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1. PURPOSE

The purpose of this memo is to provide draft results from the Lake Loading Response Model (LLRM) developed for Pleasant Lake. 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 the deep spot and tributary outlets, lake volume, septic system loading estimates, and more.

The following describes the process by which these critical inputs were determined and input to the LLRM using available resources and advanced GIS modeling. It 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.

2. WATERSHED AND SUB-BASIN DELINEATIONS

Watershed and tributary drainage basin (sub-basin) boundaries are needed to determine both the amount of water flowing into the lake and the type of land uses contributing to nutrient loading. Revised watershed and sub-basin shapefiles for Pleasant Lake were generated using GIS modeling tools in ArcMap™. The following sources were used to help create these files:

- Streams [NHDFlowline.shp], GRANIT
- Little Suncook River Watershed, HUC12 [wbdhu12_a_nh015], GRANIT
- Digital Elevation Models (DEM) – Quads #138, 139, 152, 153, GRANIT [Updated March 1999]

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 GIS modeling steps to generate a stream network (i.e., “flowacc”) and sub-basins based on assigned “pour points.” These pour points are located at major tributary outlets and at the lake outlet on the north side of Pleasant Lake. The sub-basins were dissolved into a single watershed shapefile.

Due to its small watershed size, Pleasant Lake does not have its own watershed in GRANIT’s HUC12, but it is a part of the Little Suncook River watershed. A comparison of the watershed boundary of the Little Suncook River, the boundary generated using GIS modeling (2,258 acres), and the finalized watershed boundary edited after ground-truthing (2,315 acres) are shown in Figure 1. The Little Suncook River HUC12 and the model-generated boundary are fairly similar along the southern border of the watershed.

The stream network from the National Hydrography Dataset (NHD) mapped 5 major tributaries in the watershed (Figure 1), though additional drainages and streams were identified during ground-truthing and in discussion with watershed residents. These sub-basin delineations are shown in Figure 2. Delineations
of both the watershed and sub-basins were confirmed in the field by L. Diemer, FBE. Changes of note include the expansion of the watershed in the northwest corner to accommodate man-made ditching of stormwater flow toward the lake (Figure 1) and the addition of a small drainage area (called Branch Brook) along the northeast shore (Figure 2).

**FIGURE 1.** LEFT: Pleasant Lake watershed boundary comparison between that obtained from GRANIT’s HUC12 watershed shapefile (for Little Suncook River) and that generated by GIS modeling tools with ground-truthing. RIGHT: Pleasant Lake watershed stream network obtained from GRANIT (National Hydrography Dataset).
FIGURE 2. Pleasant Lake watershed with sub-basin delineations for major tributaries.
3. LAND USE UPDATE

Land use is the essential element in determining how much phosphorus is contributing to a lake from the watershed. 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 (Figure 3; refer to Attachment 1). Next, rectangular grids (or quads) were made to break up the watershed into more manageable portions for review.

2014 NAIP aerials were uploaded and compared to 05/07/2015 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:

- Default for forest was “Forest 3: Mixed”
- Agricultural fields that were clearly not pasture or row crops were defaulted to “Agric 4: Hayfield.”
- Residential or commercial lawns, cemeteries, and athletic fields were labeled as “Urban 5: Mowed Fields”.
- 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 (refer to Attachment 2 for examples).
- Shrubby areas that did not seem to be the result of a recent logging operation were labeled as “Open 2: Meadow”.
- Major bare soil areas that were not associated with new residential home construction were labeled as “Open 3: Excavation”.
- Areas that appeared to have been very recently logged were labeled as “Other 4: Logged”.
- Polygons were relabeled forested wetlands (Forest 4: Wetlands) if they were listed as any type of forest category in the NHLCO1 shapefile and overlapped with National Wetlands Inventory (NWI) polygons.
- A new land cover category was generated for unpaved roads (Other 1: Unpaved Roads) by overlaying the roads layer (with a 25 ft buffer) with the land use file. Paved roads (Urban 3: Roads) were further refined using the 25 ft buffer as the original polygons were generated from a raster image, which caused the roads to appear much wider than in reality (e.g., overestimated impervious surface area, see Figures 3 and 5).
- The final land cover shapefile was compared to the NHD lake shoreline, and any areas that extended into the defined lake area were relabeled as “Open 1: Wetland/Lake.”

The resulting updated land use file is a more accurate representation of current land use within the Pleasant Lake watershed (refer to Figure 4 for zoomed-in examples of “before” and “after” modifications; refer to Figures 5 and 6 for the final land use). The most significant changes to land use were the addition
of grazing/pasture areas throughout the watershed and low density residential development where houses are located along the shoreline.

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.

Within the LLRM, an export coefficient is assigned to each land use to represent typical concentrations of phosphorus in runoff and baseflow from those land use types. Unmanaged forested land, for example, tends to deliver very little phosphorus downstream when it rains, while row crops and low to high density urban development 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 via groundwater under baseflow conditions. This nutrient load is delivered with groundwater to the lake directly or to tributary streams. 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 all sub-basins as hectares (ha) and percentage of total. One hectare is equivalent to 2.5 acres. These coefficients were based on values from Tarpey 2013, Reckhow et al. 1980, Dudley et al. 1997, Dennis and Sage 1981, Hutchinson Environmental Sciences Ltd 2014, Schloss and Connor 2000, and Mitchell et al. 1989. Figure 7 shows a basic breakdown of land use by major category for the entire watershed, as well as total phosphorus (TP) load by land use type.
FIGURE 3. NH Land Cover Assessment 2001 (NHLC01) data with LLRM land use categories before edits were made. Quads 1-12 split the watershed into manageable sections for review.
FIGURE 4. Examples of “before” and “after” land use file modifications for the Pleasant Lake watershed for agricultural and residential areas.
FIGURE 5. NH Land Cover Assessment 2001 (NHLC01) data with LLRM land use categories after edits were made. Quads 1-12 split the watershed into manageable sections for review.
FIGURE 6. Land cover in the Pleasant Lake watershed.
### Table 1

Land use phosphorus export coefficients and land use areas for all sub-basins. Summed area of sub-basins equals total watershed area minus lake area.

<table>
<thead>
<tr>
<th>LAND USE</th>
<th>Runoff P export coefficient used</th>
<th>Baseflow P export coefficient used</th>
<th>Area (hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban 1 (Low Density Residential)</td>
<td>0.79</td>
<td>0.010</td>
<td>17.4</td>
</tr>
<tr>
<td>Urban 2 (Mid Density Residential/Commercial)</td>
<td>0.90</td>
<td>0.010</td>
<td>2.1</td>
</tr>
<tr>
<td>Urban 3 (Roads)</td>
<td>1.05</td>
<td>0.010</td>
<td>47.0</td>
</tr>
<tr>
<td>Urban 4 (Industrial)</td>
<td>1.10</td>
<td>0.010</td>
<td>175.6</td>
</tr>
<tr>
<td>Urban 5 (Mowed Fields)</td>
<td>0.60</td>
<td>0.010</td>
<td>21.3</td>
</tr>
<tr>
<td>Agric 1 (Cvr Crop)</td>
<td>0.60</td>
<td>0.010</td>
<td>111.7</td>
</tr>
<tr>
<td>Agric 2 (Row Crop)</td>
<td>1.23</td>
<td>0.010</td>
<td>67.8</td>
</tr>
<tr>
<td>Agric 3 (Grazing)</td>
<td>0.80</td>
<td>0.010</td>
<td>188.2</td>
</tr>
<tr>
<td>Agric 4 (Hayfield)</td>
<td>0.50</td>
<td>0.010</td>
<td>38.9</td>
</tr>
<tr>
<td>Forest 1 (Deciduous)</td>
<td>0.03</td>
<td>0.004</td>
<td>73.3</td>
</tr>
<tr>
<td>Forest 2 (NonDeciduous)</td>
<td>0.03</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>Forest 3 (Mixed)</td>
<td>0.03</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>Forest 4 (Wetland)</td>
<td>0.03</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>Open 1 (Wetland/Lake)</td>
<td>0.03</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>Open 2 (Meadow)</td>
<td>0.20</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>Open 3 (Excavation)</td>
<td>0.80</td>
<td>0.010</td>
<td></td>
</tr>
<tr>
<td>Open 4: (Logged)</td>
<td>0.20</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>Other 1: Unpaved Road</td>
<td>0.83</td>
<td>0.010</td>
<td></td>
</tr>
<tr>
<td>Other 2: Orchard</td>
<td>0.30</td>
<td>0.010</td>
<td></td>
</tr>
<tr>
<td>Other 3: Tree Farm</td>
<td>0.14</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>17.4</strong></td>
<td><strong>2.1</strong></td>
<td><strong>47.0</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>175.6</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>21.3</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>111.7</strong></td>
</tr>
<tr>
<td></td>
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<td></td>
<td><strong>67.8</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>188.2</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>38.9</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>73.3</strong></td>
</tr>
</tbody>
</table>
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 15% of the watershed, these areas are contributing 66% of the TP load to Pleasant Lake.

4. OTHER MAJOR LLRM INPUTS

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

- Annual precipitation data were obtained from NOAA National Climatic Data Center (NCDC) for Epping, NH (COOP:272800). The recent annual precipitation totals from 2006-2014 were averaged and used in the model (51.38”).
- Lake area was based on GRANIT NHDWaterbody shapefile.
- Lake volume was based on GRANIT bathymetry shapefile. Data were available from both NH Fish and Game Department (NHFGD) and NHDES, but only the NHDES data were used to determine lake volume. The lake surface area did not match the NHDWaterbody shape completely, but the difference was minor (3%; NHD = 193.8 ha, NHDES = 200.3 ha).
- Septic system data were based on a variety of sources and assumptions, including the Pleasant Lake Septic Survey conducted by the Southern New Hampshire Planning Commission (SNHPC) in 2015, 2010 US Census data for New Hampshire, Pleasant Lake buildout analysis results, and ArcGIS area calculations. 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 the Pleasant Lake Water Quality Report (prepared by FBE 2016). Model was calibrated to PLEDEED data (Pleasant Lake Deep Spot).
- Assumed 30 waterfowl 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; even so, the phosphorus excreted may be in a form that can be readily used by algae and plants.
- Dissolved oxygen (DO) and water temperature profiles were available for some years at the PLEDEED station in the lake. We estimated internal loading based on recent data (2006-2015). First,
we calculated the difference between the overall median epilimnion TP and hypolimnion TP for 2006-2015. The difference was then multiplied by the median anoxic volume (< 1 ppm DO) for 2006-2015 and converted to kg/yr for model input. However, only one year of data (2010) recorded anoxic conditions. DO profiles were not consistently recorded every year and tended to be measured in June or July before the peak stratification period when thermal stratification is strongest and dissolved oxygen depletion is greatest (typically mid-September). We assumed that the August 2010 profile represented typical late summer conditions in Pleasant Lake across all recent years.

5. 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 Pleasant Lake LLRM, the in-stream and in-lake phosphorus concentrations were used as guideposts, and phosphorus attenuation factors in the tributary drainages, were adjusted to better match the monitoring data (if adequate data in recent years were available; Table 2). Future monitoring can be designed to reduce the uncertainty encountered in modeling and help assess changes made during calibration.

6. LIMITATIONS TO THE MODEL

- **Median in-lake TP concentration (2006-2015) was based on detectable limit assumptions.** In-lake TP concentrations typically fell below laboratory detection limits (< 5 ppb), particularly in the last 10 years. General practice is to assume half the detectable limit, but with more than half the data points falling below detection, we assumed that the actual TP concentration was closer to 5 ppb than 2.5 ppb. As such, we used 5 ppb as an input value to the model, but the actual median value is likely somewhere between 4 and 5 ppb. Future monitoring of epilimnion TP in Pleasant Lake should use a laboratory capable of achieving a 1 ppb detection limit.

- **Data are missing for the tributary in the Unknown sub-basin, and other tributaries are lacking recent data.** More data are needed to effectively calibrate the model to known observations for some tributary sub-basins. One tributary (Branch Brook) has only been sampled six times in the last ten years. Until more data are available, we have to make large assumptions based on land use or other contributing factors. Model outputs for the Unknown and Branch Brook sub-basins in particular should be interpreted with caution until more data are collected.

- **Internal loading estimates are based on limited data.** Phosphorus that enters the lake 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 at the
Pleasant Lake Deep Spot (at least annually in late August and September), along with consistent sampling of hypolimnion TP and epilimnion TP.

- Waterfowl counts are based on estimates. In the future, a more precise bird census would help improve the model.

- Reality checks from 2002 Diagnostic Study outdated and likely not representative of typical conditions. A comprehensive study of flow and phosphorus loading from the major tributaries and direct shoreline to Pleasant Lake was conducted from 1999-2000. Comparing study results to model output showed that the model was underestimating flow; however, local historical weather during the study period showed that rainfall may have been higher than normal. The model output loads for phosphorus were generally in acceptable range with a few exceptions (Clark Brook and Rt 107 Inlet), which may have been due to the wetter conditions during the study period. The data was also collected more than 10 years ago and were included in the model, but not calibrated to the data.

- Average of empirical formulas for predicting TP concentration limited to only three of the six available models. Pleasant Lake represents a unique oligotrophic lake system with extremely-low in-lake TP, despite the historical and current land use. Several of the empirical formulas for predicting in-lake TP were consistently predicting in-lake concentrations much higher than those typically observed in Pleasant Lake. This may be because the data set used to derive these formulae were collected from more nutrient-rich lakes. Given this, we selected the three formulas predicting the lowest in-lake TP (Kirchner-Dillon 1975, Reckhow General 1977, and Nurnberg 1998) for averaging.

- Assumed median standard water yield and slightly more water attenuation than standard factor. Water can be lost through evapotranspiration, deep groundwater, and wetlands. We generally expect at least a 5% loss (0.95) for each tributary. Larger losses (<0.95) can be expected with lower gradient or wetland-dominated landscapes. In this case, we assumed a water attenuation factor of 0.90 due to some additional loss to wetlands and deep groundwater. Although much of Pleasant Lake is hilly, the tributaries flow through some lower gradient areas that may attenuate more water. However, the calculated flow to flow from areal yield ratio was consistently high across all sub-basins, indicating that some of our assumptions for calculated flow may be too high (i.e., land use coefficients or basin attenuation factors may be lower than assumed) or our assumptions for areal yield may be too low (i.e., median standard water yield may be higher than assumed).

- Assumed standard factors for P attenuation factors unless adequate data available to calibrate model. The model uses a default of 0.90 to represent a small amount of removal by infiltration processes. Additional infiltration, filtration, detention, and uptake will lower the attenuation value, such as sub-basins dominated by small ponds or wetlands (0.75), larger ponds or wetlands (0.5), or channel processes that favor uptake (0.85). For this model, we assumed a default of 0.85 for all tributaries if adequate data were not available and a default of 0.90 for direct shoreline drainage or tributaries with real data higher than model calculations (Clark Brook, Loon Cove Brook, and Philbrick Brook). Measured TP for Loon Cove and Philbrick Brooks were much higher than model predictions, both of which are located on the east side of the lake where development is
concentrated near the outlet of these streams. The near-outlet development may be functioning as a point source to the sample location. Further investigation may be warranted to adjust the model in the future. In general, the model applies a single attenuation factor for all loads within a sub-basin, but loads may enter at different points within the basin so that attenuation does not apply equally to all sources.

**TABLE 2.** Sub-basin attenuation factors, along with a brief account for the assigned factor.

<table>
<thead>
<tr>
<th>Sub-Basin</th>
<th>Water Atten. Factor</th>
<th>P Atten. Factor</th>
<th>Reasoning (water; TP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown</td>
<td>0.90</td>
<td>0.85</td>
<td>Slightly more atten. than standard factor; some atten. from tributary drainage</td>
</tr>
<tr>
<td>Branch Brook</td>
<td>0.90</td>
<td>0.70</td>
<td>Slightly more atten. than standard factor; adjusted P atten. to better reflect in-stream data</td>
</tr>
<tr>
<td>Clark Brook</td>
<td>0.90</td>
<td>0.90</td>
<td>Slightly more atten. than standard factor; little atten. from tributary drainage</td>
</tr>
<tr>
<td>Direct</td>
<td>0.90</td>
<td>0.90</td>
<td>Slightly more atten. than standard factor; direct drainage so little atten.</td>
</tr>
<tr>
<td>Farrelly Brook</td>
<td>0.90</td>
<td>0.45</td>
<td>Slightly more atten. than standard factor; adjusted P atten. to better reflect in-stream data</td>
</tr>
<tr>
<td>Loon Cove Brook</td>
<td>0.90</td>
<td>0.90</td>
<td>Slightly more atten. than standard factor; little atten. from tributary drainage</td>
</tr>
<tr>
<td>Philbrick Brook</td>
<td>0.90</td>
<td>0.90</td>
<td>Slightly more atten. than standard factor; little atten. from tributary drainage</td>
</tr>
<tr>
<td>Rt 107 Inlet</td>
<td>0.90</td>
<td>0.85</td>
<td>Slightly more atten. than standard factor; some atten. from tributary drainage</td>
</tr>
<tr>
<td>Veasey Brook</td>
<td>0.90</td>
<td>0.50</td>
<td>Slightly more atten. than standard factor; adjusted P atten. to better reflect in-stream data</td>
</tr>
<tr>
<td>Wilsons Brook</td>
<td>0.90</td>
<td>0.60</td>
<td>Slightly more atten. than standard factor; adjusted P atten. to better reflect in-stream data</td>
</tr>
</tbody>
</table>

**7. RESULTS**

Watershed loads for each sub-basin are presented 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. The Direct sub-basin had the highest TP mass exported to Pleasant Lake at 46.1 kg/yr. This is expected given the development around the shorelines and the proximity of P sources to the lake. Route 107 Inlet, Clark Brook, and Loon Cove Brook sub-basins had the next highest TP loadings. On a per hectare basis, the Direct and Clark Brook sub-basins had the highest TP loadings. Loon Cove and Philbrick Brooks may be underestimated given that the measured TP concentration for these tributaries is much higher than the calculated TP concentration (see Limitations to the Model).

**TABLE 3.** Summary of land area, water flow, and total phosphorus (TP) loading by sub-basin.

<table>
<thead>
<tr>
<th>Sub-Basin</th>
<th>Land Area (ha)</th>
<th>Water Flow (m³/year)</th>
<th>Calculated P Concentration (mg/L)</th>
<th>Measured P Concentration (mg/L)*</th>
<th>P mass (kg/yr)</th>
<th>P mass by area (kg/ha/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown</td>
<td>17.4</td>
<td>122,965</td>
<td>0.023</td>
<td>no data</td>
<td>2.8</td>
<td>0.16</td>
</tr>
<tr>
<td>Branch Brook</td>
<td>2.1</td>
<td>14,971</td>
<td>0.017</td>
<td>0.017</td>
<td>0.3</td>
<td>0.12</td>
</tr>
<tr>
<td>Clark Brook</td>
<td>47.0</td>
<td>321,639</td>
<td>0.035</td>
<td>0.046</td>
<td>11.4</td>
<td>0.24</td>
</tr>
<tr>
<td>Direct</td>
<td>175.6</td>
<td>1,216,786</td>
<td>0.038</td>
<td>no data</td>
<td>46.1</td>
<td>0.26</td>
</tr>
<tr>
<td>Farrelly Brook</td>
<td>21.3</td>
<td>149,063</td>
<td>0.011</td>
<td>0.010</td>
<td>1.6</td>
<td>0.08</td>
</tr>
<tr>
<td>Loon Cove Brook</td>
<td>111.7</td>
<td>766,350</td>
<td>0.015</td>
<td>0.034</td>
<td>11.1</td>
<td>0.10</td>
</tr>
<tr>
<td>Philbrick Brook</td>
<td>67.8</td>
<td>476,448</td>
<td>0.006</td>
<td>0.022</td>
<td>3.1</td>
<td>0.05</td>
</tr>
<tr>
<td>Rt 107 Inlet</td>
<td>188.2</td>
<td>1,310,871</td>
<td>0.011</td>
<td>0.013</td>
<td>13.9</td>
<td>0.07</td>
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<td>Veasey Brook</td>
<td>38.9</td>
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<td>0.019</td>
<td>0.015</td>
<td>5.0</td>
<td>0.13</td>
</tr>
<tr>
<td>Wilsons Brook</td>
<td>73.3</td>
<td>513,356</td>
<td>0.009</td>
<td>0.010</td>
<td>4.9</td>
<td>0.07</td>
</tr>
</tbody>
</table>

*Median TP, 2006-2015*
FIGURE 8. Total phosphorus mass loading (kg/ha/yr) by sub-basin in the Pleasant Lake watershed.
Overall, watershed runoff (65%) was the largest loading contribution across all sources, followed by septic systems (15%), atmospheric deposition (14%), internal loading (4%), and waterfowl (2%; Table 4; Figure 9).

**TABLE 4.** Pleasant Lake total phosphorus (TP) and water loading summary by source.

<table>
<thead>
<tr>
<th>INPUT CATEGORY</th>
<th>LOAD</th>
<th>WATER (CU.M/YR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATMOSPHERIC</td>
<td>21</td>
<td>1,532,355</td>
</tr>
<tr>
<td>INTERNAL</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>WATERFOWL</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>SEPTIC SYSTEM</td>
<td>23</td>
<td>23,475</td>
</tr>
<tr>
<td>WATERSHED LOAD</td>
<td>100</td>
<td>5,162,276</td>
</tr>
<tr>
<td>TOTAL LOAD TO LAKE</td>
<td>153</td>
<td>6,718,106</td>
</tr>
</tbody>
</table>

The model predicted in-lake phosphorus within 6% (relative percent difference) of observed median TP (Table 5). Interestingly, despite the model predicting higher median TP concentrations than observed data, the model predicted lower-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 lake that contribute to the overall water quality condition). For example, Chl-a is estimated strictly from nutrient loading, but other factors strongly affect algal growth, including low light from suspended sediment, grazing by zooplankton, presence of heterotrophic algae, and flushing effects from high flows. Therefore, close agreement between predicted and measured Chl-a is difficult to achieve.

**TABLE 5.** In-lake water quality predictions for Pleasant Lake watershed.

<table>
<thead>
<tr>
<th>Waterbody</th>
<th>Median TP (ppb)*</th>
<th>Predicted TP (ppb)</th>
<th>Mean Chl-a (ppb)</th>
<th>Predicted Mean Chl-a (ppb)</th>
<th>Mean SDT (m)</th>
<th>Predicted Mean SDT (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pleasant Lake</td>
<td>5.0 (6.0)</td>
<td>6.4</td>
<td>2.5</td>
<td>1.7</td>
<td>6.4</td>
<td>5.6</td>
</tr>
</tbody>
</table>

*Median TP concentration of 5.0 represents existing in-lake summer epilimnion TP from observed data. Median TP concentration of 6.0 represents 20% greater than actual median values as the value used to calibrate the model. Most lake data are collected in summer when TP concentrations are typically lower than annual average concentrations for which the model predicts.
Past and Future Phosphorus Loads

Once the model was calibrated for the current in-lake TP concentration, we were able to 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. Detailed results by sub-basin and input category are presented in Tables 6 and 7. A comparison of historical, current, and future in-lake TP concentrations for Pleasant Lake is shown in Figure 10.

The historical TP load for pre-development conditions was lower than current conditions. Historical TP loads for each sub-basin ranged from 0.1-5.6 kg/yr compared to 0.3-46.1 kg/yr for current conditions. Predicted historical median in-lake TP concentration was 1.8 ppb compared to 6.4 ppb under current conditions. This represents an increase of more than 250% to current conditions. The Direct sub-basin changed the most from historical to current conditions, likely a result of concentrated development along the shoreline. Clark Brook, Loon Cove Brook, and Rt. 107 Inlet sub-basins also had large changes in phosphorus loads from historical to current conditions. Assessment of historical conditions is useful to provide an estimate of the best possible water quality for the lake.

The future TP load was estimated at full buildout when there would be a possible 238 additional buildings in the watershed by 2062 (based on conservative 20-year average annual growth rate of 1.24%). The future TP load analysis also included an adjustment for predicted increases in annual mean precipitation due to climate change. Table 8 shows the predicted percent increases in mean annual precipitation for the northeastern United States (NOAA Technical Report NESDIS 142-1, 2013). The two scenarios (A2 and B1) are emissions scenarios that have been modeled by the Intergovernmental Panel on Climate Change (IPCC). We chose to use a 5% increase in annual precipitation for our future loading model (the A2 (high emissions), 2041-2070 scenario) as this reflected the most likely scenario for the full buildout time frame of Pleasant Lake. However, we also ran the model under the other three scenarios, but results were very similar (0.1 ppb difference in in-lake TP among scenarios).

The model predicted an in-lake TP concentration of 10.1 ppb, which falls in the middle of the range for mesotrophic Aquatic Life Use nutrient criteria for New Hampshire. This represents an increase of 58% 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. The Direct (shoreline) and Rt. 107 Inlet sub-basins are most at risk for increases in TP loading as a result of increased development. Septic system TP loading is estimated to increase by 27% from 23
kg TP/yr to 29 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 sub-basin.

<table>
<thead>
<tr>
<th>Sub-Basin</th>
<th>Land Area (ha)</th>
<th>HISTORICAL WATERSHED LOADS</th>
<th>CURRENT WATERSHED LOADS</th>
<th>FUTURE WATERSHED LOADS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>WATER (CU.M/YR)</td>
<td>P (KG/YR)</td>
<td>WATER (CU.M/YR)</td>
</tr>
<tr>
<td>Unknown</td>
<td>17.4</td>
<td>122,715</td>
<td>0.5</td>
<td>122,965</td>
</tr>
<tr>
<td>Branch Brook</td>
<td>2.1</td>
<td>15,007</td>
<td>0.1</td>
<td>14,971</td>
</tr>
<tr>
<td>Clark Brook</td>
<td>47.0</td>
<td>321,332</td>
<td>1.4</td>
<td>321,639</td>
</tr>
<tr>
<td>Direct</td>
<td>175.6</td>
<td>1,235,639</td>
<td>5.4</td>
<td>1,216,786</td>
</tr>
<tr>
<td>Farrelly Brook</td>
<td>21.3</td>
<td>149,819</td>
<td>0.3</td>
<td>149,063</td>
</tr>
<tr>
<td>Loon Cove Brook</td>
<td>111.7</td>
<td>773,757</td>
<td>3.4</td>
<td>766,350</td>
</tr>
<tr>
<td>Philbrick Brook</td>
<td>67.8</td>
<td>475,628</td>
<td>2.1</td>
<td>476,448</td>
</tr>
<tr>
<td>Rt 107 Inlet</td>
<td>188.2</td>
<td>1,317,649</td>
<td>5.6</td>
<td>1,310,871</td>
</tr>
<tr>
<td>Veasey Brook</td>
<td>38.9</td>
<td>273,603</td>
<td>0.7</td>
<td>269,826</td>
</tr>
<tr>
<td>Wilsons Brook</td>
<td>73.3</td>
<td>515,714</td>
<td>1.5</td>
<td>513,356</td>
</tr>
<tr>
<td>TOTAL</td>
<td>743.2</td>
<td>5,200,863</td>
<td>21.0</td>
<td>5,162,276</td>
</tr>
</tbody>
</table>

TABLE 7. Historical, current, and future phosphorus loading by input category.

<table>
<thead>
<tr>
<th>INPUT CATEGORY</th>
<th>PLEASANT LAKE</th>
<th>HISTORICAL</th>
<th>CURRENT</th>
<th>FUTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P (KG/YR) %</td>
<td>WATER (CU.M/YR)</td>
<td>P (KG/YR) %</td>
<td>WATER (CU.M/YR)</td>
</tr>
<tr>
<td>ATMOSPHERIC</td>
<td>21 47%</td>
<td>1,532,355</td>
<td>21 14%</td>
<td>1,532,355</td>
</tr>
<tr>
<td>INTERNAL</td>
<td>0 0%</td>
<td>0</td>
<td>6 4%</td>
<td>0</td>
</tr>
<tr>
<td>WATERFOWL</td>
<td>3 7%</td>
<td>0</td>
<td>3 2%</td>
<td>0</td>
</tr>
<tr>
<td>SEPTIC SYSTEM</td>
<td>0 0%</td>
<td>0</td>
<td>23 15%</td>
<td>23,475</td>
</tr>
<tr>
<td>WATERSHED LOAD</td>
<td>21 46%</td>
<td>5,200,863</td>
<td>100 65%</td>
<td>5,162,276</td>
</tr>
<tr>
<td>TOTAL LOAD TO LAKE</td>
<td>45 100%</td>
<td>6,733,218</td>
<td>153 100%</td>
<td>6,718,106</td>
</tr>
</tbody>
</table>

TABLE 8. Median of simulated change in annual mean precipitation (%) from the 14 (B1) or 15 (A2) CMIP3 models for the Northeast region. Data from NOAA Technical Report NESDIS 142-1: Regional Climate Trends and Scenarios for the U.S. National Climate Assessment (2013).

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>DATE RANGE</th>
<th>MEDIAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2 (high emissions scenario)</td>
<td>2041 - 2070</td>
<td>5%</td>
</tr>
<tr>
<td>B1 (low emissions scenario)</td>
<td>2041 - 2070</td>
<td>4%</td>
</tr>
<tr>
<td></td>
<td>2070 - 2099</td>
<td>6%</td>
</tr>
</tbody>
</table>
Additional Modeling Scenarios

Analyses of additional modeling scenarios were completed based on stakeholder interest. These scenarios are divided into two categories below: watershed-wide and sub-basin specific investigations. Refer to Attachment 3 for details on methodology for each scenario.

Watershed-Wide Investigations

- **Deforested Condition (Early Settlement):** Early settlers cleared much of the landscape near Pleasant Lake, so a deforested condition was modeled. Forested and urban land use was converted to meadow, and all paved road area was converted to unpaved road. Interestingly, the deforested condition was similar to current conditions, with only slightly less phosphorus load (150 kg/yr deforested vs. 153 kg/yr current conditions; Figure 11). However, the in-lake phosphorus concentration was higher in the deforested condition (8.5 ppb deforested vs. 6.4 current conditions), due to the increased P export coefficient of the forest-to-meadow conversion (0.03 vs. 0.20, respectively).

- **Buildout resulting in 2 ppb increase in in-lake TP:** 2 ppb roughly represents the remaining reserve capacity available in Pleasant Lake to assimilate any future increased TP load from the watershed. How much additional TP load would need to be exported from the watershed to result in 2 ppb increase to the current in-lake condition? How many new buildings would need to be added to result in this increase? We estimated the approximate TP load per new home (0.39 kg/yr) based on the number of new homes added at full buildout and the corresponding watershed-wide increase in TP load from the model. We then manipulated total TP load (i.e., decreased the load) using the Full Buildout (2062) model until the predicted in-lake concentration was approximately 2 ppb above the current median in-lake (6.0 annual median). The TP load at 8.0 ppb in-lake TP would be 195 kg/yr, or an increase of 42 kg/yr (109 new homes) on top of current load conditions.

**FIGURE 11.** Watershed-wide phosphorus loading under different land use scenarios in the Pleasant Lake watershed.
Sub-Basin Specific Investigations

- **Rt. 107 Inlet - Tree Farm:** A tree farm currently exists in the Rt. 107 Inlet, and we investigated the potential change in phosphorus load should this be converted back to forested land use. The reforested (post-conversion) condition was similar to current conditions, with only slightly less phosphorus load in the Rt. 107 Inlet sub-basin (13.6 kg/yr post-conversion vs. 13.9 kg/yr current conditions; Figure 12). In-lake phosphorus concentrations were nearly identical (0.02 ppb difference between post-conversion and current condition).

- **Clark Brook – 100 ft. Buffer:** The Clark Brook sub-basin has one of the highest phosphorus loads in the watershed. This sub-basin is located within Northwood, and we investigated if expanding the Town’s current waterbody buffer ordinances to 100 ft would affect the phosphorus loading in this sub-basin. Any human land use located within 100 ft. of any waterbody or wetland in this sub-basin was converted to forest in the model to add a vegetated buffer around the waterbodies. The buffered condition resulted in a 2.1 kg/yr reduction in phosphorus load from this sub-basin. However, in-lake phosphorus concentrations were not strongly affected (0.1 ppb difference between post-conversion and current condition).

- **Pleasant Hill Road Development:** The Pleasant Hill Road area is a newer development in the watershed. We investigated what the loading may have been like before the development by converting any human land use in this area to forest. The majority of the homes are within the Veasey Brook and Farrelly Brook sub-basins, so we approximated this pre-development condition by converting the land use in those two sub-basins only. The forested condition (post-conversion) had a lower phosphorus load than current conditions (1.0 kg/yr forested vs. 6.6 kg/yr current conditions for Veasey and Farrelly combined; Figure 12). The in-lake phosphorus concentrations were 6.1 ppb forested vs. 6.4 current conditions.

![PHOSPHORUS LOADING](image)

**FIGURE 12.** Phosphorus loading for sub-basins under different land use scenarios in the Pleasant Lake watershed.
**ATTACHMENT 1: Land Use File Update Workflow Record**

LLRM Land Use Update Workflow  
07/13/15 Lauren Bizzari  
Project #212 Pleasant Lake WRP  

All data projected in NAD_1983_StatePlane_New_Hampshire_FIPS_2800_Feet Transformation NAD_1983_to_WGS_1984_5 used for geographic coordinate system when necessary.

### Data

- **2014 NAIP Imagery**
  

- **NH Land Cover Assessment 2001**
  
  [http://www.granit.sr.unh.edu/data/search?dset=nhlc01#47;nh](http://www.granit.sr.unh.edu/data/search?dset=nhlc01#47;nh)

  Data Management Tools > Raster > Raster Processing > Clip  
  Extent clipped to "watershed"  
  Set display transparency to 70%  
  file = "nhlc01_clip2"

- **Conversion Tools > From Raster > Raster to Polygon**
  
  file = "nhlc01_pleasant_poly_before"

- **ArcCatalog > Copy "nhlc01_pleasant_poly_before" > Rename "nhlc01_pleasant_poly_after"**

- **Joined "nhlc01_pleasant_poly_after" with data in "nhlc01_pleasant_llrmcode" CSV table to convert GRIDCODE to LLRM categories**

- **Export "nhlc01_pleasant_poly_after" > to "nhlc01_pleasant_poly_after2" (to permanently save Join)**

### 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) / 790
- Urban 2 (Mid Den Res/Comm) / 790
- Urban 3 (Roads) / 140
- Urban 4 (Industrial) / NA
- Urban 5 (Mowed Fields) / NA
- Agric 1 (Cover Crop) / NA
- Agric 2 (Row Crop) / 211, 221
- Agric 3 (Grazing) / 212
Land Use Analysis

Step 1: Zoom to Quad #X; compare 2014 NAIP aerials to 05/07/2015 Google Earth satellite images for major land use changes

Step 2: Compare 2014 NAIP aerials to "nhlc01_poly_after2" 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

Changes

Default: Mixed Forest, Agric 4: Hayfield

Urban 5: Mowed Fields = residential/commercial lawns, cemeteries, athletic fields (none found in Pleasant Lake watershed)

Agric 2: Row Crop = Orchards, Tree farms

Open 2: Meadow = shrubby areas

Open 3: Excavation = major bare soil areas

Open 4: Logged = recently logged areas (visible in 2014 and/or 2015 aerials)

DISTINGUISH ORCHARDS AND TREE FARMS

> Changed "Agric 2: Row Crop" to "Other 2: Orchards" or "Other 3: Tree Farm", wherever applicable

> "watershed" = watershed outline

> "nhlc01_pleasant_poly_after2" = editable and most up to date land cover for LLRM

> "pleasant_lu_dissolve" = dissolved land cover

> "pleasant_lu_dissolve2_watershed_clip" = dissolved land cover clipped to watershed

EXPAND WATERSHED BOUNDARY

> Use Editor tool to reshape the polygon in the northwest corner - output file:

> "watershed_boundary_edited_110315.shp"

> Geoprocessing > Clip > Input "pleasant_lu_dissolve2" and clip file

> "watershed_boundary_edited_110315.shp" -> output file:

> "pleasant_lu_dissolve2_watershed_addition_clip_110315.shp"

> Geoprocessing > Merge > Input "pleasant_lu_dissolve2_watershed_addition_clip_110315.shp" and

> "pleasant_lu_dissolve2_watershed_addition_merge_110315.shp"-> output file:

> "pleasant_lu_dissolve2_watershed_addition_merge_110315.shp"

> Geoprocessing > Multipart to Single part > Input

> "pleasant_lu_dissolve2_watershed_addition_merge_110315.shp" -> output file: "pleasant_lu_dissolve2_newwatershed_clip_110315_singlepart.shp"

ADD NWI FORESTED WETLANDS

> Geoprocessing > Clip > Input "nwinhp.shp" and

> "watershed_boundary_edited_110315.shp" -> output file:

> "nwinhp_Clip_pleasantLake.shp"

> Geoprocessing > Dissolve > Input "nwinhp_Clip_pleasantLake.shp" with only NWITYPE = P selected -> output file: "nwinhp_Clip_pleasantLake_P_only_dissolve.shp"

> Geoprocessing > Union> Input "nwinhp_Clip_pleasantLake_P_only_dissolve.shp" and

> "pleasant_lu_dissolve2_newwatershed_clip_110315_singlepart.shp" -> output file: "pleasant_lu_dissolve2_newwatershed_clip_110315_singlepart_nwi.shp"
> Label polygons with both NWI and pleasant_lu attributes as “Forest 4: Wetlands”. These are forested wetland areas missed by nhc101
> “pleasant_lu_dissolve2_newwatershed_clip_110315_singlepart_nwi.shp” = with new NWI forested wetlands

ADD UNPAVED ROADS LAND COVER TYPE, REFINE PAVED ROADS
> Clip roads to Watershed
> Geoprocessing > Union > Input “pleasant_lu_dissolve2_newwatershed_clip_110315_singlepart_nwi.shp” and “Roads_DOT_Clip_PleasantLake_buffer.shp” -> output file: “pleasant_lu_dissolve2_newwatershed_clip_110315_singlepart_nwi_w_roads.shp”
> Rerelabeled added road polygons field LLRM_CAT either “Urban 3: Roads” (for polygons with “paved” under SURF_TYPE) or “Other 1: Unpaved Roads” (for polygons with “paved” under SURF_TYPE);
> Also relabeled polygons labeled “Urban 3: Roads” that did not overlap with SURF_TYPE:paved from “Roads_DOT_Clip_PleasantLake_buffer.shp” as “Forest 3: Mixed” or “Urban 1: Low Den Res”, depending on satellite image land use (this action narrowed the width of the main paved road, Rt. 107 which was likely over estimated in the NHLC01 raster because of raster size).
> Final shapefile: “pleasant_lu_110415_singlepart_clip_dissolve.shp”
> Note: need to change LU coefficient in LLRM to account for additional gravel roads layer (current coeff. already accounts for roads)

ALIGN WITH NHD SHORELINE AND CLIP TO FINAL, GROUND TRUTHED WATERSHED BOUNDARY
> “PleasantLake_WatershedBoundary_Final021916.shp” = final edited watershed boundary after ground truth field visit by L. Diemer
> Clip “PleasantLake_LU_Final021916.shp” to new watershed boundary
> “PleasantLake_LU_Final021916_2.shp” = final land cover for input to LLRM
ATTACHMENT 2: Examples of Distinguishing Agricultural Land Uses in Aerials

Other 3: Tree Farm  Agric 4: Hayfield

Agric 4: Hayfield  Agric 3: Grazing
Agric 4: Hayfield

Agric 2: Row Crop

Urban 5: Mowed Field
ATTACHMENT 3: Estimating Historical and Future TP Loads

HISTORICAL TP LOAD

1. Convert all human land use to mixed forest (Forest 3) for each sub-basin and update model. Human land use categories converted: Urban 1-5, Agric 1-4, Open 3-4, Other 1-3.
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 sub-basin.** 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 sub-basin at full buildout.

2. **Identify current land use at location of projected new buildings.** The number of buildings on each land use type within each sub-basin was determined using a Spatial Join in ArcGIS. If a new building was projected on to already developed land (e.g. Urban 3: Road or Urban 1: Low Density Residential), then the land use to be converted to development was changed to Forest 3: Mixed instead, assuming that new, undeveloped areas will be converted to development. This information was used to estimate the type of land use that could be converted to development.

3. **Calculate developed land coverage after full buildout projection.** Each new building was assumed to generate new residential (Urban 1) and road (Urban 3, Other 1) land uses. Commercial land use (Urban 2) was excluded for Pleasant Lake due to the rural nature of the watershed. Specifically, the value of 0.34 ha of Urban 1, 0.12 ha of Urban 3, and 0.07 ha of Other 1 were multiplied by the number of new buildings in each sub-basin (total 0.53 ha converted per new building).

4. **Incorporate land use changes into LLRM for P loading predictions.** Add the new developed land use figures to the LLRM. Within each sub-basin, existing undeveloped land uses were replaced based on the percentage of projected new buildings on that land use type.

   Example:

   \[
   \left( \frac{\text{# new buildings on Forest3 in sub--basin}}{\text{total # new buildings in sub--basin}} \right) \times 0.53 \text{ ha} = \text{ha Forest 3 replaced by new dev. in sub -- basin}
   \]

   Forest 1: Deciduous, Forest 2: Non-Deciduous, Forest 3: Mixed, Agric 4: Hayfield, Agric 3: Grazing, Open 2: Meadow, Open 4: Logged, and Other: Tree Farm were replaced to account for new developed land use increases.

5. **Incorporate septic system loading into LLRM for P loading predictions.** The number of new buildings within 250 feet of water within each sub-basin was estimated from the CommunityViz output shapefile of projected new buildings. All other assumptions were kept the same based on 2010 census data and Pleasant Lake Septic System Survey.

6. **Adjust precipitation data based on potential climate change scenarios for the time frame of the projected build-out (2047-2062).** For the 2041-2070 projections, annual mean precipitation in the northeastern US is expected to increase by a median of 4% (B1, “low climate change” scenario) to 5% (A2, “high
climate change scenario). By the end of the century (2099), annual mean precipitation is expected to increase by approximately 10%.

7. **Keep all else the same, unless there are enough data to make appropriate model assumptions.**

**HISTORICAL TP LOAD - DEFORESTED CONDITION (EARLY SETTLEMENT)**

1. Convert all Urban land use and Forest to Meadow (Open 2) for each sub-basin and update model. Categories converted: Urban 1,2,4; Forest 1-3. All paved road land use (Urban 3) was converted to unpaved roads (Other 1). All other land use types remained the same.
2. Do not change septic inputs and do not remove internal loading (assuming the area was populated and internal loading was similar after human settlement began). Difficult to make assumptions about septic inputs, considering that the method of waste disposal was likely not as well managed despite a lower population. Much of the land was likely cleared for sheep farming, which would be another potential source of waste unaccounted for by converting land to meadow.
3. Keep all else the same, assuming waterfowl counts and atmospheric inputs did not change (though it likely did).

**RT. 107 INLET - CONVERT TREE FARM TO FOREST**

1. Convert all Other 3: Tree Farm land use to Forest 3: Mixed. All other land use types remained the same.
2. Do not change septic inputs and do not remove internal loading.
3. Keep all else the same, assuming waterfowl counts and atmospheric inputs did not change.

**CLARK BROOK - 100 FT BUFFER AROUND WATERBODIES AND WETLANDS**

1. Clip all land use within 100 ft. of waterbodies and wetlands in the sub-basin.
2. Convert all human land use from this clip (Open 3: Excavation, Other 2: Unpaved Roads, Urban 1: Low Den. Residential, Urban 3: Road) to Forest 3: Mixed. All other land use types remained the same.
3. Do not change septic inputs and do not remove internal loading.
4. Keep all else the same, assuming waterfowl counts and atmospheric inputs did not change.

**PLEASANT HILL ROAD - NO DEVELOPMENT**

1. Within the Veasey and Farrelly Brook sub-basins, convert all human land use to mixed forest (Forest 3) for each sub-basin and update model. Human land use categories converted: Urban 1-5, Agric 1-4, Open 3-4, Other 1-3. All other land use types remained the same.
2. Do not change septic inputs and do not remove internal loading as this cannot be separated by sub-basin.
3. Keep all else the same, assuming waterfowl counts and atmospheric inputs did not change.