August 2022

PARTRIDGE LAKE
WATERSHED RESTORATION PLAN

Prepared for:

Partridge Lake Property Owners Association

Comprehensive Environmental Inc. • 21 Depot Street, Merrimack, NH 03054 • www.ceiengineers.com

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Introduction

Partridge Lake

The Town of Littleton, New Hampshire (NH) (the Town), in cooperation with the Partridge Lake Property Owners Association (PLPOA), selected Comprehensive Environmental, Inc. (CEI) in 2020 to lead development of a Watershed Restoration Plan (WRP) for Partridge Lake. This project was funded by a Clean Water State Revolving Fund Loan awarded to the Town by the New Hampshire Department of Environmental Services (NHDES).

The 896-acre Partridge Lake watershed (Figure 1) is located in Littleton and Lyman, NH. Partridge Lake (99 acres) has experienced an increasing occurrence of cyanobacteria blooms, decreased lake water transparency, increased chlorophyll-*a* concentrations, and anoxic conditions in the lake's hypolimnion (deep water) zone. Because some forms of cyanobacteria are toxic to people and animals, the blooms have resulted in lakewide cyanobacteria advisories in 2017 and 2020. Partridge Lake is now on the NHDES 2020-2022 303(d) list as impaired for Primary Contact Recreation (swimming) due to cyanobacteria blooms (cyanobacteria hepatoxic microcystins). Other impairments noted in the 303(d) list include Fish Consumption due to mercury in fish tissue and Aquatic Life Integrity due to low pH levels.

The primary goal of this WRP is to assess Partridge Lake and its watershed and provide a plan for implementing actions that will result in measurable improvements in water quality and aquatic habitat. To achieve this goal, this WRP was developed to include the following nine elements in conformance with the United States Environmental Protection Agency's (USEPA) guidance for watershed-based plans:

USEPA Watershed-Based Plan Elements		WRP Section
Element A	Identify causes and sources of pollution that need to be controlled.	Sections 1-2
Element B	Determine pollutant load reductions needed to meet water quality goals.	Sections 1-2
Element C	Develop management measures to achieve water quality goals.	Section 3
Element D	Technical and financial assistance needed.	Section 4
Element E	Public information and education	Section 3.4.1
Element F	Implementation schedule	Section 5
Element G	Interim measurable milestones	Section 5
Element H	Criteria to measure progress	Section 6.1
Element I	Monitoring	Section 6.2

Recommended actions to restore water quality and meet long-term water quality goals established in this WRP include a variety of structural and non-structural practices as described in Section 3:

- Structural stormwater management improvements (Section 3.1)
- On-site wastewater management strategies (Section 3.2)
- In-lake phosphorus inactivation (Section 3.3)
- Non-structural practices, including recommendations for public education, land conservation, regulatory tools, and changes to institutional practices (Section 3.4)

A recommended schedule for implementing these watershed management actions over the next five years is provided in Section 5. Successful implementation of the WRP will require continued collaboration and partnerships between watershed residents, state and federal government agencies, local stakeholder groups such as the PLPOA, and nonprofit organizations such as local land trusts, the New Hampshire Lakes Association, the Society for Protection of New Hampshire Forests, New Hampshire Charitable Foundation, etc.


Figure 1:
Partridge Lake Watershed
Comprehensive
Environmental
Incorporated
Data Sources: GRANIT, CEI, USGS
Reynolds Pond
Partridge Lake
846
PARTRIDGE LAKE ROAD
GANNON RD
GANNON
Littleton
Lyman
Flag Pond
879
900
1000
1100
1200
1300
0
1,000
Feet
N
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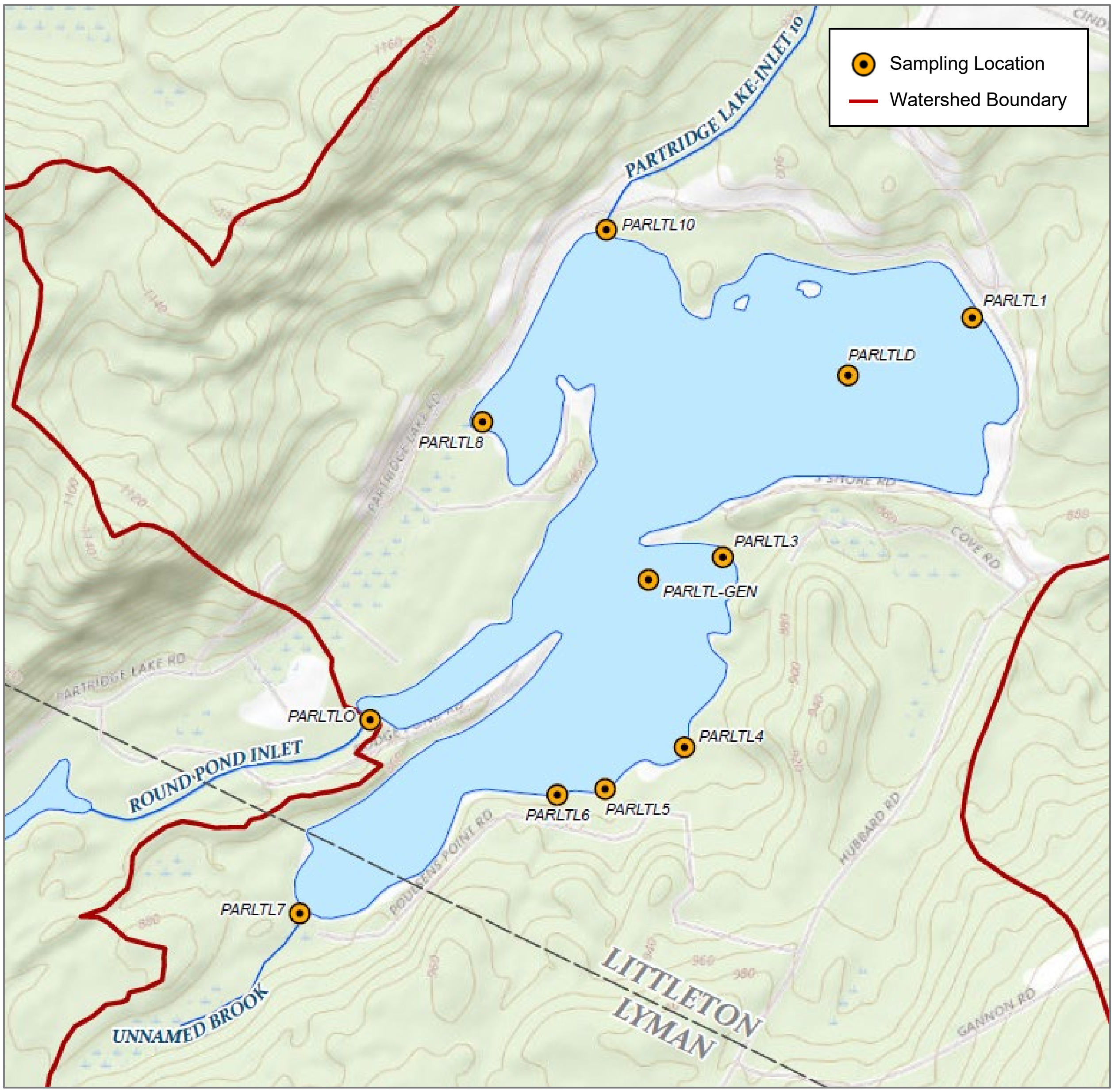
8/26/2021

1. Partridge Lake Water Quality

Water quality data for Partridge Lake have been collected by a variety of sources since 1989, including the NHDES Lake Trophic Study, the NHDES Clean Lakes Project, and the New Hampshire Volunteer Lake Assessment Program (NHVLAP). Additional data were collected by NHDES to support this watershed-based plan in 2020. Parameters collected included alkalinity, Kjeldhal nitrogen, nitrite, nitrate, color, calcium, chloride, chlorophyll-*a*, pH, potassium, Secchi disk transparency, total phosphorus, specific conductance, turbidity, dissolved oxygen, and temperature. The epilimnetic (surface water) data included measurements from the deep spot location as well as various locations around the lake, including multiple inlet tributaries and the outlet of the lake (Figure 2).

Figure 2. Partridge Lake Water Quality Sampling Locations



1.1. Water Quality Assessment

CEI obtained data from the NHDES Environmental Database and reviewed the phosphorus, chlorophyll-*a*, Secchi disk transparency, and dissolved oxygen data for the Partridge Lake Deep Spot. Data and trends for these parameters are presented in Sections 1.1.2 through 1.1.5. Data for phosphorus, chlorophyll-*a*, and Secchi disk transparency are also summarized in Table 1.

Table 1. Partridge Lake Deep Spot Summer Median Water Quality Data, 1989-2020

Parameter	1989-2020	1989-2009	2010-2020
Total Phosphorus (µg/L)	9.0	9.0	8.0
Chlorophyll-*a* (ppb)	5.8	5.4	6.4
Secchi Disk (m)	4.8	4.9	4.6

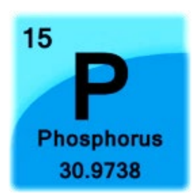
1.1.1 Lake Trophic State Categories

The sections below discuss lake water quality with regard to trophic state categories. For reference, these categories are summarized below.

Table 2. Summary of Lake Trophic State Categories

Category	Description
Oligotrophic	Low biological productivity. Oligotrophic lakes are very low in nutrients and algae, and typically have high water transparency and a nutrient-poor inorganic substrate. Oligotrophic water bodies are capable of producing and supporting relatively small populations of living organisms (plants, fish, and wildlife). If the water body is stratified, hypolimnetic oxygen is usually abundant.
Mesotrophic	Moderate biological productivity and moderate water transparency. A mesotrophic water body is capable of producing and supporting moderate populations of living organisms (plant, fish, and wildlife). Mesotrophic water bodies may begin to exhibit periodic algae blooms and other symptoms of increased nutrient enrichment and biological productivity.
Eutrophic	High biologically productivity due to relatively high rates of nutrient input and nutrient-rich organic sediments. Eutrophic lakes typically exhibit periods of oxygen deficiency and reduced water transparency. Nuisance levels of macrophytes and algae may result in recreational impairments.
Hypereutrophic	Dense algae growth throughout the summer. Dense macrophyte beds, but growth extent is light-limited due to dense algae and related low water transparency. Summer fish kills are possible.

1.1.2 Total Phosphorus



Total phosphorus (TP) is a measure of all organic and inorganic phosphorus forms present in the water. In freshwater lakes, phosphorus is usually the most important nutrient determining the growth of algae and aquatic plants. Because phosphorus is typically relatively less abundant than nitrogen, it is considered the "limiting nutrient" for biological productivity. The New Hampshire criteria for total phosphorus (for epilimnetic or surface measurements) by lake trophic class[1] are as follows:

Trophic Class	TP (µg/L)
Oligotrophic	< 8
Mesotrophic	≤ 12
Eutrophic	≤ 28

Partridge Lake Median Summer TP, 2010-2020 = 8.0 µg/L

1. Sources and Explanation of Lake Trophic Data. New Hampshire Department of Environmental Services, April 2018.

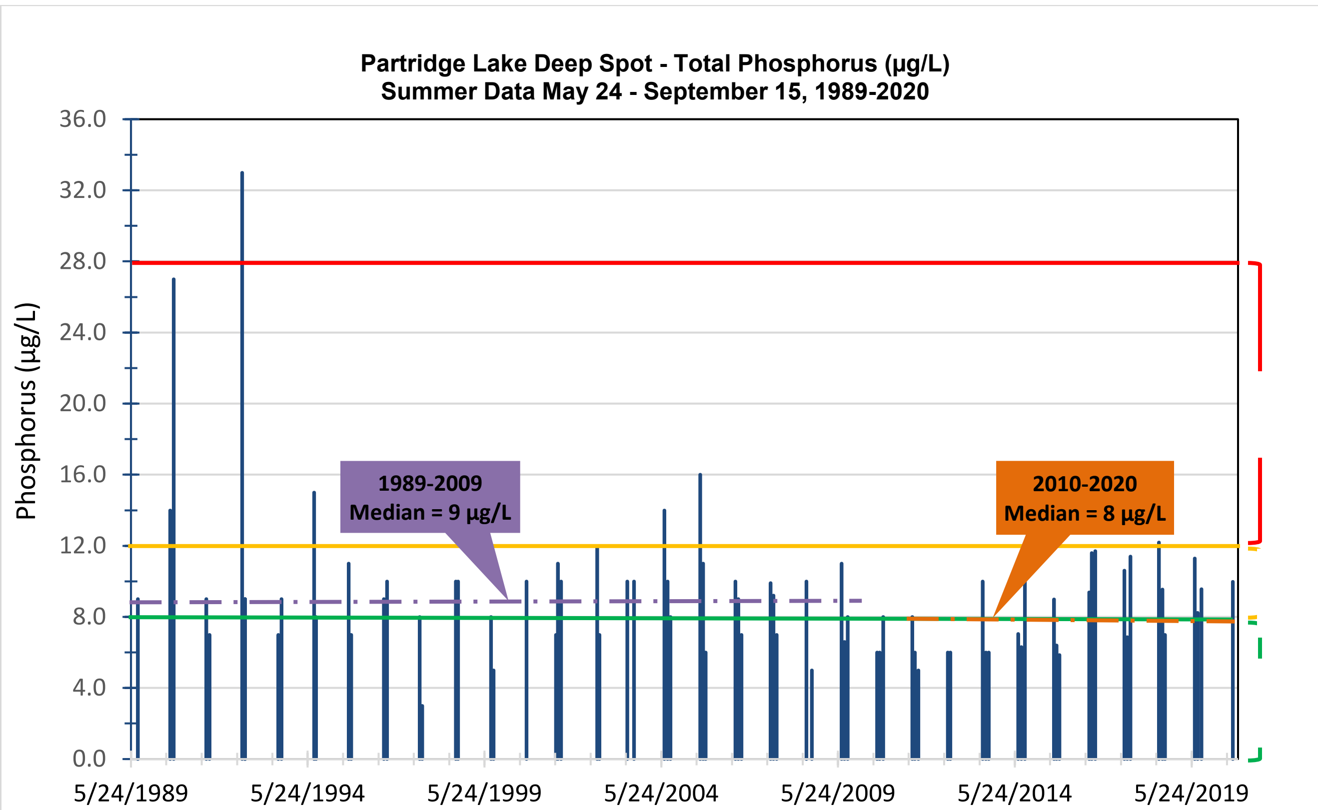
With regard to the use of TP as a water quality indicator for lakes, the *2018 Section 305(b) and 303(d) Consolidated Assessment and Listing Methodology*[2] (CALM) states:

> "*Assessments shall be based on data collected between May 24th to September 15th that is 10 years or less in age and the median value is used to make the indicator comparison.*"

The date range specified in the CALM (May 24-September 15) is referred to hereafter in this report as "summer data". Epilimnetic summer phosphorus data collected at the deep spot in Partridge Lake from 1989-2020 are presented in Figure 3. The median epilimnetic phosphorus concentration in the past ten years (2010-2020) was 8.0 µg/L, which is the lower (better) threshold of the mesotrophic range for phosphorus. The median of data prior to 2010 (1989-2009) was slightly higher at 9.0 µg/L.

For comparison, NHDES reports[3] that data from 213 oligotrophic waterbodies resulted in a TP median of 6.7 µg/L, with the 25th percentile at 4.5 µg/L and the 75th percentile at 10.1 µg/L. Data from 305 mesotrophic waterbodies had a TP median of 11.4 µg/L, with the 25th percentile at 8.3 µg/L and the 75th percentile at 15.7 µg/L.

Figure 3. Summer Epilimnetic Total Phosphorus Data from the Partridge Lake Deep Spot



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2. 2018 Section 305(b) and 303(d) Consolidated Assessment and Listing Methodology. New Hampshire Department of Environmental Services. January 3, 2020.

3. New Hampshire Lake Trend Report: Status and trends of water quality indicators. New Hampshire Department of Environmental Services. R-WD-20-08. June 2020.

1.1.3 Chlorophyll-*a*

Chlorophyll-*a* is a green pigment used by plants, phytoplankton and cyanobacteria to convert sunlight into the chemical energy needed to convert carbon dioxide into carbohydrates. The abundance of this pigment provides an indirect measure of algal biomass and is therefore an indicator of a lake's trophic status. As stated in the NHDES *Sources and Explanation of Lake Trophic Data*[1], the New Hampshire criteria for chlorophyll-*a* by lake trophic class are as follows:

Trophic Class	Chl- *a* (µg/L)
Oligotrophic	< 3.3
Mesotrophic	≤ 5.0
Eutrophic	≤ 11

Partridge Lake Median Summer Chlorophyll-*a*, 2010-2020 = 6.4 ppb

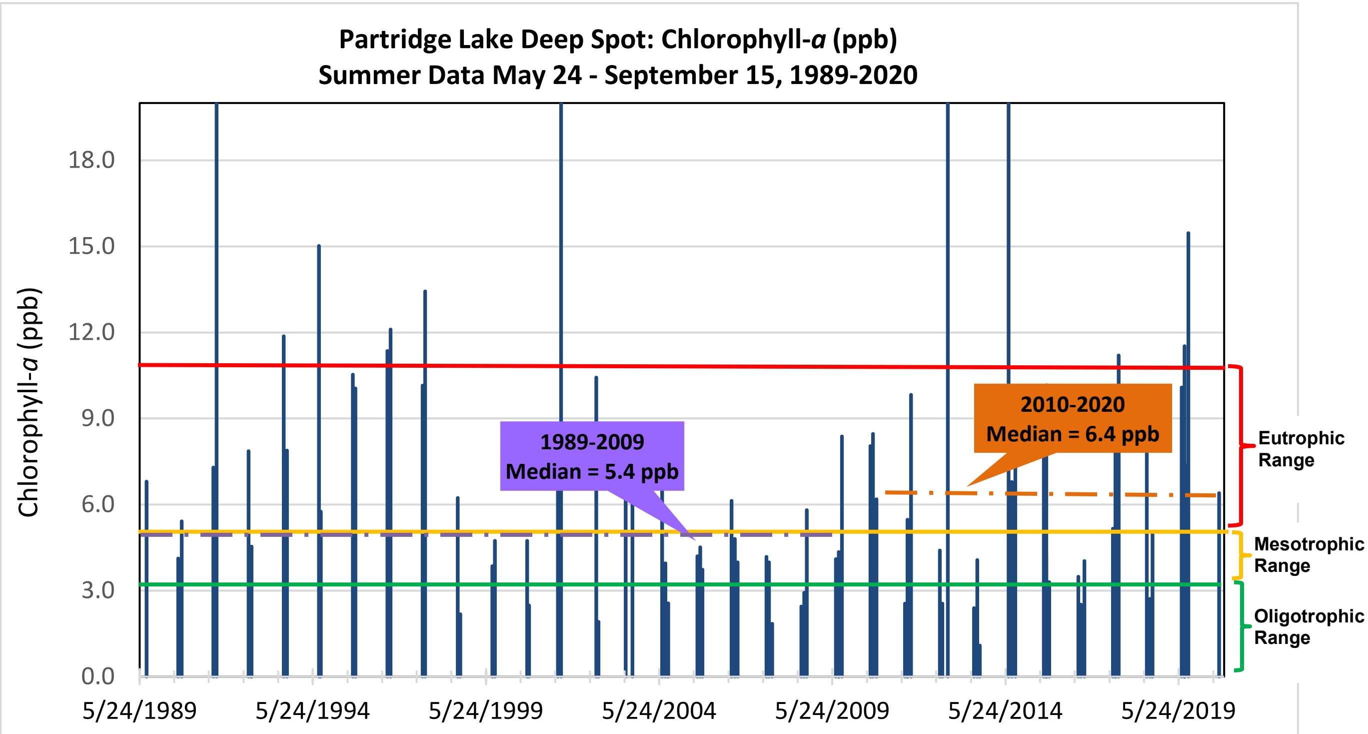
With regard to the use of chlorophyll-*a* data as a water quality indicator for lakes, the 2018 CALM states:

> *"Assessments shall be based on data collected between May 24th to September 15th that is 10 years or less in age and the median value is used to make the indicator comparison."*

Summer chlorophyll-*a* data collected at the deep spot in Partridge Lake from 1989-2020 are presented in Figure 4. The 2010-2020 median summer chlorophyll-*a* concentration was 6.4 ppb (parts per billion), within the lower (better) end of the NHDES eutrophic range for this parameter and moderately higher than the 1989-2009 median concentration of 5.4 ppb. In water, 1 ppb is equivalent to 1 µg/L.

For comparison, NHDES reports[1] that New Hampshire oligotrophic waterbodies have a median chlorophyll-*a* of 2.51 µg/L, with the 25th percentile at 1.76 µg/L and the 75th percentile at 3.58 µg/L. Mesotrophic waterbodies had a chlorophyll-*a* median of 4.55 µg/L, with the 25th percentile at 3.15 µg/L and the 75th percentile at 6.59 µg/L.

Figure 4. Summer Chlorophyll-*a* data from the Partridge Lake Deep Spot



1.1.4 Secchi Disk Transparency

The Secchi disk is a weighted black and white disk that is lowered into the water by a calibrated chain until it is no longer visible. This method provides a measure of water transparency (light penetration), which is primarily a function of algal productivity, water color, and turbidity caused by suspended particulate matter. Water transparency influences the growth of rooted aquatic plants by determining the depth to which sunlight can penetrate to the lake sediments. As stated in the NHDES "*Sources and Explanation of Lake Trophic Data*[1], the New Hampshire criteria for Secchi disk transparency by lake trophic class are as follows:

Secchi disk being lowered into the water

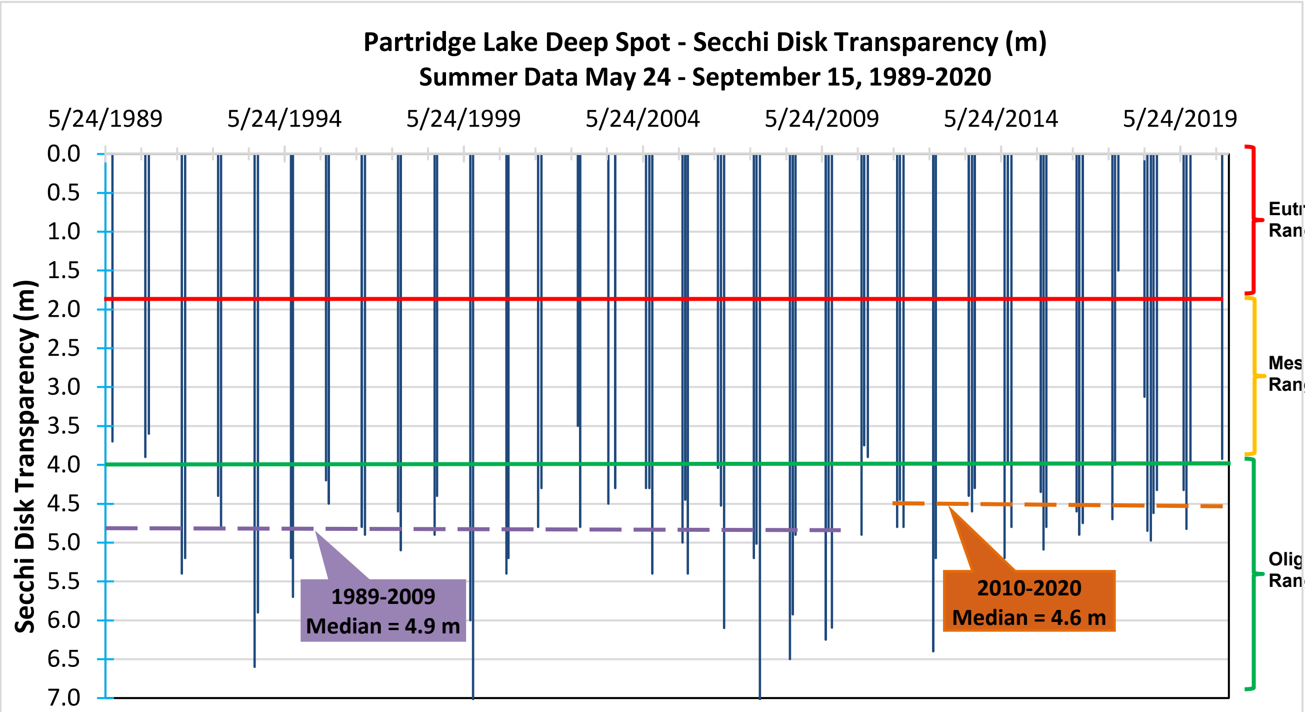
Trophic Class	Transparency (m)
Oligotrophic	> 4
Mesotrophic	1.8 - 4
Eutrophic	< 1.8

Partridge Lake Median Summer 2010-2020 Secchi Disk = 4.6 m

Secchi disk transparency data collected at the deep spot in Partridge Lake from 1989-2020 are presented in Figure 5. The median summer Secchi disk transparency for 2010-2020 was 4.6 meters, slightly lower than the median of data prior to 2010 (4.9 meters), and within the NHDES oligotrophic range for this parameter.

For comparison, NHDES reports[3] that New Hampshire oligotrophic waterbodies had a Secchi disk tranparency median of 4.53 meters, with the 25th percentile at 3.44 meters and the 75th percentile at 5.96 meters. Mesotrophic waterbodies had a median of 2.68 meters, with the 25th percentile at 2.07 meters and the 75th percentile at 3.48 meters.

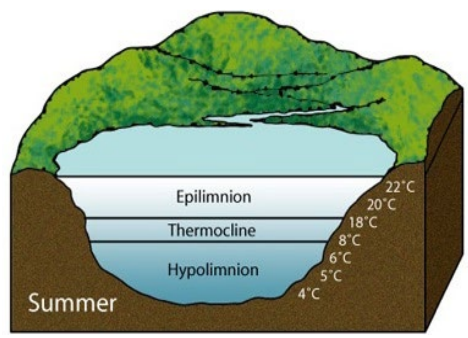
Figure 5. Summer Secchi disk transparency data from the Partridge Lake Deep Spot



1.1.5 Dissolved Oxygen

Dissolved oxygen (DO) profiles are measurements taken at regular intervals (e.g., 1 meter) from the surface to the bottom of the lake. These profiles help to characterize conditions associated with a lake's seasonal thermal stratification and related habitat for fish and other aquatic organisms. A lake of sufficient depth (such as Partridge Lake) will typically be well mixed in the early spring (immediately after ice-off) and then gradually separate into three thermal layers throughout the summer:

- The **epilimnion** (upper layer) will contain warmer water with high levels of dissolved oxygen due to contact with the atmosphere and wind/wave mixing.
- The **metalimnion** (middle layer, also known as the **thermocline**) is a transition zone between the warm upper layer and the cooler, denser lower layer. Due to the rapid change in temperature and water density in this layer, it acts as a barrier to mixing between the top and bottom waters.



- The **hypolimnion** (deepest layer) typically exhibits lower temperature and lower DO concentrations. Although cold water has a higher oxygen solubility than warm water, decomposition of organic sediments gradually depletes the available oxygen in this layer during summer stratification.

DO levels have an important impact on fish and other aquatic biota. Low DO concentrations can impair the health and spawning of fish and other organisms at sustained concentrations below 5 mg/L. Anoxic conditions (oxygen depleted, i.e. DO<1 mg/L) in the hypolimnion are also associated with the release of phosphorus from lake sediments into the water column, helping to fuel algal blooms.

CEI reviewed the historic dissolved oxygen profiles for Partridge Lake to determine the frequency, duration, and severity of anoxic conditions in the Partidge Lake hypoliminion. Because of the effect of temperature on thermal stratification and oxygen solubility, CEI looked at a subset of dissolved oxygen profiles which represented mid-summer conditions (July and August), when thermal startification was expected to be well-developed. Profiles available from July and August were as follows:

- **July DO profiles**: Deep spot profiles on 15 dates ranging from 1990 to 2019
- **August DO profiles**: Deep spot profiles on 14 dates ranging from 1989 to 2006

The July and August DO profiles are presented below in Figures 6 and 7. The data from these months are presented separately for ease of viewing, and to help separate temporal differences between the months.

Figure 6. Partridge Lake July DO Profiles (1990-2019)

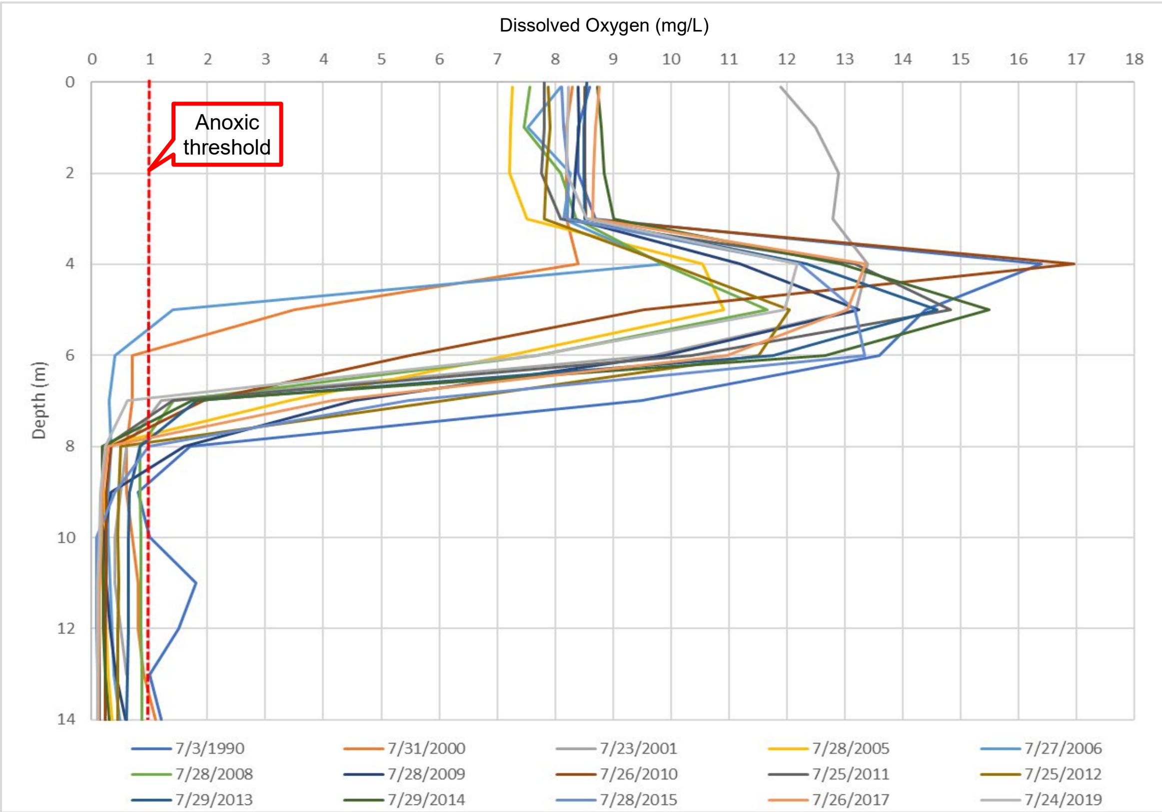
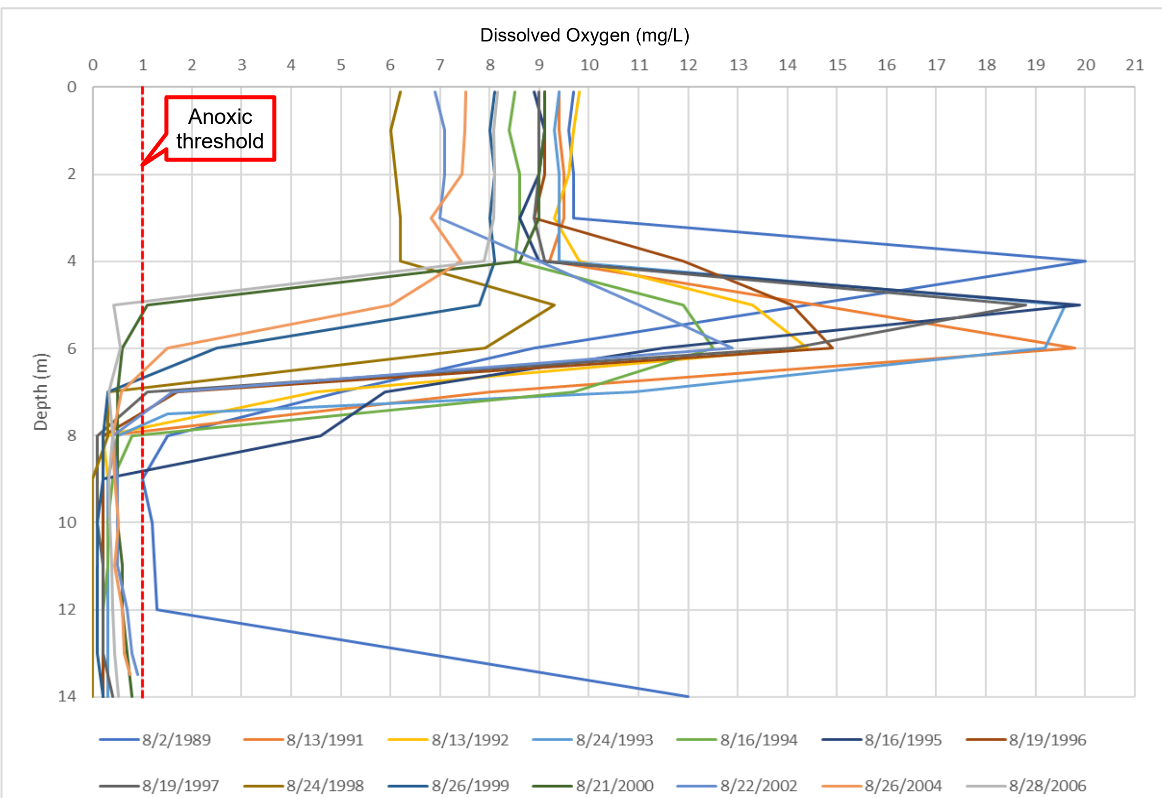


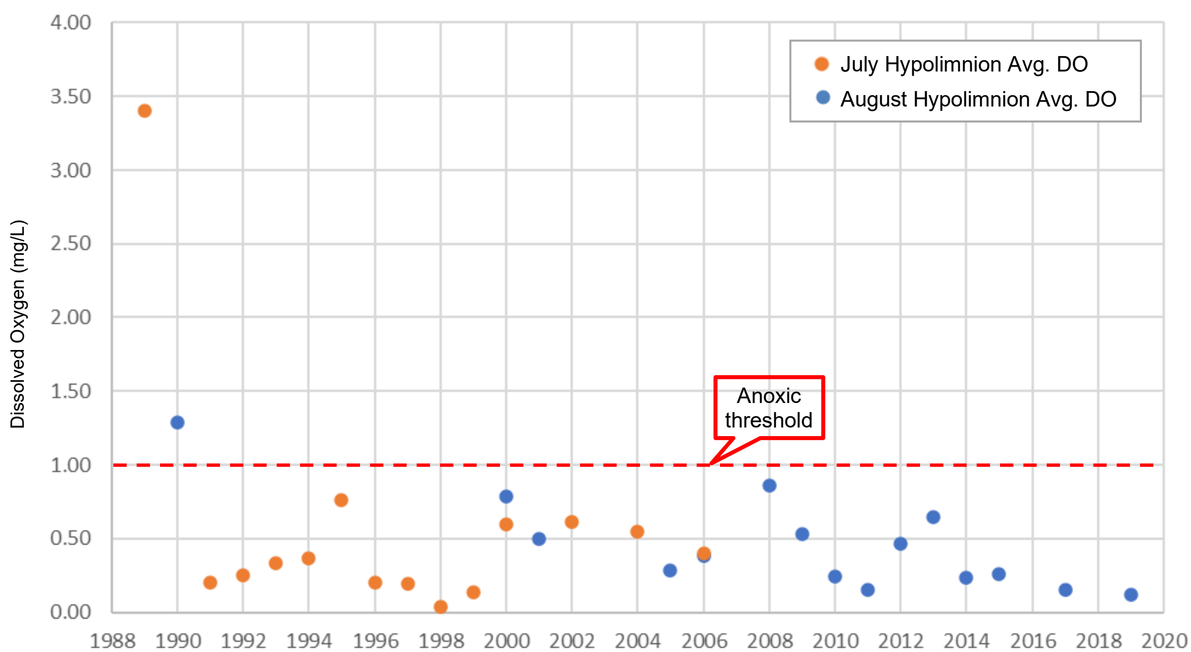
Figure 7. Partridge Lake August DO Profiles (1989-2006)



The data presented in Figures 6 and 7 show that Partridge Lake has a consistent pattern of hypolimnetic anoxia in the summer over the 1989-2019 period of record. Related observations are summarized below:

- In July and August, the metalimnion develops at depths between 3-4 meters and the hypolimnion at 7-8 meters.
- As shown in Figure 8, hypolimnetic DO levels (for depths ≥8m) were below the anoxic threshold of 1 µg/L for all years from 1989-2019, with the exception of 1989 and 1990. These anoxic conditions are clearly supportive of seasonal phosphorus release from sediments, also known as "internal loading".
- Although the 1989 and 1990 profiles show less anoxic conditions in the hypolimnion, the available data does not appear to indicate a clear trend of worsening conditions. The median hypolimnetic DO was very similar for the July (1990-2019) and August (1989-2006) profiles, 0.38 mg/L and 0.35 mg/L respectively. CEI notes that the median for the last 10 years of summer data (2008-2019) is somewhat lower (0.25 mg/L), and future DO profiles should be evaluated to see if this potential trend continues.

Figure 8. Partridge Lake Average July/August Hypolimnetic DO (1989-2019)



- Most of the July and August DO profiles exhibit a strong DO maximum in the metalimnion, known as a **positive heterograde** curve. This is usually caused by an abundance of algae in the metalimnion and associated photosynthetic activity, which can result in supersaturated oxygen levels. Metaliminetic algal blooms can be supported by high water transparency and low algal abundance in the epilimnion, allowing light to penetrate to the metalimnion and promote algal growth. As the thermocline breaks down later in the season, these algae can move to the surface and contribute to late-season algae/cyanobacteria blooms.

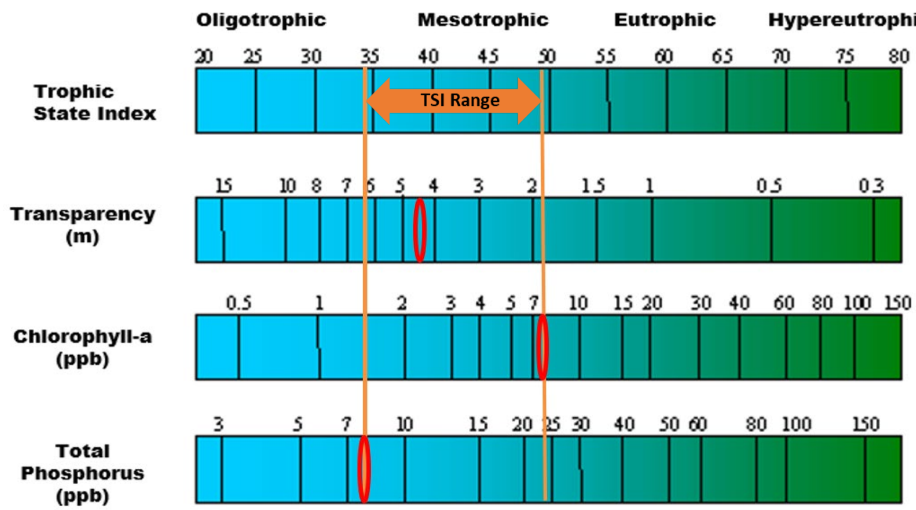
1.2. Carlson Trophic Status Index Analysis

As an additional point of reference for comparison to the NHDES trophic categories presented in Section 1.1, CEI calculated the trophic status for Partridge Lake using the Carlson Trophic Status Index (TSI), which is one of the most commonly used means of characterizing a lake's trophic state. As illustrated in Figure 9, the TSI assigns values based upon logarithmic scales which describe the relationship between three parameters (total phosphorus, chlorophyll-*a*, and Secchi disk transparency) and the lake's overall biological productivity. TSI scores relate to trophic categories as shown to the right.

Trophic Class	Carlson TSI
Oligotrophic	<40
Mesotrophic	40-50
Eutrophic	50-70
Hypereutrophic	70-100

Figure 9 depicts Partridge Lake on the Carlson TSI scale, based on the data discussed below.

Figure 9. Carlson Trophic State Index for Partridge Lake



(*Figure adapted from 1988 Lake and Reservoir Restoration Guidance Manual. USEPA EPA 440/5-88-002*)

The Partridge Lake TSI was calculated based on 2010-2020 data presented in Section 2.1, as follows:

Secchi Disk Transparency: Partridge Lake median summer 2010-2020 Secchi disk (m)= 4.6m;
TSI_{Secchi}, = 60 - 14.41ln Secchi disk (m)
TSI_{Secchi}, = 38.0 (oligotrophic)

Chlorophyll-*a*: Partridge Lake median summer 2010-2020 chl-*a* = 6.4 ppb;
$TSI_{chlor\text{-}a}$ = (9.81) (ln chlorophyll-*a*) + 30.6
$TSI_{chlor\text{-}a}$ = 48.8 (upper mesotrophic)

Total Phosphorus: Partridge Lake median summer 2010-2020 TP = 8.0 µg/L;
TSI_{TP} = (14.42) (ln TP µg/L) + 4.15
TSI_{TP} = 34.1 (oligotrophic)

Note: ln = log-normal

Although median summer Secchi disk transparency and TP for Partridge Lake are in the Carlson TSI oligotrophic range, chlorophyll-*a* is near the upper (worse) threshold of the mesotrophic range. For comparison, the NHDES trophic categories presented in Section 1.1 are more conservative, placing Partridge Lake in the lower (better) end of the mesotrophic range for TP and the lower end of the eutrophic range for chlorophyll-*a*.

C1.3 Cyanobacteria Data

The occurrence of cyanobacteria blooms has been a concern for Partridge Lake stakeholders since the lake's first cyanobacteria advisory was issued in September of 2017. Although cyanobacteria are commonly referred to as blue-green algae, they are actually a unique type of bacteria that is capable of photosynthesis. Cyanobacteria can be found in almost all upland and aquatic habitats on earth, and are found in a vast majority of New Hampshire lakes.

Some cyanobacteria species found in lakes have the potential to produce toxins, which can be released into the water as the cells decompose. Even where potentially toxin-producing species are present, toxin levels are often either undetectable or at extremely low levels, well within accepted guidelines for safe swimming and water contact recreation. However, during cyanobacteria "blooms" (periods of rapid population growth) and subsequent mass die-off of cells, toxin levels can become high enough to present a health threat to humans, pets and other mammals. Cyanobacteria blooms can occur in lakes at any time, but are most common in late summer and early fall when many lakes are at their peak annual phosphorus concentration due to seasonal release of phosphorus from bottom sediments. Health threats are typically caused by ingestion of water, which can cause symptoms including stomach and intestinal illness, allergic responses, liver damage and neurotoxic reactions (e.g. tingling fingers/toes).

In New Hampshire, cyanobacteria advisories are issued when there are blooming conditions and cyanobacteria cell concentrations exceed 70,000 cells/ml in recreational waters. As stated above, only some cyanobacteria species are potentially toxin-producing, and the presence of these species does not imply that unsafe levels of toxin are present.

Partridge Lake Cyanobacteria Advisories

NHDES reports[4] that there have been two cyanobacteria advisories issued for Partridge Lake, in 2017 and 2020 as follows:

- **2020 Advisory** (8/18/20 - 9/4/20): This advisory started on 8/18/2020. Although cyanobacteria cell counts were low on 9/4, the entire lake was still green. As such, the advisory was removed but an alert statement was issued so the public could remain on the look-out. Surface blooms were observed on both 9/21 and 9/25 and the alert status was maintained. Bloom conditions were later observed during NHDES sampling conducted on 12/13. An alert was issued but an official advisory was not issued due to the time of year and difficulty in re-sampling.

- **2017 Advisory** (9/17/2017-10/6/2017): This advisory was stopped by NHDES on October 6, noting that the swim season was completed. However, cell counts were still elevated on October 22 and November 5, 2017.

Table 3 provides a summary of the results of sampling conducted at Partridge Lake to identify and enumerate cyanobacteria and other phytoplankton species.

4. Email dated 12/111/202 from Amanda McQuaid, Ph.D., Harmful Algal and Cyanobacterial Bloom Program Watershed Management Bureau Water Division, NH Department of Environmental Services.

Table 3. Summary of Partridge Lake Cyanobacteria Sampling, 2002-2020

Sample Date		Cyano Taxa	Total Cells (cells/ml)	Lake Warning/ Advisory
2020	8/18	Anabaena, Microcystis	100000	**Yes** (**A**dvisory 8/18-9/4)
	8/31	Woronichinia, Microcystis, Dolichospermum, Aphanizomenon	20500	
		Dolichospermum, Aphanizomenon, Microcystis, Woronichinia	20500	
	9/16	Dolichospermum planctonicum, Aphanizomenon	24250	
		Dolichospermum planctonicum, Aphanizomenon	25250	
		Dolichospermum planctonicum, Aphanizomenon	23750	
		Dolichospermum planctonicum, Aphanizomenon	25000	
		Dolichospermum planctonicum, Spirulina	7000	
	9/29	Dolichospermum planctonicum	22000	
		D. circinalis, D. planctonicum	22000	
	10/27	D. planctonicum, D. circinalis, Aphanizomenon	10000	
		D. planctonicum, D. circinalis, Aphanizomenon	8250	
	12/15	Aphanizomenon	1.26 million (bloom); 500 (deep surface)	Elevated count in bloom, but no advisory (late in season)
2019	7/24	None observed	0	
2018	8/22	Lyngbya	1000	
2017	8/29	Anabaena/Dolichospermum	44400	
		Anabaena/Dolichospermum	42600	
	9/17	Anabaena/Dolichospermum	32890	**Yes** (Advisory 9/19-10/6)
		Anabaena/Dolichospermum	38480	
		Anabaena/Dolichospermum	28600	
	9/25	Pico-cyanobacteria	>1,000,000	
	10/2	Anabaena/Dolichospermum	1450000	
		Anabaena/Dolichospermum	12800	
	10/10	Anabaena/Dolichospermum	17920	
		Anabaena/Dolichospermum	250000	
	10/22	Anabaena/Dolichospermum	6720	Elevated counts, but no advisory (swim season over)
		Anabaena/Dolichospermum	1400000	
	11/5	Anabaena/Dolichospermum and Woronichinia	87750	Elevated counts, but no advisory (swim season over)
		None Observed	0	

Sample Date		Dominant Taxa
2015	7/28	Anabaena (77%), Fragilaria, Asterionella
2014	7/29	Anabaena (27%), Aphanizomenon, Tabellaria
2013	7/29	Anabaena (28%), Fragilaria, Asterionella
2010	7/26	Anabaena (52%), Synedra, Ceratium
2009	7/28	Ceratium (40%), Fragilaria, Tabellaria
2008	7/28	Ceratium (34%), Dinobryon, Anabaena
2007	7/24	Dinobryon (35%), Synedra, Synura
2006	7/27	Chrysophaerella (45%), Dinobryon, Mallomonas
	11/23	90% Anabaena
2005	7/28	Dinobryon (72%), Ceratium, Anabaena
2004	8/26	Synedra (48%), Anabaena, Chrysophaerella
2003	6/5	Rhizosolenia (37%), Dinobryon, Synedra
2002	8/22	100% Aphanizomenon

1.4 Water Quality Goals and Assimilative Capacity

1.4.1 Water Quality Goal Setting Meeting

On February 4, 2021, a meeting was held with project partners to discuss the water quality data presented in Sections 1.1 – 1.3 and to establish a water quality goal for Partridge Lake for summer median epilimnetic total phosphorus (TP) concentration. Project partners in attendance at the meeting are listed below.

Table 4. Attendees of Partridge Lake Water Quality Goal Setting Meeting, 02/04/2021

Name	Organization
John Shultz, PLPOA President	Partridge Lake Property Owners Association (PLPOA)
Burt Bechtel, PLPOA	
Doug Damko, Director of Public Works	Town of Littleton
Steve Landry, Watershed Assistance Section Supervisor	New Hampshire Department of Environmental Services
Amy Smagula, Limnologist/Exotic Species Program Coordinator	
Sara Steiner, VLAP Coordinator	
Jeff Marcoux, Watershed Supervisor	
Katie Zink, Watershed Specialist	
Amanda McQuaid, Harmful Algal and Cyanobacterial Bloom Program	
Bob Hartzel, Principal	Comprehensive Environmental, Inc.
Emily DiFranco, Senior Scientist	

As stated in Section 1.1.2, phosphorus is usually the most important nutrient determining the growth of algae and aquatic plants in freshwater lakes. Because phosphorus is typically less abundant than nitrogen, it is considered the “limiting nutrient” for biological productivity. For this reason, the water quality goal established for the Partridge Lake Watershed Restoration Plan is based on TP.

1.4.2 Water Quality Standards and Key Data for Goal Setting

CEI presented the following information for discussion during the goal setting meeting.

- NHDES classifies Partridge Lake as a mesotrophic lake, and therefore the baseline water quality standard for goal setting is 12 μg/L (median summer epilimnetic TP), which is the upper TP limit for mesotrophic lakes in New Hampshire. However, based on data review and locally-defined goals for the lake, project partners may opt to set a water quality goal that is more conservative (lower) than the 12 μg/L standard.
- As defined by NHDES, assimilative capacity (AC) describes the amount of pollutant that can be added to a water body without causing an exceedance of water quality criteria. New Hampshire requires that lakes maintain 10% of their AC in reserve. The “reserve assimilative capacity” required for Partridge Lake is therefore 1.2 μg/L, which is 10% of the 12 μg/L mesotrophic standard. This means that, to maintain at least a 10% reserve assimilative capacity, the maximum median epilimnetic phosphorus concentration for Partridge Lake is 10.8 μg/L (12 μg/L - 1.2 μg/L).
- Using data obtained from the NHDES OneStop Environmental Monitoring Database (as required for AC calculations), CEI calculated that Partridge Lake’s summer median epilimnetic phosphorus

concentration is 8.0 µg/L, based on 2010-2020 data (Figure 10). The "remaining assimilative capacity" for Partridge Lake is 2.8 µg/L (10.8 µg/L – 8.0 µg/L).

- Since the Partridge Lake median TP for 2010-2020 is 8.0 µg/L, and because reduction in TP is desirable to prevent nuisance cyanobacteria blooms, CEI recommended that the Partridge Lake TP goal should be lower than the state standard for mesotrophic lakes. CEI suggested the following for discussion as a possible TP goal:
  - **Maintain a long-term summer epilimnetic median TP of 8.0 µg/l as land development continues in the watershed. To achieve 10% reserve assimilative capacity for this goal (0.8 µg/L), the TP goal would be 7.2 µg/L or lower.**

Project partners discussed the proposed TP goal, including the following key points:

- The group discussed that the primary objective in setting a TP goal for Partridge Lake is to eliminate the occurrence of cyanobacteria blooms.
- There was general consensus that the Partridge Lake TP goal should be lower than the New Hampshire mesotrophic lake standard, and that 7.2 µg/L may represent a TP goal that is both realistically achievable and consistent with the objective of preventing cyanobacteria blooms. As such, the preliminary **summer epilimnetic TP goal for Partridge Lake was set at 7.2 µg/L**.
- At the time of the February 2021 water quality goal setting meeting, the Lake Loading Response Model (LLRM) results for Partridge Lake (see Section 2) were pending completion and not available for consideration. While the data and preliminary TP goal discussed above are based on summer epilimnetic median TP (as specified in the project SSPP), the LLRM model predicts in-lake TP during fully-mixed conditions (i.e., spring ice-out and fall turnover).

  Given the observed summer TP levels in the hypolimnion, it is clear that internal phosphorus load is a significant driver of late season (late summer/fall) cyanobacteria productivity. As such, Partridge Lake's relatively low summer epilimnetic TP levels may be misleading as an indicator of potential for cyanobacteria blooms. The group agreed that TP water quality goals would be re-evaluated based on completion of the LLRM model. As presented in Section 2.7, CEI recommends a **TP target of 10 µg/L during fully mixed conditions** as a conservatively protective goal. 10 µg/L is widely cited in the literature as a threshold where little-to-no algal blooms are typically observed in freshwater lakes.

Figure 10. Partridge Lake Deep Spot -Total Phosphorus (µg/L)

Summer Epilimnetic Data (May 24-September 15), 2010-2020

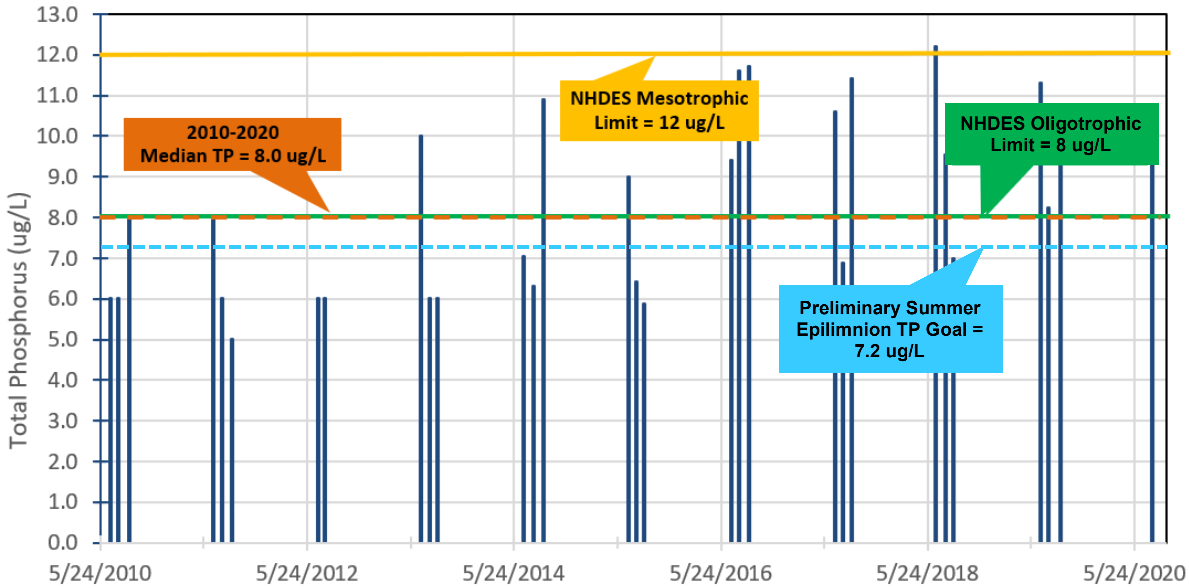


Figure 10 Note: The dark blue vertical bars on the graph represent values from summer sampling dates.

2. Phosphorus Load Estimation

2.1 Purpose

This section details the methodology and results for developing total phosphorus (TP) load estimates for the Partridge Lake watershed. Comparative estimates were developed for existing conditions, predevelopment conditions, and potential future build-out conditions by subwatershed and by source (i.e., land uses, septic systems) to better prioritize and direct TP reduction efforts.

2.2 Methods

2.2.1 Model Overview

The Lake Loading Response Model (LLRM) was used to develop TP loading estimates. LLRM is a spreadsheet-based model used to evaluate nutrient loading to a waterbody and the consequences of that loading in terms of resulting in-lake concentration. The LLRM model is configured for a period of interest based on user-specified inputs such as watershed boundaries, land cover, and precipitation. Embedded calculations are then executed based on reference equations and commonly used coefficients from scientific literature to predict subwatershed runoff, resulting nutrient loads, and other variables.

2.2.2 Data Collection

Data collection, model setup, and calibration were performed in accordance with the approved Site Specific Project Plan (SSPP). Data needed for input to the LLRM includes water quality monitoring data (TP); field measured tributary or outflow discharge (if available, for model calibration purposes); land use data; subwatershed land area delineations; precipitation data; and information on the location of septic systems.

Daily precipitation data was acquired from the National Climatic Data Center (NCDC) gauge in Berlin, NH. Land use data was retrieved from the USGS 2016 National Land Cover Database (NLCD). Water quality monitoring data was obtained from the 2020 NHDES Surface Water Quality Assessment. See Section 2.2.4 for more information on data used for specific model inputs.

2.2.3 Observed Water Quality Data

Water quality data relevant to this study has been collected by various projects, including NHDES Lake Trophic Surveys, the Partridge Lake Clean Lakes Project, and Volunteer Lake Assessment Program (VLAP). See Figure 2 for locations of available water quality monitoring stations. Water quality data from these programs are publicly available from the 2020 NHDES Surface Water Quality Assessment Viewer. The following water quality data were available for this analysis.

- **Epilimnion Data (In-Lake).** The *2018 Section 305(b) and 303(d) Consolidated Assessment and Listing Methodology* (CALM) from NHDES specifies that epilimnetic (upper/surface layer) data collected between May 24th and September 15th (summer data) from the previous ten years be used in the assessment of lake trophic conditions. As such, summer data collected at the epilimnion of the Partridge Lake Deep Spot sampling station from 2010 through 2020 was used to calculate Partridge Lake median phosphorus levels. The median epilimnetic summer TP concentration at the Deep Spot sampling station was 8.0 µg/L over the ten-year sampling period (see Figure 3).

- **Fully Mixed Data (In-Lake).** CEI conducted a data review and determined that the best available data representing the lake water column in a fully mixed state was collected by NHDES on December 13, 2020. The average TP concentration throughout the water column on this date was 25.4 µg/L.

- **Tributary Data.** Phosphorus data was sporadically collected by NHDES at select tributaries from 1989 to 2020. Tributary concentrations ranged from approximately 4 µg/L to 17 µg/L during the period from 2010 to 2020. This data was not used for calibration purposes. Given the intermittent nature of most tributaries in the watershed, tributary input concentrations are expected to be highly variable and would require a longer record length to produce reliable results for calibration purposes (e.g., three to five years of monthly sampling data for the entire calendar year).

2.2.4 Model Inputs

A time period of 2010-2020 was selected for the analysis based on CALM methodology and available water quality data. All corresponding inputs were computed during the specified time period. Select inputs were modified during the calibration process as discussed in Section 2.3.

Precipitation

Annual average precipitation data from 2010-2020 was compiled and calculated from Global Historical Climatology Network (GHCN) station USC00270690 in Berlin, NH, approximately 36 miles northeast of Partridge Lake. This is the closest available station to Partridge Lake with a similar elevation and daily precipitation data available for the ten-year analysis period. As shown in Table 5, the annual average precipitation during this period was 1.11 m (i.e., 43.4 inches).

Table 5. Annual Precipitation

Year	Precipitation (m)
2010	1.34
2011	1.29
2012	1.17
2013	0.97
2014	1.08
2015	0.95
2016	0.92
2017	1.21
2018	1.09
2019	1.14
2020	1.09
Average:	**1.11**

Subwatershed Delineations

Subwatersheds were delineated to represent watersheds for the primary tributaries to Partridge Lake, as shown on Figure 11. The Partridge Lake Watershed was divided into 10 subwatersheds based on boundaries from the National Hydrography Dataset Plus (NHDPlus) and topography from University of New Hampshire's Earth Systems Research Center. The area of each delineated subwatershed was calculated using GIS tools as summarized by Table 6.

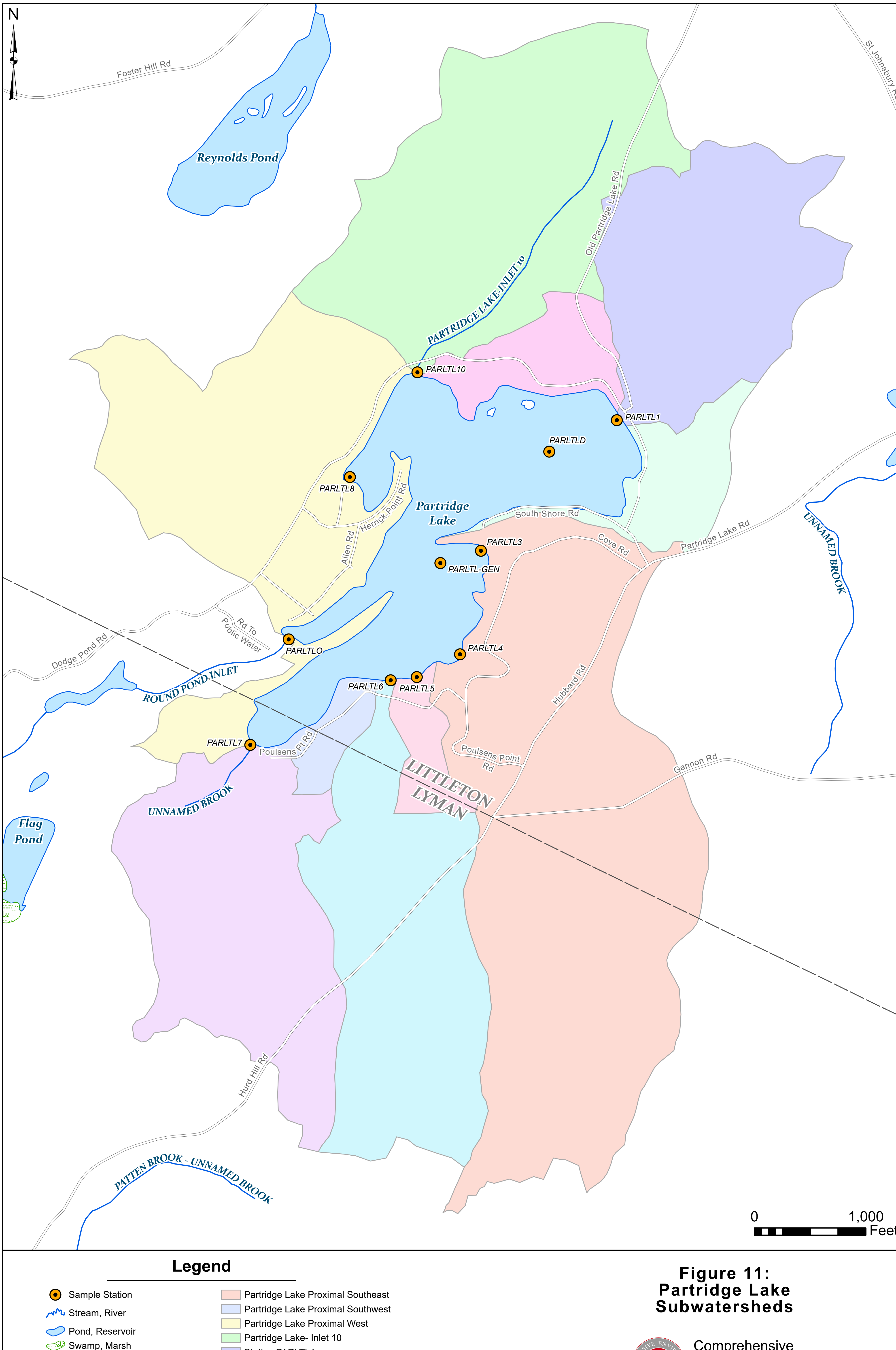


Figure 11: Partridge Lake Subwatersheds

Comprehensive Environmental Incorporated

Data Sources: GRANIT, CEI

12.29.2020

Table 6. Calculated Subwatershed Areas

Subwatershed	Name	Subwatershed Area (ha)
W1	Inlet 10	56.1
W2	Proximal NW	9.7
W3	PARLTL1	37.0
W4	Proximal NE	10.4
W5	Proximal SE	92.8
W6	PARTLTL5	5.1
W7	PARTLTL6	42.8
W8	Proximal SW	4.1
W9	Unnamed Brook	42.6
W10	Proximal W	54.2
	Totals:	**354.8**

Note: Subwatershed names are based on nearest NHDES sample station or tributary as shown on Figure 11.

Land Use

LLRM includes 14 pre-defined land use categories (Table 7). Each land use category is assigned runoff and baseflow export coefficients to enable calculation of nutrient export (i.e., kg/ha/yr). GIS tools were used to apply the NLCD data to each delineated subwatershed and to calculate the area and percentage comprised by each category (Table 8).

> ***Note:*** *Table 9 and Table 10 below provide land use inputs relative to a predevelopment analysis and buildout analysis, respectively. Refer to Section 2.4 for more information on the predevelopment analysis and to Section 2.5 for information on the buildout analysis.*

Table 7. LLRM Specified Land Uses

LLRM Land Use Classification	Land Use Description
Urban 1 (LDR)	Low density residential (>1 ac lots)
Urban 2 (MDR/Hwy)	Medium density residential (0.3-0.9 ac lots) + highway corridors
Urban 3 (HDR/Com)	High density residential (<0.3 ac lots) + commercial
Urban 4 (Ind)	Industrial
Urban 5 (P/I/R/C)	Park, Institutional, Recreational or Cemetery
Agric 1 (Cvr Crop)	Agricultural with cover crops (minimal bare soil)
Agric 2 (Row Crop)	Agricultural with row crops (some bare soil)
Agric 3 (Grazing)	Agricultural pasture with livestock
Agric 4 (Feedlot)	Concentrated livestock holding area
Forest 1 (Upland)	Land with tree canopy over upland soils and vegetation
Forest 2 (Wetland)	Land with tree canopy over wetland soils and vegetation
Open 1 (Wetland/Lake)	Open wetland or lake area (no substantial canopy)
Open 2 (Meadow)	Open meadow area (not clearly wetland, but no canopy)
Open 3 (Barren)	Mining or construction areas, largely bare soils

Table 8. Subwatershed Area Based on LLRM Land Use Classification (ha) - Existing Conditions

LLRM LU Classification	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	Total	Percent
Urban 1 (LDR)	0.15	0.03	0.18	0.36	0.18	0.12	0.42	0.00	0.00	0.18	1.62	0.5%
Urban 2 (MDR/Hwy)	0.00	0.00	0.09	0.00	0.09	0.00	0.09	0.00	0.00	0.00	0.27	0.1%
Urban 3 (HDR/Com)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
Urban 4 (Ind)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
Urban 5 (P/I/R/C)	1.78	2.90	3.40	1.75	8.15	0.17	2.07		1.15	3.64	25.01	7.0%
Agric 1 (Cvr Crop)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
Agric 2 (Row Crop)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
Agric 3 (Grazing)	0.32	0.38	4.16	0.00	2.38	0.00	8.24	0.00	1.26	0.00	16.74	4.7%
Agric 4 (Feedlot)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
Forest 1 (Upland)	51.49	6.34	28.23	8.28	81.26	4.80	31.86	4.04	38.47	47.57	302.34	85.2%
Forest 2 (Wetland)	2.22	0.03	0.96	0.00	0.72	0.00	0.00	0.00	1.44	2.72	8.09	2.3%
Open 1 (Wetland/Lake)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.0%
Open 2 (Meadow)	0.18	0.03	0.00	0.00	0.00	0.03	0.09	0.03	0.27	0.06	0.69	0.2%
Open 3 (Barren)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
Totals	56.14	9.70	37.02	10.39	92.79	5.12	42.76	4.07	42.59	54.18	354.8	100.0%

Table 9. Subwatershed Area Based on LLRM Land Use Classification (ha) – Predevelopment Conditions

LLRM LU Classification	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	Total	Percent
Urban 1 (LDR)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Urban 2 (MDR/Hwy)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Urban 3 (HDR/Com)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Urban 4 (Ind)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Urban 5 (P/I/R/C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Agric 1 (Cvr Crop)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Agric 2 (Row Crop)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Agric 3 (Grazing)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Agric 4 (Feedlot)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Forest 1 (Upland)	53.7	9.6	36.1	10.4	92.1	5.1	42.7	4.0	40.9	51.4	346.0	98.0%
Forest 2 (Wetland)	2.2	0.0	1.0	0.0	0.7	0.0	0.0	0.0	1.4	2.7	8.1	1.8%
Open 1 (Wetland/Lake)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Open 2 (Meadow)	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.1	0.7	0.2%
Open 3 (Barren)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Totals	**56.1**	**9.7**	**37.0**	**10.4**	**92.8**	**5.1**	**42.8**	**4.1**	**42.6**	**54.2**	**354.8**	**100%**

Notes:

1. Includes land use results from predevelopment analysis as detailed by Section 2.4.

Table 10. Subwatershed Area Based on LLRM Land Use Classification (ha) – Projected 2040 Buildout Conditions

LLRM LU Classification	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	Total	Percent
Urban 1 (LDR)	1.0	0.0	0.2	0.4	1.0	0.1	1.3	0.0	0.0	1.0	4.9	1.3%
Urban 2 (MDR/Hwy)	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.3	0.1%
Urban 3 (HDR/Com)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Urban 4 (Ind)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Urban 5 (P/I/R/C)	1.8	2.9	3.4	1.7	8.2	0.2	2.1	0.0	1.2	3.6	25.0	7.1%
Agric 1 (Cvr Crop)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Agric 2 (Row Crop)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Agric 3 (Grazing)	0.3	0.4	4.2	0.0	2.4	0.0	8.2	0.0	1.3	0.0	16.7	5.6%
Agric 4 (Feedlot)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Forest 1 (Upland)	50.7	6.3	28.2	8.3	80.5	4.8	31.0	4.0	38.5	46.8	299.1	83.9%
Forest 2 (Wetland)	2.2	0.0	1.0	0.0	0.7	0.0	0.0	0.0	1.4	2.7	8.1	1.8%
Open 1 (Wetland/Lake)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Open 2 (Meadow)	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.1	0.7	0.2%
Open 3 (Barren)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Totals	**56.1**	**9.7**	**37.0**	**10.4**	**92.8**	**5.1**	**42.8**	**4.1**	**42.6**	**54.2**	**354.8**	**100%**

Notes:

1. Includes land use results from buildout analysis as detailed by Section 2.5.

Precipitation Coefficients

Runoff and baseflow precipitation coefficients were assigned to each land use category to indicate the fraction of overall rainfall that is converted to overland flow ("runoff") or baseflow, respectively (0 = none; 1 = all). LLRM provides default coefficients for each land use category from the published scientific literature. Default LLRM values were used for initial model inputs.

Phosphorus Export Coefficients

Phosphorus export coefficients were assigned to each land use category to enable estimation of phosphorus export via runoff and baseflow. LLRM provides default coefficients for each land use category, including an overall range from the published scientific literature. Default coefficients were used for most initial model inputs for both runoff and baseflow based on the median value. Due to a lack of variation between median urban land use runoff values, urban coefficients were proportionally adjusted from the medium density residential value based on the 2017 New Hampshire Small Municipal Separate Storm Sewer System (MS4) General Permit. For example, the MS4 high density residential coefficient is 18% higher than the medium density residential coefficient, so the LLRM high density coefficient was raised by 18%. Table 11 provides a summary of the urban land use runoff modifications.

Table 11. Initial LLRM Phosphorus Runoff Coefficients Adjustment

Land Use	LLRM Median Coefficient (kg/ha/yr)	MS4 Coefficient (kg/ha/yr)	MS4 Percent Difference	Adjusted LLRM Coefficient (kg/ha/yr)
Urban 1 (LDR)	1.1	1.7	-29%	0.78
Urban 2 (MDR/Hwy)	1.1	2.2	0%	1.10
Urban 3 (HDR/Com)	1.1	2.6	18%	1.30
Urban 4 (Ind)	1.1	2.0	-9%	1.00
Urban 5 (P/I/R/C)	1.1	1.7	-29%	0.78

Notes:

1. MS4 Percent Difference is relative to medium density residential land use.

2. See Table 14 for initial export coefficients as input into the model.

Subwatershed Routing

LLRM includes a subwatershed routing mechanism for nutrients, baseflow, and runoff. Since attenuation in a downstream subwatershed can affect inputs from an upstream subwatershed that passes through the downstream subwatershed, the model must be directed as to where to apply attenuation factors and additive effects. Since all tributaries discharge directly to Partridge Lake, subwatershed routing was not applicable for this model.

Atmospheric Deposition

Atmospheric deposition was calculated to be 4.6 kg/year based on the surface area of the Lake (420,873 m^2) and the LLRM default phosphorus deposition rate for New Hampshire lakes (Schloss and Craycraft, 2013).

Internal Loading

Internal loading reflects rates of seasonal phosphorus recycling from lake bottom sediment. To calculate internal loading for input into LLRM, a simple internal load calculation was performed by comparing the difference between the lake's hypolimnetic TP concentration in a "fully mixed" state (ideally just after ice-out and associated spring "turnover") and at the time of the highest observed hypolimnetic concentrations (i.e., prior to fall turnover). The estimated depth zone for the Partridge Lake hypolimnion during summer thermal stratification is from 8 to 14.5 meters, based on analysis of the lake's temperature and dissolved oxygen profiles.

For purposes of this internal load calculation, the lake's fully mixed hypolimnetic TP concentration was estimated using data collected by NHDES on December 13, 2020. Although TP data had also been collected by NHDES to represent conditions following ice-out on April 5, 2021 (the day following ice-out), this data showed TP levels in the hypolimnion that were significantly higher than in the epilimnion, likely because the lake had not yet had enough time following ice-out to fully mix. The December 13, 2020 data from the lake deep spot was therefore determined to be the best available data to represent the lake in a fully mixed state.

The difference between the fully mixed hypolimnetic TP concentration and the estimated peak fall concentration was then multiplied by the estimated volume of the hypolimnion to estimate the mass of phosphorus derived from internal loading. This estimate was further adjusted to account for the fraction of total particulate phosphorus assumed to be exchanged with the epilimnion during summer stratification. As indicated by Table 12, internal phosphorus loading is estimated to be 61.5 kg/yr (order-of-magnitude estimate).

This internal load estimate was compared to the sediment chemistry of three preliminary sediment samples collected by NHDES (see Table 26 in Section 3.3). The sum of iron-bound P (FE-P) and loosely-bound P (LB-P) from these samples were used for this analysis, because these P fractions are the most readily available for release from sediments under anoxic conditions. The mass of these P fractions in the surface sediments (top 10 cm) was calculated, as this layer is the most likely to release phosphorus. The portion these P fractions that is released and later available for biological uptake in the epilimnion is typically between 10 to 30%. Based on the range of results from 3 samples, CEI determined that the modeled estimate was reasonable. When averaging the releasable P levels for the three samples and assuming a 30% P loading rate, the estimated annual internal load is 56.6 kg, or 92% of the modeled internal loading estimate of 61.5 kg/yr. This estimate can be further refined based on additional sediment sampling as discussed in Section 3.3.

Table 12. Estimated Annual Average Internal Total Phosphorus Loading

Input Variable	Units	Result
Average Hypolimnetic Total Phosphorus Concentration (December 13, 2020)[1]	µg/L	26.8
Average Hypolimnetic Total Phosphorus Concentration (October)[2]	µg/L	355.5
Accumulated Hypolimnetic Total Phosphorus Concentration (peak fall TP minus fully mixed state)[3]	µg/L	328.7
Estimated Volume of Hypolimnion[4]	Liters	2.87E+08
Accumulated Hypolimnetic Total Phosphorus Mass (October minus December)[5]	kg/yr	94.5
Adjustment Factor[6]	%	0.65
Estimated Internal Load	kg/yr	61.5

Notes:

1. *Based on 2 measurements from 12 m and 14.5 m on 12/13/2020 at the Partridge Lake deep spot*
2. *Based on 2 measurements from 12 m and 13.5 m on 9/27/2020 at the Partridge Lake deep spot*
3. *Difference from fully mixed state to peak fall hypolimnetic TP concentration*
4. *Based on bathymetry data from >8 meters.*
5. *Mass calculated as concentration multiplied by volume, then converted to kg.*
6. *Calculated based on Nürnberg Retention Parameter (R) (i.e., fraction of sediment retained by lake) (Nurnberg, 1984)*
    a. *R = 15 / (18+ Hydraulic Overflow Rate)*
    b. *Hydraulic Overflow Rate = Annual Average Discharge / Lake Surface Area*
    c. *Annual Average Discharge (from LLRM) = 2,112,046 m^3/yr; Surface Area = 420,873 m^2*
    d. *R = 15 / (18 + 5.018) = 0.651*

Septic System Loading

Septic systems located in close proximity to receiving waters can significantly contribute to nutrient loading. The purpose of this calculation is to estimate the amount of annual nutrient loading from septic systems within approximately 200 feet of receiving waters within the watershed (Figure 12). LLRM provides default estimates of factors that contribute to septic systems. For existing conditions, approximately 71 homes (22 year-round homes and 49 seasonal homes) potentially have septic systems with an estimated occupancy of 2.5 people per home (Table 13). This number increases to approximately 75 (26 year-round homes and 49 seasonal homes) for projected 2040 buildout conditions. See Section 2.5 for more discussion on the buildout analysis methods. Default LLRM median estimates were used to estimate septic loading from homes based on an assumed initial concentration, people per home, occupancy days per year, and attenuation factor (i.e., portion of load that reaches the lake). As presented in Section 2.6.1, septic systems represent approximately 6% of the phosphorus loading to Partridge Lake (Table 17).

Table 13. Estimated Number of Septic Systems Within 200 Feet of Surface Waters in Partridge Lake Watershed
(existing conditions vs. projected 2040 buildout conditions)

Subwatershed	Subwatershed Name	Existing Conditions	Projected 2040 Buildout
W1	Inlet 10	3	4
W2	Proximal NW	13	13
W3	PARLTL1	5	5
W4	Proximal NE	8	8
W5	Proximal SE	13	14
W6	PARLTL5	3	3
W7	PARLTL6	1	2
W8	Proximal SW	3	3
W9	Unnamed Brook	1	1
W10	Proximal W	21	22
Total Estimated Septic Systems		**71**	**75**

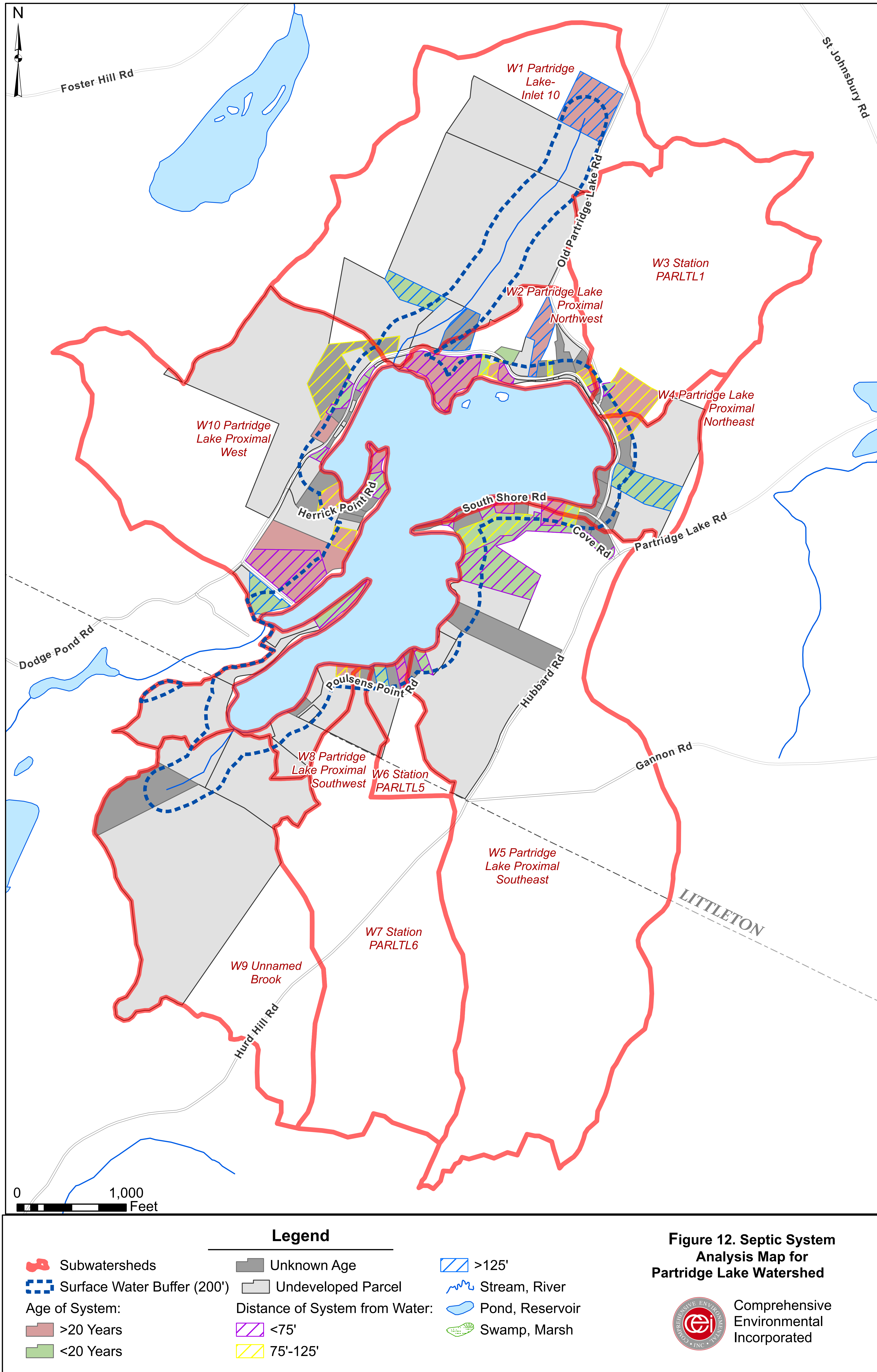


Figure 12. Septic System Analysis Map for Partridge Lake Watershed

2.3 Calibration

Once model inputs were configured, initial model outputs were evaluated relative to available monitoring data. As discussed below, two values were used to calibrate the model: 1) the summer epilimnion TP concentration and 2) the fully mixed TP concentration. As indicated in Section 2.2.3, observed tributary water quality data were not used to calibrate the model given limited data availability and potential for high variability (i.e., intermittent streams).

Preliminary model results are summarized below:

- **Initial results, summer epilimnion**. LLRM does not include a built-in tool to calculate summer epilimnion concentrations. Therefore, initial LLRM loading results, **excluding** internal loading, were input into the Nürnberg model (1998). The Nürnberg model assumes that internal loading is sequestered in the hypolimnion during stratification and is not available for uptake, settling, and flushing. The predicted concentration was 18.0 µg/L, which is significantly higher than the existing median summer epilimnion concentration of 8.0 µg/L.
- **Initial results, fully mixed**. LLRM predicts fully mixed total phosphorus concentrations throughout the water column based on several prediction models. These models include: Kirchner-Dillon (1975), Vollenweider (1975), Larsen-Mercier (1976), Jones-Bachmann (1976), Reckhow General (1977), and Nürnberg (1998). Initial LLRM loading results, including internal load estimates, were input into each prediction model. The average predicted fully mixed concentration was 39.5 µg/L, which is significantly higher than the measured fully mixed concentration of 25.4 µg/L (average of all measurements at Partridge Lake Deep Spot on 12/13/2020).

Inputs were adjusted based on these initial results to obtain a more reasonable output for both calibration methods. See below for a summary of adjustments that were made.

2.3.1 Flow Attenuation

Estimates of average annual outflow (runoff plus baseflow) from each subwatershed were reviewed to determine if it was necessary to adjust precipitation runoff coefficients or assign water attenuation factors to account for mechanisms such as depression storage, wetlands, or infiltration.

Tributary flow data from the 2004 NHDES Partridge Lake and Watershed Diagnostic Study was reviewed, but was not used in the flow calibration process due to sampling gaps and the number of intermittent streams with varying levels of flow in individual subwatersheds. Instead, outflow predictions from each subwatershed were compared with a standard water yield of 1.5 cfs per upstream square mile. This standard water yield value is on the low end for typical New England rivers. Based on this comparison, outflow from each subwatershed was within 15% (±) of the standard water yield.

Flow attenuation factors were therefore not assigned to any of the study subcatchments due to their relatively small size, steep slopes, lack of significant wetland coverage (i.e., < 5%), and modest margin of error relative to the standard water yield.

2.3.2 Nutrient Attenuation

Based on LLRM guidance, nutrient attenuation can vary widely based on removal processes such as infiltration and filtration provided by wetlands, ponds, and other features. Nutrient attenuation within an individual subwatershed can range from 0% removal to 60% removal. Similar to flow attenuation, nutrient attenuation factors were not assigned to any of the study subcatchments due to their relatively small size, steep slopes, and lack of significant wetland coverage (i.e., < 5%).

2.3.3 Phosphorus Coefficients

Nutrient runoff and baseflow export coefficients for each land use classifications were initially input into the LLRM model based on the median LLRM default values (Table 14). These coefficients can vary widely based on site-specific factors. To refine predicted concentrations to more accurately reflect available water quality data, export coefficients were iteratively adjusted to obtain reasonable results (Table 14). The adjusted calibration values were generally on the lower end of the LLRM reference range, as would be expected from a mostly undeveloped watershed with residential lot sizes that are typically larger than average.

Table 14. LLRM Export Coefficients

LLRM LU Classification	P Runoff Export Coefficient (kg/ha/yr)				
	LLRM Minimum	LLRM Median	LLRM Maximum	Initially Selected Value	**Adjusted Calibration Value**
Urban 1 (LDR)	0.2	1.1	6.2	0.8	**0.3**
Urban 2 (MDR/Hwy)	0.2	1.1	6.2	1.1	**0.5**
Urban 3 (HDR/Com)	0.2	1.1	6.2	1.3	**0.6**
Urban 4 (Ind)	0.2	1.1	6.2	1.0	**0.4**
Urban 5 (P/I/R/C)	0.2	1.1	6.2	0.8	**0.3**
Agric 1 (Cvr Crop)	0.1	0.8	2.9	0.8	**0.4**
Agric 2 (Row Crop)	0.3	2.2	18.6	2.2	**1.0**
Agric 3 (Grazing)	0.1	0.8	4.9	0.8	**0.4**
Agric 4 (Feedlot)	21.3	224.0	795.2	224.0	**100.8**
Forest 1 (Upland)	0.0	0.2	0.8	0.2	**0.1**
Forest 2 (Wetland)	0.0	0.2	0.8	0.2	**0.1**
Open 1 (Wetland/Lake)	0.0	0.2	0.8	0.2	**0.1**
Open 2 (Meadow)	0.0	0.2	0.8	0.2	**0.1**
Open 3 (Barren)	0.1	0.8	4.9	0.8	**0.4**

2.3.4 Calibration Results

After making the adjustments to the model described above, the summer epilimnion concentration and fully mixed concentration predictions were both within 3% of observed water quality data (Table 15). Note that calibration results are based on long-term average summer epilimnion data and fully mixed data from one sampling event – tributary data were not used given limited availability and the potential for high variability (see Section 2.2.3).

Table 15. LLRM Calibration Results

Total Phosphorus Concentration	Initial Predictions (µg/L)	Calibrated Prediction (µg/L)	Observed WQ Data (µg/L)	Percent Difference (Calibrated)
Summer Epilimnion	18.0	8.2	**8.0**	**2.5%**
Fully Mixed	39.5	25.3	**25.4**	**0.1%**

2.4 Predevelopment Analysis

A predevelopment analysis was performed to estimate background conditions for the watershed and lake. To simulate predevelopment conditions, all developed land uses were converted to either forest, wetland, or water. Land use inputs from Table 9 were entered into the calibrated LLRM model to calculate the baseline P load. An internal load was not included in the predevelopment scenario model, based on an assumption that internal load would be small enough to have an insignificant impact on in-lake phosphorus concentrations. A summary of changes for the predevelopment scenario are as follows:

- Internal load was reduced to 0 kg/yr.
- 43.64 ha of urban and agricultural land use was converted to upland forest.

See Section 2.6 for a comparison of existing conditions results vs. predevelopment conditions results.

2.5 Buildout Analysis

A buildout analysis was performed to estimate the effects of projected increased land development within the watershed for the year 2040. Methods and results are summarized below.

- The increase in population size from 2015 to 2040 was calculated using watershed town (Littleton and Lyman) projections provided by the North Country Council. The year 2015 was chosen as the starting point because 2015 was the closest year with a population estimate to the 2016 land use layer used in the initial LLRM model.
- The projected population increases for each watershed town were converted to an estimate of projected new residential lots based on the New Hampshire average household size according to the US Census Bureau (2.46 people/household).
- Projected new residential lots in the Partridge Lake watershed were then determined by (1) assuming that growth will be proportional throughout Littleton and Lyman and (2) multiplying the town-wide new lot projections by the fraction of each town's land area that is within the Partridge Lake watershed.
- Three (3) new residential lots are projected to be built in the Littleton portion of the watershed (Table 16).
  - According to Littleton's zoning ordinance, minimum lot size is based on the presence of on-site sewage and/or an on-site water supply. It was conservatively assumed that all new residential lots will be served by both on-site sewage disposal and water supply, resulting in a 2-acre minimum lot size.
  - It is assumed that these three new lots will result in conversion of 2 acres of upland forest to low-density residential land use in each of the three largest sub-watersheds with land area in Littleton (6 acres total, one new 2-acre lot in each of the three largest subwatersheds).
- One (1) new residential lot is projected to be built in the Lyman portion of the watershed.
  - As shown in the Table 16, the estimated number of new lots based on 2040 population growth is less than one (0.53). This value has been rounded up to the nearest whole number (1).
  - The new lot is assumed to be a single-family residential home. In accordance with town zoning, this lot will have a minimum lot size of 90,000 square feet (2.07 acres).

- It is assumed that this lot will result in conversion of 2.07 acres of upland forest to low-density residential land use in the sub-watershed with the largest land area in Lyman.

***Note**: Due to the small size of the watershed and its associated sub-watersheds, nutrient attenuation factors were not assigned to any sub-watersheds in the LLRM model (see Section 2.3.2). With equal attenuation (i.e., none), the specific location of new lots within the watershed will have no influence on the in-lake conditions at predicted at buildout in LLRM.*

Table 16. Buildout Analysis Results

Description	Littleton	Lyman
Projected population increase, 2015-2040	405	71
New built lots projected for entire town	164.63	28.86
Portion of town within watershed	1.87%	1.24%
New built lots projected within watershed	3.08	0.53
Projected new lots, rounded to nearest whole number	3	1
Area (ac) needed for new built lots	6	2.07

To estimate the increased P load from septic systems at buildout, septic systems were assigned to each potentially buildable lot. Septic systems were conservatively assumed to be located within 200 feet of receiving waters.

After the model was calibrated to existing conditions (see Section 2.3), the results of the buildout analysis were applied to a second iteration of the model. Land use inputs were updated to reflect the changes predicted by the buildout analysis. Septic systems were also increased based on the buildout results. Model inputs from the buildout analysis can be viewed in Table 10. A summary of projected changes from the buildout analysis is as follows:

- 0.84 hectares (2.08 acres) of upland forest being converted to low-density residential land use in the sub-watershed with the largest land area (W7) in Lyman
- 0.81 hectares (2 acres) of upland forest being converted to low-density residential land use in each of the three largest sub-watersheds with land area in Littleton (2.43 hectares total, one new 0.81-hectare lot in each of the three largest sub-watersheds (W1, W5, and W10).
- Septic systems within 200 feet of receiving waters within the watershed could potentially increase from 71 to 75, an increase of 4 septic systems (Table 13).

See Section 2.6 for a comparison of existing conditions results vs. projected buildout conditions results.

2.6 Results

This section presents results from the calibrated LLRM model by showing comparisons between existing conditions, predevelopment conditions and projected buildout conditions.

2.6.1 Phosphorus Loading by Source

Estimated annual watershed TP loading under predevelopment conditions (30.9 kg/yr) is significantly less than existing conditions (111.2 kg/yr) and projected buildout conditions (113.0 kg/yr) (Table 17) for two reasons:

1) There is an assumption of no internal phosphorus loading under predevelopment conditions. In contrast, internal load is estimated to comprise approximately 55% and 54% of the lake's estimated TP load for existing conditions and buildout conditions, respectively.
2) There is no "developed" land (i.e., residential, agricultural, etc.) in the predevelopment scenario, and the vast majority of the watershed is assumed to be forested. In contrast, developed land (predominantly residential and agricultural) comprises 43.6 hectares under existing conditions and 46.9 hectares under buildout conditions. These developed land use types typically export more phosphorus than forested areas.

TP loading estimates for existing conditions vs. buildout conditions are similar because of the small projected increase in residential land use (i.e., 3.3 hectares) and associated increase of four (4) septic systems within 200 feet of waterbodies.

Table 17. Estimated Watershed Loading by Source

Source	Predevelopment Conditions		Existing Conditions		2040 Buildout Conditions	
	TP Load (kg/yr)	TP Load (%)	TP Load (kg/yr)	TP Load (%)	TP Load (kg/yr)	TP Load (%)
Internal	0.0	0	61.5	55	61.5	54
Watershed	26.3	85	38.9	35	39.9	35
Septic System	0.0	0	6.2	6	7.0	6
Atmospheric Deposition	4.6	15	4.6	4	4.6	4
Total	**30.9**	**100**	**111.2**	**100**	**113.0**	**100**

2.6.2 In-Lake Phosphorus Concentrations

The estimated predevelopment in-lake TP concentrations for the summer epilimnion condition (5.0 µg/L) and fully mixed condition (6.2 µg/L) are indicative of pristine conditions (Table 18) that should not typically be supportive of nuisance algal blooms.

The estimated in-lake TP for the summer epilimnion condition under existing conditions (8.2 µg/L) and buildout conditions (8.5 µg/L) are also indicative of relatively pristine conditions. However, estimated TP for the fully mixed lake is significantly higher for these model scenarios (25.3 µg/L for existing conditions; 25.7 µg/L at buildout). Internal P loading is by far the largest driver of these elevated in-lake P conditions, comprising over half of the lake's P load. Although the second largest P source in the current condition comes from watershed land uses (38.9 kg, 35%), less than one-third of this P load (12.6 kg, 32%) represents a net increase in load from fully forested predevelopment land cover conditions.

Table 18. In-Lake Total Phosphorus Concentration Predictions (µg/L)

Total Phosphorus Concentration	Predevelopment	Existing Conditions	2040 Buildout Conditions
Summer Epilimnion	5.0	8.2	8.5
Fully Mixed	6.2	25.3	25.7

2.6.3 Secchi Disk Transparency, Chlorophyll-*a*, and Algal Bloom Probability

LLRM provides predictions of Secchi disk transparency*,* chlorophyll-*a* concentrations, and algal bloom probability. The following sections provide model predictions relative to observations summarized in the Section 1 of this report. The intent of these model predictions is to enable comparison of potential changes from existing conditions to buildout conditions. As such, these predictions were not calibrated, as the calibration process was focused on phosphorus as the primary pollutant of concern for Partridge Lake.

Secchi Disk Transparency

Average Secchi disk transparency is predicted to slightly decrease between existing watershed conditions and 2040 buildout conditions (Table 19).

Table 19. Mean Secchi Disk Transparency

Existing Conditions Modeled Secchi Transparency (m)[1]	2040 Buildout Secchi Transparency (m)
1.94	1.92

Notes:

1. LLRM predicts Secchi transparency based on the Oglesby and Schaffner (1978) prediction model.

Chlorophyll-*a*

Both mean and peak chlorophyll-*a* concentrations are expected to increase by approximately 2% from existing conditions to 2040 buildout conditions (Table 20). In both scenarios, concentrations are predicted to peak in the “severe nuisance condition” condition above 30 µg/L as categorized by Walker (1984) (see “algal bloom probability” section for categories).

Table 20. Predicted Chlorophyll-*a* Concentration Results

Mean (µg/L)		Peak (µg/L)	
Existing Conditions	*Buildout Conditions*	*Existing Conditions*	*Buildout Conditions*
10.1	10.3	34.2	34.8

Notes:

1. LLRM predicts mean chlorophyll-a concentrations based on mean of several prediction models including Carlson (1977), Dillon and Rigler (1974), Jones and Bachmann (1976), Oglesby and Schaffner (1978), modified Vollenweider (1982) and NH DES (2009).

2. LLRM predicts peak chlorophyll-a concentrations based on mean of several prediction models including: Vollenweider (1982), modified Vollenweider (1982) and modified Jones, Rast and Lee (1979).

Algal Bloom Probability

LLRM uses the mean chlorophyll-*a* concentration to predict the probability and potential severity of algal blooms. Probabilities are calculated for several different concentration scenarios including “scum evident” (>10 µg/L), “nuisance conditions” (>15 µg/L), “severe nuisance conditions” (>30 µg/L) and “even worse” (>40 µg/L) as categorized by Walker (1984). As indicated by Table 21, algal bloom probabilities are predicted to be similar for existing conditions and projected 2040 buildout conditions – both are predicted to be in “scums evident” condition at least 40% and “nuisance conditions” about 15% of the time. More severe algal blooms are modeled as occurring less than 1% of the time.

Table 21. Algal Bloom Probability Results

Chlorophyll-*a* Concentration (µg/L)	Existing Condition Probability (% of time)	2040 Buildout Condition Probability (% of time)
>10	40.5	42.1
>15	14.7	15.6
>20	5.2	5.6
>30	0.7	0.8
>40	0.1	0.1

Notes:

1. LLRM predicts bloom probability based on the Walker (1984) model.

2.7 Load Reduction Analysis

The purpose of this section is to determine the phosphorus load reductions needed to achieve water quality goals under considered model conditions. There are two proposed water quality goals for Partridge Lake:

1. **Summer Median Epilimnetic TP Target**. As indicated in Section 1 of this report, one water quality goal is to maintain a long-term median of 8.0 µg/L as land development continues in the watershed. To achieve 10% reserve assimilative capacity for this goal, the summer median epilimnetic TP target would be **7.2 µg/L**.
2. **Meet Fully Mixed Target**. As indicated in the Section 1 of this report, in recent years Partridge Lake has experienced more frequent nuisance algal blooms that in some cases have extended well into the fall. It is likely that internal loading is the primary driver for these algal blooms. To mitigate these algal blooms, a TP target of **10 µg/L** during fully mixed conditions should be considered as a conservatively protective goal. 10 µg/L is widely cited in the literature as a threshold where little-to-no algal blooms are typically observed in freshwater lakes.

To determine the TP reductions needed to achieve the water quality targets described above, P loading scenarios were input into the LLRM model for computation of "Fully Mixed" conditions and the Nürnberg model (1998) for computation of "Summer Epilimnetic" conditions. Loading scenarios were input into the models that increased at set intervals (i.e., 25 kg/yr, 50 kg/yr, 75 kg/yr, 100 kg/yr etc.). Results of this exercise as depicted by Figure 13 were used to define a relationship between hypothetical loading and resulting in-lake nutrient concentrations based on best fit trend lines. The resulting relationships are:

$$L_{phosphorus} = 6.0 \cdot C_{phosphorus\ (summer\ epi)} + 61.6$$

$$L_{phosphorus} = 4.4 \cdot C_{phosphporus\ (fully\ mixed)} - 0.02$$

Where:

L = Predicted annual average loading (includes all potential loading sources: tributary, internal, septic, atmospheric) (kg/yr)

$C_{summer\ epi}$ *= Predicted median in-lake summer epilimnetic total phosphorus concentration (µg/L).*

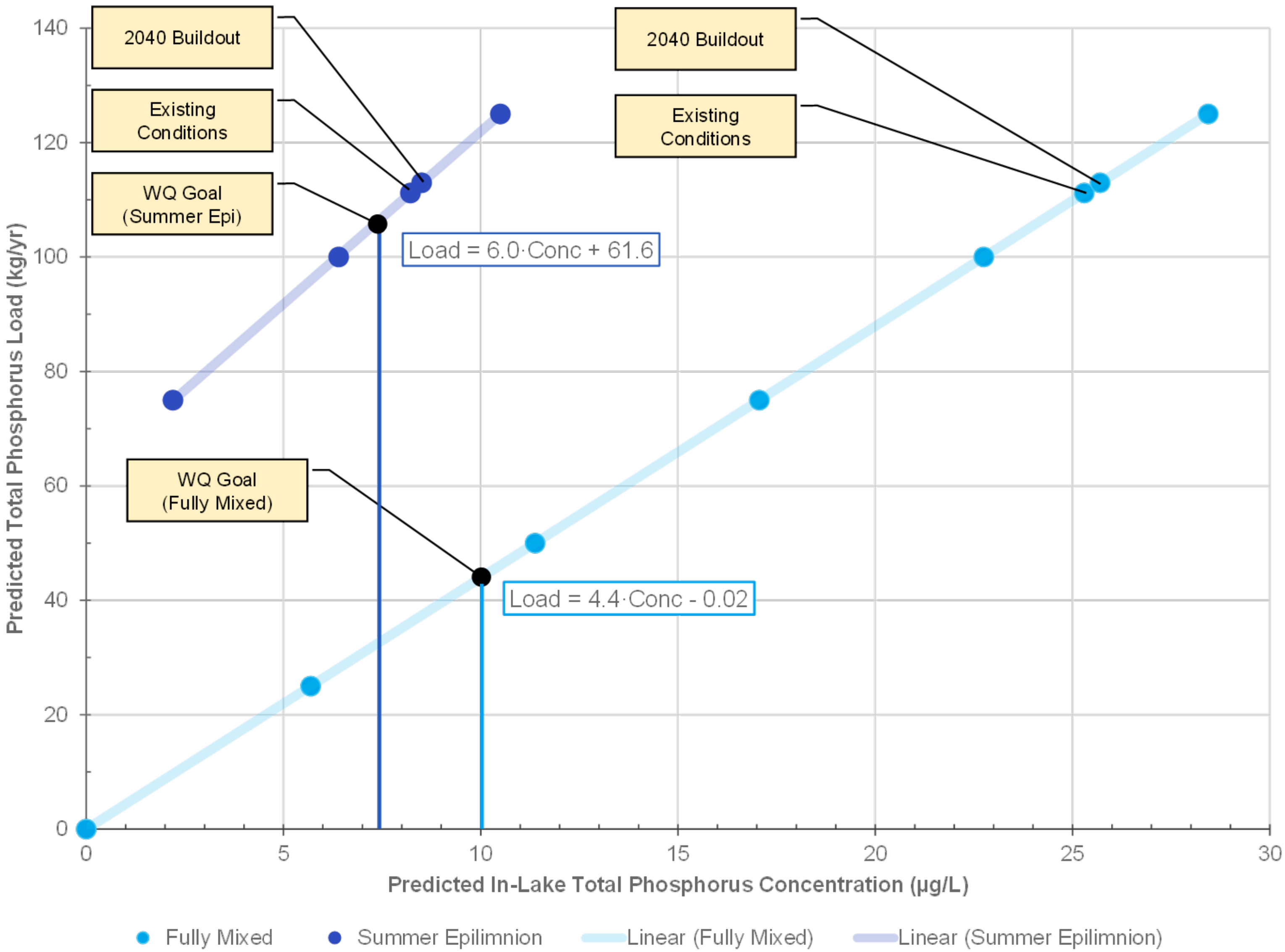
$C_{fully\ mixed}$ *= Predicted fully mixed total phosphorus concentration (µg/L).*

These relationships were used to estimate the resulting required load reductions to meet water quality targets using projected 2040 buildout conditions as a basis. As indicated by Table 22, an estimated 8.0 kg/yr (7% reduction) would be required to meet the summer epilimnetic target and an estimated 69 kg/yr (61.1% reduction) would be required to meet the fully mixed target.

Table 22. Nutrient Load Reduction Predictions

Model Predictions	**Summer Epilimnetic Target (7.2 µg/L)**		**Fully Mixed Target (10 µg/L)**	
	Existing Conditions *(Calibration Period)*	*Load Reduction* (WQ Target)	Existing Conditions *(Calibration Period)*	*Load Reduction* (WQ Target)
In-Lake Concentration (µg/L)	8.5	7.2	25.7	10.0
Total Loading (kg/yr)	113	105	113	44
Required Reduction (kg/yr)	-	8	-	69
Required Reduction (%)	-	**7.0%**	-	**61.1%**

Figure 13. Predicted relationship between total phosphorus loading and in-lake concentration (summer epilimnion and fully mixed)



2.8 Summary of Findings

- Projected 2040 buildout is expected to result in minor increases to TP loading and resulting in-lake TP concentrations.
- Internal load is the primary source of estimated phosphorus loading to Partridge Lake (i.e., > 54%) and is likely the primary driver of recurring nuisance algal blooms.
- An approximate 8 kg/yr TP load reduction will be required to meet the summer epilimnetic target of 7.2 µg/yr.
- An approximate 69 kg/yr of TP load reduction will be required to meet the fully mixed target of 10 µg/L. This target is intended to represent in-lake conditions that should typically not support nuisance algal conditions. However, this target represents over 61% of the lake's total P load and is not likely achievable with watershed management efforts alone, even with extreme efforts and very high expense. Any long-term efforts to achieve fully mixed conditions close to this target will certainly need to include a comprehensive approach which includes in-lake sediment phosphorus inactivation, septic system improvements, and watershed best management practices.
- See Section 3 for recommended actions to reduce phosphorus loads to achieve the water quality goals established for Partridge Lake.

3. Watershed Management

This section of the Partridge Lake WRP presents recommended best management practices (BMPs) according to the following categories:

- Structural Best Management Practices (Section 3.1)
- On-Site Wastewater Management (Section 3.2)
- In-lake Phosphorus Inactivation (Section 3.3)
- Non-structural Best Management Practices (Section 3.4)

3.1 Structural Best Management Practices

3.1.1 Field Watershed Investigation

CEI conducted a watershed field investigation on June 24, 2021 to identify locations where structural BMPs and other restoration practices could be implemented to reduce pollutant loads within the Partridge Lake watershed. CEI identified potential structural BMP locations based on a variety of factors, including the following:

- Connectivity to Partridge Lake, its tributaries and wetlands;
- Existing “available” space (i.e., land without buildings, structures, or other logistical constraints);
- Below-ground infrastructure/utilities;
- Site drainage patterns and proximity to existing inlets to enable overflow drainage;
- Locations of existing infrastructure in poor condition where strategic improvements can be made to serve dual benefits (e.g., replace eroding base of drainage ditch with soil with high infiltration rate and add check dams);
- Constructability concerns (proximity to foundations, overhead utilities, wetlands and other permitting constraints, etc.); and
- Access and ease of long-term maintenance to ensure BMP performance.

The potential structural BMP locations described in the sections below are not intended to be an all-inclusive listing of potential structural retrofit improvements possible within the watershed.

3.1.1.1 Summary of Structural BMP Recommendations

Potential BMP improvement sites were identified based on findings from the field watershed investigation and are summarized in Table 23. Locations and conceptual plans for BMP sites are provided in Appendix 1, including:

- An overview map showing the location of each BMP site
- A site description that summarizes current conditions and stormwater drainage patterns;
- A description of proposed structural BMP(s) and related improvements;
- Site photos and schematic rendering of proposed BMPs
- Typical designs details for proposed BMPs
- Estimated costs

- Site soils information. Soil types help inform where conditions are suitable for infiltration practices (e.g., rain gardens, infiltration basins, etc.) or where soil amendments may be needed.
- Estimated annual phosphorus, nitrogen, and TSS load reduction for the proposed structural BMP, assuming that the practice is properly designed, installed, maintained according to guidelines in the New Hampshire Stormwater Manual (NHDES, 2008; currently under revision); and
- Potential site constraints.

Construction of all of the proposed BMPs would reduce the annual total phosphorus load to Partridge Lake by an estimated 7.8 pounds per year at an estimated cost of $604,400 (includes construction, engineering, and associated costs such as survey, design, and permitting). These cost and pollutant reduction estimates result in a cost of **$77,190 per pound of phosphorus removed**. This cost for P removal is over 50 times higher than the middle of the cost range for the in-lake phosphorus inactivation options presented in Tables 27 and 28 (Section 3.3), and over 90 times higher than the middle of the cost range for alum treatment, the recommended option. Project costs may be reduced if multiple improvement sites are designed and constructed at the same time.

See Appendix 2 for supporting information related to BMP sizing and pollutant removal estimates. See Appendix 3 for supporting information on planning-level cost estimates, site-specific notes, and detailed cost breakdowns for recommended BMP location.

Table 23. Summary of Conceptual Structural Stormwater Improvements

Site	Existing Issues	Proposed Improvements	Planning Level Cost Estimates			Pollutant Load Reduction[1] Estimates (lb/yr)			Cost Per Pound of Pollutant Removal[1] ($/lb)		
			Construction	Engineering	Total (with 20% contingency)	TP	TN	TSS	TP	TN	TSS
Site 1: Cindys Drive Culvert	Direct runoff from gravel roadway entering stream.	Enhance ditch areas along edge of roadway. Armor slopes near culvert headwalls.	$ 14,000	$ 3,000	**$ 20,000**	0.16	-	580	$ 125,000	-	$ 35
Site 2: Farm Pond	Undersized culvert/outlet structure discharging from former farm pond; discharge from pond (including abundant algae) likely reaches lake during storm	Constructed wetland with "no-mow/no-disturb" zone Upsize outlet structure Install new culvert/headwall	$ 117,000	$ 24,000	**$ 165,000**	2.19	18.3	1704	$ 76,000	$ 10,000	$ 100
Site 3: Old Partridge Lake Road Culvert	Roadside ditch conveys water through culvert, indirect discharge to Partridge Lake.	Inspect culvert and replace if necessary. Retrofit drainage ditch for increased infiltration. Armor downstream channel to limit erosion.	$ 8,000	$ 2,000	**$ 12,000**	0.3	0.5	600	$ 40,000	$ 24,000	$ 20
Site 4: Old Partridge Lake Road Erosion	Section of roadway has multiple areas of erosion along the edge of pavement.	Water quality swale with check dams; riprap stabilization Fill and compact areas of heavy erosion.	$ 30,000	$ 6,000	**$ 42,000**	0.12	-	521	$ 350,000	-	$ 90
Site 5: Intersection of Old Partridge Lake Rd. / Partridge Lake Rd.	Sediment and debris build-up in intersection after rain storms and winter sanding.	Install a rain garden to treat runoff from catch basin. Install asphalt berm to direct water to raingarden. Expand vegetated buffer around stream channel.	$ 16,000	$ 4,000	**$ 24,000**	0.74	5.7	1042	$ 33,000	$ 5,000	$ 30
Site 6: North Shore Culverts[4]	Multiple culverts and associated ditches observed discharging into Partridge Lake.	Inspect culvert and replace if necessary. Retrofit drainage ditch for increased infiltration. Armor downstream channel to limit erosion.	$ 3,000	$ 1,000	**$ 5,000**	0.23	0.4	577	$ 22,000	$ 12,000	$ 10
Site 7: Boat Ramp[5]	Access road, parking area and boat ramp are dirt, allowing for erosion and sediment runoff.	Articulated concrete block boat ramp; water bars to direct water to vegetated areas next to boat ramp.	$ 27,000	$ 6,000	**$ 39,000**	-	-	-	-	-	-
Site 8: Driveway Erosion and Retaining Wall Failure	Erosion through dirt driveway and the failure of small retaining wall causing excess sediment to enter Partridge Lake.	Install upgradient catch basin to capture runoff. Install infiltration basin with sediment forebay. Install outlet control structure and culvert.	$ 55,000	$ 11,000	**$ 77,000**	0.40	3.4	418	$ 193,000	$ 23,000	$ 190
Site 9: South Shore Road	Majority of South Shore Road directly abuts Partridge Lake with a steep slope.	Add fill to stabilize slope and tree roots. Install shoreline restoration/protection measures. Install plantings to enhance vegetated buffer.	$ 97,000	$ 20,000	**$ 137,000**	2.20	4.3	5200	$ 63,000	$ 32,000	$ 30
Site 10: Partridge Lake Road / Hubbards Road Intersection	Sediment in runoff enters grassed area, potentially reaching Partridge Lake during large storm events.	Install asphalt berm to direct water to swale. Install vegetated swale with check dams. Install infiltration basin with sediment forebay.	$ 18,000	$ 4,000	**$ 26,000**	0.34	2.9	358	$ 77,000	$ 9,000	$ 80
Site 11: Southern Culverts	Multiple culverts and associated ditches observed discharging into Partridge Lake.	Inspect culvert and replace if necessary. Retrofit drainage ditch for increased infiltration. Armor downstream channel to limit erosion.	$ 3,000	$ 1,000	**$ 5,000**	0.05	0.1	200	$ 100,000	$ 50,000	$ 30
Site 12: Gannon Road Erosion	Roadside erosion was observed along the southern edge of Gannon Road.	Excavate soils; replace with well-drained soils. Install non-woven erosion control fabric. Install riprap with check dams.	$ 36,000	$ 8,000	**$ 52,000**	1.10	2.3	2600	$ 48,000	$ 23,000	$ 20
		Totals:	**$ 424,000**	**$ 90,000**	**$ 604,000**	**7.83**	**38.0**	**13800**	**-**	**-**	**-**

Notes:

1. See **Appendix 2** for supporting information related to BMP sizing and pollutant removal estimates. See **Appendix 3** for supporting planning-level cost estimates and site-specific notes and detailed cost breakdowns for each improvement area.
2. Load reduction key: TP (Total Phosphorus), TN (Total Nitrogen), TSS (Total Suspended Solids).
3. Engineering cost estimates include survey, design, and permitting. Construction estimates do not include construction quality assurance.
4. Site 6: Pollutant load reductions are an average of the nine culverts identified in this assessment. Costing is for a single culvert.
5. Site 7: Insufficient published data on the pollutant reduction of narrow width vegetated buffers and concrete block boat ramps.
6. Site 11: Pollutant load reductions are an average of the three culverts identified in this assessment. Costing is for a single culvert.

3.2 On-Site Wastewater Management

All residents of the Partridge Lake watershed rely on septic systems to treat their wastewater as they do not have access to a public sewer system. Septic systems have been identified as a source of phosphorus to Partridge Lake. Actions which can be taken to reduce phosphorus loading to the lake from septic systems include:

- Conduct investigations to identify failing septic systems in the watershed.
- Replace or upgrade old and failing septic systems, with a priority on such systems that are located closest to Partridge Lake and its tributaries. When replacing or upgrading systems, consider increasing the setback distance to surface water and constructing systems where adequate soils with sufficient depth to bedrock and groundwater exist to maximize phosphorus uptake by soils.
- Strengthen local regulations related to septic systems (e.g., siting, setbacks, etc.)
- Educate watershed residents on proper septic system maintenance and other practices that they can implement to reduce septic-based phosphorus contributions to the lake.

The sections below provide: background information on conventional septic systems; the results of a Septic System Database for the Partridge Lake watershed; information on local and state septic system regulations; options for municipal septic system programs that may be developed in watershed towns, and options for additional methods to detect failing septic systems.

3.2.1 Conventional Septic Systems

Septic systems are the primary method for treating wastewater in areas without a sewer system. If properly installed and maintained, septic systems remove many of the pollutants that could cause water quality problems. However, if systems are not working properly, nutrients and bacteria could enter nearby waterbodies.

Conventional septic systems (Figure 14) include a septic tank, distribution box, and soil absorption system, all connected by pipes (called conveyance lines). These systems can remove suspended solids, biodegradable organic compounds, and pathogens if properly designed, sited, operated and maintained.

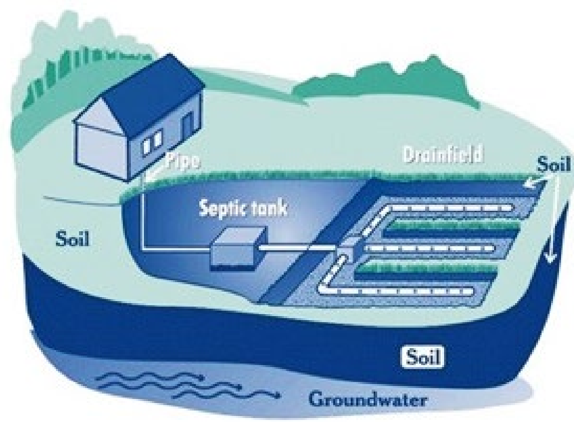


Figure 14. Conventional septic system and leachfield

Septic systems treat household wastewater by temporarily holding it in the septic tank where heavy solids and lighter scum separate from the wastewater. This separation process is known as primary treatment. Solids stored in the tank are decomposed by bacteria and later removed, along with the lighter scum, by a septic tank pumper.

After partially treated wastewater leaves the tank, it flows into a distribution box and then into a network of soil absorption system trenches or chambers. Drainage holes at the bottom of each line allow wastewater to drain into trenches for temporary storage. These trenches are typically filled with aggregate (gravel/crushed stone), or use other approved materials such as molded polyethylene. This effluent then slowly seeps into the subsurface soil where it is further treated and purified (secondary treatment).

3.2.1.1 Limitations to Conventional Septic System Treatment

In environments with adequate soil and hydrological conditions, conventional septic systems are appropriate for wastewater treatment. However, in areas that are not considered adequate, conventional septic systems may provide incomplete treatment of effluent, resulting in pollutants such as phosphorus reaching nearby waterbodies. Incomplete treatment may occur in the following instances:

1. **Depth to water table/bedrock:** Multiple studies have shown a clear link between the vertical separation of the septic system from the water table or impermeable layer (bedrock). The USEPA recommends that the soil available for treatment be at least three feet thick but ideally up to five feet thick for adequate treatment. Temporary reduction in the vertical separation (due to seasonal changes, rain storms) is enough to reduce the effectiveness of the soil to treat pollutants (Mallin, 2004).

2. **Soil type:** The type of soil available for treatment is important to determine the effectiveness of the soil to absorb pollutants. For instance, sandy soils or other rapidly draining soils generally allow water to pass to rapidly to absorb pollutants effectively. At the other extreme, poorly draining soils such as clay soils may result in surface ponding. Ideal soils lie between the two extremes, delaying effluent from the septic system long enough to provide good treatment, but not so long as to not accept all of the effluent (Mallin, 2004).

3. **Proximity to surface waters and wetlands:** Proximity to the shoreline increases the risk of incomplete treatment. Many studies have been conducted to determine the appropriate distance between the leachfield and nearby water and wetlands. These studies showed the average plume length was approximately 80 feet with a range from 30 to 300 feet depending on factors such as soil type and septic system use (MPCA, 1999 and Schneeberger et al, 2015).

4. **The number of septic systems in a watershed:** Too many septic systems in an area may overwhelm the area's carrying capacity for treatment because individual septic system plumes may intermingle and pollute large areas of groundwater. The density of septic systems in an area has been shown to be potentially problematic for surface water quality in areas with a density of more than 0.06 septic systems per acre to 0.26 septic system per acre (Mallin, 2004 and Yates, 1985).

5. **Improper maintenance:** As with any type of system, improper maintenance will prevent a conventional septic system from operating as it was designed. For conventional septic systems, general maintenance includes regular inspection and pumping of the primary tank. This maintenance typically occurs every three to five years, but may need to occur more often in certain environmental conditions. In addition, septic systems are only designed to work effectively for 20-30 years and need to be replaced to ensure they are removing pollutants effectively.

3.2.2 Local and State Regulations

The installation of new septic systems and the replacement of old septic systems are regulated by both the State of New Hampshire and the watershed towns of Littleton and Lyman. A review of these regulations is summarized below.

3.2.2.1 New Hampshire Septic System Regulations

Septic systems are currently regulated by the State of New Hampshire under Chapter Env-Wq 1000 (Subdivisions; Individual Sewage Disposal Systems) in the New Hampshire Code of Administrative Rules and promulgated under the authority of Statute Title 50, Water Management and Protection, Chapter

485A, Water Pollution and Waste Disposal. These regulations outline all aspects of septic system installation and maintenance. Some key regulations are summarized below.

- **Setbacks -** Chapter Env-Wq 1008 addresses setbacks for septic tanks and leachfields. These regulations require a setback of 75 feet from all surface waters (for both tank and leachfield) and a setback of 50 to 75 feet from all wetlands depending on the type of wetland soils.

- **Leachfields** - Chapter Env-Wq 1014 addresses the requirements for the leachfield including the requirements for the receiving soil layer. Chapter 1014.07 requires at least two feet of permeable soil above any impermeable sub-soil and four feet of soil above bedrock. The regulations do not specify the nature of the "permeable" soil although "impermeable" soil is defined as having a percolation rate of greater than 60 minutes per inch. Chapter 1014.08 addresses the distance above the seasonal high water table (SHWT) which is defined under Env-Wq 1002.61 as the level at which the uppermost soil horizon contains 2% or more distinct or prominent redoximorphic features that increase in percentage with increasing depth. The state requires the bottom of the Effluent Disposal Area (EDA) to be at least four feet above the SHWT and in no case less than two feet above the SHWT if a conventional system is used.

- **Maintenance -** NH State Statute RSA-A:37 Maintenance and Operation of Subsurface Septic Systems requires that all subsurface septic systems must be operated and maintained to prevent a nuisance or potential health hazard due to a failing system. Further, the state and its agents may enter properties for the purpose of inspecting and evaluating the maintenance and operating conditions of all septic systems, and where appropriate, issue compliance orders.

- **Failure -** Chapter Env-Wq 1004.20: Replacement of Systems in Failure cites NH State Statute RSA 485-A:2, IV. Failure is defined as "*the condition produced when a subsurface sewage or waste disposal system does not properly contain or treat sewage or causes the discharge of sewage on the ground surface or directly into surface waters, or the effluent disposal area is located in the seasonal high groundwater table*".

  If a system is identified as failing, the use of the current septic system and leachfield must be stopped, either by (1) vacating the premises served by the system or (2) having a licensed septage hauler pump out the septic tank at sufficient frequencies to prevent wastewater from otherwise exiting the septic tank. If the owner chooses to pump the tank in lieu of vacating the premises, the owner must notify NHDES and the local health officer and retain all pumping receipts for inspection by NHDES staff or the health officer.

  When submitting an application to NHDES to replace the failing system, the owner must include a written statement from the town health officer or a permitted designer confirming that the existing system is in failure.

3.2.2.2 Municipal Regulations

Many town regulations regarding septic systems follow the state regulations. However, in an effort to protect water quality, some town regulations impose stricter requirements on some aspects of the septic systems than the state regulations. A review of local ordinances and regulations identified any local septic system regulations. Some of these regulations reference State regulations while others may be more protective than State regulations.

Littleton

- **Zoning Ordinance, Amended March 2020**
  - Section 5.06 (On-Site Sewage Disposal Systems Adjoining Water Bodies) requires all new septic systems leachfields to be setback at least 125 feet from the shoreline of a year-round stream or water body. Replacement systems can be situated in their existing location with Water Supply and Pollution Control approval.
- **Subdivision Regulations, Amended July 2016**
  - Section 5. Standards. Section B. Utilities requires the permittee to provide information to prove that the area of each lot is adequate to permit the installation and operation of an individual septic system, including approval on less than five acres and a report of the Town's Health Officer.

Lyman

- **Zoning Ordinance, Amended March 2020**
  - Section 706. Construction requires all dwelling to have a state approved septic system.
- **Subdivision Regulations, Amended May 2014**
  - Section 7.27. Sewage Disposal requires the subdivider to provide adequate information to prove that the area of each lot is adequate to permit the installation and operation of an individual sewage disposal system (septic tank and drainfield). Such information shall consist of a report showing the results of a series of percolation tests taken in accordance with the existing State regulations. Based on these tests the engineer shall locate the best position of each private system and shall submit a typical design for each system also done in accordance with State regulations.

3.2.3 Septic Systems in the Partridge Lake Watershed

Although the installation of new and replacement septic systems is regulated by both the state and local regulations, information on older systems is often unknown. As a first step in providing a method for tracking septic system installation and replacement, an inventory of septic systems in the near-shore area (200 feet from a waterbody) was developed and is presented in Appendix 4. This inventory was developed by reviewing town records and the state permitting database for all homes within the 200-foot buffer of Partridge Lake.

Based on this review, there are 120 parcels in the 200-foot buffer of Partridge Lake. Of these parcels, 49 are undeveloped and 71 are developed. Of these 71 parcels, information about septic systems was available for 40 properties. A summary of findings is provided in Table 24 and a map showing the location of septic systems in the watershed is provided as Figure 12 (Section 2.2.4).

Table 24. Parcels Within the 200-foot Buffer of Partridge Lake

Septic System Information	No Replacement Record	Septic System Replacement Record
Number of Developed Parcels	31	40
Range of Home Age	1870 - 2003	1890-2020
Range of Replacement Dates	--	1970-2021
Replaced > 20 Years Ago	--	19
Distance to Partridge Lake *(if available)*		
< 75 feet	--	16
75 feet – 125 feet	--	15
> 125 feet	--	6

As shown in Table 24, more information is needed to fully assess the contribution of septic systems in the 200-foot buffer to the phosphorus load in Partridge Lake. With the information available, it is likely that many of these systems are not functioning effectively based on the age and/or location of the system and may be contributing elevated amounts of phosphorus to Partridge Lake as compared to newer, properly functioning systems.

3.2.4 Septic Systems Management Strategies

Septic system management strategies are anticipated to be an important part of the long-term approach to achieving and maintaining the phosphorus concentration goals established in this watershed-based plan. The management strategies described below provide a suite of options for reducing the phosphorus load to Partridge Lake from septic systems. Please note that septic systems are primarily regulated at the State level and alternative on-site wastewater treatment practices have not yet been approved in New Hampshire. Therefore, changes in current state regulations would be needed to allow for implementation of the alternative treatment systems discussed in Section 3.2.4.2.

3.2.4.1 Regulatory Changes

As discussed in Section 3.2.2, the construction and operation of septic systems are regulated by a comprehensive set of state regulations. Municipalities may enact local regulations or ordinances that have stricter septic system requirements, but never ones that are more lenient. Many municipalities in New Hampshire have adopted stricter ordinances and regulations regarding septic systems.

Board of Health Regulations may be enacted where existing state laws are determined to be insufficient for the protection of public health. For example, Boards of Health can regulate septic systems more stringently than required under state law, and can further regulate the use, storage and handling of fuel and other hazardous materials in specified areas. Some communities have adopted septic system pump-out regulations, requiring residents to pump their septic systems regularly (typically once every three years) and provide documentation to the town. Several examples are provided below.

Example 1. Town of Meredith, NH: Health Ordinance for Inspection

The Town of Meredith, NH enacted a health ordinance that requires the evaluation of all septic systems within 250 feet of Lake Waukewan that do not have an approved operational permit. In addition, the health ordinance requires that septic systems are replaced under certain conditions such as for those properties lacking a valid subsurface system design approval and a proposed expansion is submitted to the Planning Board.

Example 2. Town of Rye, NH: Design Criteria and Pump-out Ordinance

Septic systems are regulated by the Town of Rye under the Section 7.9 of the Building Code most recently revised in March 2017. Many town regulations regarding septic systems follow the state regulations. However, in an effort to protect water quality, the town requires additional design criteria such as requiring the bottom of the leachfield to be a minimum of six feet above an impermeable layer and a minimum of four feet above the water table. In addition, septic systems are prohibited in areas with the following conditions:

- Lands within 100 feet of protected wetlands (as indicated in Section 301.7 of the Zoning Ordinance)
- Soils with a water table at or within 24 inches of the surface.
- Soils with bedrock or impervious substratum within 36 inches of the surface.
- Any land having a natural slope of 15% or greater.
- Soils with a percolation rate greater than 60 minutes per inch.

Septic systems can be installed in areas meeting these prohibited conditions with a town-approved waiver. In addition to stricter design criteria, the Town of Rye recently adopted an ordinance requiring that all septic tanks are pumped out once every three years in specific areas of town.

3.2.4.2 Alternative Treatment Systems

In areas where conventional septic systems are not appropriate due to soil or environmental conditions, alternative systems may provide adequate treatment. Alternative systems are typically upgraded from traditional septic systems by adding a component that reduces phosphorus concentrations from the effluent before it is discharged to the ground. They are installed at an individual home, or cluster of homes, and usually cost more to operate and maintain than a traditional septic system. The increased maintenance costs are due to power needs for the system (e.g., pumps, aerators), required water quality sampling, and other elements that are not needed for a traditional on-site system.

Advanced On-Site Treatment

Alternative treatment components can be added to a conventional system, often between the septic tank and the leachfield, to provide advanced treatment of phosphorus (Figure 15). Reactive media filters, such as sand or gravel filters, are often used as advanced treatment in septic systems. For phosphorus removal specifically, additional media such as iron, aluminum, or calcium compounds are added to these systems with the goal of immobilizing phosphorus. These systems have been shown to reduce phosphorus by up to 90 percent.

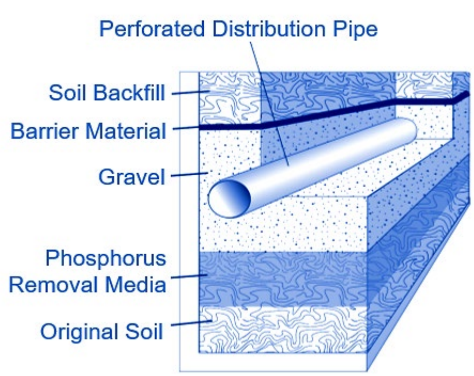


Figure 15. Alternative On-Site System with Phosphorus Treatment (Source: EPA, 2013)

Alternative Toilets

Approximately 60-75 percent of phosphorus is contained in toilet wastewater, also known as blackwater. Removing blackwater from septic tank influent greatly reduces the phosphorus in the effluent. Composting toilets offer a different solution by eliminating much of the liquid waste. Composting toilets retain solid and liquid excrement in a contained unit that facilitates natural breakdown of material, or composting. This process results in 'finished' compost free of pathogens, with the potential to serve as a soil amendment. There are many different types of composting systems that range in cost, size, and maintenance requirements.

The cost of upgrading a residential property to alternative toilets varies greatly and is based on a number of factors including: number of bathrooms, extent of remodeling work required, greywater management (i.e., hand and dish washing, showers, laundry, etc.), permitting requirements, and the type of system. Table 25 summarizes the potential cost range for alternative toilets based on these factors.

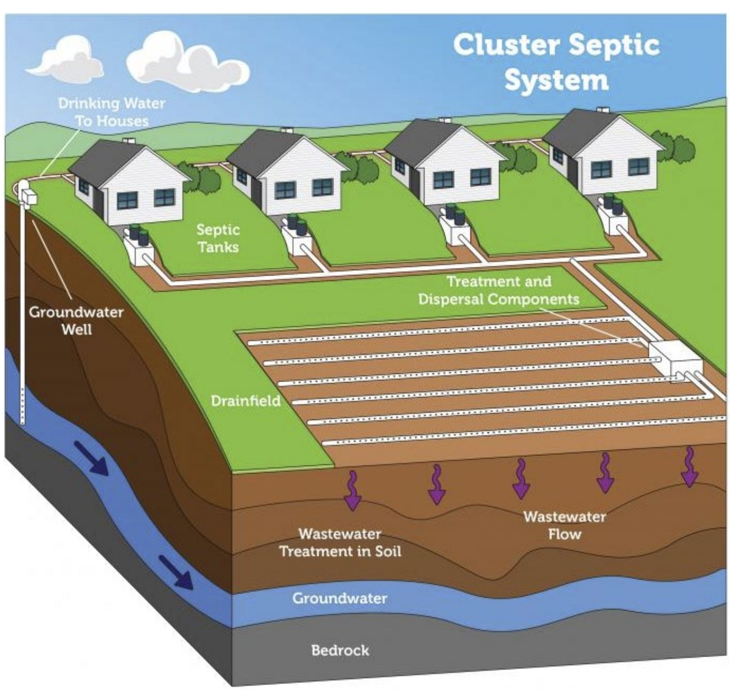
Table 25. Estimated Alternative Toilet Cost (Source: EPA, 2013)

Cost Element	Cost Range
Materials	$2,000 - $10,000
Design and Installation	$2,000 - $4,000
Greywater Management	$1,000 - $5,000
Permitting	$1,000 - $3,000

Cluster or Neighborhood Treatment Systems

Cluster or shared systems provide an opportunity for cost savings in both the construction and operation of the system. Building and operating one larger system is often less expensive than operating many small individual systems unless the homes using the system are far apart and the costs to connect them by sewer are high. Cluster systems also provide an opportunity to offset nutrient discharges from other systems where upgrades are less feasible.

Figure 16. Cluster Septic System (Source: EPA)



While cluster systems can be easily implemented for new development, retrofitting an existing area to a cluster system may pose both financial and engineering challenges. For example, the cost of piping wastewater from each individual property to the cluster system could be a significant expense, particularly in low density areas. The construction of new collection systems and the availability of land for cluster systems also pose engineering challenges. Densely developed areas or areas with historical septic system failures might provide the best opportunities for retrofitting conventional systems to cluster systems.

The cost for a cluster system to meet the current state-of-the-practice is approximately $35,000 to $48,000 per property and $52,000 per property if optimized for nitrogen (Horsley Witten Group, 2015 and Cape Cod Commission, 2013). These cost estimates are highly dependent on site-specific factors.

3.2.4.3 Detection of Failing Septic Systems

Failing septic systems have been identified in many watershed-based plans as potential sources of bacteria and nutrients to impaired waters. However, identifying the location of failing and malfunctioning septic systems is often difficult as little information is known about private systems, failure is generally only noted when there is a surface outbreak, and lack of access to private property may prevent the discovery of failing systems.

Many municipalities have worked to identify areas of their community most at risk for septic failure based on factors including soil type, proximity to surface water, age of home, and slope. This information is often paired with obtaining local pump-out records, municipal records involving septic system replacement, and other information to begin to develop a septic system database. However, these records are often incomplete and do not positively identify failing or malfunctioning systems.

Although identification of failing septic systems may be difficult, characteristics of a failing system have been documented in other studies. Failing systems are characterized by dead or stressed vegetation, high soil moisture, and surface effluent as the partially treated or untreated wastewater moves toward the ground surface. If the plume is located near or at the ground surface, temperature differentials may occur.

Figure 17. Examples of failing leachfields

Most failing systems are identified by surface effluent (middle and right). However, most failing systems are not visible to the naked eye and may appear as a green lawn (left)

On-Site Investigations

The most effective way to detect a failing septic system is to have it inspected by a licensed septic inspector. Septic inspectors generally discuss with the homeowner the history of the system, review permits for the system, and conduct a thorough tank, distribution box, leachfield, and house inspection to ensure all parts of the system are operating properly. Tanks are inspected for obvious leaks or cracks and to ensure water is flowing properly from the house. During the tank inspection, the inspector will determine if it needs to be pumped. The inspector will dig test pits to determine if the leachfield is draining properly. Mechanical equipment, including pumps, aerators, and alarms will be tested.

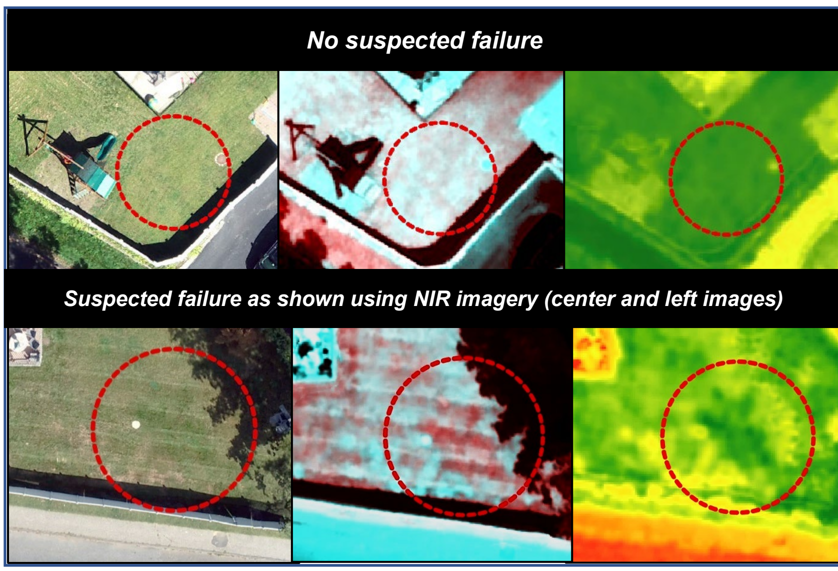
Inspectors often use a fluorescent dye solution to visually identify any problems with the septic system. The dye can be flushed down the toilet to determine connection with the septic tank. Water can then be added to the tank to flush the dye into the leachfield. Once the leachfield is saturated to capacity with dyed water, any broken or disconnected pipes can be identified as the dye solution will be visible at the surface. Generally, dye should make it through the system within a few hours.

Drone Investigations

Watershed surveys using unmanned aerial vehicles (drones) can be effective at identifying failing septic sytems. By combining the use of drones, readily available information on septic systems, and color (CIR) and near-infrared (NIR) imagery, failure signatures such as vegetation stressors, soil moisture, and other indicators that are not visible to the naked eye can be identified. This type of imaging has been successful in identifying failing systems in other studies (Huron watershed Council, 2012 and Roper, 2008).

As shown in Figure 18, CIR and NIR can be combined with site information (i.e., septic leachfield location) to identify potentially failing systems that may be contributing to surface water impairments. Drones are able to screen large areas very efficiently for potential problem sites, allowing staff and financial resources to focus on the highest priority areas for follow-up investigations and improvements.

Figure 18. Example Septic System Imagery Collected Using Drones



Location of septic systems identified from site plans (in red circles).

Left images: Typical camera images.

Center and right images: NIR images (deeper red color (center) and dark green (right) indicates more productive vegetation.

Top panel: No suspected failure as NIR images do not indicate stressed vegetation.

Bottom panel: “Signature” of septic failure can be seen faintly with drone imagery from a standard image and is significantly improved through the use of NIR imagery.

3.2.4.4 Developing Septic System Programs

In addition to regulatory changes outlined in Section 3.2.4.1, other programs can be developed to address septic systems. Other lake communities in New Hampshire have developed programs focused on septic system education, septic system inspection and/or replacement, and group maintenance programs.

Public Education

Public education is vital to prevent septic system malfunction and failure. Many of the problems associated with septic system malfunction may be attributed to a lack of homeowner knowledge of proper operation and maintenance of their systems. Educational materials for homeowners regarding the need to pump out their systems regularly and the linkage between septic systems and water quality are effective. There are many resources for public education brochures and flyers, including the examples below:

- EPA Septic Systems Outreach Toolkit
- Winnipesaukee Environmental and Community Action Network
- Massachusetts Clean Water Toolkit

Inspection and Replacement Programs

Once a septic system has been identified as needing replacement, the cost of replacement can be prohibitive for homeowners. To address nutrient loading from failing septic systems in the Lake Waukewan Watershed, the Lake Waukewan Watershed Septic System Improvement Initiative was developed to provide cost share incentives to property owners for the evaluation of septic systems and the repair or replacement of the system if necessary. As Lake Waukewan is the municipal drinking water source for the Town of Meredith and is located within the watershed of Lake Winnipesaukee, the Lake Winnipesaukee Association (LWA) was awarded a Source Water Protection grant to provide cost sharing incentives to property owners located within 250 feet of Lake Waukewan to conduct septic system evaluations. Grants provided 50% of the cost of each evaluation, or $250. Sixteen evaluations were completed through LWA's Evaluation program.

A second part of the Waukewan Watershed Septic System Improvement Initiative provided cost sharing grants to property owners whose septic systems were found to be in failure through the evaluation program or were documented in failure. A NHDES Watershed Assistance Grant provided funds for the improvement of 10 septic systems found in or near failure; cost share grants covered one third of the cost toward repair, upgrade, or replacement of an existing system, up to a maximum of $4,000. Priority was given to properties with septic systems identified as high risk located within 250 feet of Lake Waukewan and Lake Winona as nutrient loading in these critical areas poses a threat to public health. Through the cost share program, nine septic systems were replaced with new systems. In addition, because of Meredith's health regulation, five more properties had their septic systems replaced, for a total of 14 new systems installed. The estimated reduction in phosphorus loading to Lake Waukewan from the installment of new septic systems is 5.3 kg

3.2.5 On-Site Wastewater Management Recommendations for the Partridge Lake Watershed

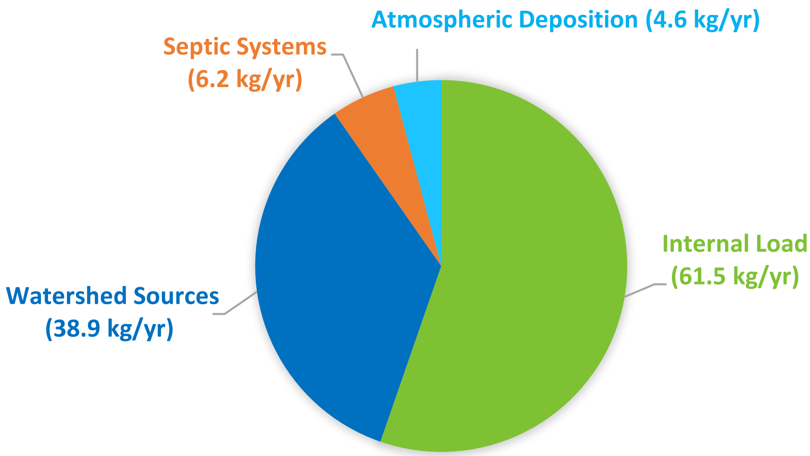
As shown in Table 24 and Figure 12, more information is needed to fully assess the contribution of septic systems in the 200-foot buffer to the phosphorus load in Partridge Lake. With the information available, it is likely that many of these systems are not functioning effectively based on the age and/or location of the system and are a source of phosphorus to Partridge Lake. Specific recommendations for addressing septic systems in the Partridge Lake watershed include:

1. Develop an education and outreach program (information on town website, mailings to homeowners, education workshops, etc.);
2. Consider regulatory changes to include mandatory septic system pump out and inspection or requiring advanced treatment systems upon replacement; and
3. Explore the possibility of grant programs to assist homeowners with septic system replacement.
4. Groups of homeowners and/or the PLPOA could schedule multiple pump-outs on the same day/trip for septage haulers and secure a group discount offered by the hauler(s) since they only have to make one trip to service multiple systems.

3.3 In-Lake Phosphorus Inactivation

As discussed in Section in Section 2.6.1, seasonal phosphorus recycling from lake bottom sediments (internal loading) is estimated to be the largest source of phosphorus to Partridge Lake. Internal load is estimated to contribute 61.5 kg annually to the lake, which is over half (55%) of the total phosphorus load.

Figure 19. Phosphorus Sources to Partridge Lake



When internal phosphorus loading exceeds external loads, lake water quality problems such as cyanobacteria blooms cannot typically be adequately addressed with watershed management measures alone. Efforts to achieve the TP water quality targets established in Section 2 (7.2 µg/L for summer epilimnion and 10 µg/L for fully mixed conditions) will need to include a comprehensive approach which includes in-lake sediment phosphorus inactivation to control internal loading, septic system improvements, and watershed best management practices.

The sections that follow discuss phosphorus inactivation methods, typical cost ranges, and additional data needs to implement this technique for Partridge Lake.

3.3.1 Phosphorus Inactivation Methods

Phosphorus Inactivation Overview

Alum being applied Nippo Lake in Barrington, NH in 2021.

- Phosphorus inactivation uses materials that bind to soluble phosphorus in water, making it unavailable for biological uptake by algae. Phosphorus inactivation techniques can be used to treat phosphorus in lake water, lake sediments, and from tributary sources before they reach a lake.
- When applied to the lake water column, phosphorus binding agents create a floc which settles to the bottom sediments. Although this floc contributes to the buildup of sediments, it is typically an insignificant amount (MA EOEA, 2004). Water column treatments tend to have relatively short periods of effectiveness, controlling algal abundance only until a more phosphorus flows into the lake. The duration of effectiveness for this approach

will vary from lake to lake depending on factors such lake residence time (how quickly the lake water volume is replaced with new inflowing water) and the phosphorus concentration of inflowing surface and groundwater.

- For lakes such as Partridge Lake, where internal loading from sediments is the dominant source of phosphorus, binding agents can be used to cap the upper sediments and sequester phosphorus as it is released seasonally during summer/fall periods of hypolimnetic anoxia.
- The primary criteria that determine longevity of treatment are proper dosing based on sediment chemistry, lake morphology, and watershed to lake area ratio (Huser, 2016).
    - With regard to lake morphology, treatment duration tends to be longer in deeper, stratified lakes such as Partridge Lake, particularly when external phosphorus sources are relatively low. A study of 114 lakes treated with aluminum salts in the United States and Europe (Huser, 2016) reported significant differences in treatment longevity for deeper, stratified lakes (mean of 21 years) and shallow, polymictic lakes (mean of 5.7 years). Polymictic lakes are too shallow to develop sustained thermal stratification and therefore have water that can mix from top to bottom when ice is not covering the lake.
    - Partridge Lake has a low watershed area (WA) to lake area (LA) ratio of 8.9:1, which favors treatment longevity. Low WA:LA ratios indicate both a longer residence time and a higher percentage of P load from internal sources, both of which increase the influence of sediment P sources on water quality (Welch and Jacoby, 2001). In the study of 114 lakes cited above, lakes with WA:LA ratios less than 8.8:1 (slightly lower than Partridge Lake) had an average treatment longevity of 26 years (Huser, 2016).
- With proper dosing based on sediment chemistry, sediment capping projects have the potential for a high rate of effectiveness in reducing internal phosphorus loading from sediments. Internal loading reduction ranges for dimictic lakes from various multi-lake studies include: 75-89% (Pilgrim, 2007), 68-94% (Angstam-Norlin, 2021), and an average of 80% (Welch and Cooke, 1995). Based on these reported ranges, an 80% rate of internal TP load reduction is a reasonable estimate for planning purposes.

In summary, phosphorus inactivation by sediment capping appears to be a good option for consideration at Partridge Lake, based on the lake/watershed characteristics listed below:

- The lake thermally stratifies in the summer and has an extended period of stable anaerobic conditions in the hypolimnion during periods of anoxia.
- Significant sediment release from phosphorus has been documented during anaerobic conditions, and is estimated to be the lake's largest source of phosphorus.
- Sediment capping would provide much longer effectiveness than a water column treatment to precipitate phosphorus. Based on results for deeper, stratified lakes with low WA:LA ratios, a 15- to 20-year effective treatment duration is a reasonable estimate.
- At an 80% reduction rate, the TP load to Partridge Lake would be reduced by an estimated 49.2 kg/yr. This reduction represents 71% of the 69 kg/yr TP load reduction required to meet the lake's fully mixed target of 10 µg/L. Based on the LLRM model, reducing the TP load by this amount would reduce the lake's fully mixed TP concentration by almost half, from 25.3 µg/L to 14.0 µg/L.

Phosphorus Inactivation Materials

A summary of the most commonly used phosphorus inactivation materials is provided below.

Aluminum

- Aluminum compounds such as aluminum sulfate (also known as alum) are the most commonly used phosphorus binding agents. Alum is typically applied as a liquid at the lake surface for water column treatments or at a higher dose to deeper water for sediment capping.
- Outside of a pH range of 6-8, aluminum can be toxic to fish, zooplankton, and other aquatic organisms. To prevent toxicity issues such as fish kills, a buffering agent such as sodium aluminate is often applied to keep pH stable. Use of a buffering agent is necessary for most lakes when high doses of alum are used for sediment capping. When applied properly, alum has been used safely and effectively in a wide range of conditions. Water use/contact restrictions for alum treatments are typically only for the day of treatment.
- Polyaluminum silicate chloride is also used for tributary inflow and lake water column treatments (*not recommended for Partridge Lake*).

Lanthanum Modified Clay (Phoslock)

- Phoslock is bentonite clay that has been modified with embedded lanthanum. Phoslock is applied in the form of either granules or slurry at the lake surface, which settles to the lake bottom.
- Phoslock is significantly more expensive than alum, but can be an effective material for binding with phosphorus in both the water column and from sediments.
- Phoslock has the advantage of having much lower toxicity risks than alum in poorly buffered lakes (Nürnberg, 2017).

Calcite:

- Calcite is a naturally occurring mineral found in many aquatic ecosystems. Calcite materials that can be used for phosphorus inactivation include pure calcite, powdered limestone, ground carbonate rock, and industrially produced synthetic calcite minerals (Bankowska-Sobczak, 2020).
- Calcite is effective for P inactivation at pH levels of 8 or higher, which is higher than in Partridge Lake and most lakes in the northeastern U.S. Although pH can be elevated by chemical addition to enable the effectiveness of calcite, this can have adverse impacts on lake biota that have adjusted to lower pH. For this reason, calcite is used primarily in alkaline lake regions and has not been applied in the northeastern U.S. except on a pilot basis (Mattson, 2004).

Iron:

- Iron is less commonly used for phosphorus inactivation. Because iron requires sufficient oxygen to maintain iron-phosphorus bonds, it’s effectiveness can be greatly reduced in lakes where internal phosphorus loading results from low hypolimnetic oxygen levels. For this reason, iron tends to be used only used in well-aerated lakes with naturally low iron levels, or in lakes where an aeration system has been installed (Mattson, 2004).

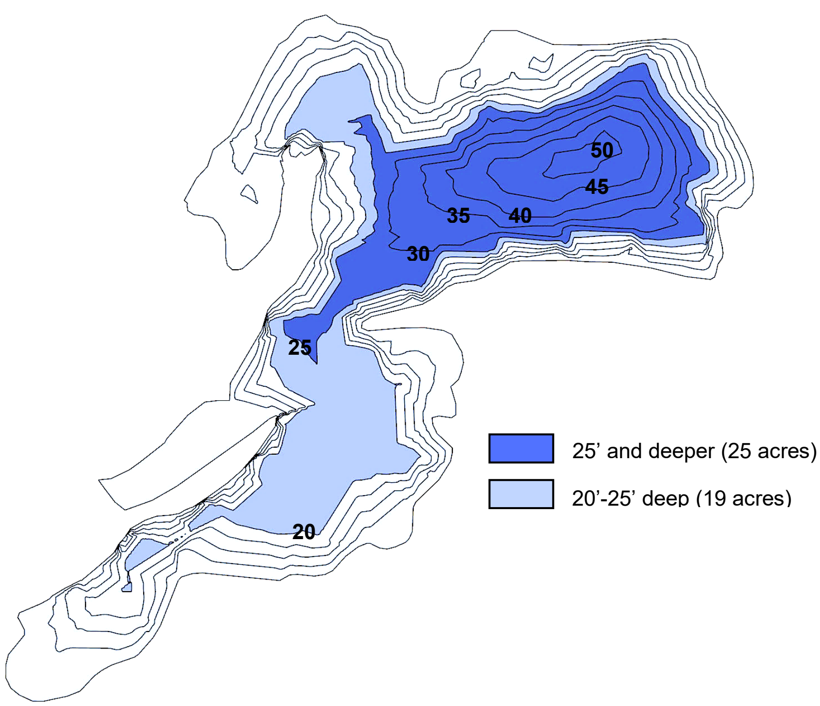
Based on the conditions at Partridge Lake (i.e., average hypolimnetic pH of 6.7 and sustained hypolimnetic summer anoxia), calcite and iron are not recommended for phosphorus inactivation. As such, the sections below provide additional information with a focus on alum and Phoslock.

3.3.2 Phosphorus Inactivation Costs

Preliminary cost estimates are provided below for phosphorus inactivation by sediment capping. These costs are intended for planning purposes and should be refined based on additional data collection as discussed below and in Section 3.3.3.

- Factors that influence cost variations, regardless of the P-inactivation material used, include:
  - **Dose**: The required concentration of P-binding agent is determined by sediment P concentrations in the surface sediment, typically within the top 10 cm.
  - **Application Area**: Areal costs (cost per acre) generally decrease for larger application areas due to mobilization costs and other economies of scale.
  - **Monitoring** required during treatment and post-treatment.
- The cost estimates provided below are based on the following treatment area options:
  - A 25-acre capping zone which includes all areas with a depth of 25 feet (7.6 meters) or greater. This is the recommended primary treatment area because the lake's hypolimnion begins at a depth of 7-8 meters (see section 1.1.5, Figures 6 and 7) and the greatest phosphorus inactivation benefits are expected from treating this zone.
  - As shown in Figures 6 and 7, anoxic conditions occur to a lesser degree and less frequently in the 19-acre depth zone from 20-25 feet. This area should be considered as a potential extension of the capping zone based on additional sediment chemistry data and available funds.
  - Figure 20 depicts the >25-foot and 20- to 25-foot depth zones.

Figure 20. Potential Partridge Lake Sediment Capping Zones



Alum:

- Typical doses for sediment capping range from 10-150 g/m^2 (for treatment of the top 10 cm of sediment), with an average dose around 50 g/m^2 (Wagner, 2017). Treatment costs will vary based on alum dose and the need for buffering agents such as sodium aluminate to maintain stable pH.

- Project costs will be slightly higher for higher doses requiring treatments to be split into multiple days. Split treatments are typically conducted when alum dose rates are higher than 25 g/m^2, to minimize potential aluminum toxicity issues.

- The U.S. Army Corps of Engineers (USACE) reports that alum sediment inactivation costs typically range from $600 to $1,800 per acre in 2022 dollars (USACE, 2016).

- The cost range reported by USACE is lower than the range reported in a review of alum treatments for ten lakes on Cape Cod, MA (Wagner, 2016), which found an average cost based on dosage of approximately $73/$g/m^2$ (2022 dollars) of applied aluminum per acre. For example, when the average dosage for the 10 lakes (56 g/m^2) is applied to the average treatment area (28.6 acres), the resulting cost is approximately $117,000, or $4,088 per acre.

  Note: The cost estimates above do not include permitting or monitoring costs.

- As a recent point of reference, Nippo Lake in Barrington, NH was treated in 2021 with an alum dose of 53 g/m^2 over a 56-acre area (depths of 15 feet or greater). This project included a 10-acre pilot treatment (with monitoring to ensure effectiveness and water quality conditions), followed by an application that was split over 2 days. The application included aluminum sulfate and sodium aluminate for pH buffering. The alum application cost (including pilot treatment) was $116,915, or $2,088 per treated acre. An additional $12,500 was spent on project planning, pre-application submittals and a post-project report.

  The Nippo Lake treatment provides a reasonable predictor of likely costs of an alum treatment at Partridge Lake because it is a recent project in New Hampshire, dosage was in the mid-range for most lakes, and pre-treatment sediment P chemistry at Nippo Lake appears to be similar to that of Partridge Lake. Preliminary sediment sampling was conducted in 2021 by NHDES staff alongside volunteers from naturesource communications and the PLPOA. Sampling was conducted at three hypolimnetic stations with depths of 25 feet, 36 feet, and 47 feet (Figure 21). Sampling results are shown in Table 26.

Sediment core from 2021 sampling led by NHDES

Table 26. Partridge Lake Preliminary Sediment Sampling Results (NHDES, 2021)

Station depth (feet)	Moisture Content (%)	Dry bulk density (g/cm^3)	Dry bulk weight (g/m^2 in top 10 cm)	Loosely-bound P (mg/g)	Iron-bound P (mg/g)	Aluminum-bound P (mg/g)	Total P (mg/g)	Releasable P[1] (mg/g)
25	94.0	0.062	6215	0.064	0.174	0.311	1.541	1.042
36	96.0	0.041	4142	0.044	0.160	0.288	1.177	0.616
47	95.7	0.044	4397	0.038	0.156	0.269	1.157	0.588
Avg.	95.2	0.049	5178	0.049	0.163	0.289	1.292	0.749

1. Releasable P is the sum of loosely-bound P, iron-bound P (Fe-P), and labile organic P.

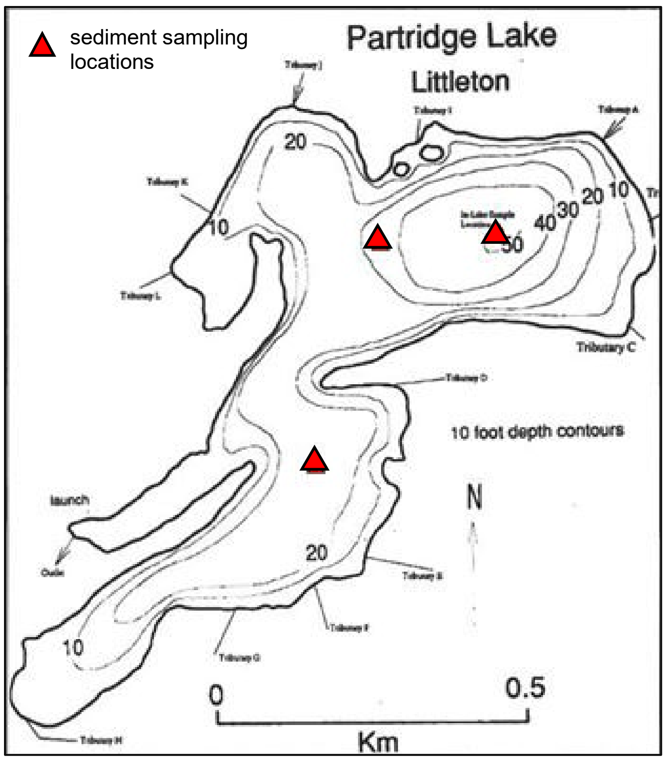


Figure 21. NHDES 2021 Sediment Sampling Locations

The pre-treatment average releasable P concentration for seven Nippo Lake samples within the treatment area was 0.690 mg/g (Kretchmer, 2019), slightly lower than the preliminary Partridge Lake sample average of 0.749 mg/g. In addition to basing dosing on the concentration of sediment P fractions, the total mass of releasable P within the treatment zone (top 10 cm) must be calculated based on dry bulk density of the sediment. The average sediment dry bulk density in the Nippo Lake treatment area samples was 0.084 g/cm^3. Given these two dosing factors and the need for additional sediment sampling at Partridge Lake, the per acre cost for the Nippo Lake treatment appears to provide a reasonable proxy for estimating potential costs at Partridge Lake.

Estimated treatment costs for Partridge Lake are summarized in Table 27, with a 20% contingency (for higher or lower costs based on future sampling) applied to a cost of $2,088/acre:

Table 27. Alum Treatment Cost Estimate Summary

Treatment Area	Estimated Cost Range ($1,670 – $2,506/ac)	Planning, pre-application submittals, and reporting	**Total Cost Range**
Depths >25 feet (25 ac)	$41,760 - $62,640	$12,000 - $20,000	**$53,760 - $82,640**
Depths >20 feet (44 ac)	$73,498 - $110,246	$12,000 to $20,000	**$85,498 - $130,246**
Based on an assumed 80% reduction in P-release from sediments (108.5 pounds/year), the total cost ranges above would result in a cost of **$495 to $1,200 per pound of P load reduction**.			

Phoslock:

- Reported Phoslock doses for actual and proposed Phoslock sediment P inactivation projects have ranged from 100 to 670 g/m^2 (Spears et al. 2016, Nürnberg, 2017). Costing for several sediment capping project case studies is summarized below (costing in U.S. 2022 dollars):
    - The Phoslock cost for a project at Hendersen Lake in Alberta was $4,500 per treated acre ($4,218 per ton). This lake had a recommended dosing of 360 g/m^2 (Nürnberg, 2017).
    - The estimated Phoslock cost for a project at Elk Lake in British Columbia (Nürnberg, 2017) was $5,874 per treated acre ($2,865 per ton). This lake had a recommended dosing of 460 g/m^2.
    - The estimated cost of Phoslock for a project at Ann Lake in Minnesota (Wenk Associates, 2018), was $19,472 per treated acre ($3,000 per ton). This lake had a recommended dosing of 1,455 g/m^2, which is much higher than the typical dose ranges cited above.
- If Partridge Lake had a mid-range Phoslock dosage based on the typical ranges cited above (100-670 g/m^2), that would result in a dosage similar to the Elk Lake and Hendersen Lake examples. Based on the per-acre cost range for these projects ($4,218 - $5,874 per acre), the estimated treatment cost for Partridge Lake is summarized in Table 28.

Table 28. Phoslock Treatment Cost Estimate Summary

Treatment Area	Estimated Cost Range ($4,218 - $5,874/ac)	Planning, pre-application submittals, and reporting	**Total Cost Range**
Depths >25 feet (25 ac)	$105,450 - $144,600	$12,000 - $20,000	**$117,450 - $164,600**
Depths >20 feet (44 ac)	$185,592 - $254,496	$12,000 to $20,000	**$197,592 - $274,496**
Based on an assumed 80% reduction in P-release from sediments (108.5 pounds/year), the total cost ranges above would result in a cost of **$1,082 to $2,530 per pound of P load reduction**.			

As shown in the cost ranges above, a Phoslock treatment for Partridge Lake is expected to cost more than twice as much as an alum treatment. Given that the effectiveness and duration of treatment is expected to be similar for alum and Phoslock, alum is recommended as a more cost-effective option.

3.3.3 Phosphorus Inactivation - Next Steps

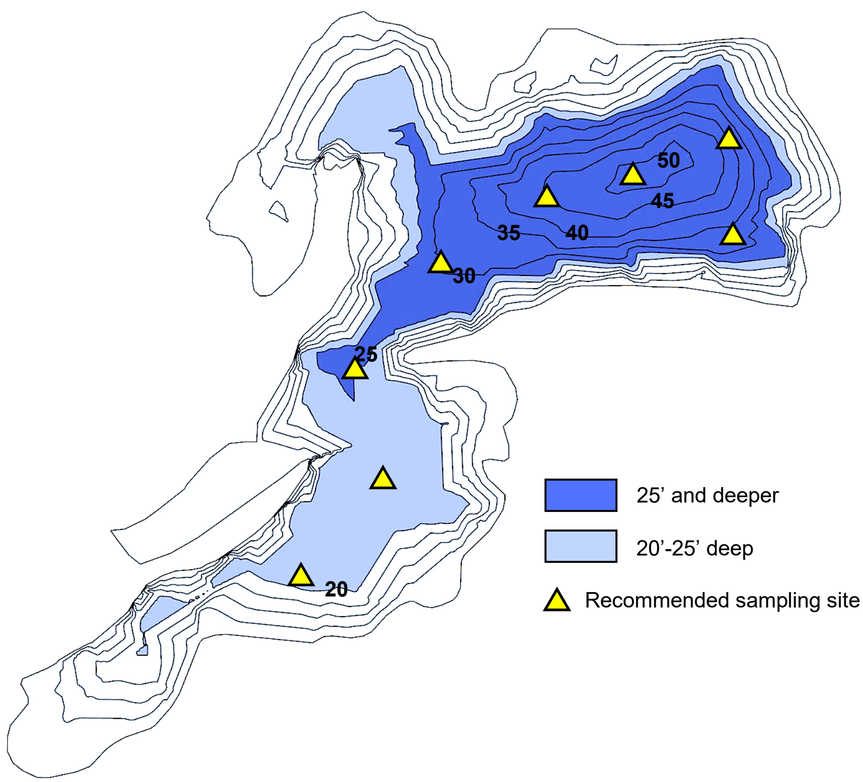
To implement a phosphorus inactivation sediment capping project for Partridge Lake, the following data collection and assessment steps will be needed:

Sediment Sampling and Assessment

The three preliminary sediment samples (see Table 26) had a fairly wide range of results for releasable P (0.588 to 1.042mg/g. Additional sediment sampling will be needed to fully characterize sediment P levels for calculation of appropriate dosing throughout the potential treatment areas. Depending on the results, dosing could vary within multiple treatment areas.

Sediment sampling parameters should be the same as those listed for the preliminary samples in Table 26. CEI recommends that a minimum of eight samples should be sampled in the depth zone of 20 feet or greater, with approximate locations as shown in Figure 22.

Figure 22. Recommended Partridge Lake Sediment Sampling Sites



In addition to determining sediment chemistry at additional locations, lab testing should be conducted to determine the site-specific treatment response of sediments to varying doses of P inactivation materials such as alum or Phoslock. The results of this type of testing are used to develop a dosage-response curve to determine optimal dosing. Because higher doses result in higher project costs, this kind of assessment is helpful in determining the internal P load reduction achieved with each increment of dose increase and the associated increase in project cost. (Wagner, 2017)

Permitting

Permitting for phosphorus inactivation at Partridge Lake is expected to be similar to what was required for the 2021 alum treatment at Nippo Lake. This project required a State Surface Water Discharge Permit from NHDES, pursuant to RSA 485-A13 I(a). Required information is expected to include the following:

- Proposed dosing
- Application method and proposed dates/timing (e.g., single or multiple split treatments)

- Mitigation of risks to aquatic life
- Development of a treatment operations and management plan which includes an activity hazard analysis, spill response plan, and health and safety plan.
- Monitoring plan (e.g., pH monitoring during alum treatment to ensure that safe pH levels are maintained to avoid aluminum toxicity)

Post-project Monitoring

Long-term post-project monitoring is recommended for any phosphorus inactivation project, to determine how in-lake conditions are responding to treatment and varying over time. Recommended monitoring should include, at a minimum, measurements at multiple locations within the treatment area (deep spot plus minimum of two additional areas representing different depth zones) for the following:

- Total Phosphorus (surface, mid, and near bottom)
- Chlorophyll-*a* (composite samples including the epilimnion and half of the metalimnion, which is approximately from the surface to a depth of 5.5m for Partridge Lake)
- Temperature/Dissolved oxygen profiles (surface to bottom at 1m intervals)
- Secchi disk transparency (surface measurement)

Monitoring would ideally be conducted at least three times during the growing season (e.g., early May, late June, and late August), to reflect how conditions in the hypolimnion progress from spring through late summer/early fall when phosphorus levels in the hypolimnion typically peak. Sediment sampling (as listed in Table 26) is also recommended at 5-to-10-year intervals to help assess the status of treatment effectiveness over time.

3.4 Non-Structural Best Management Practices

Unlike structural BMPs, non-structural BMPs do not involve construction of site-specific infrastructure and generally focus on reducing pollutant loads through the following:

1. **Public Information and Education:** Changing behavior and land use patterns through efforts to inform, educate, and engage the public on issues related to protection of water quality and aquatic habitat.
2. **Land Conservation:** Reducing pollutants at the source through natural systems, such as land conservation and protection through purchase, easements, etc.;
3. **Regulatory Tools:** Changing behavior and land use patterns through regulation (e.g., state laws, municipal ordinances)
4. **Institutional Practices and Programs:** Reducing pollutant loads through improved institutional practices such as enhanced street sweeping, catch basin cleaning, leaf litter pickup programs, etc.

The pollutant load reductions associated with non-structural measures are generally more difficult to estimate than those for structural BMPs. Strategies for reducing pollutant loads in the Partridge Lake watershed through non-structural BMPs are discussed in the sections below.

3.4.1 Public Information and Education

Public outreach to communicate the findings of this WRP is important to both educate watershed residents and coordinate efforts of the municipalities and other entities working within the watershed. Education and outreach efforts are often more effective if complementary programs work together. Public information and education (I/E) efforts associated with the Partridge Lake WRP may include the following:

A variety of education and outreach programs could be developed for the Partridge Lake watershed. Several examples are summarized below.

Workshop: Low Impact Development for Homeowners

The Town or PLPOA could provide a public education workshop for property owners in the Partridge Lake watershed. This type of workshop would focus on the concepts of low impact development (LID) and ways that homeowners can implement LID on their properties, such as raingardens, bioretention, rain barrels, infiltration trenches, etc. Topics addressed during the workshop could include:

- Stormwater and LID concepts
- Why LID? Case study of benefits and costs
- LID Practices (including step-by step instruction on how to design and build a residential raingarden)
- Recommended native plantings
- Tools for estimating cost and pollutant load reductions
- Construction Do's and Don'ts

Example residential raingarden

Soak up the Rain NH

Soak up the Rain NH is a voluntary program managed by NHDES. The goal of this program is to engage home and small business owners to do their part to help protect and restore clean water in the state's lakes, streams, and coastal waters from the negative impacts of stormwater pollution. The program provides information about stormwater pollution and how to prevent it with rain gardens, infiltration trenches, and other practices. A key program resource is the New Hampshire Homeowner's Guide to Stormwater Management.

The program also builds partnerships with local watershed groups by providing messaging, training, and assistance to promote and install practices to reduce stormwater runoff. The Town of Littleton and PLPOA could work with the Soak up the Rain program to identify specific projects in the Partridge Lake watershed.

NHDES Green SnowPro

The voluntary Green SnowPro Certification program is offered by NHDES for Commercial Salt Applicators to obtain a NHDES Salt Applicator Certification. The program offers information and training on Best Management Practices for winter road, parking lot, and sidewalk maintenance developed through partnerships with the University of New Hampshire Technology Transfer program, the Snow and Ice Management Association (SIMA), and the Smart About Salt Council (SASC) with the goal of reducing use of de-icing salt in New Hampshire. Commercial Salt Applicators certified by NHDES Green SnowPro and the property owners or managers who hire them are granted limited liability protection against damages arising from snow and ice conditions. The Town and the PLPOA could work with the Green SnowPro program to provide information to commercial property owners about the program to promote sensible salt application in the Partridge Lake watershed.

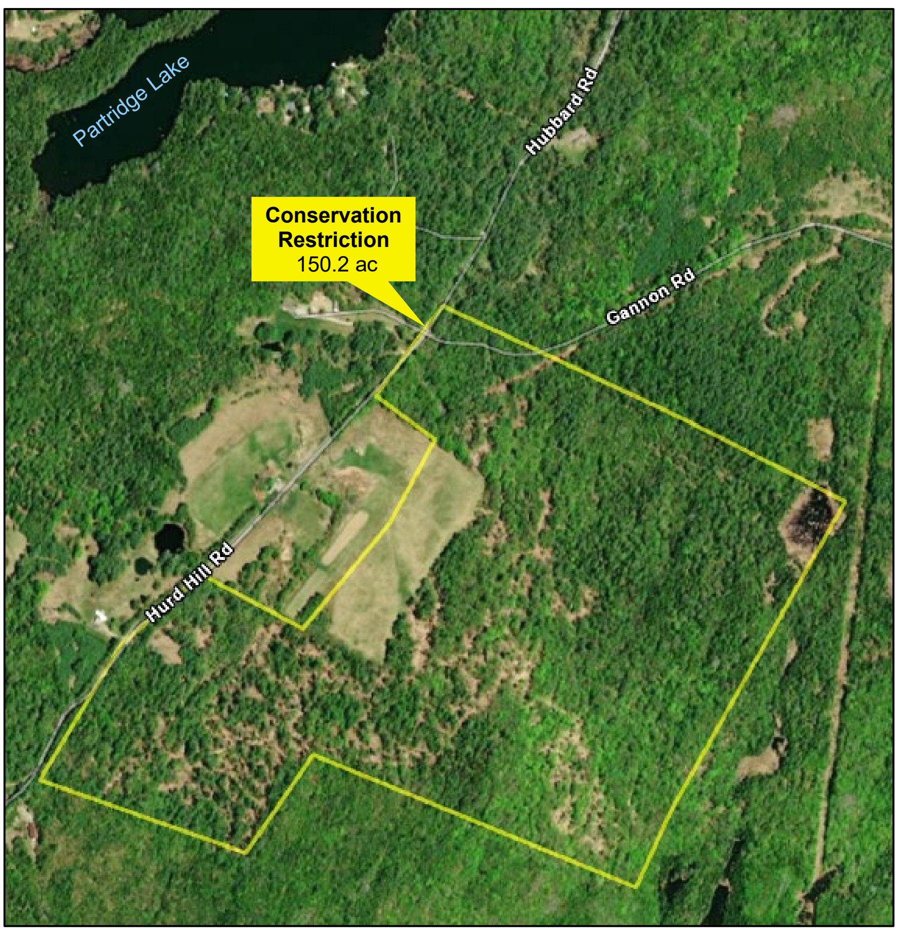
3.4.2 Land Conservation

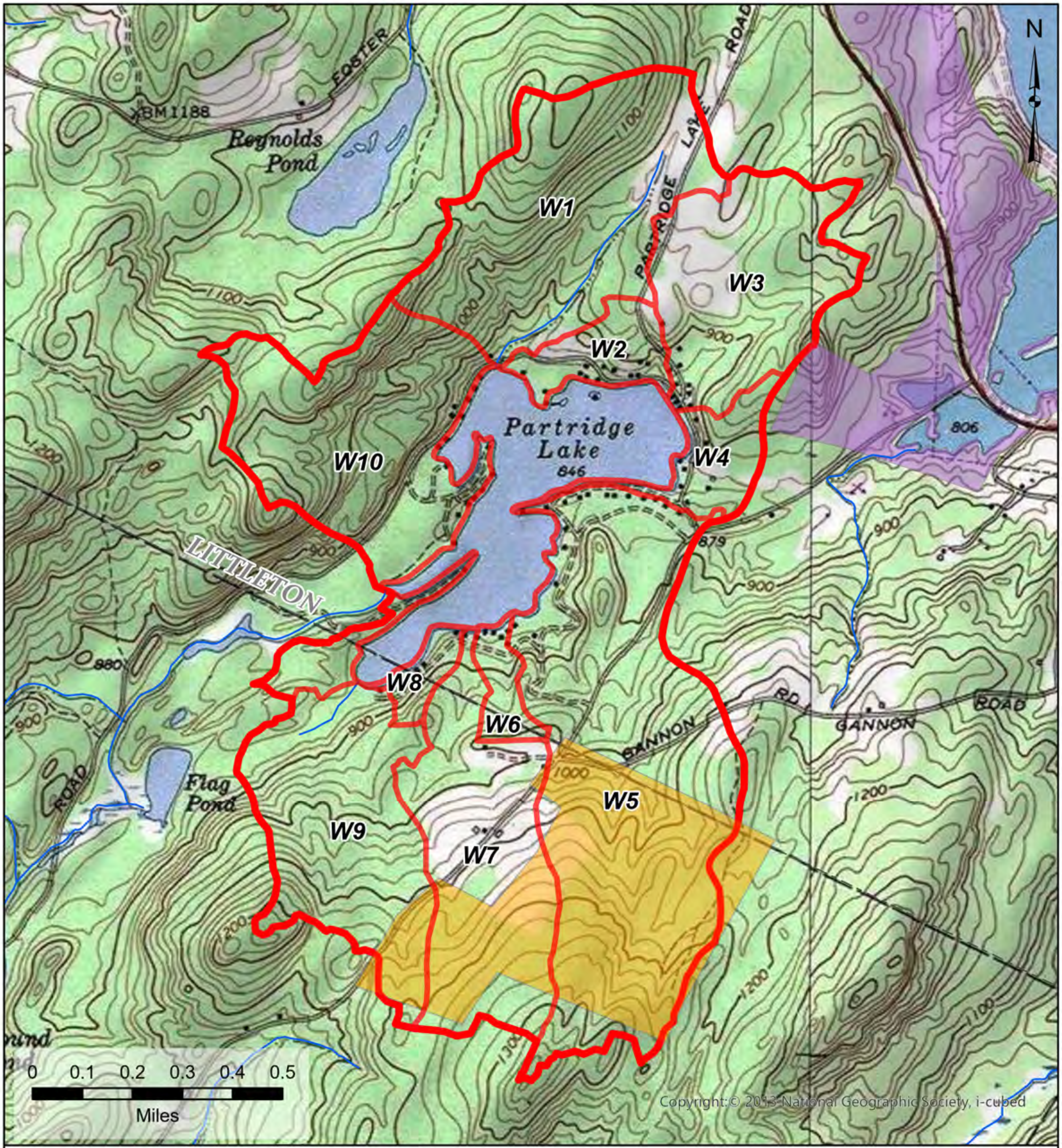
Land conservation efforts can include strategies to protect and limit future development of sensitive parcels through purchase, donations, conservation easements, deed restrictions, and other real estate legal agreements. Land conservation can contribute to the long-term water quality goals established in this WRP by preventing pollutant load increases associated with land development.

Although prioritization of specific parcels for land conservation is beyond the scope of this WRP project, CEI conducted a review of conservation land in the Partridge Lake watershed. A single contiguous area of approximately 150 acres (17% of the Partridge Lake watershed) is currently protected as private land with a permanent conservation restriction. This predominantly forested land is located in the southeast portion of the lake's watershed, to the east of Hurd Hill Road (Lyman) in subwatersheds W5, W7, and W9 as shown in Table 29 and Figure 23.

Table 29. Conservation Land in Partridge Lake Watershed

Location	Conservation Area (ac)	Total Area (ac)	Percent of Total
Subwatershed W5	100.2	230.7	43%
Subwatershed W7	37.8	105.7	36%
Subwatershed W9	12.2	105.2	12%
Partridge Lake Watershed	**150.2**	**882.9**	**17%**





Legend

Subwatersheds

Partridge Lake Watershed

Stream, River

Conservation Lands:

Conservation Easement; Permanent Conservation

Private; Permanent Conservation

Figure 23.
Conservation Lands
Partridge Lake Watershed

Comprehensive Environmental Incorporated

Data Sources: GRANIT, CEI, USGS

6/9/2022

3.4.3 Regulatory Tools

Local ordinances can provide effective protection against nonpoint source pollution and other factors that impact water quality. This section provides examples of model ordinances that can be used to regulate and improve the quality of stormwater runoff from developed areas, and a summary of the status of local stormwater regulations in the Partridge Lake Watershed.

Zoning

Zoning ordinances are used to specify and regulate land use activities that are permitted in each section of a town, as well as the allowable density of development. Zoning typically applies only to future site development and redevelopment, and does apply to existing land uses. Table 30 provides a list of examples zoning ordinances that may be used to protect water resources.

Table 30. Examples of Zoning Ordinances to Protect Water Resources

Example Ordinance	Web Link
Post-Construction Stormwater Management Standards for Site Plan Review Regulations (Rockingham Planning Commission and UNH Stormwater Center, 2017)	https://scholars.unh.edu/cgi/viewcontent.cgi?article=1034&context=stormwater
Cobbett's Pond and Canobie Lake Watershed Protection Ordinance, Windham, NH; (*see page 60*)	https://www.windhamnh.gov/DocumentCenter/View/365/Zoning-Ordinance
Aquifer Protection: Stratham, NH Aquifer Protection District Ordinance (*see page 137*)	www.stormwatercenter.net/Model%20Ordinances/Source_Water_Protection/Aquifer%20district%20ordinance.htm
Model Groundwater Protection Ordinance (NHDES/NHOEP)	https://www.nh.gov/osi/planning/resources/documents/model-groundwater-protection-ord-wd-06-41.pdf
Subsurface Wastewater Disposal Regulations (Meredith, NH)	https://www.meredithnh.org/sites/g/files/vyhlif4681/f/uploads/septic_regs_.pdf
New Hampshire Model Floodplain Ordinances	www.nh.gov/oep/planning/programs/fmp/regulations.htm
Impervious Surface Zoning Bylaw (Based on Town of Mashpee, MA zoning bylaw)	www.mass.gov/eea/agencies/massdep/water/drinking/sample-impervious-surface-zoning-bylaw.html
Open Space Design / Natural Resource Protection Zoning Bylaw (MA Smart Growth/Smart Energy Toolkit)	https://www.mass.gov/service-details/case-studies-open-space-design-osdnatural-resource-protection-zoning-nrpz
Additional Related Resources	
Limiting Impervious Surface Cover and Protecting Water Resources through Better Site Design and Planning (Rockingham Planning Commission)	http://scholars.unh.edu/cgi/viewcontent.cgi?article=1198&context=prep
Innovative Land Use Planning Techniques: A Handbook for Sustainable Development (NHDES, et al.)	https://www.nh.gov/osi/planning/resources/documents/ilupt-front-cover.pdf
Massachusetts Citizen Planner Training Collaborative - Publications	https://masscptc.org/docs/publications.html

Table 31 summarizes a comparison of municipal regulations in the Partridge Lake watershed to select model Post-Construction Stormwater Management Standards developed by the Southeast Watershed Alliance (SWA) in cooperation with the UNH Stormwater Center and Rockingham Planning Commission. These model standards were developed to help guide the development of stronger municipal stormwater standards for protection of surface waters for New Hampshire communities and should be discussed further with municipal Planning Boards for adoption of potential amendments to local regulations.

Table 31. Comparison of Selected SWA 2017 Post-Construction Stormwater Standards to Municipal Stormwater Regulations; Partridge Lake Watershed

Selected 2017 Post-Construction Stormwater Standards (SWA)	**Littleton Regulations**	**Lyman Regulations**
	Littleton Zoning Ordinance (Amended March 2020) Littleton Subdivision Regulations (Amended July 2016)	Lyman Zoning Ordinance (Amended March 2017) Lyman Subdivision Regulations (May 2014)
Minimum Thresholds for Applicability: Any development or redevelopment subject to Site Plan Review that disturbs more than 5,000 square feet or disturbs more than 2,500 square feet within 100 feet of a surface water body.	**Subdivision regulations** apply "*Whenever any subdivision of land is proposed*"…".	**Subdivision regulations:** Stormwater management and erosion control plan required when one or more of the following are proposed: 1) Cumulative disturbed area >20,000 sf. 2) Construction of a street. 3) Subdivision involving 3+ lots or dwelling units. 4) Disturbance of critical areas (e.g., slopes >15%, wetlands, floodplains, streams, etc.)
Exemption Threshold: For disturbances < 5,000 sf, Town may grant an exemption if total site impervious cover created does not exceed 1,000 square feet (Note: must meet performance standards)	No relevant standard	No relevant standard
Treatment of Runoff from Impervious Surfaces (IC): Runoff from IC shall be treated to achieve ≥ 80% TSS removal and ≥ 60% removal of total nitrogen and total phosphorus	No numeric performance standard for IC pollutant removal.	No relevant standard.
LID Design Requirements: LID design strategies must be used to the maximum extent practicable to reduce runoff volumes, protect water quality, and maintain pre-development site hydrology.	**Zoning:** 6.11.03 (Landscaping/Lot Coverage): It is therefore the objective of these recommendations to encourage on-site development of no more than 50% lot coverage (i.e., impervious surfaces), with at least 30% remaining as "natural green space".	No relevant standard
Post-Development Peak Runoff Standards: Control post-development peak runoff rate to not exceed pre-development runoff. Drainage calculations shall compare pre- and post-development stormwater runoff rates and volumes for the 1-inch rainstorm and 2-year, 10-year, 25-year, and 50-year 24-hour storm events.	**Subdivision Regulations:** Standards for New Roads. 15. (Storm Drainage): The drainage system shall be designed so that the post-development runoff rate does not exceed the pre-development runoff rate. **Zoning** 6.11.03 (Stormwater Management/Snow Storage): Storm drainage should be designed for the retention and gradual release of stormwater. Drainage facilities should be designed to accommodate a 25-year storm. Where drainage is being calculated for a compacted gravel surface such as a parking lot, the calculations should reflect a paved surface so that future paving does not significantly alter site drainage.	**Subdivision Regulations:** All stormwater management and erosion control measures in the plan shall adhere to the "New Hampshire Stormwater Manual," current edition, published by NHDES, to the extent practicable.

Lawn Fertilizer Reduction Regulations and Programs

Landscaping fertilizers can be a significant source of phosphorus and nitrogen from residential areas and other areas where turf grass lawns are maintained (e.g., golf courses, schools, sports fields, etc.). The New Hampshire Fertilizer Law (RSA:431) helps to limit the impacts of fertilizer use by limiting the allowable content of nitrogen and phosphorus in turf fertilizer sold at retail.

The Towns of Littleton and Lyman could develop municipal landscaping fertilizer ordinances to further reduce the use of fertilizers or restrict the use of fertilizer in sensitive areas. There are numerous successful regulations that limit the use fertilizer on lawns, including statewide programs in Maine and Minnesota and county programs in Dane County (WI), Muskegon County (MI), and Ottawa County (MI). Several New England examples include:

- Bridgewater, NH Zoning Ordinance. Includes a fertilizer prohibition zone as part of the *Pemigewasset River Shoreline Protection* regulations: http://www.bridgewater-nh.com/docs/planning_docs/masterordinances-d-revised-02-26-18.pdf
- 2016 zoning regulations adopted by Exeter, NH. These regulations incorporated fertilizer prohibition zones into the town's Shoreland Protection District and Aquifer Protection District, with these zones varying from 150-300 feet depending on the water body. http://exeternh.gov/sites/default/files/fileattachments/building/page/13081/2016_final.pdf
- Town of Orleans, MA *Fertilizer Nitrogen and Phosphorus Control Bylaw*: http://ecode360.com/28460572.
- Town of Brewster, *MA Fertilizer Nutrient Control Bylaw* https://ecode360.com/29998492

In addition to using regulatory tools, public education programs can also play an important role in curbing nutrient loads from landscaping fertilizers. Fertilizers are often over-applied in areas where soils naturally have adequate nutrient content to support landscaping needs. Education and outreach efforts such as are recommended as part of the long-term approach to reducing this source of pollutants. Soil testing can also be done through the University of New Hampshire Cooperative Extension - Soil Testing Services. Soil tests provide home owners with soil analysis and nutrient recommendations for lawns that are in compliance with the New Hampshire Fertilizer Law.

3.4.4 Institutional Practices and Programs

Common institutional practices and programs are described below. Although some of these strategies are more commonly employed in more developed areas than the Partridge Lake watershed (i.e., higher population density, greater prevalence of paved roads, subsurface stormwater infrastructure, etc.), they are included below for general consideration and may be useful in targeted areas or in the future as land development continues.

Catch Basin Cleaning

Catch basin cleaning is an infrastructure maintenance practice that can be used to reduce pollutant discharge to receiving waters. Frequent clean-out can retain the volume in the catch basin sump available for capture of suspended sediments and treatment of stormwater flows. At a minimum, catch basins should be cleaned once or twice per year. Increasing the frequency of clean-out can improve the performance of catch basins, particularly in industrial or commercial areas. Although literature on this topic is relatively scarce, a frequently cited study of the benefits of catch basin cleaning (Mineart, P. and S. Singh. 1994. Storm Inlet Pilot Study) found that monthly cleaning yielded the best results in terms of pollutant removal per cleaning. This study concluded that the pollutant removal benefit of more frequent clean outs should be balanced against the associated increases in municipal costs.

As a general guideline, catch basin cleaning schedules should be established with a goal of ensuring that no catch basin is more than 50 percent full. Local residents can contribute to these efforts by clearing catch basin grates of debris and sediment after large storm events.

The water quality benefits (i.e., pollutant reduction) of catch basin cleaning will vary considerably, depending on site-specific conditions such as land use, the size of the drainage area contributing to each basin, catch basin sump volume, extent of localized erosion, time elapsed since last cleaning, etc. As a reference, the 2017 New Hampshire Small MS4 General Permit (Appendix F, Attachment 2) provides a method for calculating phosphorus and nitrogen reduction credits for catch basin cleaning, as follows:

$$\text{Credit}_{P\ CB} = IA_{CB} \times PLER_{IC\text{-land use}} \times PRF_{CB}$$

$$\text{Credit}_{N\ CB} = IA_{CB} \times NLER_{IC\text{-land use}} \times PRF_{CB}$$

Where

Credit_{CB} = Amount of phosphorus load removed by catch basin cleaning (lb/year)

IA_{CB} = Impervious drainage area to catch basins (acres)

$PLER_{IC\text{-land use}}$ = Phosphorus Load Export Rate for impervious cover and specified land use (lb/acre/yr) (*see Table 2-1*)*

$NLER_{IC\text{-land use}}$ = Nitrogen Load Export Rate for impervious cover and specified land use (lb/acre/yr) (*see Table 2-2**)

PRF_{CB} = Phosphorus Reduction Factor for catch basin cleaning *(see Table 2-4*)*

NRF_{CB} = Nitrogen Reduction Factor for catch basin cleaning (see Table 2-4*)

** Table references are to Appendix F, Attachment 2 of 2017 NH MS4 General Permit*

Enhanced Street /Pavement Cleaning Programs

Street sweeping can be an effective practice to reduce watershed nutrient loading. Street sweeping provides cleanup and removal of solids, including organic debris (leaves, pine needles), sand, and fines that accumulate on roads. In absence of street sweeping, these materials contribute nutrients and other pollutants such as salt to receiving waters, and increase the frequency of maintenance required to maintain performance of catch basins and other storm water infrastructure.

The Littleton Department of Public Works (DPW) conducts annual street sweeping each spring for all paved roads in the Partridge Lake watershed, using either a vacuum sweeper or broom sweeper. Enhancements to street sweeping programs are recommended, with a focus on increased frequency in the spring and summer months when buildup of organic materials on roads tends to be highest. The benefits of increased street sweeping will also be greatest in areas with highest tree canopy cover, as these areas produce the most leaves that can contribute nutrient to surface waters through decomposition. Specific target areas and sweeping frequencies should be established based on coordination with municipal DPWs, Highway Departments, and NHDOT.

As a reference, the 2017 New Hampshire Small MS4 General Permit (Appendix F, Attachment 2) provides a method for calculating phosphorus and nitrogen reduction credit for enhanced street sweeping, as follows:

The credit shall be calculated by using the following equations:

$$\text{Phosphorus Credit}_{\text{sweeping}} = \text{IA}_{\text{swept}} \times \text{PLER}_{\text{IC-land use}} \times \text{PRF}_{\text{sweeping}} \times \text{AF}$$

$$\text{Nitrogen Credit}_{\text{sweeping}} = \text{IA}_{\text{swept}} \times \text{NPLER}_{\text{IC-land use}} \times \text{NRF}_{\text{sweeping}} \times \text{AF}$$

Where

$\text{Credit}_{\text{sweeping}}$ = Amount of phosphorus load removed by enhanced sweeping program (lb/year)

IA_{swept} = Area of impervious surface that is swept under the enhanced sweeping program (ac)

$\text{PLER}_{\text{IC-land use}}$ = Phosphorus Load Export Rate for impervious cover and specified land use (lb/acre/yr) (*see Table 2-1**)

$\text{NLER}_{\text{IC-land use}}$ = Nitrogen Load Export Rate for impervious cover and specified land use (lb/acre/yr) (*see Table 2-2**)

$\text{PRF}_{\text{sweeping}}$ = Phosphorus Reduction Factor for sweeping based on sweeper type and frequency. (*see Table 2-4)*

AF = Annual Frequency of sweeping. For example, if sweeping does not occur in Dec/Jan/Feb, the AF would be 9 mo./12 mo. = 0.75. For year-round sweeping, AF=1.0

** Table references are to Appendix F, Attachment 2 of 2017 NH MS4 General Permit*

Enhanced Organic Waste and Leaf Litter Collection Programs

Enhanced organic waste and leaf litter collection programs are similar and complementary to street sweeping programs, in that they remove organic material that can decompose and contribute nutrients and other pollutants to surface waters. These programs typically include regular gathering, removal, and disposal of landscaping wastes, organic debris, and leaf litter from roads and parking lots. The Towns of Littleton and Lyman do not currently have programs to collect organic waste and leaf litter.

As a reference, the 2017 New Hampshire Small MS4 General Permit (Appendix F, Attachment 2) provides a method for calculating phosphorus and nitrogen reduction credits for enhanced organic waste and leaf litter collection programs. The credit formula below applies to programs that collect organic waste and leaf litter at least once per week during the period of September 1 to December 1 of each year:

$$\text{Credit P}_{\text{leaf litter}} = (\text{IA}_{\text{leaf litter}}) \times (\text{PLER}_{\text{IC-land use}}) \times (0.05)$$

$$\text{Credit N}_{\text{leaf litter}} = (\text{IA}_{\text{leaf litter}}) \times (\text{NLER}_{\text{IC-land use}}) \times (0.05)$$

Where

$\text{Credit}_{\text{leaf litter}}$ = Nutrient load reduction credit for organic waste/leaf litter collection program (lb. /year)

$\text{IA}_{\text{leaf litter}}$ = Impervious area (acre) in applicable watersheds that are subject to enhanced organic waste and leaf litter collection program

$\text{PLER}_{\text{IC-land use}}$ = Phosphorus Load Export Rate for impervious cover and specified land use (lbs./acre/yr.) (*see Table 2-1*)

$\text{NLER}_{\text{IC-land use}}$ = Phosphorus Load Export Rate for impervious cover and specified land use (lbs./acre/yr.) (*see Table 2-1*)

0.05 = 5% nutrient reduction factor for organic waste and leaf litter collection program in the applicable watershed

** Table references are to Appendix F, Attachment 2 of 2017 NH MS4 General Permit*

Table 32 presents a summary and prioritization ranking of the recommended non-structural BMPs.

Table 32. Non-Structural BMP Prioritization Summary

BMP Priority Ranking Factors*

L = Low	M = Medium	H = High

Non-structural BMP Category	BMP Description	Relevant Authorities	How BMP Achieves Pollutant Load Reductions or Other WRP Goals	Pollutant Load Reduction Potential	Cost *(lower cost = higher priority)*	Feasibility	PRIORITY
Watershed Education and Outreach	Updates to the PLPA Facebook page and Town of Littleton website to inform watershed residents about the Partridge Lake WRP and implementation efforts	PLPOA, Town of Littleton	Serves as the primary web-based means of informing watershed residents on progress to develop, implement, and update the Partridge Lake WRP.	L	H	H	**Medium**
	Conduct LID for Homeowners workshop	PLPOA, watershed homeowners	Reduces pollutant (P and N) loading by educating homeowners and promoting adoption of LID practices such as raingardens, vegetated buffers, etc.	L	H	H	**Medium**
	Soak up the Rain NH Program	PLPOA, NHDES, watershed homeowners	Reduces pollutant loads by working with local residents and businesses to identify and implement stormwater improvement project in the Partridge Lake watershed.	L	H	H	**Medium**
	NHDES Green Snow-Pro Voluntary Certification Program	Town of Littleton, commercial salt applicators, watershed residents	Reduces water quality impacts associated with de-icing salt.	L	H	H	**Medium**
	Develop an education and outreach program on septic system maintenance (information on town website, mailings to homeowners, education workshop, etc.);	PLPOA, Town of Littleton	Reduces P and N load from on-site wastewater sources	L	H	H	**Medium**
Land Conservation	Coordinate with local conservation groups to prioritize land conservation goals/target parcels.	Town planning staff, North Country Council, local land trusts and conservation orgs.	Prevents increases in pollutant loading associated with land development.	H	H	H	**High**
Regulatory Tools	Strengthen town stormwater regulations based on SWA model standards; Consider adopting other local regulatory tools such (e.g., watershed protection ordinance).	Littleton and Lyman Planning Boards and Boards of Selectmen	Reduces future increases in pollutant loads associated with land development by improving regulatory standards for new development and redevelopment projects.	M	H	H	**High**
	Develop landscaping fertilizer ordinances	Littleton and Lyman Planning Boards and Boards of Selectmen	Reduces P and N loading from landscaping fertilizer applications.	M	H	M	**Medium**
	Town regulations to enable/promote alternative wastewater systems based on proximity to a waterbody (i.e., 200 m) for new development, redevelopment, and replacement of failed systems. Consider requirements for septic pump out and inspection.	Littleton and Lyman Planning Boards, Boards of Selectmen, and Boards of Health	Reduces nutrient and bacteria loading from wastewater sources.	M	M-H	M	**Medium**
Institutional Practices	Catch basin cleaning	Town DPW/Highway Depts., NHDOT	Reduces P and N load as calculated according to NH Small MS4 General Permit formulas for each practice.	L	L	M	**Low**
	Develop Enhanced Street/Pavement Cleaning Programs	Town DPW/Highway Depts., NHDOT		L	L-M	M	**Low**
	Develop Enhanced Organic Waste and Leaf Litter Collection Programs	Town DPW/Highway Depts., NHDOT		L	L-M	M	**Low**

4. Summary of Technical and Financial Support

4.1 Technical Support

Structural BMPs

The structural BMPs described in Section 3.1 will require varying levels of technical support related to implementation complexity. Implementation complexity is a qualitative indicator based on the level of detail required for engineering designs (e.g., conceptual designs vs. detailed site design plan prepared by a registered professional engineer), construction (e.g., underground utility conflicts, site access, traffic impacts, etc.), and other factors (e.g., property ownership, potential for wetland permitting). The proposed stormwater improvement sites from Section 4.1 are listed in Table 33 according to the anticipated level of required technical support.

Table 33. Level of Technical Support Anticipated for Stormwater Structural BMP Sites

Low	Moderate	High
Site 1: Cindys Drive Culvert	Site 3: Old Partridge Lake Road Culvert	Site 2: Farm Pond
Site 4: Old Partridge Lake Road Erosion	Site 5: Old Partridge Lake Road / Partridge Lake Road	Site 7: Boat Ramp
Site 6: North Shore Culverts	Site 10: Partridge Lake Road / Hubbards Road	Site 8: Driveway Erosion and Retaining Wall Failure
Site 11: Southern Culverts		Site 9: South Shore Road
Site 12: Gannon Road Erosion		

In addition to the technical support described above, construction of some of the proposed BMPs may require wetlands permitting through NHDES. Wetlands were not delineated as part of this WRP project. As such, technical support from a New Hampshire certified wetland scientist would be required on sites where wetlands are present for wetland delineation and permitting support.

Wastewater Management

Improvements related to the wastewater management alternatives in Section 3.2 require a high degree of technical support from a wastewater engineering firm. Such support is expected to include a feasibility study with detailed site investigations and recommendations on siting options and costing for the proposed wastewater treatment systems. Detailed engineering plans for the systems would be required.

In-lake Phosphorus Inactivation

In-lake phosphorus inactivation by sediment capping as discussed in Section 3.3 will require a high degree of technical support. Such support is expected to include:

- sediment sampling and assessment for dosing calculations
- preparation of permit application and supporting technical information as discussed in Section 3.3
- application of phosphorus inactivation material and required project-phase monitoring
- post-project water quality and sediment chemistry monitoring

Other

Other technical support that may be required for the non-structural measures in Section 3.4 includes:

- graphic design and printing support for public outreach and educational materials
- septic system inspection services
- legal assistance for conservation land real estate transactions and development of regulatory language for future municipal ordinances

4.2 Financial Support

Site improvements and management recommendations described in Section 4 will require funding for implementation, including construction and ongoing maintenance. Likely sources of funding include, but are not limited to, U.S. EPA Clean Water Act Section 319 Nonpoint Source Pollution funds, which are distributed by NHDES through Watershed Assistance Grants.

Brief descriptions of potential grant funding sources are provided in Table 34. Additional resources can be found on the NHDES Loans and Grants webpage. Although NHDES updates this page regularly, please note that funding programs are constantly changing.

Table 34. Summary of Funding Programs (*adapted from NHDES summary*)

Funding Program	Description
Aquatic Resource Mitigation Fund Program	Focuses on projects to restore natural resources within the context of a proposed land conservation effort. NHDES encourages projects providing connectivity to other protected resources or in close proximity to wetland impacts. Projects to benefit rare resources are viewed favorably.
American Rivers - NOAA Community-Based Restoration Program Partnership	Grant funding provided for stream barrier removal projects that help restore riverine ecosystems, enhance public safety and community resilience, and have clear and identifiable benefits to diadromous fish populations.
Boston Foundation Fund for the Environment - Open Door Grants	Grants focus on protection of bird habitat. The grant program is an open process and responds to the expressed ideas and needs of the community.
Center for Land Conservation Assistance	Funds transaction costs for permanent land protection projects within NH's coastal watershed area. Funding level: up to $3,000
Community Grants	Funds projects that are actively engaged with the ecosystem and that work to increase the understanding of environmental sustainability.
Conservation Grant Program (Moose Plate)	Funding focus includes: preservation, protection, and conservation of water quantity and quality; restoration, enhancement, or conservation of wildlife habitat; soil erosion prevention; flood mitigation; installation of BMPs for agriculture; forestry; stormwater management; and land protection.
Davis Conservation Foundation	Supports organizations with projects related to wildlife, wildlife habitat, environmental protection, or outdoor recreation. Projects that strengthen volunteer activity and community involvement in these categories are of particular interest. Funding range: $2,000 - $150,000; average $10,000.
Fields Pond Foundation	Funds trail making and other enhancement of public access to conservation lands, land acquisitions for conservation, and establishing funds for stewardship. Funding levels: $25,000 maximum, $2,000 - $10,000 typical.
Land and Community Heritage Investment Program (LCHIP)	The LCHIP is an independent state authority that makes matching grants to NH communities and non-profits to conserve and preserve New Hampshire's most important natural, cultural and historic resources.
National Fish and Wildlife Foundation (NFWF), *Five Star and Urban Waters Restoration Program*	Provides funds to local partnerships for wetland, forest, riparian and coastal habitat restoration, with a focus on urban waters and watersheds. Average grants are between $25,000 to $35,000, with a 1:1 match requirement.

National Park Service – Rivers and Trails Program	Funds projects focused on protection of natural resources and enhancement of outdoor recreational opportunities.
Natural Resource Conservation Service (NRCS)	NRCS offers financial/technical assistance to landowners and agricultural producers for conservation practices to address natural resource concerns or opportunities to help save energy, improve soil, water, plant, air, animal and related resources on agricultural lands and non-industrial private forest.
New England Grassroots Environmental Fund	Funds projects focused on forestry and trails, with a focus on community-based environmental work. Funding level: $500 - $2,500
New England Forests and Rivers Fund	Dedicated to restoring and sustaining healthy forests and rivers that provide habitat for diverse native bird and freshwater fish populations in New England. Annually awards grants ranging from $50,000 to $200,000 each.
Norcross Wildlife Foundation	While the Norcross board has decided to suspend the unsolicited grants program for the foreseeable future, Norcross will continue to support conservation efforts via the land loan program, wildlife sanctuary, and various partnerships with conservation and environmental organizations.
Profits for the Planet	Stonyfield Farm's Profits for the Planet supports efforts to protect and restore the environment and generate measurable results.
Shared Earth Foundation Category: Non-Federal	Funds projects that promote protection and restoration of habitat for the broadest possible biodiversity. Funding level $5,000 - $20,000.
Tom's of Maine- Corporate Giving	Funds projects focused on protection and conservation of natural resources, wildlife and wildlife habitat. Funding level: $500 - $5,000
Trout Unlimited (TU) Embrace-A-Stream Grant Program	Provides grants for coldwater fisheries conservation projects to address the needs of native and wild trout.
U.S. Fish and Wildlife Service, Division of Bird Habitat Conservation: U.S. Standard Grants	This competitive, matching grants program supports public-private partnerships for projects in that further the goals of the North American Wetlands Conservation Act. Projects must involve long-term protection, restoration, and/or enhancement of wetlands and associated uplands habitats for the benefit of all wetlands-associated migratory birds.
NHDES Watershed Assistance Grants	Water Quality Planning and 604(b) grants are available for water quality planning purposes. Eligible projects include water quality monitoring, stormwater retrofits, green infrastructure projects, adopting ordinances, meeting MS4 permit requirements to address priority water quality planning concerns, and development of watershed-based plans (WBPs). NHDES also provides funding appropriated through the USEPA under Section 319 of the Clean Water Act for projects to restore impaired waters or protect high quality waters. 319-grant funds are targeted toward implementation of completed WBPs. 40% non-federal match is required.
NHDES Clean Water State Revolving Fund (SRF)	The SRF Clean Water program provides low-cost financial assistance for planning, design, and construction projects to communities, nonprofits, and local government entities for wastewater infrastructure projects (collection systems, pumping stations, and wastewater treatment) and water pollution control projects (nonpoint source, watershed protection/ restoration).
NHDES Drinking Water Ground Water Trust Fund	Provides grants and low interest loans for the protection, preservation, and enhancement of all drinking water and groundwater resources of the state. Projects include infrastructure improvement and land conservation.

5. Schedule and Interim Milestones

The schedule below is based on a five-year planning and implementation period from July 2022 to July 2027.

Table 35. Schedule and Interim Milestones

BMP CATEGORY	TASKS (lead organizations)	Year 1 (2022–2023)	Year 2 (2023–2024)	Year 3 (2024)	Year 4 (2024–2025)	Year 5 (2025–2026)
In-Lake Phosphorus Inactivation	Prepare application for NHDES Section 319 grant / SRF grant for project funding	→				
	Conduct sediment sampling and assessment for dosing calculations		→			
	Prepare and submit permit application and supporting technical information		→			
	Application of P inactivation material and required project-phase monitoring		→	→		
	Post-project water quality and sediment chemistry monitoring			→	→	→
Structural Stormwater BMPs	Select priority sites for structural stormwater BMPs described in Section 4.1 (PLPOA, Town of Littleton, NHDES)	→				
	Prepare application for NHDES Section 319 NPS Grant for final design/construction of priority BMP sites (Town, NHDES)		→			
	Prepare priority BMP final designs and permitting (Town, NHDES)		→	→		
	Construct priority BMP Sites (Town, contractor)			→		
Public Information and Education	Conduct *LID for Homeowners* Workshop		→			
	Soak up the Rain NH Program (NHDES and PLPOA)		→	→		
	Outreach program on septic system maintenance			→		
	NHDES Green SnowPro (NHDES, PLPOA and Towns of Littleton and Lyman)			→	→	
	Project updates posted to PLPOA Facebook site and Town website	→	→	→	→	→
Land Conservation	Coordination meetings with Towns, North Country Council and local orgs. to prioritize conservation goals and target parcels.	→	→			
Regulatory Tools	Strengthen Town stormwater regulations (Town Boards)		→	→	→	→
	Develop landscaping fertilizer ordinances (Town Boards)		→	→	→	→
	Develop Town regulations to (1) enable/promote alternative wastewater systems based on proximity to a waterbody for new development, redevelopment, and failed systems and (2) require scheduled septic pump out and inspection.		→	→	→	→

BMP CATEGORY	**TASKS** (lead organizations)	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
		Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	
Institutional Practices	Increase frequency of catch basin cleaning (Town DPWs, Highway Depts.)	*Not recommended for Years 1-5; Implement as needed based on future development in watershed*					
	Enhanced Street/Pavement Cleaning Programs (Town DPWs, Highway Depts.)						
	Enhanced Organic Waste and Leaf Litter Collection Programs (Town DPWs, Highway Depts.)						
Monitoring	Conduct annual lake and tributary monitoring (PLPOA, NHDES) ** Includes ongoing VLAP monitoring conducted by PLPOA*	→	→	→	→	→	→
Adaptive Management	Review progress towards meeting water quality targets and project-specific goals and update WRP as needed (Town, PLPOA, NHDES)				●		●

6. Evaluation Criteria and Monitoring

This Section of the Partridge Lake WRP addresses Elements H and I of the USEPA requirements for a watershed-based plan, as defined below.

Element H: A set of criteria used to determine (1) if loading reductions are being achieved over time and (2) if progress is being made toward attaining water quality goals. Element H asks "***how will you know if you are making progress towards water quality goals?***" The criteria established to track progress can be direct measurements (e.g., total phosphorus concentrations) or indirect indicators of load reduction (e.g., number of advisories related to cyanobacteria blooms).

Element I: A monitoring component to evaluate the effectiveness of implementation efforts over time, as measured against the Element H criteria. Element I asks "***how, when, and where will you conduct monitoring?***"

6.1 Evaluation Criteria

Evaluation criteria (Element H) for Partridge Lake include the categories below.

- **Water Quality Targets:** Section 2 of this WRP presents a target summer epilimnetic TP concentration summer of 7.2 µg/L and a target fully mixed TP concentration summer of 10 µg/L.

- **Project-Specific Indicators:** The project-specific performance indicators listed in Table 36 may be used as criteria for activities recommended in this WRP. These project-specific indicators are generally intended to quantify an activity and, whenever possible, explain how that activity achieves load reductions for targeted pollutants. In cases where it is not possible to quantify a pollutant load reduction, the project-specific indicator states the target pollutant(s) expected to be reduced as a result of the activity.

Table 36. Project-Specific Indicators for Partridge Lake Watershed Restoration Plan

BMP Type	Quantified Activity	How Activity Achieves Pollutant Load Reductions or Other WRP Goals
In-lake Phosphorus Inactivation	Acres of lake treated with P-inactivation material; Dose applied to treated area and volume of material applied; annual internal P load reduced	Reduces P load from internal loading by binding P released from sediments with P-inactivation material.
Structural Stormwater BMPs	Number of structural stormwater BMPs implemented; annual P load reduced	Pollutant (P) load reductions from specific structural BMPs as presented in Section 3.1.
Non-structural BMPs: **Public Information and Education**	Conduct *LID for Homeowners* Workshop: Number of workshop attendees and commitments from homeowners to implement LID practices.	Reduces pollutant (P and N) loading by educating homeowners and promoting adoption of LID practices such as raingardens, vegetated buffers, etc.
	Soak up the Rain NH Program: Number of attendees at trainings; number of stormwater improvement projects identified and built	Reduces pollutant loads by working with residents and businesses to identify and implement stormwater improvement project in the Partridge Lake watershed.
	NHDES Green SnowPro: Number of local salt applicators certified; estimated reduction in de-icing salt applied per year	Reduces surface and groundwater water quality impacts associated with de-icing salt.
	Project updates posted to PLPOA Facebook site and Town website: Number of project updates and associated news releases.	Serves as the primary web-based means of informing watershed residents on progress to develop, implement, and update the Partridge Lake WRP.
	Outreach program on septic system maintenance: # of mailings sent; information posted on town website/PLPOA Facebook page; number of workshop attendees	Reduces P and N load from on-site wastewater sources
Non-structural BMPs: **Land Conservation**	Coordination (via meetings) with Towns, North Country Council and local conservation groups to prioritize conservation goals and target parcels.	Contributes to the long-term water quality goals established in this WRP by reducing pollutant load increases associated with land development.
	Acres of land protected through acquisition, easements, or other real estate tools.	Prevents increases in pollutant loading associated with land development.
Non-structural BMPs: **Regulatory Tools**	Completion of strengthened stormwater regulations or other bylaws related to land development (e.g., watershed protection ordinance)	Reduces future pollutant load increases from land development by improving regulatory performance standards for new development and redevelopment.
	Fertilizer ordinances drafted and adopted by watershed towns; Quantify area (acres) within each town that is regulated by each ordinance.	Reduces P and N loading from landscaping fertilizer applications.
	Town regulations established to enable/promote alternative wastewater treatment (based on proximity to waterbody) for new development, redevelopment and replacement of failed systems.	Reduces nutrient and bacteria loading from wastewater sources.
Non-structural BMPs: **Institutional Practices**	Number of catch basins included in catch basin cleaning program	Reduces P and N load as calculated according to NH Small MS4 General Permit formulas for each practice.
	Number of road miles where street sweeping was conducted each year, and increase in frequency.	
	Number of road miles/area covered under organic waste and leaf litter collection programs.	

6.2 Monitoring

Annual lake and tributary water quality monitoring is recommended to address Element I requirements and help document the extent that WRP implementation efforts are succeeding.

- Data from the lake deep spot (and other in-lake stations) should continue to serve as the basis for comparison to the TP water targets established by this WRP (7.2 µg/L for summer epilimnion and 10 µg/L for fully mixed conditions).
- Recommended in-lake monitoring should include, at a minimum, the following key parameters:
    - Total Phosphorus (surface, mid, and near bottom)
    - Chlorophyll-*a* (composite samples including the epilimnion and half of the metalimnion, which is approximately from the surface to a depth of 5.5m for Partridge Lake)
    - Secchi disk (surface measurement)
    - Temperature/dissolved oxygen profiles (surface to bottom at 1m intervals)
- As noted in Section 3.3, monitoring following a phosphorus inactivation treatment would ideally be conducted at least three times during the growing season (e.g., early May, late June, and late August), to reflect how conditions in the hypolimnion progress from spring through late summer/early fall when phosphorus levels in the hypolimnion typically peak. Sediment sampling (as listed in Table 26) is also recommended at 5- to 10-year intervals to help assess the status of treatment effectiveness over time

6.3 Adaptive Management

If, after five years of implementation of WRP management measures, the direct measurements and indirect indicators do not show progress towards meeting the water quality targets established in this WRP, the management measures and water quality targets should be revisited and modified accordingly.

7. References

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Appendix 1:

Partridge Lake Stormwater Improvements – Conceptual Best Management Practices (BMPs)

Partridge Lake Watershed Stormwater Improvements
Littleton, NH

CONCEPTUAL BEST MANAGEMENT PRACTICES

July 2022

Sheet No.	Description
G-1	Site Identification
G-2	Soil Map
G-3	Soil Data
G-4	Subwatersheds
C-1 – C-23	Site Information
D-1 – D-5	Typical Details

General Notes:

1. Blue arrows contained herein denote flow direction 
2. Conceptual plans and details are not suitable for permitting or construction.
3. See accompanying Conceptual Design Report and Attachments for more information on each proposed improvement site.

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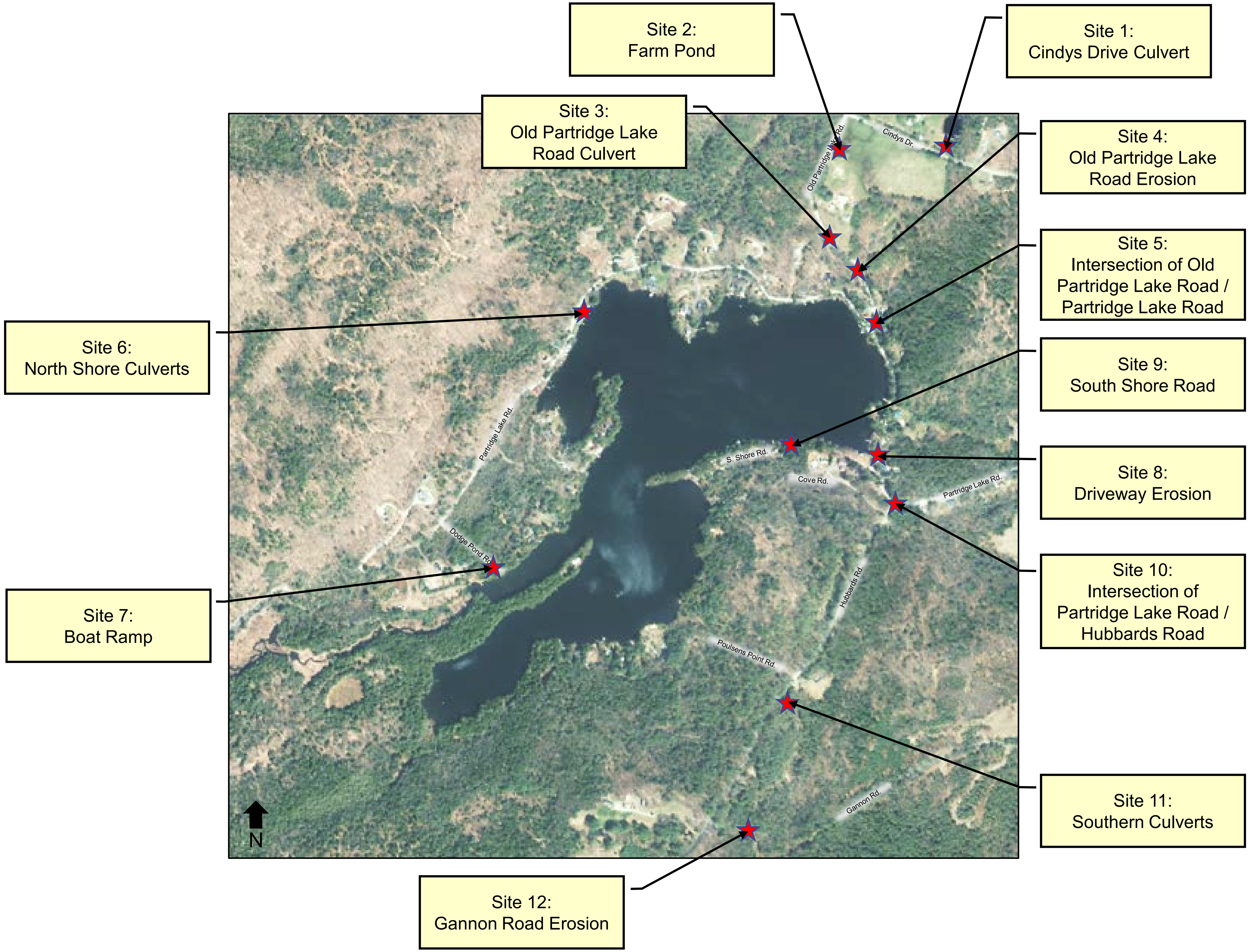


GENERAL NOTES

No.	Revision/Issue	Date

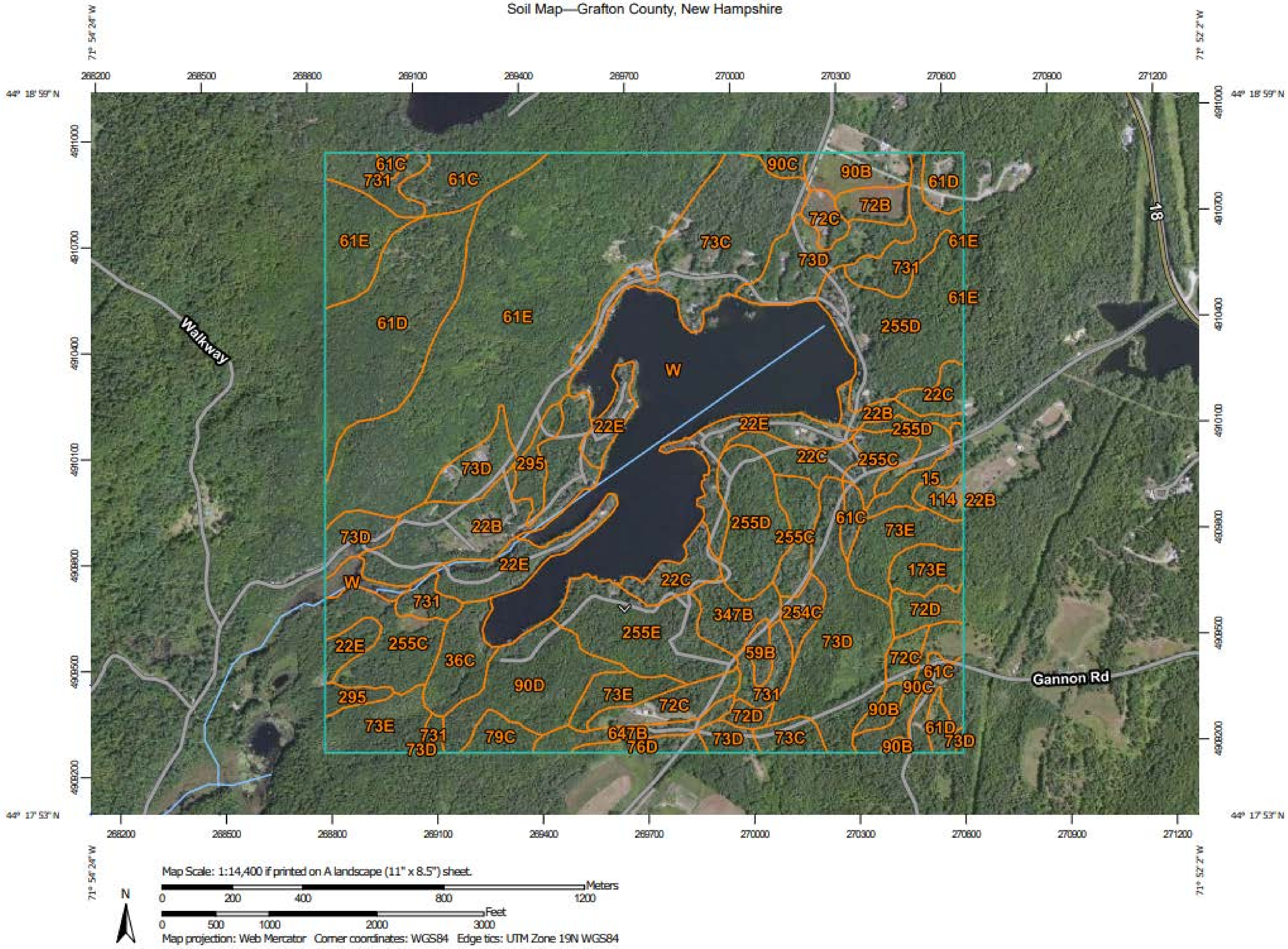
COMPREHENSIVE ENVIRONMENTAL INCORPORATED

21 Depot Street, Merrimack, NH 03054

Conceptual BMP Site Locations

Project No.: 366-01	Sheet
Date: July 2021	
Drawn By: NP	
Checked By: NC	
Scale: As Shown	G-1

Soil Map—Grafton County, New Hampshire



GENERAL NOTES

- Soils Data from NRCS Web Soil Survey.

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED

21 Depot Street, Merrimack, NH 03054

Soils Map

Project No.: 366-01	Sheet	
Date: July 2021		G-2
Drawn By: NP		
Checked By: NC		
Scale: As Shown		

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
15	Searsport mucky peat	5.3	0.7%
22B	Colton gravelly sandy loam, 3 to 8 percent slopes	32.5	4.3%
22C	Colton gravelly sandy loam, 8 to 15 percent slopes	18.2	2.4%
22E	Colton gravelly sandy loam, 15 to 60 percent slopes	30.8	4.0%
36C	Adams loamy sand, 8 to 15 percent slopes	10.1	1.3%
59B	Waumbek loamy sand, 3 to 8 percent slopes, very stony	2.4	0.3%
61C	Tunbridge-Lyman-Rock outcrop complex, 8 to 15 percent slopes	20.2	2.6%
61D	Tunbridge-Lyman-Rock outcrop complex, 15 to 25 percent slopes	46.3	6.1%
61E	Tunbridge-Lyman-Rock outcrop complex, 25 to 60 percent slopes	129.1	16.9%
72B	Berkshire fine sandy loam, 3 to 8 percent slopes	4.8	0.6%
72C	Berkshire fine sandy loam, 8 to 15 percent slopes	14.5	1.9%
72D	Berkshire fine sandy loam, 15 to 25 percent slopes	7.3	1.0%
73C	Berkshire fine sandy loam, 8 to 15 percent slopes, very stony	36.5	4.8%
73D	Berkshire fine sandy loam, 15 to 25 percent slopes, very stony	62.2	8.1%
73E	Berkshire fine sandy loam, 25 to 50 percent slopes, very stony	27.6	3.6%
76D	Marlow fine sandy loam, 15 to 25 percent slopes	3.5	0.5%
79C	Peru fine sandy loam, 8 to 15 percent slopes, very stony	4.2	0.6%
90B	Tunbridge-Lyman complex, 3 to 8 percent slopes, rocky	10.8	1.4%
90C	Tunbridge-Lyman complex, 8 to 15 percent slopes, rocky	8.6	1.1%
90D	Tunbridge-Lyman complex, 15 to 25 percent slopes, rocky	21.6	2.8%

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
114	Walpole-Binghamville complex	2.8	0.4%
173E	Berkshire fine sandy loam, 15 to 35 percent slopes, extremely stony	6.1	0.8%
254C	Hermon and Monadnock soils, 8 to 15 percent slopes	3.9	0.5%
255C	Hermon and Monadnock soils, 8 to 15 percent slopes, very stony	28.6	3.8%
255D	Monadnock and Hermon soils, 15 to 25 percent slopes, very stony	51.7	6.8%
255E	Monadnock and Hermon soils, 25 to 35 percent slopes, very stony	22.8	3.0%
295	Greenwood mucky peat	7.4	1.0%
347B	Lyme and Moosilauke soils, 3 to 8 percent slopes, very stony	8.1	1.1%
647B	Pillsbury fine sandy loam, 0 to 8 percent slopes, very stony	6.1	0.8%
731	Peacham and ossipee soils, very stony	27.5	3.6%
W	Water	101.6	13.3%
Totals for Area of Interest		**763.4**	**100.0%**

GENERAL NOTES

- Soils Data from NRCS Web Soil Survey.

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED

21 Depot Street, Merrimack, NH 03054

Soils Data

Project No.: 366-01
Date: July 2021
Drawn By: NP
Checked By: NC
Scale: As Shown

Sheet G-3

GENERAL NOTES

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED

21 Depot Street, Merrimack, NH 03054

Partridge Lake Watershed

Project No.: 366-01		Sheet
Date: July 2021		
Drawn By: NP		G-4
Checked By: NC		
Scale: As Shown		

Site 1: Cindys Drive Culvert

Site Description

- Corrugated metal pipe (CMP) culvert under Cindys Drive (unpaved road)
- Culvert has stone headwalls with steep slopes on both the inlet and outlet sides.
- Shallow roadside drainage ditches receive runoff from roadway and discharge into the stream at both headwalls.

Proposed Improvements

- Enhance ditches by converting to water quality swales; install check dams.
- Armor slopes down to stream at ditch discharge points near headwalls to lessen the chance of erosion.
- Ensure culvert is clear of debris in order to provide proper flow.

***See next sheet for site plan of proposed improvements.**

Estimated Cost: **$20,400**

**See Appendix 3 for detailed breakdown*

Estimated Pollutant Reductions

- Total Phosphorus: **0.16 lb/yr**
- Total Nitrogen: **N/A**
- Total Suspended Solids: **580 lb/yr**

Potential Conflicts:

- Limited space in ROW.
- Site construction may take place on private property.

Approximate ditch locations

Roadway crown

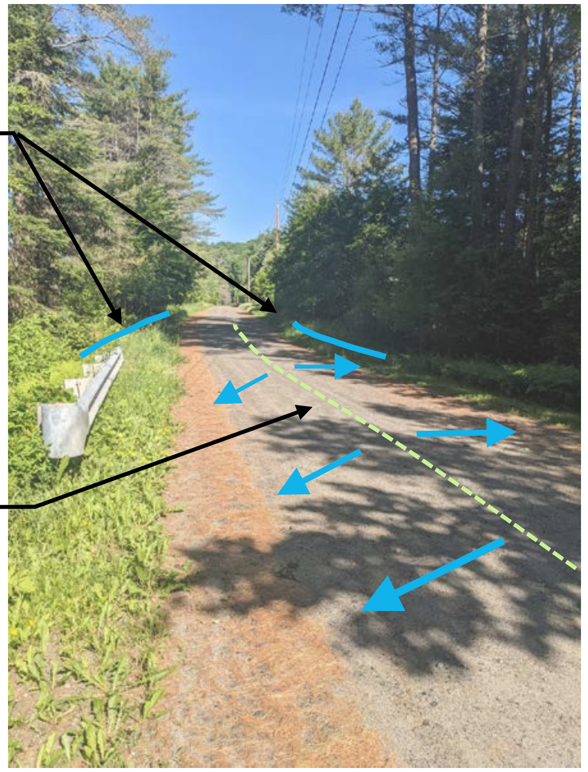


Photo 1-1: Cindys Drive looking northwest

Approximate ditch channel location

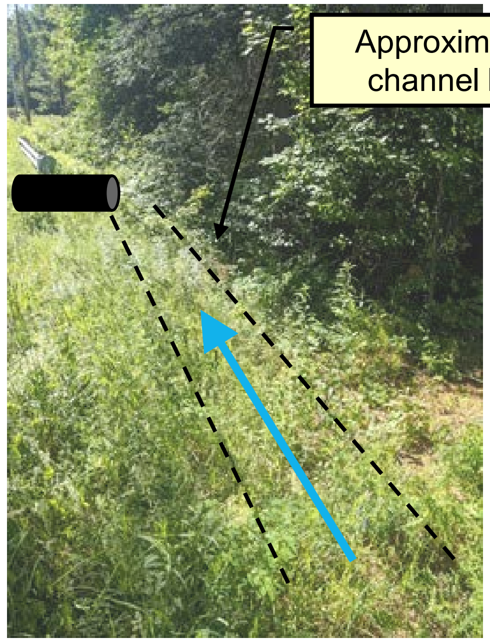


Photo 1-2: Southern drainage ditch

Approximate downstream channel

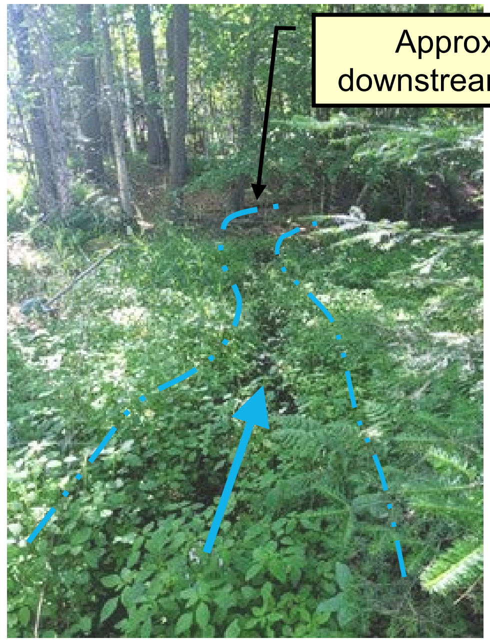


Photo 1-3: Stream

Photo 1-4: Culvert outlet

GENERAL NOTES

- Contributing watershed area for Site 1 is approximately 0.57 acres.
- Discharge location is approximately 0.24 miles from Partridge Lake.

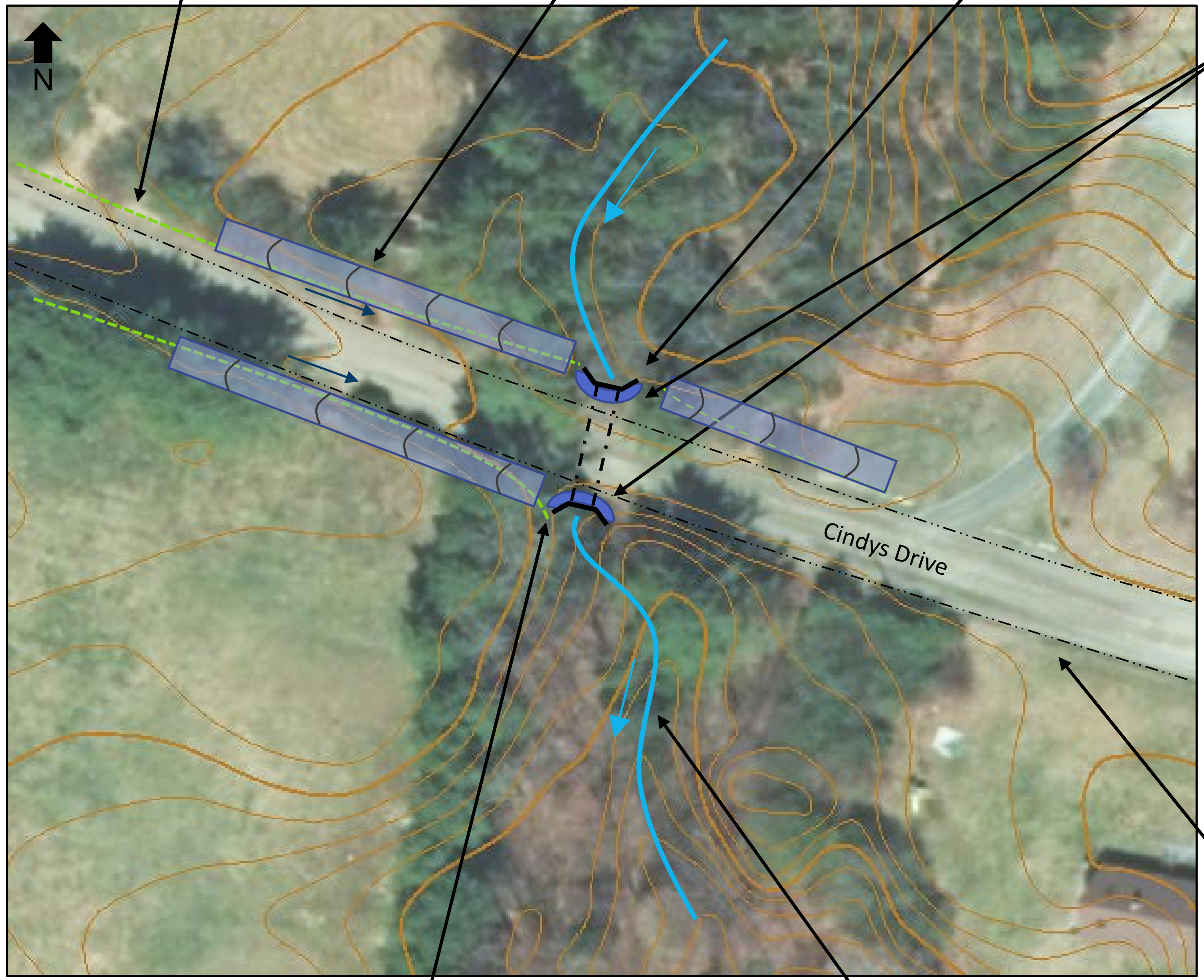
No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED

21 Depot Street, Merrimack, NH 03054

Site 1

Project No.: 366-01	Sheet
Date: July 2021	C-1
Drawn By: NP	
Checked By: NC	
Scale: As Shown	



Water Quality Swale Area Notes:

- Install approximate 100’ long water quality swale on both northern and southern sides of Cindys Drive, west of the culvert. Install approximate 75’ long water quality swale on the northern side of Cindys Drive, east of the culvert.
- Install check dams within the swales.
- Install riprap on side slopes adjacent to the northern and southern headwalls to limit erosion from water exiting the bioretention cell.

Soils Data:

- Berkshire Fine Sandy Loam – HSG: B
- Tunbridge-Lyman Complex – HSG: C

GENERAL NOTES

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED
21 Depot Street, Merrimack, NH 03054

Site 1 Proposed Conditions

Project No.: 366-01
Date: July 2021
Drawn By: NP
Checked By: NC
Scale: As Shown
Sheet C-2

Site 2: Farm Pond

Site Description

- Former farm pond at edge of an open grassed field, adjacent to Old Partridge Lake Road.
- An outlet pipe controlled by a ball valve controls the pond water level. Once water flows through the valve, it enters a high-density polyethylene (HDPE) culvert and crosses under Old Partridge Lake Road.
- The culvert discharges into a wooded area, west of the roadway before flowing south towards Partridge Lake (approximately 0.32 miles).
- Significant growth of green algae was observed in the pond.
- Pond size is roughly 100' by 50' and roughly 2' – 3' deep.

Proposed Improvements

- Convert pond area to a constructed wetland.
- Provide upsized outlet control structure to replace the ball valve.
- Install new culvert and headwall.
- Armor the downstream end of the culvert to limit erosion and sediment in runoff.
- Establish a “no mow”/”no disturb” buffer area around the constructed wetland.

***See next sheet for site plan of proposed improvements.**

Estimated Cost: **$165,000**

**See Appendix 3 for detailed breakdown*

Potential Conflicts:

- Site construction would take place on private property
- NHDES wetland permitting will be required.

Estimated Pollutant Reductions

- Total Phosphorus: **2.19 lb/yr**
- Total Nitrogen: **18.3 lb/yr**
- Total Suspended Solids: **1704 lb/yr**

Photo 2-1: View of farm pond to southeast

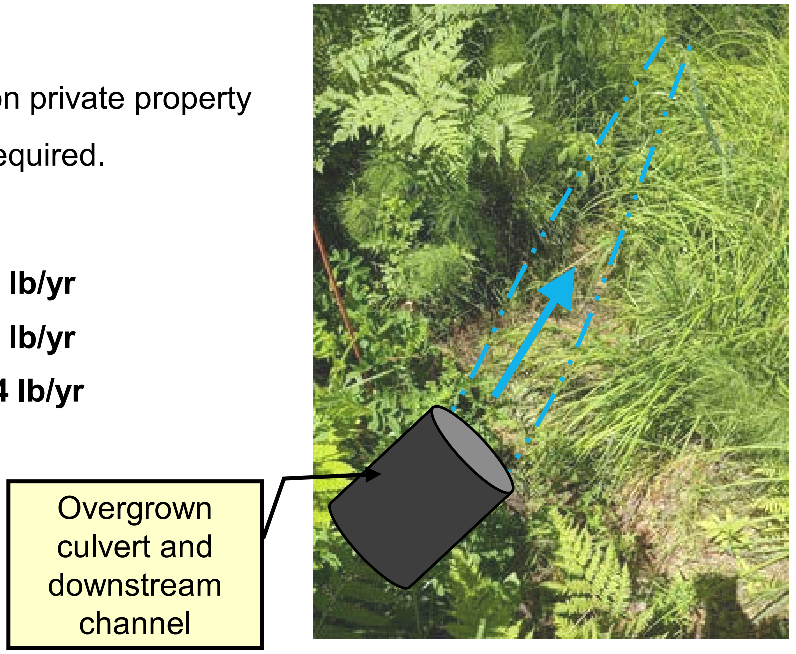


Photo 2-2: Culvert outlet location

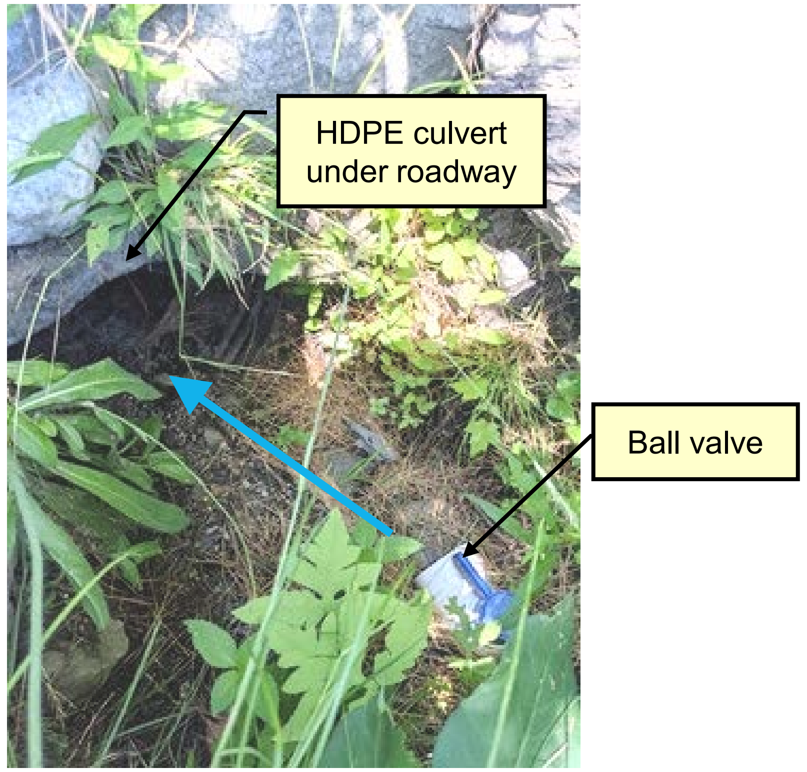


Photo 2-3: Ball valve and culvert inlet

GENERAL NOTES

- Contributing watershed area for Site 2 is approximately 2.4 acres.
- Discharge location is approximately 0.26 miles from Partridge Lake.

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED
21 Depot Street, Merrimack, NH 03054

Site 2

Project No.: 366-01
Date: July 2021
Drawn By: NP
Checked By: NC
Scale: As Shown
Sheet C-3

Approximate stream channel location

Existing HDPE culvert

Existing ball valve location

Existing pond location

Retrofit new outlet structure

Proposed constructed stormwater wetland area with a 25' "no disturb" zone around wetland.

Constructed Stormwater Wetland Notes:

- Regrade squared-off artificial pond into constructed stormwater wetland.
- Constructed stormwater wetland has a 40%-60% total phosphorus removal efficiency.
- Install using native wetland vegetation, prioritizing perennial species that establish themselves rapidly.
- Frequent small-scale levels of maintenance is required to evaluate the health of the wetland plant species.
- During the first three years after construction, the wetland should be inspected twice a year. Once in growing season and once in non-growing season.

Soils Data:

- Tunbridge-Lyman Complex – HSG: C

GENERAL NOTES

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED

21 Depot Street, Merrimack, NH 03054

Site 2 Proposed Conditions

Project No.: 366-01
Date: July 2021
Drawn By: NP
Checked By: NC
Scale: As Shown

Sheet C-4

Site 3: Old Partridge Lake Road Culvert

Site Description

- A culvert under Old Partridge Lake Road conveys water collected in a roadside drainage ditch north of the roadway and discharges it on the southern side of the road. This is an indirect discharge to Partridge Lake.
- Minor erosion channel observed downgradient of the culvert.
- Roadway deterioration over culvert.

Proposed Improvements

- Inspect culvert condition and replace if necessary.
- Excavate drainage ditch and install soils with high infiltration rates.
- Cover fill with riprap to limit erosion.
- Armor the downstream end of the culvert to limit erosion and sediment in runoff.

***See next sheet for site plan of proposed improvements.**

Estimated Cost: **$12,000**

**See Appendix 3 for detailed breakdown*

Estimated Pollutant Reductions

- Total Phosphorus: **0.3 lb/yr**
- Total Nitrogen: **0.5 lb/yr**
- Total Suspended Solids: **600 lb/yr**

Photo 3-1: Roadside drainage ditch

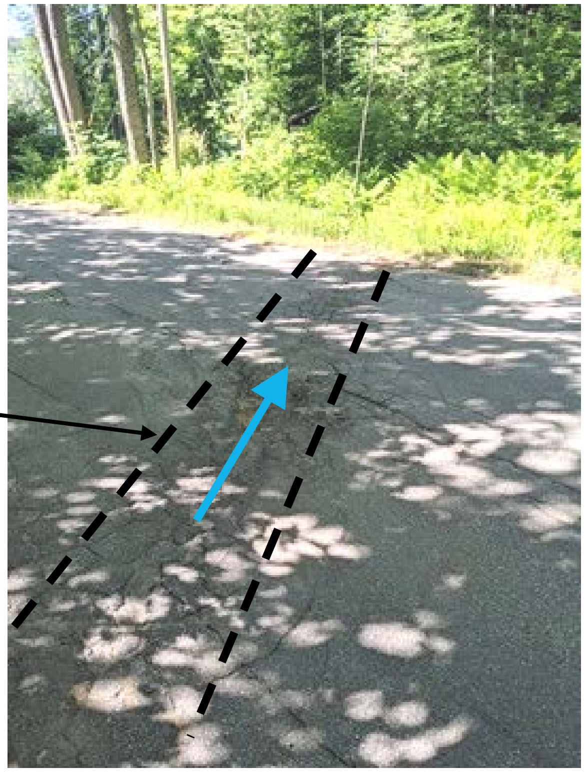


Photo 3-2: Cracks in roadway from culvert

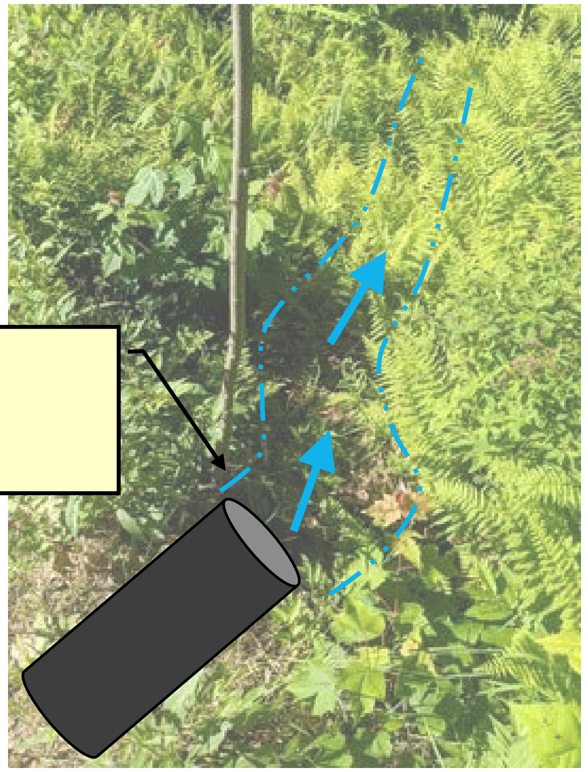


Photo 3-3: Downstream end of culvert

GENERAL NOTES

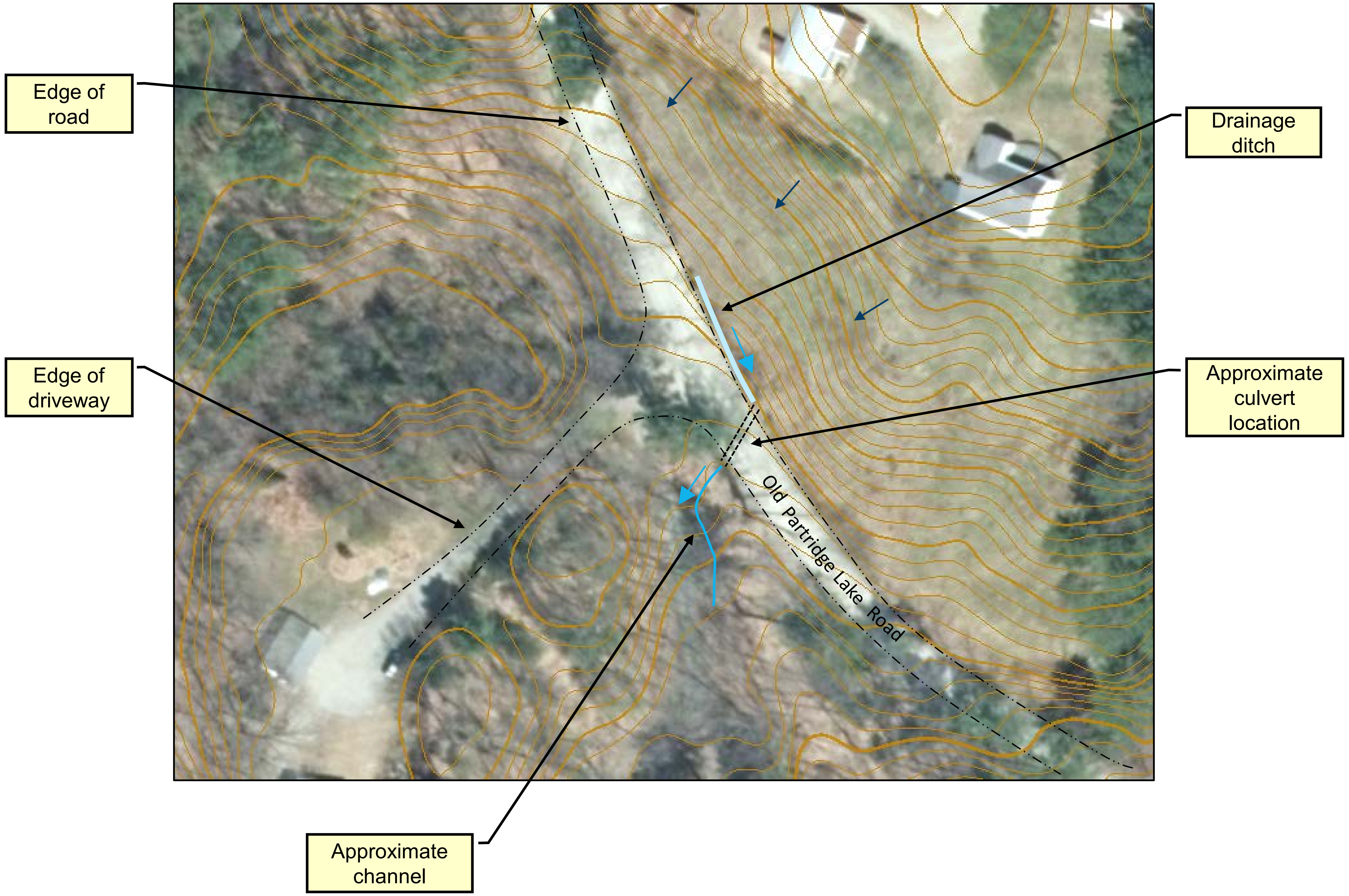
- Contributing watershed area for Site 3 is approximately 1.17 acres.
- Discharge location is approximately 0.1 miles from Partridge Lake.

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED
21 Depot Street, Merrimack, NH 03054

Site 3

Project No.: 366-01
Date: July 2021
Drawn By: NP
Checked By: NC
Scale: As Shown
Sheet C-5



GENERAL NOTES

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED
21 Depot Street, Merrimack, NH 03054

Site 3 Proposed Conditions

Project No.: 366-01		Sheet
Date: July 2021		C-6
Drawn By: NP		
Checked By: NC		
Scale: As Shown		

Site 4: Old Partridge Lake Road Erosion

Site Description

- A roughly 600’ long section of Old Partridge Lake Road displayed multiple instances of erosion along the edge of pavement. Steeper upgradient slopes allow for faster and more destructive flows.

Proposed Improvements

- Install water quality swale with check dams when appropriate, discharging to level spreader into vegetated area.
- Install riprap when appropriate.
- Fill and compact areas of heavy erosion.
- Optional paved driveway with shallow catch basin and pipe water quality swale.

Estimated Cost: **$42,000**

**See Appendix 3 for detailed breakdown*

***See next sheet for site plan of proposed improvements.**

Estimated Pollutant Reductions

- Total Phosphorus: **0.12 lb/yr**
- Total Nitrogen: **N/A lb/yr**
- Total Suspended Solids: **521 lb/yr**

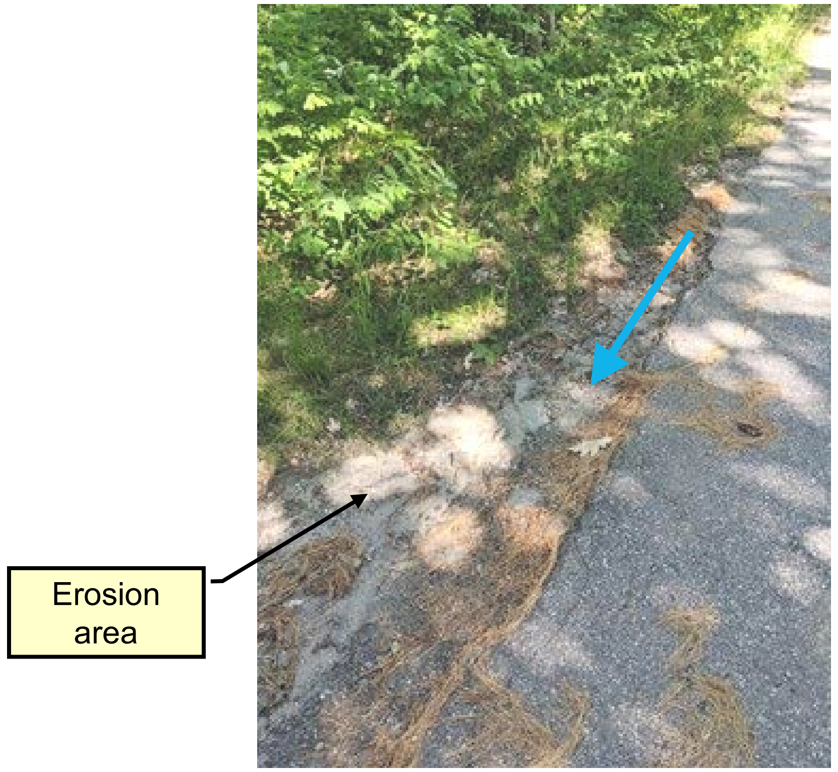


Photo 4-1: Roadside erosion

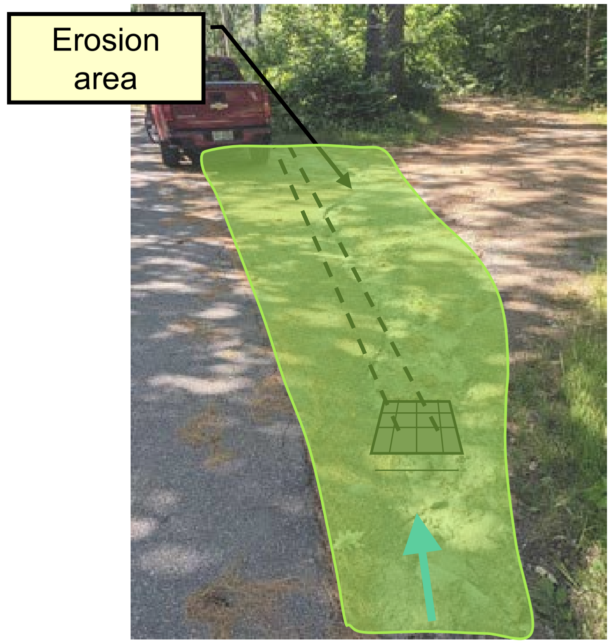


Photo 4-2: Erosion channel across driveway

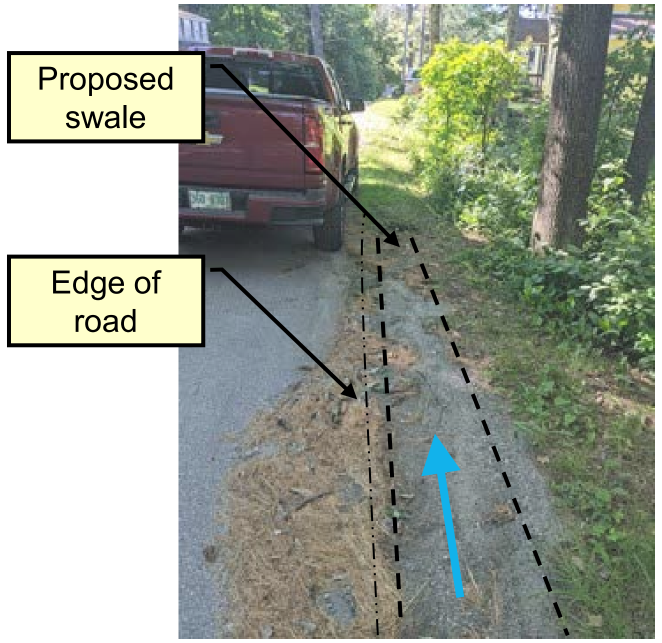


Photo 4-3: Roadside erosion

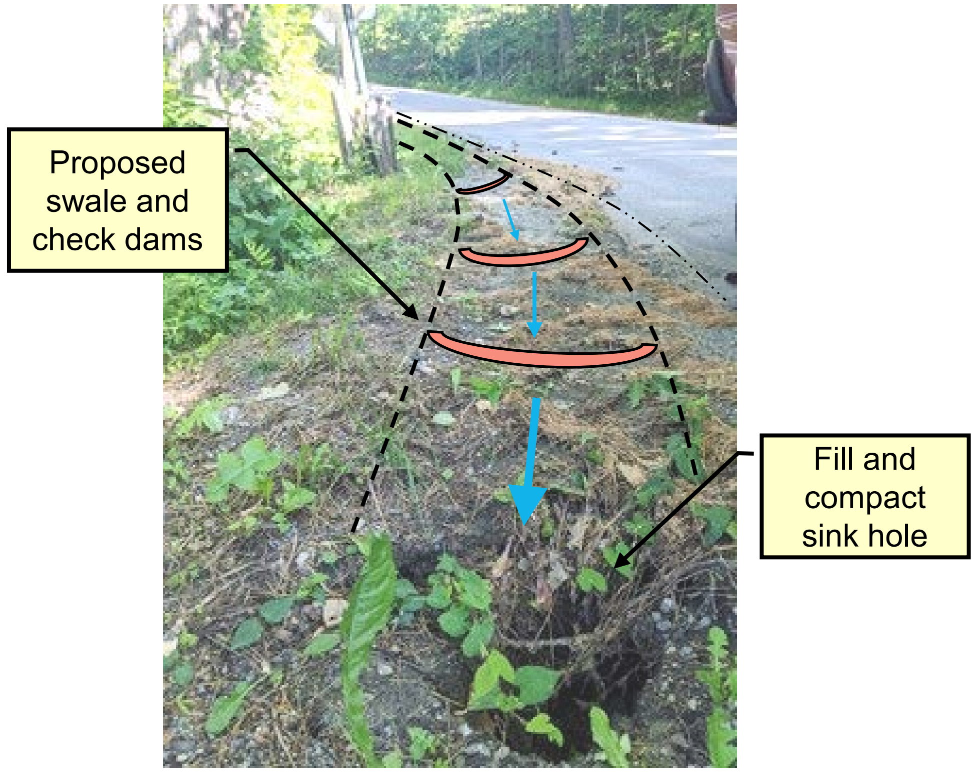


Photo 4-4: Minor sink hole

GENERAL NOTES

- Contributing watershed area for Site 4 is approximately 0.44 acres.
- Discharge location is approximately 260 feet from Partridge Lake.

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED
21 Depot Street, Merrimack, NH 03054

Site 4

Project No.:	366-01	Sheet
Date:	July 2021	C-7
Drawn By:	NP	
Checked By:	NC	
Scale:	As Shown	

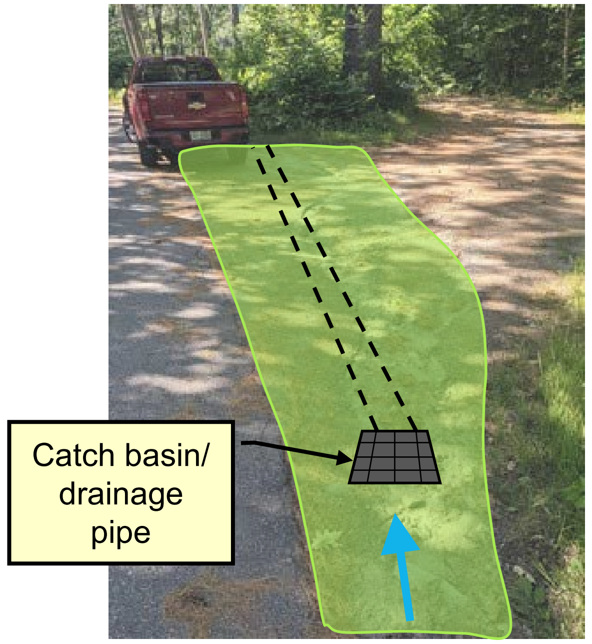


Photo 4-5: Proposed Conditions

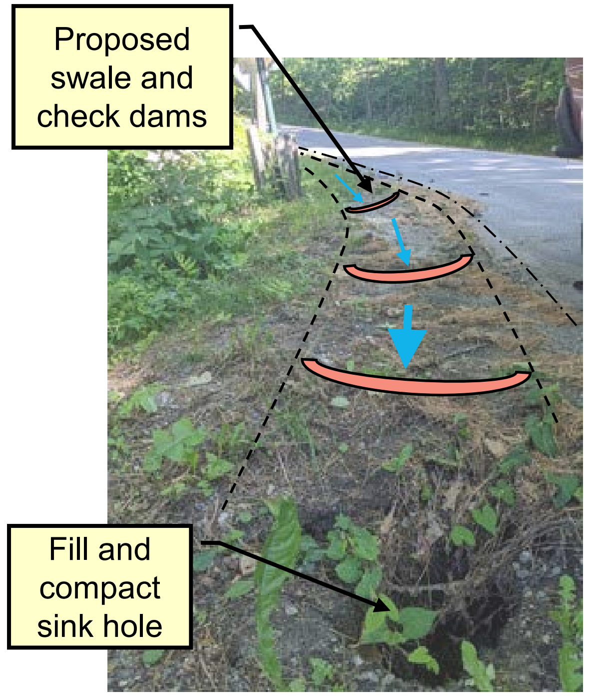


Photo 4-6: Minor sink hole

GENERAL NOTES

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED

21 Depot Street, Merrimack, NH 03054

Site 4 Proposed Conditions

Project No.: 366-01		Sheet
Date: July 2021		C-8
Drawn By: NP		
Checked By: NC		
Scale: As Shown		

Site 5: Old Partridge Lake Road & Partridge Lake Road Intersection

Site Description

- The intersection of Old Partridge Lake Rd. and Partridge Lake Rd. includes a stream outlet, culvert, catch basin with outfall, and steep grades to the north.
- The steep grades to the north result in elevated runoff volumes and speed.
- Residents noted the presence of excess sediment and debris within the roadway after rainstorms and winter sanding.

Proposed Improvements

- Install a rain garden to treat water from catch basin outfall. During winter months, snow should not be plowed onto the rain garden or stream.
- Install asphalt berm to direct runoff from Old Partridge Lake Road to rain garden for treatment prior to discharging into Partridge Lake.
- Optional: Expand buffer around stream.

***See next sheet for site plan of proposed improvements.**

Estimated Cost: **$24,000**

**See Appendix 3 for detailed breakdown*

Estimated Pollutant Reductions

- Total Phosphorus: **0.74 lb/yr**
- Total Nitrogen: **5.7 lb/yr**
- Total Suspended Solids: **1042 lb/yr**

Potential Conflicts:

Site construction on private property.

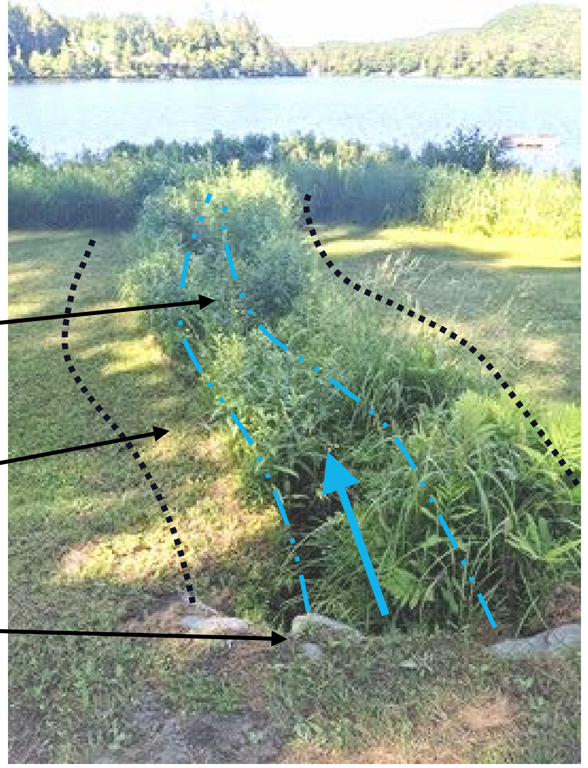


Photo 5-1: Southern headwall and discharge to Partridge Lake

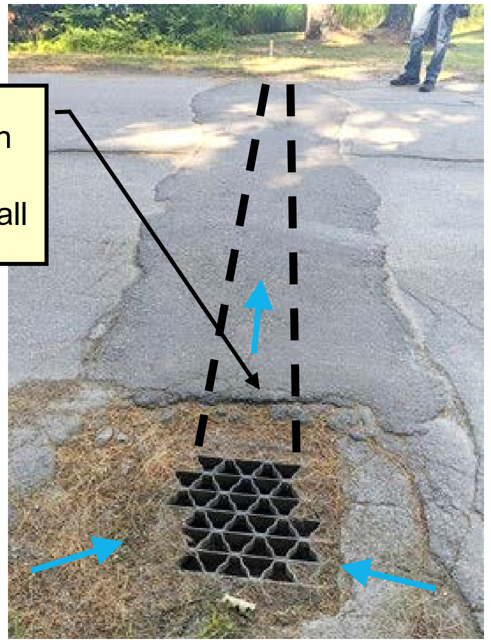


Photo 5-2: Single catch basin on Partridge Lake Road

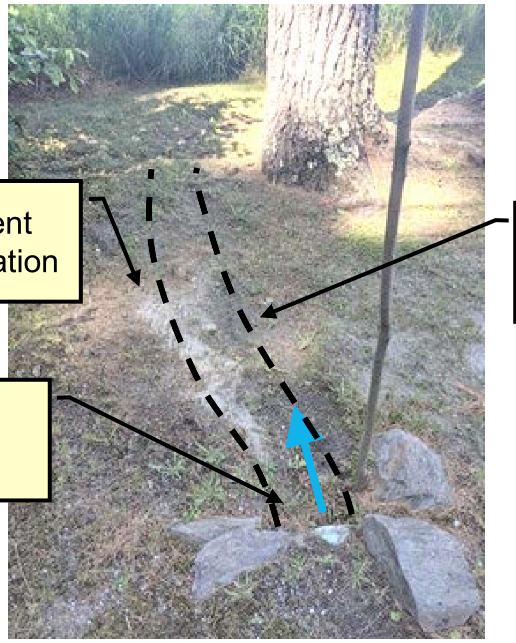


Photo 5-3: Outfall from catch basin

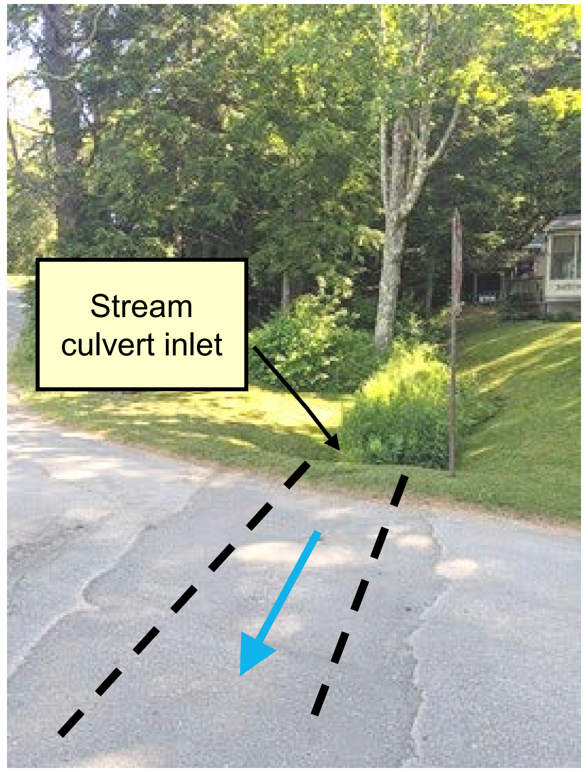


Photo 5-4: Culvert view to the north

GENERAL NOTES

- Contributing watershed area for Site 5 is approximately 1.17 acres.
- Discharges directly to Partridge Lake.

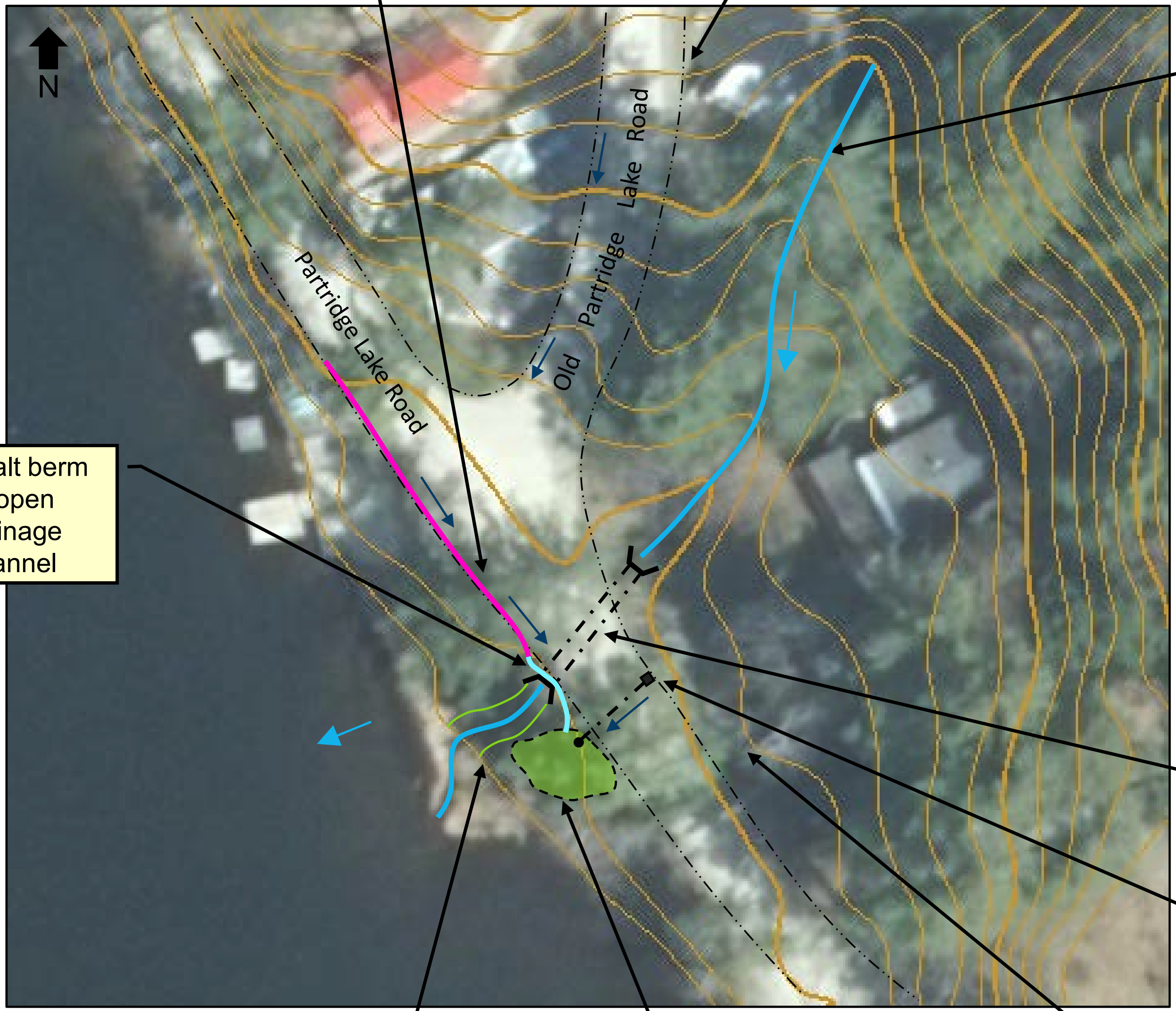
No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED

21 Depot Street, Merrimack, NH 03054

Site 5

Project No.:	366-01
Date:	July 2021
Drawn By:	NP
Checked By:	NC
Scale:	As Shown
Sheet	C-9



Rain Garden Notes:

- Install a minimum of 18” of bioretention soils.
- Install using native vegetation, prioritizing perennial species that establish themselves rapidly.
- Install level spreader at catch basin outfall point.

Soils Data:

- Monadnock and Hermon Soils– HSG: B

GENERAL NOTES

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED

21 Depot Street, Merrimack, NH 03054

Site 5 Proposed Conditions

Project No.: 366-01		Sheet
Date: July 2021		C-10
Drawn By: NP		
Checked By: NC		
Scale: As Shown		

Site 6: North Shore Culverts

Site Description

- Nine culverts were observed beneath Partridge Lake Road along the northwestern and northern shorelines of Partridge Lake.
- In general, the culverts received water from elevated areas north and west of Partridge Lake Road, and conveyed runoff to the culverts via roadside ditches.
- Most culverts inspected either displayed structural damage, were partially clogged with sediment and/or organic debris or were completely buried.
- Culverts generally discharged directly into Partridge Lake or immediately upgradient. Limited options for retrofitting was observed.

Proposed Improvements

- Clean culverts of sediment and debris.
- Excavate upgradient drainage ditch and install soils with high infiltration rates.
- Cover fill with riprap to limit erosion.
- Armor the downstream end of the culvert to limit erosion and sediment in runoff.

Potential Conflicts:

- Limited space to no space for improvements.
- Generally steep slopes on northern side of ditches.

***See next sheets for site plan of proposed improvements.**

Estimated Cost:	**$5,000 (Per Culvert)** **See Appendix 3 for detailed breakdown*

Estimated Pollutant Reductions

• Total Phosphorus:	**0.23 lb/yr**
• Total Nitrogen:	**0.4 lb/yr**
• Total Suspended Solids:	**577 lb/yr**

*Pollutant reduction numbers are an average of all nine culverts and displayed as such.

Photo 6-1: Culvert Partially Filled with Sediment

Photo 6-2: Culvert Completely Buried

Photo 6-3: Culvert Channel Extension Filled with Sediment

GENERAL NOTES

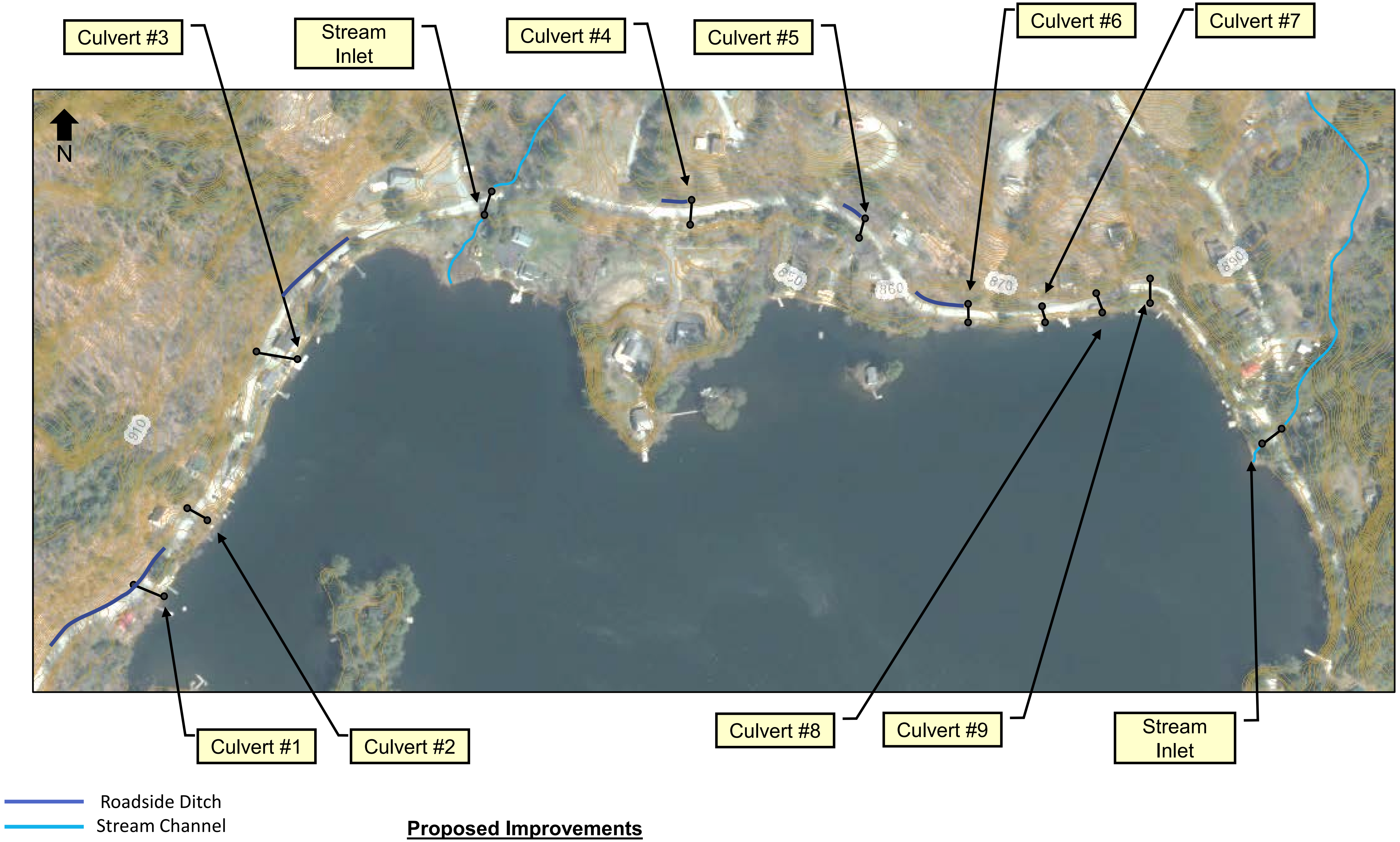
- Estimated cost is for a single culvert.
- Estimated pollutant reductions are averages from calculations for all nine culverts.

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED
21 Depot Street, Merrimack, NH 03054

Site 6

Project No.: 366-01	Date: July 2021	Sheet
Drawn By: NP	Checked By: NC	C-11
Scale: As Shown		



Proposed Improvements

- Clean culverts of sediment and debris.
- Excavate upgradient drainage ditch and install soils with high infiltration rates.
- Cover fill with riprap to limit erosion.
- Armor the downstream end of the culvert to limit erosion and sediment in runoff.

GENERAL NOTES

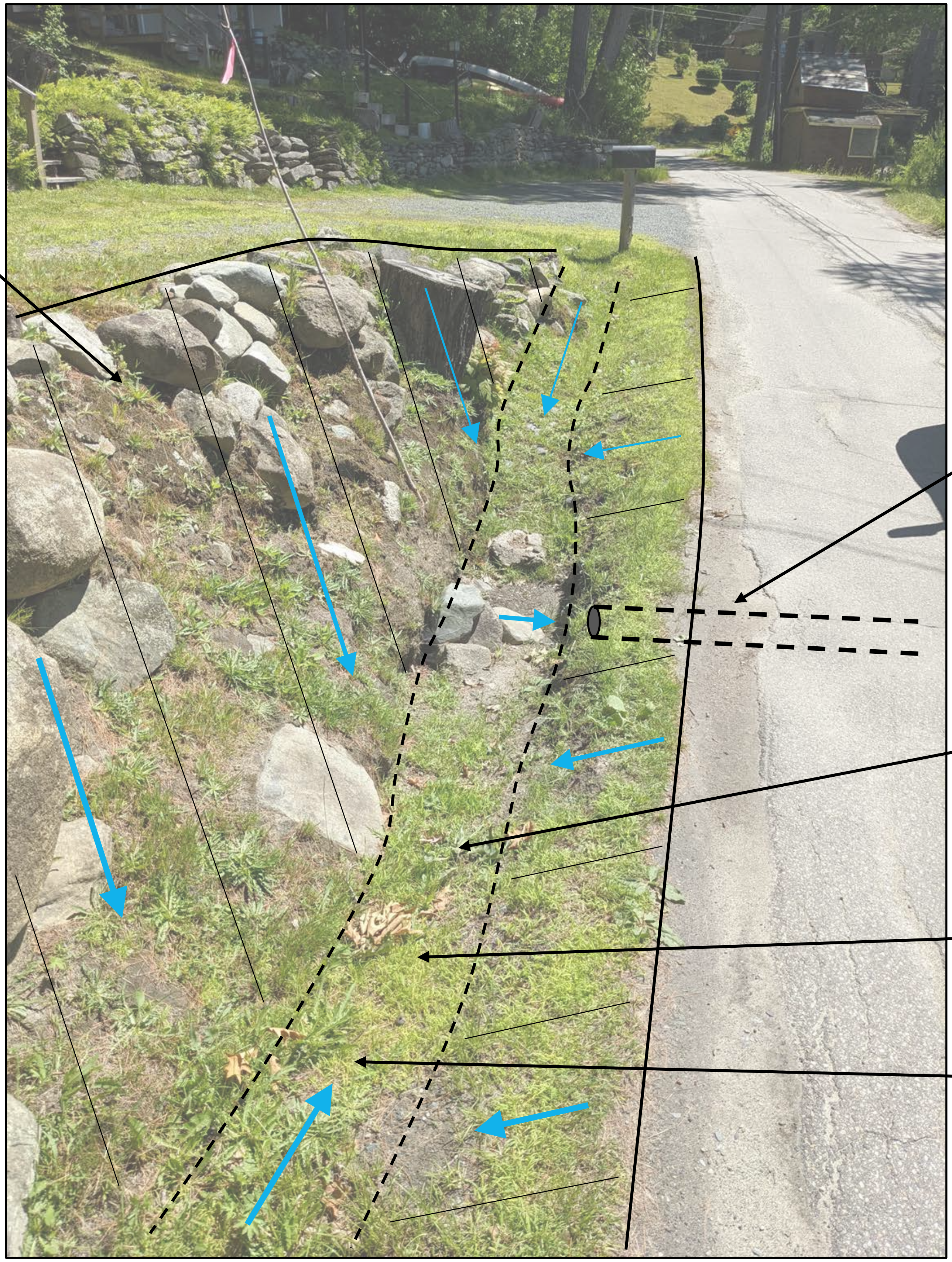
- Culvert locations are approximate.
- Stream channels are approximate.

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED
21 Depot Street, Merrimack, NH 03054

Site 6
Culvert Map

Project No.: 366-01		Sheet
Date: July 2021		C-12
Drawn By: NP		
Checked By: NC		
Scale: As Shown		



GENERAL NOTES

- Culvert locations are approximate.

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED

21 Depot Street, Merrimack, NH 03054

Site 6
Ditch
Improvements

Project No.: 366-01	Date: July 2021	Sheet
Drawn By: NP	Checked By: NC	C-13
Scale: As Shown		

Site 7: Boat Ramp

Site Description

- The public boat ramp at the end of Dodge Pond Road serves as the only public access point to Partridge Lake. The roadway and ramp are both gravel/dirt in construction. Minor erosion channels were observed throughout the road and ramp, as well as a sediment plume from historical runoff entering the lake.

Proposed Improvements

- Replace gravel boat ramp with an articulated concrete block ramp (40’ long and 20’ wide).
- Install three 8” high earthen water bars (approximately 20’ in length) to direct all flow from parking area to vegetated area adjacent to boat ramp.
- Earthen water bars should be constructed at an angle of 30 degrees downslope of perpendicular to roadway and have an armored outlet.

***See next sheet for site plan of proposed improvements.**

Estimated Cost: **$39,000**

**See Appendix 3 for detailed breakdown*

Estimated Pollutant Reductions

- Total Phosphorus: **N/A lb/yr**
- Total Nitrogen: **N/A lb/yr**
- Total Suspended Solids: **N/A lb/yr**

*Insufficient published data on the pollutant reduction of narrow width vegetated buffers and concrete block boat ramps.

Photo 7-2: Boat ramp

Photo 7-1: Boat ramp

Photo 7-3: View of sediment plume from boat ramp

GENERAL NOTES

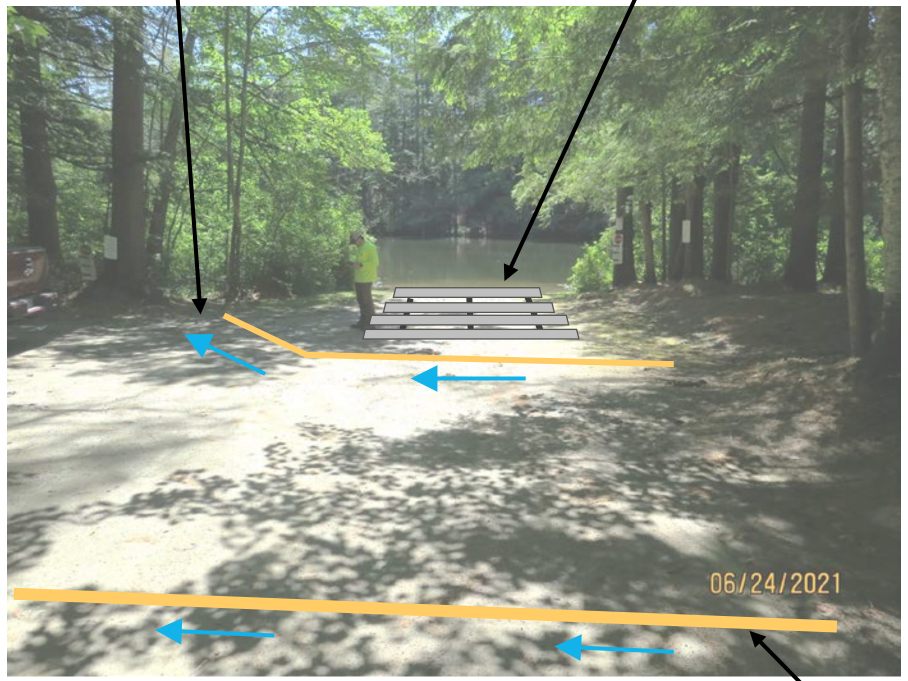
- Contributing watershed area for Site 7 is approximately 0.15 acres.
- Discharges directly into Partridge Lake, but at a location very close to the lake outlet. As such, pollutant loading from this location will have very little influence on overall lake conditions.

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED
21 Depot Street, Merrimack, NH 03054

Site 7

Project No.: 366-01		Sheet
Date: July 2021		C-14
Drawn By: NP		
Checked By: NC		
Scale: As Shown		



Armored outlet area

Concrete boat ramp

Photo 7-4: Minor boat ramp erosion

Water bar at 30-degree downslope from perpendicular to roadway

Concrete boat ramp

Multiple water bars

Photo 7-5: Proposed improvements

GENERAL NOTES

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED

21 Depot Street, Merrimack, NH 03054

Site 7 Proposed Conditions

Project No.:	366-01
Date:	July 2021
Drawn By:	NP
Checked By:	NC
Scale:	As Shown
Sheet	C-15

Site 8: Driveway Erosion and Retaining Wall Failure

Site Description

- Runoff from an elevated section of Partridge Lake Road runs north to the driveway of 360 Partridge Lake Road (unpaved), carrying sediment across driveway and eroding channels.
- Flow enters a culvert and discharges to Partridge Lake.
- Failed 2' retaining wall resulting in large sediment accumulation in grassed area

Proposed Improvements

- Install a catch basin south of driveway to catch runoff coming from Partridge Lake Road
- Install infiltration basin with sediment forebay in grassed area north of the driveway.
- Install water quality swale to capture and convey water to the infiltration basin from the east.
- Install outlet control structure and new culvert to Partridge Lake.
- Repair eroded areas and stabilize retaining wall.

***See next sheet for site plan of proposed improvements.**

Estimated Cost: **$77,000**

**See Appendix 3 for detailed breakdown*

Estimated Pollutant Reductions

- Total Phosphorus: **0.4 lb/yr**
- Total Nitrogen: **3.4 lb/yr**
- Total Suspended Solids: **418 lb/yr**

Potential Conflicts:

Site construction on private property

Photo 8-1: View across dirt driveway, up Partridge Lake Road

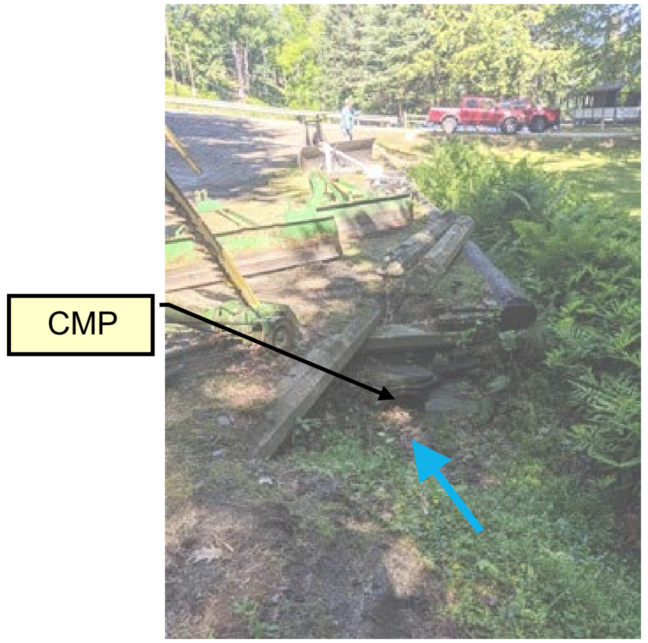


Photo 8-2: CMP for runoff from the east

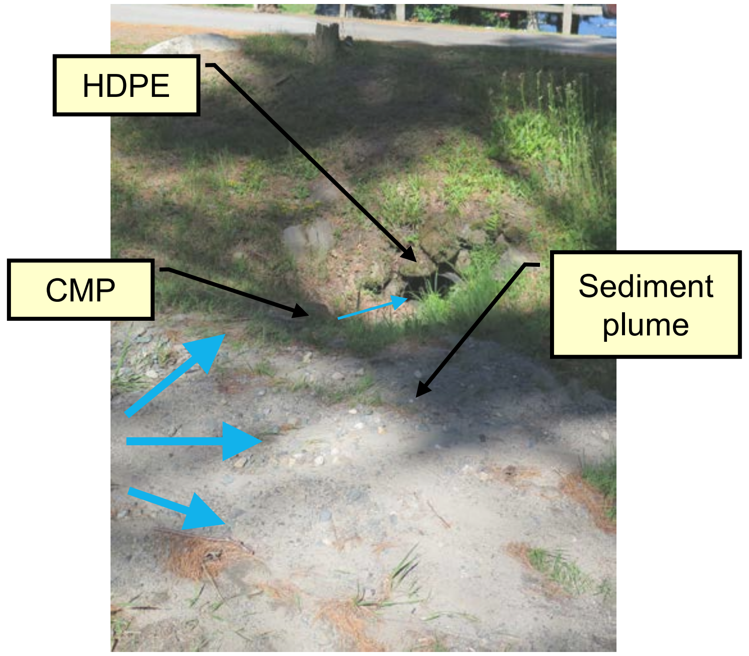


Photo 8-3: CMP to HDPE culvert and sediment plume/accumulation

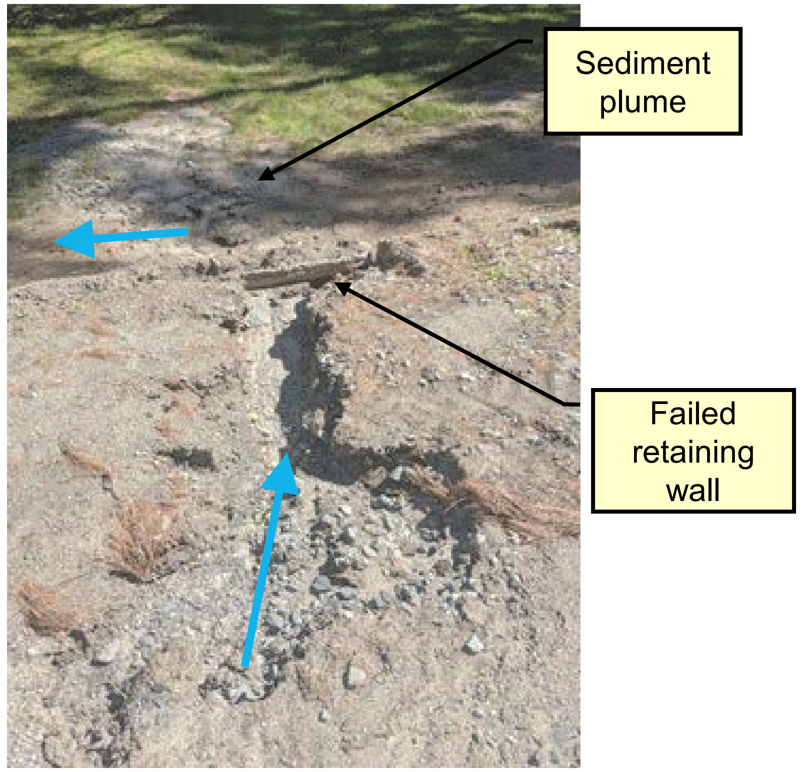


Photo 8-4: Driveway erosion

GENERAL NOTES

- Contributing watershed area for Site 8 is approximately 0.9 acres.
- Discharges directly into Partridge Lake.

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED
21 Depot Street, Merrimack, NH 03054

Site 8

Project No.: 366-01	Sheet
Date: July 2021	C-16
Drawn By: NP	
Checked By: NC	
Scale: As Shown	

Infiltration Basin and Swale Notes:

- Install approximate 60' by 50' infiltration basin in grassed area adjacent to driveway.
- Install outlet control structure with new culvert and headwall under Partridge Lake Road.
- Install new catch basin and drainage pipe to new forebay.
- Install grassed water quality swale to convey runoff from the east to the infiltration basin.

Soils Data:

- Colton Gravelly Sandy Loam – HSG: A

GENERAL NOTES

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED
21 Depot Street, Merrimack, NH 03054

Site 8
Proposed
Conditions

Project No.: 366-01
Date: July 2021
Drawn By:
Checked By:
Scale:
Sheet
C-17

Site 9: South Shore Road

Site Description

- The majority of South Shore Road directly abuts Partridge Lake at a near vertical slope.
- Various trees along the slope aid in the structural integrity of the slope itself.
- Many exposed tree roots were observed due to loss in slope material due to erosion.
- The edge of South Shore Road is approximately 3 feet to 5 feet above the water line.

Proposed Improvements

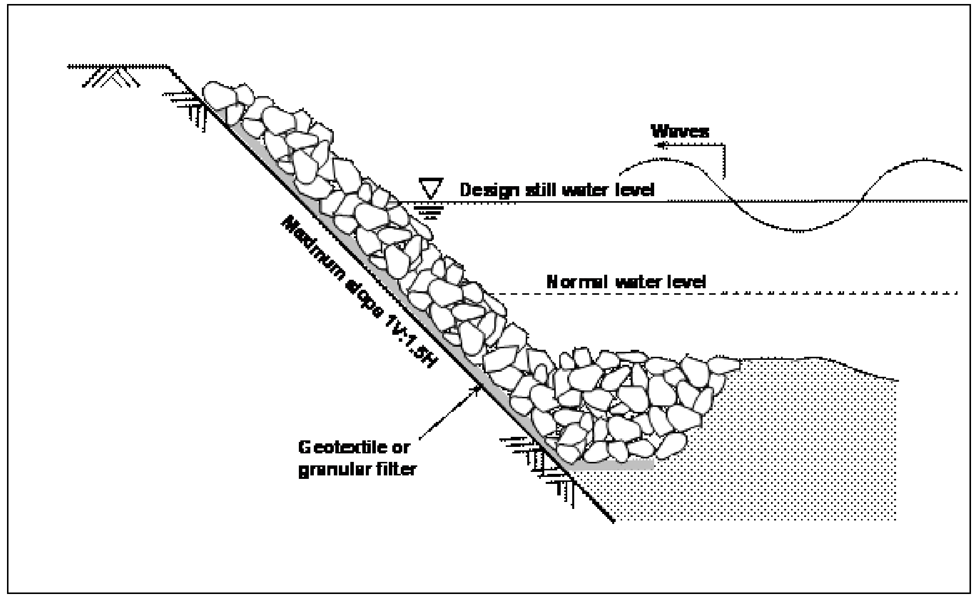
- Add fill to build back slope and stabilize tree roots.
- Install shoreline restoration and protection measures along South Shore Road to lower the chance of a washout.
- A stone retaining wall is recommended in areas where slope is greater than 1V : 1.5H.
- Riprap slopes are recommended in areas where slopes are less than 1V : 1.5H. Where possible, erosion control fabric and biostabilization techniques (e.g., live stakes and live fascines) should be used to further stabilize the slope.
- Install plantings along areas with limited vegetation.

Estimated Cost: **$137,000**

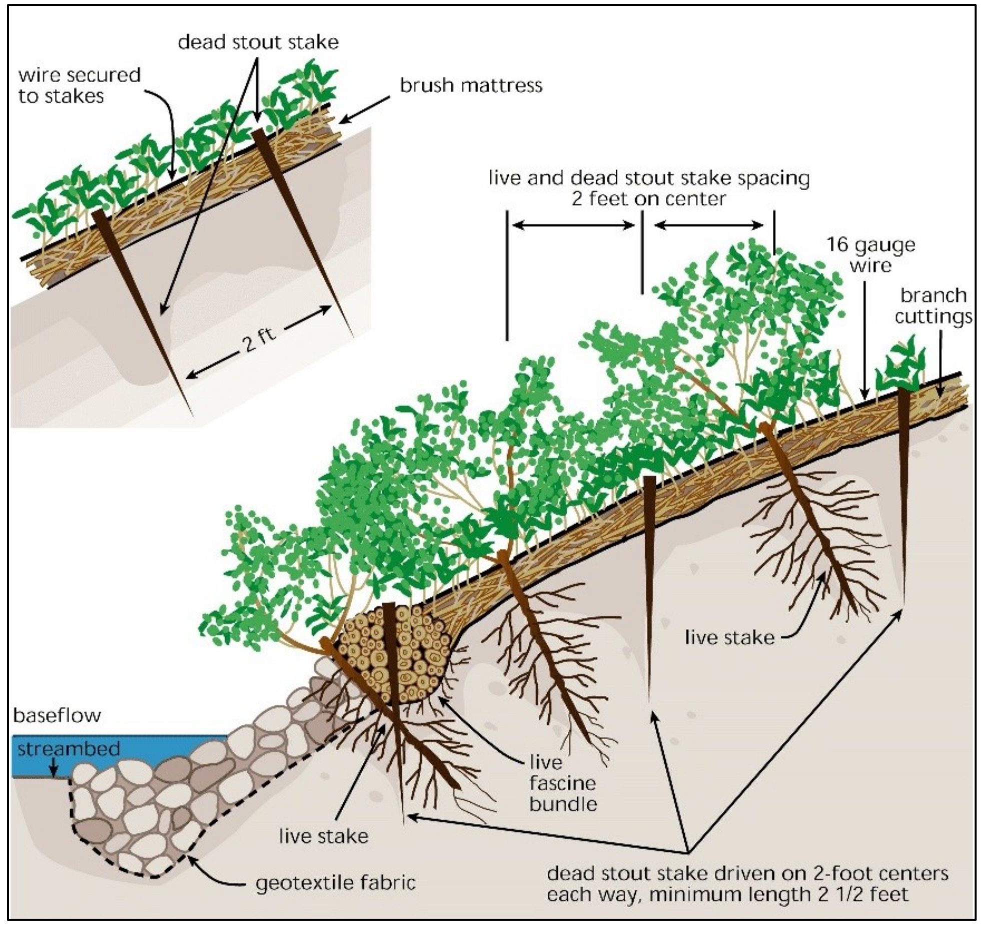
**See Appendix 3 for detailed breakdown*

Estimated Pollutant Reductions

- Total Phosphorus: **2.2 lb/yr**
- Total Nitrogen: **4.3 lb/yr**
- Total Suspended Solids: **5200 lb/yr**



Source: Federal Highway Administration



Slope Stabilization with Toe Protection

Source: Stream Corridor Restoration: Principles, Processes and Practices, 1998, Federal Interagency Stream Restoration Working Group.

GENERAL NOTES

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED
21 Depot Street, Merrimack, NH 03054

Site 9

Project No.: 366-01		Sheet
Date: July 2021		C-18
Drawn By: NP		
Checked By: NC		
Scale: As Shown		

Site 10: Partridge Lake Road / Hubbards Road Intersection

Site Description

- Runoff from the intersection of Partridge Lake Road and Hubbards Road runs down a grassed slope before pooling in a grassed area.
- Erosion along the shoulder of Partridge Lake Road was observed.
- Sediment buildup can be seen in the low-lying grass area. CEI is unsure if the runoff reaches Partridge Lake.

Proposed Improvements

- Install asphalt berm to direct runoff to swale and infiltration basin.
- Install infiltration basin with sediment forebay.
- Construct vegetated swale with check dams.

***See next sheet for site plan of proposed improvements.**

Estimated Cost: **$26,000**

**See Appendix 3 for detailed breakdown*

Estimated Pollutant Reductions

- Total Phosphorus: **0.34 lb/yr**
- Total Nitrogen: **2.9 lb/yr**
- Total Suspended Solids: **358 lb/yr**

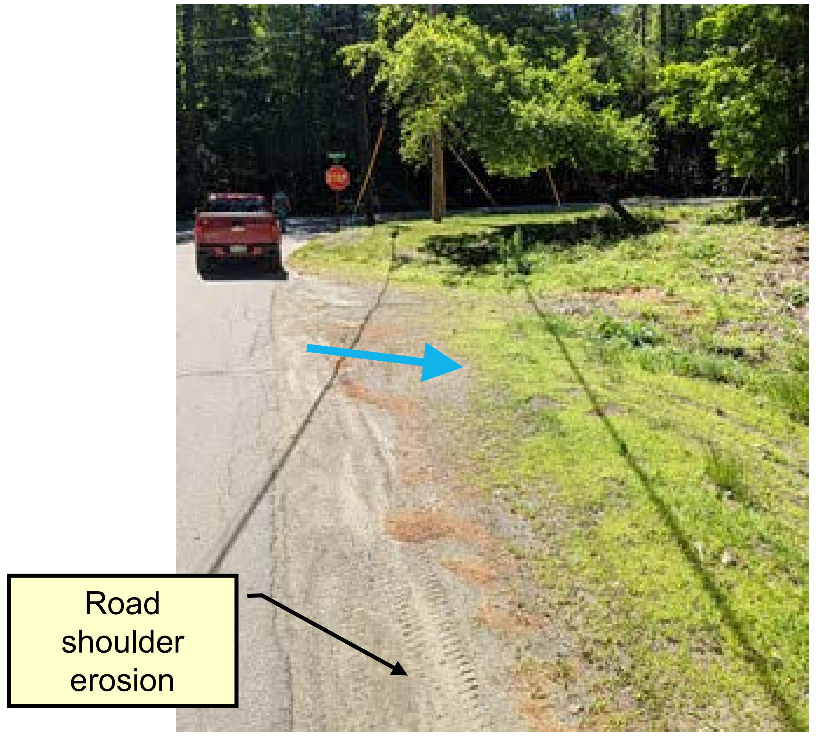


Photo 10-1: Intersection of Partridge Lake Road and Hubbards Road

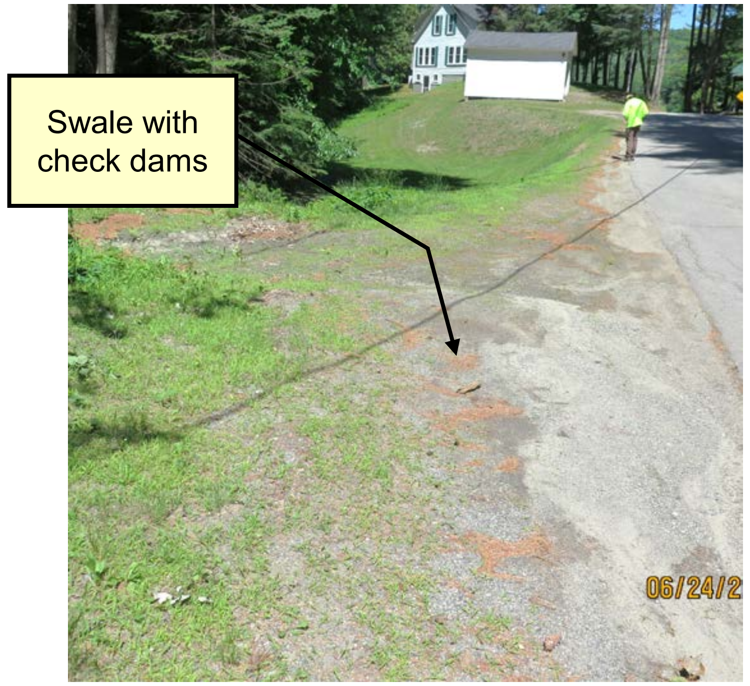


Photo 10-2: Runoff carrying sediment down slope

Photo 10-3: Sediment buildup in flat grassy area

Photo 10-4: View of slope and minor erosion

GENERAL NOTES

- Contributing watershed area for Site 10 is approximately 0.77 acres.
- Discharges directly into Partridge Lake.

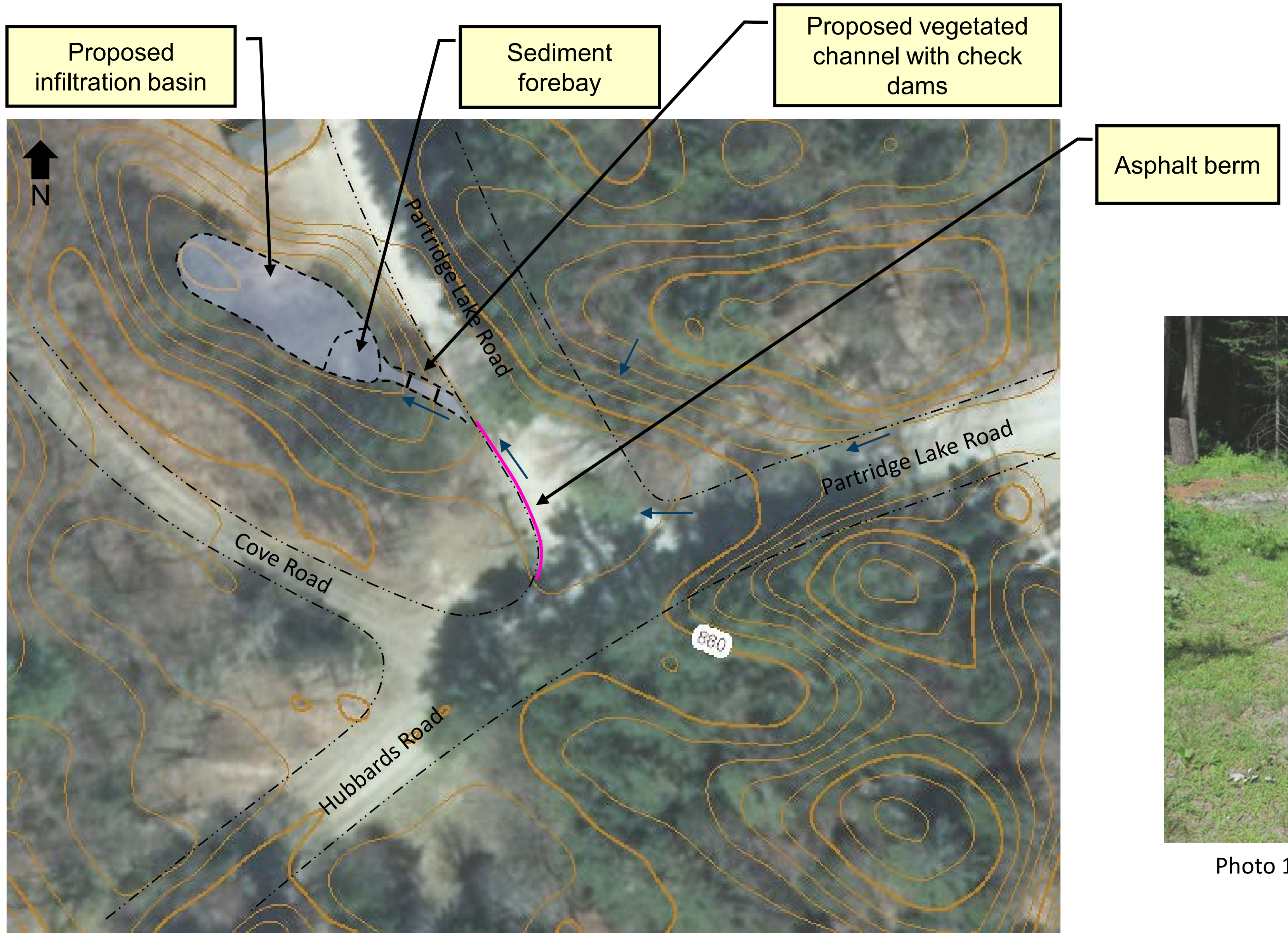
No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED

21 Depot Street, Merrimack, NH 03054

Site 10

Project No.: 366-01	Sheet	
Date: July 2021	C-19	
Drawn By: NP		
Checked By: NC		
Scale: As Shown		



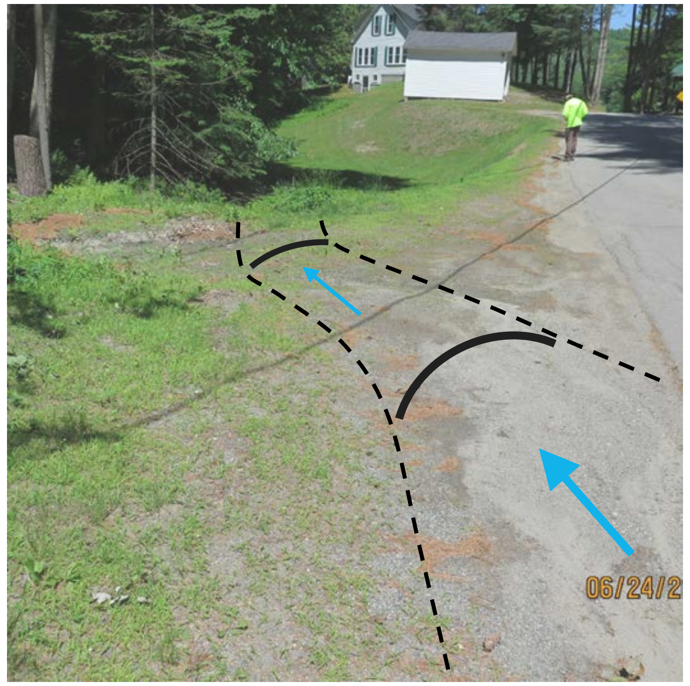


Photo 10-5: Proposed vegetated swale with check dams

Infiltration Basin Notes:

- Install approximate 80’ by 30’ infiltration basin in grassed area with sediment forebay.
- After construction is complete, do not direct water into basin until the side slopes and bottom are fully stabilized.
- Inspections and preventative maintenance must occur, at a minimum, twice a year.
- Remove built up sediment from the bottom of the basin as needed.

Soils Data:

- Colton Gravelly Sandy Loam – HSG: A
- Hermon and Monadnock Soils – HSG: A

GENERAL NOTES

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED
21 Depot Street, Merrimack, NH 03054

Site 10 Proposed Conditions

Project No.: 366-01	Sheet
Date: July 2021	C-20
Drawn By: NP	
Checked By: NC	
Scale: As Shown	

Site 11: Southern Culverts

Site Description

- Multiple culverts were observed beneath Hubbards Road, Cove Road and Poulsens Point Road.
- In general, the culverts received water from elevated areas east of Hubbards Road, and conveyed runoff to the culverts via roadside ditches.
- Most culverts inspected either displayed structural damage, were partially clogged with sediment and/or organic debris or were completely buried.
- Most drainage channels were dry during the site visit, although some showed signs of flow due to recent wet weather.

Proposed Improvements

- Clean culverts of sediment and debris.
- Excavate drainage ditch and install soils with high infiltration rates.
- Cover fill with riprap to limit erosion.
- Armor the downstream end of the culvert to limit erosion and sediment in runoff.

Estimated Cost: **$5,000 (per culvert)**

**See Appendix 3 for detailed breakdown*

Estimated Pollutant Reductions

- Total Phosphorus: **0.05 lb/yr**
- Total Nitrogen: **0.1 lb/yr**
- Total Suspended Solids: **200 lb/yr**

*Pollutant reduction numbers are an average of all 3 culverts and displayed as such.

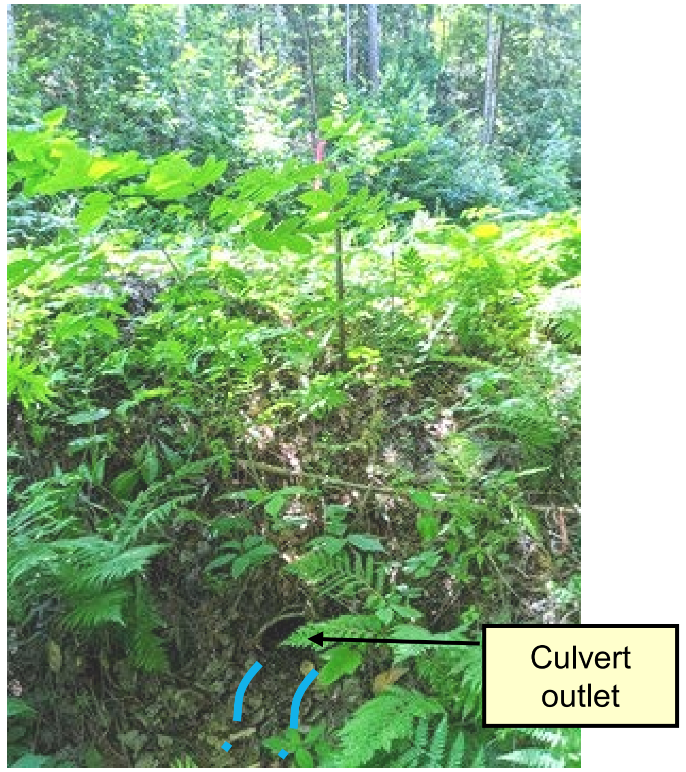


Photo 11-1: Culvert Under Hubbards Road

Photo 11-2: Culvert Under Hubbards Road

GENERAL NOTES

- Estimated cost is for a single culvert.
- Estimated pollutant reductions are averages from calculations for all 3 culverts.

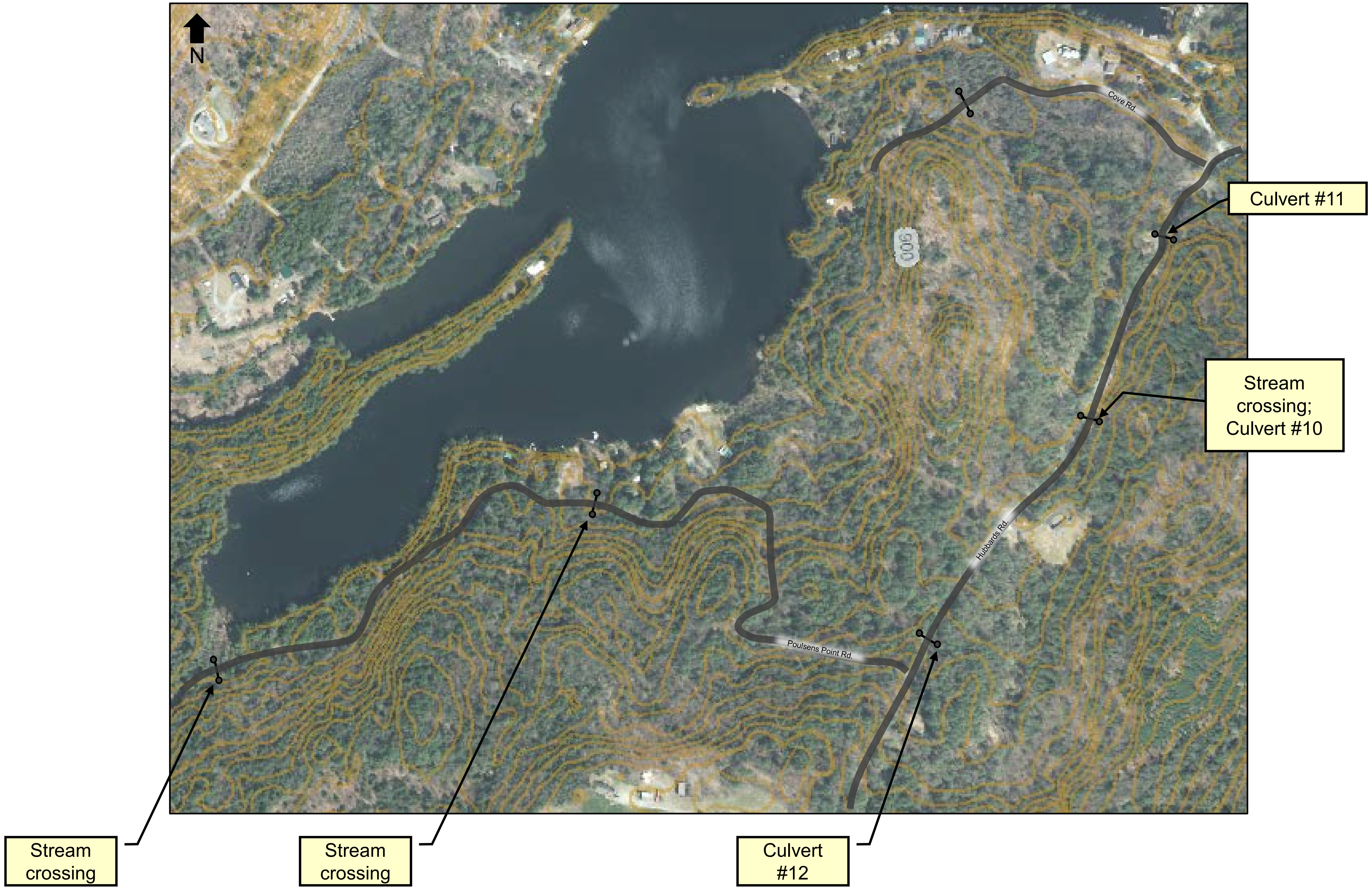
No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED

21 Depot Street, Merrimack, NH 03054

Site 11

Project No.: 366-01
Date: July 2021
Drawn By: NP
Checked By: NC
Scale: As Shown
Sheet: C-21



GENERAL NOTES

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED
21 Depot Street, Merrimack, NH 03054

Site 11 Culvert Map

Project No.:	366-01	Sheet
Date:	July 2021	C-22
Drawn By:	NP	
Checked By:	NC	
Scale:	As Shown	

Site 12: Gannon Road Erosion

Site Description

- Roadside Erosion was observed along the southern edge of Gannon Road. Water flows down to Gannon Road from elevated areas to the South. The erosion channel is roughly 250’ long and terminates at the intersection of Gannon Road, Hubbards Road and Hurd Hill Road.

Proposed Improvements

- Excavate edge of road and install soils with high infiltration rates.
- Install non-woven erosion control fabric.
- Install small diameter culvert under driveway access area.
- Cover fill and fabric with riprap.
- Install checkdams.

Estimated Cost: **$52,000**

**See Appendix 3 for detailed breakdown*

Estimated Pollutant Reductions

- Total Phosphorus: **1.1 lb/yr**
- Total Nitrogen: **2.3 lb/yr**
- Total Suspended Solids: **2600 lb/yr**

Photo 12-1: Roadside erosion

Photo 12-2: Roadside Erosion - Steep Slope

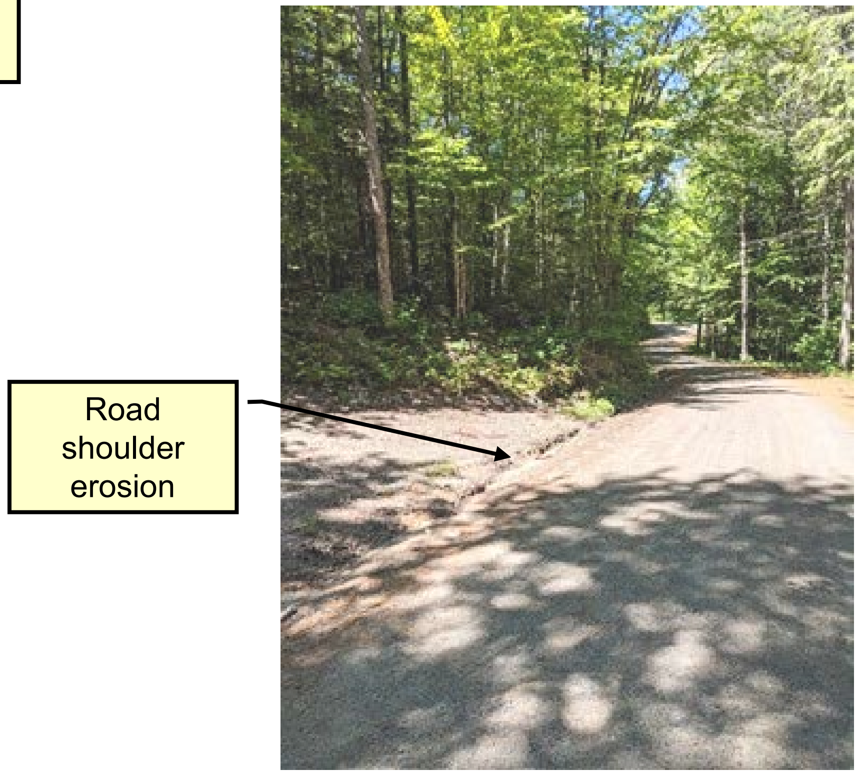


Photo 12-2: Roadside erosion, view looking east

GENERAL NOTES

No.	Revision/Issue	Date

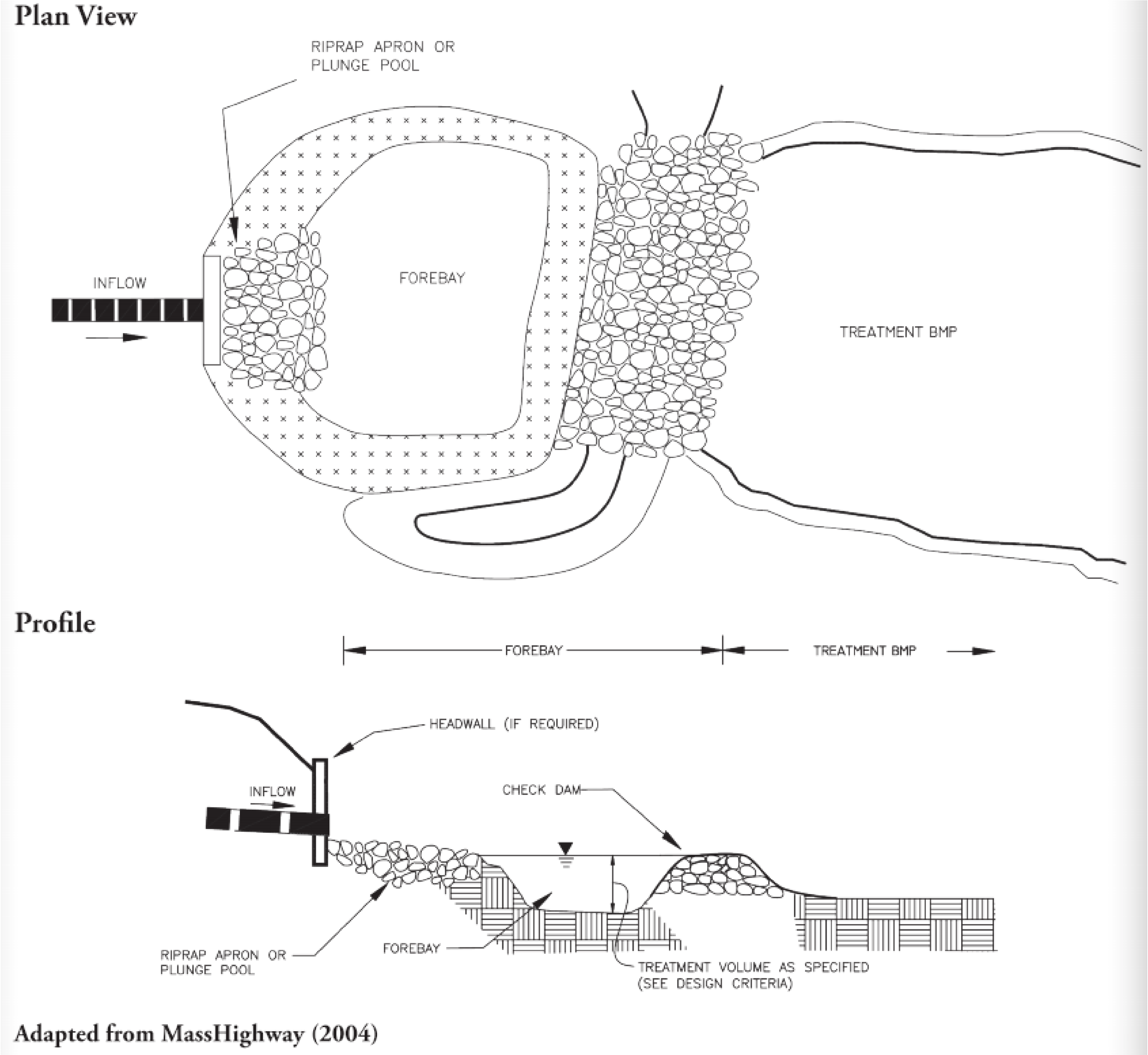
COMPREHENSIVE ENVIRONMENTAL INCORPORATED

21 Depot Street, Merrimack, NH 03054

Site 12

Project No.: 366-01		Sheet
Date: July 2021		C-23
Drawn By: NP		
Checked By: NC		
Scale: As Shown		

Source: NHDES



Typical Sediment Forebay Detail

GENERAL NOTES

BMP Detail Source is from past CEI Project unless noted otherwise.

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED

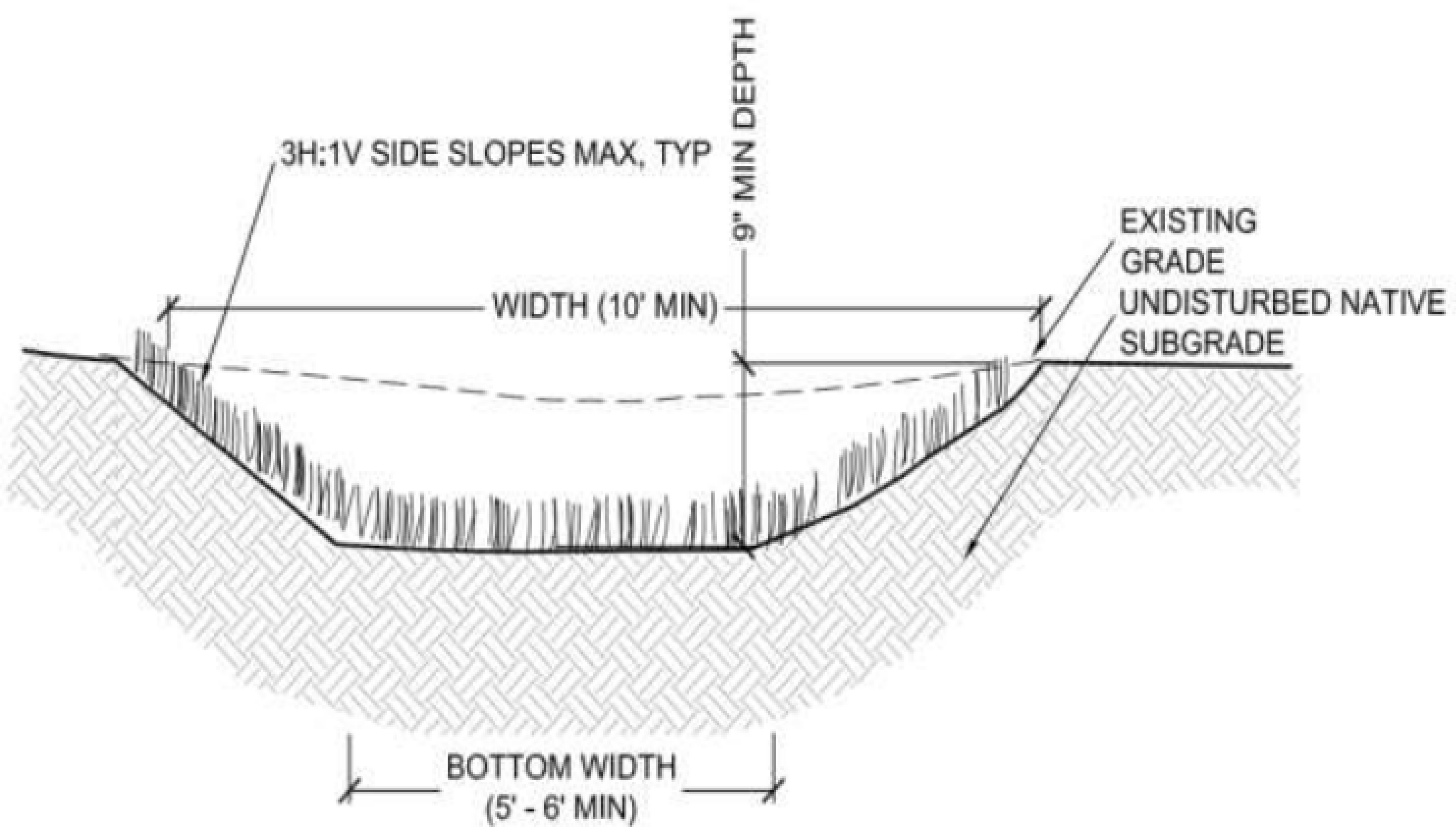
21 Depot Street, Merrimack, NH 03054

Typical Details

Project No.: 366-01
Date: July 2021
Drawn By: NP
Checked By: NC
Scale: As Shown

Sheet D-1

Source: Town of Nags Head, NC



Typical Infiltration Basin Detail

GENERAL NOTES

BMP Detail Source is from past CEI Project unless noted otherwise.

No.	Revision/Issue	Date

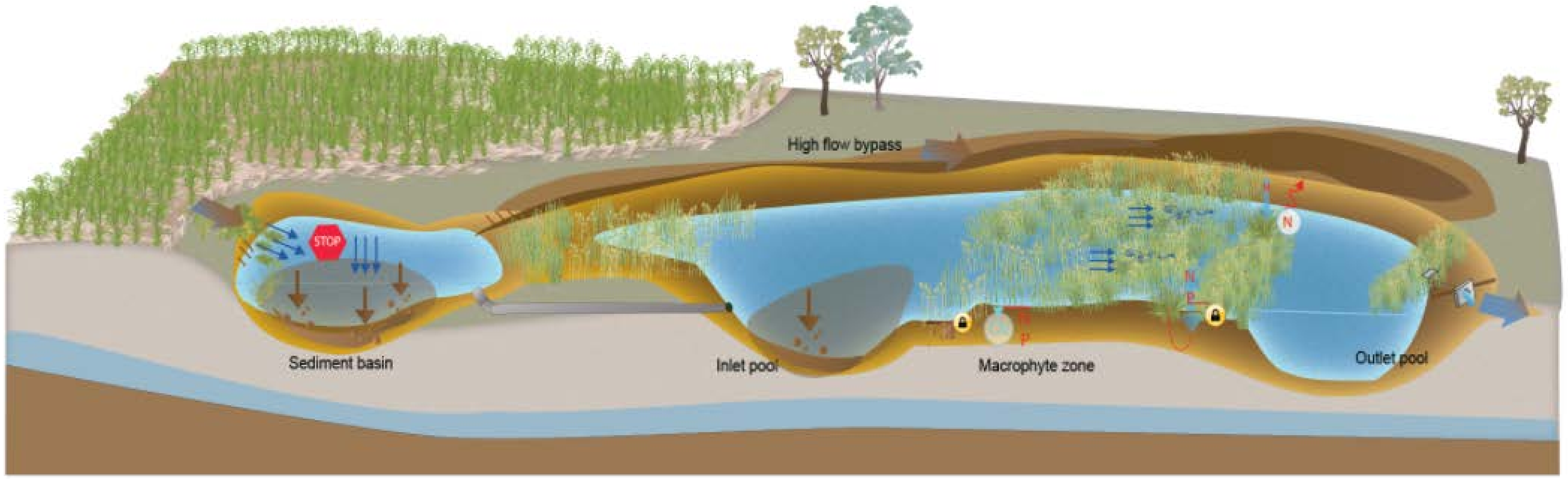
COMPREHENSIVE ENVIRONMENTAL INCORPORATED

21 Depot Street, Merrimack, NH 03054

Typical Details

Project No.:	366-01	Sheet
Date:	July 2021	D-2
Drawn By:	NP	
Checked By:	NC	
Scale:	As Shown	

Source: Town of Nags Head, NC



Water run-off, carrying sediment particles (coarse and fine) and dissolved pollutants (nutrients and pesticides)

Slowing of run-off. Holding water on site increases sediment deposition rate.

Multi stemmed vegetation, slowing run off velocity, reducing erosion and increasing infiltration

Processing of nutrients into wetland vegetation and biofilms

Wetting and drying of sediments leads to fixation of pollutants in sediments

Deposition of coarse (and some fine) sediment particles

Wetland vegetation inhibits the release of deposited nutrients by pumping oxygen into the soil.

Vegetation provides a carbon source and a surface for biofilms to undertake denitrification, removing nitrogen from the water column.

Water leaving treatment system with reduced sediment and nutrient loads

Typical Constructed Wetland Detail

GENERAL NOTES

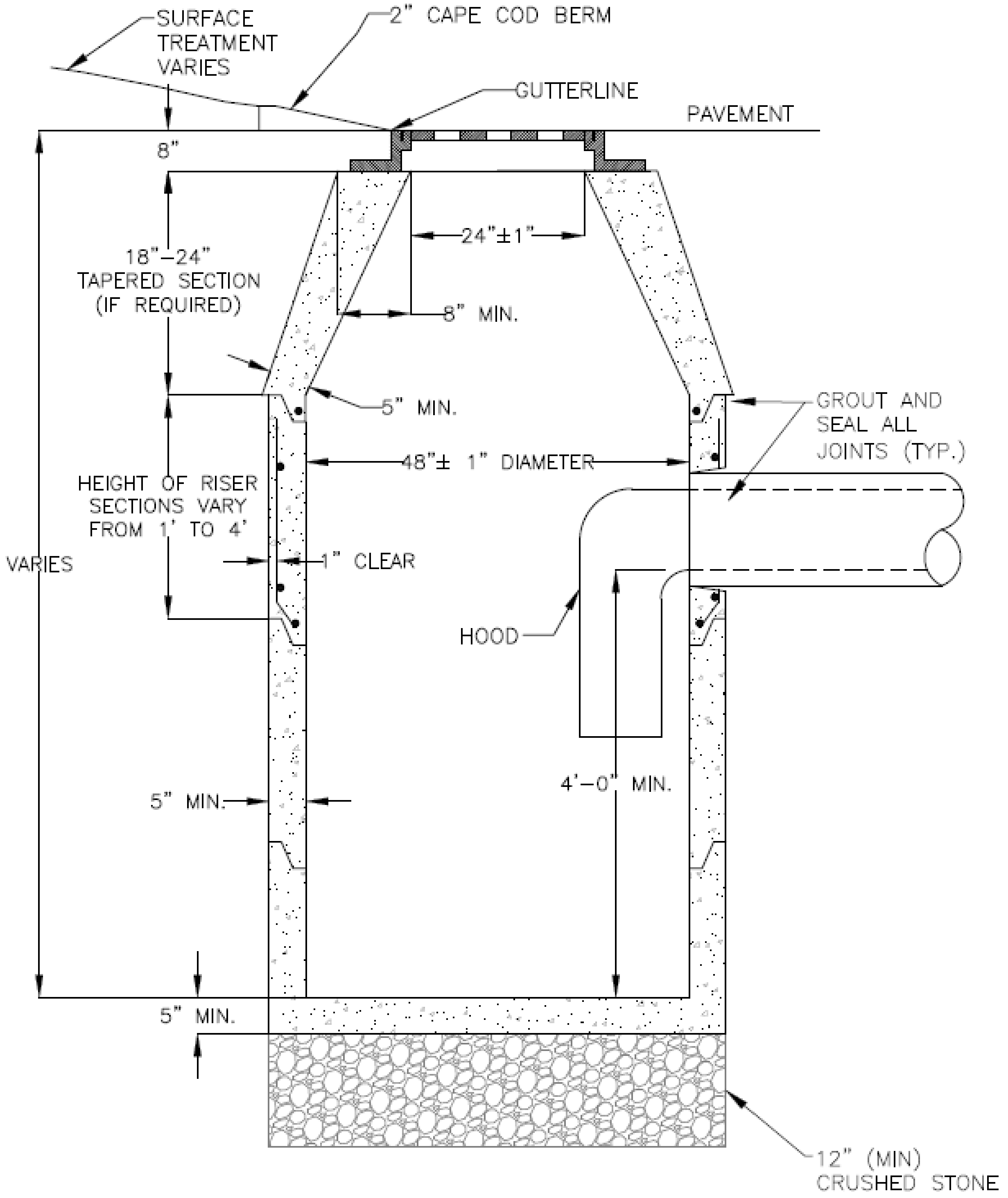
BMP Detail Source is from past CEI Project unless noted otherwise.

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED
21 Depot Street, Merrimack, NH 03054

Typical Details

Project No.: 366-01
Date: July 2021
Drawn By: NP
Checked By: NC
Scale: As Shown
Sheet: D-3



Typical Catch Basin Detail

GENERAL NOTES

BMP Detail Source is from past CEI Project.

No.	Revision/Issue	Date

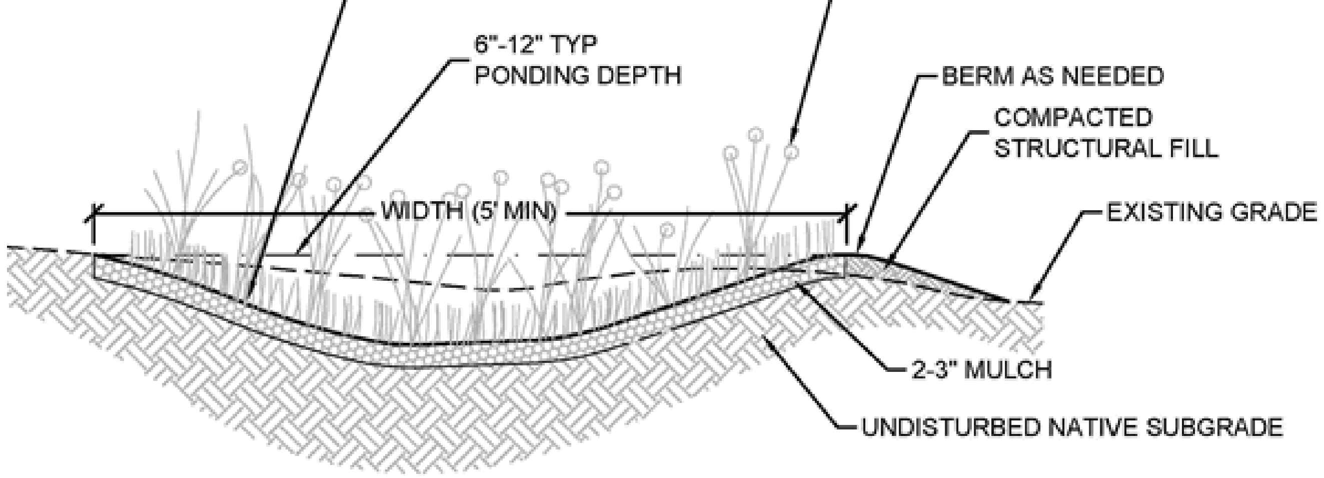
COMPREHENSIVE ENVIRONMENTAL INCORPORATED
21 Depot Street, Merrimack, NH 03054

Typical Details

Project No.: 366-01
Date: July 2021
Drawn By:
Checked By:
Scale:

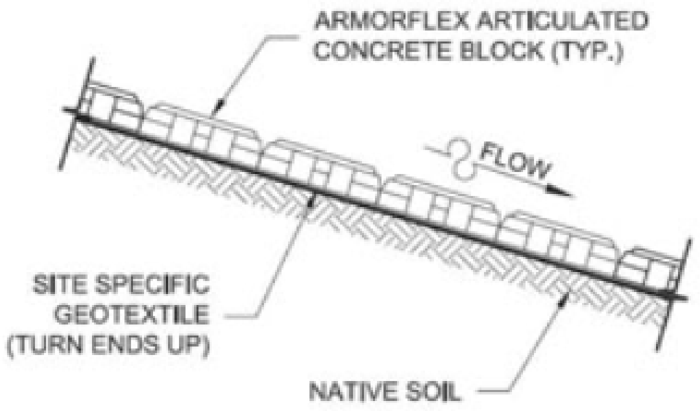
Sheet D-4

Source: Oregon State University



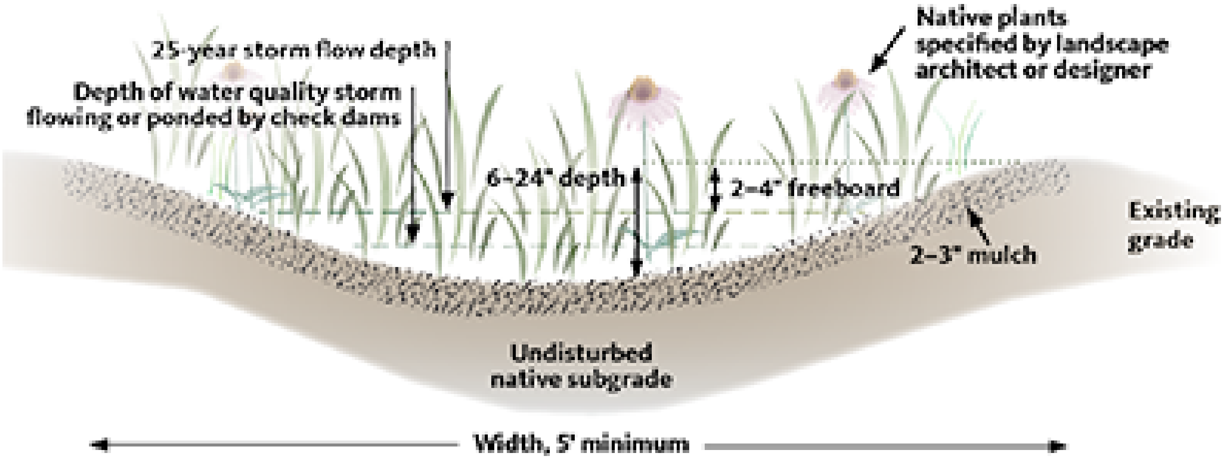
Typical Rain Garden Detail

Source: Contech Engineered Solutions



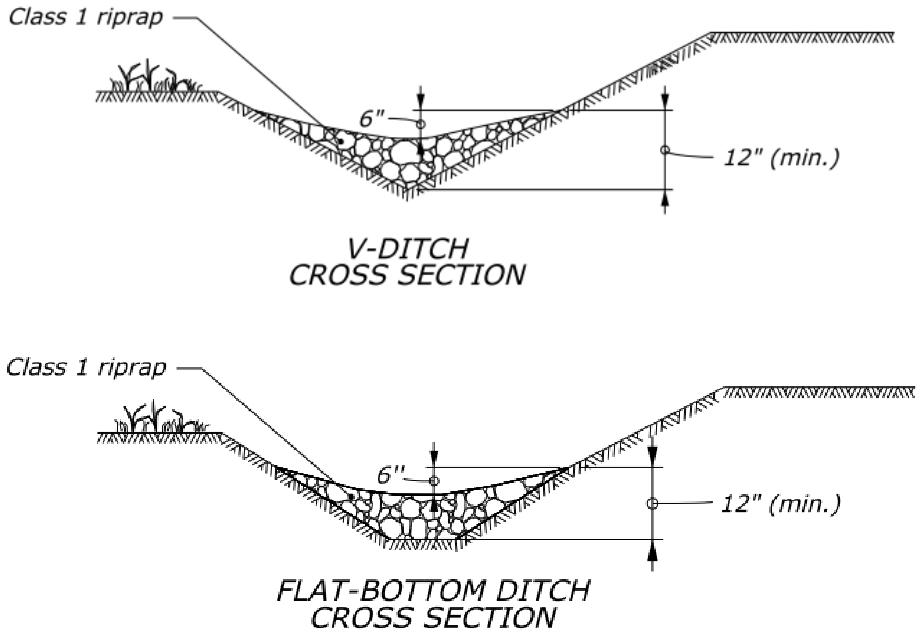
Typical Block Ramp Detail

Source: Oregon State University



Typical Water Quality Swale

Source: Federal Highway Administration



Typical Check Dam Details

GENERAL NOTES

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED

21 Depot Street, Merrimack, NH 03054

Typical Details

Project No.: 366-01	Sheet
Date: July 2021	D-5
Drawn By: NP	
Checked By: NC	
Scale: As Shown	

Appendix 2:

Pollutant Load Reduction Calculations for Conceptual Stormwater BMPs

Appendix 2 - Load Reduction Estimates (Watershed Based Planning Tool)

Notes:
1. Calculation Source: http://prj.geosyntec.com/MassDEPWBP.

Site 1: Cindys Drive Culvert

BMP TYPE (edit)
GRASSED CHANNEL/ WATER QUALITY SWALE

BMP SIZE (design storm depth; inches): 1.00
DRAINAGE AREA (acres): 0.57

BMP LOCATION
Cindys Drive

LAND USE/COVER TYPE (in drainage area)	% OF DRAINAGE AREA
HIGHWAY, Impervious	80
LOW DENSITY RESIDENTIAL, Impervious	20

+ land use/cover

ESTIMATED POLLUTANT LOAD REDUCTIONS (lbs/yr)

TN:	TP:	TSS:
	0.16446	579.98308

Site 2: Farm Pond

BMP TYPE (edit)
CONSTRUCTED WETLAND W/ SEDIMENT FOREBAY

BMP SIZE (design storm depth; inches): 1.00
DRAINAGE AREA (acres): 2.40

BMP LOCATION
Farm Pond

LAND USE/COVER TYPE (in drainage area)	% OF DRAINAGE AREA
HIGHWAY, Impervious	10
OPEN LAND, Impervious	90

+ land use/cover

ESTIMATED POLLUTANT LOAD REDUCTIONS (lbs/yr)

TN:	TP:	TSS:
18.30241	2.19434	1704.36695

Site 4: Old Partridge Lake Road Erosion

BMP TYPE (edit)
GRASSED CHANNEL/ WATER QUALITY SWALE

BMP SIZE (design storm depth; inches): 1.00
DRAINAGE AREA (acres): 0.44

BMP LOCATION
Old Partridge Lake Road

LAND USE/COVER TYPE (in drainage area)	% OF DRAINAGE AREA
HIGHWAY, Impervious	100

+ land use/cover

ESTIMATED POLLUTANT LOAD REDUCTIONS (lbs/yr)

TN:	TP:	TSS:
	0.12366	521.00494

Site 5: Old Partridge Lake Rd. & Partridge Lake Rd. Intersection

BMP TYPE (edit)
BIORETENTION AND RAIN GARDENS

BMP SIZE (design storm depth; inches)	DRAINAGE AREA (acres)
1.00	1.17

BMP LOCATION
Old Partridge Lake Road & Partridge Lake Road Intersection

LAND USE/COVER TYPE (in drainage area)	% OF DRAINAGE AREA
HIGHWAY, Impervious	60
LOW DENSITY RESIDENTIAL, Pervious	40

+ land use/cover

ESTIMATED POLLUTANT LOAD REDUCTIONS (lbs/yr)

TN:	TP:	TSS:
5.72518	0.74243	1042.30018

Site 8: Driveway Erosion & Retaining Wall Failure

BMP TYPE (edit)
INFILTRATION BASIN W/ SEDIMENT FOREBAY

BMP SIZE (design storm depth; inches)	DRAINAGE AREA (acres)
1.00	0.90

BMP LOCATION
Driveway Erosion

LAND USE/COVER TYPE (in drainage area)	% OF DRAINAGE AREA
HIGHWAY, Impervious	30
LOW DENSITY RESIDENTIAL, Pervious	70

+ land use/cover

ESTIMATED POLLUTANT LOAD REDUCTIONS (lbs/yr)

TN:	TP:	TSS:
3.40729	0.40399	418.18291

Site 10: Partridge Lake Road & Hubbards Road Intersection

BMP TYPE (edit)
INFILTRATION BASIN W/ SEDIMENT FOREBAY

BMP SIZE (design storm depth; inches)	DRAINAGE AREA (acres)
1.00	0.77

BMP LOCATION
Partridge Lake Road & Hubbards Road Intersection

LAND USE/COVER TYPE (in drainage area)	% OF DRAINAGE AREA
HIGHWAY, Impervious	30
LOW DENSITY RESIDENTIAL, Pervious	70

+ land use/cover

ESTIMATED POLLUTANT LOAD REDUCTIONS (lbs/yr)

TN:	TP:	TSS:
2.91513	0.34564	357.77871

Notes:
1. Calculation Source: http://it.tetratech-ffx.com/steplweb/models$docs.htm.

Site 3 - Old Partridge Lake Road Culvert

Gully Stabilization

These may include:

- Grade Stabilization Structure
- Grassed Waterway
- Critical Area Planting in areas with gullies
- Water and Sediment Control Basins

Please select a soil textural class:

- ○ Sands, loamy sands
- ○ Sandy loam
- ● Fine sandy loam
- ○ Loams, sandy clay loams, sandy clay
- ○ Silt loam
- ○ Silty clay loam, silty clay
- ○ Clay loam
- ○ Clay
- ○ Organic

73D - Berkshire fine sandy loam

Please fill in the gray areas below:

Parameter	**Gully**	**Example**
Top Width (ft)	2	**15**
Bottom Width (ft)	1	**4**
Depth (ft)	1	**5**
Length (ft)	20	**20**
Number of Years	3	**5**
Soil Weight (tons/ft^3)	0.0425	**0.05**
Soil P Conc (lb/lb soil)* DEFAULT	0.0005	**0.0005** *
Soil N Conc (lb/lb soil)* DEFAULT	0.001	**0.001** *

* If not using the default values, users must provide input (in red) for Total P and Total N soil concentrations

Estimated Load Reductions

	BMP Efficiency*	**Gully**	**Example**
Sediment Load Reduction (ton/year)	0.75	0.3	**7**
Phosphorus Load Reduction (lb/year)		0.3	**6**
Nitrogen Load Reduction (lb/yr)		0.5	**12**

* BMP efficiency values should be between 0 and 1, and 1 means 100% pollutant removal efficiency.

Notes:
1. Calculation Source: http://it.tetratech-ffx.com/steplweb/models$docs.htm.

Site 6 - North Shore Culverts: Culvert 1

Gully Stabilization

These may include:

Grade Stabilization Structure
Grassed Waterway
Critical Area Planting in areas with gullies
Water and Sediment Control Basins

Please select a soil textural class:

- ○ Sands, loamy sands
- ○ Sandy loam
- ● Fine sandy loam
- ○ Loams, sandy clay loams, sandy clay
- ○ Silt loam
- ○ Silty clay loam, silty clay
- ○ Clay loam
- ○ Clay
- ○ Organic

73C - Berkshire fine sandy loam

Please fill in the gray areas below:

Parameter		Gully	Example	
Top Width (ft)		1	**15**	
Bottom Width (ft)		0.5	**4**	
Depth (ft)		1	**5**	
Length (ft)		200	**20**	
Number of Years		3	**5**	
Soil Weight (tons/ft^3)		0.0425	**0.05**	
Soil P Conc (lb/lb soil)*	DEFAULT	0.0005	**0.0005**	*
Soil N Conc (lb/lb soil)*	DEFAULT	0.001	**0.001**	*

* If not using the default values, users must provide input (in red) for Total P and Total N soil concentrations

Estimated Load Reductions

	BMP Efficiency*	Gully	Example
Sediment Load Reduction (ton/year)	0.50	1.1	**5**
Phosphorus Load Reduction (lb/year)		0.9	**4**
Nitrogen Load Reduction (lb/yr)		1.8	**8**

* BMP efficiency values should be between 0 and 1, and 1 means 100% pollutant removal efficiency.

Appendix 2 - Load Reduction Estimates (EPA Region 5 Calculation Sheet)

Notes:
1. Calculation Source: http://it.tetratech-ffx.com/steplweb/models$docs.htm.

Site 6 - North Shore Culverts: Culvert 2

Gully Stabilization

These may include:
- Grade Stabilization Structure
- Grassed Waterway
- Critical Area Planting in areas with gullies
- Water and Sediment Control Basins

Please select a soil textural class:

- ○ Sands, loamy sands
- ○ Sandy loam
- ● Fine sandy loam
- ○ Loams, sandy clay loams, sandy clay
- ○ Silt loam
- ○ Silty clay loam, silty clay
- ○ Clay loam
- ○ Clay
- ○ Organic

73C - Berkshire fine sandy loam

Please fill in the gray areas below:

Parameter		Gully	Example	
Top Width (ft)		1	**15**	
Bottom Width (ft)		0.5	**4**	
Depth (ft)		1	**5**	
Length (ft)		10	**20**	
Number of Years		3	**5**	
Soil Weight (tons/ft^3)		0.0425	**0.05**	
Soil P Conc (lb/lb soil)*	DEFAULT	0.0005	**0.0005**	*
Soil N Conc (lb/lb soil)*	DEFAULT	0.001	**0.001**	*

* If not using the default values, users must provide input (in red) for Total P and Total N soil concentrations

Estimated Load Reductions

	BMP Efficiency*	Gully	Example
Sediment Load Reduction (ton/year)	0.50	0.1	**5**
Phosphorus Load Reduction (lb/year)		0.05	**4**
Nitrogen Load Reduction (lb/yr)		0.1	**8**

* BMP efficiency values should be between 0 and 1, and 1 means 100% pollutant removal efficiency.

Notes:
1. Calculation Source: http://it.tetratech-ffx.com/steplweb/models$docs.htm.

Site 6 - North Shore Culverts: Culvert 3

Gully Stabilization

These may include:

- Grade Stabilization Structure
- Grassed Waterway
- Critical Area Planting in areas with gullies
- Water and Sediment Control Basins

Please select a soil textural class:

- ○ Sands, loamy sands
- ○ Sandy loam
- ● Fine sandy loam
- ○ Loams, sandy clay loams, sandy clay
- ○ Silt loam
- ○ Silty clay loam, silty clay
- ○ Clay loam
- ○ Clay
- ○ Organic

73C - Berkshire fine sandy loam

Please fill in the gray areas below:

Parameter		Gully	Example	
Top Width (ft)		1	**15**	
Bottom Width (ft)		0.5	**4**	
Depth (ft)		1	**5**	
Length (ft)		10	**20**	
Number of Years		3	**5**	
Soil Weight (tons/ft^3)		0.0425	**0.05**	
Soil P Conc (lb/lb soil)*	DEFAULT	0.0005	**0.0005**	*
Soil N Conc (lb/lb soil)*	DEFAULT	0.001	**0.001**	*

* If not using the default values, users must provide input (in red) for Total P and Total N soil concentrations

Estimated Load Reductions

	BMP Efficiency*	Gully	Example
Sediment Load Reduction (ton/year)	0.50	0.1	**5**
Phosphorus Load Reduction (lb/year)		0.05	**4**
Nitrogen Load Reduction (lb/yr)		0.1	**8**

* BMP efficiency values should be between 0 and 1, and 1 means 100% pollutant removal efficiency.

Notes:
1. Calculation Source: http://it.tetratech-ffx.com/steplweb/models$docs.htm.

Site 6 - North Shore Culverts: Culvert 4

Gully Stabilization

These may include:

- *Grade Stabilization Structure*
- Grassed Waterway
- Critical Area Planting in areas with gullies
- Water and Sediment Control Basins

Please select a soil textural class:

- ○ Sands, loamy sands
- ○ Sandy loam
- ◉ Fine sandy loam
- ○ Loams, sandy clay loams, sandy clay
- ○ Silt loam
- ○ Silty clay loam, silty clay
- ○ Clay loam
- ○ Clay
- ○ Organic

73D- Berkshire fine sandy loam

Please fill in the gray areas below:

Parameter		**Gully**	**Example**	
Top Width (ft)		1	**15**	
Bottom Width (ft)		0.5	**4**	
Depth (ft)		1	**5**	
Length (ft)		60	**60**	
Number of Years		3	**5**	
Soil Weight (tons/ft^3)		0.0425	**0.05**	
Soil P Conc (lb/lb soil)*	DEFAULT	0.0005	**0.0005**	*
Soil N Conc (lb/lb soil)*	DEFAULT	0.001	**0.001**	*

* If not using the default values, users must provide input (in red) for Total P and Total N soil concentrations

Estimated Load Reductions

	BMP Efficiency*	**Gully**	**Example**
Sediment Load Reduction (ton/year)	0.50	0.3	**14**
Phosphorus Load Reduction (lb/year)		0.27	**12**
Nitrogen Load Reduction (lb/yr)		0.5	**24**

* BMP efficiency values should be between 0 and 1, and 1 means 100% pollutant removal efficiency.

Notes:
1. Calculation Source: http://it.tetratech-ffx.com/steplweb/models$docs.htm.

Site 6 - North Shore Culverts: Culvert 5

Gully Stabilization

These may include:

- Grade Stabilization Structure
- Grassed Waterway
- Critical Area Planting in areas with gullies
- Water and Sediment Control Basins

Please select a soil textural class:

- ○ Sands, loamy sands
- ○ Sandy loam
- ◉ Fine sandy loam
- ○ Loams, sandy clay loams, sandy clay
- ○ Silt loam
- ○ Silty clay loam, silty clay
- ○ Clay loam
- ○ Clay
- ○ Organic

73D - Berkshire fine sandy loam

Please fill in the gray areas below:

Parameter		Gully	Example	
Top Width (ft)		1	**15**	
Bottom Width (ft)		0.5	**4**	
Depth (ft)		1	**5**	
Length (ft)		50	**60**	
Number of Years		3	**5**	
Soil Weight (tons/ft^3)		0.0425	**0.05**	
Soil P Conc (lb/lb soil)*	DEFAULT	0.0005	**0.0005**	*
Soil N Conc (lb/lb soil)*	DEFAULT	0.001	**0.001**	*

* If not using the default values, users must provide input (in red) for Total P and Total N soil concentrations

Estimated Load Reductions

	BMP Efficiency*	Gully	Example
Sediment Load Reduction (ton/year)	0.50	0.3	**14**
Phosphorus Load Reduction (lb/year)		0.23	**12**
Nitrogen Load Reduction (lb/yr)		0.5	**24**

* BMP efficiency values should be between 0 and 1, and 1 means 100% pollutant removal efficiency.

Appendix 2 - Load Reduction Estimates (EPA Region 5 Calculation Sheet)

Notes:
1. Calculation Source: http://it.tetratech-ffx.com/steplweb/models$docs.htm.

Site 6 - North Shore Culverts: Culvert 6

Gully Stabilization

These may include:
- Grade Stabilization Structure
- Grassed Waterway
- Critical Area Planting in areas with gullies
- Water and Sediment Control Basins

Please select a soil textural class:

- ○ Sands, loamy sands
- ○ Sandy loam
- ◉ Fine sandy loam
- ○ Loams, sandy clay loams, sandy clay
- ○ Silt loam
- ○ Silty clay loam, silty clay
- ○ Clay loam
- ○ Clay
- ○ Organic

73D - Berkshire fine sandy loam

Please fill in the gray areas below:

Parameter		Gully	Example	
Top Width (ft)		1	**15**	
Bottom Width (ft)		0.5	**4**	
Depth (ft)		1	**5**	
Length (ft)		80	**20**	
Number of Years		3	**5**	
Soil Weight (tons/ft^3)		0.0425	**0.05**	
Soil P Conc (lb/lb soil)*	DEFAULT	0.0005	**0.0005**	*
Soil N Conc (lb/lb soil)*	DEFAULT	0.001	**0.001**	*

* If not using the default values, users must provide input (in red) for Total P and Total N soil concentrations

Estimated Load Reductions

	BMP Efficiency*	Gully	Example
Sediment Load Reduction (ton/year)	0.50	0.4	**5**
Phosphorus Load Reduction (lb/year)		0.4	**4**
Nitrogen Load Reduction (lb/yr)		0.7	**8**

* BMP efficiency values should be between 0 and 1, and 1 means 100% pollutant removal efficiency.

Notes:
1. Calculation Source: http://it.tetratech-ffx.com/steplweb/models$docs.htm.

Site 6 - North Shore Culverts: Culvert 7

Gully Stabilization

These may include:

- ~~*Grade Stabilization Structure*~~
- Grassed Waterway
- Critical Area Planting in areas with gullies
- Water and Sediment Control Basins

Please select a soil textural class:

- ○ Sands, loamy sands
- ○ Sandy loam
- ◉ Fine sandy loam
- ○ Loams, sandy clay loams, sandy clay
- ○ Silt loam
- ○ Silty clay loam, silty clay
- ○ Clay loam
- ○ Clay
- ○ Organic

73D - Berkshire fine sandy loam

Please fill in the gray areas below:

Parameter		Gully	Example	
Top Width (ft)		1	**15**	
Bottom Width (ft)		0.5	**4**	
Depth (ft)		1	**5**	
Length (ft)		10	**20**	
Number of Years		3	**5**	
Soil Weight (tons/ft^3)		0.0425	**0.05**	
Soil P Conc (lb/lb soil)*	DEFAULT	0.0005	**0.0005**	*
Soil N Conc (lb/lb soil)*	DEFAULT	0.001	**0.001**	*

* If not using the default values, users must provide input (in red) for Total P and Total N soil concentrations

Estimated Load Reductions

	BMP Efficiency*	Gully	Example
Sediment Load Reduction (ton/year)	0.50	0.1	**5**
Phosphorus Load Reduction (lb/year)		0.05	**4**
Nitrogen Load Reduction (lb/yr)		0.1	**8**

* BMP efficiency values should be between 0 and 1, and 1 means 100% pollutant removal efficiency.

Notes:
1. Calculation Source: http://it.tetratech-ffx.com/steplweb/models$docs.htm.

Site 6 - North Shore Culverts: Culvert 8

Gully Stabilization

These may include:

- Grade Stabilization Structure
- Grassed Waterway
- Critical Area Planting in areas with gullies
- Water and Sediment Control Basins

Please select a soil textural class:

- ( ) Sands, loamy sands
- ( ) Sandy loam
- (•) Fine sandy loam
- ( ) Loams, sandy clay loams, sandy clay
- ( ) Silt loam
- ( ) Silty clay loam, silty clay
- ( ) Clay loam
- ( ) Clay
- ( ) Organic

73D - Berkshire fine sandy loam

Please fill in the gray areas below:

Parameter		Gully	Example	
Top Width (ft)		1	**15**	
Bottom Width (ft)		0.5	**4**	
Depth (ft)		1	**5**	
Length (ft)		10	**20**	
Number of Years		3	**5**	
Soil Weight (tons/ft^3)		0.0425	**0.05**	
Soil P Conc (lb/lb soil)*	DEFAULT	0.0005	**0.0005**	*
Soil N Conc (lb/lb soil)*	DEFAULT	0.001	**0.001**	*

* If not using the default values, users must provide input (in red) for Total P and Total N soil concentrations

Estimated Load Reductions

	BMP Efficiency*	Gully	Example
Sediment Load Reduction (ton/year)	0.50	0.1	**5**
Phosphorus Load Reduction (lb/year)		0.05	**4**
Nitrogen Load Reduction (lb/yr)		0.1	**8**

* BMP efficiency values should be between 0 and 1, and 1 means 100% pollutant removal efficiency.

Appendix 2 - Load Reduction Estimates (EPA Region 5 Calculation Sheet)

Notes:
1. Calculation Source: http://it.tetratech-ffx.com/steplweb/models$docs.htm.

Site 6 - North Shore Culverts: Culvert 9

Gully Stabilization

These may include:

Grade Stabilization Structure
Grassed Waterway
Critical Area Planting in areas with gullies
Water and Sediment Control Basins

Please select a soil textural class:

- ○ Sands, loamy sands
- ○ Sandy loam
- ● Fine sandy loam
- ○ Loams, sandy clay loams, sandy clay
- ○ Silt loam
- ○ Silty clay loam, silty clay
- ○ Clay loam
- ○ Clay
- ○ Organic

73D - Berkshire fine sandy loam

Please fill in the gray areas below:

Parameter		Gully	Example	
Top Width (ft)		1	**15**	
Bottom Width (ft)		0.5	**4**	
Depth (ft)		1	**5**	
Length (ft)		10	**20**	
Number of Years		3	**5**	
Soil Weight (tons/ft^3)		0.0425	**0.05**	
Soil P Conc (lb/lb soil)*	DEFAULT	0.0005	**0.0005**	*
Soil N Conc (lb/lb soil)*	DEFAULT	0.001	**0.001**	*

* If not using the default values, users must provide input (in red) for Total P and Total N soil concentrations

Estimated Load Reductions

	BMP Efficiency*	Gully	Example
Sediment Load Reduction (ton/year)	0.50	0.1	**5**
Phosphorus Load Reduction (lb/year)		0.05	**4**
Nitrogen Load Reduction (lb/yr)		0.1	**8**

* BMP efficiency values should be between 0 and 1, and 1 means 100% pollutant removal efficiency.

Appendix 2 - Load Reduction Estimates (EPA Region 5 Calculation Sheet)

Notes:
1. Calculation Source: http://it.tetratech-ffx.com/steplweb/models$docs.htm.

Site 9 - South Shore Road

Bank Stabilization

If estimating for just one bank, put "0" in areas for Bank #2.

Please select a soil textural class:

- ○ Sands, loamy sands
- ◉ Sandy loam
- ○ Fine sandy loam
- ○ Loams, sandy clay loams, sandy clay
- ○ Silt loam
- ○ Silty clay loam, silty clay
- ○ Clay loam
- ○ Clay
- ○ Organic

22E - Colton Gravelly Sandy Loam

Please fill in the gray areas below:

Parameter		Bank #1	Bank #2	Example	
Length (ft)		300	0	**500**	*Bank is 800 ft long by 4 foot elevation drop
Height (ft)		4	0	**15**	** Roughly 300 ft will contribute to loading
Lateral Recession Rate (ft/yr)*		0.1	0	**0.5**	
Soil Weight (tons/ft^3)		0.0425	0.0425	**0.04**	
Soil P Conc (lb/lb soil)**	DEFAULT	0.0005	0.0005	**0.0005**	**
Soil N Conc (lb/lb soil)**	DEFAULT	0.001	0.001	**0.001**	**

** If not using the default values, users must provide input (in red) for Total P and Total N soil concentrations
*Lateral Recession Rate (LRR) is the rate at which bank deterioration has taken place and is measured in feet per year. This rate may not be easily determined by direct measurement. Therefore best professional judgement may be required to estimate the LRR. Please refer to the narrative descriptions in Table 1.

Estimated Load Reductions

	BMP Efficiency* Bank #1	BMP Efficiency* Bank #2	Bank #1	Bank #2	Example
Sediment Load Reduction (ton/year)	0.50		2.6	0.0	**75**
Phosphorus Load Reduction (lb/year)			2.2	0.0	**75**
Nitrogen Load Reduction (lb/yr)			4.3	0.0	**150**

* BMP efficiency values should be between 0 and 1, and 1 means 100% pollutant removal efficiency.

Table 1

LRR (ft/yr)	Category	Description
0.01 - 0.05	Slight	Some bare bank but active erosion not readily apparent. Some rills but no vegetative overhang.
0.06 - 0.2	Moderate	Bank is predominantly bare with some rills and vegetative overhang.
0.3 - 0.5	Severe	Bank is bare with rills and severe vegetative overhang. Many exposed tree roots and some fallen trees and slumps or slips. Some changes in cultural features such as fence corners missing and realignment of roads or trails. Channel cross-section becomes more U-shaped as opposed to V-shaped.
0.5+	Very Severe	Bank is bare with gullies and severe vegetative overhang. Many fallen trees, drains and culverts eroding out and changes in cultural features as above. Massive slips or washouts common. Channel cross-section is U-shaped and streamcourse or gully may be meandering.
Source:	Steffen, L.J. 1982. Channel Erosion (personal communication), as printed in "Pollutants Controlled Calculation and Documentation for Section 319 Watersheds Training Manual," June 1999 Revision; Michigan Department of Environmental Quality - Surface Water Quality Division - Nonpoint Source Unit. EQP 5841 (6/99).	

Notes:
1. Calculation Source: http://it.tetratech-ffx.com/steplweb/models$docs.htm.

Site 11 - South Shore Culverts: Culvert 10

Gully Stabilization

These may include:

- Grade Stabilization Structure
- Grassed Waterway
- Critical Area Planting in areas with gullies
- Water and Sediment Control Basins

Please select a soil textural class:

- ○ Sands, loamy sands
- ◉ Sandy loam
- ○ Fine sandy loam
- ○ Loams, sandy clay loams, sandy clay
- ○ Silt loam
- ○ Silty clay loam, silty clay
- ○ Clay loam
- ○ Clay
- ○ Organic

22C - Colton Gravelly Sandy Loam

Please fill in the gray areas below:

Parameter		Gully	Example	
Top Width (ft)		1	**15**	
Bottom Width (ft)		0.5	**4**	
Depth (ft)		1	**5**	
Length (ft)		10	**20**	
Number of Years		3	**5**	
Soil Weight (tons/ft^3)		0.0425	**0.05**	
Soil P Conc (lb/lb soil)*	DEFAULT	0.0005	**0.0005**	*
Soil N Conc (lb/lb soil)*	DEFAULT	0.001	**0.001**	*

* If not using the default values, users must provide input (in red) for Total P and Total N soil concentrations

Estimated Load Reductions

	BMP Efficiency*	Gully	Example
Sediment Load Reduction (ton/year)	0.50	0.1	**5**
Phosphorus Load Reduction (lb/year)		0.05	**4**
Nitrogen Load Reduction (lb/yr)		0.1	**8**

* BMP efficiency values should be between 0 and 1, and 1 means 100% pollutant removal efficiency.

Notes:
1. Calculation Source: http://it.tetratech-ffx.com/steplweb/models$docs.htm.

Site 11 - South Shore Culverts: Culvert 11

Gully Stabilization

These may include:

- Grade Stabilization Structure
- Grassed Waterway
- Critical Area Planting in areas with gullies
- Water and Sediment Control Basins

Please select a soil textural class:

- ○ Sands, loamy sands
- ○ Sandy loam
- ● Fine sandy loam
- ○ Loams, sandy clay loams, sandy clay
- ○ Silt loam
- ○ Silty clay loam, silty clay
- ○ Clay loam
- ○ Clay
- ○ Organic

73D - Berkshire fine sandy loam

Please fill in the gray areas below:

Parameter		Gully	Example	
Top Width (ft)		1	**15**	
Bottom Width (ft)		0.5	**4**	
Depth (ft)		1	**5**	
Length (ft)		10	**20**	
Number of Years		3	**5**	
Soil Weight (tons/ft^3)		0.0425	**0.05**	
Soil P Conc (lb/lb soil)*	DEFAULT	0.0005	**0.0005**	*
Soil N Conc (lb/lb soil)*	DEFAULT	0.001	**0.001**	*

* If not using the default values, users must provide input (in red) for Total P and Total N soil concentrations

Estimated Load Reductions

	BMP Efficiency*	Gully	Example
Sediment Load Reduction (ton/year)	0.50	0.1	**5**
Phosphorus Load Reduction (lb/year)		0.05	**4**
Nitrogen Load Reduction (lb/yr)		0.1	**8**

* BMP efficiency values should be between 0 and 1, and 1 means 100% pollutant removal efficiency.

Appendix 2 - Load Reduction Estimates (EPA Region 5 Calculation Sheet)

Notes:
1. Calculation Source: http://it.tetratech-ffx.com/steplweb/models$docs.htm.

Site 11 - South Shore Culverts: Culvert 12

Gully Stabilization

These may include:

- Grade Stabilization Structure
- Grassed Waterway
- Critical Area Planting in areas with gullies
- Water and Sediment Control Basins

Please select a soil textural class:

- ○ Sands, loamy sands
- ◉ Sandy loam
- ○ Fine sandy loam
- ○ Loams, sandy clay loams, sandy clay
- ○ Silt loam
- ○ Silty clay loam, silty clay
- ○ Clay loam
- ○ Clay
- ○ Organic

731 - Peacham and Ossipee soils very stony

Please fill in the gray areas below:

Parameter		Gully	Example	
Top Width (ft)		1	**15**	
Bottom Width (ft)		0.5	**4**	
Depth (ft)		1	**5**	
Length (ft)		10	**20**	
Number of Years		3	**5**	
Soil Weight (tons/ft^3)		0.0425	**0.05**	
Soil P Conc (lb/lb soil)*	DEFAULT	0.0005	**0.0005**	*
Soil N Conc (lb/lb soil)*	DEFAULT	0.001	**0.001**	*

* If not using the default values, users must provide input (in red) for Total P and Total N soil concentrations

Estimated Load Reductions

	BMP Efficiency*	Gully	Example
Sediment Load Reduction (ton/year)	0.50	0.1	**5**
Phosphorus Load Reduction (lb/year)		0.05	**4**
Nitrogen Load Reduction (lb/yr)		0.1	**8**

* BMP efficiency values should be between 0 and 1, and 1 means 100% pollutant removal efficiency.

Appendix 2 - Load Reduction Estimates (EPA Region 5 Calculation Sheet)

Notes:
1. Calculation Source: http://it.tetratech-ffx.com/steplweb/models$docs.htm.

Site 12 - Gannon Road Erosion

Gully Stabilization

These may include:
- Grade Stabilization Structure
- Grassed Waterway
- Critical Area Planting in areas with gullies
- Water and Sediment Control Basins

Please select a soil textural class:

- ○ Sands, loamy sands
- ○ Sandy loam
- ◉ Fine sandy loam
- ○ Loams, sandy clay loams, sandy clay
- ○ Silt loam
- ○ Silty clay loam, silty clay
- ○ Clay loam
- ○ Clay
- ○ Organic

73C - Berkshire fine sandy loam

Please fill in the gray areas below:

Parameter		Gully	Example	
Top Width (ft)		1.5	**15**	
Bottom Width (ft)		0.5	**4**	
Depth (ft)		0.5	**5**	
Length (ft)		250	**20**	
Number of Years		3	**5**	
Soil Weight (tons/ft^3)		0.0425	**0.05**	
Soil P Conc (lb/lb soil)*	DEFAULT	0.0005	**0.0005**	*
Soil N Conc (lb/lb soil)*	DEFAULT	0.001	**0.001**	*

* If not using the default values, users must provide input (in red) for Total P and Total N soil concentrations

Estimated Load Reductions

	BMP Efficiency*	Gully	Example
Sediment Load Reduction (ton/year)	0.75	1.3	**7**
Phosphorus Load Reduction (lb/year)		1.1	**6**
Nitrogen Load Reduction (lb/yr)		2.3	**12**

* BMP efficiency values should be between 0 and 1, and 1 means 100% pollutant removal efficiency.

Appendix 3:

Cost Estimate Calculations for Conceptual Stormwater BMPs

Appendix 3 - Cost Estimate Calculations for Conceptual Stormwater BMPs

Notes:

1. Costs are planning level based on preliminary conceptual designs and are intended for budgeting purposes.
2. Cost estimates rounded to nearest thousand.
3. Engineering estimate is for design, permitting, and survey - does not include bidding or construction oversight.

Site 1: Cindys Drive Culvert					
ITEM #	**DESCRIPTION**	**QUANTITY**	**UNIT**	**UNIT COST**	**TOTAL COST**
1	Water Quality Swale (3)	1,375	SF	$ 6	$ 7,700
2	Riprap Side Slopes	200	SF	$ 18	$ 3,640
3	Mob/Demob	1	LS	$ 2,000	$ 2,000
				Construction Estimate:	**$ 14,000**
				Engineering Estimate (20%):	**$ 3,000**
				Contingency (20%):	**$ 3,000**
				Total Estimate:	**$ 20,000**

Site 2: Farm Pond					
ITEM #	**DESCRIPTION**	**QUANTITY**	**UNIT**	**UNIT COST**	**TOTAL COST**
1	Constructed Stormwater Wetland	12,000	CF	$ 7	$ 84,000
2	Outlet Control Structure	1	EA	$ 5,000	$ 5,000
3	Small Diameter Culvert with FES	1	LS	$ 15,000	$ 15,000
4	Riprap	100	SF	$ 18	$ 1,800
5	Mob/Demob	1	LS	$ 18,000	$ 11,000
				Construction Estimate:	**$ 117,000**
				Engineering Estimate 20%):	**$ 24,000**
				Contingency (20%):	**$ 24,000**
				Total Estimate:	**$ 165,000**

Site 3: Old Partridge Lake Road Culvert					
ITEM #	**DESCRIPTION**	**QUANTITY**	**UNIT**	**UNIT COST**	**TOTAL COST**
1	Culvert Inspection	0.5	HR	$ 100	$ 50
2	Roadside Ditch Retrofit	150	SF	$ 20	$ 3,000
3	Riprap	200	SF	$ 18	$ 3,600
4	Mob/Demob	1	LS	$ 1,000	$ 1,000
				Construction Estimate:	**$ 8,000**
				Engineering Estimate (20%):	**$ 2,000**
				Contingency (20%):	**$ 2,000**
				Total Estimate:	**$ 12,000**

Site 4: Old Partridge Lake Road Erosion					
ITEM #	DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	Water Quality Swale with Check Dams	1,800	SF	$ 6	$ 10,800
2	Erosion Repair	200	SF	$ 3	$ 600
3	Driveway Paving	300	SF	$ 10	$ 3,000
4	Shallow Catch Basin and Culvert	1	LS	$ 12,000	$ 12,000
5	Mob/Demob	1	LS	$ 3,000	$ 3,000
				Construction Estimate:	**$ 30,000**
				Engineering Estimate (20%):	**$ 6,000**
				Contingency (20%):	**$ 6,000**
				Total Estimate:	**$ 42,000**

Site 5: Old Partridge Lake Rd. & Partridge Lake Rd. Intersection					
ITEM #	DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	Rain Garden	450	CF	$ 25	$ 11,250
2	Asphalt Berm	100	LF	$ 8	$ 800
3	Expand Vegetated Buffer	150	SF	$ 7	$ 1,050
4	Mob/Demob	1	LS	$ 2,000	$ 2,000
				Construction Estimate:	**$ 16,000**
				Engineering Estimate (20%):	**$ 4,000**
				Contingency (20%):	**$ 4,000**
				Total Estimate:	**$ 24,000**

Site 6: North Shore Culverts					
ITEM #	DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	Culvert Inspection	0.5	HR	$ 100	$ 50
2	Clear Culvert of Sediment/Debris	1	HR	$ 40.00	$ 40
3	Retrofit Ditch Areas	30	SF	$ 20	$ 600
4	Riprap	25	SF	$ 18	$ 450
5	Mob/Demob	1	LS	$ 1,000	$ 1,000
				Construction Estimate:	**$ 3,000**
				Engineering Estimate (20%):	**$ 1,000**
				Contingency (20%):	**$ 1,000**
				Total Estimate:	**$ 5,000**

*** Total estimated cost is per culvert location**

Site 7: Boat Ramp					
ITEM #	**DESCRIPTION**	**QUANTITY**	**UNIT**	**UNIT COST**	**TOTAL COST**
1	Install Articulated Concrete Block Boat Ramp	800	SF	$ 20	$ 16,000
2	Install Water Bar and Riprap Apron	3	EA	$ 2,500	$ 7,500
3	Mob/Demob, E&S Controls (5%)	1	LS	$ 3,000	$ 3,000
				Construction Estimate:	**$ 27,000**
				Engineering Estimate (20%):	**$ 6,000**
				Contingency (20%):	**$ 6,000**
				Total Estimate:	**$ 39,000**

Site 8: Driveway Erosion & Retaining Wall Failure					
ITEM #	**DESCRIPTION**	**QUANTITY**	**UNIT**	**UNIT COST**	**TOTAL COST**
1	Infiltration Basin	4,000	CF	$ 6	$ 24,000
2	Sediment Forebay	1,000	CF	$ 3	$ 3,000
3	Water Quality Swale	300	SF	$ 6	$ 1,800
4	Outlet Control Structure	1	EA	$ 5,000	$ 5,000
5	Catch Basin and Drainage Piping	1	LS	$ 13,750	$ 13,750
6	Erosion and Retaining Wall Repair	200	SF	$ 10	$ 2,000
7	Mob/Demob	1	LS	$ 5,000	$ 5,000
				Construction Estimate:	**$ 55,000**
				Engineering Estimate (20%):	**$ 11,000**
				Contingency (20%):	**$ 11,000**
				Total Estimate:	**$ 77,000**

Site 9: South Shore Road					
ITEM #	**DESCRIPTION**	**QUANTITY**	**UNIT**	**UNIT COST**	**TOTAL COST**
1	Bank Stabilization (Fill, Riprap, Fabric, Plantings)	1,200	SF	$ 60	$ 72,000
2	Expand Vegetated Buffer	600	SF	$ 7	$ 4,200
3	Mob/Demob	1	LS	$ 20,000	$ 20,000
				Construction Estimate:	**$ 97,000**
				Engineering Estimate (20%):	**$ 20,000**
				Contingency (20%):	**$ 20,000**
				Total Estimate:	**$ 137,000**

*** Mobilization Cost Includes the Construction of Cofferdam to Work Within the Limits of the Lake.**

Site 10: Partridge Lake Road & Hubbards Road Intersection					
ITEM #	DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	Infiltration Basin	5,400	CF	$ 2	$ 10,800
2	Sediment Forebay	1,200	CF	$ 3	$ 3,600
3	Vegetated Conveyance Swale with Check Dams	150	SF	$ 6	$ 900
4	Asphalt Berm	65	LF	$ 8	$ 520
5	Mob/Demob	1	LS	$ 2,000	$ 2,000
				Construction Estimate:	**$ 18,000**
				Engineering Estimate (20%):	**$ 4,000**
				Contingency (20%):	**$ 4,000**
				Total Estimate:	**$ 26,000**

Site 11: Southern Culverts					
ITEM #	DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	Culvert Inspection	0.5	HR	$ 100	$ 50
2	Clear Culvert of Sediment/Debris	1	HR	$ 40.00	$ 40
3	Retrofit Ditch Areas	30	SF	$ 20	$ 600
4	Riprap	25	SF	$ 18	$ 450
5	Mob/Demob	1	LS	$ 1,000	$ 1,000
				Construction Estimate:	**$ 3,000**
				Engineering Estimate (20%):	**$ 1,000**
				Contingency (20%):	**$ 1,000**
				Total Estimate:	**$ 5,000**

Site 12: Gannon Road Erosion					
ITEM #	DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	Retrofit Erosion Area	750	SF	$ 20	$ 15,000
2	Install Non-Woven Erosion Control Fabric	750	SF	$ 2	$ 1,500
3	Install Small Diameter Culvert	1	LS	$ 1,200.00	$ 1,200
4	Install Riprap and Check Dams	750	SF	$ 18	$ 13,500
5	Mob/Demob	1	LS	$ 4,000	$ 4,000
				Construction Estimate:	**$ 36,000**
				Engineering Estimate (20%):	**$ 8,000**
				Contingency (20%):	**$ 8,000**
				Total Estimate:	**$ 52,000**

Appendix 4:

Septic System Inventory in the 200-foot Buffer of the Partridge Lake Watershed
(Developed Parcels Only)

Parcel ID	Street Address	Town Name	Year House Built	DATE OF SYSTEM	Type of System	Distance of Septic System from	Approval # and other information
206-005	418 DODGE POND RD	Lyman	1984				
52-17-0	642 PARTRIDGE LAKE RD	Littleton	2020	2021	Advanced Enviro-septic leaching system	600	Approval # eCA2020061501-A
52-20-0	721 PARTRIDGE LAKE RD	Littleton	1950	2018	Envirofin	52	Approval # ECA2018102910
52-23-0	640 PARTRIDGE LAKE RD	Littleton	1982	X		560	Approval # eCA2018102910
52-25-0	595 PARTRIDGE LAKE RD	Littleton	1976	2021	Geomat 3900 leaching system	83	Approval # ECA2021071203
52-27-0	593 PARTRIDGE LAKE RD	Littleton	1999	1997	Enviro-septic	80	Approval # CA199704561
52-28-0	577 PARTRIDGE LAKE RD	Littleton	1995	1994	unknown	45	Approval # CA1994206466
52-29-0	702 PARTRIDGE LAKE RD	Littleton	2003	X		110	
53-10-0	542 PARTRIDGE LAKE RD	Littleton	1935	X			
53-11-0	540 PARTRIDGE LAKE RD	Littleton	1940	2019	Advanced Enviro-septic leaching system	105	Approcal # ECA2019091307
53-13-0	482 OLD PARTRIDGE LAKE RD	Littleton	1880	X			
53-15-0	528 OLD PARTRIDGE LAKE RD	Littleton	1920	X			
53-16-0	536 OLD PARTRIDGE LAKE RD	Littleton	2003	2000	unknown	100	Approval # CA2000031061
53-17-0	546 OLD PARTRIDGE LAKE RD	Littleton	1920	2005	unknown	80	Approval # CA2005076170
53-5-0	264 OLD PARTRIDGE LAKE RD	Littleton	1990	1983	unknown	140	
53-7-0	580 PARTRIDGE LAKE RD	Littleton	1956	2005	unknown		Approval # CA2005073221
53-9-0	480 OLD PARTRIDGE LAKE RD	Littleton	1955	1970	unknown	500	Approval # 11947
72-10-0	991 PARTRIDGE LAKE RD	Littleton	1980	2021	Advanced Enviroseptic	185	Approval # ECA2021070603
72-12-0	1047 PARTRIDGE LAKE RD	Littleton	1940	2021	Enviroseptic leaching system	42	Approval # ECA2021040108
72-13-0	40 ALLEN RD	Littleton	1989	1988	unknown	70	
72-14-0	39 ALLEN RD	Littleton	1939	1988			
72-17-0	15 ALLEN RD	Littleton	1947	1985	unknown	110	
72-19-0	1 ALLEN RD	Littleton	1964	X			
72-20-0	64 HERRICK POINT RD	Littleton	1935	X			
72-21-0	66 HERRICK POINT RD	Littleton	1964	X			
72-22-0	68 HERRICK POINT RD	Littleton	1911	2001	unknown	75	Approval # CA2001032916
72-23-0	130 HERRICK POINT RD	Littleton	1900	1977	Leach bed	37	
72-24-0	57 HERRICK POINT RD	Littleton	1994	1992	unknown	84	Approval # 193760
72-25-0	37 HERRICK POINT RD	Littleton	1994	X			
72-27-0	811 PARTRIDGE LAKE RD	Littleton	1940	2018	Presby septic system	75	Approval # ECA2018090608
72-28-0	799 PARTRIDGE LAKE RD	Littleton	1920	X			
72-31-0	769 PARTRIDGE LAKE RD	Littleton	1948	X			
72-33-0	749 PARTRIDGE LAKE RD	Littleton	1950	X			
72-34-0	737 PARTRIDGE LAKE RD	Littleton	1960	2006	unknown	63	Approval # CA2006083414
72-35-0	637-681 PARTRIDGE LAKE RD	Littleton	1930	1992-1998	unknown	55	
72-38-0	146 SOUTH SHORE RD	Littleton	1928	X			
72-39-0	144 SOUTH SHORE RD	Littleton	1928	2003	unknown	25	Approval # CA2003052211-A
72-40-0	151 SOUTH SHORE RD	Littleton	1905	X			
72-41-0	153 SOUTH SHORE RD	Littleton	1920	2005	unknown	65	Approval # CA2005076158
72-43-0	154 SOUTH SHORE RD	Littleton	1930	2020	Geomat 3900 leaching system	78	Approval #ECA2020112322
72-44-0	150 COVE RD	Littleton	1890	2009	unknown	60	Approval #CA2009098860
72-46-0	94 POULSENS POINT RD	Littleton	1948	X			
72-49-0	114 POULSENS POINT RD	Littleton	1940	2003	unknown	53	Approval #CA2003054830
72-5-0	776 PARTRIDGE LAKE RD	Littleton	2001	2000	unknown		
72-50-0	116 POULSENS POINT RD	Littleton	1948	X			
72-51-0	128 POULSENS POINT RD	Littleton	1970	1996	unknown	50	Approval # CA1996002894: no additional loading permitted
72-52-0	140 POULSENS POINT RD	Littleton	1980	X			
72-53-0	146 POULSENS POINT RD	Littleton	2017	2019	Enviro-fin	175	Approval # ECA2019040105
72-54-0	168 POULSENS POINT RD	Littleton	1948	X			
72-55-0	182 POULSENS POINT RD	Littleton	1950	1976	unknown	100	Approval # 58812
72-56-0	190 POULSENS POINT RD	Littleton	1950	1977	unknown	120	Approval # 61897
72-59-0	240 POULSENS POINT RD	Littleton	1956	X			
72-6-0	764 PARTRIDGE LAKE RD	Littleton	1910	X			
72-7-0	758 PARTRIDGE LAKE RD	Littleton	1960	PROPOSED 2021	Geomat 3900 leaching system	20	
73-11-0	411-413 PARTRIDGE LAKE RD	Littleton	1900	X			
73-12-0	385 PARTRIDGE LAKE RD	Littleton	1920	X			
73-15-0	85 SOUTH SHORE RD	Littleton	1970	1995	unknown	60	Approval # CA1995002354
73-16-0	73-75 SOUTH SHORE RD	Littleton	1870	X			
73-18-0	58 COVE RD	Littleton	1920	1977	unknown	75	Approval # 66255
73-19-0	56 COVE RD	Littleton	2005	2004	unknown	90	Approval # CA2004060898
73-20-0	38 COVE RD	Littleton	1940	X			
73-21-0	359 PARTRIDGE LAKE RD	Littleton	1925	X			
73-25-0	548 OLD PARTRIDGE LAKE RD	Littleton	1920	1977	unknown	60	Approval # 64672
73-26-0	558 OLD PARTRIDGE LAKE RD	Littleton	1920	X			
73-27-0	564 OLD PARTRIDGE LAKE RD	Littleton	1907	X			
73-29-0	557 OLD PARTRIDGE LAKE RD	Littleton	1970	2009	unknown	25	Approval # CA2009097102
73-30-0	474 PARTRIDGE LAKE RD	Littleton	1900	X			
73-31-0	464 PARTRIDGE LAKE RD	Littleton	1900	1993	unknown	81	Approval # 199822-A
73-32-0	425 PARTRIDGE LAKE RD	Littleton	1906	X			
73-34-0	406 PARTRIDGE LAKE RD	Littleton	1976	2019	Advanced Enviroseptic	160	Approval # ECA2019071210
73-36-0	360 PARTRIDGE LAKE RD	Littleton	2002	X			