Water Quality Protection Plan for Robinson Pond

Hudson, NH

August 2024

Prepared by the

Nashua Regional Planning Commission

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1.0 Introduction

Robinson Pond is an important and popular natural resource for residents of Hudson, New Hampshire. The 88-acre pond within its 832-acre watershed is home to the town's swimming beach, boat launch, and picnic area. An extensive trail system and wildlife sanctuary exists adjacent to the pond. Despite the best efforts of conservationists, water quality monitoring volunteers, and citizens working on behalf of the pond's health, historic trend analyses indicate that the pond is affected by constantly high and/or worsening levels of several nutrient pollution parameters, particularly phosphorus. These conditions promote algal and cyanobacteria levels that exceed water quality thresholds. In the last few years Robinson Pond has experienced longer and more frequent cyanobacteria blooms caused by an abundance of phosphorus. In 9 of the last 19 years, NH Department of Environmental Services (NHDES) has issued health advisories for elevated cyanobacteria levels in Robinson Pond.

In May 1994 NHDES published The *Robinson and Ottarnic Ponds Diagnostic / Feasibility Study Final Report* (NHDES, 1994). It recommended decreasing non-point source sources of phosphorus to Robinson Pond by utilizing Best Management Practices (BMPs) to decrease phosphorus from stormwater runoff, groundwater seepage, and inflowing tributaries.

The *Robinson Pond Nonpoint Implementation Project* was completed in 2000 (NRPC) and focused on training volunteers to gather water quality data, mailing educational materials to residents in the watershed, providing landowners with information on Best Management Practices, investigating catch basins and swales, and a septic system survey of shoreline residents.

In 2009, AECOM completed A Total Maximum Daily Load (TMDL) study with final revisions by the NHDES in January 2011 (AECOM, 2011). The TMDL identifies sources of phosphorus and ways to reduce the amount of phosphorus entering the lake.

This Water Quality Protection Plan is part of the collaboration among residents, town staff, the regional planning commission, and private consultants to identify specific actions to improve Robinson Pond's water quality.

Figure 1 below shows the drainage areas and land cover around Robinson Pond.

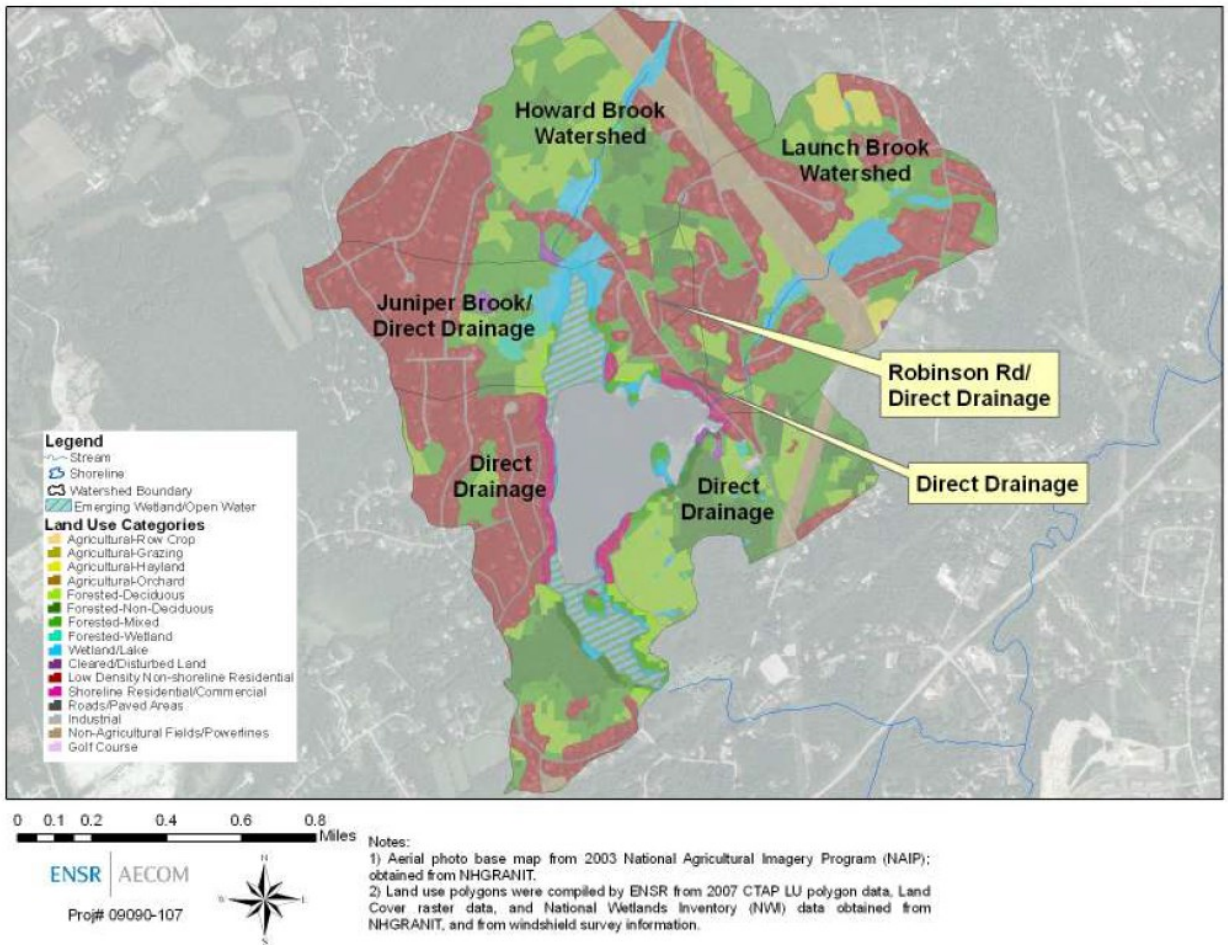

Figure 1. Drainages and land cover of Robinson Pond.
Source: AECOM, 2011

2.0 Plan Process

The Robinson Pond Water Quality Protection Plan process began when Nashua Regional Planning Commission (NRPC) partnered with the Town of Hudson to apply for a section 604(b) grant from NHDES. The Town of Hudson falls under the 2017 Small NH Municipal Separate Storm Sewer System (MS4) General Permit which requires the town to work towards improving stormwater management, especially related to impaired waters.

The grant was awarded in July of 2021 and NRPC facilitated a competitive Request for Qualifications (RFQ) process. In January 2022 the consultant VHB was selected, with DK Water Resource Consulting as a subconsultant. A kickoff meeting with stakeholders was held in March 2022 and a mid-project update meeting in November 2022. A final wrap-up meeting was held in July 2024.

The Friends of Robinson Pond and Volunteer Lake Assessment Program (VLAP) volunteers shared their local knowledge about conditions at the pond and, in addition to continuing their standard VLAP duties, contributed additional time and personal equipment towards extra water and lake

sediment sampling. Over the course of the project, VHB and their subconsultant, DK Water Resource Consulting, created the following:

- Robinson Pond Water Quality Protection Plan Technical Memo (Appendix I)
- Structural BMP Matrix (Appendix II)
- Non-Structural BMP Matrix (Appendix III)
- Shoreland Survey (Appendix IV)
- A crosswalk between the NH MS4 permit and the Environmental Protection Agency's (EPA) Nine Elements of a Watershed Plan (Appendix V)
- Locations for potential structural stormwater Best Management Practices (BMP) (Appendix VI)
- Recommendations for Wetland Overlay District Updates (Appendix VII)
- Robinson Pond Sediment Analysis (Appendix VIII)

This plan, with its detailed appendices, is an abbreviated version of a traditional USEPA watershed plan with "a – i" elements. Table 1 below describes the elements a - e addressed in this plan.

Table 1. USEPA's elements of watershed planning

Element	Plan Section	Element Description
a	5	Identify causes and sources of pollution
b	6	Estimate pollution load reductions needed for restoration
c	7	Identify actions needed to reduce pollution
d	7	Estimate costs and authority to implement restoration actions
e	7	Implement outreach and education to support restoration

3.0 Characteristics of Robinson Pond

Robinson Pond, NHLAK700061203-06-01, is a Class B water in the Merrimack River Basin. It is contained entirely within the northeast corner of the town of Hudson, New Hampshire. As detailed in

Table 2, it is 88 acres and has a maximum depth of 9.0 meters (29.5 ft) and a mean depth of 3.3 meters (10.8 ft). The lake volume is 1,189,000 cubic meters with a flushing rate of approximately 1.3 times per year. Robinson Pond is relatively shallow, with one deep spot in the center, as seen in the rough bathymetric chart in Figure 2. It was likely formed as a kettle hole after the glaciers receded. Its watershed is 832 acres.

In 2022 the Town of Hudson had a population of 25,910 with a density of 916.52 people per square mile (NHOPD, 2023). Hudson grew 3.8% between the years 2010 and 2020 and is projected to grow another 7.6%, to 27,313 people, by the year 2030 (NRPC, "Housing", 2023).

Robinson Pond is a warm water fishery with brown bullhead (*Ictalurus sp.),* largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), eastern chain pickerel (*Esox niger*), black crappie (*Pomoxis nigromaculatus*), smallmouth bass (*Micropterus dolomieu*), and yellow perch (*Perca flavescens*) as the most common species (NH Fish and Game, 2023). Variable milfoil (*Myriophyllum Heterophyllum*) and fanwort (*Cabomba caroliniana*), non-native aquatic plants, are present.

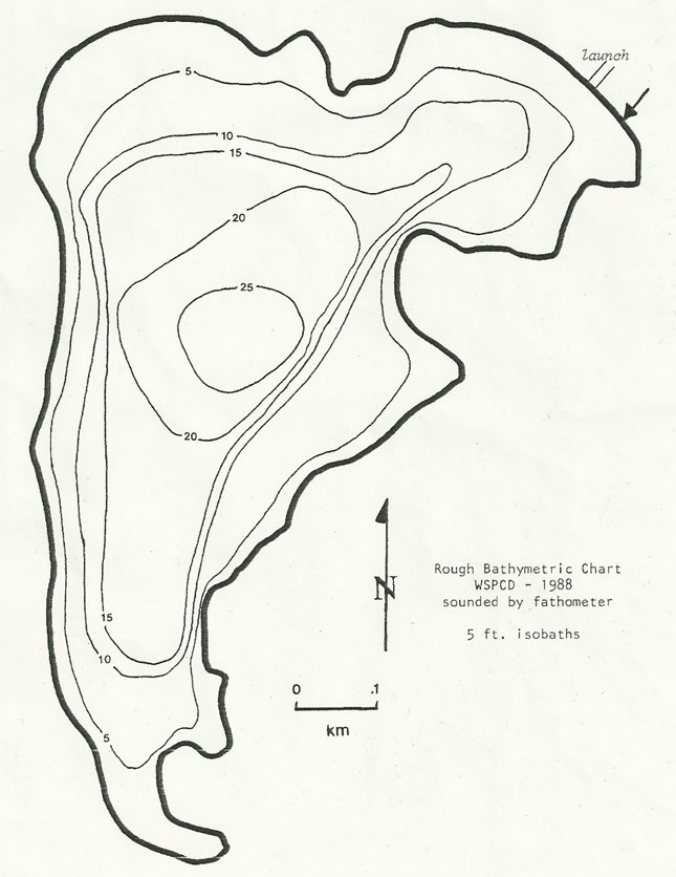

Figure 2. Rough Bathymetric Chart, 1988.
Source: NH Water Supply and Pollution Control Division.

Table 2. Characteristics of Robinson Pond, Hudson, NH.

Parameter	**Value**
Assessment Unit Identification	NHLAK700061203-06-01
Lake Area (ac)	88
Lake Volume (m^3)	1,189,000
Watershed Area (ac)	832
Mean Depth (m)	3.3
Max Depth (m)	9
Flushing Rate ($year^{-1}$)	1.3
Epilimnetic TP (*u*g/L mean)*	21
Hypolimnetic TP (*u*g/L mean)*	102
Impaired Uses and Cases of Impairment**	*Primary Contact Recreation:* chlorophyll *a* hepatotoxic cyanobacteria *E. Coli* bacteria *Aquatic Life:* Chlorophyll-*a*

	Dissolved Oxygen Saturation Non-native aquatic plants Total Phosphorus pH
Hypolimnetic Anoxia	Yes

**TP mean from 2023 sampling season, VLAP*

***Source: 2020/2022, NHDES 305(b)/303(d) Surface Water Quality Assessment*

In September 1938 a major hurricane uprooted countless mature trees in Hudson and surrounding communities. A Town Timber Committee was formed, and they decided to store the logs in Robinson Pond to prevent insect damage and preserve them for future use. Logs were moved from Pelham, Litchfield, Nashua, and Hudson and sunk in Robinson Pond. The majority of the logs were removed from the water starting in 1940 and milled at portable mills at Sawdust Island, the point at Robinson Pond. Some logs remain submerged in the pond. One or two resurfaces occasionally, as shown below in Figure 3.

Figure 3. Log from Hurricane of 1938.
Source: Glen and Jane Bowles

3.1 Dams

The Robinson Pond Dam (D122016) is an active 55 ft long by 3 ft tall dam owned by the Town of Hudson. It sits at the outlet of Robison Pond where Beaver Brook begins. Its hazard class is non-menace (NM) (NH GRANIT, 2022). It is located within the 1% annual floodplain and is considered valuable to flood control (NRPC, “Hazard”, 2018).

3.2 Land Uses

Robinson Pond is home to the town's boat launch, swimming beach, and picnic area, accessible from Robinson Road and limited to residents of Hudson. The Robinson Pond Recreation Area is a 47-acre parcel that includes the town beach and picnic areas and extensive hiking trails. The land for the beach, pictured below in Figure 4, was donated to the Town of Hudson in the 1970s and the General Federation of Women's Clubs (GFWC) Junior Women's Club originally developed the beach and the recreation area. The Parker Wildlife Sanctuary, on the north side of the pond, is a 41-acre parcel with woods and wetlands that are home to many species of birds and land and water mammals (Jutras, 2006). Two parcels at the south end of the pond, 43 acres at 13 Tiger Road and 30 acres at the Berrigan Property, were purchased by the town in recent years to help protect the watershed from development.

Figure 4. Robinson Pond Town Beach, 2021

Aside from recreation and conservation land, the primary land use surrounding the pond is single family residential. There are 35 private waterfront residences on the pond, primarily along the western shoreline, with some along the northeastern and eastern shorelines, as seen below in Figure 5. All the homes have private septic systems as municipal sewer service is not available.

VHB conducted a shoreline survey on July 19, 2022, evaluating parcels with shoreline development and looking for the presence and quality of buffer, bare soil, erosion, distance of structures from the shore, and the slope of the parcel. Most parcels (18) were assessed as "Fair," while 8 were assessed as "Good" and 5 as "Poor." The parcel with the worst assessment was the town-owned recreation property that includes the town beach. The complete results can be found in Appendix IV.

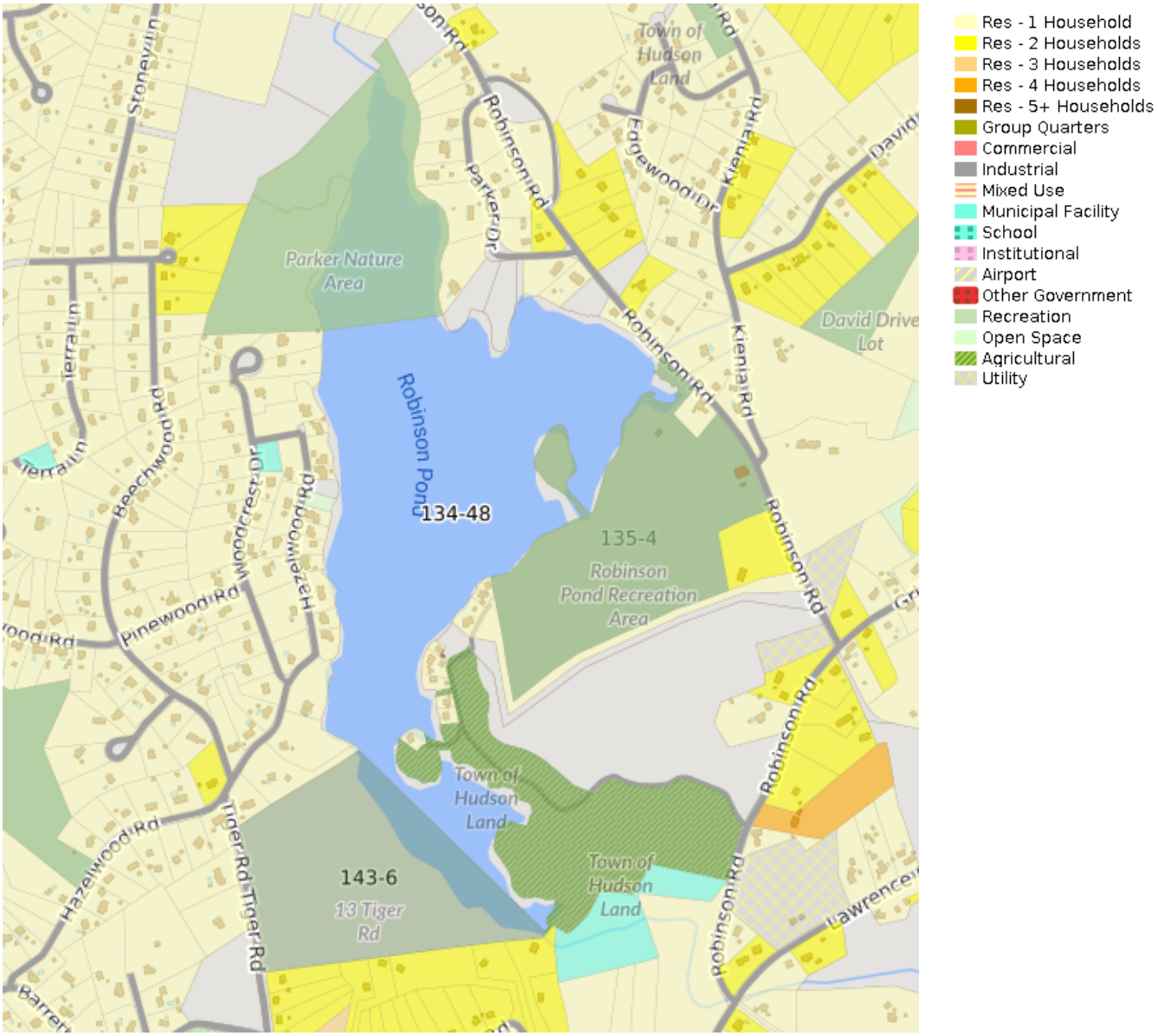

Figure 5. Map of Current Land Uses.
Source: NRPC GIS, 2024

3.3 Aquatic Vegetation

Robinson Pond has an overgrowth of the following non-native plant species, first documented in 2000:

- Variable milfoil *(Myriophyllum heterophyllum)*, an aquatic plant with "fine, densely packed, feather-like leaves whorled around a main stem" which can grow up to 15 feet and spreads rapidly (NHDES, "Fact Sheet Variable Milfoil", 2019),

- Fanwort *(Cabomba caroliniana)*, an aquatic plant with "leaves arranged in a fan shape manner oppositely located on a long narrow stem" that will grow from 2 to 12 feet tall and quickly invades shoreline areas (NHDES, "Fact Sheet Fanwort", 2019),

While aquatic vegetation is critical for lake ecosystems, excessive growth can impact other aquatic species and the overall water quality. Non-native species can out-compete native species, forming dense growths or monocultures, and they often do not provide the same food and habitat quality as native species.

The *Long-Term Variable Milfoil and Fanwort Management Plan* (NHDES, February 2022) recommends herbicides as a primary treatment to reduce the amount of vegetation, due to the extent of infestation, and individual stems should be hand-pulled when encountered by residents. Herbicide treatments were first applied in 2002 and have been applied at least once a year during most years from 2012 to the present.

Figure 6 below shows the historical locations of Variable Milfoil and Fanwort. In recent years, the densest infestations have been in the north and south ends of Robinson Pond.

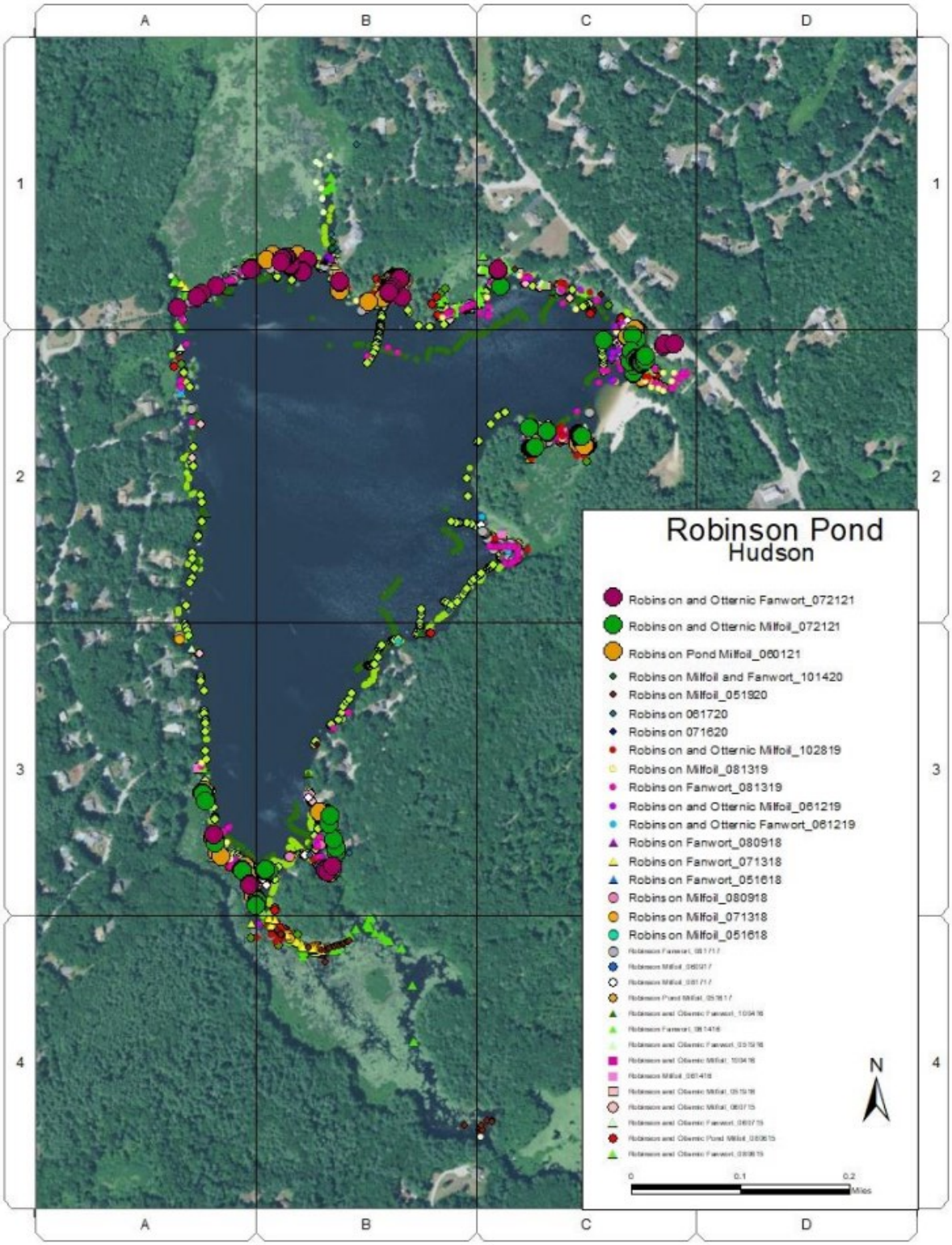

Figure 6. Map of Variable Milfoil and Fanwort Infestations Over Time
Source: NHDES, Long-Term Variable Milfoil & Fanwort Management Plan, February 2022

Cyanobacteria are organisms that photosynthesize, are typically microscopic, and naturally occur in freshwater. Under the right conditions, they can multiply very quickly and increase in numbers to reach a high enough density that they can be seen without a microscope. They may discolor the surface of water, forming scum, discolor the whole water, or form mats on the bottom of the water body. This rapid increase in growth is called a "bloom." Blooms occur when there is enough light, heat, and nutrients for the population to explode. Figure 7 shows a cyanobacteria bloom.

Figure 7. Cyanobacteria Bloom
Source: NHDES News Release (September 2022)

Cyanobacteria blooms are a water quality issue because they can be hazardous to human and animal health. Cyanobacteria can produce cyanotoxins which, when touched, inhaled, or ingested, affect multiple organs, including the liver, stomach, skin, and nervous system, which can cause gastroenteritis, headache, diarrhea, and vomiting (NHDES, "Cyanobacteria Plan", 2023). When a member of the public reports a potential cyanobacteria bloom, the NHDES Cyanobacteria Harmful Algal Bloom Program monitors the affected waterbody. They assess how severe a bloom is based on the concentration of cyanobacteria cells. When a cell count is above 70,000 cells/mL it is likely that there are toxins present. NHDES issues two types of notifications: warnings, when the density of cyanobacteria exceeds 70,000 cells/mL, and alerts, when the cell density is below that threshold but increasing and approaching it. Once a warning is issued, NHDES resamples weekly until the cell density falls below the 70,000 cell/mL threshold. NHDES issues warnings from May 15 through October 15.

NHDES has issued cyanobacteria warnings for Robinson Pond in 9 of the last 19 years. Notably, one warning in 2022 lasted for an astonishing 49 days, running from late September until early November. Table 3 below shows the history of cyanobacteria warnings issued by NHDES since 2004.

Table 3. Cyanobacteria Bloom Warning History for Robinson Pond

Type of Notification	Date Issued	Date Removed	# of Days Issued	*Dominant Taxa*	Initial Cyanobacteria Cell Density (cells/mL)
Warning	8/18/2004	9/3/2004	16	*unidentified*	>70,000 or >50%
Warning	7/16/2008	7/24/2008	8	*Anabaena*	>70,000 or >50%
Warning	8/8/2008	8/21/2008	13	*Coelosphaerium*	>70,000 or >50%
Warning	7/10/2009	7/13/2009	3	*Anabaena*	>70,000 or >50%
Warning	8/31/2009	9/11/2009	11	*Oscillatoria*	>70,000 or >50%
Warning	7/13/2010	7/16/2010	3	*Oscillatoria*	>70,000 or >50%
Warning	8/17/2015	8/25/2015	8	*Oscillatoria*	300,000
Warning	10/14/2020	10/22/2020	8	*Woronichinia, Microcystis, Dolichospermum*	1,167,000
Warning	6/1/2021	6/8/2021	7	*Dolichospermum, Woronichinia, Microcystis*	780,000
Warning	8/3/2021	8/12/2021	9	*Dolichospermum, Woronichinia, Aphanizomenon*	849,500
Warning	6/13/2022	6/20/2022	7	*Dolichospermum, Woronichinia*	356,933
Warning	9/20/2022	11/8/2022	49	*Chrysosporum, Aphanizomenon, Dolichospermum*	140,900
Warning	7/5/2023	7/12/2023	7	*Dolichospermum,Woronichinia, Microcystis*	1,372,000

Source: NHDES Cyanobacteria Harmful Algal Bloom Program, May 2024

When active, warnings (advisories) and alerts are widely publicized and physically posted at the beach and boat launch, as shown in Figure 8. People and their pets should avoid swimming, wading, or drinking the water during an active warning, and be aware of increasing concentrations of cyanobacteria during alerts.

Figure 8. Beach Advisory Posting, 2021

4.0 Assessment of Water Quality

Federal and state water quality standards apply to Robinson Pond. Understanding the state's assessment process and water quality parameters is essential to monitoring the water quality of Robinson Pond and choosing appropriate management actions.

4.1 Applicable Surface Water Quality Standards and Criteria

In New Hampshire, water quality standards are used to protect the quality of the state's surface waters. Public waters include natural waterbodies of 10 acres or more in size, public rivers and streams, and tidal waters. Standards consist of three parts: designated uses, criteria to protect the designated uses, and an antidegradation policy. Those criteria are established by statute and administrative rules, including the federal Clean Water Act (CWA), NH RSA 485-A Water Pollution and Waste Disposal, and Env-Wq 1700, the NH Surface Water Quality Regulations.

States are required to submit water quality status reports to Congress by way of the US Environmental Protection Agency every two years. The reports, referred to as the Section 303(d) Surface Water Quality List and the Section 305(b) Report, include a list of all waters assessed by the state and their status as meeting or not meeting NH water quality standards.

Designated uses are activities and services that the water should be able to support, including aquatic life, fish consumption, shellfish consumption, drinking water supply, primary contact recreation (swimming), secondary contact recreation (boating and fishing) and wildlife. Descriptions of designated uses can be found in Table 4.

Table 4. Designated Uses for New Hampshire Surface Waters

Designated Use	NH Code of Administrative Rules (Env-Wq 1702.17) Description	Applicable Surface Waters
Aquatic Life Integrity	The surface water can support aquatic life, including a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar natural habitats of the region.	All surface waters
Fish Consumption	The surface water can support a population of fish free from toxicants and pathogens that could pose a human health risk to consumers.	All surface waters
Shellfish Consumption	The tidal surface water can support a population of shellfish free from toxicants and pathogens that could pose a human health risk to consumers.	All tidal surface waters
Potential Drinking Water Supply	The surface water could be suitable for human intake and meet state and federal drinking water requirements after adequate treatment.	All surface waters
Swimming and Other Recreation In and On The Water	The surface water is suitable for swimming, wading, boating of all types, fishing, surfing, and similar activities.	All surface waters
Wildlife	The surface water can provide habitat capable of supporting any life stage or activity of undomesticated fauna on a regular or periodic basis.	All surface waters

Source: Adapted from the 2020/2022 NH Consolidated Assessment and Listing Methodology

Water quality criteria are designed to protect those designated uses. If a surface water meets the water quality criteria, it supports its designated uses, and if it does not meet water quality criteria, then it is considered impaired for those designated uses. Water quality criteria are detailed in RSA 485-A:8 Standards for Classification of Surface Waters of the State and in the state Surface Water Quality Regulations.

Antidegradation is a provision of the water quality standards that maintains and protects existing water quality and uses, with a focus on protecting waters of high quality.

In 2018, the 2017 NH Small Municipal Separate Storm Sewer System (MS4) General Permit became effective. The MS4 permitting process, a federal requirement based in the Clean Water Act, brought a major focus to proper stormwater management to protect the quality of public waters. Any town subject to MS4 requirements much develop a Stormwater Management Program that includes six focus areas:

- Public Education and Outreach
- Construction Site Erosion Control
- Public Participation and Involvement

- Post Construction Stormwater Management
- Illicit Discharge Detection and Elimination
- Pollution Prevention and Good Housekeeping

An impaired waterbody is one that does not meet water quality criteria that support its designated use. The criteria can include specific quantitative parameters that can't be exceeded, such as a certain concentration, duration, or frequency, or it can include a qualitative description of conditions such as the absence of smells or scum. If a waterbody is impaired, NHDES will place it on the Section 303(d) list.

Robinson Pond is listed on the 2020/2022 303(d) list as impaired for:

- Aquatic Life Integrity due to chlorophyll-a, low dissolved oxygen saturation, non-native aquatic plants, pH, and total phosphorus,
- Fish Consumption due to mercury, and for
- Primary Contact Recreation (swimming) due to chlorophill-a, cyanobacteria blooms and the presence of *Escherichia coli* (*E. coli*), as seen in Figure 9.

Assessment Unit ID: NHLAK700061203-06-01
Assessment Unit Name: Robinson Pond
Town(s) Primary Town is Listed First: Hudson

Size: 128.2410 ACRES
Assessment Unit Category: 5-M
Beach: N

2020/2022, 305(b)/303(d) - All Reviewed Parameters by Assessment Unit

Designated Use Description	Desig. Use Category	Parameter Name	Parameter Threatened (Y/N)	Last Sample	Last Exceed	Parameter Category	TMDL Priority
Aquatic Life Integrity	5-M	ALKALINITY, CARBONATE AS CACO3	N	2007	2007	3-ND	
		CHLORIDE	N	2019	N/A	3-PAS	
		CHLOROPHYLL-A	N	2019	NLV	4A-P	
		DISSOLVED OXYGEN SATURATION	N	2019	2016	4A-M	
		Non-Native Aquatic Plants	N			4C-M	
		OXYGEN, DISSOLVED	N	2019	2014	3-PNS	
		PH	N	2019	2019	4A-M	
		PHOSPHORUS (TOTAL)	N	2019	NLV	4A-M	
		TURBIDITY	N	2019	2019	3-PNS	
Fish Consumption	4A-M	MERCURY - FISH CONSUMPTION ADVISORY	N			4A-M	
Potential Drinking Water Supply	2-G	ESCHERICHIA COLI	N	2019	2019	3-PNS	
Primary Contact Recreation	4A-M	CHLOROPHYLL-A	N	2019	2017	4A-M	
		Cyanobacteria hepatotoxic microcystins	N	2019	2015	4A-M	
		ESCHERICHIA COLI	N	2019	2019	4A-M	
Secondary Contact Recreation	2-M	ESCHERICHIA COLI	N	2019	N/A	2-M	
Wildlife	3-ND						

Good	Marginal	Likely Good	No Current Data	Likely Bad	Poor	Severe
Meets water quality standards/thresholds by a relatively large margin.	Meets water quality standards/thresholds but only marginally.	Limited data available. The data that is available suggests that the parameter is Potentially Attaining Standards (PAS)	Insufficient information to make an assessment decision.	Limited data available The data that is available suggests that the parameter is Potentially Not Supporting (PNS) water quality standards.	Not meeting water quality standards/thresholds. The impairment is marginal.	Not meeting water quality standards/thresholds The impairment is more severe and causes poor water quality.

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02/18/2022

Figure 9. 2020/2022 Water Quality Report Card for Robinson Pond
Source: NHDES 303(d) List for 2020/2022

The Robinson Pond Town Beach receives a separate report card and is also listed as impaired for:

- Fish Consumption due to mercury, and for
- Primary Contact Recreation (swimming) due to cyanobacteria blooms and the presence of *Escherichia coli* (*E. coli*), as seen in Figure 10.

Assessment Unit ID: NHLAK700061203-06-02 **Size:** 0.5820 ACRES **2020/2022, 305(b)/303(d) - All Reviewed Parameters by Assessment Unit**
Assessment Unit Name: Robinson Pond - Town Beach **Assessment Unit Category: 4A-P**
Beach: Y
Town(s) Primary Town is Listed First: Hudson

Designated Use Description	Desig. Use Category	Parameter Name	Parameter Threatened (Y/N)	Last Sample	Last Exceed	Parameter Category	TMDL Priority
Aquatic Life Integrity	3-ND	Chlorophyll-a	N	N/A	NLV	3-ND	
		Dissolved oxygen saturation	N	2007	2000	3-ND	
		Oxygen, Dissolved	N	2007	2000	3-ND	
		pH	N	2007	2007	3-ND	
Fish Consumption	4A-M	MERCURY - FISH CONSUMPTION ADVISORY	N			4A-M	
Potential Drinking Water Supply	2-G	ESCHERICHIA COLI	N	2019	2019	3-PNS	
		FECAL COLIFORM	N	1991	1991	3-ND	
Primary Contact Recreation	4A-P	Cyanobacteria hepatotoxic microcystins	N	2015	2015	4A-M	
		ESCHERICHIA COLI	N	2019	2019	4A-P	
Secondary Contact Recreation	2-G	ESCHERICHIA COLI	N	2019	N/A	2-G	
Wildlife	3-ND						

Good	Marginal	Likely Good	No Current Data	Likely Bad	Poor	Severe
Meets water quality standards/thresholds by a relatively large margin.	Meets water quality standards/thresholds but only marginally.	Limited data available. The data that is available suggests that the parameter is Potentially Attaining Standards (PAS)	Insufficient information to make an assessment decision.	Limited data available The data that is available suggests that the parameter is Potentially Not Supporting (PNS) water quality standards.	Not meeting water quality standards/thresholds. The impairment is marginal.	Not meeting water quality standards/thresholds The impairment is more severe and causes poor water quality.

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Figure 10. 2020/2022 Water Quality Report Card for Robinson Pond Town Beach
Source: *Source: NHDES 303(d) List for 2020/2022*

4.2 Trophic Status

NHDES started the Lake Trophic Survey Program in 1975 to document the current conditions of publicly accessible natural and manmade waterbodies that are 10 acres or greater in size. As of 2019, most of the state's 750 such waterbodies have been surveyed at least once. Trophic status categorizes water bodies into three categories:

- *Oligotrophic* waterbodies typically have clear water, few macrophytes, high levels of dissolved oxygen, low levels of phosphorus and chlorophyll-*a*,

- *Mesotrophic* waterbodies are either in-between or transitioning between oligotrophic and eutrophic conditions,
- *Eutrophic* waterbodies typically have cloudier water, many macrophytes, low levels of dissolved oxygen, and higher levels of phosphorus.

A quickly-shifting trophic class may be a sign of declining water quality, as they usually only shift over long geologic periods.

In stratified lakes, where during warmer months there are distinct thermal layers, water samples are collected at the mid-epilimnion (top water layer), mid-metalimnion (middle water layer) and mid-hypolimnion (bottom water layer), and in unstratified lakes, at one-third and two-thirds the water depth (NHDES, "Lake Tropic Survey," 2019).

Robinson Pond has been surveyed twice by this program: in 1979 and 1988. It was originally classified as eutrophic in 1979 but was classified as mesotrophic in 1988. The change in classification was due to a revised rating system and there was little change in water quality between the surveys. NH water quality assessments are based on the "cleanest" trophic status reported for a lake, so Robinson Pond is considered a mesotrophic waterbody.

To assess compliance with state water quality regulations, nutrients and nutrient impact are both monitored. Phosphorus and chlorophyll-a concentrations are measured because phosphorus is the limiting nutrient in freshwater lakes and chlorophyll-a is a measure of algae growth. Table 5 shows the target concentration thresholds by trophic class.

Table 5. Concentration Thresholds by Trophic Class

Trophic Class	TP (µg/L)	Chl-a (µg/L)
Oligotrophic	< 8.0	< 3.3
Mesotrophic	≤ 12.0	≤ 5.0
Eutrophic	≤ 28	≤ 11

Source: NHDES 2020/2022 Consolidated Assessment and Listing Methodology

4.3 Designated Use of Concern: Primary Contact Recreation

The criteria for Primary Contract Recreation is detailed in Env-Wq 1703.03, "General Water Quality Criteria" and says: "all surface waters shall be free from substances in kind or quantity that: a) settle to form harmful benthic deposits; b) float as foam, debris, scum or other visible substances; c) produce odor, color, taste or turbidity that is not naturally occurring and would render the surface water unsuitable for its designated uses; d) result in the dominance of nuisance species; e) interfere with recreation activities."

Cyanobacteria blooms pose a health hazard and form visible scum on water surfaces. The 2020/2022 305(b)303(d) Surface Water Quality Report Cards for Robinson Pond and for the Robinson Pond Town Beach found that Primary Contact Recreation were impaired due to *E. coli* and cyanobacteria blooms. The goal of this Water Quality Protection Plan is to focus on activities that will reduce the frequency and intensity of cyanobacteria blooms, including reducing the concentration of total phosphorus.

5.0 Water Quality Data (Element A)

To improve and protect the water quality of Robinson Pond, we must understand how much phosphorus is entering Robinson Pond, and where it is coming from.

An interactive Lake Information Mapper, a valuable tool for accessing water quality data for Robinson Pond and other lakes throughout New Hampshire, can be found on the River and Lake Monitoring NHDES webpage.

5.1 Total Maximum Daily Load (TMDL) and Phosphorus Control Plan

A Total Maximum Daily Load (TMDL) study evaluates and identifies sources of nutrient contributions to a lake and calculates how much those contributions need to be reduced to meet New Hampshire's water quality standards. A TMDL for Robinson Pond for the nutrient Phosphorus (P) was completed in 2011. Phosphorus is a limiting nutrient for vegetation in the pond, which means that if more phosphorus is introduced, plants will grow very quickly. If the amount of phosphorus entering the pond can be reduced, the number of cyanobacterial blooms should decrease, improving water quality, and improving the quality of recreation and aquatic life uses.

The 2017 Small NH MS4 General Permit requires that municipalities that have an EPA-approved lake phosphorus TMDL must develop a Phosphorus Control Plan. The Phosphorus Control Plan identifies actions that the Town can take to reduce stormwater-related phosphorus contributions to the pond to meet the goals of the TMDL. VHB completed a draft of the Phosphorus Control Plan in June 2023. That document, and other MS4-related documentation, can be found on the Town's Storm Water/MS4 Public Outreach webpage.

The 2011 TMDL recommended that the average annual phosphorus watershed load should be reduced by 40%, to about 102 pounds per year in order to decrease the average in-lake phosphorus concentration to 12µg/L, a typical concentration level for mesotrophic lakes in New Hampshire. The TMDL estimated that the total phosphorus load is currently about 254 pounds per year.

The Phosphorus Control Plan updated and revised the load estimates for Robinson Pond and its catchment area, as seen in Table 6. Areas with impervious cover tend to generate more stormwater runoff, bringing more phosphorus-containing sediment into the pond. These revised estimates include only watershed sources and do not include phosphorus from the atmosphere, waterfowl, septic systems, or internal loading.

Table 6. Preliminary Phosphorus Loading Estimates by Catchment Area

Catchment Area	Land Area (acres)	Impervious Cover Area (acres)	Estimated P Load (lbs/year)	% of Estimated Load
Launch Brook	241	25.4	36.6	22%
Launch Brook (Londonderry)	80	9.0	14.2	8%
Direct Drainage 1	25	3.8	3.2	2%
Direct Drainage 2	198	23.1	27.4	16%
Direct Drainage 3	159	8.8	21.2	12%
Howard Brook	335	25.1	43.5	26%

Juniper Brook Direct Drainage	128	13.8	17.9	11%
Robinson Rd Direct Drainage	49	5.4	5.2	3%
North Wetland	21	0.00	0.3	0%
South Wetland	20	0.02	0.2	0%
Total	**1256**	**114**	**170**	**100%**

Source: Adapted from the Town of Hudson, NH DRAFT Year 5 2023 Phosphorus Control Plan

5.2 Volunteer Lake Assessment Program (VLAP)

NHDES coordinates a Volunteer Lake Assessment Program (VLAP) where volunteers, often residents with waterfront property, collect water samples and other water quality data from public lakes and ponds in New Hampshire. They gather information on chlorophyll-a, conductivity (chloride), color, *E. coli*, total phosphorus, transparency, turbidity, and pH. The data gathered helps NHDES and lake associations track and monitor the health of lakes.

Robinson Pond has seven collection stations, as pictured in Figure 11 and listed below:

- The Deep Spot
- STA 3 Howard Brook
- STA 4 Juniper Brook
- STA 2 Launch Brook
- STA 7 ROW (on the southwest shore)
- STA 5 Stoney Lane Drainage
- STA 6 Woodcrest Brook

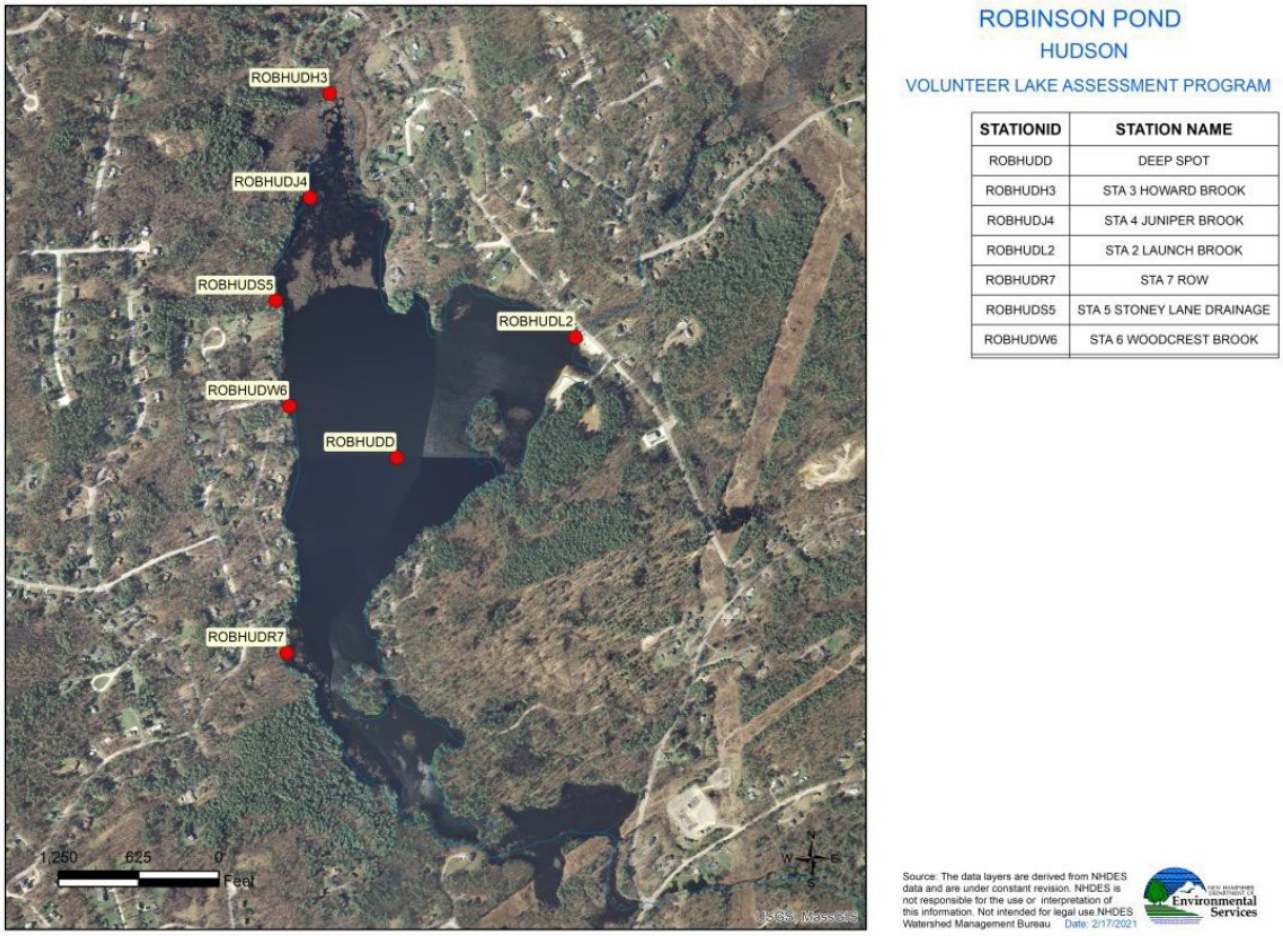


Figure 11. VLAP Sample Station Map
Source: NHDES VLAP Individual Lake Reports, Robinson Pond, Hudson (2021)

In recent years, conductivity, pH, and chlorophyll-a have been stable, while phosphorus levels (in the epilimnion and hypolimnion) and transparency have been worsening. Selected data from the last five years of sampling is shown in Table 7 below.

Table 7. VLAP Total Phosphorus, Chlorophyll-a and Transparency Data

Sample Year	Epilimnetic TP (ug/L)	Metalimnetic TP (ug/L)	Hypolimnetic TP (ug/L)	Chlorophyll-a (ug/L)	Secchi Transparency (with viewscope) (m)
2019	19	30	73	10.37	2.01
2020	18	48	215	8.75	2.81
2021	23	29	128	16.38	2.17
2022	21	39	109	14.21	2.68
2023	21	27	102	11.23	2.60

Source: NHDES VLAP Individual Lake Reports

Dissolved oxygen and temperatures profiles from 2023, shown in Figure 12, show that as the summer progresses, the water becomes stratified: the surface warms up and maintains a consistent level of dissolved oxygen, while the deeper waters remain cooler and there is no dissolved oxygen below about 3 meters (hypolimnetic anoxia).

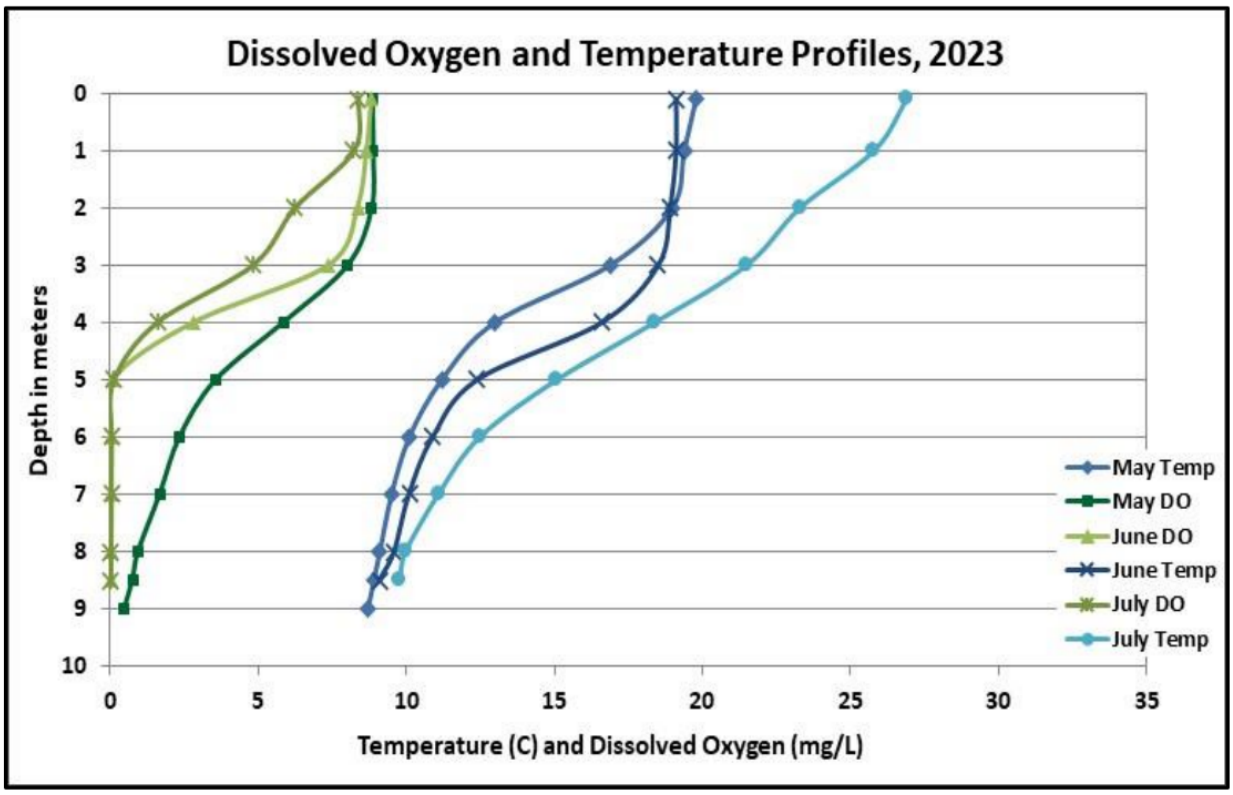


Figure 12. Dissolved Oxygen and Temperature Profiles, 2023
Source: VLAP Individual Lake Reports, Robinson Pond, Hudson (2023)

5.3 Soil Sediment Sampling

Stormwater brings phosphorus into the pond from throughout the watershed; however, there is also phosphorus present in the pond itself, in the bottom sediment. To determine how much phosphorus is leaching into the water from the sediment, called internal loading, the Town of Hudson decided to pursue soil sediment sampling during the summer of 2023.

Soil samples were taken in July and October of 2023. The previously mentioned anoxic conditions in the deep waters create an environment where phosphorus can be released from the soil sediments into the water. Analysis of the soil samples confirmed that there is phosphorus in the soil sediment of Robinson Pond that is more likely to be released under low-oxygen conditions (DK Water Resource Consulting, 2024). The sediment analysis suggests that in-lake sources of phosphorus are significantly higher than was calculated in the 2011 TMDL.

The full Sediment Analysis can be found in Appendix VIII.

6.0 Water Quality Goals (Element B)

The Robinson Pond TMDL calls for a 40% reduction in the amount of phosphorus entering the pond, a reduction of approximately 102 pounds per year. The 2017 MS4 Permit specifies a milestone target of reducing the amount of phosphorus by 30% by Fiscal Year 2026. Bringing the concentration of total phosphorus down to approximately 12µg/L is expected to reduce the frequency of cyanobacteria blooms and improve the pond's likelihood of meeting water quality standards. Phosphorus comes into the pond from many sources and it will need to be reduced from many sources using multiple strategies.

7.0 Management Actions to Control Phosphorus Loading (Elements C, D, & E)

Actions to control phosphorus loading can be categorized into two types: structural and non-structural best management practices (BMPs). Structural BMPs are physical structures that are designed to slow down the flow of stormwater and allow it to soak into the ground, or to slow down enough to allow any sediment to settle out before it flows into a lake or other surface water. Structural BMPs can include rain gardens, permeable pavement, green roofs, or any other technique that keeps stormwater close to where the rain first hits the ground. The Town of Hudson has jurisdiction to create structural BMPs on town-owned land. VHB and Town of Hudson staff scoped out potential structural BMP locations for viability and cost (Appendix VI).

Detailed descriptions of recommended BMPs for Robinson Pond can be found in the Technical Memo in Appendix I. A detailed table of seven recommended structural BMPs, with their projected costs and effectiveness, can be found in Appendix II. The town beach and town boat launch are both listed as potential BMP locations, which are high-traffic, highly visible locations right on the shoreline.

Non-structural BMPs are planning and design strategies, such as land use regulations, catch basin cleaning, and public education. Non-structural BMPs are more likely to be ongoing actions or habits. VHB suggested the following:

- revising the town's Wetland Overlay District ordinance
- educating property owners through program such as "Soak Up the Rain," lake stewards awards, and residential demonstration projects
- street sweeping, prioritizing roads around the lake in the spring and fall
- catch basin cleaning in the spring
- stabilizing roadway shoulders
- in-lake treatments

A detailed table of recommended non-structural BMPs and their effectiveness can be found in Appendix III. Recommendations for Wetland Overlay District Updates are found in Appendix VII.

Each type of BMP can be expected to reduce the annual phosphorus load by a certain number of pounds. Some BMPs are very effective at reducing the amount of phosphorus and others are less effective, just like some BMPs are very expensive to implement and others cost little. The ideal interventions are ones that are effective and economical.

Implementing these BMPs will also help the Town of Hudson meet federal MS4 requirements. VHB created a crosswalk table laying out which of their recommendations would meet which MS4 Minimum Control Measures, which can be found in Appendix V.

8.0 Next Steps

In order to improve the water quality of Robinson Pond and reduce the frequency of cyanobacteria blooms, the amount of phosphorus entering the pond must be reduced. This Water Quality Protection Plan and its appendices recommend many specific actions that the Town of Hudson and its residents can undertake to help protect and improve Robinson Pond. Potential near-term, impactful next steps include:

- Continue to collect water quality data through VLAP
- Survey condition and age of septic systems
- Build a structural BMP at the town boat launch
- Build a structural BMP at the town beach
- Work with NHDES Biology to update bathymetry
- Work with NHDES Biology to determine feasibility of deploying continuous data loggers
- Complete an updated nutrient load analysis with current data, including internal loading
- Complete a full USEPA watershed plan with “a – i” elements
- Once external phosphorus loading is controlled, seek funding and approval for in-lake treatments

References

AECOM. (2011). Total Maximum Daily Load for Robinson Pond, Hudson, NH. Prepared for US EPA Region 1, Boson, MA. https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/final-phosphorus-tmdl-report-robinson-pond.pdf

DK Water Resource Consulting LLC. (2024, January). Robinson Pond Sediment Analysis: Technical Memorandum.

Jutras, Dana. (2006). Town of Hudson Conservation Land. Booklet. https://www.hudsonnh.gov/sites/default/files/fileattachments/conservation_commission/page/7581/cc-brochure.pdf

Nashua Regional Planning Commission (NRPC). (2018). Town of Hudson, New Hampshire Hazard Mitigation Plan Update 2018. https://cms5.revize.com/revize/nrpc/Document_Center/Regional%20Plan/Hazard%20Mitigation%20Plans/Hudson_HazMit_Update2018.pdf

Nashua Regional Planning Commission (NRPC). (2023). Regional Housing Needs Assessment. https://cms5.revize.com/revize/nrpc/Document_Center/Land%20Use/NRPC%20RHNA%202023%20Final.pdf

Nashua Regional Planning Commission (NRPC). (2000, December). Robinson Pond Nonpoint Implementation Project. https://cms5.revize.com/revize/nrpc/Document_Center/Publications/Water%20&%20Watershed/2000/hudson_robinpond_dec00.pdf

NHDES. (2023). 2023 Volunteer Lake Assessment Program Individual Lake Reports, Robinson Pond, Hudson. https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2023-robinson-hudson.pdf

NHDES. (2023). Cyanobacteria Plan: A Statewide Strategy. https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/r-wd-23-12.pdf

NHDES. (2019). Environmental Fact Sheet Fanwort. WD-BB-25. https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/bb-25.pdf

NHDES. (2019). Environmental Fact Sheet NHDES' Lake Trophic Survey Program. WD-BB-16. https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/bb-16.pdf

NHDES. (2019). Environmental Fact Sheet Variable Milfoil. WD-BB-23. https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/bb-23.pdf

NHDES. (2022, February). Long-Term Variable Milfoil & Fanwort Management Plan, Robinson Pond, Hudson, New Hampshire. https://www4.des.state.nh.us/onestoppub/TrophicSurveys/Robinson%20LTMP_2022.pdf

NHDES. (1994). Robinson and Ottarnic Ponds Diagnostic / Feasibility Study. https://www4.des.state.nh.us/onestoppub/TrophicSurveys/1994_Robinson_Ottarnic_Hudson_DFS.pdf

New Hampshire Fish and Game. (2023, June). Bathymetry Depth Map, Robinson Pond, Hudson. https://www.wildlife.nh.gov/fishing-new-hampshire/nh-bathymetry-maps

New Hampshire GRANIT. (2022). NH Dam Inventory. https://www.nhgeodata.unh.edu/datasets/bc5c6b4c998b4100b7c4f8089f702717/explore

New Hampshire Office of Planning and Development. (2023, August 4). 2022 Population Estimates of New Hampshire Cities and Towns. https://www.nheconomy.com/getmedia/27cea37d-aa40-482c-bb4b-6d330cc92f2f/2022-Population-Estimates.pdf

VHB. (2023, June). Draft Year 5 Version of Phosphorus Control Plan for Town of Hudson, NH Robinson Pond. Prepared for Town of Hudson, NH. https://www.hudsonnh.gov/sites/default/files/fileattachments/stormwater_committee/page/2281/2023-06-30_year_5_robinson_pond_phosphorus_control_plan.pdf

Appendix I: Technical Memo

Memorandum

To: Nashua Regional Planning Commission
Emma Rearick
Project Manager

Date: March 11, 2024

Project #: 52868.00

From: Bill Arcieri & Garrison Beck

Re: Robinson Pond Water Quality Protection Plan

Purpose & Introduction

This technical memo is being provided to the Nashua Regional Planning Commission (NRPC) to support the development of a Water Quality Protection Plan (WQPP) for Robinson Pond in Hudson, New Hampshire. Robinson Pond has a history of declining water quality and recently has experienced more frequent and longer duration cyanobacteria blooms. Cyanobacteria blooms are generally caused by excessive nutrients in the water column, mainly phosphorus. This past September blooms were present for most of the month, making the pond essentially unusable for swimming and other recreational uses. The New Hampshire Department of Environmental Services (NHDES) 2020/2022 303(d) list identifies Robinson Pond (AUID: NHLAK700061203-06-01) as being impaired for Primary Contact Recreation due to elevated levels of chlorophyll-a (Chl-a), cyanobacteria, and *E. Coli* bacteria. The Pond is also listed as impaired for Aquatic Life Integrity due to chlorophyll-a (Chl-a), low dissolved oxygen saturation, non-native aquatic plants, total phosphorus, and pH. The Robinson Pond Town Beach (AUID: NHLAK700061203-06-02) is also listed due to elevated levels of cyanobacteria, and *E. Coli* bacteria. NHDES has been monitoring cyanobacteria levels going back to 2004 in various lakes throughout the state including Robinson Pond. Health advisories are issued if samples exceed the state water quality limit of 70,000 cells/mL or if more than 50% of the sample is comprised of cyanobacteria cells, advising recreationists to refrain from wading, swimming, or drinking the water with elevated concentrations.

NHDES has issued health advisories for elevated cyanobacteria levels in Robinson Pond in 9 out of the last 19 years going back to 2004. Typically, these advisories are associated with an early season bloom detected in June or July and a second bloom is observed in August or September with each bloom lasting 7 to 10 days. In 2022, an extended cyanobacteria advisory lasted for 49 days beginning on September 20 and extending into November. At its peak, cyanobacteria density counts reached 3.5 million cells/mL on October 3rd. In 2023, only one advisory was issued that lasted for 7 days from July 5 to the 12th, a peak time of summer activity.

Water Quality Improvement Goals

The 2011 Robinson Pond Total Maximum Daily Load (TMDL) study recommended that the average annual total phosphorous (TP) watershed load be reduced by 40% to lower the average in-lake phosphorus concentration to 12 µg/L.[1] In 2021 the average TP concentration was 18-20 µg/L in the epilimnion with even higher concentrations in the deeper water. The suggested 12 µg/L represents a typical median TP concentration for less productive, mesotrophic lakes in New Hampshire and is expected to improve Robinson Pond's water quality to support its designated beneficial uses and reduce the likelihood of cyanobacteria blooms. This 40% reduction means that the estimated TP load of 115.2 kg/yr (254 pounds/year) developed by the TMDL would need to be reduced by approximately 46.0 kg/yr (102 lbs/yr).

1 Total Maximum Daily Load for Robinson Pond, Hudson, NH. Prepared by AECOM for NHDES. EPA Region 1, Boston, MA. January 2011. https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/final-phosphorus-tmdl-report-robinson-pond.pdf

However, when focusing on only the manageable sources within the watershed area (i.e., excluding estimated loads from atmospheric deposition, waterfowl, and the watershed portion in Londonderry), the TMDL Study indicated a 48% load reduction would be needed to achieve the suggested in-lake average phosphorus concentration. As Robinson Pond has an approved phosphorus TMDL study, the 2017 NH MS4 Permit requires the Town to develop a Phosphorus Control Plan that identifies source control measures and stormwater treatment Best Management Practices (BMPs) that can be adopted to achieve the suggested reduction goal, which is also listed in Appendix F of the 2017 NH MS4 Permit as a 48% reduction target for Robinson Pond.

In response to this requirement, the Town of Hudson has also developed an interim Phosphorus Control Plan (PCP) for Robinson Pond, which was last updated in June 2023 and can be found on the Town web site (https://www.hudsonnh.gov/bc-swc). The Plan identifies various structural and non-structural measures that could be used to achieve the targeted load reduction over a 15+/- year time period. The 2017 MS4 Permit also imposes an interim milestone target of achieving a 30% load reduction by Permit Year 8 or Fiscal Year 2026. The PCP provides background information on existing conditions, potential funding sources and a list of BMPs consistent with the pending WQPP to be developed by NRPC.

Best Management Practices to Achieve Water Quality Goals

Achieving the phosphorus load reduction targets for Robinson Pond will require a multi-faceted approach as no single effort or measure is likely to reduce the current loading to levels that will result in meaningful water quality improvements. The following section describes potential structural and non-structural BMPs.

Structural BMPs

Town-owned Land & Roadways

Through field investigations, review of stormwater infrastructure, aerial imagery, and drainage patterns, VHB identified seven locations within the Robinson Pond watershed where structural BMPs may be the most plausible to treat runoff from roads and residential development. Much of the treatment potential is limited by the amount of available space within the Town owned right of way and shoulders along municipal roadways. These roads are narrow, often highly vegetated and may contain wetland areas, which represent physical and regulatory constraints that limit feasibility. Depending on the drainage area size and sizing criteria, certain structural BMPs may require a larger footprint that would extend beyond the right-of-way limits and thus would require permission property owners to establish maintenance easements to allow access to inspect and maintain any constructed BMPs.

The Town's boat launch and the Robinson Pond beach parking lots present opportunities for structural BMPs to manage and treat stormwater before it drains to the pond. Channelized scour areas have been observed at both locations, indicating that stormwater runoff, potentially carrying sediments and possibly nutrients, flows directly into the pond with minimal attenuation or treatment. Since both areas are Town owned, no additional property or drainage easements are needed, and modifications could be done in the off-season with minimal disruptions. VHB is currently evaluating potential conceptual designs to reconfigure both the beach and boat launch parking lots in an attempt to capture and treat stormwater runoff via a detention basin or a rain garden in select areas. The conceptual design process is anticipated to be completed in the spring of 2024. The next phase involves acquiring the necessary regulatory permits, potential geotechnical investigations, final engineering design for construction, and identifying the funding, equipment, and personnel resources needed to complete construction of the proposed improvements.

In addition to the parking areas, erosional scour areas have been observed along gravel road shoulders in various locations, especially along steeper roadway sections with no curbing or drainage infrastructure, caused by excessive runoff rates and volumes. The eroded sediments conveyed by stormwater could be contributing excess sediment and nutrients to Robinson Pond. Obvious eroded gullies along road shoulders should be evaluated by DPW personnel and stabilized appropriately to reduce erosion and redirect flow where appropriate to roadside ditches with turnouts. This review may need to be done on an annual or biannual basis to reduce sediment and pollutant loads to the Pond.

Non-Structural BMPs

Land Development Regulation

Existing and future development activity can often be a major source of pollution for downstream receiving water bodies. The extent of the water quality degradation depends on the level of imperviousness, stormwater volumes, and proximity and flow path to the water body (or its tributaries), as well as the measures used to limit sediment disturbances and stormwater runoff generation during construction and post-construction periods. Land use zoning, site development regulations, and other natural resource protection provisions are just some of the non-structural BMPs that towns can use to minimize stormwater pollution from development and other land disturbance activity.

The Town of Hudson has a Wetland Conservation Overlay District (Zoning Regulations Article IX), that establishes local authority for review and approval of new development and the expansion of existing nonconforming structures within 50-feet of the ordinary high-water elevation for adjacent surface water and the delineated jurisdictional limit for wetlands of any size. These regulations restrict new building construction within this 50-foot zone and requires review and approval by the Zoning Board of Adjustment for any expansion or replacement of existing nonconforming uses or structures to assess whether the proposed activity will result in additional encroachment on the wetland or surface water. Any potential increased encroachment requires review by the Conservation Commission to determine how any impact on wetland functions will be mitigated.[2] The Town Ordinance has little guidance on determining how a proposed redevelopment of nonconforming property or structure will be made more conforming or have minimal impact to wetlands. The current regulations also have no specific provisions with respect to restricting vegetation clearing in shoreland areas, minimizing soil disturbances, limiting impervious area, or managing stormwater runoff**.**

With respect to the expansion or replacement of nonconforming structures, the state RSA 483-B:11 allows expansion of existing structures within protected areas so long as the existing structure or property is made "more nearly conforming." Greater conformity may be achieved through a reduction of the structural footprint, improved stormwater management, enhanced wastewater treatment, or improvements of wildlife habitat. NHDES provides a permitting form for applicants to describe how they plan to meet this standard; however, no explicit thresholds are provided in determining when these objective standards for "more nearly conforming" redevelopment are met. The town may consider local ordinance changes or development of guidance documentation to assist waterfront landowners in understanding specific measures that can be taken when redeveloping their property to make it more nearly conforming and improve stormwater management.

As discussed further in the recommendations section, the Town should consider modifying its Wetlands Conservation Overlay District or establish a new Watershed and Wetlands Overlay District to expand the jurisdictional limits to 100-

2 Code of the Town of Hudson, New Hampshire. Part II: General Legislation, Article IX Wetland Conservation District § 334-36D(1). https://ecode360.com/35972700

feet or more and include other provisions/restrictions to enhance water quality protection. At a minimum, the Town should include provisions to be at least as protective as those in the state' Shoreland Water Quality Protection Act (RSA 483-B) regulations, with respect to limiting the amount of new impervious area, restricting the clearing of mature vegetation, increasing the setback requirements for new and replacement septic systems, and to clarify the definitions of encroachment and the mitigation measures or structures as part of any future alteration or expansion of nonconforming properties to minimize water quality impacts to adjacent water bodies and wetlands. Shoreline vegetation, especially dense groundcover and tree canopies are critical to minimizing and treating stormwater runoff and stabilizing soils.

As a separate but equally important issue, the Town should include additional erosion control inspection and reporting requirements for land disturbance activities within the watershed in the Wetland Conservation District Overlay Regulations if developed. Such a regulation could be structured to require the project owner/proponent to fund the inspections, but a third party inspector would report directly to the Town Engineer or Code Enforcement Officer. The inspection frequency and reporting format could follow the EPA Construction General Permit (CGP) provisions but could be triggered by smaller land disturbance activities such as 15,000 square feet or more, instead of the 40,000 square foot threshold used in the EPA CGP.

The NH Shoreland Water Quality Protection Act (SWQA) Regulations (Env-Wq 1400) regulate new and redevelopment activity *(e.g., construction, excavation, or filling activities)* within 250-feet of a protected shoreland area which includes areas along great ponds larger than 10 acres in size and 4th order streams and rivers (See SWQA FAQs at https://www.des.nh.gov/protected-shoreland-faq). These regulations prohibit new construction within 50 feet of a water body's reference line and restricts the amount of vegetation clearing by requiring at least 25% of the land area be maintained as native woodland, limits the amount of impervious area between 50 and 150 feet and prohibits fertilizer, pesticide, and herbicide applications within 25 feet of public waters except if done by licensed applicators. Impervious surfaces are limited to no more than 30% of the protected shoreland area unless a stormwater management system, designed and certified by a professional engineer, is implemented. If impervious surfaces within the protected shoreline exceed 20% but are less than 30% of the parcel area, a stormwater management system shall be implemented consistent with NHDES Alteration of Terrain rules.

The SWQA regulations also include a 125-foot setback for new septic system leach fields (disposal area) on properties adjacent to lakes and ponds with well-drained soils. For soils with a restrictive layer within 18 inches of the soil surface, the setback can be reduced to 100 feet, and all other soil conditions require a minimum setback of 75 feet. According to data from the USDA Natural Resource Conservation Service, most soils around Robinson Pond are well drained soils or Hydrologic Soils Group B soils meaning a 100-to-125-foot setback would be most appropriate. The setback requirements for replacement of existing systems leach fields is the same as that for new systems, "to the maximum extent feasible." Neither the statute nor NHDES rules Env-Wq 1000 for individual sewage disposal systems define criteria by which the maximum extent feasible shall be judged.

The Town of Amherst has established a Wetland and Watershed Conservation District which restricts construction of new primary structures with 100 feet around lakes and ponds. Expansion of nonconforming structures is allowed provided the expansion is located as far from the water body as possible and any decrease in wetland function is

mitigated on site.[3] Several NH communities have also established additional septic system inspection and maintenance requirements for shoreland systems, which are discussed in more detail below.

To assess the current status of developed shoreland properties around Robinson Pond, VHB also conducted a limited visual survey of the shoreline properties to assess the relative amount of naturally vegetated areas, lawn area and/or exposed soil areas along the shoreline, especially developed properties. Each property was assigned a relative rating score based on the visual observations. Properties with relatively more woody vegetation, limited lawn area and less exposed soil area were generally rated as in good condition and had lower scores whereas shoreland properties with limited or no vegetation, extensive lawn area and exposed soil areas were generally rated as being in poor condition with relatively higher scores indicating a higher potential for shoreline erosion. Based on this survey, approximately 25% of the parcels were rated as good condition with relatively low scores, 50% were rated as relatively fair or moderate condition, and 25% were rated as in poor condition with relatively higher scores due to limited or no woody vegetation and/or extensive lawn area across the waterfront. These parcels should be considered a priority for homeowner engagement for future improvement. Extensive lawn areas not only promote greater runoff volumes but allow for higher nutrient loads as grass clippings, pet waste, and even residual fertilizer may get washed directly in the pond. Woody vegetation also provides slope stabilization benefits and protects shorelines from erosion due to wave action. See Attachment B for a Tech Memo and Map Figure that presents the results of visual shoreland assessment.

Septic Systems

Individual Sewage Disposal Systems (ISDS, aka septic systems) are regulated by RSA 485-A Water Pollution and Waste Disposal statutes as well as NHDES rules Env-Wq 1000. Within the Robinson Pond watershed, all wastewater disposal is the responsibility of the property owner. In Hudson, the public wastewater collection system ends near the intersection of Rangers Drive and Barretts Hill Road.

The 2011 TMDL study had estimated that the average annual phosphorus load from the 21 homes utilizing septic systems within 125 feet of the Robinson Pond was approximately 8.4 lbs./year. This accounted for approximately 2% of the total phosphorus load to the pond and translates to approximately 0.4 lbs./year per home. However, these estimates were based on available literature and not field verification specific to Robinson Pond. Many New Hampshire communities have adopted larger setback or separation distances of 125 feet for septic systems from the reference line of sensitive surface waters.

Traditional septic systems are designed with the intent of removing pathogens from wastewater, not for the control of nutrients. Treatment of pathogens and some nutrient reduction typically occurs at the "biomat," or biomaterial, a layer of anaerobic bacteria which form within the saturated zone of the disposal field. If, for example, a system is incorrectly installed and wastewater drains too quickly away from the disposal field, the soils may not remain saturated long enough for the biomat to form, and domestic wastewater receives little, if any, treatment. Depending on how close the disposal field is located to a surface water body or groundwater and native soil conditions, poorly treated wastewater can flow to surface waters, negatively impacting nutrient or bacteria levels.

However, there are many reasons a septic system may not be functioning properly including failed or clogged tanks or leach fields, the current use is greater than what it was originally sized for, lack of maintenance, intrusion or tree roots,

3 Ordinances, Laws, and Regulations for the Town of Amherst, New Hampshire. Article IV Zoning Regulations, Section 4.11 Wetland and Watershed Conservation District, Part H.(4). March 2022. https://www.amherstnh.gov/sites/g/files/vyhlif4116/f/uploads/sec_a_zoning_ord_2022.pdf

or exposed to high groundwater levels. These are all risk factors which may be indicators of systems contributing excessive nutrients and bacteria. These systems can largely go unnoticed especially if used intermittently and/or if not maintained by property owners. In some cases, property owners may not be aware of their septic system location or maintenance needs. A failing septic system may go unnoticed until there is catastrophic failure, such as the clogging or backup of indoor plumbing or surface discharge breakout. In general, only one or two failed systems can be a major source of nutrients if surface outbreaks drain more or less directly to the pond.

Since 1993, NH Statute RSA 485-A:39 requires property owners of any developed waterfront property that has a septic system that is fully or partially within 200 feet of a Great Pond have septic system evaluation performed by a licensed subsurface sewer or waste disposal system designer prior to the execution of a proposed sale of such property. This evaluation is primarily for purposes of informing the potential buyers and lenders as to whether the system currently meets the state subsurface wastewater disposal design standards. An evaluation form is to be completed and included in the purchase and sale agreement of the property. The site evaluation results are *not* required to be submitted to NHDES or the local municipality. Moreover, there is no requirement for the seller or buyer to upgrade the septic system if it is deemed not to meet current design standards. Often, the cost of any potential system upgrade or replacement is negotiated as part of the selling price, but the buyer may not necessarily complete the system upgrade following the completed transaction.

Street Sweeping & Catch Basin Cleaning

Within the Robinson Pond watershed, the Town maintains approximately 11 miles of locally owned roads which represents approximately 4% of the 281 miles of the Town's roads. Data provided by the Department of Public Works indicated that approximately 974 cubic yards of sediment and organic material was removed via street sweeping between July 2021 to June 2022. For the 11 miles of Town roads in the Robinson Pond watershed, this translates to approximately 39 cubic yards of sediment and organic material removed from annual sweeping within the watershed.

The 11 miles of Town road in Robinson Pond watershed includes approximately 29.3 acres of pavement, assuming a standard width of 22 feet, which results in an estimated annual phosphorus load of approximately 39.3 lbs/year using the pollutant load estimate methodology included in Attachment 2 of Appendix F of the 2017 New Hampshire Small MS4 General Permit. Based on the EPA phosphorus load credit methodology, street sweeping twice per year in spring and fall with a mechanical broom sweeper results in approximately a 1% reduction, or an estimated 0.4 lbs of phosphorus removal per year.[4] Greater phosphorus removal could be achieved if the Town were to increase its sweeping frequency to monthly from March through November within the watershed. This would increase the phosphorus removal efficiency to approximately 3% and would result in an estimated P removal of 1.2 lbs per year.[5] Sweeping with a high efficiency regenerative air-vacuum sweeper early in the spring and twice per month in the fall (September-November) could improve removal efficiency to approximately 15%, which would result in an estimated removal of 5.9 lbs per year according to the nutrient removal credit data published by the UNH Stormwater Center.[6]

With respect to catch basin cleaning, according to the Town's GIS records, approximately 219 storm drain inlets are located within the Robinson Pond watershed. However, the actual number of catch basins may be much less as the database does not differentiate between inlets, culverts and catch basin. Using methods described in Attachment 2 to

4 (29 acres IA) x (1.96 DCIA PLER Med-Density Residential) x (0.01 Mechanical Broom PRF) x (2/12 months/year)
5 (29 acres IA) x (1.96 DCIA PLER Med-Density Residential) x (0.03 Mechanical Broom PRF) x (9/12 months/year)
6 Clean Sweep Recommendations for New and Updates Steet Cleaning Credits. https://scholars.unh.edu/prep/458

Appendix F of the 2017 NH Small MS4 General Permit and assuming the 11 miles of municipal road impervious area is collected by catch basins, approximately 1.14 pounds per year of phosphorus would be removed. The EPA calculation method assumes catch basins are maintained at no more than 50% capacity. It is understood that the Town's catch basin cleaning program rotates between the north and south sections of the Town. To maximize phosphorus reduction potential, the Town should prioritize annual spring cleaning of catch basis in the Robinson Pond watershed.

In-Lake Sediments

Internal phosphorus loading from pond bottom sediments can also have a major role in the nutrient budget of a water body. Bottom sediments can contain phosphorus and other nutrients from organic matter that accumulates over time. Phosphorus is typically bound to the sediments through chemical reactions with iron and aluminum oxides, rendering it unavailable for algal growth within the water column. However, when a lake thermally stratifies during summer months, the water at the bottom of the pond (the hypolimnion) often becomes oxygen depleted or anoxic due to the decomposition of organic matter and the lack of circulation with the more oxygenated surface waters. This anoxic water can breakdown the chemical bonds between phosphorus and metals in the sediment, thereby releasing phosphorus into the water column and making it available for algal growth. The phosphorus release can occur anytime water is anoxic near the bottom sediments but become available to cyanobacteria in the fall when the surface waters cool, and the lake turns over causing the water column to fully mix.

Internal loading can create a self-fulfilling feedback loop that can perpetuate the problem. As anoxic water facilitates a greater release of nutrients from bottom sediments, those nutrients fuel more algae growth, which creates more organic biomass when the algae die and sink to the bottom and thus adds to the decomposition process and oxygen depletion. This can create a larger anoxic zone in the summer, which may expose even more sediments to anoxia and release even more nutrients as part of the internal loading process. Even a small to moderate increase in phosphorus levels from internal loading can have a meaningful effect on algal growth.

The 2011 TMDL Study estimated that internal loading from bottom sediments contributed approximately 5.1 lbs. (2.3 kg) of phosphorus per year or 2% of the average annual phosphorus load. This estimate was based on an average in-lake phosphorus concentration differential between the deeper and upper waters of 0.039 mg/L based on VLAP data collected from 2001 to 2006. More recent VLAP data collected from 2015 to 2021 indicates a larger difference in the average concentration of approximately 0.091 mg/L between the surface and deeper waters. This change represents more than a 2.5-fold increase and suggests that internal loading is more relevant today than it was 10 years ago.

In 2023, the Town developed a separate study using funds allocated under the American Rescue Plan Act of 2021 (ARPA), to collect bottom sediment samples and analyze for phosphorus and metal content to develop a more recent estimate of the potential internal phosphorus loading to the pond. As part of this effort, additional temperature and dissolved oxygen data was also collected in summer and early fall of 2023 to assess the extent and duration of anoxic conditions at depth. The study results, described in more detail in a separate Technical Memo address to the Town Engineer dated January 15, 2024, that internal phosphorus load from bottom sediments could be as high as 26.3 kg (~58 lbs.) for the summer season, over 10 times greater than the 2.3 kg load estimate included in the 2011 TMDL Study. This revised internal load estimate would represent 23% of the total phosphorus load estimated in the TMDL Study as compared 2% of the overall TMDL Study load estimate. This is fairly substantial increase and is largely attributable to both the amount and availability of phosphorus in the sediment based on the recent analyses and the extent and duration of anoxic conditions within the deeper waters. Much of the pond area below 5 m (~15 feet) at depth was observed to have anoxic conditions for nearly 140 days, over 5 months, which is most of the summer

period based on data collected in 2023. The 2023 summer may or may not have been typical given the prevailing warm temperatures and periodic intense rainfall events. The prevailing cyanobacteria blooms recently observed during August and September could be an indication of a possible internal loading issue.

Public Education Programs

Since much of the watershed and waterfront properties are already developed, targeted public education and outreach programs can be an effective tool for achieving pollutant reductions by encouraging behavioral changes of property owners toward better land management practices that limit impacts to water quality. These best practices could include do it yourself residential landscaping for waterfront buffers, building rain gardens for stormwater treatment, appropriate use of fertilizers, or proper disposal of leaf and lawn debris. Public education programs can also build community support for watershed restoration efforts, encouraging participation in volunteer water quality programs and developing greater awareness of the Town and local organizations' role in watershed restoration. Many resources for public education programs are already publicly available and are discussed further below.

Recommendations

Recommended BMPs described below include both structural and nonstructural measures and are summarized in the attached BMP matrix. The matrix provides an estimate of the potential treated area, expected removal efficiency and the estimated average annual phosphorus load reduction for each BMP, particularly for structural BMPs where existing data allows for potential load reductions to be more easily quantified.

Estimated load reductions for nonstructural measures such as more stringent regulation updates are more difficult to quantify as their effect will depend on how much of the regulated activity occurs in the future and the degree of compliance.

Land Development Regulations

As discussed previously, local regulations for redevelopment of existing nonconforming properties and structures should be reviewed to better define acceptable practices to be protective of water quality. Proposed local changes to improve water quality protections for Robinson Pond could involve the following revisions to the existing Wetlands Conservation Overlay District (Article IX) (See previous Draft Recommendations Memo).

- District Boundary and Setbacks: Extend the Overlay District boundaries to 75 or 100 feet from wetland areas and 100 or 125 feet from a surface water reference line, and:
  - Establish a new primary structure setback of 75 feet and 100 feet for new septic systems from a wetland and surface water, respectively, within the overlay district.
  - Restrict vegetation removal within 50 feet of shoreline buffer or surface waters and require at least 30% of existing woody vegetation be retained within the shoreland overlay district.
  - Limit the amount of new impervious area within 50 feet of the surface water reference line and to no more than 30% of the total parcel area.
  - Require a copy of the septic system site assessments to be completed and submitted to the Town prior to the sale of properties that have a septic system fully or partially within the 250-foot protected shoreline (see additional discussion below).

- Establish a Town database of septic systems on properties within the 250-foot protected shoreline to track septic system assessments and assist homeowners in the design and/or funding of replacement septic systems for improved nutrient removal.

› Enhanced Erosion Control Inspections: The lack of proper erosion control measures even on smaller sites that are located near sensitive water bodies can be a significant source of phosphorus even if it occurs on a periodic basis. The following provisions should be added to the Overlay District regulations.

- The Town should consider requiring erosion control inspections for construction or land development activities disturbing more than 15,000 sq. ft. of area, which will capture smaller projects that are less than the 40,000 sq. ft. disturbance threshold included in EPA's Construction General Permit.
- In addition to the inspections, the Town should also consider requiring that a Stormwater Pollution Prevention Plan (SWPPP) be prepared and submitted for even smaller projects disturbing 15,000 sq. ft.
- The Town should also require the contractor to pay for a 3rd party erosion control inspector that reports directly to the Town or would otherwise receive copies of weekly inspections within 2 business days of inspection.

Land Conservation

The relative amount of impervious area within a watershed is often used as an indicator of surface water quality. In fact, the quantity of impervious area is a critical variable used in watershed pollutant load estimates developed for Robinson Pond as a requirement of the 2017 NH Small MS4 General Permit. Limiting the creation of new impervious areas can be an extremely cost-effective tool for preventing future pollutant loading to Robinson Pond.

The Town of Hudson has fee ownership of several large parcels with shoreline on Robinson Pond which include acres of forested land within the Pond's watershed. These include two large parcels at the northwest area of the Pond (Map-Lots 125-006 and 125-005) collectively called the Parker Nature Area, the Robinson Pond Park along the eastern shoreline of the Pond abutting Robinson Road (Map-Lot 135-004) and two parcels along the southeast shoreline at the Pond outlet (Map-Lot 144-002 and 144-001).

While these parcels may include deed covenants or have certain protections under the Town's Conservation Commission, land owned entirely by the Town could theoretically be at risk of sale if local political conditions were to change in the future or during economic downturns. NRPC and the Town may consider further land conservation protections for these parcels through the sale of conservation easements to local land conservation partners. Further research is required to determine the current conservation status of these parcels and the extent of existing protections. The protection of existing forested land and limited development of new impervious areas are cost-effective measures for protecting Robinson Pond water quality.

Structural Stormwater BMPs for Town-owned Land & Roadways

As shown in Table 1, VHB has identified several locations on Town-owned land and roadway right-of-way areas in close proximity to the pond where stormwater treatment BMPs could potentially be installed. Two key areas include the boat launch parking area and the nearby Town beach. Stormwater at both locations currently drains directly to the lake via overland flow. Several channelized scour areas are evident in both locations indicating that at times eroded sediment along the parking lot edges and beach are discharged directly to the lake. The eroded sediment could represent a significant source of phosphorus to the lake. Under the Town's separate ARPA-funded project, VHB has

developed preliminary engineering plans to treat stormwater in these locations, improve public access, and limit future erosion by installing permeable pavement within the beach parking lot, stabilize areas of erosion, and to install bioretention systems along the boat launch parking lot. The bioretention systems are listed as having a 70% phosphorus removal efficiency based on a proprietary filter media. This reported removal efficiency is similar to that provided for permeable pavement according to the EPA BMP performance curves included in Appendix F of the 2017 NH MS4 Permit. The boat launch and beach parking lot areas comprise a total of approximately 1.0 acres in area and with an estimated average annual phosphorus load of 1.34 lbs/ac/yr, according to EPA's load coefficients for roadways, the proposed stormwater treatment for these two area could result in a potential phosphorus load reduction of approximately 0.7 to 1.0 lbs/year as result of this project, dependent on final design and sizing details.

Septic Systems

As mentioned above, the Town should consider establishing a new Watershed and Wetlands Overlay District or modifying the existing Wetlands Conservation District ordinance to expand the jurisdictional review limits from 50 feet for septic systems to at least 100 feet for major surface waters and perhaps 250 feet for Robinson Pond and its tributaries (Otternick Pond could also be included) similar to the current NHDES regulations. The proposed ordinance would require septic systems within this overlay district to be inspected or assessed by a qualified individual as part of any future real estate transaction, and upgrades will be made to current design standards. These assessments help to ensure septic systems are designed and function in accordance with current state rules and provide additional assurances to the buyers purchasing properties. Septic system evaluations have also become more commonly required by mortgage lending institutions. Including this requirement into the local regulations would give the Town more oversight and authority to require a copy of the septic system assessment be provided to the Town Engineering and Planning Departments. In addition, the Town could require or at least promote the installation of septic systems with advanced wastewater treatment within this district. Septic systems with advanced treatment are specifically designed to treat nutrients in wastewater, in addition to the treatment of pathogens that most traditional systems provide. Nutrient treatment with advanced septic system designs is an increasingly common tool used to protect water quality in nutrient-impaired watersheds.

The Town should also request from NHDES copies of any recent state permit approvals for new system upgrades or replacements for systems on properties within the 200-foot shoreland buffer, if not already done. An even more protective provision would involve require submittal of any future septic system pumping records to the Town to ensure that the systems have been maintained. Any property that has not submitted a pumping record over a 10-year period would be required to have their septic system assessed and evaluated similar to that done for real estate transactions. The Town of Meredith has adopted local septic system regulations that requires property owners with septic systems within 250 feet of Lake Waukewan to have their systems evaluated by a licensed septic designer or evaluator within the 2 years of the effective date of regulations and every 5 years thereafter regardless of property sale activity.[7] The Town of Sunapee recently adopted similar regulations but only requires a copy of the system evaluation form done as part of a property sale be provided to the Town within 10 days of the sale execution.[8]

Elsewhere in New England, the town of Charlestown, Rhode Island completed a Coastal Watershed Protection and Restoration Program project from 2016 through 2020 which was funded by USEPA through the Southeast New England Coastal Watershed Restoration Program. The project was successful in requiring landowners to upgrade

7 Town of Meredith Septic System regulations. https://www.meredithnh.org/sites/g/files/vyhlif4681/f/uploads/septic_regs_.pdf
8 Town of Sunapee Septic System regulations. https://www.town.sunapee.nh.us/sites/g/files/vyhlif5056/f/uploads/septic_rules.pdf

septic systems to advanced treatment systems for nutrient removal. The project's final technical and financial report includes several examples of notable ordinance changes and opportunities for technical assistance which the Town could consider for Robinson Pond.[9]

Alternatively, or in addition to new regulations, it is recommended that the current status of the septic system within 250 feet of Robinson Pond be inventoried in terms of type, location, age, number of bedrooms and recent maintenance activity. This inventory could initially rely on review of recent NHDES and Town records of installations/ system upgrades and inspection results conducted during property sale, as well as through a voluntary survey questionnaire perhaps with assistance of the Friends of Robinson Pond, in terms of reaching out to shoreland property owners as well as other stakeholders. Landowner participation from could be incentivized by septic system pump-out coupons or free inspection. Such a survey would provide a baseline of the homeowner's knowledge of their systems and maintenance needs.

Street Sweeping & Catch Basin Cleaning

Hudson Department of Public Works (DPW) staff currently rotate the annual start dates of street sweeping and catch basin between the north and south sides of the Town. DPW should consider prioritizing street sweeping sand in the Robinson Pond watershed as early as possible in the spring to remove winter sand and again in October for lawn debris pickup. To achieve the maximum benefit, the Town should either lease or hire a contractor with regenerative air vacuum sweeper to perform street sweeping in the Robinson Pond watershed. Per recent street sweeping credit updates published by UNH Stormwater Center, sweeping every other week from September to November (~ 6 events) in the fall with vacuum sweeper could increase phosphorus removal efficiency from 2% to 15% per year or more than a 10-fold increase in removal efficiency. The added cost to perform this higher level of sweeping service should be investigated.

In addition, catch basin cleaning within the Robinson Pond watershed should begin as early as possible in the spring to significantly reduce the potential for accumulated winter sand to fill catch basin sumps and transport pollutants downstream into the pond. Cleaning and maintaining catch basin sump capacity early in the season also restores the stormwater volume reduction and pollutant removal capacity within the closed drainage system.

In-Lake Sediments

Based on the results of the 2023 study that suggests that internal phosphorus loading may be a much larger component of the lake nutrient inputs to the Pond than previously thought, the Town should begin to evaluate possible various internal loading controls through consultation with NHDES and subject technical experts.

Potential in-lake control strategies may involve mechanical aeration to reduce the extent and duration of anoxic conditions and associated internal phosphorus loading, increased water circulation, and phosphorus inactivation through alum or other chemical treatments. Each of these strategies have varying levels of potential effectiveness, costs, regulatory limitations and longevity. As indicated in the recent Bottom Sediment Analysis Report, the potential costs for these in-lake controls can widely vary and could range in an order-of-magnitude from $250,000 to $500,000 or more depending on the control measure and various other factors. NHDES generally considers the benefits of in-

9 Town of Charlestown, R.I. Coastal Watershed Protection and Restoration Program. Final Technical and Financial Report. March 24, 2021. https://www.charlestownri.org/vertical/sites/%7BDF68A5B8-A4F3-47A1-AE87-B411E21C6E1C%7D/uploads/EPA_SNEP_Grant_Final_Technical_Report_3-24-21.pdf

lake strategies to be temporary as their effects will likely diminish over time if phosphorus inputs from watershed sources are not curtailed was well. Approval of any future in-lake strategy will likely be contingent on a long-term plan be developed for watershed-based source control measures.

Public Education Workshops of Shoreland Buffers and Lake Stewardship

The Town of Hudson should seek to engage available technical resources though the NH Lakes Program or NHDES "Soak up the Rain" Program to host targeted education events and workshops focusing on best practices for shoreland and low tech, residential stormwater management practices. Specifically, these events and workshops could focus on best practices for homeowners to install small scale stormwater practices to promote infiltration and reduce runoff, vegetated plantings, and septic system maintenance.

Suggested Roles and Responsibilities for Executing Potential Next Steps

The following is list of suggested roles and responsibilities for various near term follow-up activities and next steps identified as part of this process and information collected to date. The identified next steps and priorities are likely to change as new data is collected and additional activities are completed and are dependent on available funding.

Town of Hudson

- Evaluate the feasibility and potential cost of hiring a more efficient, air-regenerated vacuum sweeper for initial Spring sweeping (March-April) and monthly from September to November to achieve the higher phosphorus removal credits outlined by the UNH Stormwater Center.
- Develop a process to review, identify and repair eroded scour areas along roadside shoulders and ditches that lead to catch basins and culverts that discharge directly to the pond and reduce sediment erosion.
- Identify and pursue funding sources to fund stormwater management improvements at the boat launch and beach parking lots and town roadways that drain to the pond, as well as potential in-lake treatment strategies.
- Work with NRPC circuit rider planner, Town Planner, Planning Board and Conservation Commission members to review and update the Wetlands Conservation Overlay District regulations to expand jurisdictional limits and add greater water quality provisions similar to those adopted in other NH communities to limit vegetation clearing, reduce impervious areas, minimize soil disturbances and add septic system inspection and maintenance requirements for applicable systems with the designated shoreland zone.
- Maintain a shoreland septic system data base to track and retain the status of existing septic systems with regard to installation dates, replacement and upgrade approvals and inspection and maintenance activity.
- As part of the local regulation update, implement additional erosion control inspection and reporting provisions for larger development and soil disturbance activities (e.g. transmission line upgrades) in the watershed.

VHB

- Work with Town officials to facilitate initial permitting discussions with NHDES for the proposed stormwater management improvements at the beach and boat launch facility and discuss the potential feasibility for future in-lake alum treatment(s). Additional funding will be needed to finalize engineering plans and fully develop all of the necessary permitting materials and any related studies.

- Discuss with NHDES personnel the possibility of obtaining or developing updated bathymetric data for the pond through the existing ongoing bathymetric survey programs and use updated data to finalize internal load estimates.

Nashua Regional Planning Commission

- Work with the Town to assist in modifying existing ordinances and/or establishing new regulations and language to enhance water quality protection provisions for developed shoreland properties and new development or other soil disturbing activities in the watershed.
- Work with the Town to identify funding sources and pursue grant opportunities to help fund structural improvements, enhanced long-term planning studies and public outreach/engagement activities.
- Finalize the pending Water Quality Protection Plan to help set the stage for identifying priorities for future implementation and funding needs.

Appendix II: Structural BMP Matrix

Table 1 Robinson Pond BMP Matrix – Structural BMPs

Estimated Source Contributions		Implementation								
Location/ Area to be Treated (ac)	Est. Annual Phosphorus Load (lbs/yr)[1]	Est. Treatment Volume (cu. ft.)	Preliminary Assumed Treatment Measures[2]	Design Storage Volume (in)[3] – High/ Low Estimate	Est. TP Removal Efficiency	Est. TP Load Reduction (lbs/yr)	Order of Magnitude Construction Cost[4]	Cost per Pound Reduced	Constraints	Priority
East										
Town Boat Launch / 0.6 ac	0.66	1,200	Filterra bioretention	0.20"/0.60"	35% / 70%	0.22 /0.48	$20k - $30k	$35k - $75k	Depth to GW table	High
Town Beach / 2.7 ac	0.42	4,900	Permeable pavement	12" / 24" Filter depth	62% / 75%	0.26 / 0.31	$150k-$220k	$700k - $800K	Depth to GW table, space, chloride contamination	High
			Bioretention basin	0.20"/0.60"	60% / 90%	0.25 / 0.38	$50k - $90k	$200k - $300k		
			Perched Beach	-	-	-	TBD			
David Drive / 7.5 ac	1.25	13,200	Bioretention / Rain Garden	0.20" / 0.60"	25% / 44%	0.31 / 0.55	$50k- $500k	$900k - $1M	ROW space	Mod
Kienia Rd @ Edgewood / 2.3 ac	0.46	4,200	Bioretention / Rain Garden	0.20"/ 0.60"	25% / 44%	0.11 / 0.20	$50k -150K	$800k - $1.5M	ROW Space	Low
West										
Boulder Dr @ Beechwood /1.9 ac	1.10	3,500	Bioretention / Rain Garden	0.20"/ 0.60"	25% / 44%	0.27 / 0.66	$50k- $130k	$200k - $500k	ROW space	High
Stoney Lane / 44.8 ac	2.20	78,500	Bioretention / Rain Garden	0.20"/ 0.60"	25% / 44%	0.55 / 0.97	$50k- $1.0M	$3.0M - $5.3M	ROW space	Mod
Hazelwood Road / 15.7 ac	1.00	22,300	Bioretention / Rain Garden	0.20"/ 0.60"	25% / 44%	0.25 / 0.44	$50k-$500k	$1.9M - $3.3M	ROW space	Mod
Total	**7.1 lbs/yr**				**Low / High**	**~ 2.5/ 4.5 lbs/yr**				

Notes:

1 Estimated phosphorus loads are based on the pollutant load methodology included in Attachment 2 of Appendix F of the 2017 MS4 Permit. Total phosphorus load rate for roadways is 1.34 lbs/yr. Estimated load reduction assumes the entire IC area is treated by the proposed BMP which is likely not feasible in most cases given the limited ROW space for BMP implementation.

2 Preliminary assumed treatment BMPs assume either infiltration where possible or bioretention with filter media – final selection of BMP will depend on site constraints.

3 Preliminary sizing assumes BMP sizing with a low estimate of 0.2" and high estimate of 0.60" of runoff from the treated area. The limiting factor to how much road area can be treated will be available ROW area for BMP implementation which will likely be 0.10 to 0.25 acres.

4 BMP costs estimated by UNH in 2019 and adjusted for inflation by VHB to September 2022 and assumes perhaps as much as 1.0 to 2.0 acres of roadway area could be treated.

Appendix III: Non-Structural BMP Matrix

Table 2 Robinson Pond BMP Matrix – Non Structural BMPs

Source	Responsibility	Potential Treatment Measures	Est. Annual Phosphorus Load	Removal Efficiency[1]	Est. Load Reduction (~ lbs/yr)	Ease of Implement.	Priority Ranking
Residential Development	Hudson Planning Dept./ Conservation Commission	Consider revisions to Town Wetland Overlay District ordinance	Based on direct shoreline areas or % of Res. Dev. load in watershed	5-10%[1]	~ 0.4 - 0.8[1]	Moderate	High
Public Education and Incentive Programs	Hudson Engineering Dept./ Conservation Commission	Work with NHDES "Soak up the Rain" Program to host at least one workshop per year. Establish Lake Steward Award Program to promote good shoreland mgt practices. Establish fund to host tech assistance/ demo projects.	Unknown	Assume 2 property upgrades/yr will treat 0.1-0.2 ac of direct shoreline	~ 0.2 - 0.5[2]	Moderate	High
Street Sweeping	Hudson DPW	Prioritize roads for Spring and Fall sweeping. Contract vendors with regenerative air vacuum sweepers: Increase fall sweeping to 2x month from September to November.	~ 39.3 lbs/yr	2 to 15%	~1.2 – 5.9[3]	Low	High
Catch Basin Cleaning	Hudson DPW	Schedule cleanings in the Spring – track sediment volumes removed	Same as above	~ 2 %	~ 1.0 – 1.5[4]	Low	High
Stabilize Roadway Shoulders	Hudson DPW	Inspect and restore eroded and channelized gravel shoulders following winter snowmelt / major rain events	TBD	Unknown	Unknown	More difficult	Moderate
In-Lake Sediments	Hudson DPW through Consultant	A recent bottom sediment study completed in 2023 indicated that internal P loading from bottom sediments could be as high as 28 kg or ~58 lbs per year or 10x higher that estimated in the 2012 TMDL P study. A separate Jan. 15, 2024 summary memo describes several available in-lake treatment options that should be evaluated in greater detail to identify a feasible solution to reduce P loads from bottom sediments. The potential load reduction effectiveness could likely range from 10% to 90%.	~58 kg	~10%-90%	~5 -50[5]	More difficult due to permit approval needs and cost	High

Notes:

1 Estimated septic system removal efficiency assumes all existing septic systems are properly functioning - higher load reductions may occur if any failed or poorly functioning systems are replaced.

2 The estimated phosphorus load reductions for homeowner stormwater mgt practices assume approximately 0.25 to 0.5 acre is treated by a stormwater BMP with an approximate 50% removal rate.

3 The estimated range of load reductions for street sweeping assume monthly sweeping from March to November using a conventional sweeper versus a vacuum-assisted, regenerative air sweeper for the low and high estimate, respectively.

4 The estimated load reductions for catch basin cleaning assumes catch basins are cleaned often enough such that the catch basins sumps are never more than 50% full to achieve a 2% load reduction.

5 The estimated load reductions for bottom sediment inputs represent a general estimated range of effectiveness for various in-lake treatments where the lower and higher end estimates reflect the expected effectiveness for aeration techniques and a lake-wide alum treatment, respectively. These estimated would need to be verified and adjusted accordingly with additional information.

Appendix IV: Robinson Pond Shoreland Survey

Memorandum

To: Emma Rearick
Nashua Regional Planning Commission

Date: November 8, 2022

Project #: 52868.00

From: Bill Arcieri & Garrison Beck, VHB

Re: Robinson Pond Shoreland Survey

Introduction

VHB and DK Water Resources Consulting (DKWRC) performed a field shoreline survey of properties adjacent to Robinson Pond in Hudson, NH on July 19, 2022. The survey was conducted to gather additional data relevant to the development of a Water Quality Protection Plan for Robinson Pond. This memo summarizes the methods and data collected during the survey.

Methods

VHB developed a shoreline condition assessment based on similar surveys conducted on other lakes in New Hampshire. The assessment was conducted for each waterfront parcel with shoreline development and included six variables which were ranked numerically based on observed conditions. The shoreline features assessed, and the associated ranking criteria is included in the table below. Features were assigned point values based on observed conditions and summed to give a total score for the parcel. Notably, high quality shorelines were rated with low point values, whereas parcels with high total scores those of poorest condition.

Shoreline Feature	Rating Criteria
Shoreline	Qualitative: beach, riprap, natural, lawn, etc.
Buffer	1 – 5: excellent to poor
Bare Soil	1 – 4: area of exposed soils
Shoreline Erosion	1 – 3: little to severe shoreline erosion
Distance	1 – 3: distance of structures from shore
Slope	1 – 3: estimated slope of the parcel
Total	Sum of all numeric columns

Results

The total score assigned to each parcel during field data collection was mapped to the corresponding land use parcel from the Town's GIS database. The range of scoring results are included below. These condition assessments are being considered in the development of a matrix for potential stormwater best management practices.

Total Score	Relative Assessment	Number of Parcels
1-9	Good	8
10-12	Fair	18
13-17	Poor	5

Memorandum

Robinson Pond Shoreline Survey Results

Appendix V: MS4 Permit Crosswalk and EPA Nine Element Crosswalk Tables

Memorandum

To: Emma Rearick, Regional Planner
Nashua Regional Planning Commission

Date: April 17, 2023

Project #: 52868.00

From: B. Arcieri and Garrison Beck

Re: Task 14: MS4 Permit Crosswalk and EPA Nine Element Crosswalk Tables for the Robinson Pond Water Quality Protection Plan

MS4 Crosswalk Table

2017 NH Small MS4 General Permit	Robinson Pond Water Quality Protection Plan (WQPP)
MCM 1: Public Education & Outreach	**Similar Recommended Measures for WQPP**
› Distribute annual public education messages including: • Pet waste collection and disposal • Septic system management • Proper disposal of grass clippings • Use of slow-release or phosphorus-free fertilizers • Proper disposal of leaf litter	› Establish Fund to cover costs to host workshops and invite independent experts on technical assistance and demonstration projects: › Coordinate with NHDES and NH Lakes Program to schedule educational events and workshops including workshops on the following topics: • Annual "Soak Up the Rain" workshop with NHDES • Landscaping for Stormwater Management: Rain Gardens, Waterfront Buffers, and Debris Disposal • Proper Fertilizer Usage (Note: current Hudson Wetland Conservation Overlay District prohibits use of lawn fertilizer w/in 50 feet of reference line) • Best Practices for Lawn and Septic System Maintenance • Post signs to prohibit waterfowl feeding and establish penalties for feeding • More Info on Public Education Messaging Materials can be found at: https://www.nhms4.des.nh.gov/ • NH Lakes Assoc. Members also have access to various resources at: https://nhlakes.org/local-partner-resources/
MCM 2: Public Involvement & Participation	
› Provide opportunity for public review of the Stormwater Management Plan	› Consider becoming a member of the NH Lakes Assoc., if not already, to gain access to technical resources and assistance in creating a Lake Steward Award Program to promote good shoreland management › Conduct property owner survey to inventory status of septic systems and increase homeowner knowledge on system maintenance needs within 250 feet of Robinson Pond
MCM 3: Illicit Discharge Detection & Elimination (IDDE)	
› Investigate, identify, and eliminate illicit sources of non-stormwater discharges into the Town's storm drain system and implement procedures to prevent such discharges. This involves three phases of field efforts to sample and inspect SW outfalls over a 10-yr period or until 2028: • Dry-weather Screening • Wet-Weather Sampling • Catchment Investigations	› Coordinate with Hudson DPW/ Engineering to review IDDE sampling and inspection results to determine if any illicit connections were identified within storm drain system in the watershed, › Coordinate with Town and beach/launch maintenance staff to insure no leakage from dumpster or porta-potty facility, › Post signage promoting pet waste cleanup and perhaps implement administrative fine for not cleaning pet waste, › The Town should consider amending regulations to require septic systems be inspected at least once every 20 years if not previously inspected as part of real estate transactions in that time frame.

Memorandum

MCM 4: Construction Site Stormwater Runoff Control	
› Implement a program to review and inspect erosion control measures for new- and re-development projects disturbing greater than 1 acre of land	› Consider amending the Town Wetlands Conservation Overlay District to extend the district boundaries to 125 or 250 feet of a wetland or surface water reference line instead of 50 feet (See separate Memo on Regulation Update Recommendations) › The authority and purpose section (Item C) of the Town's Wetlands Conservation Overlay District specifies that vegetation removal & land disturbance are subject to the District requirements, but additional clarity may needed to specify how much clearing and disturbance is allowed even on existing residential parcels; e.g., require a % of the parcel width be maintained in wooded vegetation, require a CU permit for proposed land disturbance of 2,500 sf or more within district boundary › Amend Town Site Plan regulations to require any land disturbance activity of >10,000 sf within 250 feet of surface water or wetland to have 3rd party erosion control inspection and reporting directly to Town Engineer. The current Town regs and EPA Construction GP require detailed EC inspections for disturbance of 40,000 sf or more
MCM 5: Post Construction Stormwater Management in New Development and Redevelopment	
› Adopt or update local stormwater regulations to ensure adequate stormwater treatment measures are included in new- and re-development projects disturbing greater than 1 acre of land	› As noted above, amend the Town Wetlands Conservation Overlay District to extend district boundaries to 125 or 250 feet of a wetland or surface water reference line instead of 50 feet consistent with other community regulations and/or NHDES Shoreland Permit requirements. › Establish new setback requirement of 75 feet for new primary structures and septic systems from wetland or surface water reference line (Note: the NH Shoreland Permit Regs establishes a septic setback of 75 feet and 100 feet in soil areas with restrictive layers within 18 inches) › Establish vegetation clearing limits for new construction & expansion of nonconforming structures on shorefront properties as noted above › Update Overly District regs to prohibit any new IC area within 50 feet of shorefront and limit no more than 30% of total parcel area within 150 feet from reference line (see separate memo on regulation updates) › Update Overlay District regs to add more clarity on the mitigation measures that will make a proposed replacement or expansion of a nonconforming structure within the District more nearly conforming than existing conditions, especially if the proposed expansion or replacement involves greater buffer encroachment, increased impervious area or additional vegetation clearing. › NH Homeowners Guide to Stormwater Management can be found at https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/homeowner-guide-stormwater.pdf › Amend regulations to require the Town Engineer be provided a copy of the septic system evaluation as required during real estate transactions of developed waterfront property on lakes and ponds greater than 10 acres per RSA 485 A:39. See DES Fact sheet SSB-10 at NHDES web site: https://www.des.nh.gov/land/waterfront-development

Memorandum

MCM 6: Good Housekeeping and Pollutant Prevention for Municipal Operations	
› Implement an operations and maintenance program which minimizes the potential for stormwater pollutant export from municipal operations	› Prioritize roads in watershed for early street sweeping Spring and Fall and increase sweeping frequency to monthly from March through November and twice monthly from September through November › Contract vendors with regenerative air vacuum sweeper › Schedule cleanings in the Spring and track sediment volumes removed › BMP installation at the town's boat launch at Robinson Pond: installation of subsurface storage / infiltration chambers (or porous pavement) and redefining parking spaces. Additional improvement of launch ramp to minimize sediment disturbances. › BMP installation at the town's parking lot at Robinson Pond: re-grading slope away from pond into detention basin / rain garden. › Implement road shoulder stabilization and maintenance where necessary as observed by DPW
Appendix F: Lake Phosphorus Control Plan	
› Year 5 (June 2023) • Cost & funding source assessment • Description of planned structural & nonstructural controls • Description of operations & maintenance plan • Implementation schedule • Complete written LPCP within 5 years › Year 6 (June 2024) • Full implementation of nonstructural controls › Performance evaluations each year thereafter	› Coordinate with Town on potential funding of future BMP Implementation through CIP plan, recreation impact fees, capital reserve funds, state/federal grant, and revolving loan opportunities › Coordinate with Town Planning Dept. & Conservation Commission on suggested regulation updates discussed above › See proposed stormwater treatment BMP listing in Draft Technical Memo, › Review UNH SC "hot-spot" mapping data developed for Robinson Pond to compare potential BMP sites, pollutant load reduction and preliminary cost estimates https://www.unh.edu/unhsc/ms4-resources https://www.nhms4.des.nh.gov/nh-resources/permittee-specific-resources/hudson › Establish long-term BMP implementation schedule for next 15 years › Develop process to initiate preliminary engineering of proposed BMPs › Target implementation of at least one BMP by end of 2024 (e.g., beach parking and boat launch area are good candidates)
Appendix H: Bacteria & Pathogen Impairments	
› Public Education • Distribute annual educational materials encouraging the proper disposal of pet waste and septic system maintenance › Illicit Discharge • Catchments draining to waters impaired due to bacteria or pathogens shall be designated high priority for conducting the illicit discharge detection and elimination program required by this permit	› Town DPW / Engineering provides a general public information brochure during summer months to promote septic system pumping but Friends of Robinson Pond may want to implement more targeted information using the NH Lakes Program resources and perhaps raffle off or award free pumping service for good stewardship practices. › More innovative controls and public messaging may be needed to prohibit waterfowl feeding along beachfront to limit bacteria exceedances and beach closures. › Enhanced messaging and facilities may be needed for pet waste and other waste controls in beach and boat launch area

Memorandum

EPA 9-Element Watershed Plan Crosswalk Table

US EPA 9-Element Plan	Robinson Pond Water Quality Protection Plan
a. Identify & quantify sources of pollution in the watershed	› Methods to identify and quantify pollution: • Monthly temperature and dissolved oxygen profile collection in Robinson Pond to identify internal loading contributions to overall pollutant loading in the pond • Limited sediment sampling study in Robinson Pond to assess the ability for sediment to bind to or release phosphorous • Require shoreline septic systems be inspected at real estate transactions and / or once every 10 years • DPW monitoring of road shoulders for erosion due to excessive runoff • Amend regulations to require the Town to receive a copy of inspections results from septic system assessments as required by RSA 485 A:39 for real estate transactions of developed waterfront property within the 250-foot protected shoreline
b. Identify the water quality target or goal and pollution reductions needed to achieve the goal	› The 2022 303(d) list identifies Robinson Pond as impaired for Primary Contact Recreation due to elevated chlorophyll-a, cyanobacteria, and *E. coli* levels. Additional impairments for Aquatic Life Integrity are also identified. › The 2011 Robinson Pond TMDL recommended a total phosphorous reduction by 40% of the average annual total phosphorus load (reduced by approximately 46.0 kg/yr or 102.0 lbs/yr.) › The MS4 required Phosphorus Control Plan will outline approaches extending out to 2033 to achieve load reductions with interim 2026 goals, and additional updates in 2023.
c. Identify the best management practices (BMPs) that will help to achieve reductions needed to meet the water quality goal/target	› Non-structural BMPs: • Prioritize roads for Spring and Fall street sweeping and increase sweeping frequency to monthly from March through November and twice monthly from September through November • Contract vendors with regenerative air vacuum sweeper • Schedule cleanings in the Spring and track sediment volumes removed › Preliminarily Identified Structural BMP locations: • Town Boat Launch: Biofiltration and infiltration gallery • Town Beach: Permeable pavement, infiltration basin, soil stabilization • David Drive: Biofiltration, rain garden • Kienia Rd at Edgewood Road: Biofiltration, rain garden • Boulder Drive at Beechwood: Biofiltration, rain garden • Stoney Lane: Biofiltration, rain garden • Hazelwood: Biofiltration, rain garden
d. Describe the financial and technical assistance needed to implement the BMPs identified in Element C	› Allocate additional annual funding in long-term CIP Plan and seek grant funding to allow design and implementation of stormwater treatments BMP at various locations including: • Town Boat Launch • Town Beach • David Drive • Kienia Rd at Edgewood Road

Memorandum

	• Boulder Drive at Beechwood • Stoney Lane • Hazelwood › Order of Magnitude Cost will depend on Site Conditions but could range between $500K – $3.0M over ~15 to 20 years for all BMPs
e. Describe the stakeholder outreach, explain how their input was incorporated, and include the role of stakeholders in implementing the plan	› Stakeholder outreach through NHDES Soak Up the Rain and NH Lakes educational resources: • Annual "Soak Up the Rain" workshop with NHDES • Landscaping for Stormwater Management: Rain Gardens, Waterfront Buffers, and Debris Disposal • Best practices for Lawn and Septic System Maintenance • Establish Lake Steward Award Program to promote good shoreland management practices › Complete septic system inventory for shorefront properties on Robinson Pond to increase knowledge of systems and maintenance needs
f. Estimate a schedule to implement the BMPs identified in the plan	› To be developed with Final Tech Memo and with an anticipated 15-to-20-year timeframe
g. Describe the milestones and estimated timeframes for BMP implementation	› Completed Public education Outreach Events › Completed BMP Installations › Increased street sweeping and other drainage improvements
h. Identify the criteria that will be used to assess water quality improvement as the plan is implemented	› Total phosphorous load reduction (lbs / year) from various BMPs › Lower in-lake total P and chlorophyll a concentrations over time › A reduction in the # and duration of cyanobacteria blooms each year
i. Describe the monitoring plan to collect water quality data that will be used to measure improvements using the criteria described in Element H	› Continued VLAP monitoring collecting total phosphorus and chlorophyll a data and occasional temperature and dissolved oxygen profiles and aquatic vegetation surveys performed by NHDES Biologists › Continued NHDES bacteria and cyanobacteria sampling at public beach

Reference: https://www.dec.ny.gov/docs/water_pdf/9efaq17.pdf

Appendix VI: Robinson Pond BMP Review

Robinson Pond

BMP Review

September 22, 2022

Primary BMP Locations

Town Launch

- BMP Area : 18,450 sq ft
- Catchment area: 26,846 sq ft (0.6 ac)
- Est. Annual TP Load: 0.30 kg/year
- Potential BMPs:
  - Pervious pavement parking area
  - Infiltration Trench / French Drain
  - Stabilized boat launch
- Opportunities:
  - Limit sand & gravel runoff
- Constraints:
  - Space between road & lake
  - Limited subsurface treatment capacity

Town Beach

- BMP Area : 20,450 sq ft
- Catchment area: 117,616 sq ft (2.7 ac)
- Est. Annual TP Load: 0.19 kg/year
- Potential BMPs:
  - Pervious pavement road & parking area
  - Infiltration trench / French Drain
  - Define parking area
- Opportunities:
  - Limit sand & gravel runoff
  - Public education
- Constraints:
  - Depth to groundwater
  - Traffic volume

Parker Drive – Direct Drainage

- BMP Area : 2,170 sq ft
- Catchment area: 16,497 sq ft (0.8 ac)
- Est. Annual TP Load: 0.35 kg/year
- Potential BMPs:
  - Biofiltration
  - Subsurface treatment
- Opportunities:
  - Treat direct road runoff
- Constraints:
  - Wooded area
  - Possible existing wetlands
  - Depth to bedrock/groundwater

David Drive

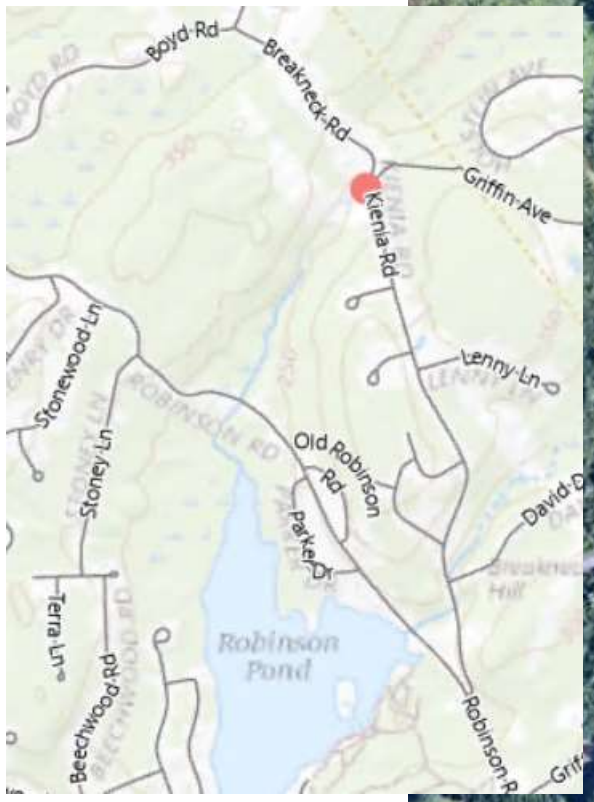
- BMP Area : 589 sq ft
- Catchment area: 315,673 sq ft (7.5 ac)
- Est. Annual TP Load: 0.57 kg/year
- Potential BMPs:
  - Biofiltration, tree filters
  - Deep sump catch basin, leaching basin
  - Infiltration basin, shallow wetland
- Opportunities:
  - Treat road & residential development
- Constraints:
  - Depth to bedrock/groundwater
  - Distance from Pond
  - Property ownership

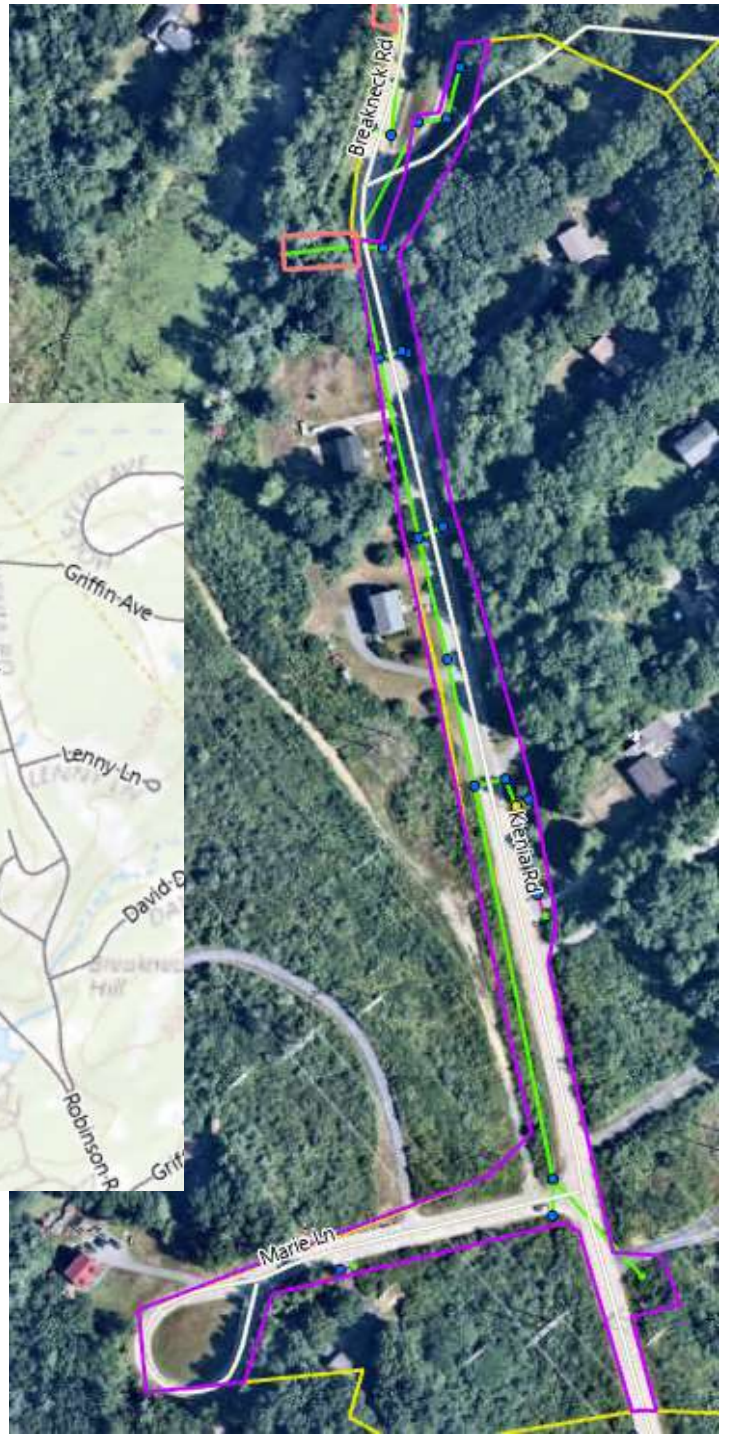
Kienia Road (#1)

- BMP Area : 750 sq ft
- Catchment area: 100,411 sq ft (2.3 ac)
- Est. Annual TP Load: 0.21 kg/year
- Potential BMPs:
  - Biofiltration, tree filters
  - Deep sump catch basin, leaching basin
- Opportunities:
  - Treat road area
- Constraints:
  - Wooded area
  - Depth to bedrock/groundwater
  - Distance from Pond
  - Property ownership

Kienia Road (#2) – Direct Drainage

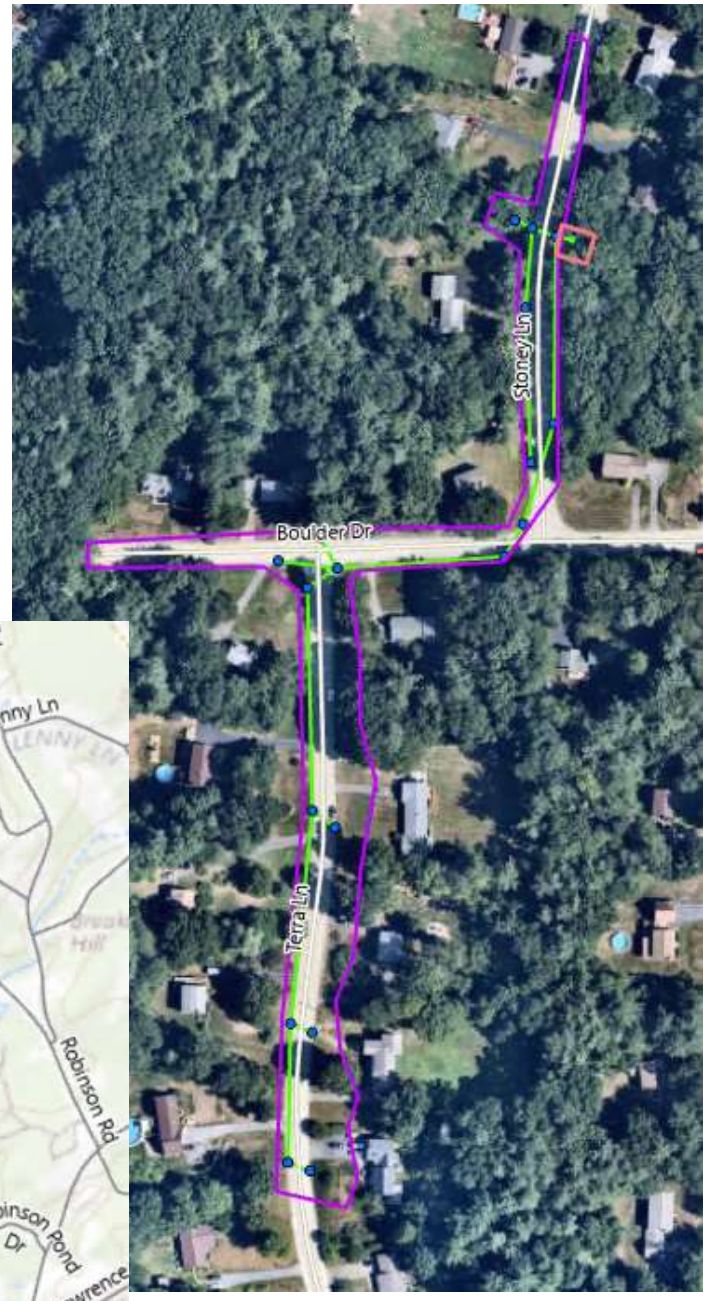
- BMP Area: 3,650 sq ft
- Catchment area: 150,156 sq ft (6.8 ac)
- Est. Annual TP Load: 0.88 kg/year
- Potential BMPs:
  - Biofiltration, tree filters
  - Deep sump catch basin, leaching basin
  - Subsurface treatment
- Opportunities:
  - Treat direct road area
- Constraints:
  - Limited road right of way
  - Property ownership

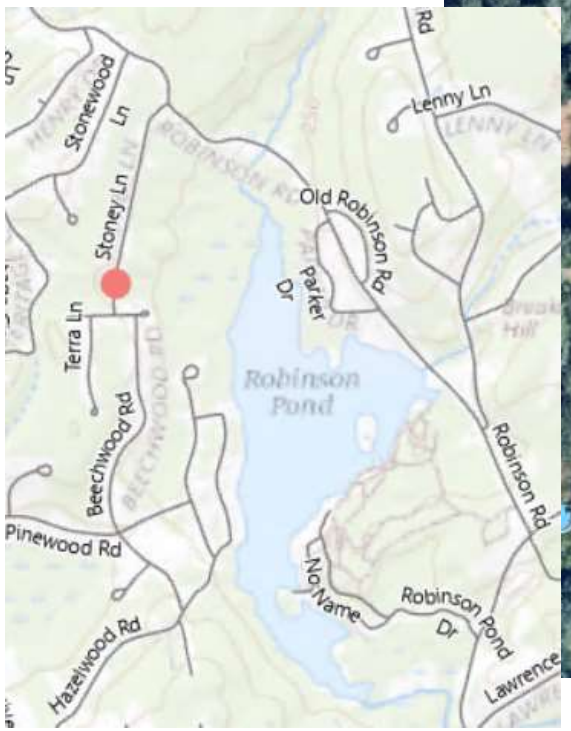




Stoney Lane – Direct Drainage

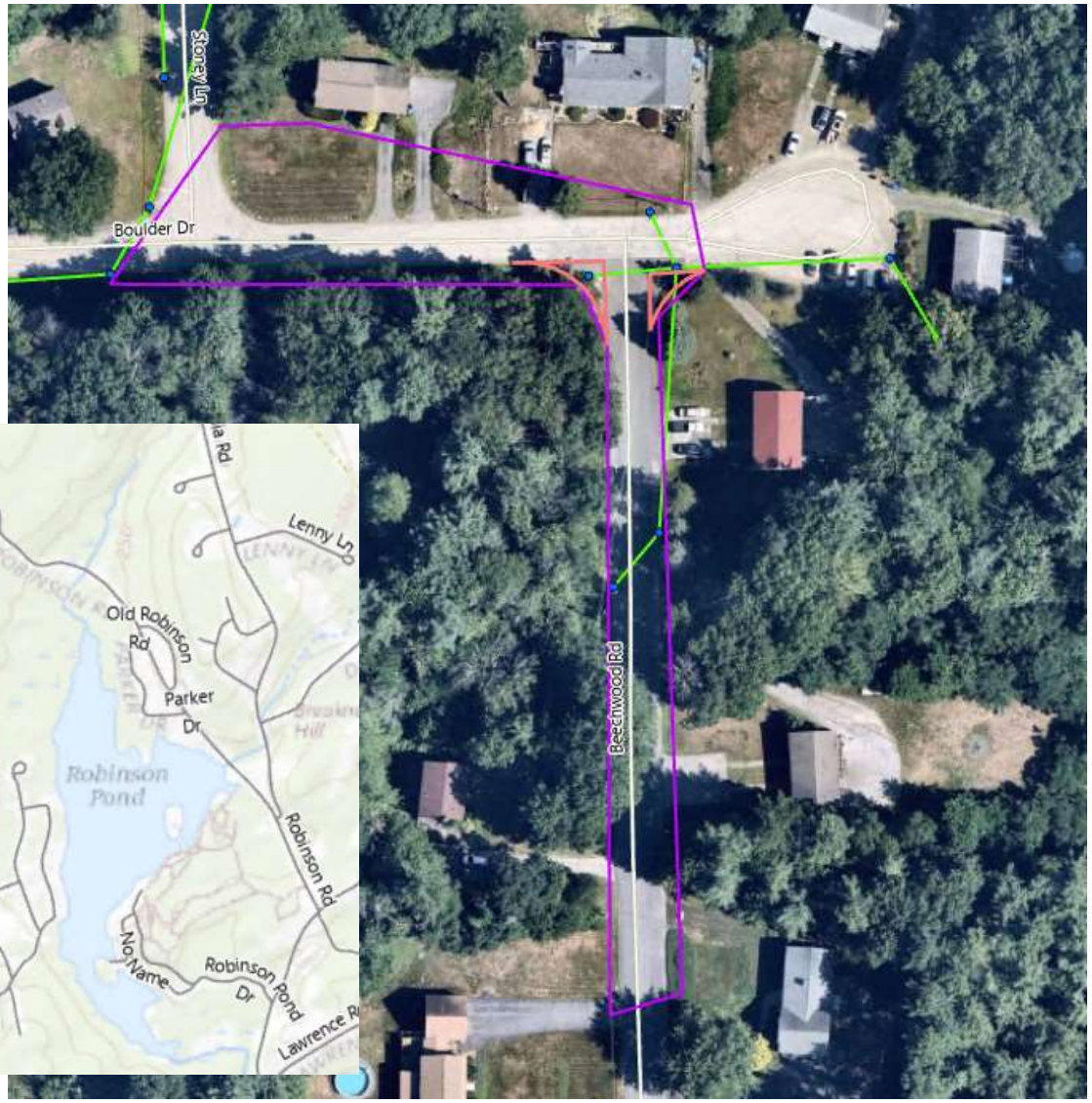
- BMP Area : 1,587 sq ft
- Catchment area: 117,043 sq ft (5.4 ac)
- Est. Annual TP Load: 1.01 kg/year
- Potential BMPs:
  - Deep sump catch basin, leaching basin
  - Subsurface treatment, infiltration basin
- Opportunities:
  - Large road area
  - VLAP sampling location
- Constraints:
  - Limited road right of way
  - Property ownership
  - Distance to surface water





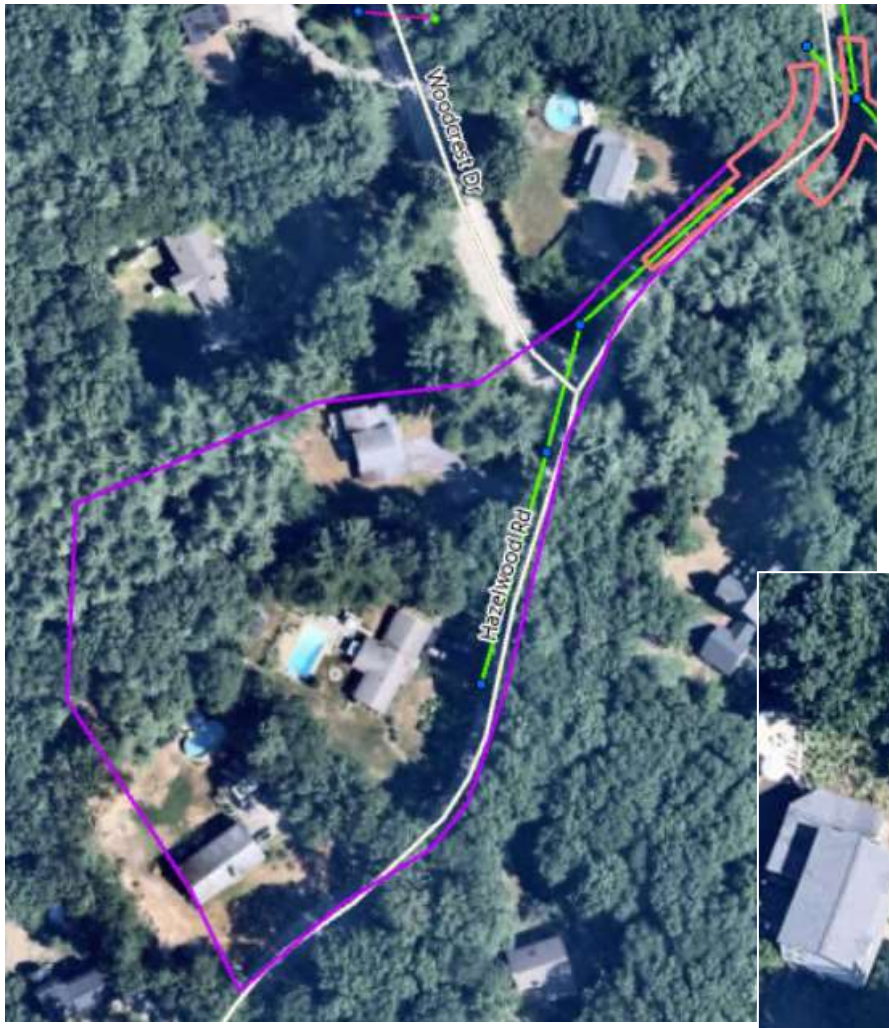
Boulder & Beechwood – Direct Drainage

- BMP Area : 879 sq ft
- Catchment area: 41,914 sq ft (1.9 ac)
- Est. Annual TP Load: 0.50 kg/year
- Potential BMPs:
  - Deep sump catch basin
  - Stormwater pond, infiltration basin
- Opportunities:
  - Reduce road, intersection width
- Constraints:
  - Limited road right of way
  - Depth to bedrock/groundwater
  - Distance to surface water



Hazelwood Road – Direct Drainage

- BMP Area : 3,206 sq ft
- Catchment area: 121,183 sq ft (6.0 ac)
- Est. Annual TP Load: 0.47 kg/year
- Potential BMPs:
  - Deep sump catch basin
  - Stormwater pond, infiltration basin
- Opportunities:
  - Road and residences along hillside
- Constraints:
  - Limited road right of way
  - Depth to bedrock/groundwater
  - Property ownership



Hazelwood Road – Direct Drainage #2

- BMP Area : 3,335 sq ft
- Catchment area: 14,272 sq ft (0.7 ac)
- Est. Annual TP Load: 0.10 kg/year
- Potential BMPs:
  - Deep sump catch basin
  - Stormwater pond, infiltration basin
- Opportunities:
  - Treat road area draining directly to Pond
- Constraints:
  - Limited road right of way
  - Potential wetlands
  - Property ownership

Secondary BMP Locations

Parker Drive

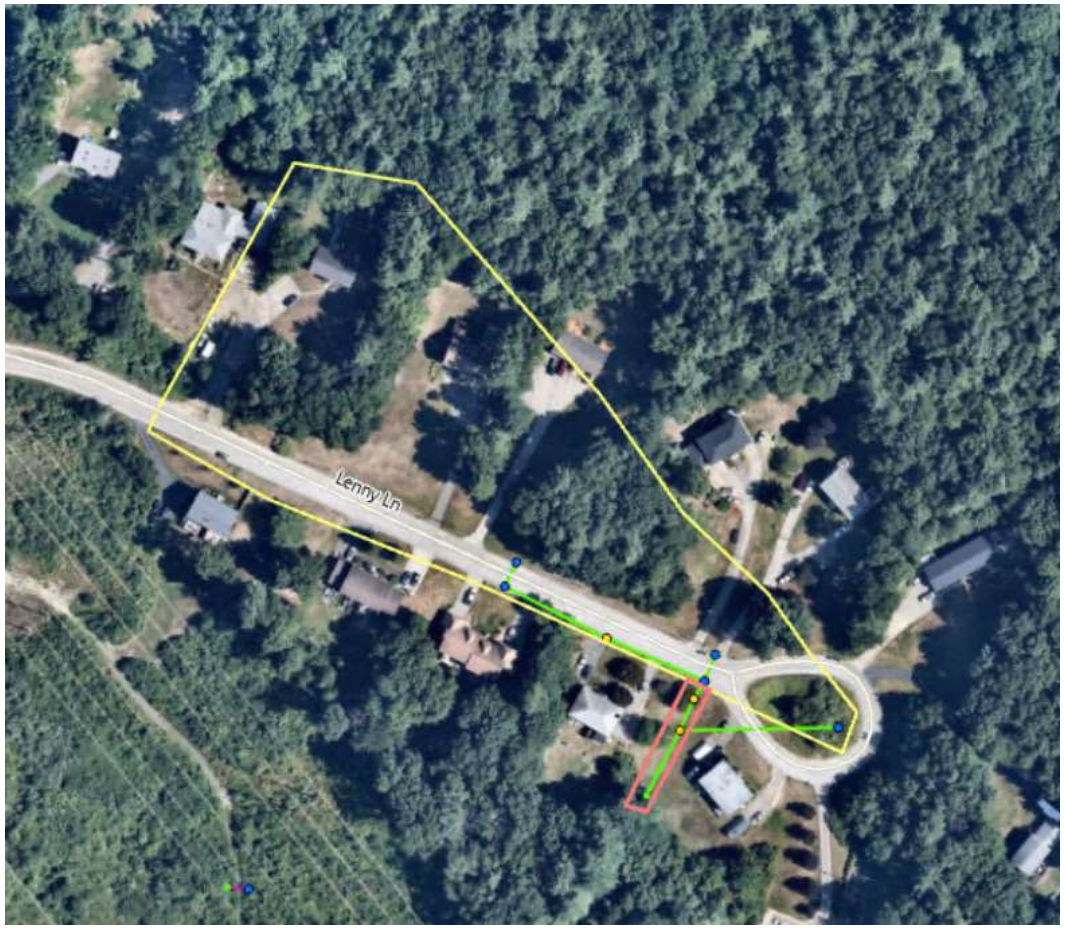
- BMP Area : 2,170 sq ft
- Catchment area: 822,885 sq ft (19.4 ac)
- Est. Annual TP Load: 1.14 kg/year
- Potential BMPs:
  - Biofiltration
  - Subsurface treatment
- Opportunities:
  - Treat large contributing area
- Constraints:
  - Wooded area
  - Possible existing wetlands
  - Depth to bedrock/groundwater

Kienia Road (#2)

- BMP Area: 3,650 sq ft
- Catchment area: 1,098,373 sq ft (25.8 ac)
- Est. Annual TP Load: 1.15 kg/year
- Potential BMPs:
  - Biofiltration, tree filters
  - Deep sump catch basin, leaching basin
  - Subsurface treatment
- Opportunities:
  - Treat large catchment area
- Constraints:
  - Limited road right of way
  - Property ownership

Lenny Lane

- BMP Area : 3,820 sq ft
- Catchment area: 190,646 sq ft (4.5 ac)
- Est. Annual TP Load: 0.59 kg/year
- Potential BMPs:
  - Biofiltration, tree filters
  - Deep sump catch basin, leaching basin
  - Infiltration basin
- Opportunities:
  - Treat road & residential development
- Constraints:
  - Depth to bedrock/groundwater
  - Distance from Pond
  - Property ownership



Breakneck Road

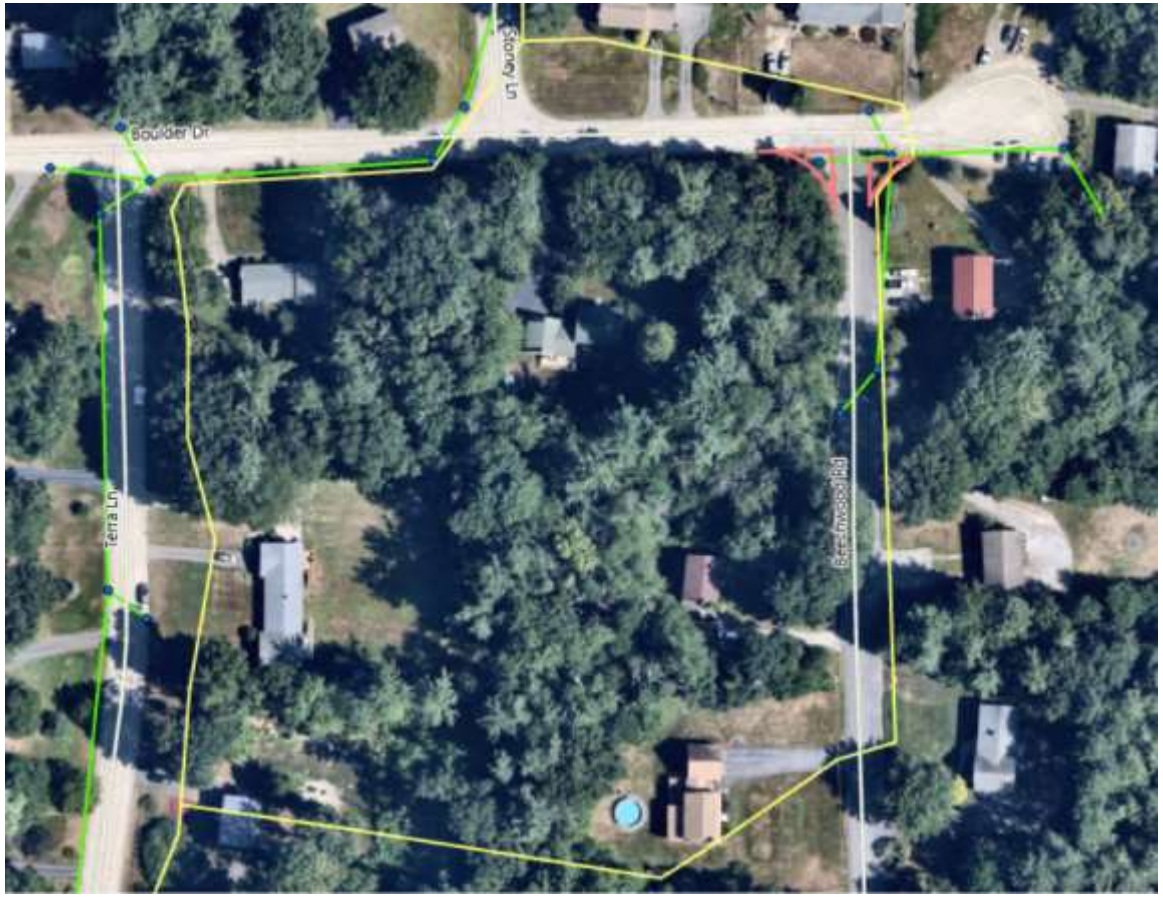
- BMP Area : 5,144 sq ft
- Catchment area: 360,809 sq ft (8.6 ac)
- Est. Annual TP Load: TBD kg/year
- Potential BMPs:
  - Deep sump catch basin, leaching basin
  - Subsurface treatment
- Opportunities:
  - Treat large catchment area
- Constraints:
  - Limited road right of way
  - Property ownership
  - Distance to surface water

Stoney Lane

- BMP Area : 1,587 sq ft
- Catchment area: 1,883,849 sq ft (44.8 ac)
- Est. Annual TP Load: 3.21 kg/year
- Potential BMPs:
  - Deep sump catch basin, leaching basin
  - Subsurface treatment, infiltration basin
- Opportunities:
  - Largest catchment area
  - VLAP sampling location
- Constraints:
  - Limited road right of way
  - Property ownership
  - Distance to surface water

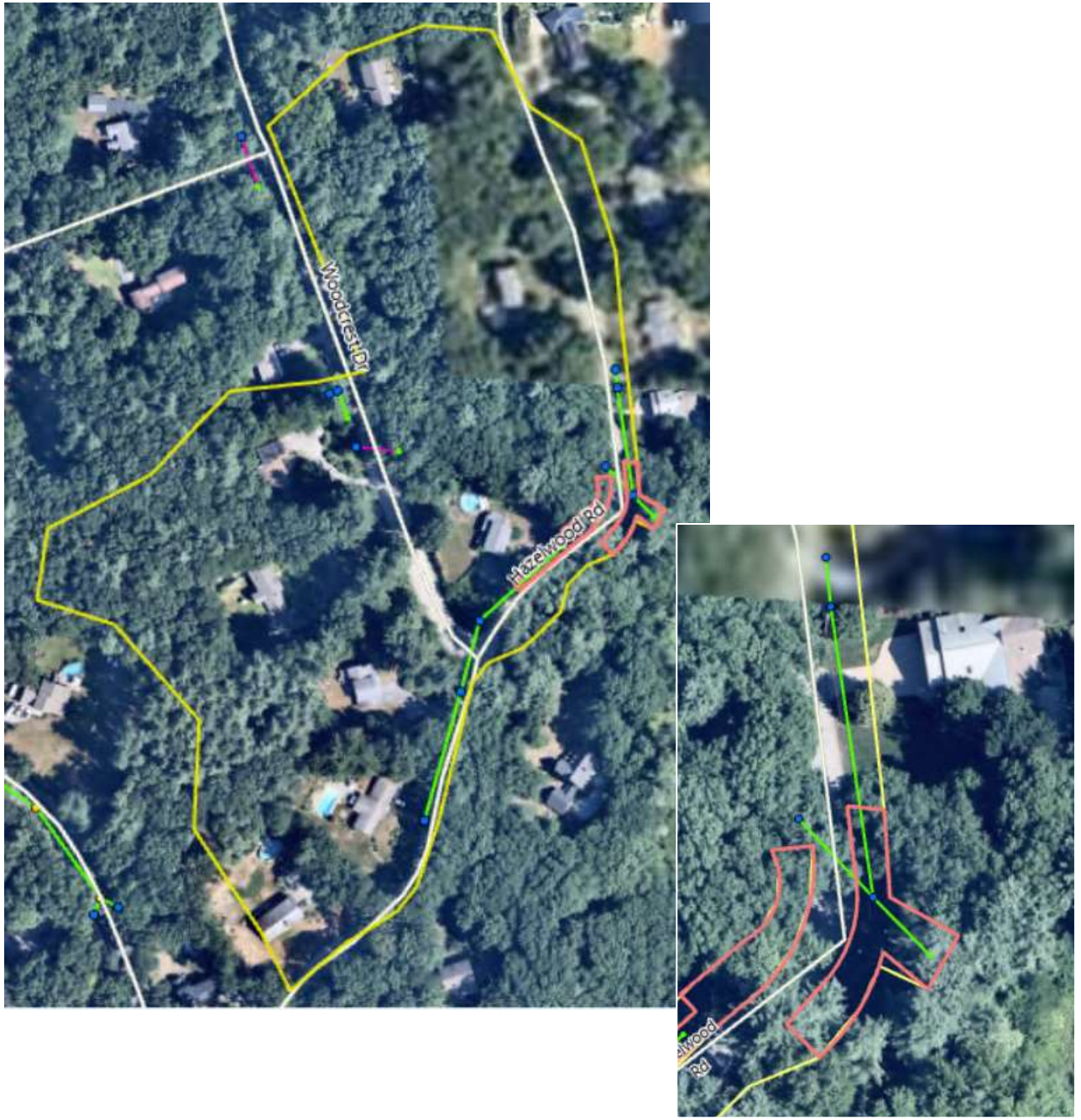
Boulder & Beechwood (x2)

- BMP Area : 879 sq ft
- Catchment area: 280,174 sq ft (6.7 ac)
- Est. Annual TP Load: 0.52 kg/year
- Potential BMPs:
  - Deep sump catch basin
  - Stormwater pond, infiltration basin
- Opportunities:
  - Reduce road, intersection width
- Constraints:
  - Limited road right of way
  - Depth to bedrock/groundwater
  - Distance to surface water



Hazelwood Road

- BMP Area : 3,335 sq ft
- Catchment area: 535,330 sq ft (15.7 ac)
- Est. Annual TP Load: 1.06 kg/year
- Potential BMPs:
  - Deep sump catch basin
  - Stormwater pond, infiltration basin
- Opportunities:
  - Large catchment area
- Constraints:
  - Limited road right of way
  - Depth to bedrock/groundwater
  - Property ownership



Appendix VII: Recommendations for Wetland Overlay District Updates

To: Emma Rearick, Nashua Regional Planning Commission

Date: March 13, 2023

Project #: 52868.00

From: Bill Arcieri and Garrison Beck

Re: DRAFT Recommendations for Wetland Overlay District Regulation Revisions for Robinson Pond

Memorandum

The following summarizes recommendations for potential regulation updates to Hudson's existing Wetland Conservation Overlay District to enhance water quality protection of the Town's water resources. These updates are especially necessary for Robinson Pond and Otternick Pond, which are both listed as impaired for excessive nuisance algae growth and nutrient inputs. The recommendations are based on language included in the Town of Amherst's Watershed and Wetland Overlay District[1])and language included in the NHDES Shoreland Water Quality Protection Act (SWQPA; RSA 483-B, Env-Wq 1400). In addition to the specific elements discussed below, the Town may want to consider changing the title of the ordinance to Wetlands and Watershed Conservation Overlay District.

Standards for Development Adjacent to Wetlands and Surface Waters

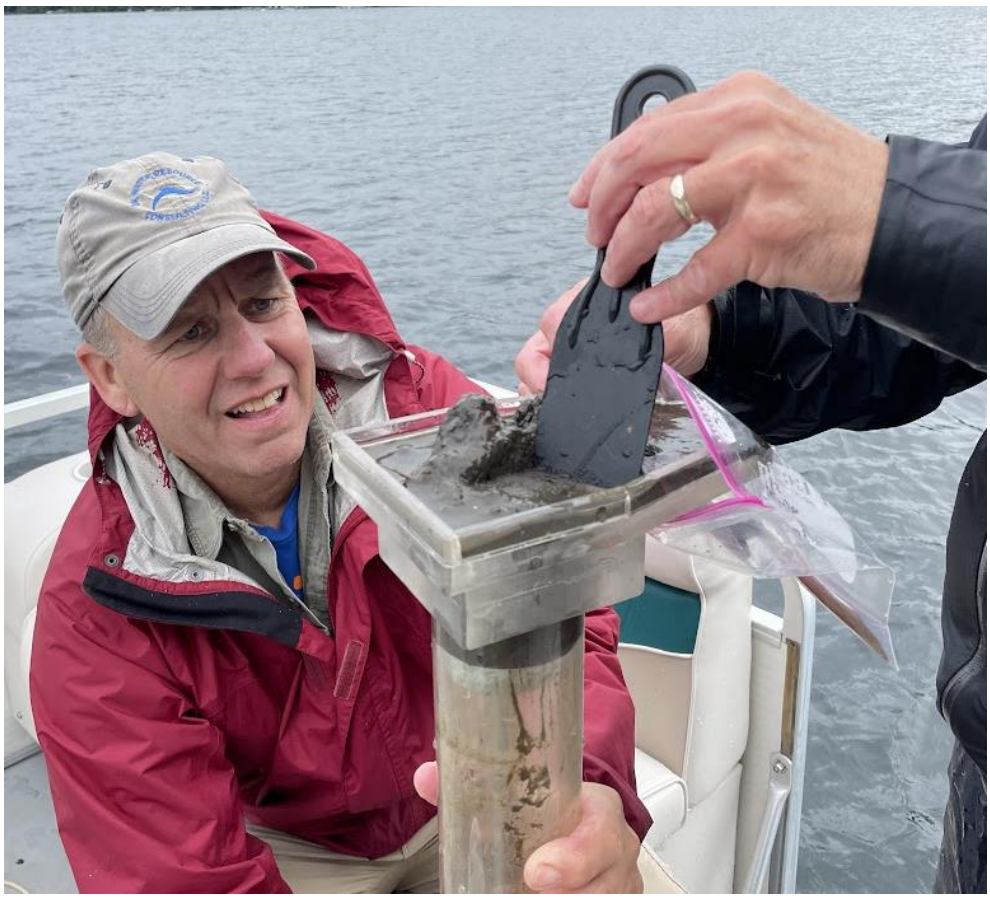
Element	Hudson Wetland Conservation Overlay District (§334-33 - §334-37)	Recommended Regulation Changes
Boundaries	› 50-foot wide buffer around all surface waters and wetlands	› Extend jurisdictional boundary of the Overlay District to 100 feet or 125 feet from the Reference Line. The NHDES SWQPA boundary is 250 feet; the extended boundary will allow additional oversight for land disturbances beyond the current 50 ft. › With new boundary limit, establish a Waterfront Buffer zone within 50 feet of reference line that would carry the same or more clarified restrictions on substantial vegetation clearing and land grading as that included in the current Overlay District (Sec. 334-36). No new construction or land disturbance without an approved Conditional Use CU permit consistent with current regs; › Consider establishing a Woodland Buffer zone from 50 to 100 or 125 feet (depending on selected District boundary) similar to the NHDES SWQPA Woodland Buffer zone that would limit vegetation clearing and also restrict impervious cover area to less than 30% of parcel area.
Newly Constructed Primary Structures	› Not expressly allowed unless granted a conditional use permit	› For surface waters, prohibit any new construction of primary structures within 75 feet instead of 50 feet from Reference Line used for wetlands. This would apply to undeveloped properties and developed conforming properties. See limits for Non-Conforming Structures below.
Vegetation Clearing	› Sec. 334-36 A: Permitted uses allows vegetation clearing in the District only if it does not involve "substantial" clearing of vegetation, except for: • Forest management using best management practices published by NH Dept. of Natural & Cultural Resources and UNH Cooperative Extension.	› Establish/clarify vegetative clearing restrictions within 50-foot Waterfront Buffer, including: • Existing trees, shrubs, ground cover in 50-foot buffer shall be retained except for a 6-foot-wide path. • Ground cover & shrubs may be trimmed to a height no less than 3 feet, and trees may be pruned. • Areas cleared of vegetation before July 2008[2] may remain but not be enlarged. • Maintain at least 25% of the area as natural woodland (may be difficult to quantify), • Alternatively, adopt a point system like the NHDES SWQPA favoring keeping mature trees
Lawn Care	› Use of fertilizer is prohibited within the District.	› Current district regulations prohibit use of lawn fertilizer or pesticides within 50 feet. Current language is good and perhaps should be a focus of future educational messaging as a reminder

Memorandum

Accessory Structures (Non-Dwelling)	› Allowed, provided that no practicable alternative exists outside the Overlay District boundary › No restriction on size, height, location, access	› Current regulations (Sec. 334-36: C) regulate accessory structures within the waterfront buffer (50 feet). Accessory structures are allowed for legally existing primary structures provided no other practicable alternative location exists on lot area. Consider adding the restrictions similar to NHDES › If District boundaries are extended to 100 or 125 feet, then may want to revise to only restrict on Accessary structure to just the 50-foot Waterfront Buffer rather than entire District. **Other Possible Considerations:** › Must first avoid, then minimize impacts to mature trees as well as established natural ground cover › Cannot be constructed on slopes >25% • Height: cannot exceed 12 feet • Size: total area cannot exceed 7.5 sq ft per linear foot of shoreland frontage › Accessory structures, including decks or porches, between the primary building and reference line cannot be converted to living space • Total length must be < 20% of the shoreline and no more than 50 feet in length, whichever is less
Nonconforming Uses and Structures	› Expansion is allowed by the ZBA provided encroachment is not increased and Conservation Commission finds any additional wetland impacts will be mitigated › Existing nonconforming structures damaged or in need of significant repair may be replaced or rebuilt provided it is not made more nonconforming using various mitigation measures such as…. › Shall not have a greater impact on the District than the original use › If an existing nonconforming use is discontinued, lapses, or is abandoned for a consecutive 12 months, subsequent uses shall conform to current standards	› Nonconforming use or structures may be expanded within the waterfront buffer as long as the following standards apply: • The expanded use or accessory structure does not encroach any closer to the reference line • The expanded use or structure is located as far from the surface water, wetland or other protected resource as practically possible and is made more conforming by increased setback and a reduced impact on vegetation, wetland functions and values, and water quality, as appropriate • The Planning Board finds that any potential decrease in wetland function and values resulting from the activity or use will be properly mitigated onsite. Mitigation strategies may include, but not be limited to, planting of native vegetation in sparsely vegetated areas, improving stormwater management to retain water onsite, reduce discharges to the resource, and management of invasive species on the property • Must receive applicable NHDES Septic System and Shoreland Permit approvals
Septic Systems (Env-Wq 1000)	› Current Overlay District regulations appear to have no septic system setback or expansion restrictions	› Recommend adding the following setbacks for all residential septic system components (tank, drainage area) consistent with (Env-Wq 1008.04): • 75 feet: surface waters & very poorly drained wetlands • 50 feet: for all wetlands › Developed properties with any portion within 200 feet of the reference line must conduct a site assessment study of the septic system prior to the purchase and sale of the property to determine whether the property meets current septic standards (Env-Wq 1025)

[1] Town of Amherst Wetland and Watershed Conservation Overlay District Regulations. https://www.amherstnh.gov/sites/g/files/vyhlif4116/f/uploads/sec_a_zoning_ord_2022.pdf
[2] Represents the date when the NHDES Shoreland Protection Act was adopted.

Appendix VIII: Robinson Pond Sediment Analysis



Robinson Pond Sediment Analysis

Technical Memorandum

Prepared By: Don Kretchmer, DK Water Resource Consulting LLC
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1.0 Background

This document characterizes the phosphorus content of the surficial sediments of Robinson Pond (approximately the upper 10 cm) at a variety of depths and locations in the pond as well as a summary of the related water quality and sediment data that will be used to help evaluate the potential internal load of phosphorus (P) from the sediments to Robinson Pond.

Robinson Pond is in the Merrimack River Basin within the town of Hudson, New Hampshire. The 52-hectare (128 acres) pond has a maximum depth of 9.0 m (29.5 feet) and a mean depth of 2.4 m (7.9 feet) (Figure 1). The pond volume is 1,249,302 cubic meters with an estimated flushing rate of approximately 2.7 times per year (AECOM 2011). More recent bathymetry is available from NH GRANIT (2016) however, these data are believed to be unreliable, showing large areas with water depths much greater than has ever been reported for Robinson Pond (NHDES 2022). As a result, bathymetric data from 1988 were used to estimate sediment release (Figure 1). These estimates can be updated if recent accurate bathymetric data are obtained.

In recent years, Robinson Pond in Hudson, NH has experienced low dissolved oxygen in the deepest sections. The AECOM (2011) suggested that dissolved oxygen was reduced below 6 m in the pond in the summer. Recent data suggests that dissolved oxygen is reduced below 3 m (VHB2023). Localized cyanobacteria blooms and related water quality impairments including contact recreation restrictions have been prevalent in recent years. In response to these episodes of poorer water quality, sediment sampling was conducted in July and October 2023 to assess the phosphorus concentration of the sediments of the pond and the likelihood that these phosphorus stores could be released back to the water column.

A comprehensive discussion of Robinson Pond water quality and watershed issues can be found in the TMDL for Robinson Pond (AECOM 2011), Volunteer Lake Assessment Program (VLAP) for Robinson Pond (NHDES 2021) and recent work by VHB (VHB 2023). Robinson Pond water quality varies from good to poor generally and is representative of a highly nutrient rich system with high productivity (eutrophic) system. Recent water quality shows evidence of even higher nutrient concentrations and associated increases in productivity suggesting that in recent years the pond is more eutrophic than in the past. Specifically, cyanobacteria have been observed more frequently and in greater density in recent years. The degree of anoxia in the deeper sections of the pond in the

summer is high. It is likely that increased phosphorus concentrations in the water column from a combination of watershed loading and loading from the sediments are a contributing factor.

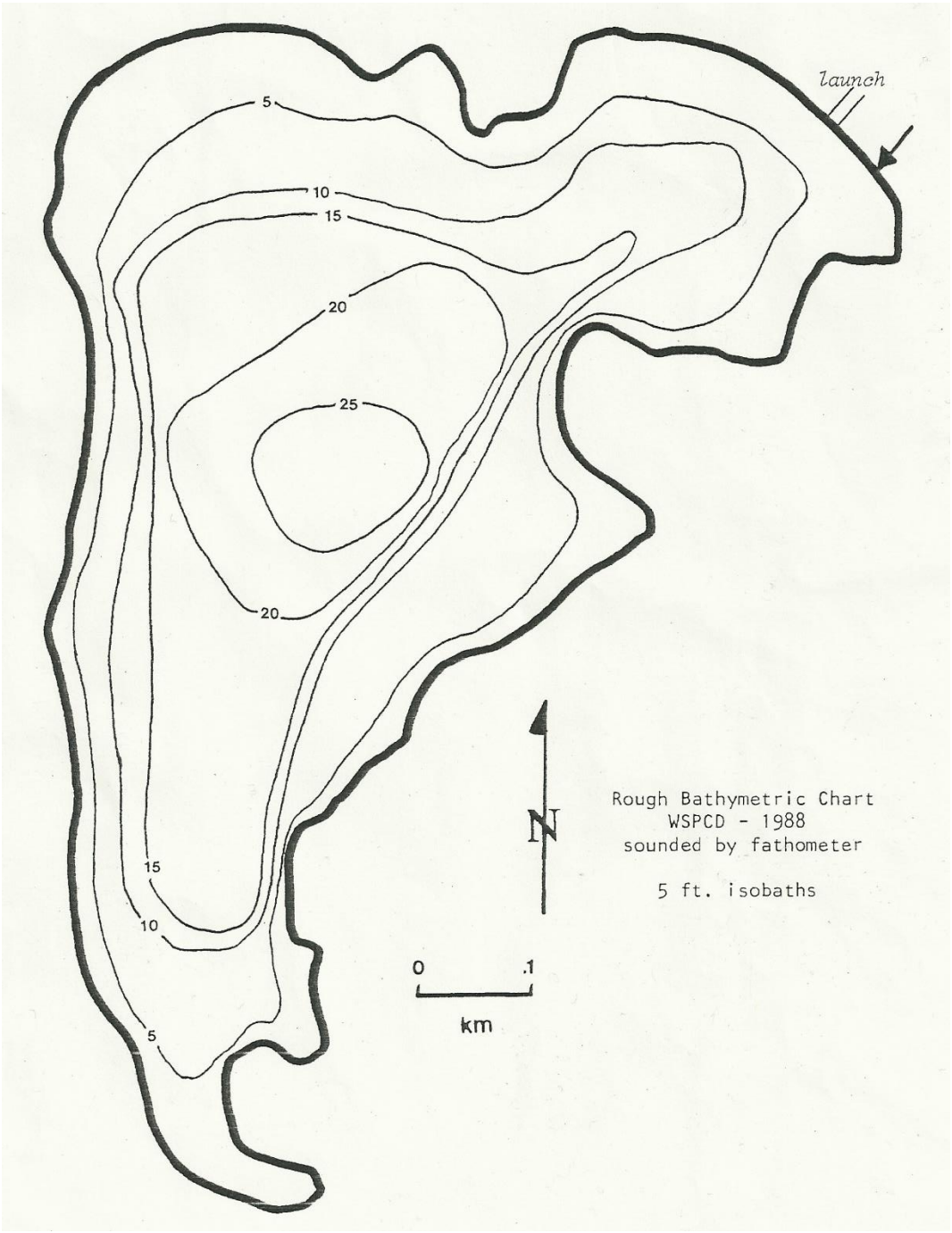

Figure 1: Robinson Pond bathymetry. (NH WSPCD 1988).

Water quality data have been collected regularly by volunteers under the NH VLAP since 2000. These data allow a look at changes in pond water quality over time as well as a comprehensive look at current water quality. Selected data from this record are presented in Figure 2 and Table 1 below.

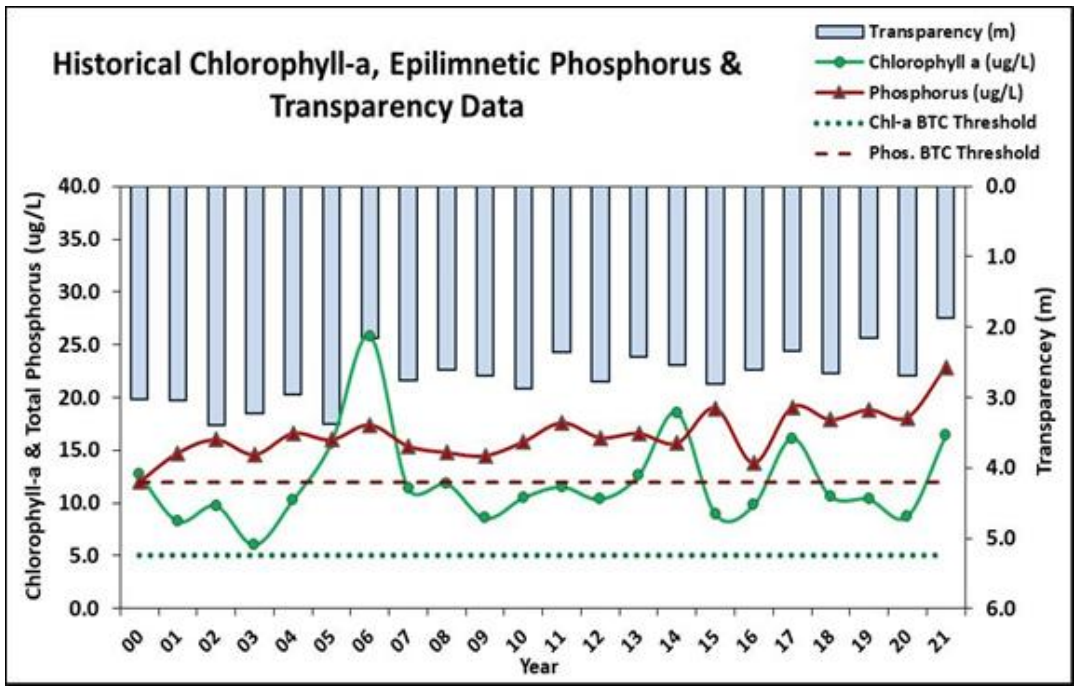

Figure 2: Historic Water Quality data for Robinson Pond, Hudson, NH (NHDES 2021).

Table 1: 2021 Water Quality data for Robinson Pond, Hudson, NH (NHDES 2021).

Station Name	2021 Average Water Quality Data for ROBINSON POND - HUDSON										
	Alk. (mg/L)	Chlor-a (ug/L)	Chloride (mg/L)	Color (pcu)	Cond. (us/cm)	E. coli (mpn/100mL)	Total P (ug/L)	Trans. (m)		Turb. (ntu)	pH
								NVS	VS		
Epilimnion	14.5	16.38	50	108	195.8		23	1.88	2.17	1.78	6.17
Metalimnion					207.2		29			3.63	6.20
Hypolimnion					225.5		128			12.40	6.32
Sta. 2 Launch Brook			57		221.5	348	35			1.01	6.72
Sta. 3 Howard Brook			17		89.4	1126	62			2.01	5.92
Sta. 4 Juniper Brook			48		210.3	232	26			8.43	5.90
Sta. 5 Stoney Lane Drainage			43		199.8	486	45			8.80	6.32
Sta. 6 Woodcrest Brook			82		292.5	1168	181			9.58	6.10
Sta. 7 Row			85		309.2	834	120			5.57	6.14

Phosphorus concentrations in the surface layers of the lake are currently high enough to support a trophic classification of eutrophic or highly nutrient rich. Robinson Pond thermally stratifies in the deep zone of the pond in the summer and during that stratification period, dissolved oxygen is depressed in the deeper waters below 3 m (10 ft). The anoxic conditions facilitate release of phosphorus from the sediments to the water column. Phosphorus concentrations in the deeper strata of the pond are much higher (Table 1) than those observed in the surface layers suggesting substantial phosphorus release from the sediments. Results from the summer of 2023 were used to estimate internal release of phosphorus.

2.0 Sediment Sampling

2.1 Approach

There are several central questions that drive the sediment assessment presented in this summary:

1. How much phosphorus is in the sediments of Robinson Pond?
2. How much of this phosphorus (internal load) could be released under low oxygen conditions?
3. How much of this phosphorus is essentially permanently bound in the sediments?
4. Is internal loading of phosphorus currently a driving factor in Robinson Pond?

These questions can be largely answered using the sediment data however, future water quality monitoring and the ongoing watershed planning projects will put these results in context with other sources.

2.2 Field Program.

The sediment sampling program was developed through collaboration between DK Water Resource Consulting LLC and VHB. The monitoring program generally follows the protocols developed as a part of the sediment sampling Quality Assurance Project Plan (QAPP) prepared for Nippo Lake in Barrington, NH (DKWRC and NHDES 2018). The

only deviation from these protocols was that samples to be analyzed for metals were collected with an Eckman dredge in October of 2023 rather than the core sampler utilized in July. This technique captures approximately 4 inches (10cm) of sediment in typical lake sediments. This change in protocol was necessitated by the shipping loss of July 2023 metals samples taken from the cores. In general, only the P in the upper 4 to 10 cm (1.6 - 4 inches) of sediment interacts with the water column (Cooke et al. 2005). Both the core samples and Eckman dredge samples were representative of the upper 4 inches (10cm) of sediment.

Sediment sampling was conducted on July 26, 2023 and October 19, 2023. Field personnel for the July event included Don Kretchmer from DK Water Resource Consulting LLC (DKWRC), Garrison Beck from VHB and Savia Berlucchi from VHB. Six samples were collected at various depths and locations across the pond along with one duplicate sample (Station Center N). The October event was conducted by Don Kretchmer from DKWRC and Garrison Beck from VHB. Sampling locations are depicted in Figure 3. Coordinates for these stations are presented in Table 2. Stations were chosen to provide a representation of sediment conditions in both the deep open water areas and shallow areas or embayments.

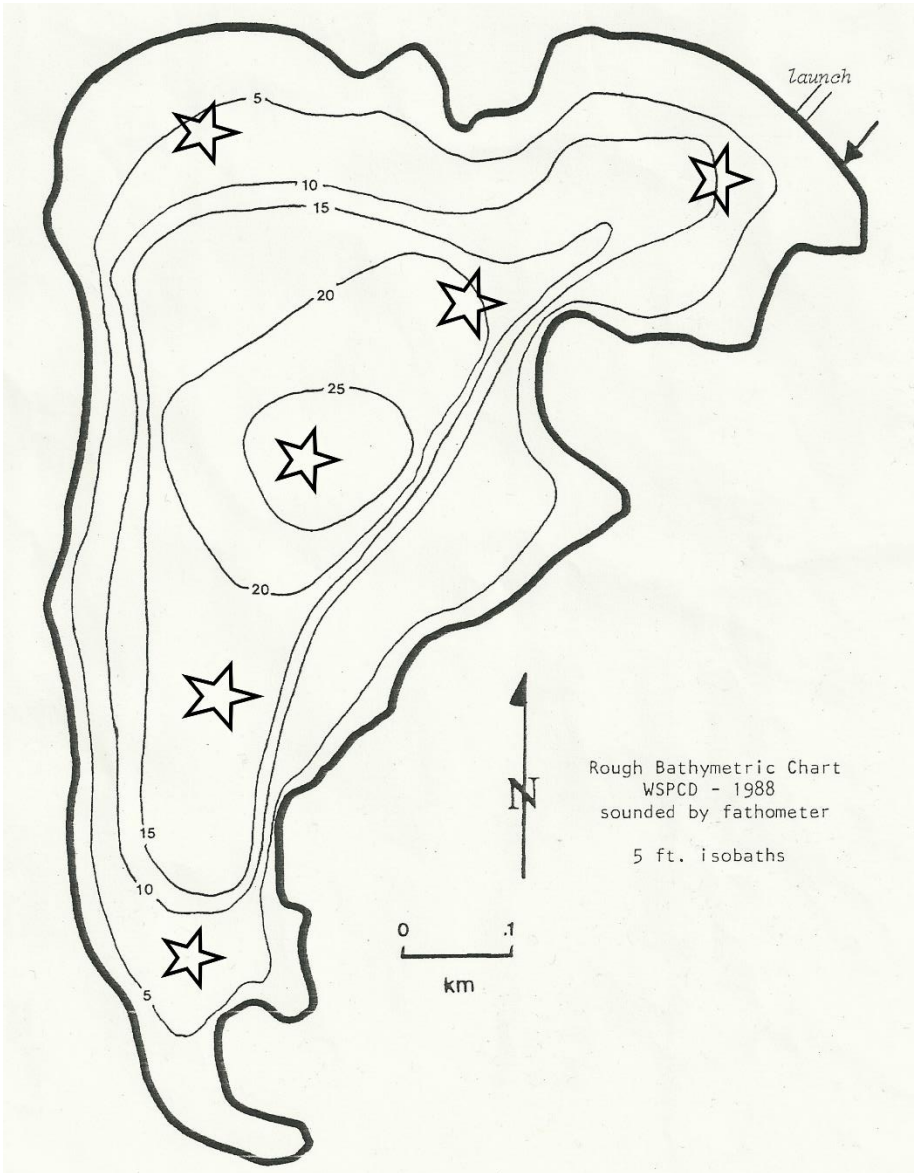

Figure 3: Sampling Locations, Robinson Pond Sediment Monitoring, July 26, 2023, and October 19, 2023.

Table 2. Sampling Coordinates, Robinson Pond Sediment Monitoring, Hudson, NH.

	Water Depth ft)	Latitude (degrees)	Longitude (degrees)
NE	15	42° 48' 2.01"	71° 22' 59.45"
NW	12	42° 48' 3.37"	71° 23' 19.28"
Center N	20	42° 48' 0.41"	71° 23' 7.19"
Center	30	42° 47' 58.56"	71° 23' 12.56"
Center S	26	42° 47' 50.23"	71° 23' 14.12"
South	10	42° 47' 39.62"	71° 23' 16.34"

2.3 Sampling Results

Phosphorus (P) in sediment originates from historic loading and, to a lesser degree, the native soils beneath a lake. In Robinson Pond, the watershed soils and settling of organic matter from plants and animals growing in the pond are likely to be more important to the phosphorus resources than native soils as the pond was formed during the last glaciation and deposits of sediments since glaciation in the pond likely bury the native soils.

The sediment P in samples was split into fractions by sequential lab extractions and reported in four categories depending on how tightly the P is bound in the sediments and under what conditions P might be released back to the water column. Loosely bound P is the most readily available fraction for uptake by algae. Iron bound P can be released from sediments under low oxygen conditions and be available to algae. Labile organic P is bound in organic matter and is slowly released as the organic matter decays and is then available for binding to iron or aluminum or release to the water column and subsequent uptake by algae. Aluminum bound P is largely permanently bound to aluminum and typically remains in the sediments regardless of the oxygen status of the overlying water or the sediment pore water. In addition to aluminum bound P there are other forms of permanently bound P including calcium bound mineral P and organic forms of P that are resistant to bacterial breakdown. These other forms are included in sediment total P but are generally not considered mobile. The physical characteristics of the sediments of Robinson Pond were typical for lake sediments in New England below the wave zone and exposed to low oxygen concentrations. At all sampling sites the sediments were gray-brown and had the consistency of mayonnaise (Photo 1).

Photo 1: Typical lake sediments from New Hampshire.

Sediment samples collected on July 26, 2023, were stored, shipped, and analyzed at University of Wisconsin-Stout (phosphorus by sequential extraction). Metal samples collected on October 19, 2023, were hand delivered to Eastern Analytical (metals) according to procedures in the QAPP document (DKWRC and NHDES 2018) used for reference in this project. Results of the analyses are presented in Table 3. These values are important to understand the likelihood of P release from the sediments of Robinson Pond under anoxia. Quality assurance data are provided in Appendix Table 1.

In Robinson Pond, sediments, concentrations of the most readily released forms of P (loosely bound P and iron bound P) are low relative to other forms of P (Table 3, Figure 4) but still sufficient to result in internal loading of phosphorus under low oxygen conditions as has been observed. A substantial amount of phosphorus in the sediment of Robinson Pond is bound to organic matter (labile organic P, Table 3, Figure 4). Much of this organic matter is likely slow to decay resulting in low release rates of P. Much of the P released by the organic matter would be expected to subsequently bind to aluminum or iron. The iron bound phosphorus may then be released to the water column under the anoxic conditions that currently exist.

Labile organic P the largest fraction of phosphorus in the sediments of Robinson Pond. Aluminum -bound P is the second largest fraction in Robinson Pond. The aluminum bound P is unlikely to be released from the sediments regardless of the oxygen content of the overlying water. The fact that most of the sediment P is bound to either aluminum or organic compounds suggests that the anoxia driven internal load would be modest however, the low oxygen status of the water column and the fact that this area appears to be expanding over time has led to a substantial internal load of P to the water column. All forms of P are near the average of other lakes in and near New Hampshire (Figures 5 and 6).

Table 3: 2023 Upper 10 cm Sediment Data for Robinson Pond, Hudson, NH

Station	Depth of Sample	Depth of Sample	Moisture content	Organic Content (LOI)	Wet bulk density	Dry bulk density	Loosely-bound P	Iron-bound P	Labile organic P	Aluminum-bound P	Total P	Total Iron	Total Aluminum	Sum of mobile P [1]	Redox P
	feet	meters	(%)	(%)	(g/cm^3)	(g/cm^3)	(mg/g)	(mg/g)	(mg/g)	(mg/g)	(mg/g)	(mg/g)	(mg/g)	mg/g or g/kg	mg/g or g/kg
NE	13.0	4.0	91.8	32.7	1.035	0.086	0.026	0.076	0.295	0.200	0.826	11.0	9.9	0.397	0.102
NW	12.0	3.7	95.4	42.9	1.017	0.047	0.036	0.087	0.301	0.171	1.033	11.0	7.0	0.424	0.123
CENTER N	20.0	6.1	93.8	37.6	1.025	0.065	0.026	0.108	0.331	0.205	0.989	11.0	9.0	0.465	0.134
CENTER	30.0	9.1	94.3	37.6	1.022	0.059	0.032	0.144	0.306	0.251	0.991	10.0	9.2	0.482	0.176
CENTER S	26.0	7.9	93.7	37.3	1.025	0.065	0.026	0.110	0.359	0.267	0.834	12.0	9.3	0.495	0.136
S	10.0	3.0	92.5	38.1	1.029	0.078	0.026	0.120	0.267	0.199	0.806	12.0	7.4	0.413	0.146
DUP [2]	20.0	6.1	92.4	38.8	1.029	0.079	0.024	0.090	0.238	0.223	0.810	11.0	10.0	0.352	0.114
Center N Ave	20.0	6.1	93.1	38.2	1.0	0.1	0.025	0.099	0.285	0.214	0.900			0.409	0.124
NE Ave												11.0	10.0		
Mean at > 4m depth	25.3	7.7	93.7	37.7	1.025	0.065	0.028	0.118	0.317	0.244	0.908	11.000	9.167	0.462	0.145
Whole Lake mean	18.500	5.639	93.470	37.794	1.026	0.068	0.029	0.106	0.302	0.217	0.898	11.200	8.560	0.437	0.135

[1] Sum of mobile P includes loosely-bound P, iron-bound-P and labile organic P

[2] Dupe for all parameters except Fe and Al was at Station Center N. Dupe for Al and Fe was at Station NE

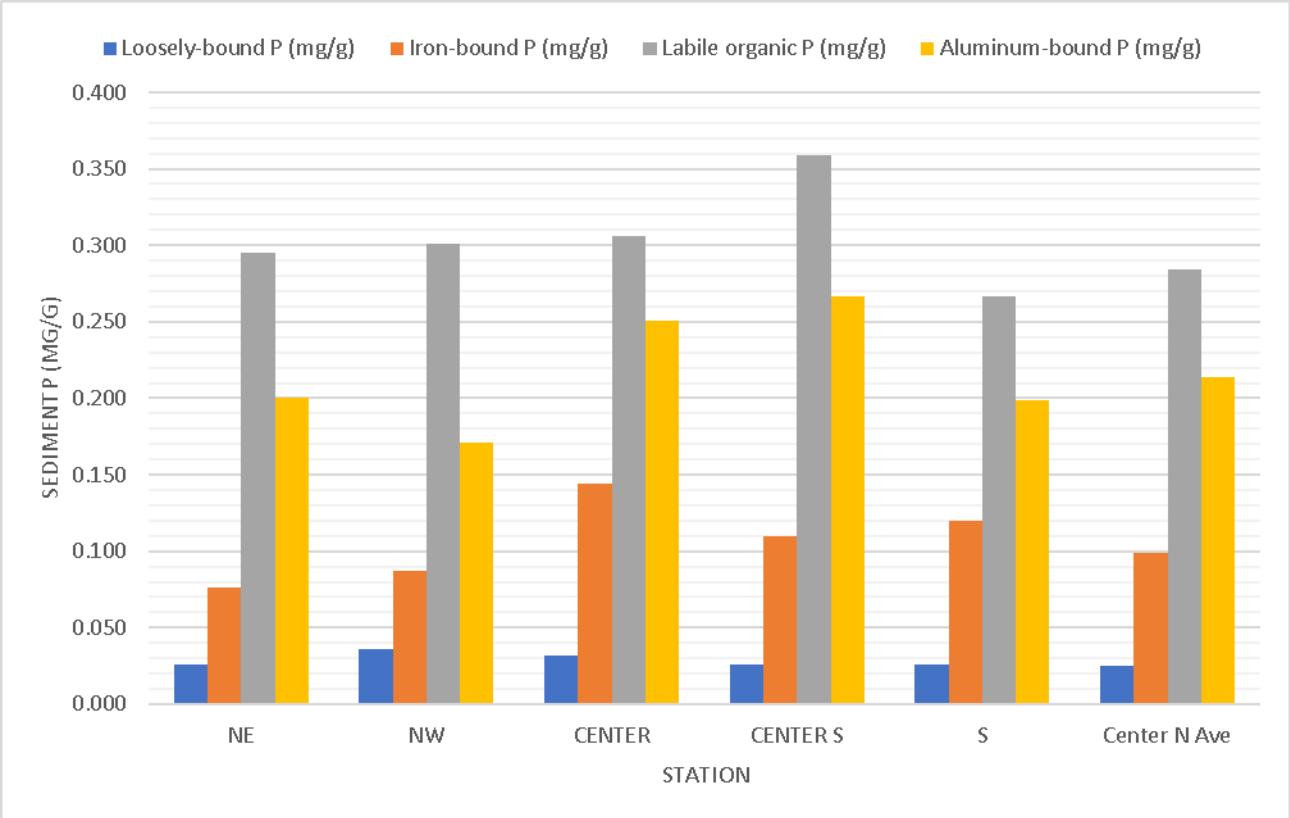

Figure 4: Phosphorus fractions in upper 10 cm of Robinson Pond, Hudson, NH sediments, 2023.

Phosphorus fractions by water depth are presented in Figure 7. In most lakes, sediments and associated phosphorus are focused to the deeper sectional of the lake by gravity. This is the case for mobile forms of P but not for total P in Robinson Pond. This is likely attributable to the proliferation of aquatic plants and plant roots in the shallow zones of the pond which trap and hold sediments before they migrate to the deep section of the pond. Although the relationships are not particularly strong, the mobile and potentially mobile fractions show an increase with water depth in Robinson Pond. This migration of mobile fractions results in a larger pool of releasable P in the deeper anoxic zones.

Iron and aluminum concentrations in conjunction with P concentrations in sediment (Table 4) can also help inform an assessment of the likelihood of release of P from the sediments to the water column. Concentrations of aluminum are low when compared to other NH lakes while iron concentrations are somewhat low. Molar ratios of aluminum to phosphorus more than 25 in the sediment indicate that available aluminum is sufficient to keep phosphorus bound in

the sediments regardless of the oxygen status of the overlying water or sediment pore water (Norton et al 2008). Al/P ratios in Robinson Pond were all well below 25 suggesting that aluminum may not be sufficient to lock up phosphorus in the sediment and avoid release back to the water column (Table 4). A molar ratio of aluminum to iron in the sediments more than 3 (Kopacek et al 2007) suggests that that there is sufficient aluminum to react with phosphorus that may be released from iron under low oxygen conditions. In Robinson Pond, aluminum to iron rations were less than 3 in all samples (Table 4) suggesting that the lake may be susceptible to phosphorus release when the sediments are exposed to anoxic conditions.

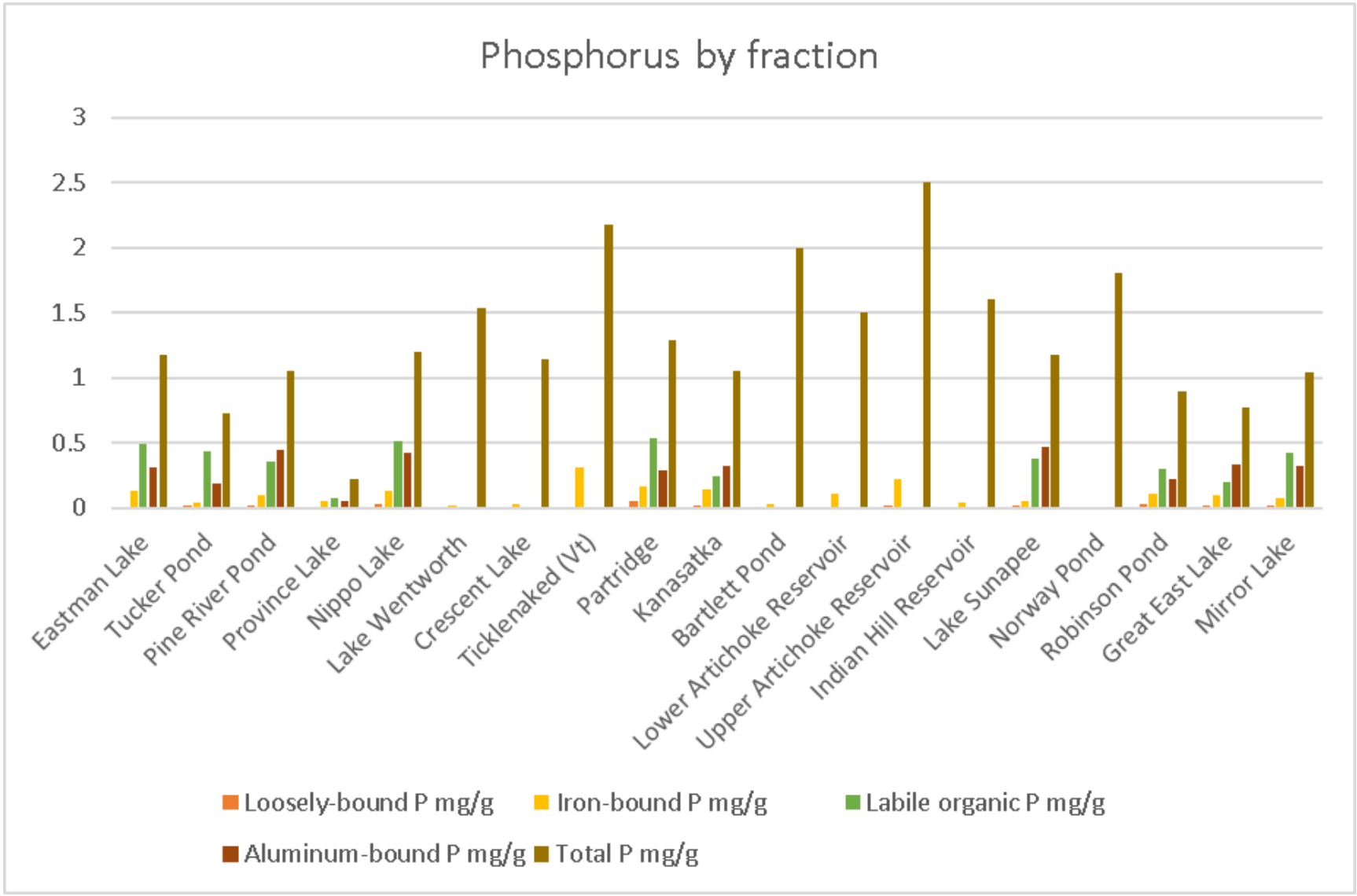

Figure 5: Sediment phosphorus fractions across selected New Hampshire and nearby lakes.

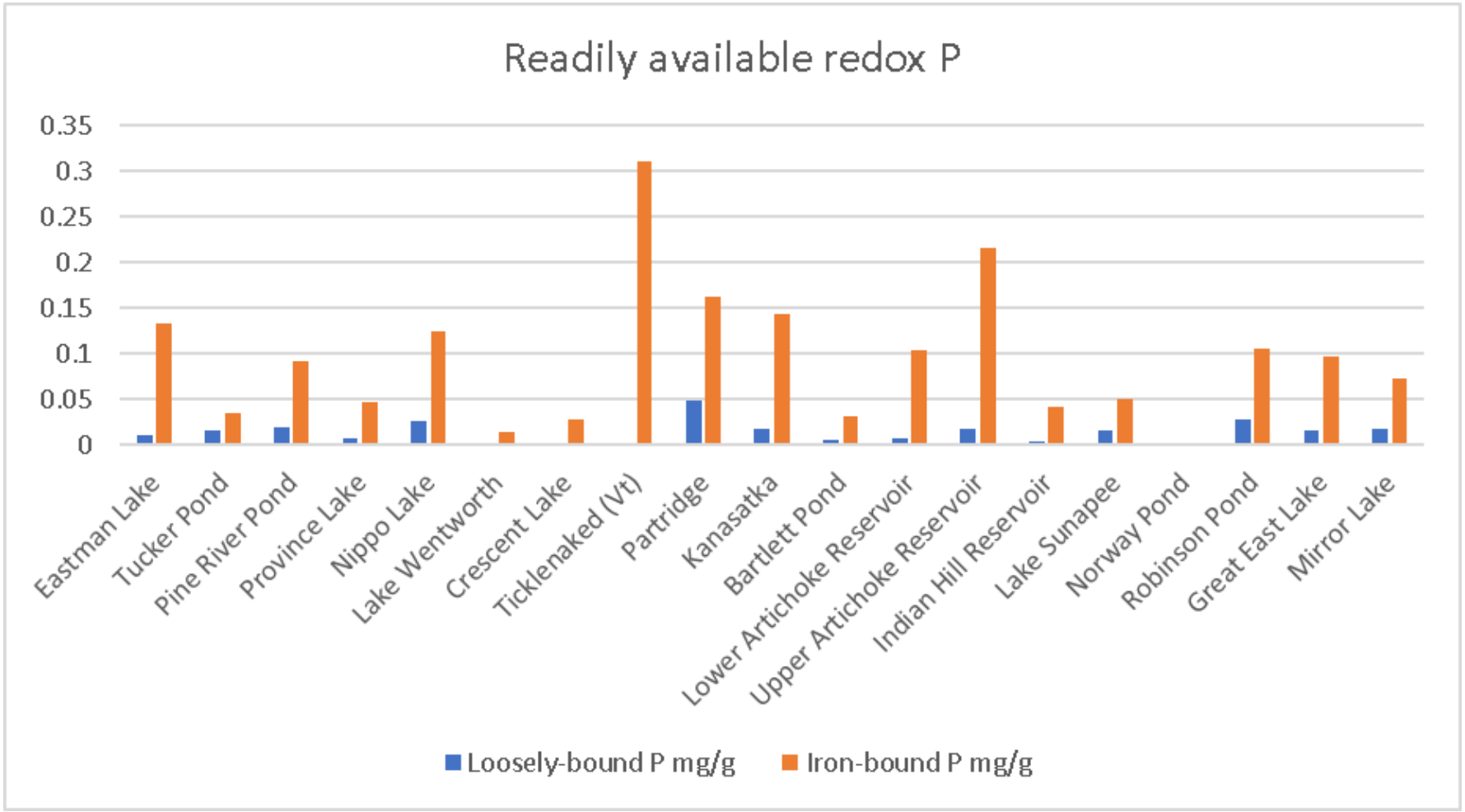

Figure 6: Phosphorus fractions likely to be released under anoxic conditions across selected New Hampshire and nearby lakes.

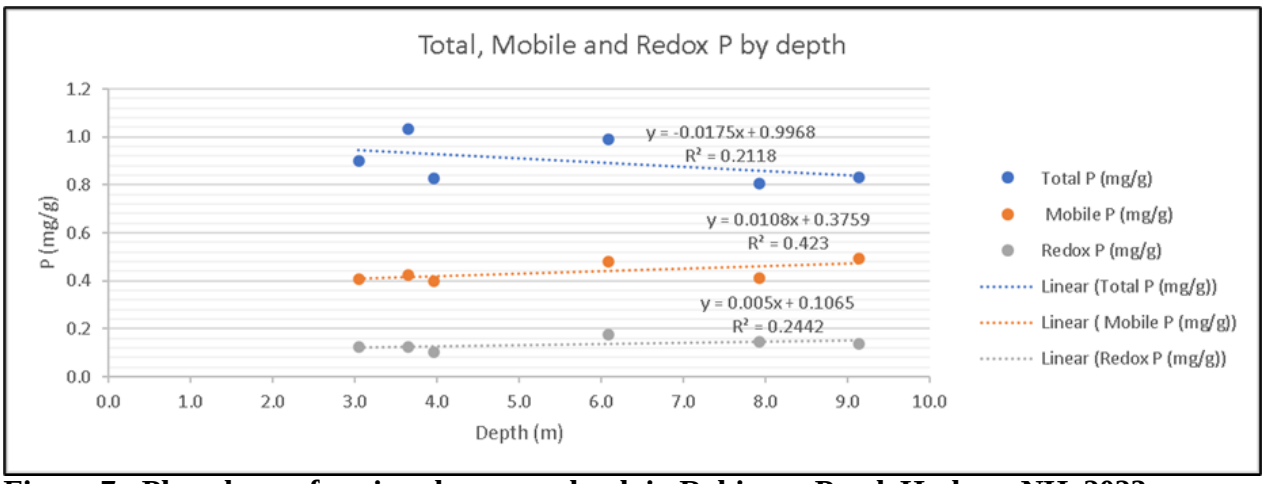

Figure 7: Phosphorus fractions by water depth in Robinson Pond, Hudson, NH, 2023.

Table 4: Sediment metals ratios for upper 10 cm of sediment in Robinson Pond, Hudson, NH, 2023.

Station	Total Phosphorus mg/g	Atomic weight P	Total Iron mg/g	Atomic weight Fe	Total Aluminum mg/g	Atomic weight Al	molar ratios Al/Fe	Al/P
NE	0.826	30.97	11	55.84	9.9	26.98	1.9	13.8
NW	1.033	30.97	11	55.84	7	26.98	1.3	7.8
CENTER N	0.989	30.97	11	55.84	9	26.98	1.7	10.4
CENTER	0.991	30.97	10	55.84	9.2	26.98	1.9	10.7
CENTER S	0.834	30.97	12	55.84	9.3	26.98	1.6	12.8
S	0.806	30.97	12	55.84	7.4	26.98	1.3	10.5
DUP 2	0.810	30.97	11	55.84	10	26.98	1.9	14.2
Center N Ave	0.900	30.97		55.84		26.98		
NE Ave		30.97	11	55.84	10.0	26.98	1.9	
Whole Lake mean	0.898	30.97	11.2	55.84	8.6	26.98	1.6	10.9

The estimated annual mass of potentially mobile sediment P in the upper 10 cm of the sediment layer was estimated using the empirical relationship developed by Nurnberg (1988) where the release rate per unit area exposed to anoxia can be calculated from the amount of redox P in the upper 10cm of sediment. The equation is:

$$\text{Release rate (mg/m}^2\text{ d)} = (13.66 * \text{Redox P in mg/g dry weight}) - 0.47$$

For Robinson Pond, the sediments deeper than 3m are estimated to release phosphorus at a rate of 1.52 mg/m^2 d for a total of 19-168 days based on 2023 water quality data. Deeper sediments are exposed to anoxia for longer periods of time (Table 5). As a result of the anoxia and available phosphorus in the sediments, Robinson Pond sediments below 3 meters were estimated to release 26.3 kg of phosphorus over the course of the summer. This internal load is approximately 23% of the non-internal load estimated from the TMDL study

(AECOM 2011). The TMDL study estimated the internal load based on 2009 data at 2.3 kg or approximately 2% of the watershed load.

Table 5: Estimated annual internal load of phosphorus in Robinson Pond 2023.

Interval (m)	Area between Contours (ha)	Release Rate (mg/m2 d)	Number of Days of Anoxia	Season Release (kg)
3 to 4	2.86	1.52	19	0.8
4 to 5	4.39	1.52	63	4.2
5 to 6	3.42	1.52	139	7.2
6 to 7	3.48	1.52	156	8.3
7 to 8	1.82	1.52	156	4.3
>8	0.59	1.52	168	1.5
Total	**16.56**			**26.3**

Robinson Pond has a modest amount of potentially available phosphorus in the sediments that is being released under severe anoxic conditions. The degree of anoxia and overall phosphorus concentrations in Robinson Pond appear to be getting larger over time despite efforts in nutrient reduction in the watershed. This increase is likely attributable, in part, to a large increase in the internal load.

The results of the sediment testing program in conjunction with a review of water quality results suggest that there is currently anoxic migration of phosphorus from the sediments to the water column. Much of the phosphorus in the sediment is currently bound to aluminum and organic compounds however there is sufficient redox P to fuel releases from the sediments deeper than 3m. It is also certainly possible that cyanobacteria cells on the pond bottom or at the thermocline pick up phosphorus directly from the sediments in shallow water or the hypolimnion, respectively, and then rise into the water column. This could be an important mechanism for the perpetuation of blooms throughout the summer.

2.4 Next Steps

The information obtained from the sediment sampling program confirms the presence of available sediment phosphorus in Robinson Pond. Because the sediment data show a reservoir of potentially mobile P in the deeper sections of the pond, continued dissolved oxygen monitoring in the deeper sections of the pond coupled with water column P measurements in the hypolimnion are suggested to confirm the persistence of the internal load. These data will be used to document changes in the current sediment release rates to overlying waters. Specific attention should be paid to periods of stratification (June through

September). The water quality data regularly collected should be sufficient to do at least preliminary design on sediment phosphorus inactivation, a hypolimnetic aeration or oxygenation project should one of these be desired in the future. Because recent bathymetric data appear to be unreliable, a resurvey of the pond is advisable. The bathymetry is an integral part of the calculation of the internal release of phosphorus and evaluation of treatment alternatives.

Continued watershed management that results in phosphorus load reduction will decrease the likelihood that internal load driven by anoxia get worse, however, inactivation of redox phosphorus in the sediments or addition of oxygen to the deep sections of the pond through aeration or oxygen injection may be needed to address the internal load. Phosphorus inactivation using aluminum is expected to cost $150,000 to $300,000 including permitting, monitoring and treatment costs. Unknowns in this estimate are the permitting requirements which have not been formalized in New Hampshire or the price of aluminum which fluctuates greatly in the market. There are numerous technologies in the market to reduce hypolimnetic anoxia by increasing oxygen through mixing or injection. Depending on the technology chosen, costs may be comparable to sediment phosphorus inactivation however, there would be an ongoing operations cost.

Watershed management should be continued regardless of the treatment of the internal load. A reduction in the external load will decrease the likelihood that internal load driven by anoxia will get worse without treatment, improve the likelihood that treatment of the internal load will succeed and increase the longevity of an internal load treatment.

3.0 References

AECOM. 2011. Total Maximum Daily Load for Robinson Pond, Hudson, NH. Prepared for USEPA Region 1, Boston, MA.

Cooke, G.D., E.B. Welch, S.A. Peterson, and S.A. Nichols. 2005. Restoration and Management of Lakes and Reservoirs, Third Edition. Taylor and Francis, Boca Raton, Fl.

DKWRC and NHDES. 2018. Quality Assurance Project Plan for Sampling and Analysis of Phosphorus in Sediments. Prepared for Nippo Lake Association.

Kopacek, J., M. Maresova, J. Hejzlar and S. A. Norton. 2007. Natural inactivation of phosphorus by aluminum in preindustrial lake sediments. Limnology and Oceanography. 52(3): 1147-1155.

NH GRANIT. 2016. Bathymetric Data for Robinson Pond, Hudson, NH.

NHDES. 2021. VLAP Report for Robinson Pond, Hudson, NH.

NHDES. 2022. EMD data for Robinson Pond, NH. Accessed 9/29/2022.

NH WSPCD. 1988. Bathymetric Map for Robinson Pond, Hudson, NH.

Norton, S.A., K. Coolidge, A. Amirbahman, R. Bouchard, J. Kopacek and R Reinhardt. 2008. Speciation of Al, Fe, and P in recent sediment from three lakes in Maine, USA. Science of the Total Environment 404: 276-283.

Nurnberg, G.K. 1988. Prediction of Phosphorus Release Rates from Total and Reductant-Soluble Phosphorus in Anoxic Lake Sediments. Can J. Fish. Aquat. Sci. 45:453-462.

VHB. 2023. Unpublished water quality data for Robinson Pond, Hudson, MA.

Appendix Table 1: QA data for Robinson Pond sediment sampling program 2023

QA Data															
					Moisture	Organic	Wet bulk	Dry bulk	Loosely-bound P	Iron-bound P	Labile organic P	Aluminum-bound P	Total	Total	Total
		Duplicates[1]	Split[2]		content	content	density	density	P	P	P	P	P	Al	Fe
					(%)	(LOI, %)	(g/cm^3)	(g/cm^3)	(mg/g)	(mg/g)	(mg/g)	(mg/g)	(mg/g)	(mg/g)	(mg/g)
Field Replicate															
Center N		1			93.8	37.6	1.025	0.065	0.026	0.108	0.331	0.205	0.989		
Center N (DUP)		1			92.4	38.8	1.029	0.079	0.024	0.090	0.238	0.223	0.810		
NE														9.9	11.0
NE(DUP)														10.0	11.0
Relative Percent Difference (%)					1.47	3.04	0.48	18.44	8.33	20.00	39.08	8.07	22.19	1.00	0.00
		[1]Duplicates represent two separate subsamples withdrawn from the same sample													

Appendix IX: Robinson Pond TMDL

Available online from NHDES: Total Maximum Daily Load for Robinson Pond, Hudson, NH: https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/final-phosphorus-tmdl-report-robinson-pond.pdf