MESSER POND

WATERSHED-BASED IMPLEMENTATION PLAN

Photo: Nancy Stetson, MPPA

Prepared by

Base Flow, LLC
3 Brimstone Hill Road
Amherst, NH 03031

Prepared for

Messer Pond Protective Association
PO Box 103
New London, NH 03257

Submitted to

New Hampshire Department of Environmental Services
Watershed Assistance Section
29 Hazen Drive, PO Box 95
Concord, NH 03302

April 4, 2016

Acknowledgements

Funding for this project was provided in part by a Watershed Assistance Grant from the NH Department of Environmental Services with Clean Water Act Section 319 funds from the U.S. Environmental Protection Agency.

Additional funding was provided by the New Hampshire State Conservation Committee through the Moose Plate Grant Program.

Technical assistance provided by the following individuals proved to be invaluable and was greatly appreciated:

Messer Pond Protective Association Members

Teri Bingham

Dick Denise

John Doyle

Scott Ellison

Patricia Harris

Dave Hennig

Curt Hineline

Marie Rossachacj

Sue Maguire Shock

Jack Shock

Richard Showalter

Ethan Simon

Bruce Stetson

Nancy Stetson

Barbara Troxell

Jeff Troxell

Others

Wendy Waskin, NHDES

Jeff Marcoux, NHDES

Contents

List of Figures

List of Tables

List of Appendices

1. Introduction

Messer Pond is 67 acres in size with a mean depth of 8.5 feet and a maximum depth of 25 feet (NHDES 2012a). Its watershed covers 1,408 acres made up of a mixture of forest, pasture/hay fields and residential development (NHDES 2012a). Both the pond and its watershed are situated entirely in the town of New London, New Hampshire.

Following a review of the 2008, 2010, 2012 and 2014 303(d) lists (NHDES 2014(b), 2012(b), 2010(a) and 2008(a)), it was found that beginning in 2010 Messer Pond was listed as impaired for Chlorophyll-a, total phosphorus and pH under the 'Aquatic Life' designated use description in the 2010, 2012 and 2014 lists.

Following initial concerns regarding water quality and pond health, in 2008 the Messer Pond Protective Association (MPPA) contracted CLD Engineering (CLD) to conduct a watershed study and to develop a best management practices (BMP) manual to be used by watershed residents to assist them in addressing erosion and stormwater management issues. CLD provided this information in a reported titled 'The Messer Pond Watershed Study' (CLD 2008). In early 2013, following discussions with New Hampshire Department of Environmental Services (NHDES) representatives regarding continued degrading pond water quality related to phosphorus and sediment, the MPPA decided to investigate further studies aimed at developing a Watershed-Based Implementation Plan (Plan). Later that year the MPPA contracted Base Flow, LLC to develop the Plan in coordination with MPPA management and volunteers. The goals of this Plan are:

- Identify and quantify pollutants being conveyed to the pond (i.e. nutrients and sediment);
- Develop a systematic approach for addressing existing pollutant sources to the pond as well as limiting future sources, such that water quality standards are met and maintained.

The Plan summarizes the field investigations data sources and land use based modeling that were used to to develop a series of structural and non-structural BMPs that will reduce phosphorus loadings and lead to impairment removal.

In addition to a large portion of this project being funded directly by the MPPA, financial support for this project was provided by a grant from NHDES with funding from the U.S. Environmental Protection Agency (US EPA) under Section 319 of the Clean Water Act. The MPPA also acquired a Moose Plate grant through the New Hampshire State Conservation Committee to help fund the project.

To achieve the goals listed above, this Plan includes the following nine elements, in conformance with the US EPA's guidance for watershed based plans:

1. Identify Pollutant Sources (Sections 2, 3 and 4)
2. Pollutant Load Reduction Estimates (Section 5 and 6)
3. Describe Nonpoint Source Pollution Management Measures (Section 8)

4. Estimate Technical and Financial Assistance (Section 9)

5. Public Information and Education (Section 10)

6. Implementation Schedule (Section 11)

7. Interim Milestones (Section 11)

8. Evaluation Criteria (Section 12)

9. Monitoring (Section 12)

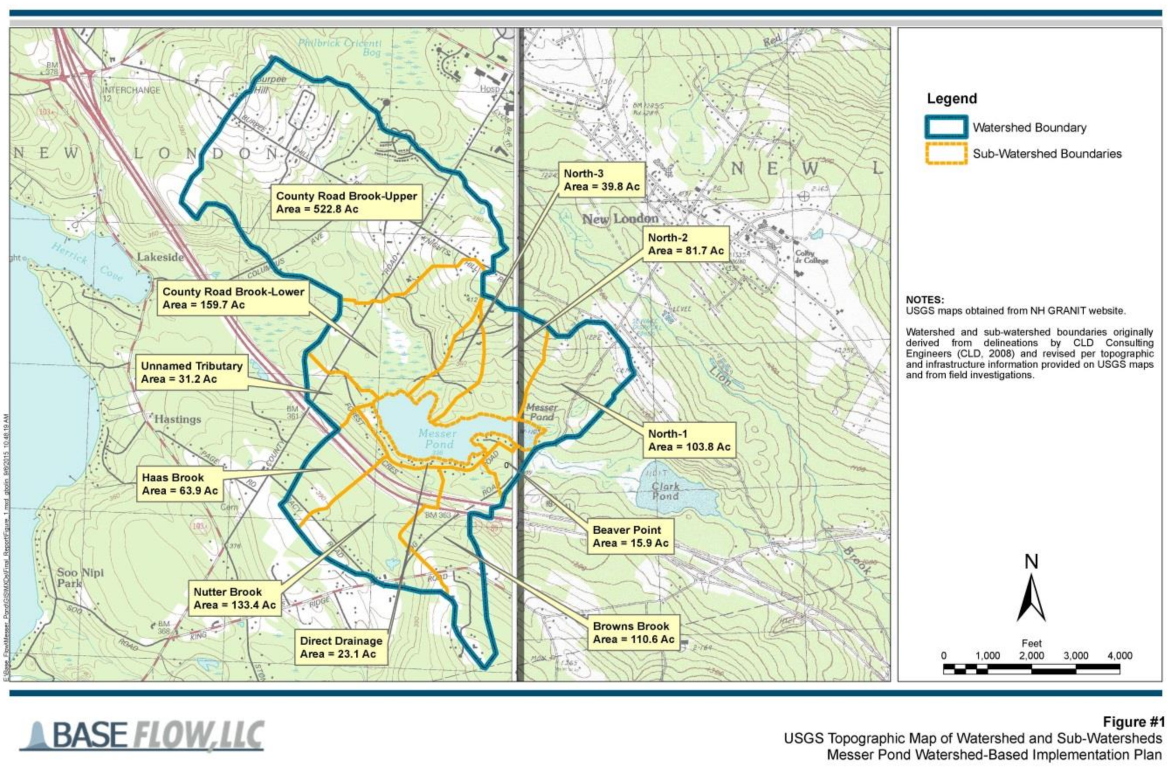

Figure 1. USGS Topographic Map of Watershed and Sub-Watersheds, Messer Pond Watershed

1.1. Pollutants of Concern

Several water parameters of Messer Pond are classified as “bad” or “slightly bad” by the NH Department of Environmental Services in the annual Volunteer Lake Assessment Program Individual Lake Reports. The following measures of water quality are unfavorable and may be trending in an unfavorable direction: phosphorus concentrations, chlorophyll-a concentrations; and the pH value, or acidity, is low.

The Waterbody Report Card tables are generated from the DRAFT 2014 305(b) report on the status of N.H. waters, and are based on data collected from 2004-2013. Detailed waterbody assessment and report card information can be found at www.des.nh.gov/organizations/divisions/water/wmb/swqa/index.htm

Designated Use	Parameter	Category	Comments
Aquatic Life	Phosphorus (Total)	Slightly Bad	The calculated median is from 5 or more samples and is > indicator and the chlorophyll a indicator is exceeded.
	pH	Bad	>10%, with a minimum of 2, samples exceed criteria, with 1 or more by a large margin.
	Oxygen, Dissolved	Encouraging	There are < 10 samples with 0 exceedances of criteria. More data needed.
	Dissolved oxygen satura	Cautionary	There are < 10 samples with 1 exceedance of criteria. More data needed.
	Chlorophyll-a	Slightly Bad	The calculated median is from 5 or more samples and is > indicator.
Primary Contact Recreation	Escherichia coli	Very Good	Where there are no geometric means, all bacteria samples are < 75% of the geometric mean. Where there are geometric means all single bacteria samples are < the SSMC and all geometric means are < geometric mean criteria.
	Chlorophyll-a	Very Good	There are a total of at least 10 samples with 0 exceedances of indicator.

Figure 2. 2014 Volunteer Lake Assessment Program Individual Lake Report for Messer Pond (NHDES 2014(a))

We focused the study on phosphorus for the following reasons. An increase in phosphorus leads to increased growth of algae; it causes the increased concentration of chlorophyll-a, a green pigment found in plants and the source of the aquatic life use impairment. Local human activity likely causes the increase in phosphorus concentration. Changes in human activity can prevent a continued increase. In contrast, the increased acidity most likely is a result of acid rain. There may be little we can do at the local level to affect this issue. As a result, our current efforts center on identifying and reducing the input of phosphorus to the pond.

The MPPA is concerned about the concentration of phosphorus for these reasons

- On-site observations indicate increased growth of weeds during the summer compared with historical observations.
- The concentration of phosphorus has been above the last 18-year average for 7 of the past 10 years.
- There is evidence of increased phosphorus concentrations in some of the tributaries, suggesting loading events may occur.

Although the average concentration of phosphorus in Messer Pondis 12 µg/L (see Figure 17), which is similar to both the NH median and similar lake median phosphorus concentrations(See Figure 4), it is more difficult for a shallow pond to recover from pollution than a deeper water body. There has been increased development of the watershed in the past 20 years, and development is likely to continue, creating the potential for additional pollutant loading on this shallow pond. As a result, it is important to understand and control the source of phosphorus input to Messer Pond to avoid reaching a ‘tipping point’ in which the phosphorus concentration begins to accelerate.

Phosphorus is a basic building block for plant and algae growth, and these organisms require it in certain ratios to nitrogen. Because less phosphorus is required in that ratio and nitrogen is relatively abundant, phosphorus is often referred to as the ‘limiting nutrient’ in New Hampshire lakes and ponds, and therefore drives the production of algae and plant growth. Because of this, increases in phosphorus levels are often strongly correlated with decreased water clarity, increased algal abundance and other indicators of declining water quality. Therefore, in this study we’ll focus on sources and conveyance of phosphorus to the pond.

In addition to phosphorus we also focus on better understanding sediment, since eroded sediments can convey varying concentrations of nitrogen and phosphorus through fluvial systems (the streams feeding Messer Pond,) depending on many factors, including the physical nature of the sediments, the typical background concentration of nitrogen and phosphorus in soils/sediment, etc. Similarly, sediment loads to the pond over time can reduce pond depth, leading to loss of assimilative capacity (i.e. 'dilution capacity') which can increase the probability of surface water quality standard exceedances.

pH Impairments

The observation of low pH values in water bodies is a common issue for ponds in the Northeast, and Messer Pond is no exception. Messer Pond has failed to meet water quality standards for pH in recent years. Some pond and tributary samples collected under the Volunteer Lake Assessment Program (VLAP) have had pH results that were below the lower recommended threshold (i.e. below 6.5; NHDES recommended range per NHDES Env-Wq 1703.18 is 6.5 to 8.0 for Class B waters).

Due to initial interest in pH impairments at the pond, a limited investigation regarding pH was conducted. However, since pH impairments are not the focus of this study and typically not the focus of a Watershed-Based Implementation Plan, additional discussion regarding pH impairments is provided in Appendix A of this report.

2. Literature and Data Review

This section provides a summary from several previous reports and data sources with regards to water quality issues at Messer Pond. The report summaries are presented below in chronological order.

2.1. Literature Review

NHDES Messer Pond Aquatic Plant Survey

On August 10, 2005 Amy Smagula of NHDES conducted a plant survey of Messer Pond (NHDES 2005). Ms. Smagula provided a summary of the survey in a letter, along with a map showing locations of species and a table summarizing specie information and abundance. Key findings included:

- The assessment determined that *'there is a healthy mix of aquatic plant growth in Messer Pond at this time. The plants that are found in Messer Pond are very common in New Hampshire, including yellow and white lilies, bladderwort, pickerelweed, and others.'*
- The most prevalent plant species was pickerelweed, distributed around nearly the entire shoreline.
- No aquatic exotic plants were found during the survey, however the NHDES advised that the MPPA *'continue to monitor once a month from May through September for these plants as a single boat could result in the introduction of an exotic plant that could pose problems for the pond.'*
- NHDES also advised that *'due to the shallow nature of the pond, and the clarity of the pond, there will be much habitat available for aquatic plant growth in the nearshore areas. Residents are advised to practice good watershed management activities to minimize nutrient loading to the pond, which will thereby slow both plant and algae growth.'*

CLD Report

See Section VIII, Concerns and Recommendations in the 2008 CLD Messer Pond Watershed Study (CLD 2008), located in Appendix B of this report. Key findings include:

- A significant portion of the recommendations discuss a buildup of sand throughout the watershed that have the ability of being conveyed to the pond during moderate to large rainfall events and/or during snow melt. CLD recommended removing these sediments and minimize impacts to the pond.
    - *Sand applications from this past winter are piled up on the local roads within the watershed.*
    - *A significant buildup of sand was noted on Forest Acres Road, Fieldstone Lane, Little Cove Road, and White Pine Lane.*
    - *Runoff from snowmelt has carried sands down into road ditches partially filling culverts, and depositing sand in streams close to Messer Pond. Any significant spring rains will carry these soils farther down the watershed and into Messer Pond. Observations of local roads in some of the other area towns did not show as much sand buildup along road shoulders. Road sweeping will remove some of this sand, but there is a lot deposited on the shoulders, on the slope into the ditch areas and in the road ditches. Much of this material will either need to be cleaned out with a small machine or by hand raking. If these sands are not removed from the ditches and culverts, the soil will be carried out into the streams and wetlands adjacent to Messer Pond.*
- Other sources of sediment within the watershed were of concern as well. Watershed surveys conducted under this study found the headwaters of Nutter Brook to be choked with sediment.
    - *Sediment carried in Nutter Brook down to the inlet area of the Pond is a major concern.*
- CLD recommended bracket sampling to further characterize pollutant sources.
    - *Bracketed sampling during both rain events and dry-weather flow in Browns' Brook, Nutter Brook, and County Road Brook can help better understand the source locations, variations in contaminant concentrations, and how they are influenced by rain events.*

Other Information

Messer Pond History - In addition to the literature sources listed above, MPPA volunteers have conducted a review of information held by the New London Historical Society and other sources to support the development of a history of Messer Pond. This summary is provided in Appendix C. The Messer Pond Protective Association website, www.messerpond.org, archives much of this information.

Septic System Investigation - Additionally, as part of the Septic System Investigation, MPPA volunteers researched town records to obtain septic system information for properties within the watershed. Septic systems are discussed further in Section 5 of this report.

Depth/Bathymetric Maps - A review of current and historical lake depth maps was conducted to assess whether there have been any significant depth changes over time. These maps are provided in Appendix D of this report (NHDES 2015).

2.2. Data Review

Eutrophication can be defined as the gradual process of nutrient enrichment in aquatic ecosystems such as lakes and ponds. Eutrophication is actually a natural process of lakes becoming more biologically productive over geological time, as they convert from lakes to wetlands over thousands of years. However, this process can be accelerated by human activities that occur in the watershed. Nutrients that contribute to eutrophication can come from many natural sources, including deposition of nitrogen from the atmosphere; and erosion of soil containing nutrients. They can also come from a myriad of anthropogenic sources, including fertilizers applied to residential lawns and agricultural fields; septic systems; and sewage treatment plant discharges. Likewise, land development and conversion of forests and fields to impervious surfaces not only increases the sources of nutrients, but also decreases opportunities for natural attenuation of these nutrients by vegetation and infiltration.

The presence of nutrients such as phosphorus and nitrogen provide for growth of algae and rooted plants in water bodies. Excessive levels of these nutrients can lead to an overabundance of plants and algae. Over time, this enhanced plant growth leads to reduced dissolved oxygen in the water, as bacteria demand oxygen as they facilitate the process of decomposing dead plant material. Since phosphorus is typically the "limiting nutrient" in freshwater systems, increases in phosphorus loadings to a lake are closely correlated with increases in plant productivity and accelerated eutrophication.

The extent of biological productivity in a waterbody can be described by its trophic state. Levels of dissolved oxygen, chlorophyll-a, transparency, and aquatic plant growth are used to determine the trophic state of New Hampshire lakes and ponds. Three trophic categories exist: oligotrophic lakes and ponds which tend to be deeper, larger lakes with low nutrient enrichment, plant and algal growth; mesotrophic lakes and ponds with moderate nutrient enrichment and plant and algal growth and moderate physical characteristics; and eutrophic lakes and ponds which are typically smaller in size and volume with a high degree of plant and algal growth, resulting in low dissolved oxygen levels. Currently Messer Pond is considered mesotrophic.

<u>NHDES and VLAP Data</u>

Following a review of the 2008, 2010, 2012 and 2014 303(d) lists (NHDES 2014(b), 2012(b), 2010(a) and 2008(a)), it was found that beginning in 2010 Messer Pond was listed as impaired for Chlorophyll-a, total phosphorus and pH under the 'Aquatic Life' designated use description in the 2010, 2012 and 2014 lists.

The MPPA has participated in the VLAP since 1996. Under this program the MPPA collects water samples from the pond at various depths and from tributaries entering Messer Pond and submits them to a certified laboratory for varied analyses, all under the guidance of the NHDES VLAP. NHDES uses this data to assess waters throughout the state; while the program serves as a means to keep track of pond or lake health, for a respective association.

Figure 3 on the following page is a graph provided in the annual lake reports published by the NHDES VLAP, and illustrates the historic trend for phosphorus and Chlorophyll-a concentrations in the epilimnion (surface water layer) of Messer Pond. This data, collected between 1996 and 2014 through the NHDES VLAP, indicated a low to moderate increase in phosphorus concentrations over the 18 year period.

Figure 4 offers a slightly different view of the data and includes trend lines. Provided as part of the older NHDES VLAP annual reports, Figure 4 provides graphs of historical transparency and epilimnion total phosphorus from the 2010 NHDES Annual Report (NHDES 2010(b)). These graphs indicate a similar low to moderate increase in phosphorus concentrations over the sampling period, and worsening transparency trends. Further review of the data collected under the VLAP program indicates the following negative trends in water quality:

- Pond transparency has steadily decreased (worsened) since sampling began in 1996
- Conductivity measurements have continued to remain much greater than the state median for similar lakes in the pond and tributaries
- Elevated phosphorus concentrations have been observed in tributaries under various weather conditions
- Measurements of dissolved oxygen in the hypolimnion (lower water layer of the pond) indicate potential for hypoxic or anoxic (low to no dissolved oxygen in saturation) conditions
- pH in the lake and tributaries are slightly acidic and oftentimes these waterbodies do not meet the state water quality standard

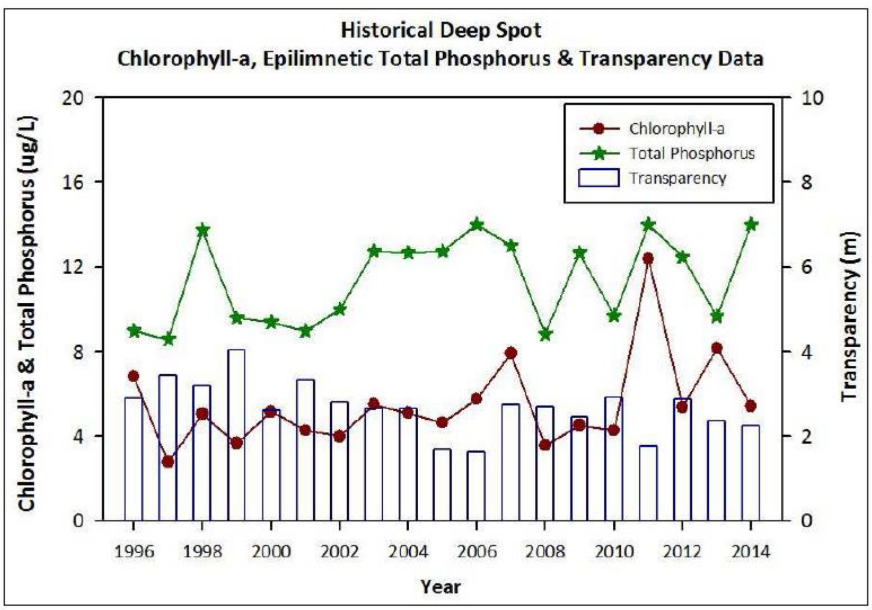

Figure 3. Historical Deep Spot Chlorophyll-a, Epilimnetic Total Phosphorus and Transparency Data for Messer Pond, New London, NH(NHDES 2014(a))

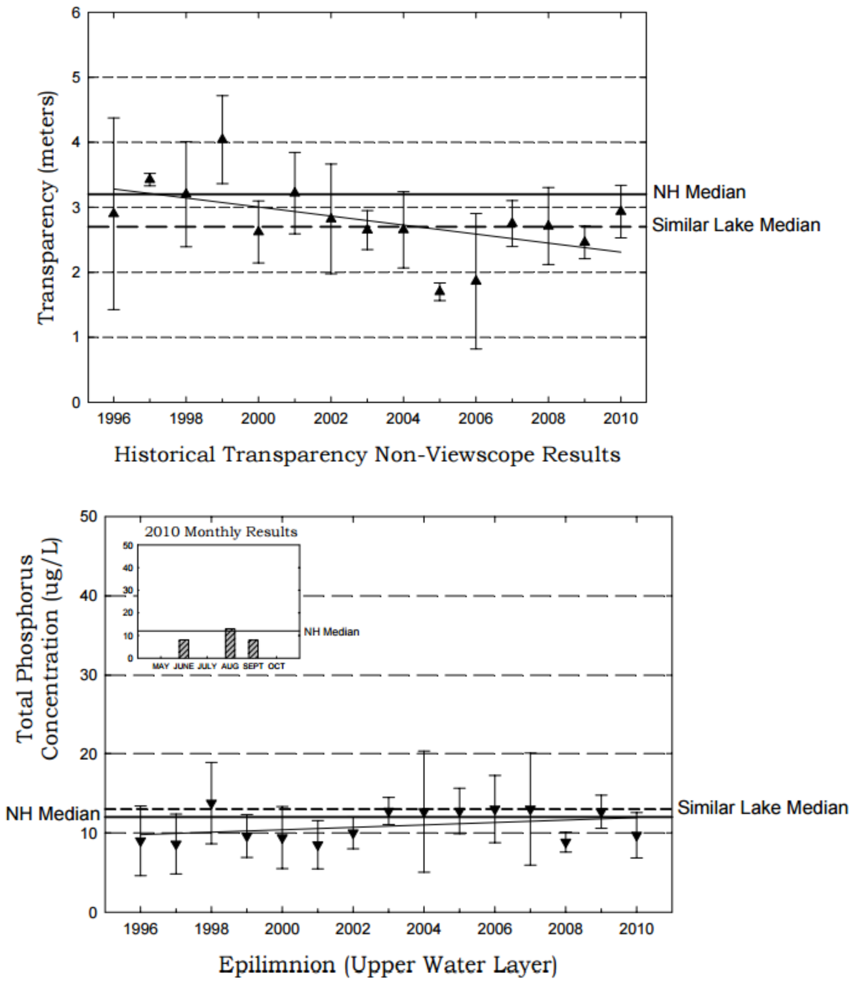

Figure 4. Historical Transparency and Epilimnion Total Phosphorus from the 2010 NHDES Annual Report for Messer Pond, New London, NH (NHDES 2010(b))

3. 2014 Monitoring Data

In order to successfully achieve the project goals, the MPPA and Base Flow agreed that a solid foundation of watershed flows, pollutant source identification and quantification was imperative. This foundation consisted of a comprehensive water budget and pollution budget, and watershed surveys that would facilitate pollution budget development via modeling, and ultimately lead to successful BMP/LID designs (Figure 5).

A water budget is a summation of water inputs, outputs, and net changes to a particular water resource system; in this case the sub-watersheds. A pollution budget is similar – a summation of pollutant inputs, outputs and net changes within a particular system; and for this Plan we focus on the export of pollutants to the pond from each sub-watershed, in addition to internal loading of pollutants from the pond bottom sediments. The purpose of the watershed surveys was to confirm sources of pollutants by visual observations. Overall the water budget, pollution budget, and surveys support the watershed modeling; which in turn was used to evaluate and design implementation projects. Water and pollution budget surveys will be discussed further and summarized in Sections 5-7 of this report.

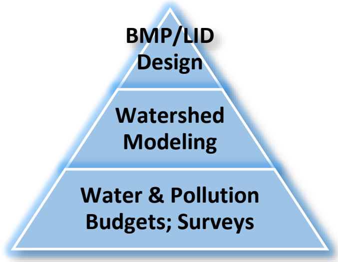

Figure 5. Illustration of the Overall Project Approach

3.1. Flow Monitoring

Base Flow conducted continuous flow monitoring at the four sampling stations shown on Figure 6 (see green dots in figure):

- Nutter Brook at Forest Acres Road
- Browns Brook at Forest Acres Road
- County Road Brook at County Road
- Pond Outlet at Bog Road

Onset HOBO® water level loggers (http://www.onsetcomp.com/products/data-loggers/u20l-04) were installed at each location at road crossings (*i.e.* culverts) in stilling wells, and water levels above a known datum were recorded every 6 minutes over the course of the monitoring period. The water levels were converted to flow (in units of cubic feet per second, cfs) using standard culvert equations available from the Federal Highway Administration (FHA 2005).

The flow data was used to calibrate the hydrologic portion of the watershed model, as discussed in Section 5 of this report.

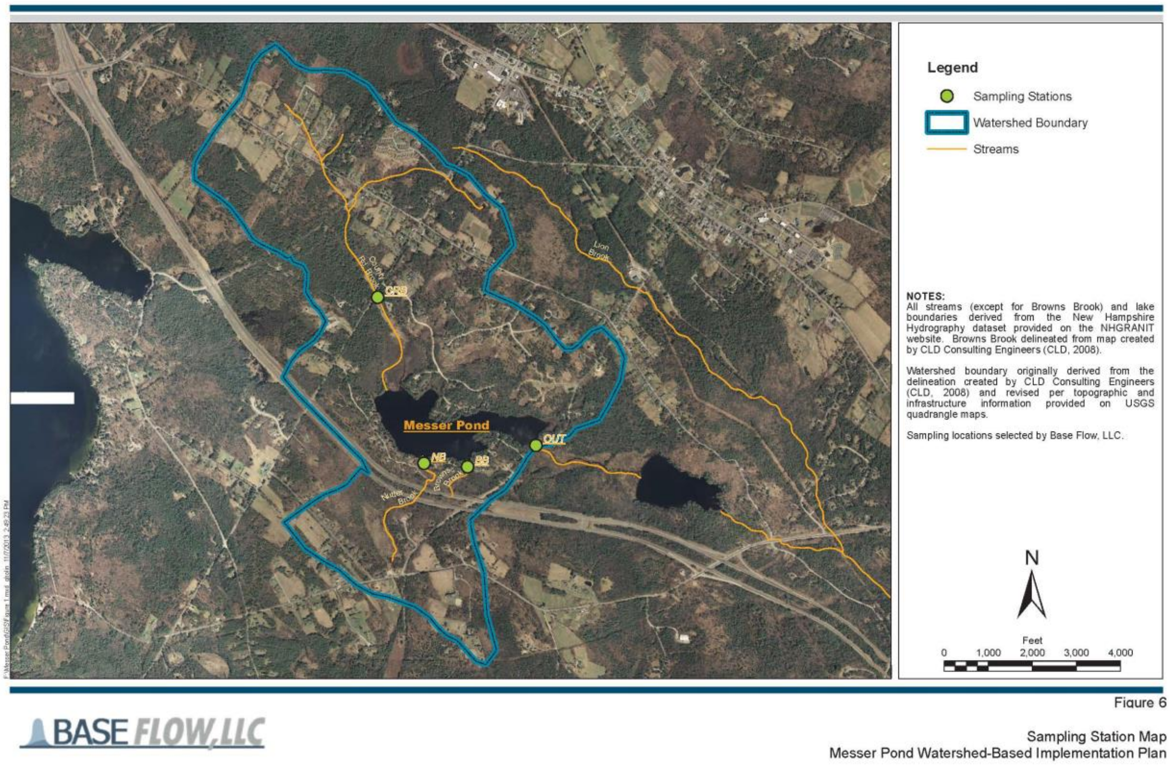

Figure 6. Sampling Station Map for the Messer Pond Watershed

3.1.1. Flow Monitoring Results

Plots of flow versus time (*i.e.* hydrograph) at each sampling station over the course of the project are provided in Figure 7.

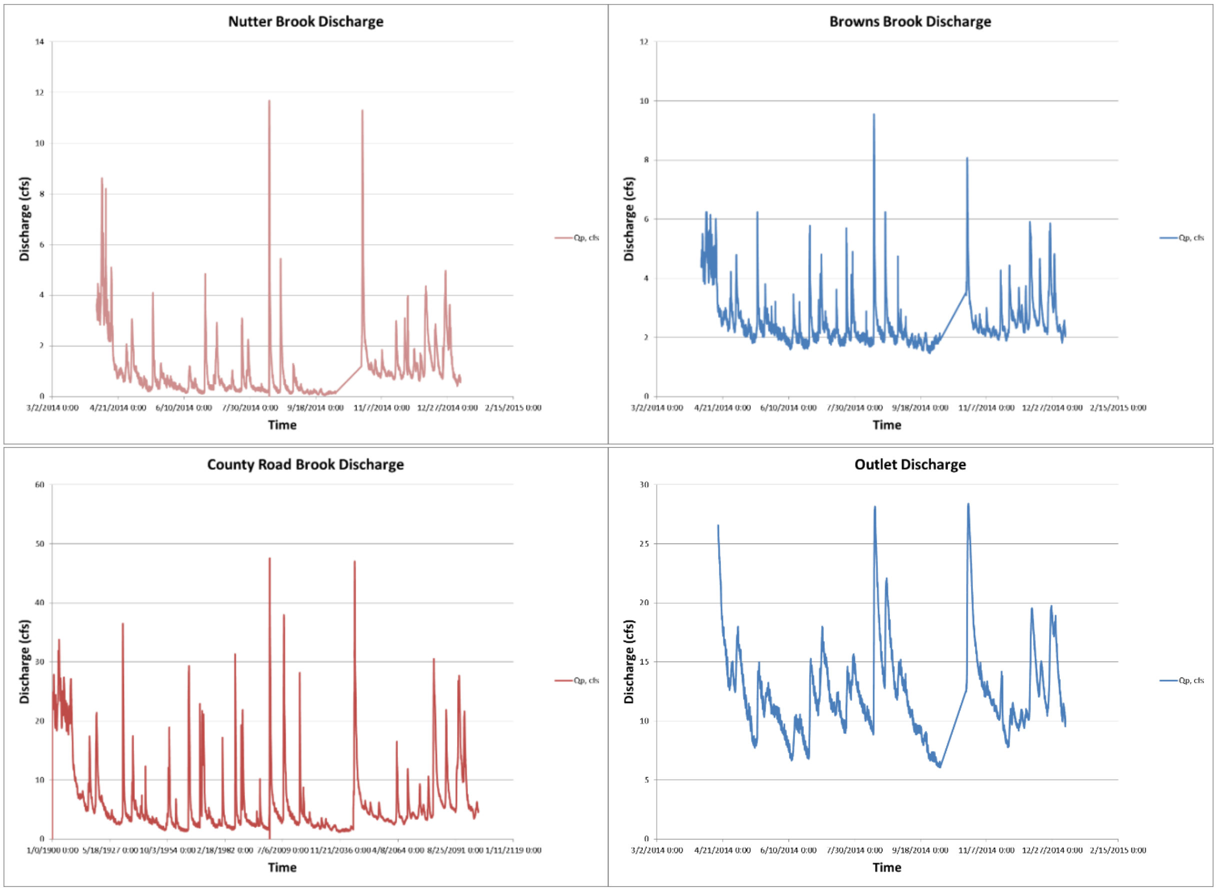

Figure 7. Flow versus time plots at Nutter Brook, Browns Brook, County Road Brook and at the Pond Outlet over the course of the project (April through December 2014).

Collection of flow data not only has utility for calibrating watershed models, but can also provide clues as to how stormwater and pollutants may potentially be transported through the watershed. The degree of impervious surfaces within a sub-watershed, the overall sub-watershed slope, amount of rainfall, rainfall intensity and where the storm occurs within a sub-watershed all play a role in the hydrograph response at a particular sampling station. For instance a hydrograph that peaks and falls very quickly is typical of a watershed that has a high degree of impervious surfaces (*i.e.* lots of paved surfaces or surfaces that do not provide for infiltration of stormwater runoff) and is sometimes referred to as ‘flashy’. Conversely, a hydrograph that is drawn out, has a dampened peak and falls slowly may be indicative of a watershed with minimal impervious surfaces and forests or open spaces that provide for infiltration. A watershed with a higher slope will typically produce a more ‘flashy’ response than one with a flatter slope because water is moving faster and may have less opportunity for infiltration. A more intense storm will also produce a higher peak than that of a less intense storm.

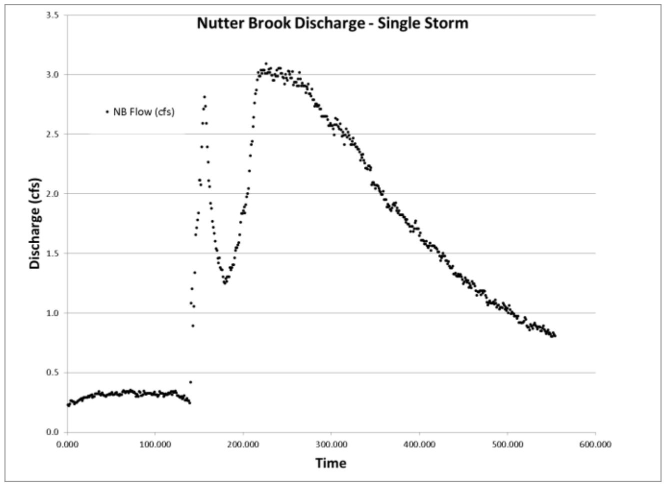

Figure 8. Flow versus time plot at Nutter Brook for a small storm event in July, 2014.

The hydrograph in Figure 8 is a hydrograph at the Nutter Brook sampling station. Nutter Brook is a moderately sloped sub-watershed with impervious surfaces associated with New Hampshire Interstate I-89, however it has other land uses, such as forests, hay/pasture and open space that provide for good infiltration and flow attenuation. This storm started with high intensity rainfall (characterized by the initial peak) followed by a break in rainfall, and finally more precipitation that fell at a moderate pace compared to the initial rainfall.

In general, the data suggest:

- Nutter Brook and County Road Brook have reasonably good flow attenuation, and are not as 'flashy', meaning it takes a moderate amount of time for the peak flows to arrive at the sampling stations
- The peak discharge rates for Browns Brook and Nutter Brook are similar, but Nutter Brook shows less of a response to modest rain events, such as the rain event near 9/14/2014, whereas Browns Brook is more flashy, potentially due to influence from I-89. Characteristics of Nutter Brook, as yet unidentified, may provide better flow attenuation.

3.2. Water Quality Sampling

Water quality samples were collected at the same sampling stations where continuous flow monitoring was performed (Figure 6). All water quality samples (dry and wet weather) were analyzed for the constituents listed below by Endyne, Inc. located in Lebanon, NH (using the sampling method noted in parentheses). The text that follows provides a summary of each constituent and explains its relevancy to the project.

- Conductivity (SM20 2510B)
- pH (SM20 4500H+ B)
- Total Phosphorus (SM20 4500 P-F)
- Total Suspended Solids (SM20 2540D)
- Turbidity (SM20 2130B)

Specific conductance – Specific conductance, or conductivity, measures the ability of water to conduct electricity by measuring the presence of ions in solution. Chloride is typically the predominant ion found in surface waters. Man-made sources of chloride ions in surface waters include road salt and wastewater, while natural sources include the weathering of soils and rocks by precipitation. Regional variations in watershed geology can result in a wide range of "background" conductance levels in our lakes and ponds. However, abnormally high conductance levels can be an indicator of pollutant sources such as road salting, wastewater discharges, and runoff from developed areas. The runoff from developed areas might contain fertilizers, animal waste, outputs from ineffective septic systems, and/or eroded soil. The median conductance value for New Hampshire's lakes and ponds is 0.04 mS/cm.

Historical VLAP conductivity samples in Messer Pond tributaries have consistently been high, potentially due to nonpoint source loadings of road salts, septic leachate and other man-made or natural influences. And anecdotal observations suggest many ponds 'downhill' from Interstate I-89 have higher than average conductance, suggesting road salt as a cause, but evidence is lacking. The measured conductivity in Messer Pond in 2014 was 140 µS/cm in the epilimnion and 150 µS/cm in the hypolimnion.

pH – pH is a measure of acidity based on the presence of hydrogen ions. A pH of 7.0 is neutral; a pH value below 7.0 indicates acidic waters and values above 7.0 indicate basic waters. Lower pH values found at depth in lakes and ponds could be due to biological decomposition that leads to the production of carbonic acid, thus leading to a lower, more acidic pH. This biological decomposition also demands oxygen, which can lead to anoxic, or oxygen-depleted conditions, in addition to other chemical reactions that reduce the magnitude of pH. Most fish cannot tolerate a pH below 4 or above 11, and their growth and health is affected by long-term exposure to a pH less than 6.0 and over 9.5.

In recent years VLAP samples have indicated low pH in many of the tributaries to Messer Pond as well as in the pond hypolimnion. Low tributary pH can be due to the breakdown of organic matter in wetlands connected to these tributaries; low pH in the hypolimnion is thought to be associated with the biodegradation of logs present at the bottom of the pond due to the use of the pond as a place for storage of fallen trees following the Hurricane of 1938 (see Pond History in Appendix C) and the production of carbonic acid. Acid rain and the degree of acid neutralizing capacity of the pond water due to surrounding geology play a role in pH levels as well.

Total phosphorus – Total phosphorus (TP) is a measure of all forms of phosphorus in the water: organic, inorganic, dissolved and particulate. As discussed above, in freshwater lakes and ponds phosphorus is usually the most important nutrient determining the growth of algae and aquatic plants because it's typically relatively less abundant than nitrogen, and is considered the "limiting nutrient" for biological productivity. Even low additions of phosphorus to a freshwater system can result in significant reductions in water quality, potentially leading to increased presence of algae, reduction in water clarity, and non-attainment of surface water quality standards. Identifying and quantifying phosphorus sources to the pond is the focus of this study in order to address the current water quality impairments due to excessive phosphorous.

Total Suspended Solids - Total Suspended Solids (TSS) are solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as sand, silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life.

High TSS can block light from reaching submerged vegetation. As the amount of light passing through the water is reduced, photosynthesis slows down. Reduced rates of photosynthesis causes less dissolved oxygen to be released into the water by plants. If light is completely blocked from bottom dwelling plants, the plants will stop producing oxygen and will die. As the plants decompose, bacteria will use up even more oxygen from the water. Low dissolved oxygen can lead to fish kills. High TSS can also cause an increase in surface water temperature, because the suspended particles absorb heat from sunlight. This can cause dissolved oxygen (DO) levels to fall even further (because warmer waters can hold less DO), and can harm aquatic life in many other ways, as discussed in the temperature section. (Mitchell and Stapp 1992).

Additionally, influx of sediment to lakes and ponds overtime is a natural process; lakes and ponds convert to wetlands over geological time as they accept sediment from their watershed through the natural erosion process. However this process can be accelerated over time as land use changes occur with water bodies experiencing losses in water volume over decades rather than centuries; thereby reducing the assimilative capacity (or dilution capacity) of the pond. Loss in assimilative capacity can lead to loss of transparency, more frequent water quality exceedances and degradation of overall water quality.

Turbidity – Turbidity is a measure of water clarity and how much the material suspended in water decreases the passage of light through the water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances. These materials are typically in the size range of 0.004 mm (clay) to 1.0 mm (sand). Turbidity can affect the color of the water as well. Similar to TSS, higher turbidity increases water temperatures because suspended particles absorb more heat and reduce the concentration of DO. As the particles settle, they can blanket the stream bottom, especially in slower waters, and smother fish eggs and benthic macro invertebrates (*i.e.*, aquatic insects.)

3.2.1. Dry Weather Sampling

Dry weather samples were collected at all four sampling stations shown in Figure 6. One sample from each location was collected during each of the four seasons to characterize dry weather water quality to support calibration of the watershed model. Samples were collected downstream of the culvert at each location with a laboratory-supplied sterile container and transferred to laboratory supplied sampling bottles, per the project Site Specific Project Plan (SSPP; Base Flow 2014). Samples were stored in coolers with ice and sent to the laboratory for analysis either the same day or the following day, and well within applicable holding times.

3.2.2. Dry Weather Sampling Results

Dry weather sampling results are provided in Table 1 below. Events were scheduled such that one event was collected in each of the four seasons throughout the project year (2014 - 2015); dates for each event are provided in the first column of the table. A statistical summary follows the results table.

Table 1. Dry Weather Sampling Data at Nutter, Browns and County Road Brook, and the Messer Pond Outlet

Event #	Nutter Brook					Browns Brook					County Road Brook					Outlet				
Date	Cond	pH	TP	TSS	Turb	Cond	pH	TP	TSS	Turb	Cond	pH	TP	TSS	Turb	Cond	pH	TP	TSS	Turb
#1 4/22/2014	250	6.6	13	<1	0.3	270	6.3	15	2	0.7	83	6.6	11	2	0.5	120	6.3	10	2	0.6
#2 6/19/2014	220	6.6	34	1	0.6	380	6.2	37	<1	1.9	100	6.7	17	<1	1.0	140	6.7	14	1	1.3
#3 9/25/2014	390	6.4	270	<1	0.9	370	6.2	820	180	160.0	110	6.5	230	20	5.6	120	6.7	110	1	0.4
#4 1/22/2015	280	6.3	24	<2	1.2	340	5.9	27	<2	1.8	85	6.4	20	2	2.2	120	6.2	18	3	1.0

Table Notes: Units: conductivity in umhos/cm; pH in standard units @20°C; TP in ug/L; TSS in mg/L; turbidity in NTUs. A sample with '<' indicates the result was below the laboratory detection limit.

- Dry weather conductivity measurements in Messer Pond tributaries ranged from 83 umhos/cm at County Road Brook to 390 umhos/cm at Nutter Brook. The average for all samples was 211 umhos/cm. The measured conductivity in Messer Pond in 2014 was 140 µS/cm in the epilimnion and 150 µS/cm in the hypolimnion (2014 VLAP report).
- Dry weather pH measurements in Messer Pond tributaries ranged from 5.9 at Browns Brook to 6.7 at County Road Brook. The average for all samples was 6.4. The measured pH in Messer Pond in 2014 was 6.5 in the epilimnion and 6.2 in the hypolimnion.
- Dry weather TP measurements in tributaries ranged from 10 at Outlet to 820 at Browns Brook. The average for all samples was 104.4. The measured TP in Messer Pond in 2014 was 14 µg/L in the epilimnion and 18 µg/L in the hypolimnion.
- Dry weather TSS measurements in tributaries ranged from <1 at numerous locations to 180 at Browns Brook. The average for all samples was 21.4.
- Dry weather turbidity measurements in tributaries ranged from 0.3 at Nutter Brook to 160 at Browns Brook. The average for all samples was 11.3. The measured turbidity in Messer Pond in 2014 was 1.5 NTU in the epilimnion and 2.3 NTU in the hypolimnion.

Sampling results for event 3 deviate significantly from the other 3 events for most of the parameters. It is expected that during dry weather conditions a given parameter will be relatively consistent over time, despite some reasonable variations due to seasonal effects related to rainfall, ground water fluctuations, air temperatures, etc. Therefore it is suspected that some kind of error occurred while collecting or analyzing the sample, including 1) sample collection error (*i.e.* stirring up of stream sediment prior to collection); and/or 2) laboratory analysis error. It is also possible that these values are accurate, and that a thunderstorm occurred in a localized portion of the watershed causing stormwater flows and transport of pollutants. The local rainfall gauge (Weather Underground – Job's Creek at Lake Sunapee [KNHSUNAP2]) recorded 0 inches of rainfall in the 5 days prior to sample collection.. An investigation of the flow gages do show some flow increase on 9/22/2015 prior to the event, however the peak flow magnitudes on each hydrograph are low. Overall, it's possible a localized thunderstorm occurred a distance away from the rain gauge which caused some hydrologic responses at the sampling stations, however the water quality results seem disproportionate to the hydrologic responses. Overall, the values from event 3 were not used to calibrate the dry weather portion of the model.

Further analysis of the data with respect to seasonal changes show that the lowest values of all parameters, for the most part, occur during event 1. This may be due to the significant amount of runoff that occurred during this event due to snowmelt. It's possible that a significant amount of sediment and other pollutants were being conveyed during this time, but due to the magnitude of meltwater in the streams sufficient dilution capacity was present to keep levels at or near the minimum values.

3.2.3. Storm Sampling

Wet weather samples were collected at all four sampling stations shown in Figure 6. One sample from each location was collected during each round of a wet weather event; 2 rounds of samples were collected per event. Events were initiated by the project team when the weather predictions met or exceeded specific criteria set forth in the SSPP (Base Flow 2014). Samples were collected downstream of the culvert at each location with a laboratory supplied sterile container and transferred to laboratory supplied sampling bottles, per the project Site Specific Project Plan (Base Flow 2014). Samples were stored in coolers with ice and sent to the laboratory for analysis.

3.2.4. Storm Sampling Results

Wet weather sampling results are provided in Tables 2 and 3 below. Results were used to calibrate wet weather TP and TSS concentrations in the watershed model. A statistical summary follows the results table.

Table 2. Wet Weather – Sampling Data at Nutter, Browns and County Road Brook, and the Messer Pond Outlet

Event #	Round #	Nutter Brook					Browns Brook					County Road Brook					Outlet					Bog Road				
		Cond	pH	TP	TSS	Turb	Cond	pH	TP	TSS	Turb	Cond	pH	TP	TSS	Turb	Cond	pH	TP	TSS	Turb	Cond	pH	TP	TSS	Turb
1	1	280	6.6	35	6	2.4	280	6.4	84	37	20	84	6.6	43	20	5.6	130	6.5	7	2	0.6	-	-	-	-	-
1	2	260	6.6	38	2	1.2	340	6.3	34	2	3.7	78	6.7	27	2	1.8	130	6.7	9	1	0.5	-	-	-	-	-
2	1	95	6.2	420	130	14	93	6.1	820	190	110	38	6.4	320	48	24	97	6.2	210	2	1.8	-	-	-	-	-
2	2	63	6.1	170	27	3.6	100	6.1	290	17	16	37	6.3	260	9	13	120	6.6	100	4	0.6	-	-	-	-	-
3	1	120	6.4	270	11	1.8	210	6.2	350	3	3.3	63	6.5	240	2	2.5	110	6.6	140	<1	0.6	160	6.5	220	30	11
3	2	79	6.1	160	12	2.7	130	5.9	170	4	6	42	6.2	250	4	7.5	110	6.5	110	<1	0.5	110	6.4	280	28	10

Table Notes: Units: conductivity in umhos/cm; pH in standard units @20°C; TP in ug/L; TSS in mg/L; turbidity in NTUs. A sample with '<' indicates the result was below the laboratory detection limit.

- Wet weather conductivity measurements in Messer Pond tributaries ranged from 37 umhos/cm at County Road Brook to 340 umhos/cm at Browns Brook. The average for all samples was 129 umhos/cm.
- Wet weather pH measurements in Messer Pond tributaries ranged from 5.9 at Browns Brook to 6.7 at County Road Brook and the Outlet. The average for all samples was 6.4.
- Wet weather TP measurements in tributaries ranged from 7 at the Outlet to 820 at Browns Brook. The average for all samples was 195.
- Wet weather TSS measurements in tributaries ranged from <1 at the Outlet to 190 at Browns Brook. The average for all samples was 24.7.
- Wet weather turbidity measurements in tributaries ranged from 0.5 at the Outlet to 110 at Browns Brook. The average for all samples was 10.2.

Table 3. Wet Weather – Physical Data, Messer Pond Watershed, New London, NH

Storm #	Date	Rainfall (in)	Duration (hrs)	Avg. Storm Intensity (in/hr)	Event # Round #	Nutter Brook	Browns Brook	Cty. Rd. Brook	Outlet	Bog Road
						Gage Height (ft)				
1	7/16/2014	0.99	7.75	0.13	1 1	0.28	0.95	1.5	0.69	-
					1 2	0.26	0.82	1.4	0.7	-
2	8/13/2014	1.76	10.75	0.16	2 1	1.78	2.56	submerged	0.88	-
					2 2	2.1	2.65	submerged	1.35	-
3	10/23/2014	1.92	13.25	0.14	3 1	0.86	1.42	2.04	0.98	no gage
					3 2	1.6	2.16	2.9	1.48	no gage

Table Notes: There was no gage installed at Brown's Brook and Bog Road; these samples were an attempt at bracket sampling during the final wet weather event of the program.
Antecedent (5 day) rainfall prior to each storm: Storm 1 – 0.15 inches; Storm 2 – 0.00 inches; Storm 3 – 0.39 inches.

- The storm with the most rainfall was storm 3, while the storm with the highest intensity was storm 2.
- The storm with the highest gage readings corresponds with the highest TP and TSS readings in Table 2.

Initial analysis of the sampling data shows that of all three storms, storm 2 (both rounds 1 and 2), for the most part, produce the highest readings of TP, TSS and turbidity at the four primary stations. These results correlate to the highest gage readings at each station in Table 3, indicating that: 1) larger flows may convey higher concentrations of target pollutants; and 2) higher intensity storms can be correlated with higher magnitudes of Non-Point Source pollution (NPS) and conveyance of target pollutants. Both of these findings are consistent with literature regarding NPS pollution and watershed hydrology. Conversely, storm 2 (both rounds 1 and 2) produce the lowest readings of conductivity at Nutter, Brown's and County Road Brooks, indicating that stormwater runoff may dilute conductivity concentrations, which may be primarily contained within groundwater, rather than surface water.

Although a lower conductivity measurement is found during storm 2 round 1, the difference is negligible.

Some of the lower readings over all storms were recorded at the Outlet. Rather than sampling at the end of a stream where measurements are directly influenced by surface water runoff and land use conditions, samples at the Outlet are collected from the Messer Pond 'reservoir' where substantial dilution and assimilative capacity is provided. Conversely, some of the higher readings over all storm events were recorded at Brown's Brook. Following watershed surveys and an assessment of this field data, it is suspected that the wetland associated with Brown's Brook came to existence as part of the construction of I-89 in the 1950s and that the flows being received by this area are altered (i.e. increased compared to pre-development flows) due to highway construction. Note that wetlands can typically take thousands of years to form; it is suspected that this 'artificial' wetland is ecologically young and in the process of breaking down a significant amount of organic matter while it converts from an upland to a wetland, and it is believed that the high nutrient levels being conveyed from this wetland are unnatural and due to this land use conversion.

Understanding that there was a significant water quality issue at Brown's Brook, an attempt at bracket sampling along Brown's Brook was made during storm event 3. Samples during rounds 1 and 2 were collected along Brown's Brook at Bog Road. Results when comparing to the original Browns Brook location were mixed for TP; TP was lower at Bog Road during round 1 but higher at round 2. Conductivity was lower at Bog Road, while pH was higher for both rounds, potentially indicating less acidic water above the Browns Brook wetland. However both TSS and turbidity were higher at Bog Road for both rounds.

4. Watershed Assessment

Watershed Soils

The soils found within the majority of the Messer Pond watershed are average to below average with respect to soil drainage and infiltration. The implementation of low impact development techniques such as bioretention cells, rain gardens and other stormwater management techniques promoting infiltration may require soil amendments or other special considerations to ensure proper function. Figure 9 (Soil Drainage Class Map) shows that most of the watershed soils are listed as Hydrologic Soil Group C, or soils that are classified as "moderately high" to "moderately low" draining soils (see Table 4). This indicates that the native soils have a fair capacity to infiltrate stormwater and that infiltrating stormwater practices can be expected to perform moderately well but again, may require soil amendments of special attention to drainage capacity and stormwater design.

Table 4. Hydrologic Soil Groups (USDA 2007)

Hydrologic Soil Group	Criteria
A	Low runoff potential when thoroughly wet. Water is transmitted freely through the soil. Typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures.
B	Moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures.
C	Moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures.
D	High runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. Typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential. All soils with a depth to a water impermeable layer less than 50 centimeters [20 inches] and all soils with a water table within 60 centimeters [24 inches] of the surface are in this group, although some may have a dual classification, if they can be adequately drained.

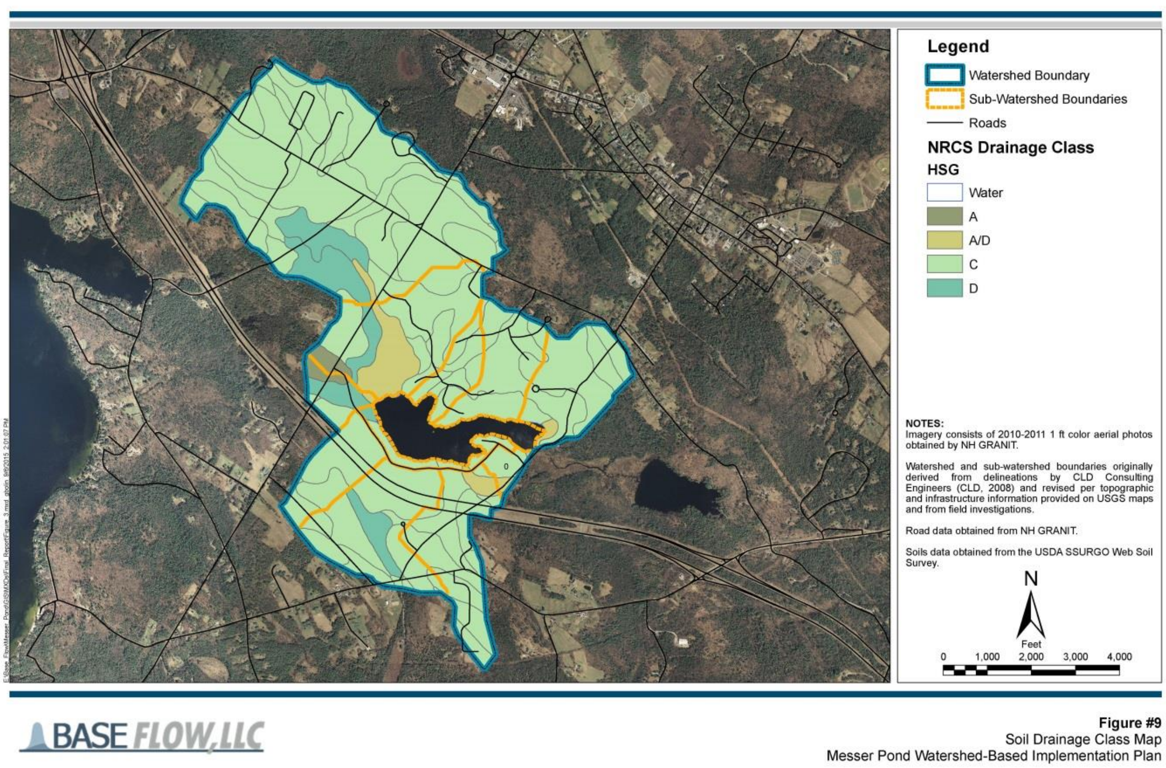

Figure 9. Soil Drainage Class Map for the Messer Pond Watershed

Watershed Land Use

Using land cover data obtained from the 2011 National Land Cover Dataset (NLCD) provided on the NH GRANIT website (http://www.granit.unh.edu/), percentages of watershed land uses for each sub-watershed and for the watershed as a whole were calculated. Table 5 provides a summary of those percentages. Note that the maximum percent land use is provided in bold.

Table 5. Percent Land Use Table for the Messer Pond Watershed

Sub-Watershed	% Land Use							
	Developed, Open Space	Developed, Low Intensity	Deciduous Forest	Evergreen Forest	Mixed Forest	Shrub/ Scrub	Herbaceous	Hay/ Pasture
CRB_Upper	8.5	5.3	7.4	**29.8**	24.5	1.1	0.0	23.4
CRB_Lower	6.1	0.0	6.1	**36.4**	28.8	15.2	1.5	6.1
Unnamed_Trib	19.3	14.5	0.0	**34.9**	16.9	0.0	0.0	14.5
Haas_Brook	13.7	22.1	8.4	8.4	**37.9**	5.3	0.0	4.2
Nutter_Brook	12.9	17.6	0.0	16.5	**32.9**	2.4	0.0	17.6
Browns_Brook	12.8	17.0	3.2	26.6	**30.9**	2.1	0.0	7.4
Beaver_Point	0.0	25.3	0.0	**44.0**	9.3	21.3	0.0	0.0
North_1	6.5	7.5	9.7	16.1	**45.2**	14.0	1.1	0.0
North_2	2.0	3.0	2.0	15.0	**45.0**	24.0	9.0	0.0
North_3	0.0	5.5	11.0	22.0	26.4	**34.1**	1.1	0.0
Direct_Drainage	16.9	22.1	0.0	**51.9**	9.1	0.0	0.0	0.0
Total Watershed	*8.8*	*8.6*	*5.7*	*26.3*	***29.5***	*7.0*	*0.9*	*13.3*

As Table 5 illustrates, the majority of the sub-watersheds have their highest degree of land use in the evergreen forest, mixed forest or shrub/scrub land use category. Figure 10 (Land Cover Map) provides this information spatially.

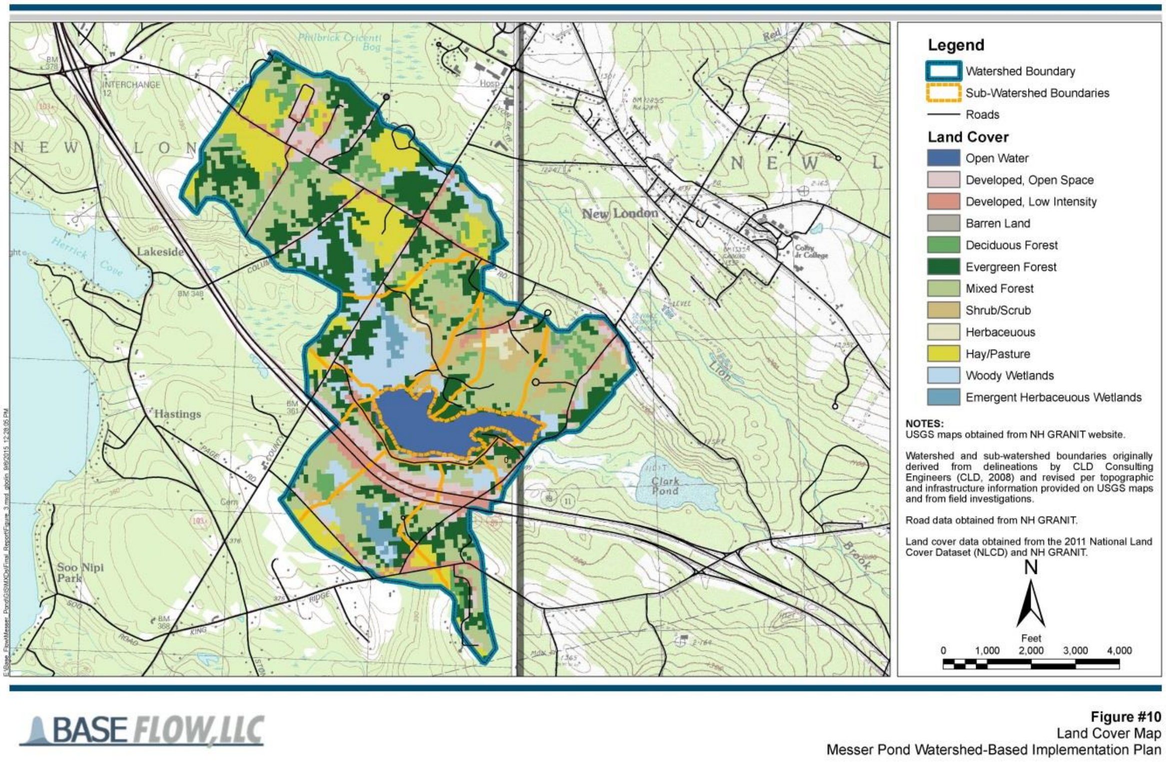

Figure 10. Land Cover Map for the Messer Pond Watershed

<u>Watershed Imperviousness</u>

Impervious surfaces are those land surfaces that are covered by impenetrable materials that do not allow for infiltration of rainfall or surface water runoff into the ground. These typically consist of asphalt, concrete, brick, stone, rooftops, etc. Heavily compacted soils can also act as impervious surfaces. Examples of these surfaces within the Messer Pond watershed are I-89 and County Road, two of the many asphalt paved roads in the watershed, and Forest Acres Road, which is a dirt road, that is well compacted and predominantly impervious.

Using land cover data obtained from the 2011 National Land Cover Dataset (NLCD) provided on the NH GRANIT website (http://www.granit.unh.edu/), percentages of watershed imperviousness for each sub-watershed and for the watershed as a whole were calculated. For this study, the 'Developed, Low Intensity' land use category was used to determine imperviousness for each sub-watershed. Approximately 7.28% of the watershed consists of impervious cover. Table 6 provides similar percentages for each sub-watershed.

Table 6. Percent Imperviousness Table for the Messer Pond Watershed

Sub-Watershed	Area (Ac)	% Imperviousness
CRB_Upper	522.8	4.7
CRB_Lower	159.7	0.3
Unnamed_Trib	31.2	12.4
Haas_Brook	63.9	20.6
Nutter_Brook	133.4	15.0
Browns_Brook	110.6	16.4
Beaver_Point	15.9	18.6
North_1	103.8	6.9
North_2	81.7	3.3
North_3	39.8	5.1
Direct_Drainage	23.1	16.8

As Table 6 illustrates, sub-watershed percent imperviousness ranges from a low of 0.28% (the wetland portion of the County Road Brook watershed) to a high of 20.56 (the Haas Brook watershed) due to the proximity of I-89. Figure 11 (Sub-Watershed Impervious Cover Percentage Map) provides this information spatially.

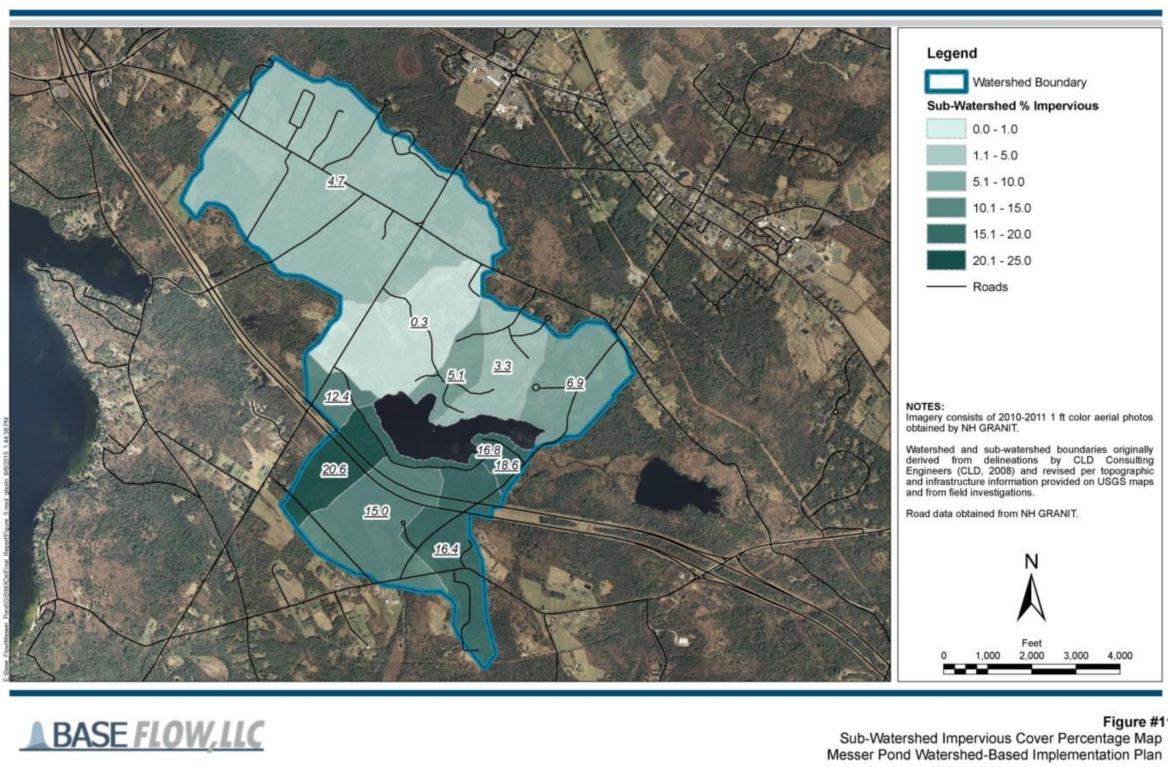

Figure 11. Sub-Watershed Impervious Cover Percentage Map for the Messer Pond Watershed

As shown below, the Impervious Cover Model developed by the Center for Watershed Protection (CWP 2003) predicts that at 10% impervious cover, streams begin to transition from the "sensitive" to "impacted" category with regard to stream quality indicators. Under 10% you would expect to see streams void of significant bank erosion, have ample riparian buffer and vegetation, and have favorable water quality. Beyond 10% impervious cover you would start to expect these conditions to degrade. Currently, the Messer Pond watershed as a whole is in the sensitive category, however, most sub-watersheds adjacent to I-89 are in the 'impacted' category due to the large percent imperviousness associated with the highway. Consistent with this model, during the watershed survey portions of Nutter, Browns and Haas Brooks were observed to have impacted physical conditions thought to be due to the highway and associated runoff from those impervious surfaces. Likewise, similar observations of channel condition and erosion were found in the Beaver Point and Direct Drainage sub-watersheds. Along County Road Brook, stream quality with respect to physical condition and bank stability were in very good condition.

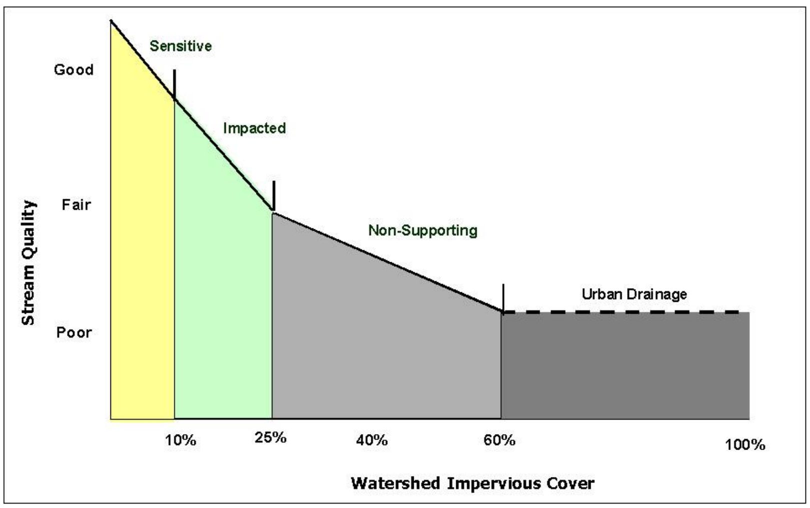

Figure 12. Impervious Cover Model, Developed by the Center of Watershed Protection (CWP 2003)

Septic System Investigation

MPPA volunteers conducted a septic system survey of waterfront lots that bordered the pond to support this project. The first step in the study was to identify the waterfront lots. Based on those lots, members researched records at town hall and obtained the following information:

- Parcel Number, Address, Block, Lot
- Age of house
- Age of septic system
- Occupancy Rating (3 bedrooms, 4 bedrooms, etc.)
- Distance of system to water
- House use (year-round/seasonal use)
- How often pumped

- Last time pumped

For those properties where records were not found at town hall, the survey team contacted homeowners individually. Records were found for 29 of 58 properties, or 50% of the properties that bordered the pond. The ages of the systems ranged from 44 years old (installed in 1971) to 2 years old (installed in 2012). Occupancy ratings ranged from 2 to 4 bedrooms. For those lots where data was obtained, the average distance between the systems and the pond shoreline was 109 feet, and 48% of the systems were associated with year-round house use (as opposed to seasonal). Very limited information was available regarding pumping frequency. A table summarizing the results of the septic survey are provided in Appendix E.

The septic system survey performed under this study, although thorough, only focuses on properties and systems that border the pond. In order to completely understand impacts from septic systems watershed-wide, if is recommended that additional survey work is needed (*i.e.* gather information on septic systems in lots along tributaries, in the 'second layer' of homes back from the shoreline, and to obtain further information from the waterfront lots where no information was collected under this initial effort.

5. Messer Pond Phosphorus Budget

The Messer Pond phosphorus and sediment budgets incorporate a number of potential sources, each one estimated by a particular method. Table 7 provides a summary of the potential source and how each load was estimated.

Table 7. Summary of Loading Type Estimate Methods

Loading Type	Estimation Methodology
Watershed Loadings	Watershed Model
Septic Loadings	Calculations
Atmospheric Loadings	Calculations
Internal Loading	Calculations

<u>Land-Use Based Pollutant Modeling</u>

Base Flow used the USEPA's Storm Water Management Model (SWMM) to model hydrologic and pollutant loading processes in the Messer Pond watershed. SWMM incorporates the dynamic interactions of the hydrology, hydraulics and pollutant transport that occur within a watershed, allowing for more accurate pollutant loading estimates. The model was able to simulate the following:

- *Meteorological* – simulates rainfall on land surfaces, air temperature, evaporation

- *Hydrology* - simulates interaction of rainfall, initial subtractions such as infiltration and interception by vegetation; and transport of water over the land surfaces to waterways (resultant runoff, runoff speed over surfaces)
- *Hydraulic* – simulates transport of water through channels, culverts, etc.
- *Pollutants* – build-up and runoff of pollutants from various land uses, transport of pollutants to edge of stream, pollutant transport through channels (and accretion/erosion and shear stresses for stream sediments)

The model was built by specifying the following parameters and linking to various data inputs:

- Simulation Options
    - The time step, which updates numerous calculations related to hydrology, pollutant buildup and runoff was set to every 5 minutes for both dry and wet weather conditions
    - The Horton Infiltration Method was selected to simulate infiltration
    - The start/end dates for model runs was set to January 1 and December 31 of 2014, respectively
- Climatology
    - Temperature at half hour increments in degrees Fahrenheit was specified for the model year
    - Parameters to define snow formation and melt were specified for the model year
- Hydrology
    - Rainfall at fifteen minute increments in inches was specified for the model year (source: Sunapee Lake Dam located at the western end of Sunapee Harbor; provided by NHDES)
    - Sub-watersheds were delineated based on topography and basic infrastructure (i.e., roads, stormwater piping, etc.)
    - Parameters for sub-watershed area, sub-watershed width, land slope, percent impervious, Manning's N values for pervious and impervious surfaces, depression storage for pervious and impervious surfaces, and infiltration parameters (maximum and minimum infiltration rates, infiltration decay constants, soil drying time) were specified for each sub-watershed
- Water Quality
    - Pollutant buildup (using a power function – maximum buildup, buildup rate constant, buildup power/saturation constant) for TP and sediment were specified for each land use, using values from literature
    - Pollutant washoff coefficients (using an exponent function – washoff coefficient and washoff exponent) for TP and sediment were specified for each land use, using values from literature
- Time Series
    - Time series of existing flow and water quality data from tributaries collected under this project were imported into the model for use in calibration and model validation

Once model development was complete, diagnostic model runs were performed to ensure preliminary results were within reasonable and expected tolerances. Following diagnostic runs, calibration runs were performed.

Calibration of the model consisted of two components – 1) hydrologic calibration, and 2) water quality calibration. Hydrologic calibration included the adjustment of up to five hydrologic-related parameters (watershed width, % impervious, maximum and minimum infiltration rate and slope, in that order) to optimize the best fit between model vs. field data for storm sampling events. An example of this best fit is provided as Figure 13. Water quality calibration was performed in a similar manner, adjusting the buildup and washoff coefficient factors using a best fit approach relative to model vs. field data. A similar example for water quality is provided as Figure 14.

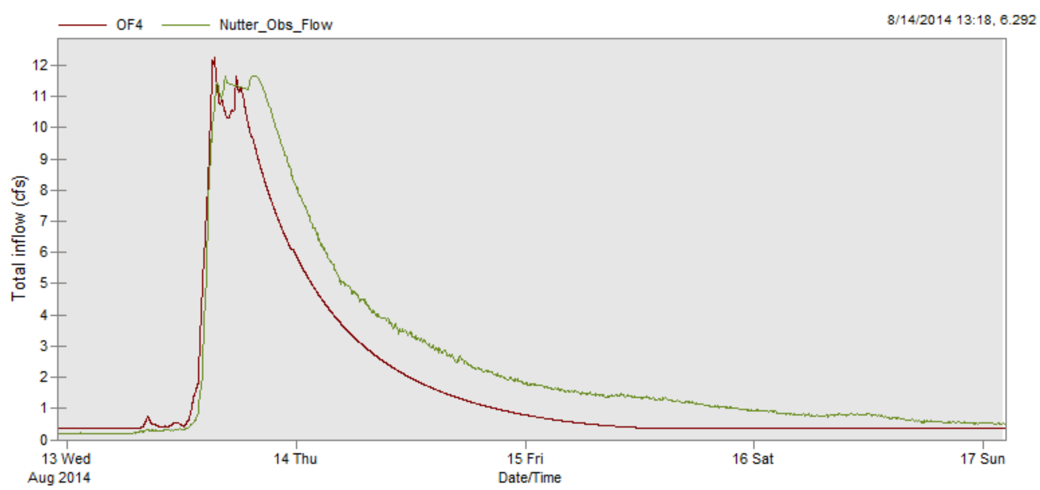

Figure 13. Hydrologic Model Calibration at Nutter Brook, During Storm Event 2

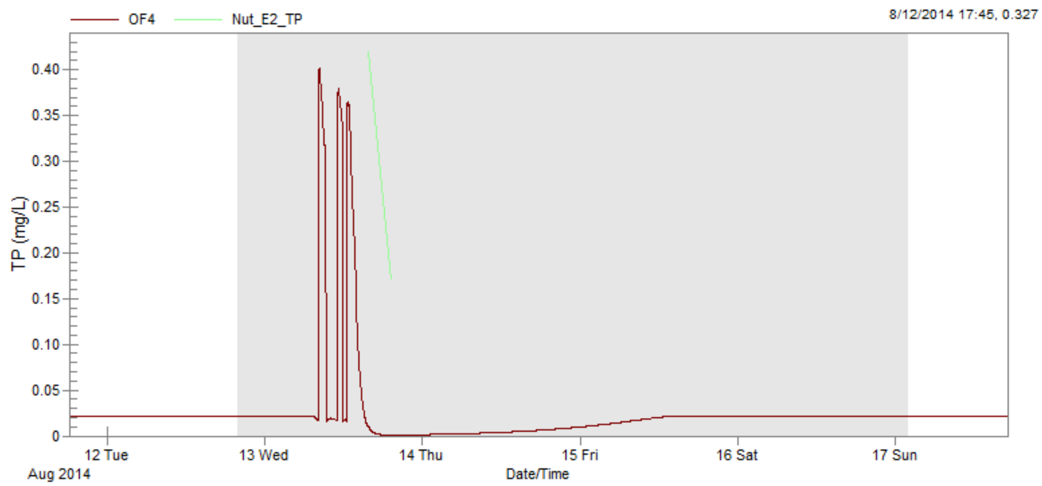

Figure 14. Water Quality Calibration at Nutter Brook, During Storm Event 2

Once model calibration was complete, the model was run for the 2014 model year and results were summarized, as provided later in this Section. An additional model run was performed for the Build Out Analysis, as discussed at the end of this Section.

Phosphorus Loading from Septic Systems

Using results from the Septic System Investigation, calculations were performed to estimate phosphorus loads from sanitary systems located around the perimeter of the pond. For these calculations, seasonal occupancy was assumed to be three months per year, resulting in an average occupancy of just over seven months per year. The estimated phosphorus load to the pond from on-site sanitary systems bordering the pond was 15.25 lbs P/yr, as calculated using the following equation:

$$M = (ES)(\#\ Capita\ Years)(1-SR)$$

Where:

M is the predicted phosphorus loading (lbs P/yr);

ES is the phosphorus export coefficient of 1.1 lbs P/capita-year. ES was determined based on literature published by the US Geological Survey and the University of Delaware extension program;

Capita Years is the product of the number of parcels with septic systems (29 lots) multiplied by the average number of residents per parcel (3.1 residents/parcel for New London, NH) and the average occupancy (7.4 of 12 months or 0.62);

SR is the soil retention coefficient (0.75). The soil retention coefficient represents an estimate of the system's ability to immobilize phosphorus and may range from 0 to 1.0. A soil retention coefficient value of 0 would be selected if it's assumed that all phosphorus from the system reaches the pond; while a coefficient of 1 is used if it's assumed that no phosphorus reaches the pond (Reckhow, 1980). Factors that influence the SR value include phosphorus adsorption capacity of the soil, natural drainage, soil permeability, and slope. Reckhow also states that because of the complexities involved, the modeler's estimation of SR still must be based on existing soil conditions, past experience with similar watersheds and professional judgment. For Messer Pond a SR value of 0.75 was used because it was consistent with the published range of SR values in the northeast, was similar to values used in other recent watershed-based implementation plans submitted to NHDES and resulted in an estimated phosphorus load that appeared to be reasonably consistent with both the overall loading model for the lake and observed TP concentrations.

The estimated total phosphorus load from septic systems (15.25 lb/year) represents approximately 13.5% of the total annual estimated phosphorus load to the pond.

The contribution could be higher if the leach fields of just a few septic systems do not function well. To know if this is the case, we would need to do further visual observation of each septic system, and/or high-density measurements of stream and shoreline water conductivity.

The model also does not account for loading from septic systems along the inlet streams.

<u>Atmospheric Deposition</u>

Atmospheric deposition of phosphorus occurs via phosphorus-containing particles delivered through precipitation (rain, snow, etc.) or during dry weather. An estimated atmospheric loading directly to the surface of Messer Pond was calculated assuming a deposition rate of 0.185 lb P/ac/yr, similar to other watershed-based implementation plans recently submitted to NHDES. A total annual atmospheric load of 13.3 lb P/yr was calculated using this method.

<u>Internal Phosphorus Loading</u>

Internal recycling of phosphorus can be a significant source of overall phosphorus load to an aquatic ecosystem. Typically, phosphorus is bound to bottom sediments and also present in the interstitial spaces between those sediments. During periods of anoxia (oxygen concentration ≤ 1 mg/l), phosphorus can be released into the water from these sediments in dissolved form, making it biologically available to algae present in the water column.

As discussed in Section 2.2 and illustrated in Figure 15, conditions at the pond during the warmer months indicate the potential for hypoxic conditions, as was the case in 2012. Aware of this, the MPPA requested that Base Flow pursue concerns regarding potential phosphorus loading from pond sediments under this study. To facilitate this evaluation, a regression equation obtained from literature was used to calculate an internal phosphorus flux from sediment based on sediment phosphorus concentration. In January 2015, MPPA and Base Flow representatives collected a sediment sample from the deep spot and sent the sample to Endyne, Inc. in Lebanon, NH for analysis of total phosphorus and total dissolved phosphorus. Results were 530 and 160 mg/kg dry weight, respectively (using analytical method SM20 4500 P-F).

Those results were used in the following regression equation, which is based on a study involving 3 to 21 cores each from 14 sample sites of 8 North American lakes and 63 literature data from lakes worldwide (Niirnburg 1994):

$$RR = -4.3 + 3.88\ TP_{sed}$$

Where:

RR is the areal release rate (mg/m^2-yr);

TP_{sed} is the sediment total phosphorus concentration (mg/g).

In order to use this areal release rate to determine an overall phosphorus load to the pond during deep anoxic conditions, an area of the pond that turns anoxic was required, in addition to an amount of days of anoxic conditions. Based on conservative judgment, values of 10 m^2 and 60 days, respectively, were assumed. The area of 10 m^2 was assumed to be centered around the pond deep spot where anoxic conditions have been previously observed.

The estimated total phosphorus load from internal phosphorus loading under summer anoxic conditions using these equations was 0.1 lbs during the 60 day period. Because this value was so low, internal phosphorus loading was thought to be insignificant and therefore not included in the overall loading analysis.

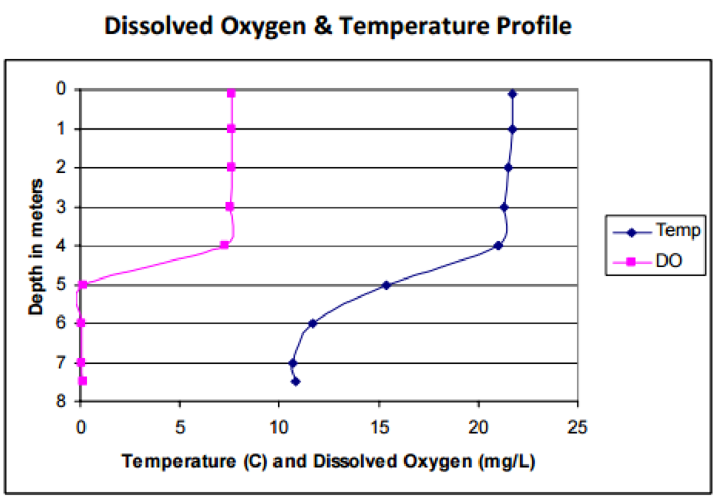

Figure 15. Plot of Depth Versus Temperature and Dissolved Oxygen from the NHDES VLAP 2012 Data Summary for Messer Pond, New London, NH (NHDES 2012(a))

<u>Estimated Annual Phosphorus Loading Budget</u>

In order to develop an estimate of the annual phosphorus loading to Messer Pond, all external loadings are combined; the phosphorus loadings from septic systems and atmospheric sources derived from calculations, plus the loading from the watershed derived from watershed modeling all contribute to the total annual external load of **113 lb/year**, as presented in Figure 16. In summary:

- The phosphorus load generated from watershed modeling (i.e. surface water runoff conveyed over land uses in the 11 sub-watersheds of Messer Pond, plus seasonal baseflow from streams) accounts for 74.8% (84.5 lb) of the annual external phosphorus load to the lake

- Phosphorus loading from septic systems is estimated to account for 13.5% (15.3 lb) of the annual external phosphorus load
- Atmospheric deposition, including wet and dry deposition, is estimated to account for 11.7% (13.3 lb) of the annual external phosphorus load to the lake

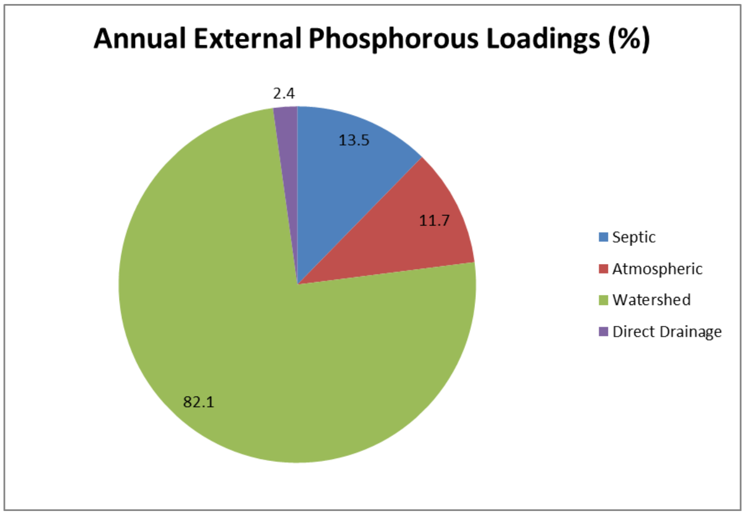

Figure 16. External Sources of Phosphorus to Messer Pond, Totaling 113 lb/year

The annual loading generated by the watershed model is broken down further in Table 8 below. The estimated annual P load in total pounds, pounds per acre and percentage of the total P load generated from each sub- watershed is provided.

Table 8. Watershed Modeling Estimated Annual P Load by Sub-Watershed for Surface Water Run-off, Messer Pond Watershed

Sub-Watershed	Size (ac)	Estimated Annual P Load		% of Watershed Total P Load
		Total (lbs)	Per Acre (lbs)	
CRB_Upper	522.8	35.7	0.07	42.2
CRB_Lower	159.7	5.5	0.03	6.5
Unnamed_Trib	31.2	3.3	0.10	3.9
Haas_Brook	63.9	6.3	0.10	7.5
Nutter_Brook	133.4	9.2	0.07	10.9
Browns_Brook	110.6	11.0	0.10	13.0
Beaver_Point	15.9	1.4	0.09	1.7
North_1	103.8	4.9	0.05	5.8
North_2	81.7	3.0	0.04	3.5
North_3	39.8	1.7	0.04	2.1
Direct_Drainage	23.1	2.4	0.11	2.9
Messer Pond Watershed (total)	**1285.9**	**84.50**	**0.07**	**100.00**

Vollenweider Equation Results

The Vollenweider model is commonly used to predict in-lake phosphorus concentrations as a function of annual phosphorus loading, mean lake depth and hydraulic residence time. Phosphorus concentrations predicted by the Vollenweider equation are based on an assumption that the lake is uniformly mixed, such as at spring turnover. The Vollenweider model is based on a five-year study of about 200 waterbodies in Europe, North America, Japan and Australia. The Vollenweider Equation is provided below, with calculations for Messer Pond based on the total annual external phosphorus loading estimate discussed above.

$$P = L_p/(q_s (1 + \sqrt{\tau_W}))$$

Where:

P = mean in-lake phosphorus concentration (mg/L);

L_p= annual phosphorus load/lake area, (grams/m2/year);

τ_w = hydraulic residence time (yr);

q_s = hydraulic overflow rate = mean depth/hydraulic residence time (m/yr) = z/τ_w;

z = average depth (m)

Hydraulic residence is calculated as follows:

$$\tau_w = Q/V$$

Where:

Q = annual discharge passing through the pond (m3/yr);

V= pond volume (m3)

Annual discharge, Q, was taken from watershed modeling and water budget calculations (Section 7). Volume, V, was taken from VLAP Individual Lake Reports (NHDES 2014(a)). Table 9 below summarizes the parameters used in the Vollenweider calculation.

The Vollenweider equation contains an implicit assumption that particulate phosphorus becomes sequestered in lake sediment via settling to the pond bottom. The formula makes the assumption that settling velocity can be approximated as:

$$v = q_s\sqrt{\tau_w}$$

Typical measured values of settling velocity range from 5 to 20 m/yr (Chapra 1975). For Messer Pond, where q_s = 2.35 m/yr and τ_w = 2.12 yr,

$$v = q_s/\tau_w = (3.4 \text{ m/yr})\sqrt{(0.8 \text{ yr})} = 3.04$$

Or 3.04 m/yr, which is lower than the typical range. Using a low settling velocity value could lead to an erroneously high modeled in-lake P concentration. To provide a better representation of conditions specific to Messer Pond, a settling velocity coefficient was included in the equation as described below.

Brett & Benjamin (Brett et al. 2008) state, "…both the particulate phosphorus fraction and the particulate settling velocity distribution vary greatly during the course of the year in most lakes and especially between lakes, and… as a result, v is likely to have different values in different lakes, and during different seasons in a single lake, thereby reducing the predictive value of the equation." They statistically analyzed several variations of the Vollenweider model, including the version above and another version that assumed:

$$v = q_s \cdot k\sqrt{\tau_w}$$

They found that the addition of a settling velocity coefficient (k) as in the above formula yielded a better statistical fit to existing data for over 300 lakes. A similar approach has been used below to calibrate the Vollenweider equation to match the observed average in-lake P concentration (12 µg/L, based on a statistical average of historical epilimnion P data, see Figure 15 below) for Messer Pond.

Table 9. Summary of Vollenweider Parameters for Messer Pond

Vollenweider Model Parameters			
Parameter	**Symbol**	**Value**	**Units**
Total P Loading Rate	W	51.3	kg/yr
Lake Volume	V	7,000,000	m3
Average Depth	z	2.6	m
Annual Discharge	Q	9,042,595	m3/yr
Lake Area	As	290,139.80	m2
Areal Loading Rate	L_p	176.7	mg/m2
Hydraulic Overflow Rate (m/yr)	q_s	3.4	m/yr
Hydraulic Residence Time (yr)	τ_w	0.8	yr
Settling Velocity Coefficient	k	3.7	-

$$\text{In-lake P concentration} = P = L_p/(q_s\,(1 + k\sqrt{\tau_W})) = (176.7)/(3.4\,(1 + 3.7\sqrt{0.8})) = 12.06\text{ ug/L}$$

The settling velocity coefficient (k) of 3.7 results in a settling velocity of 11.3 m/yr, which is approximately in the middle of the "typical range" of 5 to 20 m/yr as discussed by Chapra (Chapra 1997).

Based on the estimated annual phosphorus load of 113 lb/yr (51.3 kg/yr), the Vollenweider equation (with settling velocity coefficient adjustment) predicts an in-lake phosphorus concentration of 12.4 µg/L. This prediction matches well with the calculated average epilimnion P concentration equal to approximately 12 ug/L, as illustrated in Figure 17 below.

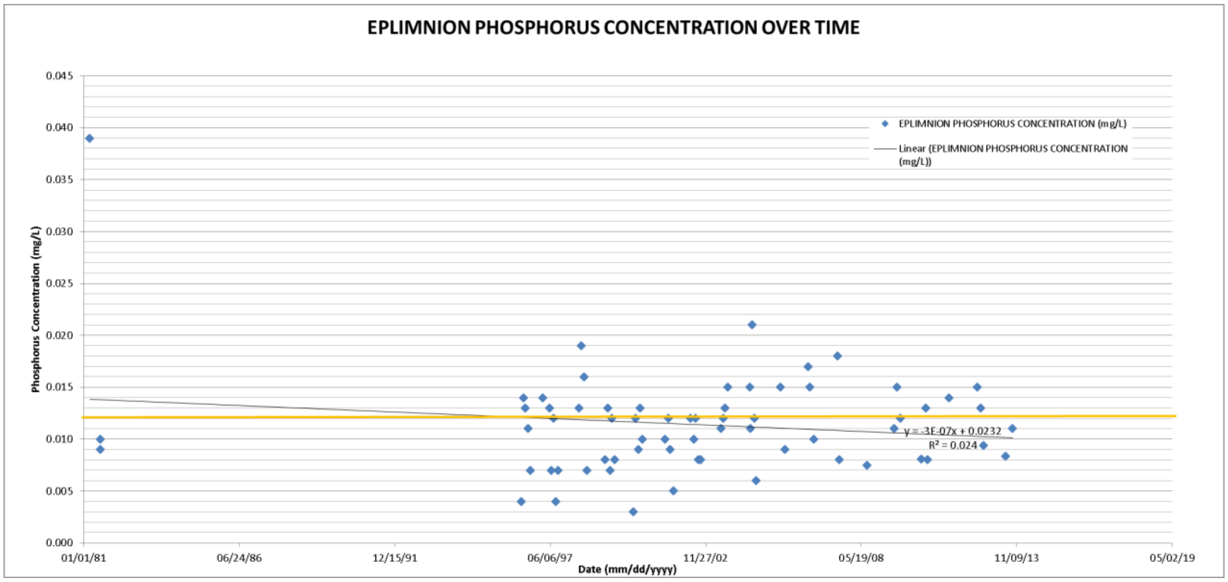

Figure 17. Epilimnion Phosphorus Concentration Over Time for Messer Pond, New London, NH

Recommended Phosphorus Reduction Goal

Establishment of Water Quality Goals

To improve water quality conditions at Messer Pond it is recommended that the MPPA target an in-pond total phosphorus concentration reduction of 2.0 µg/L, which would reduce the predicted current concentration from12 µg/L to 10 µg/L. This phosphorus concentration reduction would improve Messer Pond to match the median phosphorus concentration for similar New Hampshire lakes. This reduction is expected to improve in-lake conditions with regard to water quality indicators such as water clarity and algal abundance.

The Vollenweider equation predicts that the lake's phosphorus load must be reduced by 21.5 lb P/yr in order to achieve the recommended target in-lake phosphorus concentration of 10 µg/L. The recommended P load reduction represents approximately 19% of the estimated annual phosphorus load for the pond. Section 8 provides a discussion of how the recommended phosphorus load reduction may be achieved.

Build Out Analysis

A build out analysis was performed as part of this project in order to evaluate the impacts of future development on Messer Pond water quality. The watershed model developed for the project was used in conjunction with the Vollenweider predictions, to determine a reasonable growth rate for the watershed as a whole.

An analysis time period of 30 years was assumed. It was also assumed that during that 30 year period the 21.5 lbs/yr reduction target had been met.

The analysis was conducted assuming that the amount of impervious acres per year developed within the watershed started at 1 acre, and increased by 1 acre incrementally. Thus the first scenario assumed 1 acre of impervious surface built per year over the 30 year period, resulting in a total of 30 impervious acres built. This resulted in an increase in annual P load of 2.83 pounds and a predicted in-lake P concentration increase of 0.32 ug/L, or to a total in-lake concentration of 10.32 ug/L, per the watershed and Vollenweider models, respectively. Scenario 2 was conducted similarly, resulting in a total of 60 impervious acres built, an increased annual P load of 5.66 pounds and a predicted in-lake P concentration increase of 0.62 ug/L, or to a total in-lake concentration of 10.62 ug/L. These results are summarized in Table 10.

This exercise provides to be a useful planning tool when trying to determine a level of "acceptable" development as it relates to increases in in-lake P concentration. Considering the MPPA and stakeholders are faced with the challenging of lowering the in-lake P concentration by approximately 2 ug/L and faced with hundreds of thousands of dollars in implementation costs, it was decided that an exceedance of 0.5 ug/L of in-lake P concentration (25% of the current target reduction) seems unreasonable. Therefore 1 acre of impervious surface built per year over the next 30 years is recommended under this report. Although water quality is still expected to be favorable at 10.32 ug/L, the additional 2.83 lb/yr of P loading will require the MPPA and stakeholders to reduce P loadings from the watershed by a total of 24.33 lbs/yr over the 30 year period in order to maintain the targeted 10.0 ug/L in-lake P concentration.

Following approval of this report, the MPPA will present these findings to the Town of New London and make the following suggestions, to potentially be incorporated into the long term development planning of the Messer Pond Watershed:

- Messer Pond water quality can withstand 1 acre of impervious cover built per year, over the next 30 years
- Town officials should encourage developers to incorporate BMPs and Low Impact Development (LID) practices to reduce or eliminate impervious flows from developed lands
- Town officials should discourage 'directly connected impervious areas' during design phases, and encourage developers to direct impervious flows to pervious surfaces where impervious flow will potentially infiltrate into soils
- Strongly suggest the development of a stormwater ordinance for the town and/or for the pond and its watershed, examples:
    - 1) http://www.amherstnh.gov/sites/amherstnh/files/uploads/sec-i-stormwater-reg-2013.pdf;
    - 2) http://cobbettspond.org/images/CobbettsPondOrdinance.pdf).

Table 10. External Sources of Phosphorus to Messer Pond

Scenario	Estimated Annual P Load - Watershed		Vollenweider Predicted In-Lake P
	Total (lbs)	% Increase	(ug/L)
2014 Scenario	84.50	-	12.40
30 Yr Build Out Scenario - 1 Acre/Yr	87.33	3.35	10.32
30 Yr Build Out Scenario - 2 Acre/Yr	90.16	6.70	10.62

6. Messer Pond Sediment Budget

As discussed in Section 1.1 of this report, in addition to phosphorus loadings to the pond, sediment loadings were also incorporated into the plan. As already stated, eroded sediments can convey varying concentrations of nitrogen and phosphorus through streams and into the pond. Similarly, sediment loads to the pond over time can reduce pond depth, leading to loss of assimilative capacity (i.e. 'dilution capacity') which can increase the probability of surface water quality standard exceedances.

Estimated Annual Sediment Loading Budget

The primary tool in determining sediment sources to the pond was the SWMM watershed model. Unlike TP loadings, septic systems are typically not large sources of sediments to lakes; and atmospheric and internal sediment loadings were not considered at this time. Sediment buildup and washoff coefficients were specified during model development for each land use; those factors were adjusted until modeled results were best fit to field data (similar to TP calibration, as discussed earlier).

The watershed model estimated a total annual external sediment load to the pond of 3,418.92 lbs/year (or 1.7 tons). This loading incorporates estimates of sediment loads generated from surface water runoff conveyed over land uses in the 11 sub-watersheds of Messer Pond, plus seasonal baseflow from streams. The annual loading generated by the watershed model is broken down further in Table 11 below. The estimated annual sediment load in total pounds, pounds per acre and percentage of the total sediment load generated from the watershed is provided.

Table 11. Watershed Modeling Estimated Annual Sediment Load by Sub-Watershed for Surface Water Run-off, Messer Pond Watershed

Sub-Watershed	Size (ac)	Estimated Annual TSS Load		% of Watershed
		Total (lbs)	Per Acre (lbs)	Total TSS Load
CRB_Upper	522.8	1,448	2.8	42.4
CRB_Lower	159.7	144	0.9	4.2
Unnamed_Trib	31.2	80	2.6	2.3
Haas_Brook	63.9	119	1.9	3.5
Nutter_Brook	133.4	371	2.8	10.9
Browns_Brook	110.6	1,029	9.3	30.1
Beaver_Point	15.9	24	1.5	0.7
North_1	103.8	89	0.9	2.6
North_2	81.7	51	0.6	1.5
North_3	39.8	28	0.7	0.8
Direct_Drainage	23.1	36	1.6	1.1
Messer Pond Watershed (total)	**1285.9**	**3418.92**	**2.66**	**100.00**

7. Messer Pond Water Budget

As discussed at the beginning of Section 3, a water budget was included in this study to facilitate the development of effective pollution budgets. A water budget is a summation of water inputs, outputs, and net changes to a particular water resource system; in this case sub-watersheds.

<u>Estimated Annual Water Budget</u>

The primary tool in determining the water budget was the SWMM watershed model. The hydrology portion of SWMM incorporates mathematical models that simulate rainfall, evaporation, surface water infiltration, surface water runoff; it also includes loss of infiltrated water to surficial groundwater and deep aquifers. All of these SWMM modeling components were utilized to develop the annual water budget for Messer Pond.

The annual water budget is broken down in Figure 18 below. The largest contributor of water to the pond is via surface water runoff and baseflows from tributaries, totaling 94%; followed by precipitation and groundwater at 3.4% and 2.8%, respectively. Evaporation contributes to a loss of 0.2% of water from the pond during the warmer months.

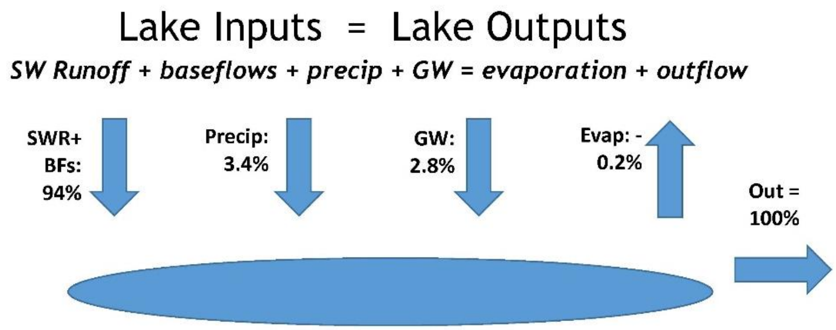

Figure 18. Watershed Modeling Estimated Annual Water Budget for the Messer Pond Watershed

8. Options for Reducing Phosphorus and Sediment Loading to Messer Pond

This section presents a discussion of potential BMP projects in the Messer Pond watershed that, once implemented, could reduce phosphorus and sediment loadings to the pond. A discussion of each site and potential project is provided, including an estimated construction cost and load reduction. Table 12 below provides an overview and prioritization of all proposed measures that are presented in this section.

8.1. Field Watershed Survey

On July 25th, 2014, Gabe Bolin of Base Flow and members of the MPPA (Dave Henning, Dick Denise and John Doyle) conducted a field watershed survey of the pond's watershed, to identify potential stormwater quality improvement sites that could reduce the loading of phosphorus and sediment to the pond. Prior to the survey, Base Flow and the MPPA conducted volunteer workshops to train volunteers on the methods and tasks that would be required during the survey. The survey consisted of teams walking all or portions of the major streams (all of Nutter and Haas Brook, portions of Browns and County Road Brook) assessing stream health related to erosion, riparian and biological conditions. Stream crossings were of concern and inspected as part of the stream surveys. Other infrastructure including dirt roads (Forest Acres Road) and facilities related to I-89 were also inspected.

On July 26th, 2014 Gabe Bolin of Base Flow and members of the MPPA (John Doyle and Bruce Stetson) conducted a shoreline survey of Messer Pond. The shorelines were inspected for signs of erosion, bank instability, degree of vegetation, and the overall condition of homeowner properties.

8.2. Best Management Practices

Descriptions of the BMP projects follow. It is important to note that the costs associated with each BMP project were developed at the conceptual level design (i.e. 15% design level) and additional costs to support further engineering design, permitting, etc. may be required.

Development of Load Reductions

The estimated pollutant load reductions for each BMP project were estimated using published pollutant reduction rates for BMPs, as follows:

- The predicted phosphorus load entering each BMP was estimated based on the BMP drainage area and was obtained from the watershed model. This represented 'existing conditions'.
- Next, published BMP phosphorus reduction values were used to estimate the total amount of phosphorus which is expected to be removed (provided that the BMP is properly installed and maintained). Reduction values were obtained from the New Hampshire Stormwater Manual, Appendix B, Volume 2 (NHDES et al., 2008(b)) for all proposed BMPs, except where noted. Table 12 provides a summary of the phosphorus load reductions estimated for each proposed BMP site.
- The BMPs proposed for all measures in Table 12 are estimated to reduce the annual phosphorus load to Messer Pond by 20.0 lb/year. This load reduction represents about 93% of the targeted phosphorus load reduction (21.5 lb/year) for Messer Pond.

Site 1: Upper County Road Brook Stream Buffers

Site Assessment
Upper County Road Brook runs through the residential areas located along roads Gay Farm Road and Carter Road. Some excellent examples of stream buffers exist in this area of the watershed (Photo 1-1), however there are some properties that lack or have minimal buffers to prevent NPS pollution from directly entering streams and resources (Photo 1-2).

Proposed Improvements
Install buffers along banks of streams where appropriate, using native vegetation at three separate properties, assuming 100 square feet at each property. Target buffers that are at minimum five feet wide.

Estimated Costs
$1,500 - $2,500

Estimated Pollutant Load Reduction
0.25 lbs P/yr
3.8 lbs sediment/yr

Photo 1-1

Resource Considerations/Constraints

Positives

- Low cost
- Low maintenance

Negatives

- Requires landowner permissions
  Space may be limited

Photo 1-2

Site 2: Forest Acres Road Runoff BMP Maintenance

Site Assessment

Forest Acres Road runs adjacent to residential homes located along the southern shoreline of the pond. It is a dirt road that is subject to sediment erosion following storm events, typical of dirt roads. Browns Brook, Nutter Brook, Haas Brook and an unnamed tributary all receive flow from I-89 and their watersheds and pass under Forest Acres Road via culverts. In order to prevent eroded road sediments and road sands/salts applied during the winter from entering the streams, the town has dug holes in the road shoulder on the up gradient sides of each stream essentially creating small 'settling basins', observed at Browns, Nutter and Haas Brooks in the recent past. Watershed survey observations indicated that these basins were very effective, however had reached their capacity and most likely weren't capturing any sediment once full.

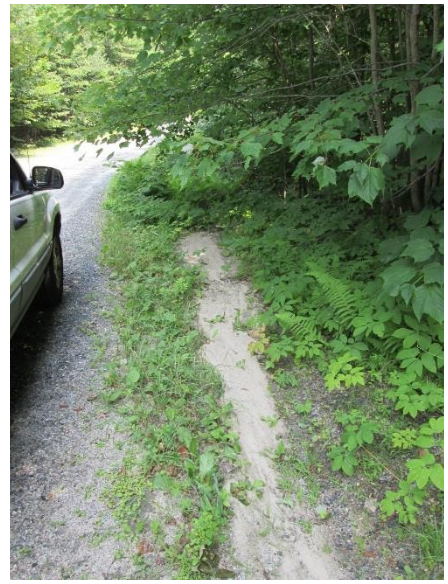

Photo 2-1

In addition to these settling basins a series of catch basins exist along the southern shoulder of Forest Acres Road. Slightly different from typical catch basins, these basins are constructed of solid concrete with a closed top but allow flow to enter the basins from the side of the basin, from the adjacent road swales. Although not opened during the watershed survey, it's suspected that these basins have a sump at the bottom (i.e. depth from the bottom of the structure to the bottom of the lowest invert out) which allows for some accumulation of sediment. The discharge location and sediment loading of these systems is currently unknown, however the town Department of Public Works (DPW) will be contacted prior to efforts regarding this BMP get underway.

Photo 2-2

Proposed Improvements

Continued maintenance of these basins on an annual basis. Maintenance would include the removal and proper disposal of trapped sediments and restoration of the basin depths and lateral extents, suggested to be 4-6 inches deep.

Although an unknown at this time regular inspection and maintenance (if required) of the concrete catch basins is also recommended at the same frequency of the settling basins.

Estimated Costs

$1,500 – $2,500

Estimated Pollutant Load Reduction
1.5 lbs P/yr
1,200 lbs sediment/yr

Resource Considerations/Constraints

Positives

- Low cost
- BMP already in place

Negatives

Coordination with partners (DPW) required

Site 3: Forest Acres Road Culverts

Site Assessment

The culverts that convey flow under Forest Acres Road at Browns Brook and Nutter Brook are undersized and have resulted in bank erosion and historical sediment inputs to the Pond. A common problem throughout the country, many of our road-stream crossings installed decades ago were sized for the 25 year storm event and cannot adequately convey larger storms and increasing flows due to climate change. The result is significant bank erosion at the downstream end of the pipe due to the 'firehose' effect during large storm events that over time results in large sediment inputs to downstream resources and potential threats to roadway infrastructure. The photos provided show erosion that has occurred over time at Nutter Brook above, below and to the sides of the pipe (shown as the blue shaded polygons), evident under dry weather conditions (photo 3-1) and a large storm event (photo 3-2).

Additionally inspections of the pipe at Nutter Brook indicate internal corrosion and potential erosion of road fill material through the corroded pipe, further contributing to sediment loads to the pond.

Photo 3-1

Photo 3-2

Proposed Improvements

Replace outdated infrastructure piping at Nutter Brook and Browns Brook and Forest Acres Road with culvert sized to pass the appropriate storm event per NHDOT and NHDES protocols (i.e. the 50 or 100 year storm event depending on stream order, and 2' of freeboard for passage of ice and debris). The NHDES stream crossing guidance rules will be followed when implementing this BMP (http://des.nh.gov/organization/divisions/water/wetlands/streams_crossings.htm;http://des.nh.gov/organization/commissioner/legal/rules/documents/env-wt900.pdf).

Estimated Costs

$20,000 – $30,000

Estimated Pollutant Load Reduction

4.0 lbs P/yr
500 lbs sediment/yr

Resource Considerations/Constraints

Positives

- High potential load reductions
- Benefits to the stream, wildlife and infrastructure
- Increases flood resiliency

Negatives

Higher costs
Will require permits and technical support
May require road closures

Site 4: Browns Brook Wetland

Photo 4-1

Photo 4-2

Site Assessment
The Browns Brook wetland is located along Brown Brook and extends from the culvert at Forest Acres Road south to the intersection of I-89 and Bog Road (photo 4-1). Initial assessments of conditions at the wetland led the project team to believe that this wetland was not natural and that its origin was anthropogenically influenced; certain species of trees indicative of uplands were destabilized and present within the wetland; and water quality was poor and not typical of a stream and wetland complex (photo 4-2). Further research pointed to this wetland potentially being created during the construction of I-89 as an area for storage of runoff from the new impervious area associated with the highway.

Prior to this study, water quality sampling results indicated high phosphorus and sediment loadings from this brook and wetland; results of this study ranks Browns Brook as one of the highest contributors of phosphorus on a per acre basis, and the highest contributor of sediment on a per acre basis.

Proposed Improvements
A wetland restoration project that will restore natural hydrologic processes to the land and restore hydraulic processes to the brook is recommended. Such a project would still allow for storage of flood flows from the highway during storm events, but would provide mechanisms for settling out sediments and organics high in nutrient concentrations thus reducing sediment and nutrient loads to the pond. Considerations of other alternative treatments such as iron media filter systems, floating wetland systems, etc. will be reviewed as part of the feasibility phase for this BMP.

Estimated Costs
$100,000 – $150,000

Estimated Pollutant Load Reduction
6.00 lbs P/yr (obtained from watershed model)
820 lbs sediment/yr (obtained from watershed model)

Resource Considerations/Constraints

Positives

- Highest potential load reduction

- Large restoration effort benefits pond, stream and ecosystem

Negatives

Higher costs
Will require permits and technical support
Requires landowner permissions and coordination
Operations and maintenance tasks may be required

Site 5: Shorefront Buffers

Photo 5-1

Photo 5-2

Site Assessment
Messer Pond is a great example of natural shorelines – along with undeveloped properties, most shorefront homes have significant buffers that consist of native vegetation and features that provided for excellent filtering capacity of stormwater runoff (photo 5-1). However, during the Shoreline Survey a small number (2-3) of properties were observed either not to have buffers or to have property configurations that allow stormwater to runoff directly to the pond (photo 5-2).

Proposed Improvements
Install buffers along banks of shoreline where appropriate, using native vegetation. Target buffers that are at minimum 10 feet wide at 3 properties.

Estimated Costs
\$3,000 – \$4,000 for all properties

Estimated Pollutant Load Reduction
0.1 lbs P/yr
2.8 lbs sediment/yr

Resource Considerations/Constraints

Positives

- Low cost
- Low maintenance

Negatives

- Requires landowner permissions
  Space may be limited

Site 6: Residential Property on Burpee Hill Road

Site Assessment

During the Watershed Survey the field team observed a residential home on Burpee Hill Road with 1 horse present on a fenced-in portion of their property. A small tributary to County Road Brook runs along the southern end of the property and the team assessed that it was possible that equine waste could enter the stream and be conveyed downstream to Country Road Brook and ultimately the Pond, as the horse had direct access to the stream.

Proposed Improvements

It is suggested that the homeowner take steps to prevent NPS runoff from entering the stream, either by installation of buffers along either side of the stream or to keep the horse on one side of the stream and provide buffer plantings along the appropriate stream bank. The project team will check sources regarding the required buffer between animals and streams; including town regulations, the NH Department of Agriculture, the UNH Cooperative Extension, and others.

Estimated Costs

$5,000 – $8,000

Estimated Pollutant Load Reduction

1.0 lbs P/yr
100 lbs sediment/yr

Resource Considerations/Constraints

Positives

- Low to moderate cost
- Low maintenance

Negatives

- Requires landowner permissions
  Space may be limited
  Permits and technical support may be required

Site 7: Browns Brook and Forest Acres Road BMPs

Photo 7-1

Photo 7-2

Site Assessment

The proximity of Forest Acres Road to Browns Brook, particularly on the downstream side of the brook is close (*i.e.* within 3-5 feet); when visiting the site it is quite evident that there is a direct input of sediment, road salts and NPS from the road into the brook adjacent to the downstream end of the culverts (i.e. the edge of traffic travels less than 5-10 feet from the bank of the brook).

Proposed Improvements

Install buffers or rain gardens within the right-of-way along both banks of the stream on the downstream side, using native vegetation. Target buffers that are at minimum 10 feet wide or rain gardens that will accommodate stormwater runoff and retention of sediment.

Estimated Costs

$3,000 – $4,000

Estimated Pollutant Load Reduction

0.1 lbs P/yr
2.8 lbs sediment/yr

Resource Considerations/Constraints

Positives

- Low cost
- Mitigates direct NPS loads to stream

Negatives

- Requires coordination with partners (town/DPW)
  Space is limited

Permits and technical support may be required

Site 8: County Road Brook and County Road BMPs

Site Assessment
The proximity of County Road to County Road Brook on both sides of the road is close (*i.e.* approximately 8-10 feet); when visiting the site it is evident that there is a direct input of sediment, road salts and NPS from the road into the brook most likely on the upstream and downstream sides. This portion of County Road is the low point adjacent to a steep hill and it is suspected that some degree of runoff and NPS is entering the brook and likewise the associated wetland.

Photo 8-1

Photo 8-2

Proposed Improvements
Install buffers within the right-of-way along each side of the road, using native vegetation. Since buffer width will be limited, plant selection and density should receive adequate attention for this BMP to be effective. Consideration of vegetation height and maintenance should also be considered with respect to maintenance and safety concerns.

Estimated Costs
$6,000 – $8,000

Estimated Pollutant Load Reduction
0.2 lbs P/yr
5.6 lbs sediment/yr

Resource Considerations/Constraints

Positives

- Low cost
- Mitigates direct NPS loads to stream

Negatives

- Requires coordination with partners (town/DPW)
  Space is limited

Permits and technical support may be required

Site 9: Septic Tank Upgrades

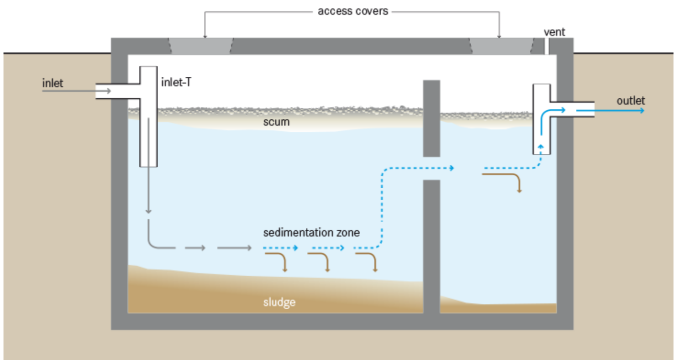

Photo 9-1 (*Source: Tilley, et al.*)

Site Assessment

Results of the septic system study indicate that 24% of septic systems were installed prior to 2000. The technology associated with septic systems and their ability to remove solids to produce an effluent less prone to impact resources has been an evolving science; therefore because some of the older septic systems may not have incorporated some of the newer technology it is suggested that any tank installed prior to 2000 should be investigated, and potentially upgraded or replaced.

Proposed Improvements

Upgrade or replace septic tank systems (i.e. leach field, tank or both as appropriate) where necessary. Prior to devoting major funds to this BMP, it is suggested that inspections of systems be performed by a person certified in septic evaluation and maintenance. The costs for this BMP assume the upgrade or replacement of seven systems.

Estimated Costs

$120,000– $140,000 ($17,000 - $20,000 per system)

Estimated Pollutant Load Reduction

2.20 lbs P/yr
lbs sediment/yr – N/A

Resource Considerations/Constraints

Positives

- High potential load reductions
- Benefits to homeowners

Negatives

Higher costs
Will require landowner permissions and coordination
Will require permits and technical support

Project 10: Stormwater Runoff Reductions

Photo 10-1 (*Source: City of Vienna*)

Site Assessment

In addition to BMPs listed above, the MPPA, other partners and residents can develop BMP projects such as rain gardens, tree boxes, and utilize rain barrels to collect roof runoff to further reduce stormwater runoff from impervious and developed areas.

Proposed Improvements

Installation of BMPs such as rain gardens is becoming more popular due to their relative ease of install and aesthetic value, both of which are attractive to watershed residents that want to take part in improving their watershed, the environment and property values.   Programs such as 'Soak Up the Rain NH' sponsored by NHDES and EPA Region 1 (http://soaknh.org/) provide a wealth of information on such projects, including step-by-step instructions on these 'do-it-yourself' projects. It is expected that these projects will take place watershed-wide and will increase in number as word gets out about the plan and public outreach continues. It is expected that the MPPA will sponsor these efforts and encourage residents and stakeholders to become involved in these programs. A tool that estimates pollutant load reductions on private properties, called the NH Residential Loading Model is an excellent tool for such projects. It is located at: http://winnipesaukeegateway.org/resources/phosphorus-calculator/.

Estimated Costs

Rain Gardens: $3-$5/SF for resident installs; $10-$15/SF if a landscaper is used for design (http://raingardenalliance.org/what/faqs)

Rain Barrels: $40-$60 (via a general internet search)

Estimated Pollutant Load Reduction (varies by size of area treated)

25-50% reduction in P (CWP 2008)

70-80% reduction in sediment for most low to moderate rainfall events

Resource Considerations/Constraints

Positives

- Low cost
- Low maintenance

Negatives

- Requires landowner permissions and coordination
  Space may be limited
  May require technical support
  Operations and maintenance tasks may be required

8.3. Non-Structural BMPs

Phosphorus Loading from Fertilizers

For years, landscaping fertilizers have been a significant source of nutrients to lakes, ponds and streams, wreaking havoc on surface water quality throughout the US, and the world. These fertilizers, usually containing very high and disproportionate concentrations of phosphorus and nitrogen, are typically applied to residential and commercial properties where grass lawns are maintained (e.g. office parks, schools, sports fields, etc.). These nutrients are typically transported to surface waters via surface water runoff, and alter the natural balance of nutrients and living organisms in ecological systems.

Following the passing of turf fertilizer laws in other states such as Minnesota, Wisconsin, Maryland, Maine, and others, because of concerns over lawn fertilizer runoff, the New Hampshire legislature passed a bill in 2013 regulating the use of nitrogen and phosphorus in turf fertilizers that are sold at retail. The goal was to help homeowners maintain healthy lawns without applying unnecessary fertilizer (UNH, 2014).

Following the commencement of this project in 2013, the turf fertilizer law was not yet passed in New Hampshire. The plan regarding fertilizers under this project was to develop a program to reduce pollution from fertilizer applications within the watershed, via an incentive program to promote the use of phosphorus free products at a reduced price. This would be done by stocking local stores with these lower priced fertilizers, and have the MPPA subsidize those retailers who sold those products. This would be followed up by the development of a municipal fertilizer ordinance spearheaded by the MPPA. It was expected that these efforts would result in a reduction of 4.3 lbs. P/year to the lake, and was planned as a major BMP that would facilitate meeting the load reduction discussed earlier in this report, such that the water quality goal could be met (see load reduction calculations and assumptions below).

Because the state law was put into effect during development of this Plan, **the MPPA requests to claim a forward credit for the calculated reduction of 4.3 lbs/ P/year**, based on the assumption that we should not expect impacts from phosphorus fertilizer applications form this point forward, because phosphorus-containing fertilizers are no longer sold at retail. Because the law is relatively new, we would expect to see some degree of water quality improvement at the pond due to the new restriction on fertilizers over the next few years, understanding that this may be a slow positive progression, as watershed soils slowly release excess phosphorus. It is also expected that this positive result will be coincident to planning and implementation of other structural and non-structural BMPs that the MPPA plans to pursue.

Fertilizer Program Load Reduction Calculations

The following summarizes the phosphorus load reductions that were anticipated via the fertilizer reduction program that was plan as part of this project. The following assumptions were made in the load reduction estimate:

- The program would be targeted to approximately 29 shorefront residential homes and approximately 20 stream front homes;
- 25% of these homes (12 homes) will fertilize their lawns;
- Each lawn is assumed to be 5,000 square foot in area;

- Each lawn is fertilized twice per growing season;
- Fertilizer type is 10-10-10 (N-P-K) formula and a typical application rate of 3.5 lbs./1000 square feet is assumed.

If 20% of the homes using fertilizer are convinced to switch to phosphorus-free fertilizer, the amount of phosphorus applied to lawns within the Messer Pond watershed would be reduced by approximately 8.6 lbs./year. If 50% of the applied fertilizer phosphorus washes into the lake via storm water runoff, then the estimated annual phosphorus load reduction would be 4.3 lbs. P/year.

Costs for a one-year fertilizer reduction program as described above are anticipated to be in the range of $1,000 to $2,000. These costs include printed outreach materials (brochure, signage, homeowner survey), and costs associated with providing a rebate or subsidy for purchase of phosphorus–free fertilizer. Assuming that 12 homes participated and purchased four bags of fertilizer, and assuming a rebate of $15 per bag, the total cost of the rebate program would be $720.

As part of this Plan, the MPPA will claim the 4.3 lbs P/year reduction due to the turf fertilizer law, and will carry that reduction through the remainder of this report.

Additionally, through future public outreach the MPPA will relay information regarding the turf fertilizer law and relay that there is sufficient phosphorus in New Hampshire soils, and that extra phosphorus is not needed. The MPPA will also recommend ***against*** organic phosphorus fertilizers (as those fertilizers still contain phosphorus) and remind shorefront homeowners that most of the shorefront properties are steeply sloped, and recommend against any fertilizer use on steep sloped lawns, due to the high possibility of applied fertilizer running right into the pond during rain events.

Wake Wave Ordinance

Over the course of this project, MPPA members have expressed concerns about the impact of boat use on overall water quality. Depending on the speed of a boating vessel, wake waves can be created that have a height and magnitude just like ocean waves. These waves can propagate towards the shore and their energy can be erosive when they meet the shoreline. Additionally, hydraulic forces from boat propellers (or 'prop wash') can have a similar erosive impact when boats are accelerated in waters that are shallow and/or boat motors are powerful enough to generate erosive prop wash forces.

Once the fine sediments associated with the pond bottom are re-suspended, the water column will become cloudy with turbidity rising and water clarity falling. Restoring the water column to natural water clarity levels will take time that is typically dependent on the fall velocities of these fine sediments. Additionally, these sediments can disperse and create a plume of low water clarity that is subject to pond currents and prevailing winds. The primary concern for these types of situations is that any phosphorus that is attached to these sediments have the potential to dissociate into the water column and increase phosphorus concentrations of pond surface waters.

Many waterbodies within the state have implemented no wake zones and banks on certain boating vehicles to protect their resources (see Division of State Police website Marine Patrol Unit website: https://www.nh.gov/safety/divisions/nhsp/fob/marine-patrol/restricted.html). Base Flow will continue to work with the MPPA regarding consideration of a future wake wave or other boating ordinance.

Overlay District

An overlay district, or more specifically overlay zoning, is a regulatory tool that creates a special zoning district, placed over existing base zone(s), which identifies special provisions that are in addition to those in the base zone. In the case of Messer Pond and current issues regarding overlay zones within the watershed, the town utilizes a wetland overlay district, to impose regulations regarding known wetlands in order to maintain water quality.

During the investigation phase of this Watershed-Based Implementation Plan, a resident proposed construction along Browns Brook, which required Zoning Board approval of a setback from the brook. During the hearing the proximity to Browns Brook was discussed, and on review of town maps, it was discovered that Browns Brook and its entire sub-watershed were not included on the towns' wetland overlay district, and therefore not subject to any setback regulations. Subsequently, members of the MPPA met with the town planner, to discuss what sections of the Messer Pond watershed were not covered by the watershed overlay plan and the process to include those tracts.

Advice from the town planner included 1) petition for inclusion of Browns Brook and it's sub-watershed into the overlay district by presenting a plan for vote at the town meeting, and 2) a more preferred approach, which would include working through the town Planning Board, with the following suggested steps:

- Complete the Watershed-Based Implementation Plan
- Write up a proposal for updating the town's Overlay District, basing the need for inclusion on the results of this Plan, as well as the goals of the town's Master Plan
- Present the request to the Planning Board, and potentially at a public hearing
- Gain Planning Board support for the recommendation and allow the Planning Board to present the change to the Town Meeting for a vote

Although these efforts may not result in direct and immediate reductions of phosphorus to the pond, inclusion of all streams and their sub-watersheds into the wetland overlay district is imperative and appropriate with regards to watershed protection, and the protection of Messer Pond. These efforts will be pursued in the near future and with respect to this plan, will be considered as development and potential implementation of a non-structural BMP.

In speaking with NHDES regarding this issue, the following link to an ordinance adopted by the Town of Windham for Cobbett's Pond was provided, which may provide additional guidance regarding watershed protection ordinances: http://cobbettspond.org/images/CobbettsPondOrdinance.pdf.

8.4. Future Investigations

Based on discussions with MPPA members over the course of this project, and items of interest found during the watershed survey, the following is a working list of items to be considered as 'Future Investigations':

- Excessive sand in the headwater portions of the Nutter Brook channel was found during the watershed survey (when hiking off of Queenswood Road cul-de-sac); further investigation of the area and surrounding wetland complex as to the source of sediment and impact on Nutter Brook is warranted

- A building thought to be a sanitary pump station located close to County Road Brook found during the watershed survey for potential impacts to water quality; future investigations will determine specifically the purpose of this structure, and develop actions based on that information
- Further septic system research, including systems located adjacent to streams, second layer of homes back from the shoreline, information on shorefront lots where no information was found during the initial investigation, etc.
- Thought to be a major impact to the pond and watershed as a whole, further investigation will be performed as warranted regarding the impact to streams by flows coming from I-89; this will be considered at Browns Brook, Nutter Brook, Haas Brook and other smaller tributaries.
- Bracket sampling along Browns Brook and other tributaries to shed light on Browns Brook system

Additionally, due to the relative ease of design and implementation, the MPPA will continue to look for opportunities to install rain gardens and other stormwater runoff reduction projects throughout the watershed (*i.e.* Project 10). An example rain garden is included in Table 12 below. Over time, it is likely multiple stormwater reduction projects will be installed, incorporating additional P reduction as the MPPA moves towards reaching the target P reduction of 21.5 lb/yr.

Table 12. Summary of BMP Projects to Reduce Phosphorus Loadings

BMP Type	Site #	Proposed Action	Estimated Cost (low)	Estimated Cost (high)	Estimated P Load Reduction	Cost Per Lb. of P Reduced (x $1,000)	Priority
Stormwater BMP	1	Upper County Road Brook Stream Buffers	$1,500	$2,500	0.25	8.0	Medium
	2	Forest Acres Road Runoff BMP Maintenance	$1,500	$2,500	1.5	1.3	High
	3	Forest Acres Road Culverts	$20,000	$30,000	4	6.3	High
	4	Browns Brook Wetland	$100,000	$150,000	6	20.8	High
	5	Shorefront Buffers	$3,000	$4,000	0.1	35.0	Low
	6	Residential Property on Burpee Hill Road	$5,000	$8,000	1	6.5	Medium
	7	Browns Brook and Forest Acres Road BMPs	$3,000	$4,000	0.1	35.0	Medium
	8	County Road Brook and County Road BMPs	$6,000	$8,000	0.2	35.0	Medium
	9	Septic Tank Upgrades	$120,000	$140,000	2.2	59.1	Low
	10	Rain Gardens - Assume 1 10'x20' Garden	$1,000	$3,000	0.3	6.7	Medium
Fertilizer Reduction	Entire Watershed	Fertilizer Reduction Program - Credit	NA	NA	4.3	-	NA
		Totals:	$261,000	$352,000	20.0		

9. Summary of Technical and Financial Support

<u>Technical Support</u>

Some of the phosphorus and sediment load reduction measures described in Section 8 will require a moderate to high level of technical support. Typically, technical support could include site topographic surveys, preparation of existing condition plans, and preparation of a construction plan set by an Engineer that would be used for permitting, contractor bidding and construction. For those BMP projects that require a low level of technical support, a design-build approach could be used using field manuals. A listing of the BMP projects according to estimated level of required technical support is as follows:

Table 13. BMP Projects and Level of Technical Support Required

BMP Project	BMP Project Description	Level of Technical Support Required
1	Upper County Road Brook Stream Buffers	Low
2	Forest Acres Road Runoff BMP Maintenance	Moderate
3	Forest Acres Road Culverts	High
4	Browns Brook Wetland	High
5	Shorefront Buffers	Low
6	Residential Property on Burpee Hill Road	Low
7	Browns Brook and Forest Acres Road BMPs	Moderate
8	County Road Brook and County Road BMPs	Moderate
9	Septic Tank Upgrades	High
10	Rain Gardens	Moderate

In addition to the technical support described above, construction of some of the projects may require a NHDES Wetlands Permit. In order to support a wetlands permit application, wetland delineation and permitting support from a New Hampshire certified wetland scientist may be required where wetlands are present.

Improvements regarding the Browns Brook wetland will require a high degree of technical support from a civil and/or water resources engineering firm. It is suspected that initial work will include a feasibility study with detailed investigations and recommendations on siting options and costing for the proposed detention basin. Detailed engineering plans would then follow the feasibility analysis.

Other types of technical support that may be required include graphic design and printing support for public outreach and educational materials, septic system inspection/evaluation services, and legal assistance for development of regulatory language for future municipal bylaws, watershed ordinances, etc.

Financial Support

Implementation of BMP projects and management recommendations described in Section 8 will require financial support consistent with the construction costs provided for each project. Potential sources of funding include, but are not limited to the following:

- Clean Water Act Section 319 Watershed Assistance Grant funding from the NHDES Watershed Assistance Section;
- New Hampshire Charitable Foundation
- NH State Conservation Committee Moose Plate Grant Program
- New Hampshire Department of Environmental Services Wetlands Bureau Aquatic Resource Mitigation Fund
- New England Grassroots Environmental Fund
- Private donations.

Alternative funding may be in the form of donated labor from the Town of New London Highway Department, MPPA volunteers and local contractors.

Stakeholder Involvement and Support

In addition to technical and financial support, involvement, coordination and support from stakeholders will be required in order to implement improvement projects. Key stakeholders include:

- The MPPA membership
- Residents of the Messer Pond watershed
- The Town Of New London, including members of the Planning Board, Zoning Board,Conservation Committee and the Department of Public Works
- Colby Sawyer College

10. Public Information and Education

The following provides a listing and brief description of the public outreach efforts performed as part of this project:

- A project kickoff meeting; attendees included the town administrator, town planner, the president of the Lake Sunapee Protective Association, MPPA members and town residents
- Several newsletters were sent to the membership stressing the importance of culvert cleaning, septic maintenance and trash and waste pickup
- Co-sponsoring a presentation with other lake associations stressing the importance of proper lawn maintenance and use of BMPs like buffer plantings, to install near shorefronts
- Two volunteer training sessions where guidelines for proper sampling and data collection were provided
- Project update presentations at the 2014 and 2015 MPPA annual meetings
- Project presentation to the New London Garden Club

11. Schedule and Interim Milestones

The improvements recommended for Messer Pond and its watershed are ranked in order of priority as described in Section 8 of this report. A proposed schedule and associated interim milestones for these improvements are provided below.

Table 14. Messer Pond Watershed Restoration Plan – Implementation Schedule and Interim Milestones

Task	2016		2017		2018		2019		2020		2021		2022		2023		2024		2025	
	Q1/Q2	Q3/Q4	Q1/Q2	Q3/Q4	Q1/Q2	Q3/Q4	Q1/Q2	Q3/Q4	Q1/Q2	Q3/Q4	Q1/Q2	Q3/Q4	Q1/Q2	Q3/Q4	Q1/Q2	Q3/Q4	Q1/Q2	Q3/Q4	Q1/Q2	Q3/Q4
Complete Final Watershed-Based Plan	○																			
Select 2 Priority BMP Projects for Final Design	○																			
Draft Budget for 2 Priority BMP Projects	→	→																		
Identify and Solicit Financial Resources for 2 Priority BMP Projects Design/Permitting		→	→																	
Prepare Final Designs/Permitting for 2 Priority BMP Projects			→	→																
Construct 2 Priority BMP Projects					→	→														
Draft Budget for 1-2 BMP Projects				→	→															
Identify and Solicit Financial Resources for 1-2 BMP Projects					→	→														
Prepare Final Designs/Permitting for 1-2 BMP Projects						→														
Construct 1-2 BMP Projects							→	→												
Draft Budget for 1-2 BMP Projects							→	→												
Identify and Solicit Financial Resources for 1-2 BMP Projects								→												
Prepare Final Designs/Permitting for 1-2 BMP Projects									→											
Construct 1-2 BMP Projects									→	→										
Draft Budget for 1-2 BMP Projects									→	→										
Identify and Solicit Financial Resources for 1-2 BMP Projects											→									
Prepare Final Designs/Permitting for 1-2 BMP Projects												→								
Construct 1-2 BMP Projects													→	→						
Draft Budget for 1-2 BMP Projects												→	→							
Identify and Solicit Financial Resources for 1-2 BMP Projects														→						
Prepare Final Designs/Permitting for 1-2 BMP Projects														→	→					
Construct 1-2 BMP Projects															→	→				
Draft Budget for 1-2 BMP Projects															→	→				
Identify and Solicit Financial Resources for 1-2 BMP Projects																→	→			
Prepare Final Designs/Permitting for 1-2 BMP Projects																	→	→		
Construct 1-2 BMP Projects																		→		
Non-Structural BMP Program(s)			→	→			→	→			→	→			→	→			→	→
Conduct VLAP Monitoring and Evaluate P Concentrations	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→

12. Evaluation Criteria and Monitoring

As discussed in Section 5, the recommended in-lake TP target concentration for Messer Pond is 10 µg/L. To achieve this TP concentration, the Vollenweider equation in Section 5 predicts that the annual phosphorus load to the lake must be reduced by an estimated 21.5 lb/year. Section 8 of this report describes management measures that may be implemented to achieve this targeted phosphorus load reduction. Base Flow recommends the following monitoring and evaluation criteria to determine the effectiveness of these proposed measures in reducing in-lake phosphorus concentrations and improving the water quality of Messer Pond.

- Phosphorus Monitoring: The MPPA should continue monitoring in-lake phosphorus concentrations through the VLAP program, sampling more than once per year and from varying water layers. In-lake phosphorus measurements will provide the most direct means of evaluating the effects of BMPs which have been implemented specifically to reduce phosphorus loading. Also, continue to sample tributaries during dry and wet weather.

- Continue efforts regarding bracket sampling in target tributaries, and the use of conductivity probes to lead these efforts.
- Public Outreach, Education and Land Use Activities: In addition to the monitoring efforts described above, the effectiveness of recommended measures related to public outreach and land use activities can be evaluated with several simple metrics, including:
    - Quantify the number of public education brochures that are distributed to watershed residents
    - Quantify the number of septic system inspections and pump-outs conducted, the number of septic systems required to perform more frequent inspections, etc.
    - Quantify other watershed improvements initiated by homeowners as a result of outreach and education efforts, such as installation of residential rain gardens and other LID practices.

13. References

Base Flow, LLC, 2014. Site Specific Project Plan, Messer Pond Watershed-Based Implementation Plan. April 18, 2014.

Brett, M. T., Benjamin M. M., 2008. A review and reassessment of lake phosphorus retention and the nutrient loading concept. Freshwater Biology 53:194–211.

Center for Watershed Protection, 2003. Watershed Protection Research Monograph No. 1. Impacts of Impervious Cover on Aquatic Ecosystems. Center for Watershed Protection. March 2003.

Center for Watershed Protection, 2008. Technical Memorandum: The Runoff Reduction Method. Center for Watershed Protection. Ellicott City, Maryland.

Chapra, 1997. Surface Water Quality Modeling. WCB McGraw-Hill, Boston, MA.

City of Vienna, WV. "What is a Rain Garden?" March 2016. http://vienna-wv.com/portal/2013/07/18/what-is-a-a-rain-garden/

CLD, 2008. Messer Pond Watershed Study. CLD Consulting Engineers, Inc., 2008.

Federal Highway Administration, 2005. Hydraulic Design of Highway Culverts.

Mitchell, M.K., W. B. Stapp. 1992. Field Manual for Water Quality Monitoring, an environmental education program for schools. GREEN: Ann Arbor, MI.

NHDES, 2005. Amy Smagula, Exotic Species Program Coordinator, New Hampshire Department of Environmental Services. Letter to: Messer Pond Protective Association. October 24, 2005. Including Messer Pond Aquatic Plant Map.

NHDES 2008(a). Appendix 8, Section 303(d) List of Impaired Waters. Found at: http://des.nh.gov/organization/divisions/water/wmb/swqa/2008/index.htm

NHDES, 2008(b). NHDES, USEPA and Comprehensive Environmental, Inc. New Hampshire Stormwater Manual. Volume 2, Post- Construction Best Management Practices, Selection and Design. December 2008.

NHDES 2010(a). 2010, Final 303(d) List. Surface Water Quality Assessment Program. April 1, 2010. Found at: http://des.nh.gov/organization/divisions/water/wmb/swqa/2010/index.htm

NHDES, 2010(b). 2010 Volunteer Lake Assessment Program Annual Reports. New Hampshire Department of Environmental Services. Graphs 2010. Found at: http://des.nh.gov/organization/divisions/water/wmb/vlap/annual_reports/2010/graphs/documents/messer_newlondon.pdf

NHDES 2012(a). Volunteer Lake Assessment Program Individual Lake Reports, Messer Pond, New London, New Hampshire. New Hampshire Department of Environmental Services, 2012.

NHDES 2012(b). 2012, Draft 303(d) List. Surface Water Quality Assessment Program. April 20, 2012. Found at: http://des.nh.gov/organization/divisions/water/wmb/swqa/

NHDES, 2014(a). Volunteer Lake Assessment Program Individual Lake Reports Messer Pond, New London Data Summary. New Hampshire Department of Environmental Services, 2014.

NHDES 2014(b). 2014, Draft 303(d) List. Surface Water Quality Assessment Program. October 14, 2015. Found at: http://des.nh.gov/organization/divisions/water/wmb/swqa/2014/index.htm

NHDES, 2015. Annual Reports, Bathymetric Maps, Messer Pond. Source: http://des.nh.gov/organization/divisions/water/wmb/vlap/annual_reports/bathymetric.htm. From Internet, October 2015.

Niirnburg, 1994. Phosphorous Release from Anoxic Sediments: What We Know and How We Can Deal With It. Freshwater Research, Baysville, Ontario, Canada. Limnetica, 10 (1): 1-4. 1994.

Reckhow, K.H., M.N. Beaulac, and J.T. Simpson, 1980. Modeling Phosphorus Loading and Lake Response under Uncertainty: A Manual and Compilation of Export Coefficients, East Lansing, Michigan. Michigan State University.

Smith, Sara. "They sawed up a storm". Presentation to Messer Pond Protective Association, 29 August 2006, as found at messerpond.org/education.html.

Tilley, Elizabeth; Ulrich, Lukas; Lüthi, Christoph; Reymond, Philippe; Zurbrügg, Chris. Compendium of Sanitation Systems and Technologies (2nd ed.). Duebendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (Eawag).

UNH, 2014. New Hampshire's Turf Fertilizer Law, What You Should Know. Agricultural Fact Sheet. University of New Hampshire Cooperative Extension. Spring 2014.

USDA, 2007. Hydrologic Soil Groups. Part 630, Hydrology, National Engineering Handbook, Chapter 7. May 2007.