to zero).
3. Remove internal loading, assuming that any anoxic conditions are a result of excess nutrient loading from human activities in the watershed.
4. Keep all else the same, assuming waterfowl counts and atmospheric inputs did not change (though it likely did).

FUTURE TP LOAD

1. **Estimate number of new buildings at full buildout by subdrainage.** CommunityViz software uses model inputs such as population growth rates, zoning, wetlands, conservation lands, and other constraints to construction, and generates a projected number of new buildings in the future. The new building count was generated for each subdrainage at full buildout.
2. **Calculate developed land coverage after full buildout projection.** Each new building was assumed to generate new residential (Urban 1), commercial (Urban 2), and road (Urban 3, Other 1) land uses. Specifically, the value of 0.22 ha of Urban 1, 0.12 ha of Urban 2, 0.12 ha of Urban 3, and 0.07 ha of Other 1 were multiplied by the number of new buildings in each subdrainage. Subdrainages within the Town of Sandwich were not included since a buildout analysis was not completed for that portion of the watershed.
3. **Incorporate land use changes into LLRM for P loading predictions.** Add the new developed land use figures to the LLRM. Hayfield (Agric 4) was replaced first, assuming cleared land is easier and more likely to be developed, and then mixed forest (Forest 3) and non-deciduous forest (Forest 2) were replaced to account for new developed land use increases.
4. **Incorporate septic system loading into LLRM for P loading predictions.** The number of new buildings within 250 feet of water within each major basin was estimated (Moultonborough buildout data were extrapolated to include Sandwich). All other assumptions were kept the same based on 2010 census data and Lake Waukewan septic system statistics.
5. **Keep all else the same, unless there are enough data to make appropriate model assumptions.**