2019 Lake Carmi Clean Water Progress Report

Photo Credit: Larry Myott

Amended: July 17, 2020

VERMONT CLEAN WATER INITIATIVE

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AGENCY OF AGRICULTURE, FOOD & MARKETS
AGENCY OF COMMERCE & COMMUNITY DEVELOPMENT
AGENCY OF NATURAL RESOURCES
AGENCY OF TRANSPORTATION

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Acknowledgements

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Report electronically available at: **https://dec.vermont.gov/watershed/restoring/carmi**.

Foreword

3 June 2020

If you Google images of Lake Carmi, you tend to get one of two things. On one hand, you see scenic pictures of this natural jewel in a quiet part of Northern Vermont – images filled with gorgeous sunsets, prize-worthy fish being pulled from its waters and, more recently, bald eagles. The other set of images show a lake that is struggling to breathe, choked with thick blooms of cyanobacteria – a symbol of the water quality challenges facing Vermont, and an example of how non-point source pollution can fundamentally alter an ecosystem and create both public health and economic challenges. For me, Lake Carmi serves as an example of how numerous partners with different priorities can come together around a shared goal and make tangible progress towards improving water quality through hard work, critical investments, behavior change, and expert input.

Following the development of a phosphorus pollution budget for Lake Carmi – also called a Total Maximum Daily Load or TMDL – in 2008, a strong coalition formed, including local farmers, non-governmental organizations, lakeshore residents, local officials, and state and federal agencies. The coalition has, and continues to, work hard to address the harmful cyanobacteria blooms that have plagued Lake Carmi for many years. Success was not immediate, and it took a particularly challenging set of conditions in 2017 – including a bloom that persisted for fifty days – to galvanize the political and financial support necessary for significant and long-term change.

Over the last three years, and as this report demonstrates, the State of Vermont has invested over $1.4 million in clean water projects in Lake Carmi and its watershed. These investments are estimated to have achieved approximately 41% of the phosphorus reduction required to meet the Lake Carmi Phosphorus Total Maximum Daily Load. This important progress is a result of many factors and projects, notably the implementation of agricultural best management practices, lake shoreland protection efforts, and controlling stormwater runoff from impervious surfaces, like roads. In addition, in 2019, the State of Vermont supported the implementation of a whole-lake aeration system for Lake Carmi – one of the largest such systems ever installed in the country – to reduce the release of phosphorus from lake bottom sediments. And although there was still a significant cyanobacteria bloom last year, both scientific and anecdotal observations suggest that the aeration system helped limit the intensity and the duration of the bloom as compared to previous years.

The aeration system is an important and valuable component of the work needed to address cyanobacteria blooms, but this is not a singular solution. Conditions in 2019 demonstrated that the more intense precipitation events and warmer temperatures associated with climate change will continue to create environmental conditions conducive to blooms. It is essential that all members of the coalition continue their individual and shared efforts to reduce phosphorus pollution if we are to achieve the shared goal of lasting water quality in Lake Carmi.

Given the strong collaboration, the use of a combination of tried-and-true and innovative solutions, and the continued support from numerous technical and financial partners, I am confident that we can achieve our clean water goals in Lake Carmi and establish a model for watershed and lake restoration that can be replicated elsewhere in Vermont. And I look forward to the day when the only images that will be brought to mind when someone mentions Lake Carmi will be similar to one on the cover of this report.

Julia S. Moore, P.E., Secretary
Vermont Agency of Natural Resources

Executive Summary

Lake Carmi was designated as a Lake in Crisis in 2018 due to persistent cyanobacteria blooms resulting from high in-lake phosphorus concentrations. In response, the State of Vermont issued a Lake Carmi Crisis Response Plan outlining several Critical Path Projects (high priority actions) aimed at reducing phosphorus loading to Lake Carmi. In the Lake Carmi Crisis Response Plan, the State of Vermont also committed to track clean water efforts in the Lake Carmi watershed and report on investments and results annually. The purpose of this report is to summarize work completed to date to meet Lake in Crisis Response Plan objectives that should translate into water quality improvements in Lake Carmi.

The State of Vermont works extensively with numerous partners and stakeholders within the Lake Carmi watershed to implement projects for improving Lake Carmi's water quality. Projects to date have reduced pollutant loads from wastewater treatment facilities, developed lands, and agricultural lands, as well as enhanced the ability of natural resources, such as wetlands and shorelines, to protect surface waters. In addition to contributions by the Town of Franklin, private land owners (including farmers), and other partners, the state has invested over $1.4 million dollars in clean water projects within Lake Carmi and its watershed from state fiscal year (SFY) 2016 to SFY 2019 (see Figure 3, page 12).

Approximately 28% of total funding from SFY 2016 to 2019 was invested in clean water projects aimed at reducing phosphorus loading from the Lake Carmi watershed. State and federal watershed investments reduced an estimated 251 kilograms (kg) of phosphorus loading in SFY 2019, which is estimated to be approximately 41% of the phosphorus reduction required to meet the Lake Carmi Phosphorus Total Maximum Daily Load (TMDL; see Figure 12, page 30). Nearly all the estimated phosphorus reductions currently quantifiable in the Lake Carmi watershed have been associated with the agricultural sector (see Figure 10, page 27). Estimated phosphorus reductions reported are expected to increase substantially in the coming years, as the State of Vermont is expanding its ability to estimate phosphorus reductions for all clean water project types, and new regulatory programs will drive additional phosphorus reductions from developed lands and agricultural sources.

In addition to external phosphorus loading from the watershed, internal phosphorus loading (the release of phosphorus from bottom sediments under low oxygen conditions) is also a significant source of phosphorus contributing to cyanobacteria blooms in Lake Carmi. To address internal phosphorus loading, the State of Vermont invested 72% of total funding from SFY 2016 to 2019 in the testing and implementation of an in-lake aeration and circulation system. The aeration system was operational during the summer of 2019 and successfully limited internal phosphorus loading from the bottom sediments. Cyanobacteria blooms still occurred in Lake Carmi during 2019, but limiting internal phosphorus loading should help reduce the frequency and duration of cyanobacteria blooms over the long-term.

The in-lake aeration system and clean water projects installed in the Lake Carmi watershed are expected to reduce internal and external phosphorus loading to Lake Carmi, respectively, and improve water quality incrementally over time. While Lake Carmi's water quality is the ultimate indicator of progress, it will take time to realize the full benefits of these projects as

measured by in-lake data. Additionally, other variables, such as climate and land use change, may affect phosphorus loading to Lake Carmi and Lake Carmi's water quality. Water clarity within Lake Carmi has improved significantly in the past several decades, indicating some progress towards achieving water quality goals (see Figure 13, page 33). Total phosphorus and chlorophyll (a proxy for lake productivity) concentrations, however, show no significant trend over the same period, and summer cyanobacteria blooms continue to impact the lake. To observe consistent improvements in water quality, in-lake phosphorus remediation efforts must be complemented by continued interventions in the watershed in order to reduce all sources of excess phosphorus loading to the lake.

As funding allows, the State of Vermont will continue investing in clean water projects in Lake Carmi and its watershed to remediate the Lake in Crisis. The state and several partners will also continue outreach and educational efforts aimed at increasing community engagement and the adoption of clean water practices. The phosphorus load reductions estimated to date were the result of many collaborative efforts and the strong engagement of Lake Carmi stakeholders, and continued community engagement in clean water efforts is necessary to achieve Lake Carmi's clean water goals.

For more information and resources regarding Lake Carmi remediation efforts, please visit: https://dec.vermont.gov/watershed/restoring/carmi.

I. Introduction

Lake Carmi is a large (1,402 acres) and relatively shallow (maximum depth 33 feet) lake located in the Town of Franklin in northwestern Vermont. The land that drains to Lake Carmi (i.e., its watershed), shown in Figure 1, is approximately 7,710 acres and drains a variety of land uses. Currently, 21 – 25% of acreage in the watershed is tilled or untilled farmland. Forty-five percent of the watershed is wooded or wetland, including a large portion of Franklin Bog. Apart from intensive shoreline development, low-density residential development is spread throughout the watershed.

Lake Carmi State Park is one of the most used state parks in Vermont. In addition to a large swimming beach, 2.9 miles of undeveloped shoreland (38% of the total shoreline) are included in the park and comprise the bulk of the undeveloped shore lake-wide. The remaining 62% of shoreland is heavily developed, including 282 seasonal camps, 30 year-round homes, 20 camp lots, 14 camp ground/seasonal rentals, three farms, three commercial properties, and an extensive road network within 1,000 feet of the shoreline (Lisa Larivee, Franklin Town Clerk, personal communication). Many of the shoreline camps are located within 50 feet of the shoreline, and most do not have significant vegetation other than a lawn between the camp driveway and the lake. In addition to a boat launch ramp in the State Park, there is a Vermont Fish and Wildlife Department access area at the northern end directly on Route 120. Many town residents park along Route 120 and swim off the shore adjacent to the boat ramp during the summer.

Lake Carmi has experienced significant water quality issues for several decades resulting from high phosphorus concentrations, including summer cyanobacteria (blue-green algae) blooms, reduced water clarity, and excessive aquatic plant growth. As these issues pose a risk to public and environmental health, the State of Vermont and many other organizations are actively working to reduce nutrient loading, improve water quality, and restore Lake Carmi.

Lake Carmi was listed as an impaired waterbody under Section 303(d) of the Federal Clean Water Act due to persistent water quality problems. In 2009, the State of Vermont and U.S. Environmental Protection Agency (EPA) established a Phosphorus Total Maximum Daily Load (TMDL) for Lake Carmi, which identifies the extent to which phosphorus pollution needs to be reduced to meet State of Vermont water quality standards.[1] According to TMDL modeling, the total phosphorus load allocation for Lake Carmi is 924 kilograms per year (kg/yr). Phosphorus loading must be reduced by 611 kg/yr (includes 103 kg/yr margin of safety) in order to reach this phosphorus target and mitigate water quality issues.

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[1] Phosphorus TMDL for Lake Carmi, submitted October 2008 and approved by EPA April 2009: https://dec.vermont.gov/sites/dec/files/documents/WSMD_mapp_2009_Carmi%20P%20tmdl.pdf.

Lake Carmi was also designated as a Lake in Crisis in 2018 under Vermont Act 168 of 2018. As a result, the State of Vermont issued a Lake Carmi Crisis Response Plan outlining several Critical Path Projects (high priority actions) aimed at reducing phosphorus loading to Lake Carmi.[2] In the Lake Carmi Crisis Response Plan, the State of Vermont also committed to track clean water efforts in the Lake Carmi watershed and report on investments and results annually.

The purpose of the Lake Carmi Clean Water Progress Report is to summarize work completed to date to meet Lake in Crisis Response Plan objectives that should translate into water quality improvements. This report uses the following categories of accountability measures to demonstrate Lake Carmi's clean water progress:

1. **Investment measures** of how State of Vermont invests in clean water projects from planning to design and implementation.
2. **Project output measures** that quantify the results of completed state and federally funded clean water restoration projects and regulatory programs.
3. **Environmental outcome measures** that estimate phosphorus pollution reductions achieved through state and federally funded clean water projects and regulatory programs.[3]
4. **Water quality trends** to illustrate how the lake is responding to watershed and in-lake management efforts, as well as external variables such as climate and land use changes.

Clean water projects target phosphorus pollution across various land use sectors. The accountability measures presented in this report are categorized by the following sectors.

Agriculture
Installation or application of conservation practices that reduce sources of nutrient and sediment pollution from farm production areas and farm fields.

Developed Lands (Stormwater)
Installation of stormwater practices that treat polluted stormwater runoff from developed lands, such as parking lots, sidewalks, and rooftops.

Developed Lands (Roads)
Installation of stormwater and roadside erosion control practices that prevent erosion and treat road-related sources of nutrient and sediment pollution.

[2] 2018 Lake Carmi Crisis Response Plan: https://dec.vermont.gov/sites/dec/files/wsm/lakes/docs/2018_08_22_Lake_Carmi_Crisis_Response_Plan_2.0.pdf.

[3] Phosphorus reduction estimates are modeled using generalized phosphorus reduction efficiency values for each clean water project type. Phosphorus reductions are not measured at the individual project-level through water quality monitoring.

Natural Resource Restoration
Restoration of "natural infrastructure" functions that prevent and abate nutrient and sediment pollution. Natural infrastructure includes floodplains, river channels, lakes, wetlands, and forest lands.

Wastewater
Decreases nutrients (phosphorus and nitrogen) through enhanced wastewater treatment and addresses aging infrastructure

Report Scope

The Vermont Agency of Natural Resources (ANR) Department of Environmental Conservation (DEC) gathered clean water project data from the U.S. Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS), Vermont Agency of Agriculture, Food and Markets (AAFM), Vermont Agency of Transportation (VTrans), and Vermont Housing and Conservation Board (VHCB) to complete this report. Projects were limited to the Lake Carmi watershed and the following conditions:

- State investments in clean water projects through State of Vermont grant, contract, and loan agreements awarded in State Fiscal Year (SFY) 2016-2019 (July 1, 2015 through June 30, 2019).[4]
- Results of state-funded clean water projects completed in SFY 2016-2019, including project output measures and estimated phosphorus reductions.[5]
- Results of USDA-NRCS-funded agricultural conservation practices completed in SFY 2016-2019, including project output measures and estimated phosphorus reductions.[6]

In addition, this report includes:

- Updates on progress towards achieving the seven objectives identified in the Lake Carmi Crisis Response Plan.
- Discussion of water quality trends in Lake Carmi since 1979.
- List of state and federally funded clean water projects funded and/or completed in the Lake Carmi watershed SFY 2016-2019 (Appendix A).

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[4] State investments are defined as dollars encumbered or awarded to clean water projects through grants and contracts, or financed through loans, administered by the State of Vermont. Investments reported include state and federal dollars awarded to projects by state agencies, but exclude federal funds awarded to projects directly by federal agencies.

[5] Work completed in the reporting period of SFY 2016-2019 includes state grants, contracts, and loan agreements closed out (all deliverables completed/approved and final payments made) between July 1, 2015 and June 30, 2019.

[6] This report only includes the USDA-NRCS-funded practices with estimated phosphorus reductions reported to DEC. Other practices have been funded by NRCS, but methods were not in place at the time of publishing this report to estimate phosphorus reductions, or practices did not directly correlate with a state-defined phosphorus reduction.

The following data are outside the scope of this report:

- State investments in projects with grant, contract, and loan agreements executed outside the reporting period (i.e., agreements executed prior to July 1, 2015 or after June 30, 2019).
- Results of clean water projects completed outside the reporting period (i.e., projects completed prior to July 1, 2015 or after June 30, 2019).
- Federal agencies' direct investments in clean water projects, unless reported as federal match on a state grant, contract, or loan agreement.
- Municipal and private investments in clean water projects necessary to comply with water quality regulations, unless reported as local match on a state grant or contract agreement.
- VTrans' investments in clean water projects to comply with water quality regulations on state highways and VTrans-owned non-road developed lands. Results of VTrans' projects to comply with water quality regulations will be included in future reporting periods once data are available through regulatory reporting avenues.

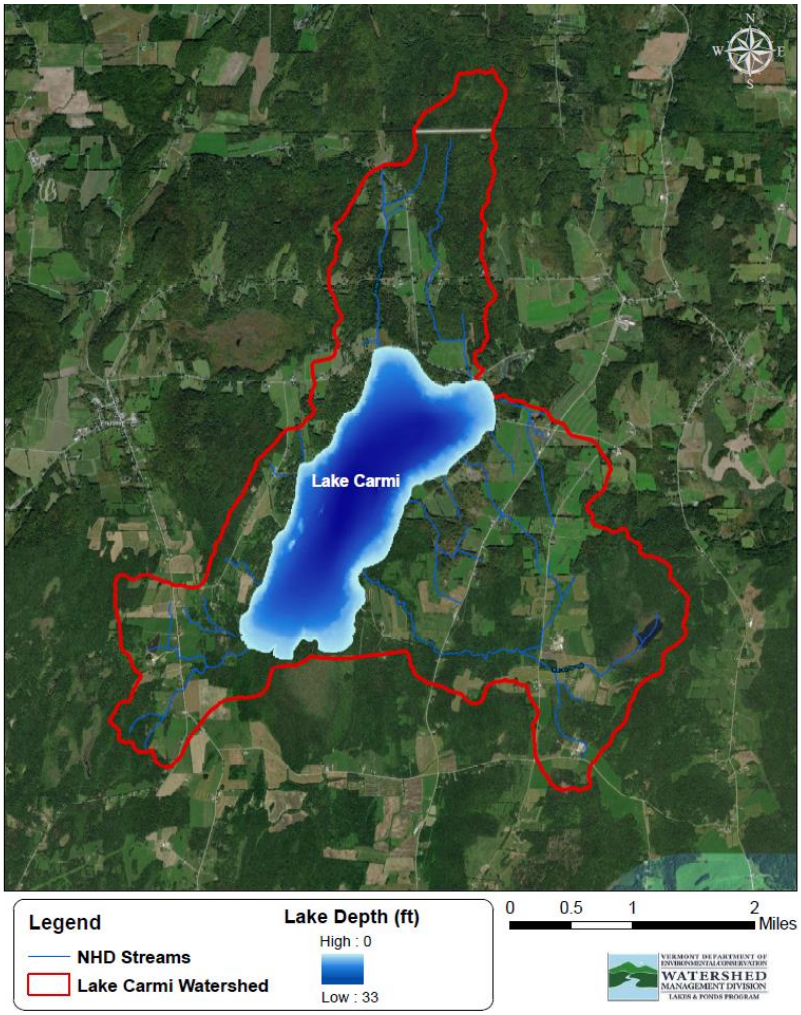

Figure 1. Lake Carmi watershed boundary (red line).

II. Lake Carmi Clean Water Investments

Restoring Lake Carmi's clean water requires investments at the state, federal, municipal, and private level. The State of Vermont's clean water investments are channeled through grants, contracts, loans, and assistance programs, shown in Table 1, to strategically and cost-effectively restore and safeguard the state's rivers, streams, lakes, ponds, and wetlands. These funds are used to help identify, prioritize, design, and implement projects. This work helps municipalities, farmers, and other landowners comply with regulations and encourages voluntary actions to address polluted runoff from unregulated sources. Figures 2-4 summarize State of Vermont's Lake Carmi clean water investments made through the funding programs shown in Table 1.

It should be noted that not all possible clean water project funding mechanisms are captured in this report. For example, agricultural best management practices, landowner lakeshore practices, and landowner stormwater practices that are implemented using personal/private funds outside of state and federal funding programs and that are not captured through regulatory program reporting are not currently captured in the state's clean water reporting.

Table 1. State of Vermont funding programs supporting Lake Carmi clean water projects funded SFY 2016-2019, by agency.

Agency	Clean Water Funding Mechanisms
Agency of Agriculture, Food and Markets (AAFM)	Best Management Practice (BMP) Program Capital Equipment Assistance Program (CEAP) Clean Water Fund Grants and Contracts Farm Agronomic Practice (FAP) Program
Agency of Natural Resources (ANR)	Clean Water Initiative Program Grants and Contracts[7] Department of Forest, Parks, and Recreation (FPR) Maintenance Funds[8] Municipal Roads Grants-in-Aid Lake in Crisis Funding
Agency of Transportation (VTrans)	Better Roads Program
Vermont Housing and Conservation Board (VHCB)	Water Quality Grants

[7] Clean Water Initiative Program grants and contracts include Lake Wise Program grants.

[8] FPR Capital Maintenance Funds have not been tracked as a clean water project funding source until this report. Clean water projects supported by this funding stream will be included in future Vermont Clean Water Initiative investment and performance reporting.

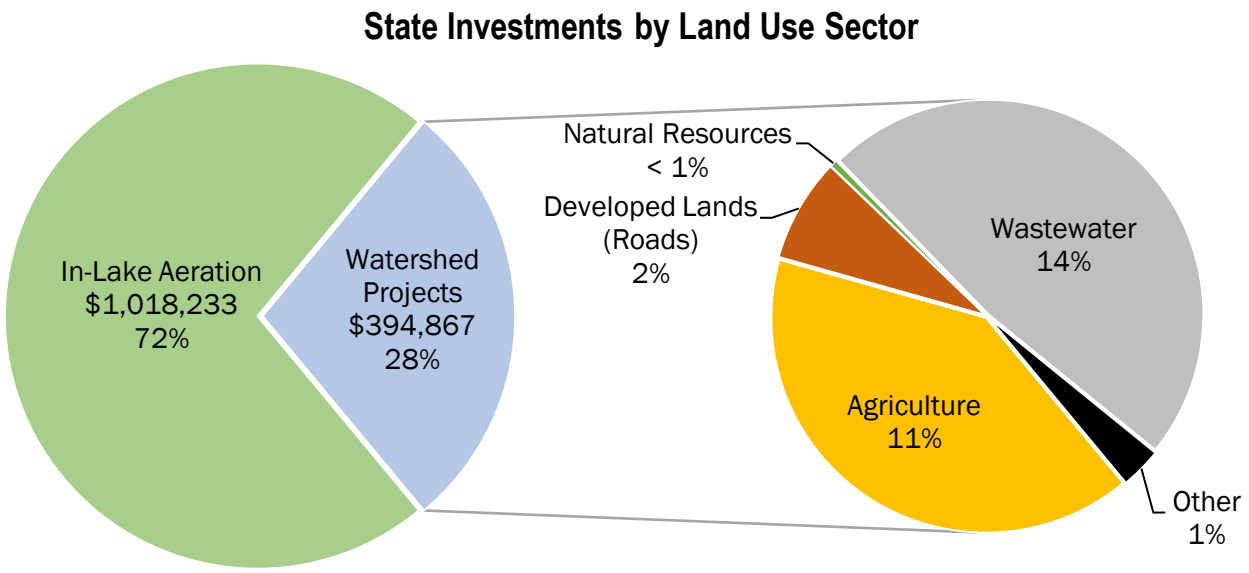

Figure 2. Percentage of dollars awarded by State of Vermont agencies to clean water projects within Lake Carmi and its watershed, SFY 2016-2019, by land use sector.

EXPLANATION OF FIGURE

Reaching Lake Carmi's clean water goals requires investments across all land use sectors, as shown in the figure above. Through SFY 2019, 72% of the state's Lake Carmi investments have been in the design and implementation of an in-lake aeration phosphorus remediation system. In 2018 and 2019, DEC and EverBlue Lake Systems tested and implemented an aeration and circulation system to address excess nutrients (eutrophication) concerns stemming from internal phosphorus loading in Lake Carmi. More information on aeration system performance in 2019 can be found in Section V below and online at https://dec.vermont.gov/watershed/restoring/carmi.

The State of Vermont has also invested in clean water projects aimed at reducing phosphorus loading across the Lake Carmi watershed (28% of total funding). Agricultural projects have included conservation tillage practices, cover cropping, and barnyard/production area best management practices. Numerous road improvement and lake shoreland improvement practices also reduced runoff within the watershed, and FPR's Maintenance Fund supported the zero-discharge wastewater system upgrade at Lake Carmi State Park. See Section III and Appendix A for more information on projects by sector within the Lake Carmi watershed.

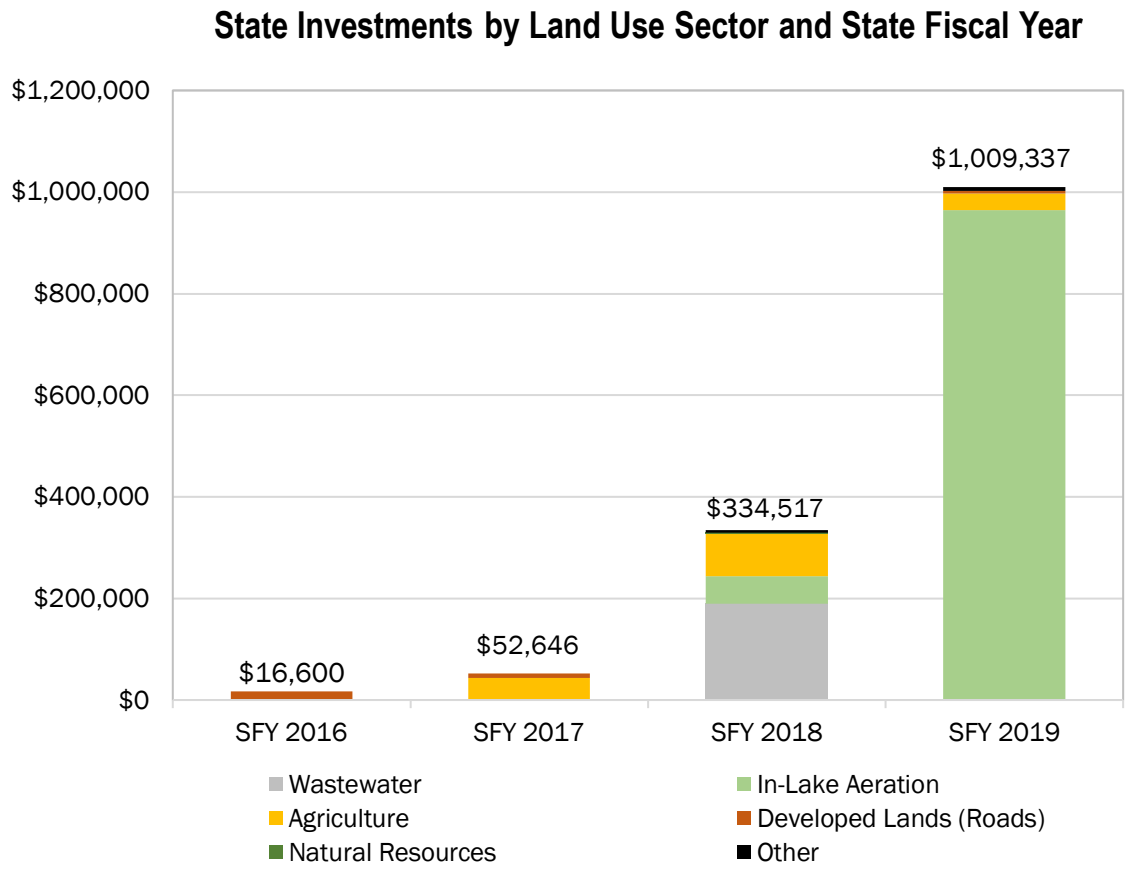

Figure 3. Dollars awarded by State of Vermont agencies to clean water projects in the Lake Carmi watershed, SFY 2016-2019, by land use sector.

EXPLANATION OF FIGURE

Reaching Lake Carmi's clean water goals requires continued investments across all land use sectors. The figure above illustrates that state investments in the Lake Carmi watershed have increased significantly from SFY 2016 to 2019. Twenty-eight percent of all funding from SFY 2016 to 2019 has been invested in reducing pollution from the Lake Carmi watershed, which includes the implementation of agricultural, wastewater, and road pollution reduction projects.

The greatest investments were made during SFY 2019. The "In-Lake Aeration" funding in SFY 2019 represents the implementation of the Lake Carmi aeration system, and the "Wastewater" funding in SFY 2018 represents the Lake Carmi State Park zero-discharge wastewater system upgrade. Agricultural funding varies from year-to-year, and the State of Vermont continues to support regulatory agricultural projects and incentivize non-regulatory agricultural projects. See Section III and Appendix A for more information on projects by sector within the Lake Carmi watershed.

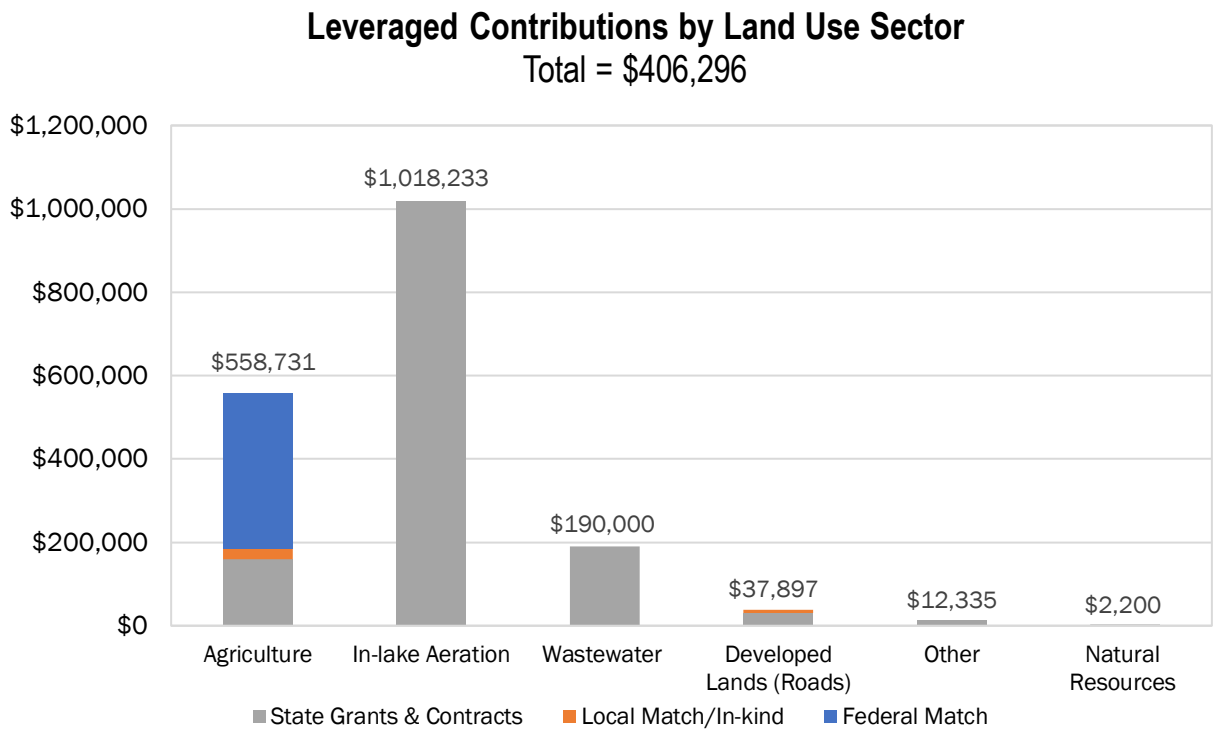

Figure 4. Leveraged contributions (i.e., local match/in-kind, federal match) reported through State of Vermont agencies in addition to state grants and contracts, SFY 2016-2019, by land use sector.

EXPLANATION OF FIGURE

State-funded clean water projects leverage local and federal contributions to help cover project costs and further clean water efforts in Vermont. During the reporting period (SFY 2016-2019), most leveraged contributions were within the agricultural sector due to USDA-NRCS match on VHCB funds. Direct investments in projects by federal agencies or other organizations are beyond the scope of this report.

III. Lake Carmi Crisis Response Plan Updates by Land Use Sector

Lake Carmi was designated as a Lake in Crisis under Vermont Act 168 of 2018. As a result, the State of Vermont issued a Lake Carmi Crisis Response Plan outlining several "Critical Path Projects" aimed at reducing phosphorus loading to Lake Carmi. In the Lake Carmi Crisis Response Plan, the State of Vermont also committed to track clean water efforts in the Lake Carmi watershed and report on investments and results annually. After this *2019 Lake Carmi Clean Water Progress Report*, future reports will be concise annual updates since the last report.

The purpose of the Lake Carmi Crisis Response Plan Updates by Land Use Sector section is to:

1) Summarize efforts underway through early 2020 in Lake Carmi's watershed that collectively contribute to meeting the seven objectives identified in the Lake Carmi Crisis Response Plan, and
2) Assess the degree to which these objectives have been met and, if necessary, recommend additional actions needed to meet these objectives.

The clean water efforts described below were implemented by the Vermont Agency of Natural Resources (DEC and FPR) and partners active in the lake's watershed, including the following:

- Lake Carmi Campers Association (LCCA)
- Franklin Watershed Committee (FWC)
- Friends of Northern Lake Champlain (FNLC)
- Northwest Regional Planning Commission (NRPC)
- University of Vermont (UVM) Extension (UVM Ext.)
- Vermont Youth Conservation Corp (VYCC)
- U.S. Department of Agriculture Natural Resources Conservation Service (USDA-NRCS)

These land and water management efforts contribute to meeting the phosphorus reductions defined in the Lake Carmi TMDL required to meet State of Vermont water quality standards. Additional information regarding project funding and phosphorus load reductions is reported in Sections II and IV of this report and in the Lake Carmi Crisis Response Plan.

The following section summarizes progress towards achieving the seven objectives identified in the 2018 Lake Carmi Crisis Response Plan. Projects with an asterisk (*) were identified as Critical Path Projects in the Crisis Response Plan. Several projects and efforts described in the following section occurred prior to SFY 2016 and are not included in the funding, project outcomes, or phosphorus reduction figures and tables.

Objective #1: Increase knowledge of water quality conditions in the watershed through short-term intensive and long-term monitoring programs.

Understanding water quality conditions within Lake Carmi and its tributaries is essential for tracking progress towards water quality goals. To assess the state of Lake Carmi and its

tributaries, ANR conducts numerous water quality monitoring efforts. Short-term monitoring projects assist in answering specific questions, while long-term monitoring of the lake and its tributaries is used to assess long-term water quality trends and progress towards achieving the TMDL. Together, these monitoring programs allow ANR to help local stakeholders understand the impacts of clean water projects and improved land use management.

ANR and numerous partners have helped support the following monitoring programs to better understand water quality in Lake Carmi, including the specific efforts defined below:

- DEC's In-lake Lay Monitoring Program has measured total phosphorus, chlorophyll, and Secchi depth (water clarity) annually since 1979 to track trends in lake health (see Section V for monitoring results).[9]
- DEC's LaRosa Volunteer Monitoring Program has conducted tributary monitoring with FWC volunteers since 2008.[10] These data help identify the best placement of projects to address sources of high pollutant loading, as well as document improvements in surface water quality from clean water projects. In addition, FWC was supported by the program to collect tributary water samples before and after a natural resource restoration project on Sandy Bay Brook in 2018* to document surface water improvements.
- DEC supported a conductivity survey with FWC volunteers in 2017 to begin the work needed to understand nearshore water quality after a busy holiday weekend.
- The Vermont Department of Health (VDH) has monitored cyanobacteria in Lake Carmi since 2013. Information on the VDH website has helped the community learn how to identify blooms and avoid contact.[11]
- DEC has conducted additional in-lake water quality monitoring to inform recommendations for in-lake phosphorus management since 2016.
- In 2020, AAFM, with support from DEC, will support an effort to evaluate the feasibility of streamflow monitoring for tributaries in the Lake Carmi watershed.
- In 2020, DEC will begin a study to determine if nutrient loading from groundwater is a significant nutrient source to Lake Carmi, supported in part with Lake Champlain Basin Program (LCBP) funding.[12]
- In 2020, DEC's Lakes and Ponds Program, a Lay Monitoring Program volunteer, and UVM will be collecting water quality samples in Lake Carmi to monitor phosphorus

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[9] For more information on the DEC Lay Monitoring Program, please visit: https://dec.vermont.gov/watershed/lakes-ponds/monitor/lay-monitoring.

[10] For Lake Carmi tributary monitoring results, please see the Gerhardt (2018) report: https://dec.vermont.gov/sites/dec/files/2017%20Lake%20Carmi%20Spatial%20Trends%20Final%20Report%20%283%29.pdf.

[11] For more information on cyanobacteria and public health, please visit: https://www.healthvermont.gov/health-environment/recreational-water/cyanobacteria-blue-green-algae.

[12] For more information on the Lake Carmi groundwater study, please see: https://dec.vermont.gov/sites/dec/files/wsm/lakes/docs/Carmi%20groundwater.pdf.

trends and assess the effectiveness of the in-lake aeration system. As the LaRosa Partnership Program is on hold for summer 2020, DEC's Lakes and Ponds Program will also collect water quality samples from five tributaries to Lake Carmi (Marsh, Dewing, Kane, Sandy Bay Brook, and Dicky) to track phosphorus loading to the lake.

LAKE CARMI AERATION SYSTEM

Through in-lake water quality monitoring, internal phosphorus loading (the release of phosphorus from the bottom sediments) was determined to be a significant source of phosphorus contributing to cyanobacteria blooms in Lake Carmi. As internal phosphorus loading typically occurs under low oxygen conditions, DEC funded the design of an in-lake aeration and circulation system in SFY 2018 and 2019. The aeration system artificially mixes the lake to allow dissolved oxygen to reach the bottom sediments, which mitigates internal phosphorus loading. The aeration system was operational in Lake Carmi during the summer of 2019 and successfully limited internal phosphorus loading from the sediment. Cyanobacteria blooms still occurred in Lake Carmi during 2019, but limiting internal phosphorus loading should help reduce the frequency and duration of cyanobacteria blooms over the long-term. More information about the aeration system can be found in Section V below and on DEC's Restoring Lake Carmi webpage available at: https://dec.vermont.gov/watershed/restoring/carmi.

Figure 5. Lake Carmi aeration system compressor cabinet at Lake Carmi State Park (left) and bubbles produced in the lake by the aeration system during operation (right).

AGRICULTURE

Objective #2: Implement agricultural best management practices (BMPs) throughout the watershed.

Agricultural land in the Lake Carmi watershed has benefited from enhanced financial and technical assistance provided by the State of Vermont and other partners, including USDA-NRCS and UVM Extension. Local farmers have demonstrated their willingness to adopt innovative practices and change the way they operate to improve water quality in Lake Carmi. The Vermont Agency of Agriculture, Food and Markets (AAFM), DEC, and USDA-NRCS have each provided technical and financial assistance to this effort, enabling UVM Extension to work directly with each farmer in the watershed on BMP implementation and nutrient management

planning. As a result, farmland has shown the greatest estimated reduction of phosphorus loading to Lake Carmi of all land use sectors (see Section IV below).

Outputs of agricultural pollution prevention projects funded by NRCS and AAFM are listed in Tables 2 and 3 below. Currently, agricultural conservation practices tracked by the State of Vermont are limited to those funded through state or federal cost-share programs or implemented to comply with regulatory programs. Farmers are also implementing practices outside of state and federal funding programs. UVM Extension is working with farms to verify additional conservation practices implemented to ensure a more complete tracking of agricultural BMPs in future reports.

Key agricultural interventions include the following efforts:

- In 2019, UVM Extension worked with the farmers in the Lake Carmi watershed to update and improve nutrient management plans. UVM Extension helped update and evaluate all farm soil test results for fields in the Lake Carmi watershed, and the results illustrated only 2% of agricultural acres were above optimum phosphorus levels according to university recommendations. UVM Extension will also be using nutrient management plan data to calculate the "mass balance" (phosphorus-in and phosphorus-out) for each farm. Altogether, these efforts may identify additional management improvements to reduce phosphorus runoff from agricultural operations.
- Many agricultural acres have changed from annual crops (corn) to hay land, which reduces phosphorus loading because corn fields have higher erosion rates and nutrient runoff.
- In 2019, AAFM provided funding to UVM Extension to purchase a grassland manure injector that will be implemented on farms in the watershed in 2020. Implementation funding is provided by DEC, AAFM, and NRCS, and acres of injection will be tracked in 2020.[13] Manure injection is expected to decrease phosphorus loading from hay fields, as manure is placed in the root zone where it is less susceptible to surface runoff.
- Increased compliance with the new Required Agricultural Practices (RAPs) is also expected to reduce phosphorus loading. Practices include adoption of increased buffers, livestock exclusion from streams, improved waste storage facilities, steep slope management, and adoption of cropland conservation practices.
- DEC, AAFM, and UVM Extension also support farmers in addressing agricultural pollution through providing education and outreach events related to agricultural water quality. This includes workshops, trainings, and stakeholder meetings on a variety of topics from nutrient management planning and implementation, to conservation and precision agricultural equipment, field research trials, and more.

[13] The manure injector is included in UVM Extension's state-wide technical assistance grant, and individual/local components of statewide agreements are not separated out for sub-watershed reporting. Funding for additional equipment to support the manure injection system was also completed through the VAAFM CEAP Program after the SFY 2019 reporting timeframe.

Table 2. Outputs of state-funded agricultural pollution prevention projects completed in the Lake Carmi watershed, SFY 2016-2019.

Agriculture Project Output Measures	2016	2017	2018	2019	Total
Acres of cover crop planted through AAFM's Farm Agronomic Practice Program	--	--	28	33	61
Estimated acres of cover crop planted through AAFM's Capital Equipment Assistance Program	--	--	--	92	92
Number of barnyard and production area practices installed	--	1	1	1	3
Acres of barnyard and production areas in full RAP compliance (based on AAFM inspections)	--	--	11	--	11

EXPLANATION OF TABLE

Agricultural conservation practices funded by the state included cover crops and production area BMPs from SFY 2016 to 2019. The table above does not include results of federally funded projects (see Table 4 for federally funded project outputs). Approximately 153 acres of agricultural lands have been treated by state-funded equipment and conservation practices since SFY 2018. Multiple barnyard and production area management practices, including waste transfer and facility closure, were also installed to contain agricultural waste within production areas. Approximately 11 acres of barnyard and production area compliance were determined to be fully compliant with Required Agricultural Practices by AAFM inspectors in the Lake Carmi watershed.

Other regional or state-wide agricultural pollution reduction efforts, such as UVM Extension's equipment assistance programs, have enhanced conservation practices in the Lake Carmi watershed, such as the use of cover crops. However, project outputs reported above only include results of Lake Carmi specific projects and not results of statewide or regional projects. Refer to the *Vermont Clean Water Initiative 2019 Performance Report* for results of statewide and regional projects, available at: https://dec.vermont.gov/water-investment/cwi/reports.

Table 3. Acres of agricultural conservation practices implemented by USDA-NRCS programs in the Lake Carmi watershed, SFY 2016-2019.

Agricultural Practice Type	2016	2017	2018	2019	Total
Conservation Tillage	196	4	168	86	454
Cover Crop	93	99	76	86	354
Forage and Biomass (Crop to Hay)	89	35	76	--	200

EXPLANATION OF TABLE

USDA-NRCS programs provide funding and technical support for agricultural conservation practices in the Lake Carmi watershed. The most common conservation field practices within the Lake Carmi watershed are conservation tillage and cover crop. Conservation tillage leaves a minimum of 30% of the soil surface covered with plant residue after the tillage or planting operations, and cover crops provide seasonal cover on annual cropland to reduce soil erosion. Based on data gathered by UVM Extension and the results of state and federal financial assistance programs, 75% of the annual cropland within Lake Carmi was cover cropped in 2018. The conversion of cropland to hay (i.e., forage and biomass) supported by USDA-NRCS is also a common practice within the Lake Carmi watershed that results in phosphorus load reductions from agricultural fields.

Figure 6. Grassland shallow slot manure injector to be used within the Lake Carmi watershed. Manure is injected subsurface to reduce surface runoff of nutrients. Equipment funds were awarded in SFY 2020 and will be reported in future Lake Carmi Clean Water Progress Report updates.

Objective #3: Manage stormwater from developed areas through the development and implementation of a stormwater master plan (Franklin) and private road assessments.

Developed lands, including impervious surfaces like roads, make up only 5.6% of Lake Carmi's watershed, but have the greatest potential for phosphorus export per acre.[14] While the town and state will be improving the management of hydrologically connected roads to meet new state permit requirements (i.e., Municipal Roads General Permit (MRGP) and Transportation Separate Storm Sewer System Permit (TS4); see Objective #5), privately owned roads and most existing developed areas have been and will continue to be addressed through voluntary efforts. To address phosphorus loading from developed lands in Lake Carmi's watershed, the state has worked with multiple partners to identify and remediate localized stormwater management concerns.

DEC and the FNLC supported the development of the Franklin Stormwater Master Plan (SWMP) to better manage stormwater runoff from developed lands in the Town of Franklin. In 2015, the SWMP identified and prioritized 11 potential projects to reduce phosphorus loading from stormwater runoff in the watershed.[15] Work has been started or completed on eight of the 11 SWMP projects based on SWMP project prioritization, including a culvert repair project (SWMP project LC-10) completed by VTrans. The state, in its Intended Use Plan for the State Revolving Loan Fund, is indicating that it will provide 100% forgiveness on a Clean Water State Revolving Fund loan to replace two failing culverts under State Route 236 that are contributing sediment from erosion in and around the structures to Dewing Brook and Lake Carmi (SWMP project LC-08).

Additionally, the FWC and NRPC supported the assessment of all private roads leading to Lake Carmi on the southwest corner of the lake. Road associations and private landowners have worked, both individually and with FWC, to address stormwater runoff and erosion problems, but not all projects have been completed to date. To build on this work, NRPC (with funding from LCBP) will formalize private and State Park road assessments to prioritize remediation projects following the MRGP road erosion inventory methodology. An NRPC contractor will implement the prioritized projects in 2021. Additional road improvement projects are described under Objective #5.

[14] For more information on watershed loading, please see the Phosphorus TMDL for Lake Carmi: https://dec.vermont.gov/sites/dec/files/documents/WSMD_mapp_2009_Carmi%20P%20tmdl.pdf.

[15] Stormwater Management Plan for Franklin: https://dec.vermont.gov/sites/dec/files/wsm/erp/docs/erp_Franklin.pdf.

Table 4. Outputs of state-funded private road erosion remediation and SWMP clean water projects on developed lands completed in the Lake Carmi watershed, SFY 2016-2019.

Developed Lands Project Output Measures	2016	2017	2018	2019	Total
Number of private road improvement projects identified	--	--	22	--	22
Number of final (100%) road drainage culvert restoration designs completed	--	4	--	--	4

EXPLANATION OF TABLE

In SFY 2017, four municipal road culvert restoration projects, identified through the SWMP, were designed to reduce active erosion along Towle Neighborhood Road. In SFY 2018, the inventory of private camp roads within the watershed identified 22 potential road and culvert remediation projects.

Objective #4: Improve shoreland management to protect water quality and protect wildlife through direct outreach with landowners to encourage participation in the Lake Wise Program.

The Lake Wise Program is a DEC initiative that promotes the implementation of lakeshore BMPs aimed at reducing runoff and erosion from lakeshore properties. The goal of Lake Wise is to establish a new culture of lakeshore landscaping that is proven to help protect the lake. DEC recognizes these efforts via the issuance of Lake Wise Awards to shoreland property owners who demonstrate a commitment to lake-friendly practices. By showcasing lake-friendly properties, Lake Wise Awards inspire others to improve their shoreline properties so they, too, can earn the Award and help protect their lake.

DEC provided funding and support to FWC to engage the Lake Carmi community in the adoption of Lake Wise practices from 2011 to 2017. Through these efforts, over 50 shoreline properties (camps and private residences) have been assessed or engaged in the Lake Wise Program, collectively installing more than 30 lakeshore BMPs along Lake Carmi. BMPs included rock lined ditches, driveway water bars, shoreland stabilization with vegetation and rip-rap, rain gardens, and no-mow zones along the shorelands. During this period, 12 properties received the Lake Wise Award by demonstrating that their property passed all four Lake Wise assessment categories: shoreland, driveway, recreation area and septic. Thirteen properties have also received Lake Wise certification by illustrating lake-friendly practices in at least two of the four categories across their property.

UVM Sea Grant promoted the Lake Wise Program and implementation of shoreline BMPs through rain garden and shoreline workshops in 2017. Due to all Lake Wise outreach efforts through 2017, more than 30 of the approximately 300 camps along Lake Carmi, or over 10%, have adopted appropriate practices. ANR will continue to encourage lakeshore property owner

involvement in the Lake Wise Program in partnership with local organizations in order to increase the overall adoption of lake-friendly practices and establish a standard for good shoreland stewardship in the Lake Carmi community.

DEC also supported 3 river assessments in the Lake Carmi watershed to identify and prioritize stream and river protection and restoration projects. In 2018, FPR enhanced 4,500 feet of Lower Marsh Brook by planting 250 trees to ensure a 100-foot buffer on State Park land.*

Table 5. Outputs of state-funded natural resource restoration projects completed in the Lake Carmi watershed, SFY 2016-2019.

Natural Resources Project Output Measures	2016	2017	2018	2019	Total
Number of Lake Wise check dams installed/repaired	--	--	3	--	3
Number of Lake Wise culvert armoring projects	--	--	6	--	6
Number of Lake Wise shoreland plantings	--	--	2	--	2
Number of riparian trees planted	--	--	250	--	250

EXPLANATION OF TABLE

DEC's Lake Wise Program has resulted in implementation of several lake-friendly shoreland practices to restore Lake Carmi's shoreland. From SFY 2016 to 2019, eleven Lake Wise practices were completed. Many other Lake Wise practices in the Lake Carmi watershed were implemented prior to the SFY 2016-2019 reporting period, and these project outputs and funding are not reported in figures or tables. More information about the Lake Wise Program is available at: https://dec.vermont.gov/watershed/lakes-ponds/lakeshores-lake-wise/.

Figure 7. Before (left) and after (right) stabilization of an eroding lakeshore access path to Lake Carmi, completed by the Franklin Watershed Committee as part of the Lake Wise Program with funding from DEC's Clean Water Initiative Program.

Objective #5: Inventory and prioritize municipal road erosion features that discharge into surface water and implement high priority actions in existing road erosion inventoried sites.

In 2017, NRPC completed a Town of Franklin road erosion inventory to comply with the Municipal Road General Permit (MRGP). The inventory separated town roads into 813 100-meter road segments and identified those that were hydrologically-connected (in close proximity to surface waters) and did not meet MRGP standards. In the Lake Carmi watershed, 6 segments did not meet MRGP standards and 12 segments partially meet MRGP standards. Assuming 100-meter road segments, this represents 5,904 feet (1.1 miles) of road improvements needed in the Town of Franklin.

The Town of Franklin used state funding to improve stormwater management on several hydrologically-connected roads, including Dewing, Dewing Shore, and Gallup Roads. The Town of Franklin also used state funding to purchase two pieces of equipment to improve road management, including shoulder disc (to remove high road shoulders that cause channelized erosion) and hydro-seeder (to accelerate revegetation of disturbed areas) equipment. Other activities under Objective #3 (related to private roads) have also contributed to meeting this objective, such as culvert replacement and ditch stabilization efforts.

Table 6. Outputs of state-funded municipal road erosion remediation clean water projects on developed lands completed in the Lake Carmi watershed, SFY 2016-2019.

Developed Lands Project Output Measures	2016	2017	2018	2019	Total
Linear feet of municipal road drainage and erosion control improvements	--	--	672	60	732

EXPLANATION OF TABLE

Municipal road work in the Lake Carmi watershed is driven by the Municipal Roads General Permit (MRGP). MRGP-related road projects were funded by the state through the Municipal Roads Grants-in-Aid Program and the VTrans Better Roads Program. In SFY 2018 and 2019, road remediation projects improved over 700 linear feet of road drainage within the Lake Carmi watershed, including Middle Road and Dewing Road.

Other town-wide or regional developed lands projects have also benefited the Lake Carmi watershed, but outputs of statewide and regional projects are not reported in the table above. For example, the Municipal Roads Grants-in-Aid Program funded road improvement equipment for the entire Town of Franklin, but the project outputs cannot be narrowed down to the Carmi watershed.

Figure 8. Before (left) and after (right) installation of stone-lined drainage ditch and road drainage culvert along Dewing Road by the Town of Franklin, in partnership with Northwest Regional Planning Commission funded through the Municipal Roads Grants-in-Aid Program.

DEVELOPED LANDS

Objective #6: Provide technical and, as available, financial assistance to the wastewater treatment facility and septic systems in meeting TMDL goals to reduce phosphorus loading to Lake Carmi.

DEC found that capacity was limited in on-site wastewater treatment systems (i.e., septic systems) in some areas around the lake in 2011. As a result, DEC supported a septic engineering feasibility study for 224 systems, which recommended pursuing a community septic system that numerous properties could utilize. The Town of Franklin, however, has not expressed interest in pursuing an alternative to individual wastewater systems, so further work on community septic systems for town residents is currently on hold. See Objective #7 for information on reducing phosphorus discharge from individual septic systems.

Lake Carmi State Park installed a zero-discharge wastewater treatment facility in 2018. The renovation improved the existing lagoon treatment system and constructed a wetland to reduce the need for the spray field system to distribute highly treated wastewater. The new wastewater system eliminates all phosphorus discharge into Lake Carmi and its watershed.[16] This project also resulted in considerable savings to wastewater system operation and management costs.

DEC will begin a study in 2020 to determine if nutrients from groundwater are a significant source of nutrient loading to Lake Carmi. Nutrients in groundwater can be derived from several sources, including natural minerals, surface water recharge to groundwater, and human-derived sources, such as septic systems. This study should help identify whether groundwater, surface water, or both are responsible for the transport of nutrients to Lake Carmi.

[16] For more information on the Lake Carmi State Park wastewater upgrade, please visit: https://anr.vermont.gov/node/1041.

Table 7. Outputs of state-funded wastewater treatment improvement projects completed in the Lake Carmi watershed, SFY 2016-2019.

Wastewater Treatment Project Output Measures	2016	2017	2018	2019	Total
Number of wastewater treatment facility upgrades completed	--	--	1	--	1

EXPLANATION OF TABLE

ANR's DEC and FPR collaborated to upgrade the Lake Carmi State Park wastewater treatment system to a zero-discharge system. The project successfully eliminated all wastewater discharge into the Lake Carmi watershed.

Figure 9. Lake Carmi State Park zero discharge wastewater treatment system under construction (left) and constructed with operational aeration "islands" (right).

DEVELOPED LANDS

Objective #7: Provide technical and financial assistance to assist private landowners in the maintenance of septic systems.

According to the Lake Carmi TMDL, septic system phosphorus discharges to Lake Carmi comprise approximately 1% of the total annual phosphorus load. While this is a relatively small source of phosphorus compared to tributary phosphorus loading, it is a source of phosphorus that can be reduced by homeowner action.

ANR has provided technical and financial assistance to Lake Carmi property owners to improve the effectiveness of their septic systems. From 2008 to 2012, the FWC and LCCA supported annual pump out events for Lake Carmi watershed residents. In 2009 and 2010, FWC and LCCA also supported septic surveys for 94 systems. Although most of these efforts were nearly a decade ago, DEC is still able to assist with helping property owners improve the performance of their septic systems, such as via Septic Socials. The most recent Septic Social was

in 2018. The aforementioned groundwater study will help determine if progress has been made towards reducing phosphorus loading from septic systems in the Lake Carmi watershed.

IV. Phosphorus Reduction Outcomes

Clean water projects installed in the Lake Carmi watershed are expected to reduce phosphorus pollution to Lake Carmi and improve water quality. While Lake Carmi's water quality is the ultimate indicator of progress, it will take time for Lake Carmi to realize the benefits of these projects. Additionally, other variables, such as climate and land use change, may affect phosphorus loading to Lake Carmi and Lake Carmi's water quality. To provide some incremental measures of accountability, this section of the Lake Carmi Clean Water Progress Report summarizes the estimated phosphorus pollution reductions associated with clean water projects installed SFY 2016-2019 and reported through state and federal funding programs and regulatory programs (see Figure 10 and Figure 12).

Phosphorus pollution reduction estimates are modeled at the individual clean water project-level, since measuring phosphorus reductions at this level through water quality monitoring would be cost-prohibitive. That said, DEC will utilize these estimated phosphorus reduction outcomes along with Lake Carmi water quality and tributary monitoring to evaluate progress and target future actions. See Section V for in-lake monitoring results.

Clean water project phosphorus reduction estimates are based on the following:

1. Area of land draining to the practice or project and the average phosphorus loading rate from the land use. With these data, the state can estimate the total phosphorus load treated by a project or practice based on the area of land treated.

2. Average annual performance of the project type reducing phosphorus, also referred to as "phosphorus reduction efficiency." This information is based on research of project performance relevant to conditions in Vermont.

The average annual phosphorus reduction efficiency for a project is applied to the phosphorus load delivered from the land draining to the project to estimate the average annual phosphorus reduction. Phosphorus reductions cannot yet be estimated for all clean water project types.[17] The ability to estimate the phosphorus reduction of a project can be limited by lack of data on phosphorus loading rates for the land treated and/or lack of information on the performance of a project in treating phosphorus pollution. The Clean Water Service Delivery Act (Act 76 of 2019) requires publishing methods to estimate phosphorus reductions for all clean water project types in the Lake Champlain and Lake Memphremagog basins by November 1, 2021.

[17] For more information on phosphorus reduction calculations, see Appendix F of the *Vermont Clean Water Initiative 2019 Performance Report*: https://dec.vermont.gov/water-investment/cwi/reports.

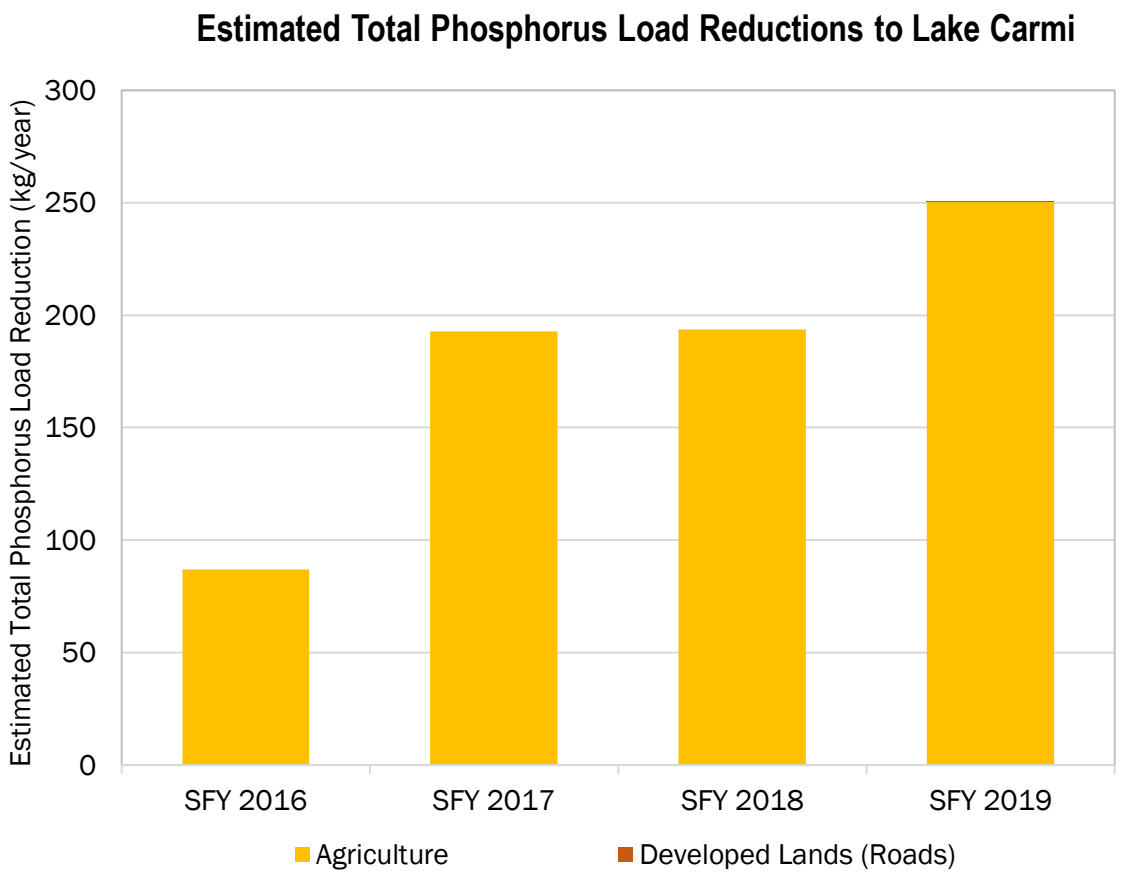

Figure 10. Annual estimated total phosphorus load reductions (kilograms/year) associated with clean water projects supported by federal funding, state funding, and regulatory programs to implement the Lake Carmi TMDL, SFY 2016-2019, by land use sector.

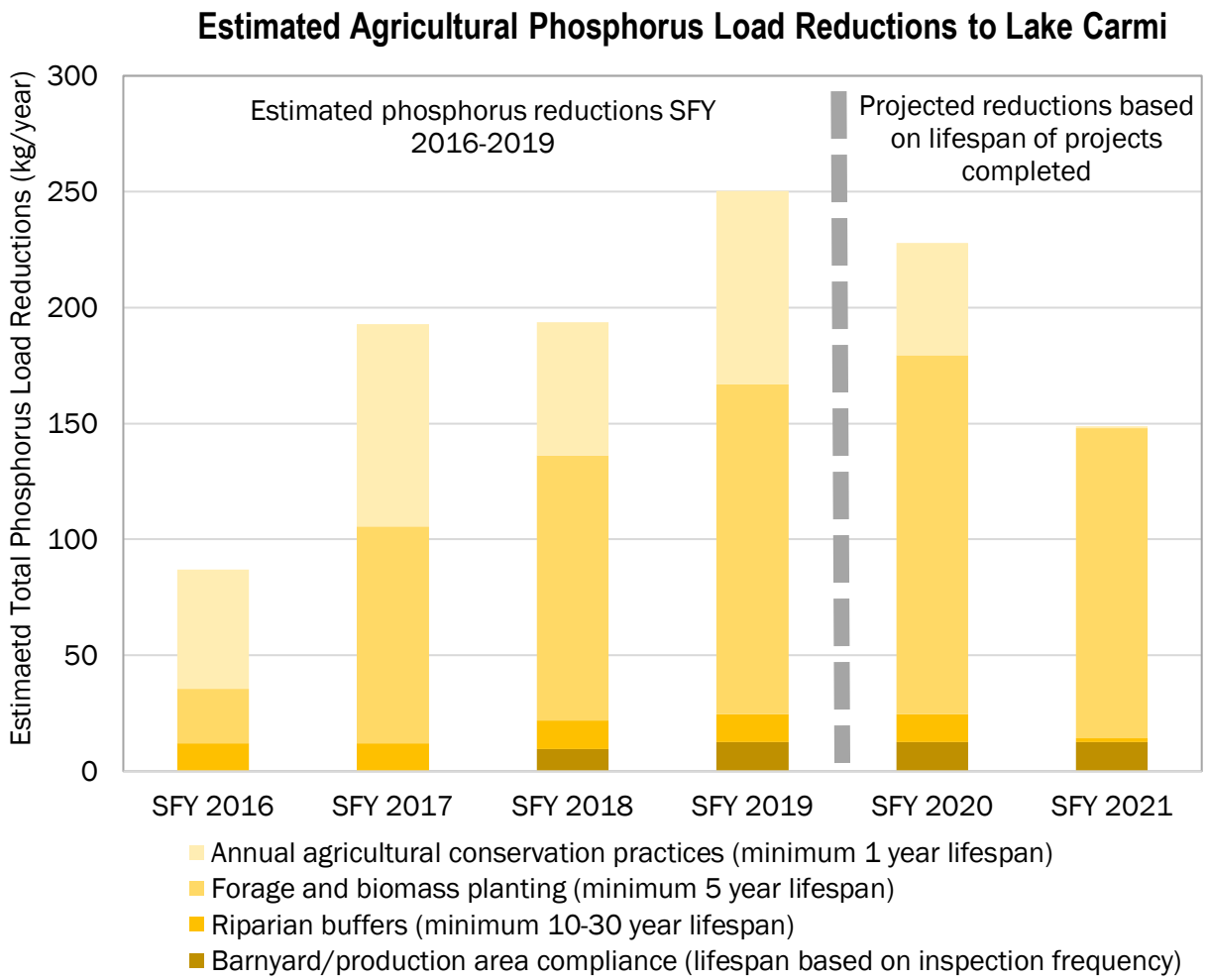

Figure 11. Annual estimated total phosphorus load reductions (kilograms/year) associated with agricultural clean water projects supported by federal funding, state funding, and regulatory programs to implement the Lake Carmi TMDL, SFY 2016-2019. Projected reductions are based on the lifespan of projects completed before the end of SFY 2019.

EXPLANATION OF FIGURES

Nearly all estimated phosphorus reductions in the Lake Carmi watershed are associated with the agricultural sector for three reasons:

1. Agricultural conservation practices are highly cost-effective in reducing phosphorus in rain and snowmelt-runoff and erosion.
2. Substantial federal funds from USDA-NRCS support agricultural water quality work. Direct federal investments are outside the scope of this report.
3. Methods are currently in place to estimate reductions associated with most types of agricultural conservation practices, while other land use sectors have gaps in methods to quantify phosphorus reductions (see Appendix F of the *Vermont Clean Water Initiative 2019 Performance Report* for summary of methods to estimate phosphorus reductions).

Farmers in the Lake Carmi have significantly ramped up water quality efforts since SFY 2016 – from SFY 2016 to SFY 2019, phosphorus reductions from agricultural pollution reduction projects have increased nearly 188%. However, approximately 39% of the agricultural reductions are associated with annual practices (one-year lifespan). If these practices are not implemented each year, the phosphorus reductions will not carry through to future years. Some conservation practices, such as forage and biomass (i.e., crop to hay conversion), in contrast, have longer term lifespans, and phosphorus reductions achieved by these projects will continue in future years if properly maintained.

The lifespans of practices reported above are established based on the typical performance of a practice, length of the practice contract, or inspection schedule. For example, agricultural riparian buffer lifespans are assigned based on the length of the funding contract, while barnyard and production area practice lifespans are assigned based on the AAFM inspection schedule to determine compliance. All practices must be maintained for phosphorus reductions to continue in future years. If practices are inspected and not operating as anticipated, phosphorus crediting will cease until the practice is fully operational according to standards.

Phosphorus reductions estimated and reported above are likely an under-estimate for the following reasons:

1. Farmers may continue implementing conservation practices beyond their initial contract period with AAFM or USDA-NRCS.
2. Farmers, municipalities, and other landowners may be implementing clean water projects voluntarily and without state and/or federal funding.
3. Methods are not yet in place to estimate phosphorus reductions for all clean water project types, including some lake shoreland and wastewater improvements.

Some investments reported in Section II are associated with projects not yet completed and estimated phosphorus reductions are only reported for completed projects. Conversely, USDA-NRCS-funded phosphorus reductions are reported here, but direct federal investments are not reported in Section II unless classified as match.

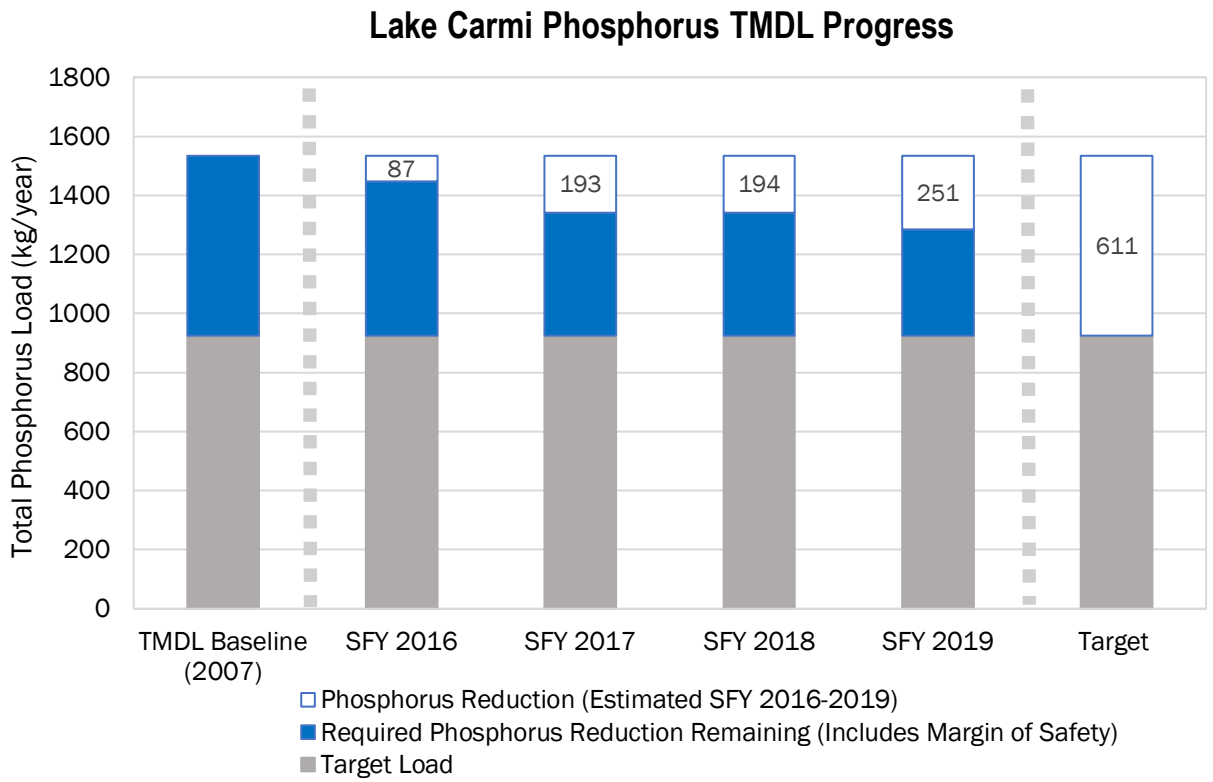

Figure 12. Lake Carmi TMDL total phosphorus load baseline (2007) compared to the target phosphorus load with estimated total phosphorus load reductions during SFY 2016-2019.

EXPLANATION OF FIGURE

This figure compares the Lake Carmi TMDL baseline (2007) and target load to the estimated total phosphorus load reductions from clean water projects from SFY 2016 to SFY 2019. The total phosphorus load allocation for Lake Carmi is 924 kg/year. In order to meet State of Vermont water quality standards, total phosphorus loading must be reduced by 611 kg/year, which includes the 10% (103 kg/year) margin of safety. As of SFY 2019, state and federal investments and regulatory programs reduced an estimated 251 kg of phosphorus loading, which is estimated to be approximately 41% of the phosphorus reduction required to meet the Lake Carmi TMDL based on modeled estimates. Continued investments and efforts across all land use sectors within the Lake Carmi watershed are needed to achieve Lake Carmi's clean water goals. This continued level of effort includes the operation and maintenance of existing clean water projects.

Lake Carmi TMDL results reported are expected to increase substantially in the coming years for the following reasons:

1. Gaps in the state's ability to estimate phosphorus reductions for all projects: The State of Vermont is expanding its ability to estimate phosphorus reductions for all project types. The Clean Water Service Delivery Act (Act 76 of 2019) requires addressing gaps and publishing methods to estimate phosphorus reductions for all clean water projects by November 1, 2021.

2. Programs are ramping up to increase the pace of phosphorus reductions: New regulatory programs are now in place that will drive phosphorus reductions from agricultural sources, developed lands, and roads, with meaningful progress expected in the coming years.

V. Water Quality Trends

Clean water projects implemented through state and federal funding programs and regulatory programs resulted in an estimated phosphorus load reduction of 251 kg in SFY 2019. This represents approximately 41% of the phosphorus reduction required to meet State of Vermont water quality targets identified by the Lake Carmi TMDL. Water quality in Lake Carmi will primarily change in response to nutrient load reductions from the watershed and, to a lesser extent, from the in-lake aeration system. Because many variables affect phosphorus loading to Lake Carmi, such as the changing climate and complexity of the Lake Carmi ecosystem, it is difficult to predict how quickly improvements will occur. Water quality monitoring in the lake and tributaries allows us to track the current state of the lake as well as trends over time.

Lake Carmi Scorecard

Vermont DEC's Lakes and Ponds Program and volunteer water quality monitors have been measuring water quality parameters in Lake Carmi annually since 1979. DEC created "Lake Scorecards" to provide the public with an annual overview of water quality in Lake Carmi (see Figure 13 below) and other Vermont lakes. Overall, Lake Carmi remains listed as "impaired" due to high phosphorus concentrations and organic enrichment.[18] The Lake Carmi watershed is scored as "highly disturbed" because of land use and development intensity which can generate nutrient-rich runoff during storm events. As a result, continued land use management efforts in the watershed are necessary to reduce nutrient loading over the long-term.

Lake Carmi water quality monitoring data show no significant trends in spring and summer total phosphorus concentrations and summer chlorophyll *a* concentrations (a proxy for lake productivity) over the past 40 years. Lake monitoring results showed unusually high spring and summer total phosphorus concentrations between 2006 and 2009, followed by slight reductions in total phosphorus concentrations since then. Furthermore, mean summer Secchi disk depth (a measure of lake water clarity) has been significantly increasing over the past several decades. The long-term stable total phosphorus concentrations and increasing water clarity trends have become evident while Vermont's surface waters, including Lake Carmi, are under increasing stress from climate change. Climate change is causing increased frequency of intense storms and annual precipitation, which increases the transport of pollution through rain and snowmelt runoff.[19] This may suggest that improved land use practices being implemented by the watershed community are offsetting the increase in nutrient runoff from changing weather patterns.

DEC and volunteer water quality monitors will continue measuring water quality parameters in Lake Carmi and its tributaries to better understand the factors affecting in-lake water quality.

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[18] For more information on impaired waterbodies in Vermont, see the State of Vermont 2018 303(d) List of Impaired Waters: https://www.epa.gov/sites/production/files/2019-02/documents/2018-vt-303d-list-report.pdf.

[19] See Figure 42 (page 53) from the *Vermont Clean Water Initiative 2019 Performance Report*: https://dec.vermont.gov/water-investment/cwi/reports.

DEC will also continue to monitor the impact of the aeration system on in-lake phosphorus concentrations during the summer months when the lake is susceptible to cyanobacteria blooms. See below for information on the impact of the aeration system on total phosphorus concentrations in 2019.

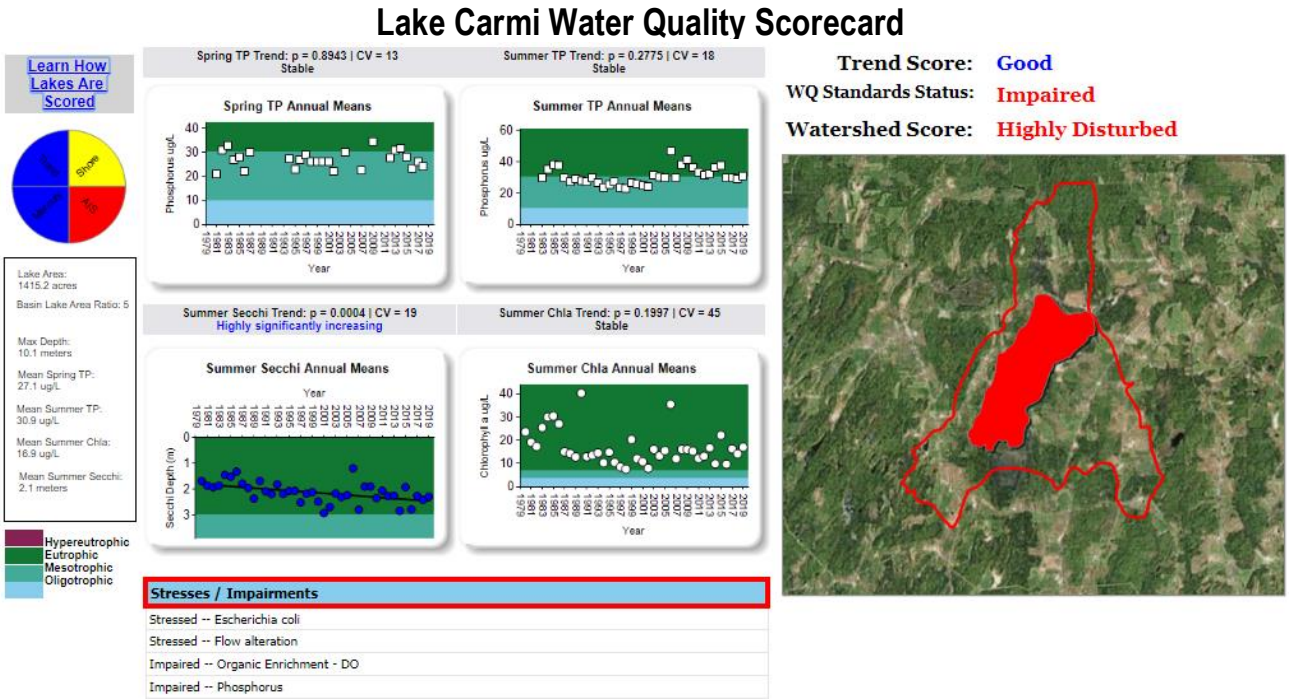

Figure 13. Lake Carmi water quality scorecard. Data and additional information are available at: https://dec.vermont.gov/watershed/lakes-ponds/data-maps/scorecard.

Aeration System Monitoring Results

The Lake Carmi aeration system operated from late June 2019 to October 2019 with a few short outages due to technical issues that were quickly resolved. Despite these challenges, monitoring data indicated that the aeration system accomplished the defined goal of mixing the water column to allow dissolved oxygen to reach the lake bottom. The presence of oxygen at the lake bottom significantly reduced internal phosphorus loading from sediments, which would otherwise be released under low oxygen (hypoxic or anoxic) conditions. Figure 14 illustrates lower phosphorus concentrations at the bottom of Lake Carmi in 2019 when the aeration system was operational.

Despite the aeration system operations in 2019, Lake Carmi did experience cyanobacteria blooms, as did other lakes in the state. Large rainfall events and high temperatures in 2019 created ideal conditions for cyanobacteria blooms in Vermont and across the Northeast. Total phosphorus concentrations in the lake peaked around 60 parts per million in late summer 2019, which was well below peak concentrations in the three previous years but still provided ample nutrients to fuel the cyanobacteria blooms at that time (see Figure 14).

Conditions during summer 2019 reinforced the need for the in-lake aeration system to be complemented by continued interventions in the watershed. Further reductions in external phosphorus loading to the lake are also needed to meet water quality improvement goals in Lake Carmi. More information about the performance of the aeration system in 2019 and general water quality monitoring efforts in Lake Carmi can be found on DEC's Restoring Lake Carmi webpage, available at https://dec.vermont.gov/watershed/restoring/carmi.

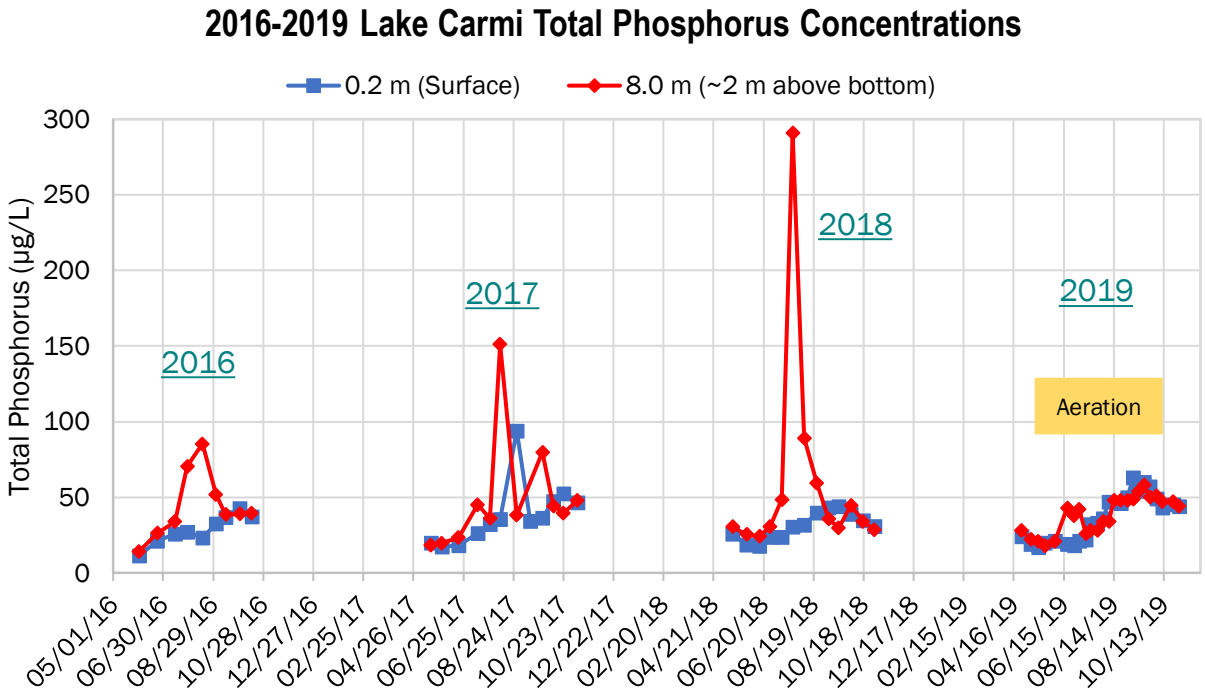

Figure 14. 2016-2019 Lake Carmi Station #1 (UVM mid-lake buoy) total phosphorus concentrations in micrograms per liter (µg/L) at the surface (blue) and two meters above lake-bottom (red). The aeration system operations (highlighted in 2019) correlated with reduced lake-bottom phosphorus concentrations.

Variables Affecting Water Quality in Lake Carmi

Although modeled phosphorus reductions suggest that approximately 41% of the reductions required to meet the Lake Carmi TMDL were met in SFY 2019, in-lake water quality parameters remain generally stable and cyanobacteria blooms continued in 2019. Due to the nature of non-point and stormwater pollution, many variables affect the amount of phosphorus load delivered to Lake Carmi and Lake Carmi's response to phosphorus loading, including climate change, human population change, land use change, and agricultural considerations. For example, increased precipitation from climate change and new development of impervious surface can both increase the volume of stormwater runoff. Furthermore, increased temperatures from climate change, combined with external loading factors that can increase

phosphorus runoff, create conditions favoring cyanobacteria blooms.[20] As we have little control over temperatures and precipitation, Vermont will need to focus on land-use management and controlling nutrient loading to surface waters in order to reduce the number of cyanobacteria blooms.

In addition to these external factors that can affect in-lake phosphorus concentrations, internal phosphorus loading from sediments is a significant source of phosphorus in Lake Carmi. Under hypoxic or anoxic conditions (low or no dissolved oxygen), total phosphorus concentrations near the bottom of the lake can exceed 250 μg/L, which can be over 5 times surface total phosphorus concentrations (Figure 14). As discussed above, the aeration system can mediate internal phosphorus loading by allowing dissolved oxygen to reach the bottom sediments, and continued aeration should have positive effects on total phosphorus concentrations over time. It is important to note, however, that total phosphorus concentrations even with aeration can still exceed 50 μg/L, which highlights the need for continued phosphorus load reductions from the Lake Carmi watershed.

VI. Summary & Next Steps

The State of Vermont, along with many partners and engaged stakeholders, have worked effectively together to implement numerous clean water projects within the Lake Carmi watershed. Due to significant state and federal investments and many engaged partners working together in the Lake Carmi watershed, it is estimated that approximately 41% of the phosphorus reductions required to meet the Lake Carmi TMDL have been achieved. Additionally, over $1 million dollars have been invested in the design, implementation, and monitoring of an in-lake aeration system that successfully reduced internal phosphorus loading from sediments in Lake Carmi during 2019. As blooms still occurred during 2019, the aeration system will be further optimized in 2020, and the in-lake efforts must be complemented by continued interventions in the watershed to reduce external phosphorus loading to the lake and achieve water quality goals.

In the coming years, the State of Vermont will continue investing in clean water projects in Lake Carmi and its watershed, as funding allows. The state will also continue outreach and educational efforts aimed at increasing community engagement and adoption of clean water practices. DEC will continue to track clean water efforts in the Lake Carmi watershed and report on investments and results through shorter annual Lake Carmi Clean Water Progress Update Reports.

[20] For more information on external variables affecting phosphorus loading, please see page 52 of the *Vermont Clean Water Initiative 2019 Performance Report*: https://dec.vermont.gov/water-investment/cwi/reports

Appendix A. Lake Carmi Watershed State and Federally Funded Clean Water Project List

Table 8. State and federally funded clean water projects within the Lake Carmi watershed, SFY 2016-2019.

Agency	Partner	Summary Title	Category	Funding Source	State Funds	Funding SFY	Status
AAFM	AAFM Capital Equipment Assistance Program	Cover Crop[21]	Ag	N/A[22]	N/A	2019	Completed
AAFM	AAFM Farm Agronomic Practice Program	Cover Crop[23]	Ag	General	$2,077	2018-2019[24]	Completed
AAFM	Franklin Watershed Committee	Pike River Watershed: Dispelling the Myths (Education and Outreach)	Ag	Other	$9,750	2018-2019	Funded, ongoing
AAFM	AAFM Best Management Practice Program	Waste Facility Closure	Ag	Capital	$25,000	2019	Completed
AAFM	AAFM Best Management Practice Program	Waste Facility Closure	Ag	CWF	$39,010	2018	Completed
AAFM	AAFM Best Management Practice Program	Waste Transfer	Ag	Capital	$43,646	2017	Completed
ANR	Franklin Watershed Committee	Effective communication materials for Pike River watershed water quality documents	Other	Other	$5,000	2018	Completed
ANR	Franklin	Franklin – Dewing Rd – Municipal Roads Grants-in-Aid	Roads	Capital	$5,000	2017	Completed
ANR	Armstrong Construction, Inc.	Lake Carmi - Inspection Services 2019	NR (In-lake)	Capital	$8,500	2019	Funded, ongoing

[21] Represents practices installed with equipment funded by AAFM.

[22] Funding source and state funds are "N/A" because practices were not directly paid for by the state.

[23] Represents practices aggregated across entire Lake Carmi watershed.

[24] Multiple years combined for agricultural conservation practices aggregated by project type.

Agency	Partner	Summary Title	Category	Funding Source	State Funds	Funding SFY	Status
ANR	EverBlue Lakes - Lake Savers, LLC	Lake Carmi Aeration - Implementation	NR (In-lake)	Capital	$935,462	2019	Funded, ongoing
ANR	Reservoir Environmental Management Inc.	Lake Carmi Aeration Design - Step 1	NR (In-lake)	CWF	$7,250	2018	Completed
ANR	Reservoir Environmental Management Inc.	Lake Carmi Aeration Design - Step 2	NR (In-lake)	CWF	$47,021	2018	Completed
ANR	Franklin Watershed Committee	Lake Carmi Private Camp Roads and Culverts Erosion Assessment	Roads	CWF	$4,000	2017	Completed
ANR	Franklin Watershed Committee	Lake Carmi Watershed Sampling Program	Other	CWF	$7,335	2019	Funded, ongoing
ANR	Franklin Watershed Committee	Lake Wise Practice Implementation - Lake Carmi, Franklin	NR	Capital	$37,125	2015[25]	Completed
ANR	Franklin Watershed Committee	Towle Neighborhood Road Erosion Control - Planning and Design	Roads	Capital	$6,600	2016	Completed
NRCS	NRCS	Conservation Tillage	Ag	Federal	N/A	2016-2019	Completed
NRCS	NRCS	Cover Crop	Ag	Federal	N/A	2016-2019	Completed
NRCS	NRCS	Crop to Hay	Ag	Federal	N/A	2016-2018	Completed
VHCB	Green Dream Farm	Wagner-Green Dream Farm - FY18 Water Quality Grant	Ag	Capital	$40,000	2018	Funded, ongoing
VTrans	Franklin	Gallup Road Ditching	Roads	VTTF	$10,000	2016	Completed
VTrans	Franklin	Middle Rd	Roads	VTTF	$5,250	2019	Completed

[25] Funding associated with the "Lake Wise Practice Implementation - Lake Carmi, Franklin" project was awarded in SFY 2015 and, therefore, this project is not included in this Report's investment data covering SFY 2016-2019. However, the project was completed in SFY 2016 and its results are reported for SFY 2016.

Agency	Partner	Summary Title	Category	Funding Source	State Funds	Funding SFY	Status
ANR	DEC Lakes and Ponds Protection Program	Pre- and Post-Aeration Water Quality Monitoring	NR (In-lake)	Lake in Crisis	$20,000	2019	Completed
ANR	UVM Extension	Manure Injection in Watershed	Ag	Lake in Crisis	$30,000	--------	Contract pending[26]
ANR	FPR Lake Carmi State Park	Zero-Discharge Wastewater Treatment System	WW	Capital	$190,000	2018	Completed
ANR	FPR Lake Carmi State Park	Lake Carmi Riparian Management Zone Tree Planting	NR	Capital	$2,200	2018	Completed

Acronyms	
AAFM	Vermont Agency of Agriculture, Food and Markets
ANR	Vermont Agency of Natural Resources
Ag	Agriculture
CWF	Clean Water Fund
NR	Natural Resources
NRCS	U.S. Department of Agriculture Natural Resources Conservation Service
SW	Stormwater
VHCB	Vermont Housing and Conservation Board
VTrans	Vermont Agency of Transportation
VTTF	Vermont Transportation Funds
WW	Wastewater

[26] Grant agreement is not yet executed at the close of SFY 2019 and is, therefore, not included in this Report's figures and tables.